METHODS OF ESTIMATING VEHICULAR TRAFFIC VOLUME WITH THE AID OF TRAFFIC PATTERNS*

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SYNOPSIS

The problem is attacked through a series of graphic analyses of vehicular traffic cycles of different lengths, depicted schematically by means of traffic patterns which reflect motorists' travel habits The controlling theme of this paper is that, through a study of the similarities and differences in the traffic patterns of various facilities and in those of the same facility at different periods of the year and over a period of years, effective methods of estimating traffic volumes can eventually be developed on the basis of a minimum of traffic data

The patterns of three types of cycles have been studied, namely the monthly cycle, which depicts the repetitive month-to-month variations within any year, the daily cycle, which is completed within a seven-day period, and the hourly cycle, which repeats itself every twenty-four hours

Among other conclusions, the paper brings out these facts

1 On selected toll crossings scattered over the United States, traffic volumes in the months of May and October were found to be closest to the average for the year

2 Monthly traffic volumes of toll crossings in the New York Metropolitan district, when adjusted for the effects of seasonal cycles, yielded traffic "levels" which reflected the effects on vehicular traffic of the economic depression and subsequent business recovery, the effects of the opening of new alternative routes, of particularly adverse weather conditions, and of important transitory factors which arose from time to time

3 Weekday traffic volumes are no criteria of weekend traffic A large weekday traffic volume on any highway does not necessarily mean large weekend volumes, and vice versa Hence, weekend and holiday traffic must be given special consideration when estimating traffic volumes

4 The traffic volume on a Wednesday is usually a fair average of the five weekdays (Monday to Friday)

5 The hourly traffic patterns of any given highway facility differ widely as between weekdays and Sundays, while those on Saturdays resemble both, being closer to one or the other depending on the extent to which the Saturday half-holiday or the five-day week has been adopted in the community

6 The hourly patterns of any highway facility, reflecting, as they do, motor travel from hour to hour in the course of any day, differ only slightly from season to season and remain remarkably stable from year to year

INTRODUCTION

Estimating Problems of Vehicular Facilities

In connection with planning, financing and operating highway traffic facilities, it is often imperative that fair approximations of the annual traffic volume be obtained on the basis of traffic data for short periods or for part of a year It would be uneconomical, in some cases prohibitive and impractical, to observe and record traffic for an entire year in order to obtain more precise data

In the case of a toll crossing which is in operation, it is of practical value to prepare an estimate, in the beginning of the year, of the probable monthly traffic for the entire fiscal year. Such an estimate may be used for budgetary purposes, or to indicate the probable effects on traffic volumes, of major events which may occur in the course of the year. Thus, a change in tolls on competitive crossings,

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or an increase in business, or the opening of a major highway artery, or prolonged adverse weather, or some other important factor, may drastically affect its traffic volume If an estimate of the probable volume has been prepared in advance, without consideration of such factors, then the difference between recorded traffic volume and the estimated volume will give an idea of their influence

Again, when a new crossing is opened it is usually of interest to the bankers, who have underwritten the bonds, to have an estimate of its traffic for the first year, on the basis of traffic records as they become available in the first month or so

In recent years, toll crossings have been planned and opened in competition with existing free crossings, such as the East River bridges, for which no annual traffic volume records exist To determine the probable annual revenue which would be derived from the annual traffic volume likely to be diverted from the existing free facilities to the new toll crossings, it has been necessary to estimate the annual traffic of the free facilities on the basis of whatever sample traffic counts were available or could be collected within the limited time available

The annual trend of traffic on highway facilities, especially toll crossings which are being used to a large percentage of their capacity at peak traffic periods in the year, is governed by the annual capacity of these facilities This annual capacity therefore must be calculated, long before it is reached, on the basis of the physical capacities of the facilities in periods of an hour Due consideration also must be given to the effects of those motor travel habits which reduce theoretical to "working" annual capacities

There is also the problem of determining the annual or average-day traffic volume carried by a county or statewide system of highways In such surveys, when traffic flows must be manually recorded, and numerous observation points over a wide area covered for an extensive period, traffic survey costs may run up to prohibitive levels However, substantial economies may be made by judicious sampling, by which is meant a reasonable balance between proper coverage, distributed according to the importance of traffic arteries, on the one hand, and sufficiently adequate individual samples on the other

General Methods of Analysis

To develop methods for solving these and other traffic-estimating problems, the approach adopted was to analyze, graphically, vehicular traffic volume cycles which result from consistently repetitive motor travel habits

Three major vehicular traffic cycles, namely—(a) twelve-month, (b) seven-day and (c) 24-hour were analyzed through the medium of graphic patterns The patterns of different facilities were first compared to determine to what extent they conformed to or differed from each other The patterns of individual facilities were then examined to determine how consistently they followed, over a period of years, the periodic cycles peculiar thereto

Based upon such graphic analyses, effective methods invariably suggested themselves for solving many of the recurring types of traffic-estimating problems which arise in planning and operating free highway facilities as well as toll crossings

Vehicular Traffic Records of Toll Crossings Furnish Data for Traffic Patterns

In order to determine the characteristics of vehicular traffic cycles, continuous records are essential Such traffic records have been available only in the last decade, (since toll crossings have been opened to traffic and accounting records began to be kept), and only in

recent years have they begun to be collected and compiled by traffic engineers.

Thus, in connection with the operation of the Port Authority's four toll bridges and the Holland Tunnel, located in the New York metropolitan district, continuous annual, monthly, weekly, daily and hourly traffic figures have become available, and similar records for 35 toll ferries in the New York metropolitan district, eight toll bridges and tunnels in different cities of the United States and two in Europe, have been compiled by The Port of New York Authority, through the courtesy of the operators

But even in the New York metropolitan district, data for the larger monthly traffic cycles exist only for a limited number of years and, in some of these years, the cycles have been radically disturbed by the economic depression, the opening of new facilities, shifts in traffic resulting from toll reductions and other factors disturbing the normal periodicities of the cycle If such records continue to be collected and analyzed, there may be gained eventually enough knowledge of motor travel habits and of the quantitative effect on vehicular traffic of economic, social, climatic and other factors to bring the forecasting of traffic volume to a high degree of accuracy

SUMMARY OF ANALYSES OF MONTHLY VEHICULAR TRAFFIC PATTERNS

Some of the results of graphic analyses of monthly patterns have been summarized in the following conclusions:

1. Characteristic monthly patterns may be constructed from the monthly vehicular traffic volumes of individual facilities by the following statistical procedure

For each year for which twelve monthly traffic volume figures are available for each crossing, twelve ratios of the traffic volumes of each month to the average of twelve months are computed From a series of ratios for the same month in individual years, a median ratio is then selected as the best representative average ratio for that month The twelve median monthly ratios, one for each of the twelve months, are then adjusted so that their sum equals 1200, or twelve times an average monthly index, considered as 100 and representing the traffic for an average of twelve months The twelve adjusted median monthly ratios, when plotted consecutively on a graph, constitute a type of "monthly traffic pattern "

2 Monthly vehicular traffic patterns of different facilities, even those in close proximity to each other, differ so widely in both shape and amplitude as to preclude the usual implicit assumption of interchangeability of patterns among different facilities

Note on Figure 1, which shows the monthly patterns of vehicular traffic for twelve American crossings and one in Europe, expressed in percentages of the average monthly volume, that:

(a) The shapes and amplitudes of the patterns very widely
(b) The maximum variations occur in the highest (July or August) and the lowest (February) monthly indexes
(c) The minimum variations occur in the May, June, September and October indexes
(d) The median May and October indexes are closest to the average month

Note on Figure 2 that the patterns of the five Port Authority crossings, all located in metropolitan New York also vary widely in both shape and amplitude

