Georgia’s Program for Automated Acquisition And Analysis of Traffic-Count Data

EMORY C. PARRISH, EDWYN D. PETERSON, and RAY THRELKELD
State Highway Department of Georgia, Atlanta

*THE measurement of traffic flow on Georgia’s highways provides basic data that are prerequisite to virtually all highway planning processes. The collection, processing and analysis of flow data constitute one of the major functions of the Division of Highway Planning, thus efficient and economical methods are essential. Because of the digital composition of traffic-flow data, the electronic computer has, of necessity, come to play an ever increasing role in the development of modern, large-scale traffic-counting and analysis programs. Georgia is currently experimenting with an expanded use of the computer to monitor and control a system of automatically collecting data accumulated at remote continuous-count station locations.

The automatic traffic data telemetry system uses a centrally located computer connected by telephone equipment to an electrical read-out counter at each remote location. The remote locations are automatically polled according to a predetermined schedule. Through the execution of a stored computer program, data are collected, edited and recorded. After a year of testing, the system is proving superior to previously used methods of collecting continuous-count data.

In conjunction with the installation of the telemetry system, the entire traffic-counting program was redesigned according to current statistical techniques. These revisions were necessary in order to extract the desired advantage from a traffic-counting program oriented toward maximum utilization of the computer.

INTRODUCTION

The scope of Georgia’s pre-1964 program of traffic counting and analysis was largely dictated by economic limitations that could be directly attributed to the fact that the program was essentially oriented toward manual data-processing procedures. Any increase in the magnitude of the program would of necessity have resulted in a proportionate increase in the office staff.

The program included 28 continuous-count stations, 326 seasonal-control stations, embracing some 1493 count locations, and a program of coverage counting that included approximately 16,500 annual 24-hour weekday counts. The continuous-count segment of the program was already at least partially automated in that data produced by the stations were keypunched into data cards, thus allowing machine summary and analysis. Printed paper tapes containing hourly measurements of flow data were retrieved on routine weekly or biweekly service visitations. In spite of the rather high cost of such a procedure, some 13 percent of the count data was being lost due to equipment failures between service visits. Also, manual editing, coding and keypunch procedures proved to be slow and costly.

The 1493 locations in the seasonal control program were counted for one 24-hour weekday period during each calendar quarter. The results were manually summarized and posted directly on county maps. Whereas the quantity of counting locations assured widespread flow measurement on the state’s highway network, the amount of data obtained provided no more than a marginal sketch of seasonal behavior patterns and gave virtually no consideration to weekend traffic.

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Traffic at coverage-count locations was counted for one 24-hour period annually. Although the count locations were generally repetitive from one year to the next, they were not in any way identified for continuing administrative purposes. The total 24-hour counts were posted on the same maps containing seasonal-control data. The only routine occasion for adjusting coverage counts to estimates of annual average daily traffic (AADT) was for the rather broad purpose of preparing the annual state traffic flow map. The individual county maps on which basic seasonal-control and coverage data were posted were not easily reproducible; thus, the distribution of data to persons requiring its use was severely limited.

Because of the voluminous amount of statistical data produced by a statewide traffic-counting program, it became apparent that an effective program could be developed only after a complete redesign of procedures, and by utilizing the most advanced computer applications and more sophisticated statistical techniques. Methods for using statistical techniques to objectively design traffic-counting programs had, by 1964, progressed to the point where the U.S. Bureau of Public Roads could draw from previous research to develop firm procedural outlines. At about the same time, the development of procedures that would permit the automatic acquisition of continuous-count data was being considered.

The basic technique employed by the State Highway Department of Georgia to obtain traffic-count data through a remote acquisition system was first subjected to field experiment in 1963. At that time a trial was conducted by Southern Bell Telephone and Telegraph Company for the Tennessee Department of Highways in which one remote vehicle detecting station was located in the Nashville area and dialed manually from the Department's headquarters office. The count data were received from the remote detector and punched into cards by an IBM keypunch machine. It was not until mid-1964, however, that Southern Bell's Data-Phone system of communication was interfaced with an IBM computer to permit a completely automated system for the acquisition of continuous-count data.

AUTOMATIC ACQUISITION AND EDITING PROCEDURES

The Highway Department embarked into the experimental field of remote acquisition of traffic data in June 1965. After having witnessed a demonstration held in Chicago, Illinois, in August 1964 by IBM in cooperation with Southern Bell and Streeter-Amet Company, a fully automated system for the collection of traffic data seemed feasible.

An IBM 1710 real-time system, necessary for interruptible computer programming, was installed in the Division of Highway Planning. The system consisted of a Model I 1620 central processor, a 1622 card reader, two 1311 disk drives, a 1443 printer, a 1711 data converter containing a real-time clock, and two 1712 terminal units (Fig. 1).

Southern Bell installed an 801-C automatic dialing unit and a 401-J Data-Phone data set in the home office. At each of the continuous traffic-counting locations selected for these tests, a 401-H Data-Phone data set was also installed. Connection between the data processing center and each of the remote locations was established by using wide area telephone service (WATS).

The traffic counters were manufactured and installed by the Streeter-Amet Company. These counters, powered by a trickle-charged battery with a reserve power adequate for a minimum of 8 hours and a maximum of 36 hours of operation in the event of loss of AC power, have nondestructive read-out capability. Up to 10 counters, each of which recycle every 9999 impulses, may be installed at any remote traffic-counting location.

Four test sites were selected randomly from 28 traffic-counting stations which were in operation at that time. Several prerequisites guided these selections. It was stipulated that each station be located at varying distances from the home office and in areas of diverse climatic conditions. It was preferred to have one of the 4 stations in an area where telephone service was supplied by a relatively small independent utility. In addition, one trial station was to be located at a site where volumes are accumulated directionally.
Various types of traffic detectors were used. Two stations employed pneumatic road tubes, one station employed an overhead ultrasonic detector, and the fourth utilized a magnetic detector. At the time of this writing, however, one of the pneumatic tube detectors had been replaced by an induction loop and the only magnetic detector used in these tests had been replaced by a pneumatic tube.

Each counting device was installed at the roadside in a weatherproof housing, which also contained each station's respective 401-H data set.

General Method of Operation

The computer program, which governs the telephone dialing of the traffic-counting stations and storage of incoming data, had been written and tested by IBM at an earlier date. However, due to desired program modification and additional debugging, this program was not operational until July 1965. Other program alterations made since that time by the Georgia Highway Department enable the polling program to monitor the entire telemetry system.

