PENNDOT'S TELECOUNT SYSTEM

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The telecount system introduced in 1971 marks the culmination of PennDOT's efforts in developing, installing, and operating a centralized statewide digital traffic reporting and processing system. It improves data flexibility, eliminates reporting time lag, and provides heretofore impossible remote monitoring capabilities. Considerable research was involved in reevaluating the original manual concept and station distribution toward interfacing the existing detection equipment, the land-line communication links, and the minicomputer peripheral components in an automated system. Some problems were encountered during initial program and hardware exercises and in coordinating the efforts of 17 independent telephone companies scattered throughout the commonwealth to provide continuous "dedicated" line service. Details of the system's operation and its performance through the first 6 months of service are included. Research is continuing in component design to reduce size and improve heat dissipation, flexibility, and reliability of the next generation of equipment. Already new capabilities have been devised to expand the present reporting to include vehicle speed, classification, and axle configuration.

•A CENTRALIZED multistation statewide traffic reporting and processing system was recently installed by the Pennsylvania Department of Transportation. This system consists of processing and transmitting equipment at 67 remote field locations, telephone transmission lines, and central data receiving and processing assembly in Harrisburg.

This report describing the approach to automating traffic data collection efforts should aid others contemplating large-scale automatic reporting systems. It is intended to be comprehensive enough to guide traffic engineers in devising their own programs along the lines followed by Pennsylvania with minimal further research.

The subject is introduced by a brief review of the original traffic data collection concept adhered to before 1970, and the shortcomings inherent in that approach will be presented. There is a description of the reevaluation of the ATR factor groupings, station distribution, and location changes submitted to the Federal Highway Administration before the final network to be incorporated in the new reporting system is selected. The report relates our decision to utilize the on-line, real-time reporting technique and the process of purchasing, installing, testing, and operating the entire telecount system. Finally, it identifies several additional capabilities available for future expansion to report vehicle speed, headway, classification, and axle configuration.

CONTINUOUS TRAFFIC COUNTING

Continuous traffic counting has become such a well-established and important program that the purpose and need for it by those involved in the process and those utilizing the results are taken for granted. For those who are less familar, a general description of the program and its relation to PennDOT's activities may be valuable.

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Continuous counting programs are the basic building blocks from which traffic volumes and traffic characteristics are determined. Once these volumes and characteristics are determined, other less expensive and quicker data collection techniques can be employed to obtain a variety of necessary information for planning, design, accident analyses, maintenance, and programming purposes.

In Pennsylvania, a small sample of 67 stations provides all the continuous counting for the 44,000 miles of state highways. These continuous counts can be grouped into 7 categories depending on the pattern of the traffic, as follows:

	Installation			
Traffic Pattern	Photoelectric	Radar	Inductive Loop	Group
Urban	2	4	7	1
Primary rural	8	3	4	2
Secondary rural	5	-	7	3
Light recreational	3	-	4	4
Moderate recreational	4	2	4	5
Extreme recreational	2	-	-	6
Autumn recreational	6	-	2	7

One group consists of the typical urban counts that remain relatively constant throughout the year but have peak hours in the morning and evening. The extreme recreational pattern has very high traffic volumes in the summer months and weekends and relatively low volumes at other times. Once all of the samples are grouped, comparisons can be made of volumes for any day of the week and yearly volumes, monthly volumes and yearly volumes, and different yearly volumes. This base is expanded further through the use of some 350 monthly traffic counts recorded for a short period of time (2 to 7 days) each month in a continuing program. Thus, more than 400 count locations grouped into 7 categories provide adequate coverage to determine into which group all state highways fall.

One can then take an inexpensive and very quick short-term count of 24 hours once a year and determine the necessary factors to convert the count into a more significant quantity regardless of the month, day of the week, or location. One is thus able to determine the annual average daily traffic, the most basic and necessary building block for planning and design purposes. One can determine the relation of the peak-hour flow to the average daily traffic (K factors).

Existing traffic volumes and historical trends can be used as a basis for expansion in forecasting future traffic volumes. In fact, even when the number of trips are determined from other means, such as home interviews in transportation studies, traffic counts are still employed as screenline checks to verify the resulting assigned traffic volumes.

Traffic volumes are used not only for broad-scale estimates of traffic (as in transportation studies) to determine project needs and priorities but also for detailed estimates of traffic to be used in the detailed design and improvement of a given facility. Without such figures, of course, it would be impossible to accurately evaluate the adequacy of an existing facility or to predict the capacity for which a future highway should be designed. Based on a given level of service, the ratio of the capacity of the highway to the volume of traffic that exists at a given time can be employed along with other elements to determine the sufficiency of the facility. Deficiencies can correspondingly be pinpointed, evaluated, and aggregated under various systems to determine present and future needs.

When supplemented with classification counts according to vehicle type, traffic counts are necessary also for the structural design of the pavement for they indicate the number of repetitions of heavy-weight axles pounding it in a given period of time.

Vehicle-miles of travel and accident statistics incorporating those figures can also be obtained through a traffic counting program. These data are used to identify hazardous locations that merit safety improvement remedies. In addition, many miscellaneous programs, such as traffic signal installation and evaluation of railroad grade-crossing protection, must have their basis in the continuous counting program.

Aside from the importance within the department for study, design, and other purposes, traffic counts are invaluable to many others. Planning commissions can often monitor and plan growth with the aid of such figures, and many businesses depend on these figures in locating their facilities in the most advantageous areas. It is indeed fortunate that the federal government not only has spurred development of traffic counting programs but also has underwritten them to the extent of providing approximately 75 percent of the cost in Pennsylvania for the basic programs. Federal programs not only provide funding for this work but also properly insist that it be done.

ORIGINAL DATA COLLECTION PROGRAM

The first large-scale, on-line, real-time, centralized, multistation, digital traffic data collection system was inaugurated in Pennsylvania on April 1, 1971. The system was developed to collect, record, and process traffic data gathered simultaneously and continuously from 67 remote locations throughout the commonwealth. This system consists of automatic vehicle-detecting and transmitting equipment at each remote field station, interconnecting telephone lines, and the central data receiving and processing assembly in the Transportation and Safety Building in Harrisburg. The statewide system is shown in Figure 1.