Figure 3 shows the patterns of three groups of New York toll crossings These groups include ferries, bridges and the Holland Tunnel, and the individual crossings of each group serve the same general areas Despite the grouping of

traffic volumes, note that the patterns still vary in both shape and amplitude

Differences in ratios among different facilities being smallest in the months of May, June, September and October, these ratios, "borrowed" from one facility mates which are considered unreliable unless positive tests are made which indicate that the patterns selected are similar within the desired limits of error

By careful analysis of the environmental factors of any given facility, it is possible, in some instances, to "borrow"

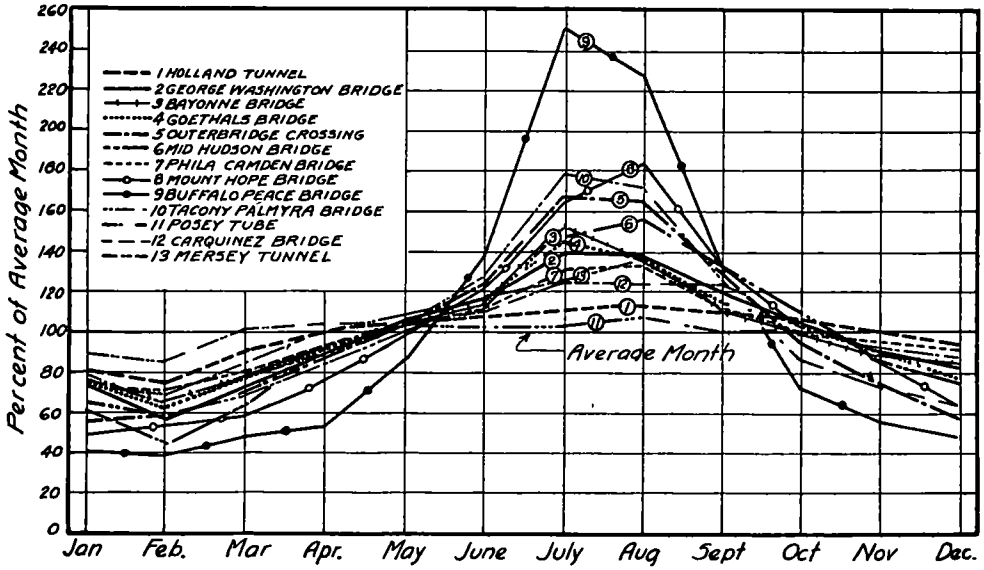

Figure 1. Monthly Patterns of Vehicular Traffic for Selected Facilities

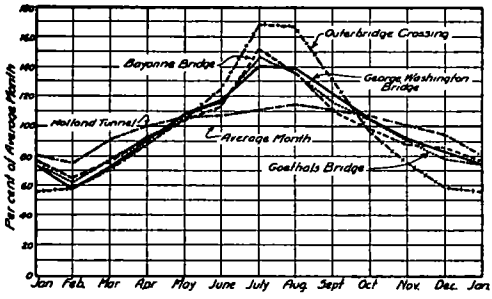

Figure 2. Seasonal Patterns of Vehicular Traffic for Port Authority Crossings

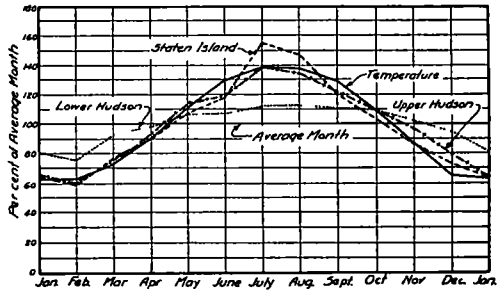

Figure 3 Median Monthly Indexes of Vehicular Traffic for Groups of Crossings, and Temperatures in the New York District

and applied to the corresponding traffic volumes of another, whose pattern is undetermined, will usually yield fair estimates of annual traffic "Borrowed" ratios for any one of the other eight months, if applied to corresponding monthly traffic volumes, will yield estipatterns which may be expected to be similar A quantitative test should be made, however, if possible, to confirm the probable similarity of the patterns by comparing the traffic of the two facilities for similar periods in different seasons of the year.

3 Monthly patterns of any individual or related group of crossings are generally stable, maintaining the same shape and amplitude from year to year, except that they are radically disturbed when new bridges, tunnels or ferries are opened, which serve as alternative routes

Note in Figure 4 how the 1931 pattern for upper Hudson River crossings is radically altered by the opening of the George Washington Bridge in October of that year Note, also, that after the disturbances, the pattern resumed its characteristic shape and amplitude

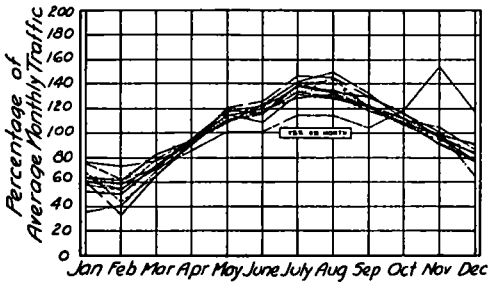

Figure 4. Seasonal Traffic Patterns for Upper Hudson River Crossings for the Years 1925–1935

4 By applying to any single month's traffic of any crossing or group of crossings the corresponding median monthly ratio, derived from its own monthly traffic volumes for a period of years, an average monthly volume is obtained which, when multiplied by twelve, yields an approximation of the annual volume

If based on the spring, summer and autumn months with no allowance made for other factors affecting traffic volume, such approximations should not be expected to be more accurate than within 10 percent, if based on December, January or February, with their wide variations in winter traffic caused by weather conditions, a much larger error should be anticipated

Figure 5 shows the median monthly indexes and standard and maximum deviations above and below the medians for the period for which data are available, excluding years when patterns were radically disturbed The deviations expressed as percentages of the medians reflect the error which might be expected in estimates of annual traffic based on any one month Note that the larger deviations occur in December, January, February and March, also that the

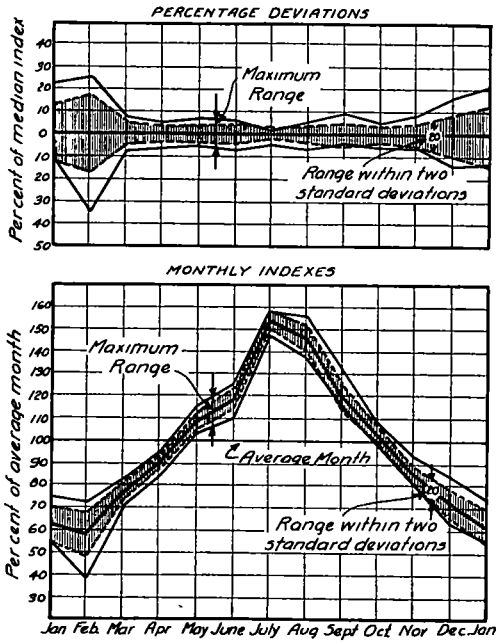

Figure 5 Median Monthly Indexes and Maximum and Standard Deviations for Lower Hudson River Crossings Vehicular Traffic.

months of April, May and October were months of minimum variation

5 Year-to-year variations in the monthly ratios of any one facility or group of facilities considered as one, may arise from the following causes·

(a) Changes in the number of weekdays and week-ends in the same month in different years

(b) Changes in the incidences of holidays on different days of the week in the same month of different years

(c) Changes in the composition of traffic by types of vehicles (passenger cars, trucks, buses, etc) as among different months
(d) Changes in the trend of traffic
(e) Opening of new alternative routes

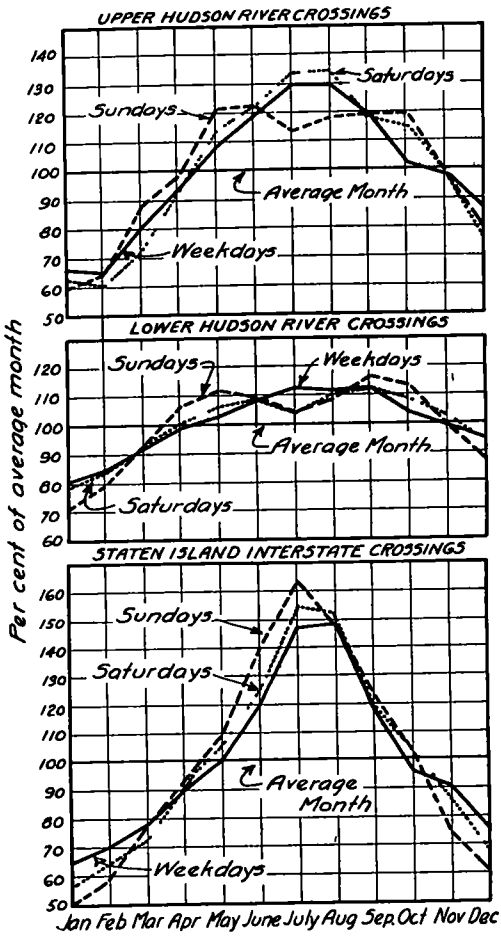

Figure 6 Seasonal Patterns for Groups of New York Crossings for Weekdays, Saturdays and Sundays.