A confederate program, which is automatically called into execution immediately after the 12 p.m. poll of traffic-counting stations, edits all traffic data collected the previous day and supplies any volumes which could not be obtained during the scheduled polls. As soon as the data are edited, it is added to a historic file from which any desired report relating to traffic volumes may be prepared.

The performance of these two programs is dependent on external interruptions of routine processing. Therefore, the 1710 system must be in the automatic and interruptible mode prior to the execution of the program. Any functional component of on-line hardware being in an interlocked status during the poll of counting stations may result in a program malfunction.
Each hundredth of an hour, an electrical impulse emitted by the 1711 data converter interrupts the main-line program currently being executed by the computer. This impulse compels a process branch to a predetermined location in core storage where instructions are stored to test programming interrupt indicators. If it is determined that the interrupt was produced by only the 0.01 hour indicator, control is returned to the main-line program with a loss of only 400 microseconds of processing time. If the program deduces that a valid external interrupt signifying a poll has occurred, the interrupted program residing in the first 20,000 positions of core storage is transferred to the monitor disk pack, and the polling program is read into core storage and the polling process commences.

To execute the poll, the program reads into core storage, from the on-line disk drive, the telephone number of the first counting station. A call request must be entered before the 801-C automatic calling unit (ACU) can be instructed to dial a digit. This is done by executing programmed instructions which close two contacts in the 1712-5 terminal unit (Fig. 2). This completes a circuit to the ACU which responds with a dial tone. The ACU, when ready for a digit to be presented for dialing, will emit an electrical impulse which turns on another process-branch indicator. The program, by
referring to an encoding table stored in core, then closes those contacts on the 1712-5 terminal unit necessary to command the ACU to dial the desired digit. These contacts and equivalent digits are shown in Figure 2. After each digit is presented to the 1712-5, another contact is closed to notify the ACU that the digit contacts have been set.

The program must then await an impulse generated by the ACU requesting the next digit. In this manner, the entire telephone number of the counting station is sequentially presented to the 801-C dialing unit. A 7-digit telephone number plus a 3-digit area code can be dialed in approximately one second.

As soon as all digits of the telephone number have been presented to the ACU through the 1712 terminal unit, the polling program is returned to the on-line disk pack, the interrupted program is read back into core storage and main-line processing is resumed. The 401-H data set at the roadside counting station, upon answering the call, transmits a 2,025-cps tune lead signal to the calling unit. The lead signal generates a second interrupt of main-line processing by impulsing its respective process branch indicator within the 1711 which again causes the polling program to be interchanged with the main-line program. Simultaneously, the remote 401-H data set has signaled the traffic accumulator to read out the current volume. This volume is relayed over the telephone facilities by the 401-H data set in parallel by bit, but serially by digit in the form of multi-frequency tones. These tones are detected by the 401-J data set in the computer center and converted to contact closures in the 1712-8 terminal unit. The digit which these parallel bits represent depends on their conversion within a 4 by 3 matrix. To facilitate decoding, the contacts associated with the three channelled dimension (B channels) of the matrix are wired directly to processing indicators, whereas the contacts associated with the four channelled dimension (A channels) are multiplexed and transmitted to a Digital Input Adapter in the 1711. This unit is designed to transmit digits in groups of four directly into four positions of core storage in 8-4-2-1 format, even though only one digit is significant in this case. The value of the transmitted digit can then be ascertained by programmed examination of the A channel digit in relation to the status of the processing indicators set by the B channel impulse. Four digits must be sequentially decoded to constitute a valid accumulated volume. The matrix and bit assignment of terminal points on the 1712-8 are shown in Figures 3 and 4.

If any counting station does not respond with a valid 4-digit volume when polled, a coded message is immediately typed defining the nature of the failure. The types of possible irregularities which have been programmed for detection are shown in Figure 5. In addition to monitoring hardware failures, each volume is immediately checked to ascertain whether or not the volume accumulated since the last poll is within expected tolerances. These tolerances, which are extracted from historical data, represent the square root of the average of the squares of a set of deviations about an arithmetic mean. These standard deviations have been calculated for every hour, day of week and month, before being stored on an on-line satellite disk drive (disk drive 1). The tolerance data for the current day are always stored with the associated telephone number for each counting station on disk drive 0. The 4-digit high and low tolerances for the current hour are replaced by the accumulated volume and time of reading after the tolerance tests have been made. These tolerance records are automatically updated at midnight of each day as the daily record of each counter is added to a historic file. This file is built on the same satellite disk drive on which the current monthly record of hourly tolerances has been stored.

As each station is called, an internal indicator is set if a valid volume is not received. After all counting stations have been called, any station for which an indicator has been set is recalled. No station is called more than twice during the same poll. The total machine time required to poll each station is approximately 4.5 sec. However, since 15 to 20 sec are required to make the connection with the counting station after the telephone call is placed, 20 to 25 sec are consumed in polling each station.

After all stations have been polled, the latest accumulated volume for each station is compared with the accumulated volume received during the two previous polls. If no change is apparent, the "check box" message shown in Figure 5 is typed. This test aids in detecting damaged detecting units which have ceased to impulse their associated accumulator.
Because the monitor disk on which the polling program and all current data are stored has limited storage capacity, each day's record of traffic volumes must be transferred to an auxiliary file. This is performed automatically after the completion of the 12 p.m. poll. At this time, the midnight program is brought into execution which edits the data collected the previous day. This edit entails the estimating of absent volumes, adjusting volumes for extra axles when necessary, and netting of each hour's accumulated total.

Two techniques are being employed to estimate the accumulated hourly volume at any station from which no reading was possible. If a successful poll was accomplished at the hour immediately prior to and after the hour, or hours, with missing volumes, the difference between the two accumulated readings is prorated in proportion to the midpoints of the tolerance ranges for the hours being estimated. For instance, had it been impossible to contact a counting station at 6, 7, and 8 p.m., but a reading had been successfully taken of 1500 at 5 p.m. and 1900 at 9 p.m., the actual difference of 400 counts would be prorated between 6, 7, 8, and 9 p.m. This would be done by accumulating the midpoints of the tolerance range of volumes for each hour and computing the percentage that each accumulated midpoint volume is of the total of the midpoint volumes for the 4 hours. This percentage is then applied to the actual accumulated volume of 400 to determine the estimated accumulated volumes to be recorded. This produces a realistic profile of hourly volumes for any given day and results in an unadjusted 24-hour total volume.