One of the first commercially produced automatic traffic counters began recording traffic in Cumberland County in 1936 (9, p. 1). This was a photoelectric device using a cumulative printing counter. The original automatic traffic recording (ATR) program consisted of 10 of these installations throughout the state. They were serviced weekly by 1 person traveling in the western portion of the state and a second person assigned to the east. The cumulative counter required manual transcription and subtraction of each recorded number from the succeeding number to obtain the hourly traffic volumes. As more installations were added, it was apparent that a direct reading recorder would improve the processing time. A new hourly recorder appeared early in the fifties and quickly replaced the early cumulative models. About this time it also was apparent that many highway facilities undergoing traffic studies carried traffic volumes that exceeded the capabilities of the photoelectric detectors. The subsequent addition of new installations and the need for lane data gradually increased the number of installations to 67 and the number of weekly data tapes to 120 by 1963. The field and support personnel directly responsible for weekly ATR data collection and processing also increased to 11. By this time too, the vehicle detectors had become more sophisticated with the introduction of radar and inductive field devices.

The original ATR stations provided one total hourly traffic volume reflecting the number of vehicles passing the detectors in both directions. Consequently, with 10 installations there were 10 data tapes. With the introduction of lane and directional counts, several selected stations were equipped to provide traffic data for each lane of traffic while other stations were equipped to record combinations of lane counts to represent traffic passing in only 1 direction. Thus, a total of 120 data tapes were reporting the traffic passing the 67 remote field locations.

The average daily traffic is an elementary basis for chronological reporting of the utilization of a specific roadway or the comparison of different roadways. Because it would be extremely expensive and time-consuming to actually count all of the traffic traversing every separate section of roadway throughout the state, the problem is simplified by grouping the various roads having similar characteristics and sampling these with a small number of continuously operating traffic recorders. These locations are strategically located, permanently constructed, and energized from utility company power and communications lines. Factors obtained from data provided by the continuously operating stations enable the engineer to expand relatively short-term machine or manual counts to represent average daily traffic. These short-term counts are obtained from seasonal control and coverage count machine recordings as well as manual classification and turning movement counts.

This information is necessary to satisfy the never ending requests for traffic data for transportation studies, design criteria, traffic control, sufficiency and need studies, commercial roadside development, signalization warrants, accident frequency studies, and capacity studies.

The original reporting process began with the field serviceman removing the data tape and mailing it to the central office (Fig. 2). Field personnel mailed tapes from the nearest district office, and the tapes were usually received in the central office by the following Monday morning. Each tape was arranged for continuous keypunching by sequencing the count data to include a full week's coverage from Monday morning through Sunday midnight. This manual preparation for keypunching required 2 days after which the tapes were carried to the Data Processing Unit where the hour, volumes, station numbers, and date were punched into 2 cards per day per tape, one for a. m. and one for p. m. The cards for the week were then sorted by station and date. Allotted time for this step was 1 week but often ran as long as 1 month. The cards were then run through the comupter to produce a magnetic tape and a proof listing. This listing was then sent to the Traffic Records Unit to be edited and analyzed. With corrections, it was returned to Data Processing for additional keypunching. Without corrections, it was sent to Data Processing Control to be entered in the processing log. This step required an average of 1 month. From Control the cards were sent through the Burroughs 5500 computer to produce the weekly and monthly tables (Figs. 3 and 4) and a magnetic accumulative tape for library storage. These forms were reviewed and, if not satisfactory, were discarded and the process repeated. If satisfactory, the process was complete and the appropriate copies were distributed. Time for the final step averaged about 1 month. Total processing time allotted by the Federal Highway Administration was approximately 3 weeks after the end of the month being reported. With these reports requiring more than 3 months for preparation, it was evident that a new approach was urgently needed.

DEVELOPMENT OF AN AUTOMATED SYSTEM

While a new processing technique for automating the central office processing operations was being contemplated, it was apparent that as much of the routine manual field work as possible should be automated. By the mid-sixties, the state of the art in the field of traffic reporting was investigated and it was found that the only system that had been installed and tested under actual traffic conditions specifically for traffic data collection was one operated by the Connecticut Department of Highways. Further investigation revealed that the system had been developed by the Automatic Signal Division of the Laboratory for Electronics and was being tested in cooperation with the Connecticut highway department and the Connecticut Telephone Company (1, pp. 21-34). Progress being made by other states was observed as the needs of the department began taking shape. Three other states, with their own planning bureau computers, had utilized dial-up installations where each remote station stores its traffic data and is polled periodically by the central computer (3, 4, 6). However, one of Pennsylvania's problems was that its system would be appreciably larger than that which any other state had developed to date. Approximately 28 min of each hour would be required for instructions and storage (5). This information was based on discussions with representatives of states using the dial-up method. Early operation with automatic dial-up systems experienced between 10 and 20 percent lost time caused by incorrect responses during polling periods. These include busy signals, wrong numbers, or no answers and thus made the counting periods even more variable depending on the number of stations to be redialed.

A dial-up system would have required replacement of all existing field cabinets and detecting equipment. The new reporting process would consist of cumulative recorders at each location and would have meant a step backward to again require a subtraction operation to obtain the hourly traffic volumes. Previous experience indicated that half of the lost time was attributable to the field recorders. Thus it was advantageous to eliminate the field storage devices.

Figure 1. Statewide communication links and ATR locations.