(f) Changes in tolls on competitive crossings
(g) Changes in economic conditions
(h) Changes in weather conditions in the same month in different years

For toll crossings, where records of daily traffic by types of vehicles are available, it is possible, to some extent, to allow for the above effects and thus improve estimates of current annual traffic

6 The use of monthly average-week indexes will tend to improve annual estimates, by allowing for differences in the incidences of weekdays and week-ends in the same month in different years

7 The use of four sets of monthly indexes, (a) weekday, Monday to Friday, (b) Saturday, (c) Sunday, and (d) holiday, is recommended for preparing accurate annual estimates

Such indexes, allow for differences in the incidences of weekdays, week-ends and holidays in the same months of different years They permit weekday volumes to be estimated more accurately than the more variable and speculative week-end and holiday traffic volumes, where the largest errors are confined

Each of the four parts of the annual traffic volume differs radically from the others in regard to (a) the proportion of recreation or business traffic (b) the composition of traffic by types of vehicles, and (c) geographical distribution

Patterns for weekdays, Saturdays and Sundays usually differ considerably from each other Note on Figure 6 the differences in the patterns for weekdays, Saturdays and Sundays for the three groups of New York crossings previously mentioned On the patterns of the lower Hudson River crossings it will be seen that the effect of the summer vacation exodus is to make Sunday and Saturday ratios lower in summer, than in spring and autumn On the other hand, the effect of the summer beach traffic on the ratios of the Staten Island crossings is to expand summer Sunday and Saturday ratios much more than weekday ratios Again, Saturday patterns on some crossings follow the weekday patterns and on others the Sunday patterns As the five-day week becomes more

widely adopted by business and industry, the Saturday patterns will probably tend to follow the Sunday patterns more closely

Then, too, travel habits on week-ends have been found to change in many respects, from time to time, whereas those on weekdays have been fairly stable Observe on Figure 7, which shows the Holland Tunnel monthly patterns for weekdays and Saturdays, for each of a series of years, that the Saturday patterns are much more variable than are

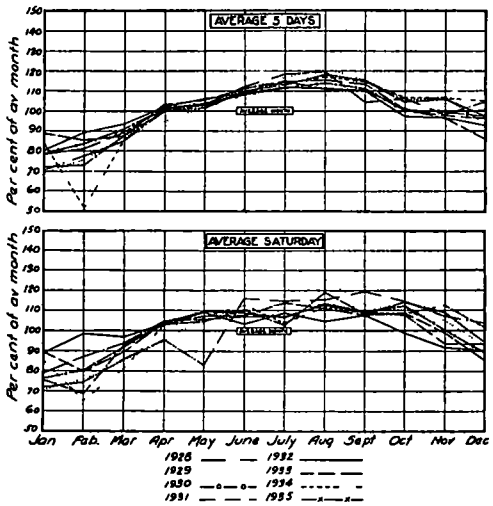

Figure 7 Holland Tunnel Seasonal Patterns for Weekdays and Saturdays

the patterns for an average weekday, average of five days, (Monday to Friday)

8 The shapes and amplitudes of monthly patterns of passenger car traffic differ radically from those of trucks and buses Consequently in preparing estimates of annual traffic of a given facility where its own monthly patterns are used, allowance should be made for appreciable changes in the composition of traffic Figure 8 shows the trends of the composition of traffic of three Port Authority crossings Note that truck traffic in the last five years has been increasing faster than passenger car traffic, and consequently the percentage of truck traffic, on some facilities, doubled between 1931 and 1935

Where the pattern has been "borrowed," allowance should be made for

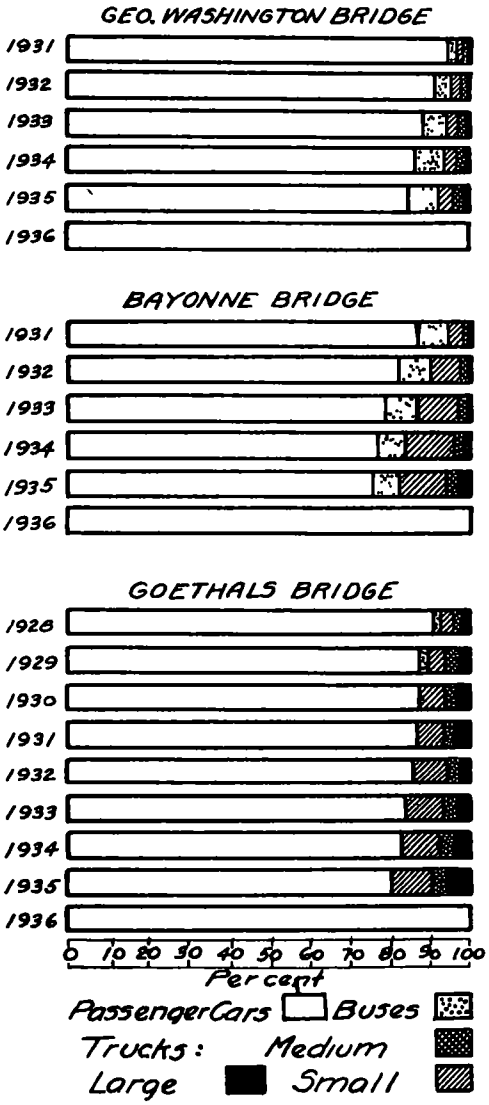

Figure 8. Annual Type Distribution of Vehicular Traffic for Three Port Authority Crossings.

appreciable differences in the composition of traffic of the two facilities.

Note on Figure 9 that truck and bus

patterns are usually much flatter than passenger car patterns, as might be expected, that bus traffic patterns, though flatter, resemble, more or less, the shape of passenger car patterns, and

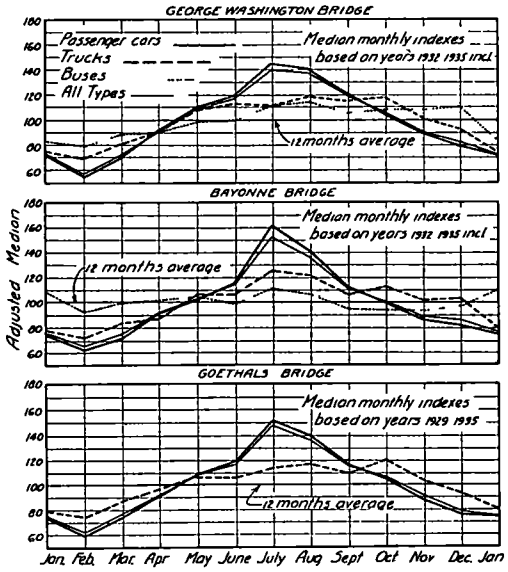

Figure 9. Monthly Vehicular Traffic Patterns for Passenger Cars, Trucks and Buses Crossing Port Authority Facilities.