Figure 5. Description of telemetry messages.

![Figure 5. Description of telemetry messages.](image)

Figure 6. Monthly occurrence of no answers.

![Figure 6. Monthly occurrence of no answers.](image)
It is necessary, however, to take a slightly different approach if a valid reading of any given counter is not taken at midnight. In this case, the volume for this hour, plus any hours with missing volumes immediately preceding midnight, is estimated by using the associated tolerance midpoint itself for each hour within the open-end time interval. The entire operation, consisting of the polling of traffic-counting station and editing of collected data, is accomplished without any operator intervention.

Evaluation of the Telemetry System

After one year of exhaustive testing, it is apparent that the telemetry technique of traffic-data acquisition constitutes an improvement over any former method employed by the State Highway Department of Georgia. The gathering of traffic data by a central collector not only lends itself to a continually current appraisal of the status of all counting stations, but maintenance personnel can be dispatched to any counting station within 3 hours after the occurrence of a failure at any remotely located field installation.

While the telemetry system is monitored by the stored program for 10 different types of irregularities (Fig. 5), only 3 have given any cause for concern. These have been: (a) failure of the remote 401-H data set to answer the call; (b) reception of invalid digits by the 1712-8 terminal block; and (c) no response from the station after the call has been answered. By consulting Figures 6, 7 and 8, it can be seen that these troubles are steadily being eradicated.
Although it cannot be expected that a zero percentage of no answers will be achieved, it is within the realm of probability to confine these to less than 2 percent of all calls placed. The no answer situation results when an incorrect telephone connection is made at the switching station, when the circuits between the computer center and the remote data set become overloaded, or when the remote data set fails to answer within 32 to 64 sec after being dialed. The latter cause is the least frequent of the three. Incorrect connections due to switching malfunctions in excess of 2 percent of all calls placed can usually be decreased by changing the telephone number of the problem traffic-counting station.

Figure 7 shows the occurrence of invalid digit receptions from August 1965 through July 1966. The abundance of these digits was caused by the voltage that is relayed to the 1712-8 by the 401-J being above designed tolerances. Reduction of the voltage of this impulse has restricted the transmittal of 4-digit volumes with an invalid character to less than 1 percent. This remaining 1 percent is a result of electrical disturbances along the transmission facilities, or improper operation of computer hardware during the polling operation.

Figure 8 shows the percentage of time during each month that less than 4 digits were received after a call was placed, even though the 401-H data set answered and returned a lead signal. This was caused either by the accumulator's failure to properly read out the volume, or by the 401-H data set's failure to transmit the volume. Although the occurrence of "no response" has been reduced to acceptable limits, improvements in the design of the field hardware should further diminish the no response problem (Fig. 9).

The efficiency of the telemetry system, at this stage, compares very favorably with former methods of traffic-data collection. Although certain components of the system were experimental in nature, the hours having no volumes due to unsuccessful polls during August 1965 through July 1966 represent only 11 percent of the total (Fig. 10). On the other hand, prior operations suffered a loss of 13 percent due to equipment failures. It also should be noted that the 11 percent unobtained volumes were scattered, thus facilitating accurate and automatic estimations.

Redesigned accumulators have recently been installed at stations 10, 22, and 24. Polling of these counting stations is now being successfully performed approximately 93 percent of the time (Fig. 9). Due to the degree of success of current operations, 9 additional counting stations are being added to the telemetry system.

Accessory computer programs are being implemented to tabulate and update the hourly volumes collected from any counting station by the telemetry process (Fig. 11). The tabulation can be scanned by a traffic analyst to insure the acceptability of all data.
Figure 9. Monthly occurrence of no answers, invalid digits and no responses for all test stations.

Based on the educated discretion of the analyst, any unacceptable recorded hourly volume may subsequently be discounted and a substitute volume mechanically estimated by the computer, or as an alternative, a volume could be estimated by the analyst. This would require introducing an appropriately coded control card to the computer system.

Since a current file of edited traffic volumes is always maintained on a directly accessible disk pack, retrieval of these data for any purpose of utilization can be effortlessly and speedily accomplished.

GENERAL METHODOLOGY FOR REDESIGNING THE RURAL COUNTING PROGRAM

Georgia's program of traffic counting through the year 1963 was probably a fairly typical result of the expansion of methodology that began with the establishment of the state highway planning surveys during the latter 1930's. The prime motivation for redesigning the 1963 traffic-counting program must be attributed to the decision to adopt the previously described automatic traffic data telemetry system. However, any effort to obtain a program of maximum efficiency could not ignore the necessity for concurrently developing a total counting and analysis program that was as refined as

Figure 10. The total percent of no answers, invalid digits, and no responses from August 1, 1965 through July 31, 1966.
the existing state of the art permitted. To have effected an advanced system of data acquisition while retaining relatively archaic portions of the existing program would have been at least incongruous, if not a total negation of any advantage that a data telemetry system might have offered.

Two considerations have emerged in the past decade that have vastly altered the concept of what constitutes a desirable program for obtaining and analyzing traffic-count data. The first is the greatly expanded availability and utilization of the electronic computer for highway-planning activities. The second is the development of techniques for applying statistical methodology to the design and objective evaluation of large-scale traffic-counting programs.

Grouping of Road Sections by Pattern Similarity

Traffic-flow measurement is used in one or more of its various forms to satisfy requirements related to the planning, programming, traffic control, design, maintenance and general administration of the highway program. To provide this required information, the traffic-counting program should ideally provide the following:

1. Values representing AADT for all system road sections;
2. Data related to trends and characteristics of design hour volumes;
3. Volume growth trend data; and
4. Composition of traffic volume by vehicle type.

With the exception of composition data, this information could very well be obtained by operating a traffic-recording device continually, over a period of years, on each road section for which the data are required. Because of the obvious financial and physical impracticality of such a procedure, historical practice has been to obtain a short-term sample count that could be used as the basis for estimating AADT for each system road section. A limited number of strategically located points could then be operated as continuous-count stations capable of producing design hour and growth trend data as well as providing the factors necessary to adjust the short-term samples into estimates of AADT.