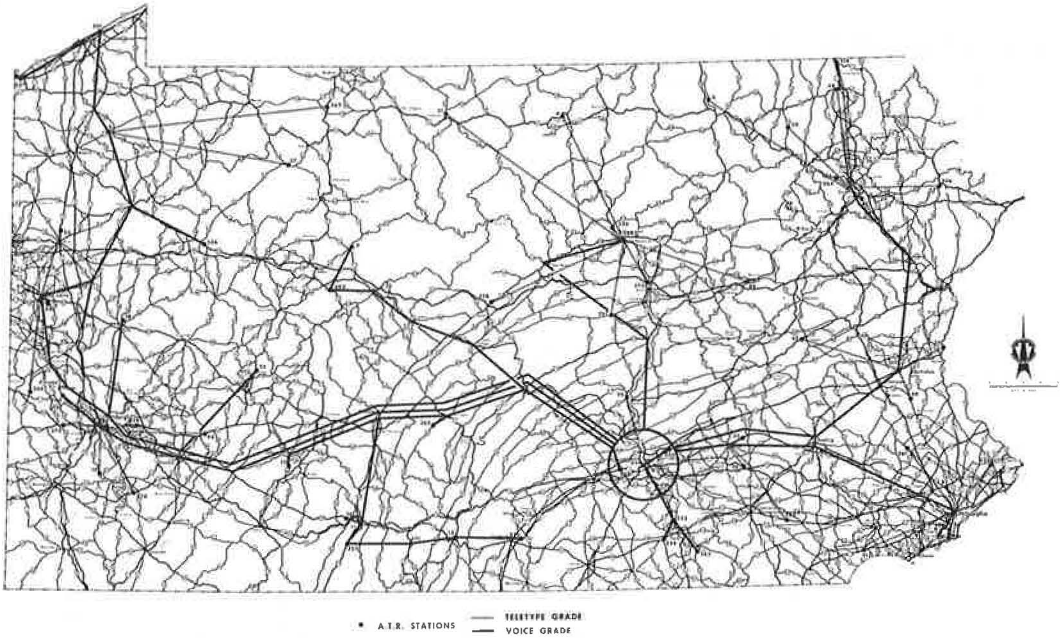


Figure 2. Manual ATR tape processing.

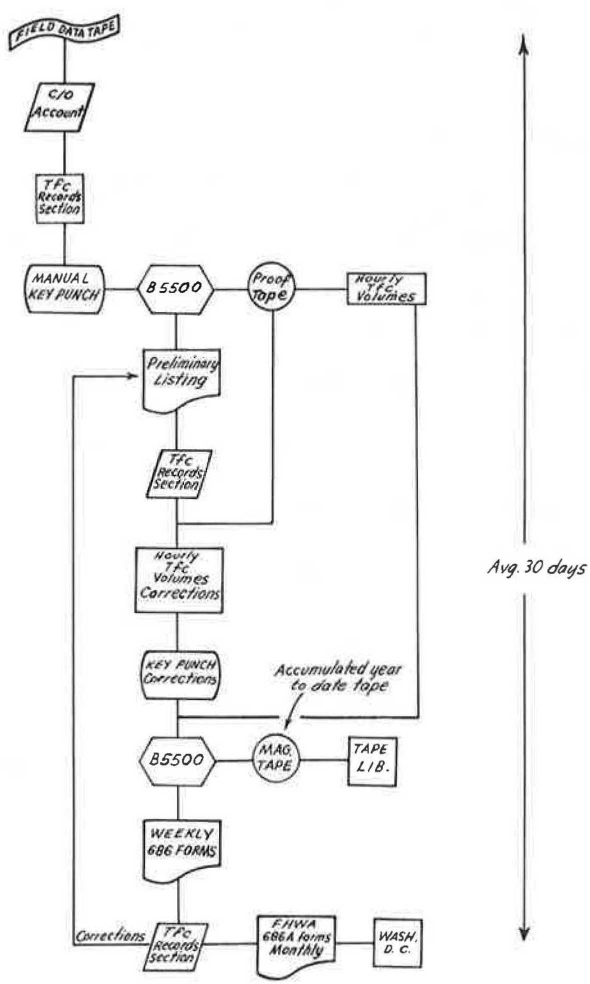


Figure 3. Weekly traffic table.

PS-686 (9-70) PENNSYLVANIA DEPARTMENT OF TRANSPORTATION HIGHWAY PLANNING STATISTICS

WEEKLY TRAFFIC TABLE NO. 1

LANE ALL DIR. BOTH STATION 001

ROUTE US 20 CO. NO. 25 NAME W SPRINGFIELD WK. BEG. 9/06/71

DAY	MON.	TUE.	WED.	THUR.	FRI.	AVERAGE WEEKDAY	SAT.	SUN.	7 DAY AVERAGE
DATE	9/06	9/07	9/08	9/09	9/10		9/11	9/12	
12-1	120	78	120	98	95	102	131	123	109
1-2	92	61	76	63	56	69	78	97	74
2-3	65	52	40	46	42	49	72	108	60
3-4	31	33	51	51	50	43	67	62	49
4-5	34	31	43	31	44	36	41	32	36
5-6	24	63	54	71	53	53	41	37	49
6-7	46	178	200	177	188	157	84	57	132
7-8	54	216	204	202	208	176	111	56	150
8-9	69	184	182	160	174	153	179	102	150
9-10	147	215	233	209	254	211	253	178	212
10-11	206	295	258	255	296	262	306	187	257
11-12	289	290	287	234	299	279	374	281	293
12-1	308	315	274	257	338	298	373	392	322
1-2	343	313	243	314	345	311	385	388	333
2-3	375	334	302	353	333	339	381	414	356
3-4	419	372	338	394	415	387	378	403	388
4-5	374	412	363	402	441	398	390	446	404
5-6	392	380	349	336	460	383	345	419	383
6-7	428	309	357	334	411	367	356	392	369
7-8	470	321	304	342	394	366	342	385	365
8-9	386	284	276	278	351	315	360	297	318
9-10	252	211	231	193	256	228	280	197	231
10-11	190	156	184	213	203	189	174	120	177
11-12	114	98	110	96	168	117	139	94	117
TOTAL	5228	5201	5079	5109	5874	5298	5640	5267	5342
%	97.86	97.36	95.07	95.63	109.95	99.18	105.57	98.59	37398

LANE J = SUM OF ODD NUMBERED LANES LANE K = SUM OF EVEN NUMBERED LANES *TOTAL 7 DAY VOLUME

Figure 4. Monthly traffic table.