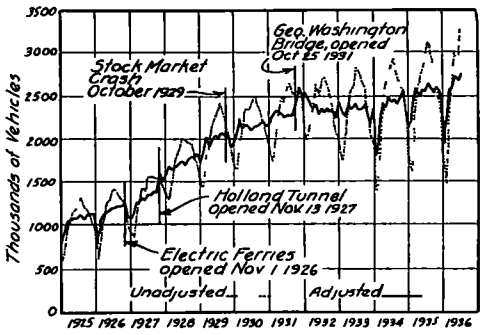

Figure 10. Seasonally Adjusted and Unadjusted Monthly Vehicular Traffic for All Hudson River Crossings.

that peak passenger car traffic occurs in the summer, while peak truck traffic usually occurs in the autumn.

9 Where the traffic of a given facility has been expanding or contracting appreciably for a number of years, monthly indexes derived from its traffic for such periods should be corrected for the influence of annual trend So corrected, monthly indexes reflect variations in traffic attributable to seasonality only

Any month's traffic volume adjusted by such an index, produces an average monthly "level" free from the effects of seasonality This "level" does, nevertheless, still reflect other major factors which affect traffic volume and for which allowance must be made

If such monthly "levels" be plotted over a sufficient period of time such factors as (a) current traffic trends, (b) effects of major economic changes, (c) effects of opening of alternative crossings, (d) changes in tolls on competitive crossings, (e) "generation" of traffic, and (f) effects of abnormal weather conditions will be brought out in bold relief

Thus Figure 10 shows the monthly traffic volume as recorded, and as adjusted for seasonality, for all Hudson River crossings between the the Battery, Manhattan and Tarrytown, N Y The latter were obtained by the application of median monthly indexes, corrected for annual trends, to the recorded monthly traffic volumes of the upper and lower Hudson River crossings, in two groups separately, because of their radically different patterns, and by summing their adjusted monthly volumes A number of interesting facts are revealed in this chart:

(a) The seasonally adjusted curve shows the current average month-to-month "level" of traffic and the current month-to-month trend
(b) When the Holland Tunnel was opened in November, 1927, the then current "levels" of traffic rose sharply to higher "levels" and then continued to rise
(c) In the latter part of 1929, following the stock market "crash," the then current month-to-month

upward trend of trans-Hudson traffic slowed down somewhat

(d) When the George Washington Bridge was opened in October 1931, the "curiosity" traffic temporarily raised the monthly "level" of trans-Hudson traffic

(e) During 1932 and 1933, the "level" of trans-Hudson traffic rose only slightly until the early part of 1934, when a more distinctive upward trend was resumed

(f) In 1934, 1935 and 1936, years of severe winter weather conditions, the February traffic "levels" dropped sharply

10 Monthly "levels" of traffic, if correlated with monthly economic indexes, may indicate how the traffic of a given facility is affected by local economic conditions In this way allowance in estimates of annual traffic may be made, for the effects of the economic cycle

A few correlations may be observed on Figure 11 which shows graphs of (a) monthly "levels" of trans-Hudson vehicular traffic, (b) the percentage share of Holland Tunnel and George Washington Bridge, combined, of all Hudson River crossings traffic since 1932, (c) the Holland Tunnel's percentage share of the lower Hudson River crossings traffic, (d) seasonally adjusted monthly sales indexes of department stores in the New York metropolitan district, and (e) payrolls in New York City It will be seen from the separate graphs on Figure 11 that, while payrolls and department store sales in New York City began to fall off in the last month of 1929, the "level" of trans-Hudson traffic continued to rise, only slightly abating its upward trend In 1932, while payrolls and department store sales were dropping to their lowest "levels," trans-Hudson traffic, after dropping from the higher "levels" reached as a result of the "curiosity" traffic created by the opening of the George Washington Bridge on October 25, 1931, continued to rise gradually In 1933, when these two economic indexes turned abruptly upward, trans-Hudson traffic also showed signs of a turn to higher "levels" From 1934 on, as these two economic indexes continued to rise, trans-Hudson traffic "levels" turned more sharply upward to approach their pre-depression "levels"

While trans-Hudson traffic "levels" were going through these various changes, the Holland Tunnel's proportion of the

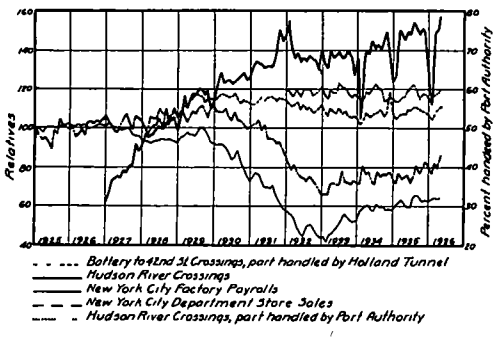

Figure 11. Hudson River Crossings Traffic versus Economic Data and Port Authority Facilities' Share of Hudson River Crossings Traffic Expressed in Relatives, Seasonally Adjusted.

lower Hudson River crossings' traffic and the proportion of the total Hudson River crossings' traffic moving via Holland Tunnel and George Washington Bridge also were going through significant changes Whereas, total trans-Hudson crossings' traffic "levels" continued to rise after the stock market "crash" of October, 1929, Holland Tunnel's proportion started to fall off at once and continued to fall until early in 1934 When the traffic trend turned sharply upward in 1934, both the Holland Tunnel's proportion of lower Hudson River crossings' traffic and the proportion of total trans-Hudson traffic, served by bridge and tunnel, began to rise once more

This comparative analysis of purchas-

ing power, trade and traffic figures leads to the following generalizations:

(a) During an economic depression, when purchasing power contracts, and retail trade declines, demand for motor vehicle transportation for business and recreational purposes is closely limited by financial considerations Nevertheless, there is a minimum transportation demand which, because of the basic necessities of business traffic, must be satisfied Thus, the purchase of a new automobile may be postponed, but the use of the old one must continue in order to get to and from business, despite its lessened activity Moreover, smaller truckloads for a decreased business volume, in some instances, may necessitate increases in the number of trips

(b) Trans-Hudson motorists, affected by the economic depression, reduced to some extent their trips for recreation On business trips, however, they maintained their travel but shifted, when possible, to the less expensive crossings These two factors caused the proportion of traffic accommodated by the more expensive bridge and tunnel to fall off temporarily When business began to recover and time savings increased in value, motorists increased their use of bridge and tunnel which provide the faster, safer and more convenient river crossings

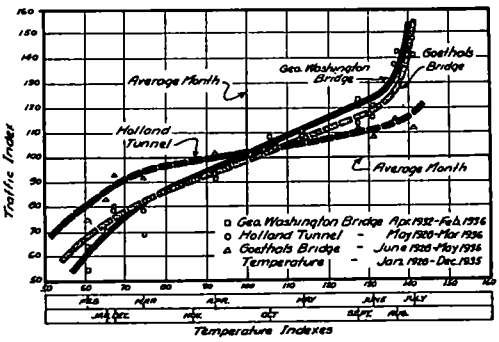

Figure 12 Median Monthly Traffic Indexes versus Temperature Indexes for Three Port Authority Facilities.

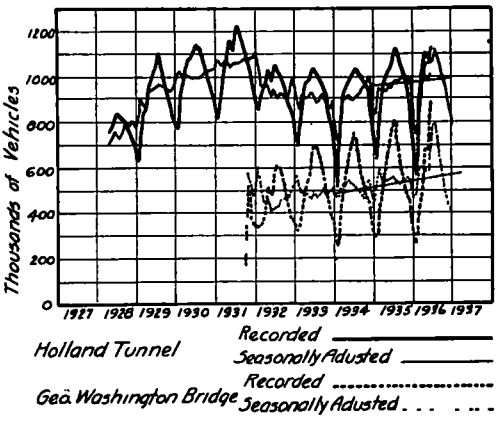

Figure 13 Recorded and Seasonally Adjusted Monthly Vehicular Traffic for Holland Tunnel and George Washington Bridge.