The problem of determining an objective method of identifying or associating the location of short-term sample-count stations with the various seasonal patterns measured at continuous-count station locations has been the object of a great deal of research.
and discussion over the past few years. In pre-1964 practice, Georgia's procedure for accomplishing this association must be described as primarily an intuitive one with the major criterion being geographic proximity. Because of the sheer size of the seasonal-control counting program, a station leg was almost never very far removed from any given coverage-count location. This meant that the majority of the coverage counts were adjusted to AADT by comparison to data produced by a control-station leg that was counted for a 24-hour weekday period 4 times per year. Earlier studies had shown that this procedure resulted in a standard error of approximately ±15 percent, a value considered unacceptably high, particularly in terms of the cost of operating such an extensive seasonal-control counting program.

The redesign of Georgia's traffic-counting procedures has generally followed the outline provided by the U.S. Bureau of Public Roads "Guide for Traffic Volume Counting Manual." The "Guide" advances a procedural outline that is based on the concept that patterns of monthly variation tend to persist over a significant number of contig-

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| 37         | 1.31| 1.25| 1.14| 1.01| 1.05| .91  | .82  | .80 | 1.09| 1.23| 1.23| 1.27|
| 38         | /   | 1.25| 1.06| 1.02| 1.02| .89  | .86 | .85 | 1.14| 1.27| 1.23| 1.35|
| GROUP MEAN | 1.58| 1.29| 1.19| 1.07| 1.09| .94  | .84  | .86 | .96  | 1.25| 1.24| 1.35|

| GROUP IV   |     |     |     |     |     |      |      |     |      |     |     |     |
| 10         | .16 | .99 | .95 | .95 | .92 | 1.12| .99  | .89 | .93 | 1.24| 1.24| 1.17|
| 36         | 1.09| .92 | .93 | .86 | 1.14| 1.22| .86  | .87 | 1.17 | 1.16| 1.14| 1.08|
| GROUP MEAN | 1.13| .96 | .94 | .89 | 1.13| .96  | .89  | .90 | 1.21 | 1.20| 1.17| 1.07|

/ VALUES FOUND UNACCEPTABLE FOR VARIOUS REASONS.
/ STATION 39 PLACED IN GROUP I AFTER EXAMINATION OF PREVIOUS RECORDS.
/ DATA MADE UNUSEABLE IN 1963 DUE TO CONSTRUCTION AND/OR OPENING OF PORTIONS OF I-20 IN ADJACENT STATE.
/ STATION 21 PLACED IN GROUP II AFTER EXAMINATION OF PREVIOUS DATA.
/ 1963 DATA UNUSEABLE DUE TO CONSTRUCTION.

Figure 12. Continuous-count station groupings, 1963.
uous road sections and are annually repetitive over relatively long periods of time. This concept is supported by studies of data produced by many continuous-count stations in various states which have revealed sufficient similarities of measured patterns to permit organizing the continuous-count stations, and consequently the road sections on which they are located, into groups such that the monthly variation pattern exhibited by individual stations comprising the group does not differ from the group mean variation pattern by more than approximately \pm 0.10. The seasonal pattern or configuration thus measured is sometimes ascribed to the general concepts of Gestalt Psychology. The bases used for comparing and grouping patterns of monthly variation are ratios obtained by dividing AADT by the average weekday volume computed for each month.

Figure 12 shows the results of the grouping of 26 rural continuous-count stations operated in Georgia during 1963. Individual ratios or factors, as described previously, are shown for each station by month along with the arithmetic average or mean by group for each month.

To investigate the dispersion of individual factors about the mean, the standard deviation for each month, by group and for all groups, was computed. Since Group I was formed by 13 of the stations, or half the total number under study, the group was randomly divided into two samples for the purpose of determining the effect of reducing the total number of stations in this group. The standard deviation for each sample was computed along with the standard error of the mean. The statistical F test of significance was used to compare the two samples. This permitted the conclusion that the samples probably did come from the same population and that the total number of stations in Group I could be reduced without seriously affecting factor data produced for the group. Because of the smaller number of stations in Groups, II, III, and IV, no consideration was given to reduction of stations in these areas. The results of the described examination of grouped data are shown in Figure 13. It is interesting to note, relative to the concept of group stability, that only 4 of the 26 stations transferred from

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</table>

Figure 13. Standard deviation, standard error of the mean and F test results on grouped data.
one group to another during the period from 1963 through 1965, and each of these transfers could be attributed to the fact that an Interstate or high type primary facility had been opened to traffic either parallel or contiguous to the station location. In each instance of the opening of a parallel route, a continuous-count station located on the new route produced data that identified with the previous behavior group.

The approach to the problem of allocating road sections to seasonal variance groups was based on the concept of similar patterns of variation persisting over significantly long sections of highway. Granted this, it became possible to associate a considerable number of intermediate road sections between continuous-count station locations by extending the measured pattern on the basis of continuity from and between the several known points. Data produced by the seasonal-control counting program offered the best available basis for group assignment of the more difficult sections. Additionally, these data provided substantiating evidence on those sections assigned by pattern extension from continuous-count stations.

In order to ascertain the identification of each control-station leg with the group means produced by the major behavior patterns, computer programs were developed to utilize a method of least squares to determine the group of best fit. Briefly, this involved comparing the factors produced by seasonal-control counts to each set of group mean monthly factors. The difference observed in the compared values were squared and summed by group. The resulting summation producing the lowest value was interpreted to be the group of best fit.

The actual mechanics of grouping road sections became relatively simple once all seasonal-control stations were analyzed and identified with the major behavior patterns. Continuous-count and seasonal-control station locations were noted on a map showing all rural state and Federal-aid system roads. The pattern group with which each location had been associated was symbolically noted and the pattern scheme extended to include the maximum number of contiguous road sections belonging to the same pattern group. With the vast amount of seasonal-control data available, this procedure permitted, with some degree of objectivity, the grouping of approximately 85 percent of all rural road sections having an AADT volume in excess of 500 vehicles per day.

The Continuous-Count Program

The approach to the overall redesign of Georgia's traffic-counting program examined continuous-count stations first because of their inherent importance as the producers of data around which other counting activities are designed, and because of the urgency introduced by the impending adoption of the traffic-data telemetry system. A very broad delineation of the needs for continuous-count data is as follows:

1. The production of factor data necessary for converting short-term count observations into reasonable estimates of AADT;
2. The determination of composite or statewide long-range travel trends;
3. The determination of the relation of design hour and other high-hour volumes to AADT; and
4. To facilitate detailed corridor analysis preceding the development of design traffic assignments.