PS-686A-(11-70) PENNSYLVANIA DEPARTMENT OF TRANSPORTATION TRANSPORTATION PLANNING STATISTICS

MONTHLY TRAFFIC TABLE NO. 2

LANE ALL DIR BOTH STATION 001

ROUTE US 20 CO. NO. 25 NAME W SPRINGFIELD MONTH 8/71

WK. BEG.	MON.	TUE.	WED.	THUR.	FRI.	WEEKDAYS	SAT.	SUN.	MONTH
7/26								6,164	
8/02	5,614	5,555	5,479	5,737	6,145		6,161	6,170	
8/09	5,646	5,493	5,503	5,568	6,299		5,801	5,836	
8/16	5,623	5,380	5,290	5,541	6,228		6,048	5,914	
8/23	5,459	5,428	5,227	5,319	5,973		5,941	6,238	
8/30	5,498	5,408							
TOTAL	27,840	27,264	21,499	22,165	24,645	123,413	23,951	30,322	177,686
AV. DAY	5,568	5,452	5,374	5,541	6,161	5,609	5,987	6,064	5,731

LANE J = SUM OF ODD NUMBERED LANES LANE K = SUM OF EVEN NUMBERED LANES

Central computer control, processing, and automatic dialing equipment monthly rentals for use in a dial-up system were estimated to be approximately $4,400, and monthly telephone charges were estimated to be approximately $1,800 for use with a dial-up system (2).

REMOTE FIELD INSTALLATIONS

By mid-1967, preliminary development of the type of installation required was completed and the overall system, including station distribution and geographical coverage, was discussed with representatives of the Federal Highway Aministration. Objectives were to provide adequate continuous traffic data with a limited number of strategically located installations to provide design, trend, and factoring data. The review considered historical coverage as well as coverage of new facilities under construction or in the planning stage (10). The product of this review was the selection of the ATR locations and the data to be reported from each of these locations. This information included the ATR number, type, site description, number of traffic lanes, and number of data inputs to the central office computer. The type of vehicle detectors used at each station is also provided as follows:

Detector	Code
Photoelectric total volume data	PE
Radar installation with only antenna suspended over the roadway	RC
Radar with transmitter and receiver suspended over the roadway	RD
Inductive wire loop installation in road surface	IL

Final confirmation of the locations to be included in the initial telemetry system provided the necessary information to complete the specifications for the computer input capacity. A single reporting input from each of 42 low-volume 2-, 3-, or 4-lane facilities, 2 inputs for directional counts from each of 20 locations, and 1 data reporting input from each traffic lane at 5 expressway locations account for a total of 105 initial data reporting inputs to the computer (8). These replace the 120 data tapes previously reported. The lane-counting facilities will be utilized to provide information for special lane studies in the future. The central office assembly is capable of receiving signals from up to 180 field sensors; therefore, adequate expansion capability is ensured.

COMMUNICATION LINKS

At the remote field installation shown in Figure 1, the photoelectric, radar, or inductive loop detectors provide 1 count for each vehicle detected. Because the photoelectric type must scan the entire width of the roadway, it was necessary to utilize either radar or inductive loops to obtain directional or lane counts. On facilities requiring directional information, 2 techniques are available. If the traffic volume is low on a 4-lane facility, the loops may be installed in each lane and the 2 loops in 1 direction attached to 1 detector. However, if the volumes exceed 900 vehicles per hour, the incidence of simultaneous passings will also be high; an accumulator is then utilized to convert these 2 parallel events to series data. The accumulator accomplishes this by momentarily delaying 1 input to follow the other so that the individual counts will both be recorded. These pulses are 100 msec long for each vehicle, and the repetition rate for the parallel to series conversion is 10 pulses/sec (7).

To obtain lane counts, each loop is attached to its individual detector, which in turn activates its assigned encoder (Fig. 5). The encoder interprets this relay closure from its detector and transmits this to the central office decoder as 1 tone pulse at the preassigned frequency. Where remote locations report to collector stations, the remote station's vehicle detector relay closure is transmitted by the telephone company over a class C teletype grade line to activate the encoder at the collector location. Then the tone pulse representing the detector's relay closure is multiplexed with 19 other frequencies on their way to the central office decoder circuits. There are 5 department maintenance building collector sites and 3 field collector sites.

Although the Bell Telephone Company of Pennsylvania has the prime responsibility of providing the necessary service, the success of the entire undertaking is largely dependent on the cooperation of 17 independent telephone companies scattered throughout the state. The development of the transmission system was the culmination of the unified efforts of all of these independent companies and the Bell System's engineering staff to provide the optimum service with minimum construction and operation costs.

The telephone companies provide 60-Ma service for all remote collector lines, and the collector relays are matched through parallel resistors. The bandwidth of the tone transmissions are designed not to exceed 3 KHz and utilize 20 frequencies between 420 and 2,820 Hz.

To summarize the field interface between vehicle detectors and the telephone facilities where a class C line is provided, the telephone company installs its Western Electric 130 or Lenkurt 25 subset equipment at the remote counting location or the nearest telephone company substation. This equipment transfers the detector output to the collector station where it is multiplexed for transmission to the central office. The telephone equipment at the remote site consists only of a small terminal block and a lightning protector if a class A line is provided and the encoder is connected directly to the detector.

Figure 6 shows a typical photoelectric installation modification to accommodate the additional telephone equipment. The extra cabinets were salvaged from discontinued ATR stations. The M type of housing illustrates the addition of the 4 encoders to provide multiplexing for the RD-2 radar detectors shown in Figure 7. The original paper recorders were connected in parallel to provide both printed field and telemetry reporting during the early installation period.

The communications problem was to transmit real-time vehicular information in the form of constant width pulses from all of the remote field stations scattered throughout the commonwealth to a central office located in Harrisburg. All transmissions had to be keyed for inclusion in the proper data block for later retrieval and processing.

Because the data transmitted emanate from such widely scattered locations, simple radial extension of the individual input channels of the computer was not economically feasible. Some form of shared facility was obviously required. The solution was the logical grouping of the sites into geographic sections served by the existing telephone links. The number of links was determined by type, capacity, cost, and present utilization of telephone links available at that time. As it developed, all service was available at each site except ATR 371 in Fulton County. This link was completed before final acceptance tests were performed for the entire system.