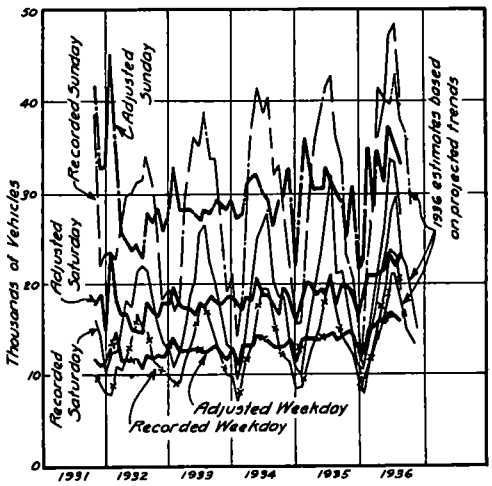

Figure 14. Recorded and Seasonally Adjusted Monthly Average Weekday, Saturday, and Sunday Vehicular Traffic for George Washington Bridge.

11 As far as its effect on traffic is concerned, weather manifests itself in two ways, (a) in determining, in part at least, the monthly traffic cycle, and (b) in diminishing or augmenting traffic on specific days

If relationships could be established between the mean monthly temperatures and monthly traffic cycles (see Figure 12), they might be utilized in determining the monthly patterns of highway facilities on the basis of minimum samples Also, if the effects of other factors on seasonally adjusted monthly, weekday, Saturday and Sunday traffic "levels" could be determined quantitatively, the effects of waether on traffic of specific days could be established

12 If, on the basis of the recorded traffic volume for one month, it is desired to estimate the annual traffic volume of a given facility, the recorded monthly volume, or the monthly weekday, Saturday and Sunday volumes, are first adjusted to monthly "levels," with the aid of one, or a set of three monthly indexes If the "levels" so derived are considered to be average or constant for the year for which the estimate is desired, then the annual volume may be readily computed If, however, traffic "levels" are considered as rising or falling, then the trend of these "levels" must first be estimated before an estimate of the annual volume can be accurately determined

13 Where continuous monthly traffic records are available and the monthly volumes may be seasonally adjusted by means of monthly indexes corrected for annual trends, the resulting series of monthly "levels" will indicate the current traffic trend, and to some extent will point to the future A projection of monthly "levels" into the twelve months for which an annual estimate is desired, if adjusted by monthly indexes, will produce a more accurate basis for an estimate of the traffic volume for the desired twelve-month period.

Thus Figure 13, which shows monthly traffic volume for the Holland Tunnel and George Washington Bridge, as recorded, and as seasonally adjusted, illustrates how current monthly "levels" indicate month-to-month trends It also shows how the trends of "levels" in 1935 were projected into 1936 and, with the aid of monthly indexes, monthly traffic volumes for 1936 estimated These estimates are shown on the chart, together with recorded traffic for part of 1936

Figure 14 shows separately the monthly weekday, Saturday and Sunday traffic volumes of the George Washington Bridge, and indicates separately the current trends of these three types of days .It also shows how the trend of these "levels" was projected into 1936 and, with the aid of monthly, weekday, Saturday and Sunday indexes, the corresponding monthly volumes for 1936 estimated These estimates are shown on the chart, together with recorded traffic to date

SUMMARY OF ANALYSES OF DAILY VEHICULAR PATTERNS

Methods of estimating annual traffic developed through analyses of monthly patterns were predicated on traffic volumes for at least one complete month Analyses of daily patterns were made with the view of developing methods of estimating monthly traffic volumes based on the traffic for part of a month, by taking advantage of the regularity of seven-day cycles

Characteristic daily patterns of the traffic volumes of individual crossings are constructed by expressing their daily traffic volume as ratios to the average weekday (Monday to Friday) volumes Such ratios, yield the characteristic graph termed a "daily traffic pattern "

Figure 15 shows "daily patterns" of each of the five Port Authority crossings and three selected Hudson River ferries in the port of New York. Detailed

analyses of such patterns yield, among others, the conclusions which follow.

1 As among different facilities, week-end traffic volumes bear no fixed or even fairly constant ratios to weekday volumes Consequently Saturday and Sunday volumes must always be established independently of weekday volume counts

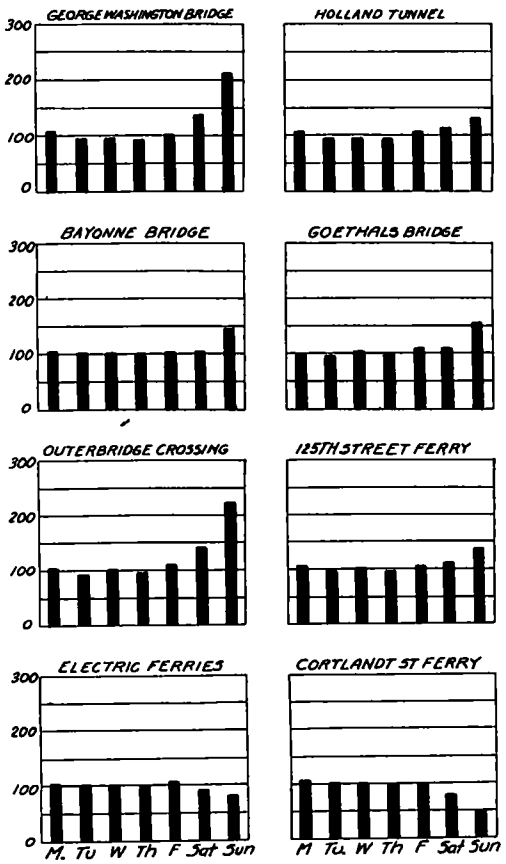

Figure 15 Daily Vehicular Traffic for Eight Selected Crossings. Based on Annual 1935 Traffic, expressed in Percentages of the Monday to Friday Average Considered as 100%.

2 The variations among the traffic volumes of the five separate weekdays is small and may therefore be generally expressed in percentage of an average Monday to Friday weekday, by the following five ratios

Monday	Tuesday	Wednesday	Thursday	Friday	Average of Five Weekdays
104	95	100	96	105	100

If applied to the annual, average volume on any one of the five weekdays, these ratios will yield an estimate of the annual average weekday (Monday to Friday) within a probable maximum error of 5 percent

If applied to the average traffic on the four or five Wednesdays or Thursdays in any month, they will yield an estimate of the monthly average weekday (Monday to Friday) within a probable maximum error of 10 percent

If applied to the monthly average traffic on four or five of any of the other weekdays, they will yield an estimate of the monthly average weekday within a probable maximum error of 15 percent

3 The average of the daily traffic volumes counted on the second and third Wednesdays, Saturdays or Sundays in any month, excluding holidays and days before and after holidays, will usually approximate the corresponding monthly averages within a probable maximum error of 10 percent

4 The traffic of one Wednesday or one Saturday about the middle of any month will usually approximate an average weekday or Saturday for that month, within a probable maximum error of 20 percent

Traffic on one Sunday about the middle of any month will probably vary from the average Sunday traffic in that month by 50 percent or more

SUMMARY OF ANALYSES OF HOURLY VEHICULAR TRAFFIC PATTERNS

There are few free highway facilities for which extensive daily traffic counts are available and still fewer for which the daily traffic has been segregated for the

24 hours so that hourly patterns may be constructed from the data Such data are practically limited to toll bridges and tunnels, and here and there for free bridges and important highway intersections On the other hand there are numerous short-period counts made at different times of the year and in different years on all types of highways Almost invariably these have been stepped up to 24-hour periods by means of "borrowed" hourly patterns

To determine how accurately such stepped up counts represent 24-hour daily traffic, hourly patterns were constructed and analyzed for a number of facilities from the ratios of the traffic on each of 24 hours to their average traffic for 24 hours The hourly patterns of different facilities were first compared, and then those of a single facility for different days and in different seasons Percentages of 24-hour traffic in periods of twelve hours were also computed for a number of different facilities and were compared, first among different facilities and then for the same facility at different times in the year and for a series of years For this purpose hourly data were available for 21 facilities, 5 Port Authority interstate (New York-New Jersey) crossings, 4 East River bridges and 8 Harlem River bridges in New York City, the Victory Bridge and Pulaski Skyway in New Jersey, the Sumner Tunnel in Boston, and the George A Posey Tube in Alameda, California

Similar comparisons will eventually be made of percentages of 24-hour traffic moving in six, three, and one-hour periods

Analyses of hourly patterns yield, among others, the following conclusions of interest.