With respect to item one, it is generally conceded that a minimum of 4 station locations are required on road sections for which an independent set of mean monthly factors is to be obtained. Thus, all rural road sections were stratified into three general classifications for the purpose of quantifying continuous-count needs in terms of AADT estimating requirements. These are termed: (a) Category I, rural road sections, AADT = 500 vpd (Interstate excepted); (b) Category II, rural road sections, AADT = 500 vpd; and (c) Category III, rural Interstate road sections.

The 1963 continuous-count program consisted entirely of station locations that could be ascribed to Category I. The grouping of data produced by these stations revealed four distinctly definable seasonal behavior patterns. In order to minimize bias that potentially could be injected into the AADT estimating procedure and to assure that
points selected would be representative of the entire statistical population to be sampled, it was decided to adhere as closely as possible to the concept of randomness in choosing future continuous-count locations for Category I. Such a procedure was possible in this category because the majority of eligible road sections had been assigned to one of the four behavior patterns (populations). From the standpoint of statistical theory, the locations could be considered randomly selected if the choosing process allowed every road section within the population an equal chance of being selected. The actual process of selecting Category I stations required that the purely random concept be modified to a degree because of the telemetry system’s requirement for the presence of electric and telephone service at each of the station locations. Another consideration was the desire to have as much assurance as possible that station locations finally selected would, in fact, produce the pattern of factor data that had been expected. This involved an examination of the history of each road section’s grouping for a period of 4 years (1961-64). Sections showing a significant tendency to transfer from one group to another were eliminated from the base from which future locations were drawn. It is thought that this procedure provided the most satisfactory method of locating the 16 Category I stations in terms of minimizing bias as well as conceding necessary considerations to practicality.

Past studies have indicated that it is impossible, within practical limits, to design a program for low-volume rural roads (Category II) that will produce estimates of AADT that are as accurate as those for high-volume roads. However, the same level of accuracy is not ordinarily required on these road sections. In Georgia, it was decided to explore the area-control method of producing AADT estimates on Category II road sections. This method implies that because of similarities in economic activity, climatic conditions, population densities and other related factors the monthly distribution of traffic flow would be reasonably constant throughout the designated area.

Since historical continuous-count data were very limited on low-volume roads, the initial step has been to divide the state into three areas generally described as Mountains and Upper Piedmont, Lower Piedmont, and Coastal Plain. Utilizing a probability procedure similar to that used in Category I, one continuous-count station was located in each area. Additionally, three seasonal-control stations operated for a 7-day period in each month were established on low-volume road sections in each of the three areas. Such an arrangement will provide monthly data from four points in each area that can be grouped to produce a set of group mean monthly factors. This procedure, established January 1, 1966, will be subject to extensive analysis once sufficient lead data are accumulated.

The selection of Category III was not subjected to any probability procedure. A general administrative criterion was established that the scope of the program should be such as to provide at least one continuous-counting point on each major segment of the Interstate System in Georgia. This dictated approximately 9 Category III continuous-count stations. Where possible these locations are being established to allow correlation with historical data produced by locations on the former Interstate travel-way and to facilitate evaluation of Interstate design traffic assignment and forecasting techniques. For purposes of AADT estimating, it is expected that these road sections will identify with the patterns established in Category I. However, a separate categorizing of Interstate sections may ultimately permit a refinement of estimating procedures for this category.

Continuous-count data accumulated by the telemetry system are, as described earlier, edited and filed on disk packs. These data are immediately accessible, through programming, for any analysis that may be desired. There are, however, certain analyses that are performed routinely to satisfy data needs of the Department as well as to fill the U.S. Bureau of Public Roads’ requirements. Figure 14 shows an example of the monthly summary of hourly data obtained at a continuous-count location. Volumes are summed for the entire month and for each day of the month individually. The average weekday, Saturday, Sunday and day of the month count is computed and listed. At directionally counted stations, a summary is made for each direction separately and for both directions combined. Using manual retrieval, coding, keypunch and card input procedures, approximately two weeks were required to produce these summaries for
Figure 14. Example of monthly computer summary of data obtained at a continuous-count station.

Figure 15. Annual computer summary of continuous-count data.
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**Figure 16.** Annual computer summary of high-hour data.

**Figure 17.** Computer summary of a 7-day seasonal-control station sample.
all stations. It is expected that approximately 1.5 hours will be required using the telemetry-disk input system.

Each month, as monthly summary reports are prepared, a summary card is automatically punched for each station. These summary cards are then used at the end of the year to produce an annual recapitulation of the station's data. Figure 15 shows this annual summary.

Programs have also been developed to extract selected high-hour data from the year's continuous-count records. The volumes, along with data related to time of occurrence, directional distribution (where available), and ratio of high-hour volume to AADT (K), are shown by Figure 16.

The Seasonal-Control Counting Program

The reasons for operating seasonal-control counting stations within the framework of the overall program may be stated as follows: (a) as a substitute for continuous-count stations to produce factor and trend data (Category II is an example); (b) to establish patterns of seasonal variation on those road sections not yet assigned to pattern groups; and (c) to study seasonal patterns in areas thought to be subject to change due to the opening of new facilities or other reasons.

The method of operating rural seasonal-control stations is to obtain a 7-day sample during each month with an hourly recording device. The initial scope of the program was dictated by equipment inventories and existing organizational capability which permitted the operation of 146 stations, 5 of which are counted directionally. During 1966, the initial year of operation, 9 locations were assigned to reason (a), 127 to reason (b), and 10 to reason (c). It is expected that all rural road sections will be grouped within a period of 2 to 3 years, after which a very great reduction in the effort devoted to seasonal-control counting activities can be effected.

Routine analysis of seasonal-control data will be very similar to that for continuous-count data. Programs have been developed to prepare a hard copy of each month's sample data (Fig. 17), as well as a summary data card that can be used for routine annual summarizing similar to that for continuous-count data.

There are several considerations under study that will permit further automation of the seasonal-control counting program, including the installation of induction loops in lieu of pneumatic road tubes for vehicle detection. These detecting devices would be used in conjunction with portable, punch tape hourly recorders that could be moved between locations as scheduling dictated. It is believed that available on-line equipment, with certain design modifications, would allow data to be introduced directly into computer core storage from the punched paper tape produced by the recorder thus eliminating existing coding, keypunch and manual editing procedures.