For a closer examination of one of the trunk lines we can look at run 2 from the Pittsburgh area carrying the data inputs listed below to the computer in Harrisburg. Class C lines connect the remote stations to the collector station in the Fort Pitt Tunnel. These 5 stations provide 8 inputs as follows:

ATR	Location	Hz	Input
19	Finleyville	1,980	1
24	New Alexandria	2,580	1
208	Monroeville	2,340-2,460	2
370	Belle Vernon	2,100-2,200	2
375	Imperial	1,500-1,620	2

Within the telephone company's circuitry these tone pulses are multiplexed through the trunk originating at ATR 203 at Leetsdale with frequencies of 1,740 and 1,860 Hz and at ATR 309 at the Fort Pitt Tunnel with frequencies of 1,260 and 1,380 Hz. These frequencies are all added to this same line, 6GM-1037, with the tone pulses from ATR 303 at the Squirrel Hill Tunnel with frequencies 540, 660, 780, and 900 Hz for a grand total of 16 frequencies assigned and 4 vacant for future expansion. Squirrel Hill Tunnel was originally assigned 5 frequencies, but one was discontinued when an experimental peak-hour, lane-reversing procedure was abandoned.

Since all of the telephone installations were made within existing facilities, the only construction necessary for the entire system was the installation of underground service

Figure 5. Tone encoder.

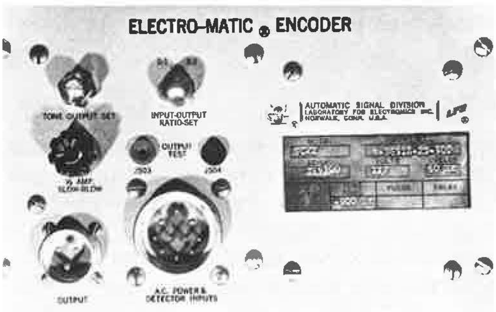


Figure 6. Photoelectric ATR installation.

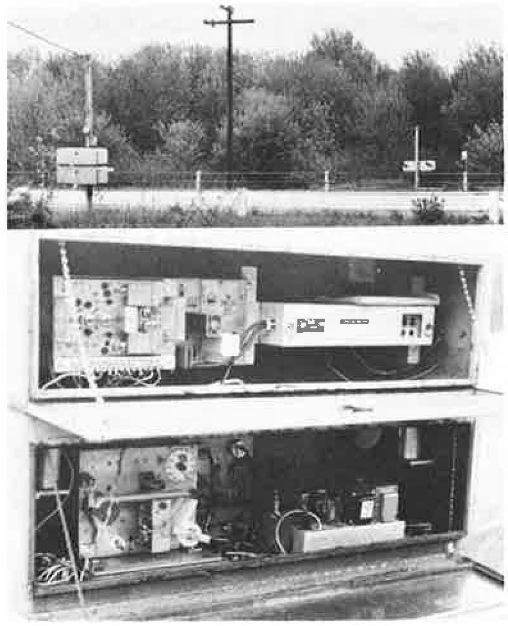


Figure 7. Telephone class A interface.

within the department's right-of-way at the Fort Pitt and Squirrel Hill Tunnels in Pittsburgh. Although the telephone companies primarily provide dedicated wire service, they have interconnected radio links in the northwestern portion of the state and these produce equally satisfactory results.

CENTRAL OFFICE FACILITIES

When the tone pulse reaches the central computer, it is received by a decoder board tuned to the specific frequency reporting from the remote field installation. In the case of ATR 309, at the Fort Pitt Tunnel, 1,380-Hz signals report the vehicles entering the downtown area of Pittsburgh. Pulses received on 1,260 Hz report the vehicles passing outbound from the City of Pittsburgh. In the case of the Schuylkill Expressway, ATR 308 in Philadelphia, 1,740-, 1,980-, and 2,220-Hz signals report vehicles detected in lanes 1, 3, and 5 moving westward out of the city and 1,860-, 2,100-, and 2,340-Hz signals report vehicles traveling eastward toward the city in lanes 2, 4, and 6.

The central computer is the brain and operational center of the system. It is located on the ninth floor of the Transportation and Safety Building in Harrisburg. Each input is assigned a separate frequency within each pair of telephone wires entering the central office. There are 7 class A lines and 1 class C line delivering all of the inputs to the decoder assembly.

Storing, processing, and reporting functions are accomplished in a Digital Equipment Corporation PDP-8L minicomputer. Instructions are entered through the automatic send-recieve model 35 teletype machine, and a wide variety of system reports may be obtained by visual display, teletype printout, or punched cards. Information is processed in binary form and is placed in a disk-oriented, real-time operating system. Inclusion and deletion of operational stations, entering and changing of detector titles, setting of short-term report intervals, and system control is handled through the teletype by the operator. Additional functions include a power downtime accumulator for automatic recovery of time, and the validation of gathered data within preselected limits as a function of detector usage type, month, day of week, and hour of day. Out-of-limit counts (based on prior data) are replaced by a calculated value and are reported as being unacceptable.

The disk-operating system allows the computer to process several items at essentially the same time. The teletype may be printing out a daily summary of the total counts for the previous day, the card punch may be punching a partial week's listing of data, and a set of illuminated numbers may be displaying the current number of vehicles in the present hour—all simultaneously.

Data transfers (vehicle actuations) between the Central Processing Unit and the various detector locations are handled on a program-interrupt basis. When a peripheral is ready to receive or transmit data, it signals the Central Processing Unit to begin the transfer process. Detector data are continually scanned at the 50-msec iteration rate (8). The present status of inputs is compared with the previous sample to determine whether or not a vehicle has entered or left the detector. This permits the appropriate counter to be incremented.

Nixie tube clock and calendar displays and a volume count display are linked with the computer. A clock and calendar show the month, day, hour, minute, and second. The time and date can be updated by the operator through the teletype. The Nixie tube volume display shows the current hourly count as it is accumulated for any particular station selected by the operator. One illumination per vehicle detected is also signaled on a wall map display indicating each remote field input (Fig. 8).