1 Hourly patterns of different facilities differ widely enough to suggest the necessity for determining, for every important facility, and from its own 24-hour traffic counts, one or more hourly patterns, rather than depend blindly on "borrowed" patterns to step up its short-period counts

Figure 16 shows the variations in hourly patterns for the traffic in each direction, into and out of the business districts tributary to the Holland Tunnel, George Washington Bridge, Queensborough Bridge and Manhattan Bridge, all in New York, the Sumner Tunnel in Boston, and the Posey Tube in Alameda, California

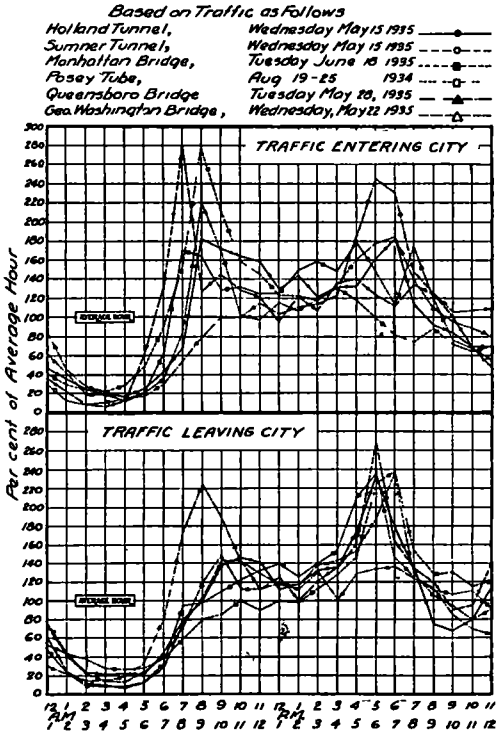

Figure 16 Hourly Vehicular Traffic Patterns for Selected Facilities

An examination of Figure 16 indicates that while the general shapes of the hourly patterns of these facilities tend to be similar, especially those for traffic leaving the city, nevertheless there are also

significant differences The peak-hour traffic leaving the city usually occurs between 5 and 6 P M or 6 and 7 P M , and the peak-hour traffic entering the city between 7 and 8 A M or between 8 and 9 A M Note, however· (a) the differences between the patterns of the George Washington Bridge and the Holland Tunnel, two Hudson River crossings only ten miles apart; (b) the striking differences in the patterns of the Holland Tunnel and the Manhattan Bridge, only two miles apart, (c) the citybound traffic of the Boston Tunnel, which follows that of the Manhattan Bridge in New York more closely than the traffic of the latter follows that of the Holland Tunnel, only two miles away

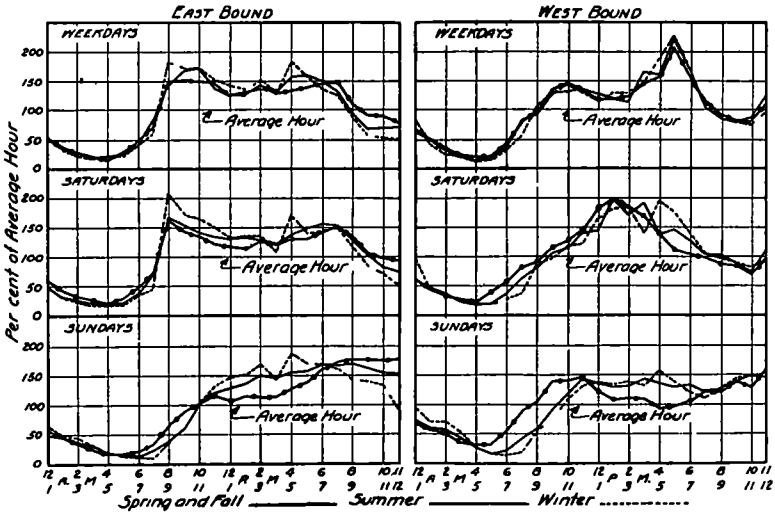

Figure 17. Standard Hourly Patterns for Holland Tunnel Vehicular Traffic Hourly Traffic Expressed in Percentage of the Average Traffic for 24 hours. Each Pattern Based on 6 typical days in 1931.

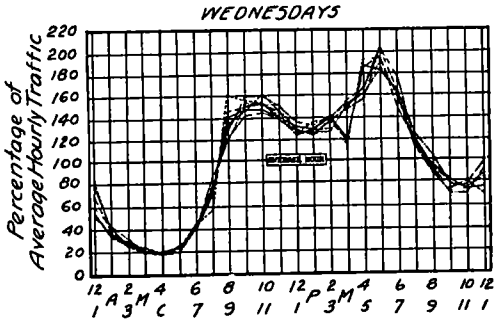

Figure 18 Holland Tunnel Hourly Traffic Patterns for Spring and Fall Seasons in each year 1928–1935. The pattern for each year is based on average of 6 typical days.

2 The hourly patterns for the traffic of a given facility differ radically as between weekdays and Sundays, and Saturday patterns resemble both, in parts In different seasons there are also significant differences but the seasonal differences are not as pronounced as those among weekdays, Saturdays and Sundays The widest seasonal differences occur in the Sunday patterns, the smallest in the weekday patterns, intermediate in the Saturday patterns See Figure 17

3 Over a period of years hourly patterns of any one facility for a specific type of day and season remain fairly stable See Figure 18

4 The percentages of the 24-hour traffic moving in the twelve hours, 7 A M to 7 P.M , on weekdays and Satur-

days, and from 8 A M to 8 P M on Sundays, were found to average as follows for 21 facilities

	Median Percentages of 24 hr	Maximum Deviation from Median Percentages
On weekdays	71	8 5
On Saturdays	67	5 2
On Sundays	64	10 6

The maximum variation from these percentages among the 21 facilities examined, was about 10 points above and below

5 It is desirable to establish twelve-hour percentages for weekdays, Saturdays and Sundays separately rather than to apply percentages determined on a weekday to estimate 24-hour traffic on Saturdays and Sundays Whereas the average differences between weekday, Saturday and Sunday twelve-hour percentages are only three or four points, on any individual facility, the twelve-hour percentages for Saturdays may be 10 points less than on weekdays, and for Sundays 20 points less

6 Twelve-hour percentages for traffic in each direction separately may differ by a maximum of 10 points on weekdays and Saturdays and 15 points on Sundays from corresponding percentages of traffic in both directions

7 Twelve-hour percentages of 24-hour weekday and Saturday traffic in any month would be within a maximum of 5 percent, and Sunday traffic within 10 percent, of an average percentage for the year (See Table 1)

8 Over a period of years twelve-hour percentages of 24-hour weekday and Saturday traffic have remained within a range of 5 points, and of Sunday traffic within a range of 10 points (See Table 2)

GENERAL RECOMMENDATIONS

Two specific applications of the results of these pattern studies will illustrate how they can be effectively utilized

Problem A Assume that no past traffic records are available and it is desired to prepare a fair estimate of the monthly and annual traffic volume of an important facility, with a minimum number of traffic counts, by taking advantage of the results thus far arrived at and set forth in this paper

If only annual volumes are desired, counts on six days in any one of the six spring and fall months should yield fair approximations if adjusted by proper indexes Thus, the annual traffic of the George Washington Bridge, for 1935, could have been estimated on the basis of two Wednesdays, two Saturdays and two Sundays in the middle of June, 1935, adjusted by its median June indexes, within an error of less than six percent