The Coverage-Count Program

The coverage-count program involves obtaining necessary short-term counts to produce annual estimates of AADT on all road sections for which these data are required. The design goal for the program was that it should produce such estimates, along with vehicle-mile summations, for all rural Federal-aid Interstate, Primary and Secondary, as well as state and major county road system sections. Special traffic survey maps were prepared that divided each county's defined road system into identified road sections (Fig. 18). A representative counting point was established for each section and the section's length determined.

Each of the coverage-count stations is operated annually for a weekday period of 24 hours either with an accumulative or hourly recorder. The sample count obtained, after having been compared to data from previous years to determine acceptability, is coded along with location identification, date obtained, peak-hour volume when available, section length and highway system. Also coded is the category and group designation for each road section. The coded data are keypunched and processed by the coverage-count computer program. An example of the program's printer listing is shown by Figure 19.
Figure 18. Rural traffic survey map, Banks County, Georgia.
To accomplish this listing, the following operational steps are noted:

1. County names are stored for on-line disk reference. The appropriate name is selected according to a numeric code in the data card and printed at the top of each page.

2. Data fields 1 through 8 are listed directly from the data card. Data for directional coverage stations are listed for each direction individually and a total or "0" line is produced by the program.

3. A value will appear in data field 9 when the sample count is obtained with an hourly recording device. This value is the ratio, expressed as a percent, computed by dividing the peak hour by the 24-hour total.

4. A value will appear in data field 10 (directional distribution) when directional hourly data are obtained, and a ratio is computed by dividing the total peak-hour volume into the volume moving in the direction of dominant flow.

5. Data field 11 lists the group mean adjustment factors used to convert that particular sample count into an estimate of AADT. All factor data for a year are filed on disk storage. The appropriate factors are referenced by noting the month and day of the week on which the sample is obtained, along with the category and group with which the subject road section is associated.

6. Data field 12 shows the computed estimate of AADT (field 8 × field 11).

7. Data field 13 is the road section length in miles and is listed directly from the data card.

8. Data field 14 shows the computed estimate of average daily vehicle-miles for the subject road section (field 12 × field 13). Data fields 13 and 14 are summed by system by county.

9. Data fields 15 through 20 list directly from the data cards a summary of significant factors related to the most current vehicle classification observation.
In Figure 19, 1966 sample data are used to produce 1966 estimates of AADT. The factor data used, however, are extracted from summaries of 1965 continuous-count data. Therefore, the estimates of AADT produced during the same year that sample data are obtained must be considered preliminary. Final 1966 estimates can be obtained after all 1966 continuous-count and seasonal-control data records are summarized to produce current road-section groupings and an updated disk file of adjustment factors. There will probably be a small number of road sections that will change groups from one year to the next. Adjustments for this can easily be made by modifying one digit in the coverage count data card for the affected section. Once disk and card files are updated, approximately 45 sec per average 75-station county is required for processing final estimates.

Because previous studies have shown pattern groupings and resulting group mean factors to be reasonably stable from year to year, the immediate availability of preliminary estimates of AADT should compensate for any error in the estimates that might result from using factor data and road-section groupings from the previous year. In any event, estimates can be easily finalized immediately after the end of the calendar year. The same disk file of factors used to finalize estimates of AADT for the previous year can then be used to produce preliminary estimates of AADT in the current year.

The weekday factors that appear in data field 11 are the group mean ratios of the average weekday for a given month to the average specific weekday, Monday through Friday, for the same month. The inclusion of these factors in the estimating procedure, in effect, first adjusts the sample count to an estimate of average monthly weekday traffic which, in turn, is adjusted by the group mean monthly factor to an estimate of AADT. A number of statistical tests have indicated that the use of group mean weekday factors provides a logical refinement to the estimating procedure. This is illustrated by the fact that the standard deviation of estimating errors was reduced from ±11.7 percent without weekday factors to ±8.2 percent with weekday factors.

**CONCLUSIONS**

The employment of documented computer programs in the collection and editing of continuous traffic-count data permits full control of standardized statistical procedures with a minimum of supervision. Since these data are edited and added to a historic file as they are collected, traffic reports necessary for continuing highway-planning activities can be readily compiled as the necessity arises.

Any estimation of hourly volumes that may be required due to an inability to poll a particular continuous-count station is more accurate than an estimation customarily supplied by traffic coders, since programmed computer estimates can be based on vast amounts of stored historical traffic data. In addition, these estimates of hourly volumes will be less in total number and concentration due to the ability to promptly detect any malfunctioning counting station. This scattering of estimates has resulted in unaffected 24-hour total volumes 98.3 percent of the time. Also, the 1.7 percent of affected 24-hour volume totals are more accurate than 24-hour totals containing manually estimated hourly volumes.

The continuous-count program, integrated with remote capabilities of data acquisition, can be expanded, when necessary, with nominal increases in cost and essentially no increase in the labor force. By taking advantage of the flexibility of a stored computer program, any given counting station can be polled as often as the location may dictate to assimilate varying time intervals of traffic accumulations. Routine reports compiled from these data can be produced in a greatly reduced number of man-hours, because manual calculations of volume estimates, coding of printed traffic recorder tapes, and keypunching of coded data are eliminated.

The revised seasonal-control count program is initially being conducted on an extensive scale until such time that all road sections within the state are classified into groups of similar traffic variances. After this classification has been established, the extent of the program can be reduced without sacrificing any of its benefits.

Since seasonal counts are compiled at each location for 7 days during each month of the year, it is impractical to attempt to conduct this type of traffic count at all locations
where traffic is not being measured by the continuous-count program. Therefore, after necessary factors essential for estimating AADT have been extracted from continuous and seasonal counts, the seasonal-counting program can, for the most part, be superseded by annual 24-hour counts obtained in the coverage-count program. These counts, which are systematically collected throughout the state each year, are sufficient for estimating statewide AADT volumes by mechanical application of factors calculated from the continuous-count program. The coverage-count locations and their resulting vital traffic statistics can, through the implementation of computer programming, be computed promptly and tabulated in a form desirable for reproduction and distribution.

The telemetry system, in conjunction with revisions in the seasonal-control counting and coverage-counting programs, has permitted a considerable expansion of the traffic-counting and analysis program within the framework of the existing organization. Without major revisions in the total traffic-counting program, maximum effectiveness of an advanced system of traffic data acquisition could not have been achieved.