Possible power failures will not affect the informational continuity of the system. A downtime accumulator, which is basically a battery-operated clock, records or accumulates the length of time that the central computer has been without power. When power is restored the computer automatically updates the clock and calendar to ensure that data being received are stored in the proper time slots. Accumulator batteries are continously charged so the unit is always ready for use. Ten hours of downtime a day can be accumulated.

Traffic count information coming into the Harrisburg computer originates at all of the 105 remote detector stations. When a vehicle is sensed, an electrical impulse is generated and relayed to the on-site encoder where it is converted to an "addressed" tone pulse. The encoded actuation is immediately sent out "party line" style over the telephone wire interconnect to a tone receiver or decoder located in the central computer assembly. This unit immediately identifies the origin of each piece of information. From the encoder it reaches the input buffer, which the computer constantly scans for a "change of state." A pulse is sent through only when a vehicle is entering or leaving the detector field to ensure only 1 count per vehicle. All other counts are rejected.

The decoded pulse is now in the computer, which instantly recognizes the data's numerical "address" and transfers it to the computer's core memory for storage. In the telecount system, this means that incoming data are stored for an hour. At the end of the hour, the data are programmed for retrieval for permanent storage. Before the hour count is accepted, however, the data must pass a limit test to prove veracity. From prior observation, there is a known "acceptable" count from each station that is scaled at about the annual average daily traffic level. If the new count is within the ±50 percent limit, it is accepted and addressed to disk storage. If for some reason, the count is unacceptable, i.e., outside the limit test parameters, a calculated value based on prior station statistics is substituted (Tables 1, 2, 3, and 4). This procedure eliminates the possibility of rare, unrepresentative, and exaggerated counts becoming a significant part of the data. At week's end 168 hours of data for each input are printed out in a single report. In addition, a "substituted" value is shown with an asterisk when the hourly count is printed, showing which particular station was out of line for this period.

Unacceptable values may be caused by variables such as an accident, a flood, or some other occurrence likely to influence traffic.

The counts are put in a format that permits fast and accurate analysis and are provided in 12-hour a.m. and p.m. counts as well as in daily totals and 5- and 7-day average.

All counts are either automatically produced according to a programmer in the memory core or furnished at the operator's command through the teletype. In addition to comparatively long period counts, the operator can ask for a count of from 5 to 60 min from any station, starting at any time. All reports are accompanied by the time, date, and station address. An hourly count, for instance, is available from a selected group of stations in any of the time parameters. In short, the operator tells what traffic count information he wants, and the computer supplies it.

Electronic memory is infinitely reusable. The short-term, hourly, and daily reports recorded are erased when the information is punched into cards or dumped through the teletype.

Accuracy is checked by the operator at any time by means of 10's count test that permits him to isolate incoming data and to verify operations of any part of the central system. This test operation is by relay that cuts off inputs to the tone receivers. Another relay, pulsing at the tail end of the tone receiver board, introduces a count of 10 vehicles for every count station. The computer then administers the test and reads 10 in all channels. It knows what went in and it knows what should come out. The computer's decision is given to the operator through the teletype. When the test is finished, the detector lamps and the computer should agree. If a count shows on the detector board and not in the computer, a computer problem is brought out. Conversely, if a station passes and shows no count, a field problem becomes apparent.

Count totals from the 105 remote stations can be supplied at 5-min intervals, by the hour, day, and week. Auxiliary equipment supplies monthly totals. Each total has its own specific use. The minimum 5-min total can pinpoint peaks in rush-hour traffic. The traffic engineer, planner, or analyst can examine these smaller increments for the precise measurement and evaluation needed for border-line decisions.

The hourly count is the traditional timing unit and is the one most used to divide the "traffic day" into workable segments. Counts by the week and by the month provide the basic traffic "character" profiles that affect medium- and long-range design and planning.

Figure 8. Illuminated wall map in central office.

Table 1. Hourly adjustment percentages.

Hour	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
12-1 a.m.	1.6	1.5	1.4	1.7	1.1	1.2	1.6
1-2	0.8	0.8	0.7	1.2	0.6	0.6	1.0
2-3	0.5	0.6	0.4	1.1	0.3	0.3	0.9
3-4	0.4	0.4	0.3	1.2	0.3	0.2	0.8
4-5	0.4	0.5	0.5	1.4	0.5	0.1	0.9
5-6	1.0	1.3	1.5	1.9	1.1	0.3	1.6
6-7	4.0	4.6	4.9	3.5	3.4	1.0	2.6
7-8	7.3	8.7	6.3	4.3	4.5	2.8	3.2
8-9	6.8	6.7	4.6	4.7	4.5	4.4	4.2
9-10	5.5	4.9	4.8	5.2	5.1	4.8	5.0
10-11	4.8	4.4	4.7	5.7	5.3	6.5	5.7
11-12	4.7	4.3	4.5	5.9	5.4	7.1	6.0
12-1 p.m.	4.6	4.3	4.9	5.8	5.9	7.3	6.2
1-2	4.9	4.5	5.8	6.0	6.5	7.5	6.8
2-3	5.4	5.2	7.2	6.3	6.7	8.0	7.1
3-4	6.7	6.3	8.5	6.8	7.8	8.4	7.6
4-5	8.1	8.6	8.7	7.2	8.2	8.9	8.0
5-6	7.6	8.5	6.7	6.7	8.1	6.6	7.2
6-7	6.0	6.2	5.0	5.9	6.4	5.4	6.0
7-8	4.7	4.5	4.7	5.0	5.5	5.3	5.2
8-9	4.1	3.7	4.2	4.1	4.4	4.8	4.1
9-10	4.0	3.9	4.0	3.5	3.8	3.9	3.5
10-11	3.3	3.1	3.3	2.8	2.8	2.6	2.8
11-12	2.8	2.5	2.4	2.1	1.8	2.0	2.0

Table 2. Daily adjustment percentages.

