U.S. Department of
Transportation

An Assessment of Automatic Passenger Counters

September 1982

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Interim Report
September 1982

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Prepared for
Urban Mass Transportation Administration
Washington, D.C. 20590

Distributed in Cooperation with
Technology Sharing Program
Office of the Secretary of Transportation

DOT-I-82-43

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT-I-82-43		

4. Title and Subtitle An Assessment of Automatic Passenger Counters Interim Report	5. Report Date September 1982 6. Performing Organization Code
7. Author(s) David Vozzolo, John Attanucci	8. Performing Organization Report No.
9. Performing Organization Name and Address Multisystems Consulting Division of Multiplications, Inc. 1050 Massachusetts Ave. Cambridge, MA 02138	10. Work Unit No. 11. Contract or Grant No. DOT-UT-9005
12. Sponsoring Agency Name and Address U.S. Department of Transportation Urban Mass Transportation Administration 400 Seventh Street Washington, D.C. 20590	13. Type of Report and Period Covered Interim Report 14. Sponsoring Agency Code

15. Supplementary Notes

UMTA Project Director-Brian McCollom. Study is conducted in cooperation with ATE Management & Service Company, Inc. This report is issued in cooperation with the Technology Sharing Program, Office of the Secretary of Transportation.

16. Abstract

This report summarizes the objectives and current application of automatic passenger counter programs in twelve North American transit properties. Findings are also presented regarding an assessment of APC technology on the basis of accuracy, equipment reliability, data turnaround time, and cost. The report concludes with a case study of the APC program in Ottawa, Ontario, the only North American property which currently depends almost entirely on APC techniques to supply their service planning needs.

The primary objective of automated passenger counters is to efficiently acquire accurate data on passenger activity and transit travel times. These data, which are essential for on-going planning and scheduling activities, may include boardings, alightings, passenger loads, and vehicle running times. Automated techniques enable the reporting and analysis of these data in varying levels of detail. Findings of this report indicate that the APC technology and its creative use may not be the "magical solution" to the bus transit monitoring dilemma; however, it does offer a reasonably cost-effective option which operators can seriously consider to satisfy their data collection needs.

17. Key Words	18. Distribution Statement
Bus, fixed route, evaluation techniques; transit management, planning analysis, methodology.	Distribution is unlimited. Document is being made available to the National Technical Information Service, Springfield, Virginia 22161 for sale to the U.S. public.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	92	

Form DOT F 1700.7 (8-69)

FOREWORD

Many transit operators have been frustrated in their attempt to implement systematic service evaluation programs because they have not been able to efficiently collect the needed information. To assist these operators, UMTA's Office of Planning Assistance, through its Special Studies Program, sponsored a study in data collection. One product of this study was the Bus Transit Monitoring Manual. This manual documents a method for developing a comprehensive, statistically based program that is based on manual (non-automated) data collection techniques.

This report summarizes a review of current applications of automated passenger counter programs. The findings from this review will be used to revise the Bus Transit Monitoring Manual to incorporate automated passenger counters in the development of data collection programs. We believe this report should be valuable to all transit operators who are interested in automated passenger counters.

Additional copies of this report are available from the National Technical Information Service (NTIS), Springfield, Virginia, 22161 at cost.

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The preparation of this report has been financed through a contract from the U.S. Department of Transportation, under the Urban Mass Transportation Act of 1964, as amended. The contents of this report were prepared by Multisystems and do not necessarily reflect the official views or policies of the U.S. Department of Transportation or the Urban Mass Transportation Administration.

ACKNOWLEDGEMENTS

This report was prepared as part of the UMTA-sponsored Bus Transit Monitoring Study being performed by Multisystems, the Consulting Division of Multiplications, Inc., and ATE Management and Service Co., Inc. The authors are David Vozzolo and John Attanucci of Multisystems. The draft and final documents were typed by Gail Pasquale, Ranwa Ramadan, and Audrey Schneider.