REFERENCES


Discussion

PATRICK J. ATHOL, Illinois Expressway Surveillance Project—This paper is an excellent report on the traffic-counting program undertaken by the Georgia Highway Department. Their approach toward automation has proved its success in improved accuracy and greater economy, and it is a credit to the Highway Department and the cooperating manufacturers who undertook the work.

The question for discussion is the applicability of this system to other states. From a technological viewpoint, the demands of a traffic-count program in terms of data transmission and computer control are relatively straightforward. In the Georgia scheme, there were two important decisions, the computer configuration and the interconnect mode, which were dictated by local conditions. The computer development appeared governed by the fact that the planning department already had its own machine and the development of the interconnect system was influenced by the regular WATS line service already used by the Highway Department.

The computer system developed from the original IBM 1401 to an IBM 1620, and then to the control and data-collection system designated as the IBM 1710. The 1710 system used depended heavily on disk storage for both programs and data; this greatly expanded the utility of the system over the basic 1620 system. These additional items were necessary to expand the system capability for real-time control and data collection.

The WATS line is a rate schedule rather than a specific data-transmission specification. The Georgia system uses a conventional telephone system to dial individual counting stations. Each station has a number which is effectively the same as any house phone number. The count data transmission has no priority in this system and
if sufficient highway personnel keep telephone lines busy, then they prevent the count
data system from working. If an automatic call is placed for traffic data at a time
when the telephone company's exchanges are busy, then the phone call is switched within
the telephone system to various links. The circuitous routing through various ex-
changes may result in electrical noise problems which impair the accuracy of the data
transmitted. Built-in automatic error checking ensures the rejection of erroneous
data, but this does not prevent the loss of data in its then present form.

Developments in the small computer field have been so rapid and numerous that
existing systems are quickly superseded by new equipment with better performance at
reduced cost. Some of the greatest advances have been in the area of small real-time
control computers. The agency considering an economical traffic acquisition system
should consider a specialized computer for this use. A separate computer in a real-
time system assures guaranteed priorities to the task undertaken and cannot be pushed
off-line for administrative emergencies which so often preempt data-processing com-
puter time. At a rental rate of from 1 to 2 times a senior engineer's monthly salary,
a very complete and adequate range of computer systems is available. Rental pricing
on control computers is based on full-time operations and does not involve additional
shift times to provide continuous year-round operations.

In comparing the speed of performance of the computer and the telephone systems,
it is quite noticeable how one deals with microseconds with a computer while the tele-
phone system is functioning in terms of seconds. The reason for this apparent system
discrepancy is one of economics. The polling of various count stations using a WATS
line is the most economical method of gaining data; but one could operate at much
faster rates, and with less interface equipment, if there were direct connections be-
tween the field detectors and the digital computer. With a direct hookup with each
detector, one could gather the traffic detector signals at very high speeds and keep
tally of the detector signals within the computer itself; this technique eliminates the
needed equipment for dialing and storing data at the count station and in the central
office. Within the framework of present highway operations and concepts, the cost of
earmarked communication links initially appears prohibitive. If, however, in the design
of the count system, adequate coordination with a total statewide communication system
is provided, then the direct communications system to the computer may be economically
feasible.

The challenge to any group undertaking the future design of a system for traffic
counting will be greatly enhanced if the group can look forward to the total developing
electronic needs of the highway department. Planning for a comprehensive approach
to many of these communication and automation needs will enhance the long-term utility
of most individual systems undertaken.

W. C. TAYLOR, Traffic Research Engineer, Ohio Department of Highways—The authors
have done a fine job of describing the techniques used for automatic acquisition and
analysis of traffic data in Georgia. Their conclusion that this technique represents a
major step forward in providing highway planning data is incontestable. However, in
reviewing this paper several questions regarding the implementation of the technique
arise. Answers to these questions may be available from the information which the
authors possess, but which did not find its way into the report. The purpose in raising
these questions is to elicit answers so that the technique might be more easily adopted
in other locations.

Specifically, two points are presented in the introduction as justification for embark-
ing on a program of automatic data acquisition and analysis. The first point was the
economic limitation of expanding the manual-count method. This is probably a valid
point, but no cost data for either the present system or the proposed system are
presented. It would be helpful if estimates of the annual cost of both systems for
several different information levels were presented.
Secondly, it was noted that some 13 percent of the count data was being lost due to equipment failures in the manual data-processing method. Yet, after one year, the data loss on the four automatic counters used in the test was still 11 percent (Fig. 9 of the paper). In fact, during March 1966, this figure reached as high as 30 percent (Fig. 9 of the paper). In reading the paper, I suspect that the reasons for this high data loss were determined and corrected.

Prerequisites for locating the test sites included varying distances from the office, diverse climate conditions, and different telephone systems. A valuable addition to the paper would be a discussion of the effect of these variables, and the reasons for the detector changes indicated. We are told that the only magnetic detector used was replaced, and that one of the pneumatic tubes was removed in favor of an induction loop, but the reasons for these changes are not presented.

The point which disturbs me the most is the use of the expected tolerances as a check of data validity. The text reads that the tolerance presents the square root of the average of the square of a set of deviations about an arithmetical mean. If I understand the wording of the text properly, the tolerance limits are set at ±1 σ. If you assume a standardized normal distribution, these limits include only about 70 percent of the data points. On the other hand, an equipment malfunction, if not complete, might not be detected. The tolerance limits are wide enough to permit a 16 percent deviation from the mean value without detecting a malfunction. The use of only one set of limits leads to this dilemma.

The point I am raising here refers to the conclusion that this technique provides increased accuracy over the manual-processing method. In the manual-processing method the authors indicated a known loss of 13 percent of the data, while the automated system checks found only an 11 percent loss of data. I would contend that these figures refer only to total losses, not to erroneous inputs. I have a suspicion, admittedly unconfirmed, that manual data-processing techniques would identify more erroneous inputs than can be found by the tolerance limit method of analysis.

JACK C. MARCELLIS, Assistant Traffic Engineer, City of Chattanooga, Tennessee—If a traffic-counting program is going to provide the required information at the appropriate time to the many highway department agencies, the data for the continuous-count, seasonal-control and coverage-count programs must be collected, processed and analyzed in an efficient and economical manner. The question is then asked: Does the current State Highway Department of Georgia traffic-counting program accomplish these two criteria in a better manner than did the previous program?