Day	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
Monday	104.7	100.7	95.4	92.4	91.7	85.8	95.9
Tuesday	103.4	99.9	93.7	94.5	90.5	86.2	91.2
Wednesday	104.6	102.8	94.3	94.9	87.4	78.9	91.0
Thursday	107.5	103.8	95.9	97.0	94.5	83.7	94.9
Friday	109.9	113.4	112.9	111.3	105.6	103.3	110.9
Saturday	91.3	93.0	110.2	103.3	112.7	104.0	107.3
Sunday	78.6	86.4	97.6	106.6	117.6	122.1	108.8

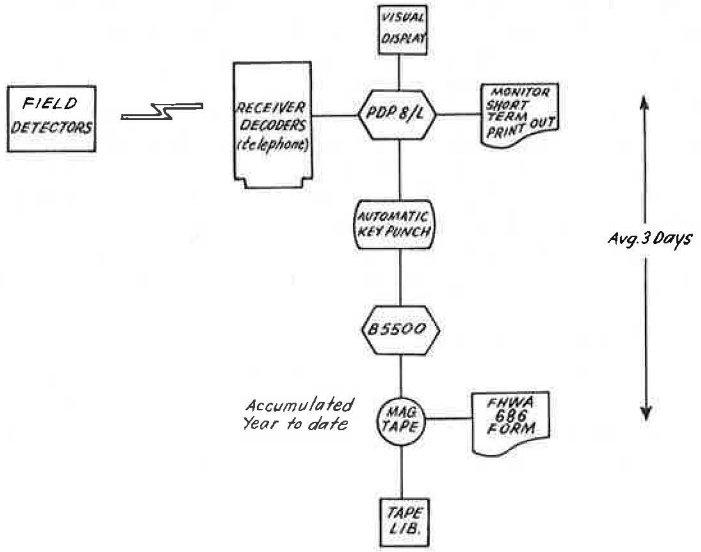
Table 3. Monthly adjustment percentages.

Month	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
January	91	84	77	73	67	42	59
February	94	87	84	78	71	46	68
March	99	93	93	88	83	51	76
April	102	101	98	96	93	64	90
May	103	106	105	108	106	89	108
June	105	107	108	112	122	125	110
July	105	108	112	122	141	242	130
August	104	107	114	123	142	220	133
September	102	106	108	110	114	115	112
October	103	105	107	106	101	90	116
November	97	99	100	98	89	63	104
December	95	93	90	86	75	58	85

Table 4. Basic station values.

ATR Station	Route	Location	Basic Value	ATR Station	Route	Location	Basic Value
0010	US-20	West Springfield	4,900	3031	I-76	Squirrel Hill	16,600
0020	Penn-77	New Richmond	1,150	3032	I-76	Squirrel Hill	16,500
0030	Penn-255	Penfield	3,600	3033	I-76	Squirrel Hill	17,200
0040	US-6	Wellsboro	2,300	3034	I-76	Squirrel Hill	17,100
0050	LR-08077	Towanda	600	3035	I-76	Squirrel Hill	2,600
0080	Penn-73	Whitemarsh	11,000	3048	US-15	Williamsport	12,600
0150	US-522	McConnelsburg	3,700	3049	US-15	Williamsport	12,600
0160	US-30	Wolfsburg	3,100	3060	Penn-507	Hawley	2,250
0170	Penn-403	Tire Hill	6,000	3081	I-76	Schuylkill Expressway	20,300
0180	Penn-38	Butler	4,750	3082	I-76	Schuylkill Expressway	18,900
0190	Penn-88	Finleyville	4,850	3083	I-76	Schuylkill Expressway	26,800
0200	Penn-65	New Castle	6,200	3084	I-76	Schuylkill Expressway	27,100
0240	US-22 and US-119	New Alexandria	12,700	3085	I-76	Schuylkill Expressway	24,500
0250	US-224	Parkstown	7,700	3086	I-76	Schuylkill Expressway	21,300
0270	Penn-68	Russell City	1,750	3098	I-79	Fort Pitt Tunnel	35,200
0290	Penn-267	Auburn Ctr	850	3099	I-79	Fort Pitt Tunnel	35,100
0350	US-422	Myerstown	9,500	3101	Penn-291	Penrose Avenue	15,600
0360	US-322	Brickerville	3,350	3102	Penn-291	Penrose Avenue	17,400
0390	US-611	Easton	3,650	3103	Penn-291	Penrose Avenue	17,000
0400	US-209	Tamaqua	2,500	3104	Penn-291	Penrose Avenue	15,600
0460	US-11	Berwick	10,400	3178	I-78	Allentown	22,900
0470	Penn-307	Scranton	5,250	3179	I-78	Allentown	22,000
0480	US-11	New Milford	2,550	3220	US-30	Leaman Place	13,300
0498	Penn-309	Coopersburg	9,300	3230	US-220	Centerville	1,850
0499	Penn-309	Coopersburg	9,300	3260	US-322	Clarion	6,100
0510	Penn-44	Coudersport	2,000	3280	US-220	Milesburg	4,850
0520	US-119	Indiana	5,150	3300	Penn-532	Newtown	2,750
0530	US-19	Mercer	6,050	3328	US-11	Hogestown	10,750
0560	US-11 and US-15	Liverpool	10,600	3329	US-11	Hogestown	10,750
2028	US-22	Paxtonia	5,800	3340	US-30	Thomasville	11,000
2029	US-22	Paxtonia	5,550	3508	US-15	Hepburnville	6,350
2038	Penn-65	Leetsdale	9,350	3509	US-15	Hepburnville	6,350
2039	Penn-65	Leetsdale	9,250	3600	US-219 and US-322	Luthburg	2,350
2058	I-83	North York	9,600	3610	Penn-63	Harleysville	5,550
2059	I-83	North York	10,200	3620	Penn-24	Red Lion	2,450
2061		Taylor Bridge (Harrisburg)	9,750	3630	US-219	Bradford	2,800
2062		Taylor Bridge (Harrisburg)	10,100	3640	Penn-307	Clarks Summit	3,350
2063		Taylor Bridge (Harrisburg)	7,450	3650	Penn-26	Marklesburg	1,700
2064		Taylor Bridge (Harrisburg)	7,350	3660	Penn-18	Mechanicsburg	2,450
2078	I-90	West Springfield	5,400	3670	Penn-45	Mifflinburg	4,150
2079	I-90	West Springfield	5,300	3708	I-70	Belle Vernon	13,050
2088	I-76	Monroeville	21,250	3709	I-70	Belle Vernon	13,050
2089	I-76	Monroeville	20,850	3718	I-70	Crystal Springs	4,500
2101	I-83	John Harris Bridge	16,900	3719	I-70	Crystal Springs	4,500
2102	I-83	John Harris Bridge	15,600	3728	I-80	Milton	2,450
2103	I-83	John Harris Bridge	9,200	3729	I-80	Milton	2,450
2104	I-83	John Harris Bridge	10,900	3738	I-81	Chambersburg	4,750
2138	US-1	Kennett Square	5,600	3739	I-81	Chambersburg	4,750
2139	US-1	Kennett Square	5,700	3748	I-79	Portersville	4,750
2168	I-81	Hallstead	4,800	3749	I-79	Portersville	4,750
2169	I-81	Hallstead	4,800	3758	US-22 and US-30	Imperial	5,500
3018	Penn-5	Erie	7,450	3759	US-22 and US-30	Imperial	5,500
3019	Penn-5	Erie	8,200				