If monthly traffic volumes are necessary, these studies suggest that traffic counts be made in twelve-hour periods on six days of each month, namely—the two middle Wednesdays, Saturdays and Sundays, excluding holidays and days before and after holidays In the months of either May or October, 24-hour counts should be made to establish typical twelve-hour percentages Also, if possible, counts should be made on the ten or eleven, or at least the important, holidays of the year

In the following year, such counts could be limited to the six months of April, May, June, September, October and November, unless absolute peaks and low points also were desired

Problem B Assume a new toll crossing were opened in the middle of a year, specifically the Triboro Birdge, which opened on July 11, 1936 It is desired to estimate its traffic for the first year of its operation, on the basis of its September traffic, considered to be the first normal month

Divide its September traffic into weekdays, Saturdays, Sundays and the Labor

TABLE 1

PERCENTAGES OF 24 HOUR TRAFFIC MOVING IN 12 DAYLIGHT HOURS IN BOTH DIRECTIONS FOR HOLLAND TUNNEL, GEORGE WASHINGTON BRIDGE AND BAYONNE BRIDGE

	Wednesdays 7 A M to 7 P M			Saturdays 7 A M to 7 P M			Sundays 8 A M to 8 P M		
	Hol Tun	G W Bdge	Bay-onne Bdge	Hol Tun	G W Bdge	Bay-onne Bdge	Hol Tun	G W Bdge	Bay-onne Bdge
Jan	76 6	72 0	75 0	68 5	68 8	66 6	68 1	63 1	62 1
Feb	74 0	73 1	71 7	68 5	70 0	66 1	59 9	64 8	61 3
Mar	73 2	72 0	70 5	69 2	69 3	63 8	58 2	68 8	62 1
Apr	74 0	72 5	72 4	70 7	69 3	65 6	61 9	69 5	63 3
May	71 8	69 6	67 5	67 4	69 2	65 1	59 8	65 0	61 2
June	70 0	69 6	68 5	67 4	67 7	63 0	58 5	60 3	60 3
July	69 5	67 1	68 0	68 9	70 5	62 9	61 1	57 1	65 8
Aug	70 9	70 4	70 0	69 1	69 9	61 8	57 9	57 9	60 0
Sept	71 6	70 4	69 3	68 5	70 6	65 3	61 3	66 9	64 8
Oct	72 6	72 5	73 3	66 8	71 8	67 0	60 6	69 5	64 4
Nov	73 3	72 8	74 4	71 1	74 0	64 3	63 4	67 1	60 5
Dec	73 1	69 5	77 3	70 8	69 3	66 5	67 3	71 4	62 8
(a) Median	72 9	71 2	71 1	68 7	69 6	65 2	60 9	66 0	62 1
(b) Maximum	76 6	73 1	77 3	71 1	74 0	67 0	68 1	71 4	65 8
(c) Minimum	69 5	67 1	67 5	66 8	67 7	61 8	57 9	57 1	60 0
(d) Maximum Deviation from Median	3 7	4 1	6 2	2 4	4 6	3 4	7 2	6 9	3 7
(e) Percentage Deviation from Median	5 1	5 8	8 7	3 5	6 6	5 2	11 8	10 5	6 0

Prepared with the assistance of U S Works Progress Administration, Project 65-97-139
The Port of New York Authority, Bureau of Commerce, N Cherniack, Analyst

TABLE 2

PERCENTAGES OF 24 HOUR TRAFFIC MOVING IN 12 DAYLIGHT HOURS IN BOTH DIRECTIONS ON ONE WEDNESDAY, SATURDAY AND SUNDAY IN MAY OF EACH YEAR

	Holland Tunnel				George Washington Bdge				Bayonne Bridge			
	Dates in May	Wed 7 A M to 7 P M	Sat 7 A M to 7 P M	Sun 8 A M to 8 P M	Dates in May	Wed 7 A M to 7 P M	Sat 7 A M to 7 P M	Sun 8 A M to 8 P M	Dates in May	Wed 7 A M t 7 P	Sat 7 A M to 7 P M	Sun 8 A M to 8 P M
1928	16-12-13	69 4	67 7	65 0								
1929	15-11-12	66 8	67 3	68 0	Opened Oct 25, 1931				Opened Nov 15, 1931			
1930	21-10-11	70 0	67 0	61 5								
1931	20-16-17	69 5	68 5	60 7								
1932	18-14-15	71 5	67 9	61 8	18-14-15	66 1	67 8	69 8	18-14-15	67 6	64 8	70 8
1933	17-13-14	70 2	69 0	61 6	17-20-21	68 8	69 8	65 5	17-20-21	72 5	68 5	65 3
1934	16-12-13	71 2	68 3	60 3	16-12-13	71 0	68 6	65 7	16-12-13	70 6	63 9	65 7
1935	22-18-19	73 5	67 4	59 8	22-18-19	69 6	69 2	65 0	15-18-19	67 5	65 1	61 2
Minimum		66 8	67 0	59 8		66 1	67 8	65 0		67 5	63 9	61 2
Maximum		73 5	69 0	65 0		71 0	69 8	69 8		72 5	68 5	70 8
Range		6 7	2 0	5 2		4 9	2 0	4 8		5 0	4 6	9 8

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Day holiday, and compute the corresponding averages for the month.

The indexes for The George Washington Bridge, being in close proximity and tapping the same and similar areas with respect to character of population, industry, etc., would approximate those of the Triboro Bridge.

Based on this assumption, the September weekday, Saturday and Sunday average volumes are adjusted to corresponding annual averages, and the annual total volumes computed therefrom by multiplying by the proper number of weekdays, Saturdays and Sundays. Holidays are estimated on the basis of the George Washington Bridge experience.

Also, since September represents the middle month of a year ending in March, 1937, and the first year of operation of the Triboro Bridge would end July 10, 1937, an adjustment is made for the proportional part of the annual growth. George Washington Bridge experience of the separate annual trends of weekday, Saturday and Sunday traffic is utilized, and the annual volume is further adjusted to reflect these trends.

By this method an estimate of an annual volume of 8,600,000 vehicles is arrived at. The actual volume will be known on July 11, 1937.

DISCUSSION ON ESTIMATING TRAFFIC VOLUME

MR. A. G. SIEGLE, *U. S. Bureau of Public Roads: Use of Automatic Traffic Recorders in Providing Data for Determining Relative Precision of Various Methods of Sampling Traffic.* In the Highway Planning Survey program now being conducted by forty of the States in cooperation with the Bureau of Public Roads, continuous records by hours of the flow of traffic are being obtained at approximately 300 points throughout the country by means of automatic traffic counting and recording machines. The counting mechanism is actuated when two parallel beams of light directed across the roadway upon photoelectric cells are intercepted by a passing vehicle. Pedestrians will not actuate the counter because they intercept only one beam at a time. Duplicate counts which could be caused by the beams passing between the body of a vehicle and protruding equipment such as trunks, spare tires, et cetera, are avoided by installing the equipment so that the light beams are at approximately a 23 degree skew with the road. Once each hour, on the hour, the recording mechanism prints the day, hour, minute, and cumulative counter reading on standard adding machine tape. Tests have shown the equipment to be generally accurate within two percent. It is sufficiently sensitive to count and record the passing of a maximum of 24,000 objects per hour, and the printing operation is timed with the same precision that a second hand of a high grade electric clock indicates the correct second.

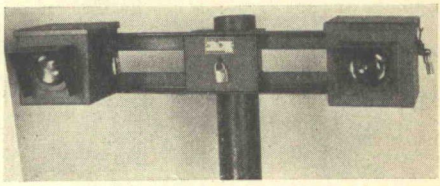

Figure 1. Light Source

In selecting sites for the installation of this equipment, the States have attempted to choose locations so that the patterns which will be developed from the records will be distinctive and yet representative of a certain type of traffic. Traffic densities at the installations are expected to vary from a minimum of approximately 100 vehicles per day to a maximum of more than 10,000 vehicles

per day. It is expected that the traffic patterns developed from these records will be so diversified that it will be possible to select one which will be representative of the traffic flow on any road that might be chosen at random throughout the country.