In the area of data collection for the former continuous-count program, it was observed that 13 percent of the data was being lost due to equipment failure between weekly or biweekly maintenance visits. During the 12-month study period of the telemetry system, volumes due to unsuccessful polls represented only 11 percent of the total, and after recent modifications at the counting station, successful polling of traffic volumes had increased to 93 percent. These unobtained volumes were randomly scattered throughout the counting duration instead of being grouped for large periods of time as in the manually collected system. These occurrences led to easier and more accurate estimation of the missing traffic volumes.

Two weeks were required to produce monthly summaries for all continuous-count stations using manual coding, keypunch and card input procedures. It was estimated by the authors that only 1.5 hours will be needed to perform the same task using the telemetry disk input system.

It is obvious that the telemetry system collects, processes and analyzes continuous-count traffic data in a more efficient manner than did the old manual methods. Still unanswered are the following questions: Is the telemetry system more economical than the previous method? Does the saving in data collection and processing personnel offset the capital and operation costs of a computer and telephone equipment?
Both the seasonal control and coverage-counting programs used pneumatic road tubes and hourly or accumulative recording devices for collecting traffic data, manual coding, keypunch and editing, and for processing traffic data and computer programs for obtaining summaries and AADT estimates. These two phases of the traffic-counting program require more traffic data on a station-day counting basis than does the continuous-count portion. Because of this, can one or more of the manual steps be eliminated and in turn improve greatly the efficiency of the total program?

Further automation of the seasonal-control counting program is currently under consideration. The authors have indicated that existing on-line equipment might be modified to allow traffic-count data to be introduced directly into the computer core storage from the punch paper tape produced by the hourly traffic counter, thus eliminating existing coding, keypunch and manual-editing procedures. Could something similar to this be used with the coverage-count data?

This author does not pretend to know the answers to these questions, but only asks them to stir the intellect of the highway engineering profession. If more efficient and economical methods are developed to collect, process and analyze the continuous-count, seasonal-control and coverage-count programs, the more complete and accurate the traffic data will be and the quicker then data will be ready for use by the various highway department agencies.

The authors are to be complimented on their substantial contribution in improving the traffic-counting program in Georgia. It is hoped that the authors and others like them will be motivated to continue the work of automating the various traffic-counting procedures.

EMORY C. PARRISH, Closure—Both Marcellis and Taylor have made reference to the cost for installing and operating the telemetry system. Prior to the time that the decision was made to go ahead with the proposed telemetry system, a rather comprehensive summary of operating cost was prepared for the procedures then being used. These costs were compared to the anticipated costs for operating the automated system that we have described. These anticipated costs were of necessity only estimates, since it is impossible to determine costs for a system that has never been operated. Any of you who are familiar with the Highway Planning Survey's relationship to the U.S. Bureau of Public Roads and to the overall Highway Department Administration are certainly aware that we could not have begun such a project without a reasonably comprehensive cost analysis.

While I do not have these exact figures before me, I can tell you that they did indicate the telemetry system would operate for about the same as existing procedures when 28 stations were "on line." We expect to ultimately expand the continuous-count program to about 80 stations at which time we anticipate a savings of some $14,000 annually.

Because we have been—and are—operating under a mixed system, no attempt has thus far been made to evaluate exactly the validity of this earlier cost comparison, but our experience to this point has uncovered no major unexpected costs. I might add that we have not placed a dollar figure on the value of continuous-count data that were lost due to equipment malfunction for days or weeks under the old system.

For information, the average costs for equipment and installation in the field for a nondirectional station are approximately $600 and for a directional station, approximately $1100. At each station the leased telephone equipment costs approximately $21 per month. The rental on telephone equipment in the Atlanta office is $570 per month which includes $500 for a WATS line that is used only 1/20th of the time for telemetry. The IBM equipment that adapts our computer to a telemetry system rents for about $1000 per month.

Mr. Taylor referred to the comparison of lost counts by the two systems as contained in the written report. The counts lost under the manual system were reported
as 13 percent of the total and 11 percent using the telemetry system. Although the percentage of unsuccessful polls by the telemetry system was approximately 11 percent of all polling attempts, it should be noted that during this time the experimental Telac device and telephone data sets were constantly undergoing minor design changes. These modifications were not possible until the hardware had been field tested and the unsatisfactory components isolated.

At the present time, operating with very limited replacement parts, the telemetry system as a whole is suffering a loss of only 7 percent of hourly volumes. Using as a guide two of our newest stations which utilize the latest versions of field equipment, we are confident that it will be possible to retrieve hourly volumes a minimum of 95 percent of the time. This results in the necessity for supplying electronically only 5 percent of the volumes. Four percent of this can be accurately recovered by pro-rating the traffic volume accumulated during the unsuccessful polling period using the midpoints of the traffic ranges for each respective hour during this period. This leaves only approximately 1 percent of hourly volumes having to be supplied by using the midpoints of the ranges.

Mr. Taylor voices a great deal of concern about the use of tolerance ranges to examine the validity of count data. To us, the use of standard deviation seems a logical tool to determine the probable variability of hourly volumes. We have retained a method of introducing human judgment into the final acceptance or rejection of a given count volume. He perhaps has a valid point about the tolerances failing to detect a partial failure of equipment—for example, a detector or counter that was very slightly under- or over-counting. However, our experience with the system, so far, has been that the failures experienced were total; i.e., they just quit working. Numerous manual counts have revealed no tendency toward these "not complete" equipment malfunctions that concern Mr. Taylor.

Mr. Marcellis has challenged us in Georgia and, I think, many of you to devise procedures that would perhaps eliminate some of the manual procedures that are now a part of collecting and processing seasonal-control and average-count data. As I mentioned previously, we have some tentative ideas concerning the seasonal-control program. However, their implementation will be delayed pending replacement of existing equipment. Our budget prevents this before existing inventories are expended.

The Georgia Highway Department has on order an IBM 360 System Computer that will have an optional scanner feature. This may permit the automated reading and processing of coverage-count field notes without manual intervention. Thought in this area is pretty much speculative at this point.

I would also like to mention, in closing, that we have extended many of the concepts advanced in this paper to a traffic-volume counting program for our 53 urban areas in Georgia. This, we think, is going to provide data in an area where we in Georgia have been significantly weak.