Figure 9. Telecount automatic ATR data processing.



Totaling is extremely flexible, and practically any variation can be selected for readout. For any specified time increment, the raw count passing a detector can be supplied. Totals for each detector station or groups of stations during specified time periods are available.

A most important advantage to this very flexible kind of counting is that it provides up-to-date real-time statistics. Annual average daily traffic, calculated by taking a theoretical count and dividing it by 365, provides a predicted traffic curve. With instantaneous processing of counts, the predicted curve can be compared immediately against actual vehicle counts.

The automatic data processing procedure is shown in Figure 9 and can be compared to the manual processing work flow shown in Figure 2.

EXPENDITURES

Expenditures for this system are as follows:

Item	Dollars
Initial expenditure	163,000
Field equipment at collection and remote stations	42,000
Central office equipment	121,000
Nonrecurring telephone charge	868
Monthly telephone charge	2,700
Underground conduit in department right-of-way	4,300

Although the annual operating costs of the telecount system are about the same as the original manual weekly servicing procedure, the central data collecting system has eliminated the manual computations and their inherent human errors, the field recorder problems, and the man-hours consumed in estimating lost hours. It not only greatly reduces the time required to produce the monthly reports but also provides the previously impossible capability of monitoring the operation of all of the field stations simultaneously and collecting real-time short-term counts.

The field equipment was installed by department technicians during the weekly inspection trips around the network under the direction of Automatic Signal Company's staff engineers. This in-house capability eliminated an intial installation charge of $10,000 that would ordinarily have been added to the cost of the system. The manufacturer's staff and service personnel cooperated fully with the department in starting up the equipment, making service adjustments, and solving prototype problems.

Prototype systems often experience intriguing start-up problems. Ninety percent of the preliminary operations were routine; only the remaining 10 percent provided the intrigue. Although the main engineering design and manufacture were sound and everything was delivered in ready-to-operate condition, as usual, several components refused to cooperate. The clock circuitry had to be modified when it was discovered that spurious line noise affected it. An intermittent short circuit developed in the interconnect between the keypunch and the teletype and was finally traced to a tiny slice in a cable and repaired. A week was lost when a power supply failed, requiring a replacement from the manufacturer. Inadvertent open or shunted telephone circuitry errors at the telephone wire centers were frequent until the various supervisors became acquainted with the operation. Similarly, telephone line test signals played havoc with hourly volumes during the early months of operation. Line noise was a problem at first until the telephone company completed balancing all of the circuits. In general, there were fewer problems than had been anticipated when the first lines were connected.

FUTURE PROGRAMS

Future expansion, particularly in urban areas, is now being considered. The additional expense of adding one data input to the present system will be approximately $410 excluding the monthly telephone charge. The field encoder and the matching central office decoder cost approximately $200 each, and the inital telephone charge is

$10. The monthly telephone charge is computed by the number of air-miles to the nearest collector or trunk-line terminal.

Consideration is also being given to the use of short-interval telemetry reporting for special purpose data collection activities connected with urban transportation studies. This would involve portable automatic traffic detectors or manually initiated traffic data reporting directly into the central office assembly. Programs for developing the software requirements to report vehicle speed, classification, and axle configuration through the present system are currently under way.

CONCLUSION

Other agencies controlling their own complete computer systems could afford to consider dial-up applications. The on-line approach is more adaptable for multiservice applications for future expansion and eventual communication link cost sharing of continuous service activities, particularly considering activities requiring real-time monitoring. Many new monitoring programs, such as large-scale air pollution, stream level, and noise level reports, will be linked to central computing storage and switching installations over the rapidly emerging public and private wire service networks. These new networks will eventually link every home and building equipped with telephone or electric service and provide every type of communications from consumer purchasing and marketing to closed-circuit duplex television programming

The on-line, real-time approach is the most appropriate for future expansion and will also contribute significantly to highway planning and the transportation effort in general. Even without utilizing the full capabilities of the present communication networks, this approach provides current data for immediate input to planning projects before the information becomes obsolete. Current traffic information provides an invaluable assist to the traffic engineers working with real-time problems. The automated real-time approach also increases the efficiency of the overall system by providing constant surveillance of the entire system to report malfunctions immediately. This automatic monitoring not only increases the system's efficiency but also relieves technical personnel of the tedious manual computations in manipulating large volumes of data and frees them for more productive assignments.

GLOSSARY

accumulator. Combines counts from several detectors into 1 counter without loss in accuracy due to coincidence of simultaneous pulses.

ATR. Automatic traffic recording.

class A line. Voice-grade telephone service.

class C line. Teletype-grade telephone service that has slow speed and usually costs 20 percent less than class A.

decoder. Interface between telephone terminal and computer.

encoder. Interface between vehicle detector and telephone terminal.

Hz. Hertz, the frequency or number of cycles in 1 second of an alternating current.

M-housing. Radar loop detector cabinet.

Ma. Milliampere, 0.001 ampere.

msec. Millisecond, 0.001 sec.

multiplex. Simultaneous transmission of several signals at different frequencies over a single circuit

PE-housing. Photoelectric roadside cabinet.

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