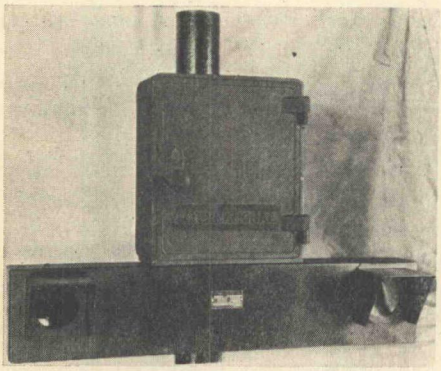

Figure 2. Recorder and Light Receiver

over the George Washington Bridge indicates that within certain limits a schedule for sampling traffic requiring a decrease in the length of each observation, or watch, and an increase in the number of observations, will result in greater precision at the same cost or the same precision at less cost. Theoretically, this theory should apply to any condition. However, if further analysis shows that there is a definite advantage in using a greater number of short watches regardless of the degree of variations or the density of traffic, conclusive evidence will be obtained showing that the theory can be generally applied. The records provided by the automatic traffic recorders will provide a basis for such an analysis.

Mr. Shelton's analysis has also indicated that the length of watch might be reduced to less than one hour. A special

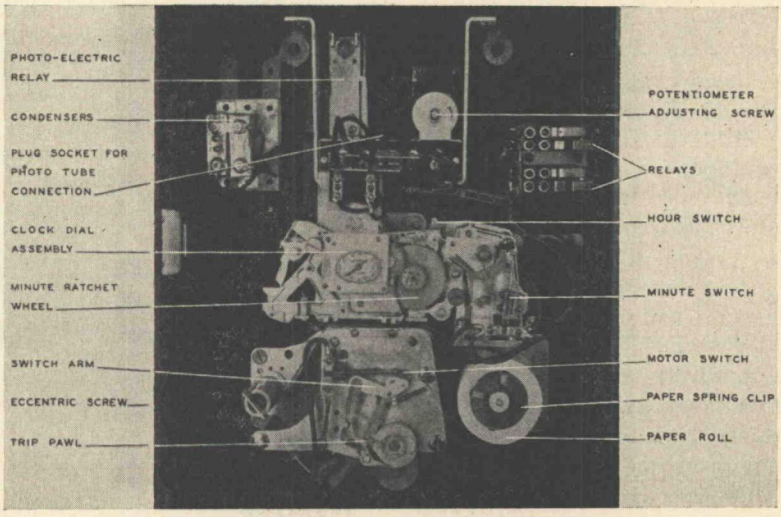

Figure 3. Recording Mechanism

One of the purposes of installing these machines in the planning surveys is to provide data which can be used as a basis for analyzing various schedules for sampling traffic. Mr. Shelton's analysis of the hourly records of the flow of traffic through the Holland Tunnel and

research program has therefore been planned, in which three automatic traffic recorders have been equipped to print the time and the cumulative counter reading at intervals of five minutes. Sites for these machines will be selected in the vicinity of Washington at three locations

where traffic densities and traffic characteristics are quite distinctive From the data provided by these machines, records of traffic may be built up for ten minute, fifteen minute, half hour, or other periods for the purpose of analyzing any schedule suggested to obtain its relative precision

MR T R KENDALL I have heard certain people make what seemed to be excessive claims for automatic counting of traffic in endeavoring to apply these counts to city streets My feeling is that there would be too much interference of traffic on city streets which would introduce such a large error that it would almost throw out that method of counting I should like to ask Mr Siegle if he has had any experience on this point

MR SIEGLE The only experience we have had with a machine installed in the city is with the one on L Street in front of our building The error of this machine normally does not exceed 3 per cent It is located where the line of standing vehicles sometimes backs up due to a traffic light at the corner

MR KENDALL· Is traffic backed up in both directions?

MR SIEGLE: Yes This 3 percent error only applies to an 8-hour period If a check were made for a short period there would be a considerably larger error The machine I have referred to is merely an experimental installation At the present time we consider our main use of these machines to be on rural roads Incidentally, L Street, where the machine is installed, is a 3-lane street Parking in one lane restricts moving vehicles to 2 lanes

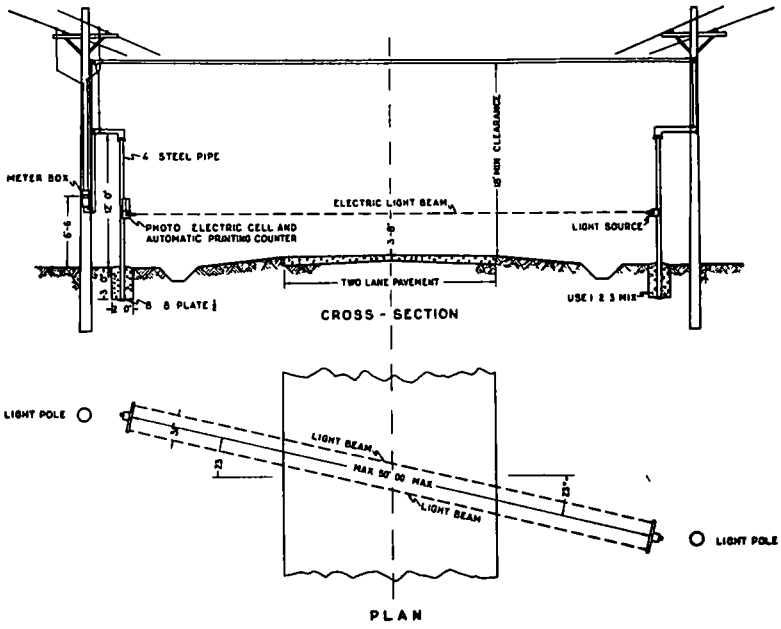

Figure 4. Proposed Layout of Automatic Traffic-Counter Installation

PROF N W DOUGHERTY, *University of Tennessee*· It is important at the present time, when a large number of the states are engaged in highway planning surveys, to know how to use small

samples of traffic to determine probable maximum and annual flow Most of the states have set up counting schedules that give samples on from 1 to 14 days during the year The 14 day schedule makes an 8 hour count at intervals of 26 days throughout the year, thus giving two samples on each day of the week at regular seasonal intervals throughout the year

TABLE 1

SERIES OF SCHEDULES OVER PERIOD OF YEARS FOR ONE STATION

	Days			Total Vehicles
	12	24	36	
1930	5 7	4 1	3 2	355
1931	4 9	3 4	2 8	323
1932	4 4	3 6	2 6	272
1933	3 7	2 7	1 8	293
	4 7	3 5	2 6	Composite

SCHEDULES AT 26 DAY INTERVALS

Days			Sta
14	28	42	
3 9	2 6	2 1	1
4 1	2 3	1 6	2
4 5	3 1	1 7	3
5 1	4 6	1 9	4
4 4	3 3	1 9	Composite

We have applied the master counting schedule to annual cycles of toll bridge collections and have determined the accuracy of the results We have also applied various seasonal schedules to the same basic data with results given in Table I

The first series of computations were made by seniors of last year as thesis studies Some of the schedules were arbitrarily chosen and others were by sequence of days of the week chosen at intervals during the year For example, one schedule might be first Monday in January, second Tuesday in February, third Wednesday in March, etc

In the second series of schedules the counts were made according to the master schedule of the Tennessee State Highway Department using twenty-six day intervals and making fourteen counts during the year

Seasonal patterns may be used to determine average flow from short time counts but the results will vary through a wide range of values Fortunately, for design, the densities do not have to be very accurate Previous reports of the Traffic Committee show wide ranges of capacities for two, three and four lane highways