The authors would like to thank Vivian Hobbs and Paul Poirier of the Transportation Systems Center for providing valuable information and resources. While the individual contributions of the participating agencies are much too numerous to itemize, their generous assistance is greatly appreciated. The authors are especially grateful to Joel Koffman from OC Transpo, Neil McEachern from Group Five Consulting, Ltd. and Paul Isaacs from Paul Isaacs Associates, all located in Ottawa, Ontario, for spending invaluable time with the authors and providing useful information. Technical input was also received from Tom Friedman at Seattle Metro and Keith Armstrong of Urban Transportation Associates, Inc. in Cincinnati, Ohio.

Finally, we would like to thank Brian McCollom of Urban Mass Transportation Administration (UMTA) for his valuable comments and assistance throughout the project and in preparing this report.

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CHAPTER 1: INTRODUCTION

The change in planning emphasis from capital intensive transit improvements to short-range transit efficiency actions, plus growing fiscal pressures, have increased the importance of transit system surveillance. A significant amount of information is necessary to properly evaluate system performance and identify potential improvements. The same information is also used for scheduling, marketing, deficit allocation or funding reimbursement, and external reporting requirements. This information includes data on patronage (boarding location, travel patterns, transfers, etc.), level of service indicators (on-time performance, travel speeds, delay points, etc.) and revenue/cost performance.

It is important to design a data collection program to obtain reliable data at a reasonable cost. In order to do this, transit managers need answers to questions such as how much data should be collected (i.e., what size sample should be obtained), which data collection techniques are most appropriate, and how often it should be collected (e.g., once a year or at every schedule change). The objective of the UMTA-sponsored Bus Transit Monitoring Study is to provide operators with the information they need to know to design their own comprehensive, statistically-based data collection programs.

In the first phase of this study, a technical manual was prepared for use by operators in the design of a data collection plan consisting of manually collected data.[1] As part of that effort, several observations were made:

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[1] Attanucci, J., I. Burns and N. Wilson, Bus Transit Monitoring Manual, Volume I: Data Collection Program Design, Multisystems, Inc., prepared for Urban Mass Transportation Administration, Washington, D.C., August, 1981.

1. The costs of manual data collection activities and subsequent processing requirements are significant. For example, based on typical industry data requirements and property characteristics, a manually-performed monitoring program would require 1-2 full-time checkers for a 50-bus property and 10-19 traffic checkers for a 1000-bus property. In addition to relatively high costs, several properties using manual techniques report difficulty in obtaining reliable data and experience long turnaround times between data collection and reporting.

2. A growing interest in automated surveillance techniques has been expressed by transit properties. The shift to automated methods is in response to the relatively high costs and operational problems associated with manual data collection programs.[1]

Previous investigations of automated surveillance techniques suggest that they can be used successfully on a regular basis. However, there has been no comprehensive assessment of how automated surveillance techniques can be used in an on-going data collection program. The purpose of this report is to evaluate the current experience with automated surveillance techniques. The report discusses how they work, their general accuracy and cost-effectiveness, and how they currently are or are planned to be integrated into bus transit data collection programs.

1.1 Background of Automated Passenger Counters (APC)

Automated data collection techniques count the number of passengers boarding and alighting a vehicle at each bus stop. Passenger activity is detected either by infrared beams or ultrasonic rays projected across the front and rear doors of the bus, or by pressure sensitive mats placed on the steps. Most of the experiments to date have involved devices which record the number of passengers boarding and alighting, the time of day and an odometer mileage reading every time the bus stops and the doors have been opened.

Most of the early research and applications focused on the use of APCs as components within an Automatic Vehicle Monitoring (AVM) system.[2] AVM systems are designed to provide continuous information on vehicle locations, emergency status and schedule adherence. Automated passenger data are

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[1] It should be noted that the ability to collect accurate bus load data has been hampered recently by the introduction of the advanced design buses with tinted windows, making it very difficult for checkers to count passengers from sidewalk locations outside the vehicle.

[2] See various references in the bibliography for more information on early AVM work.

periodically transmitted through a radio or another communication network to a central processing location. This information is used by transit "controllers" to modify bus schedules as conditions warrant on a "real-time," instantaneous basis. This information is also used "off-line" to perform operational analyses.

Recently, this approach has been demonstrated in two U.S. locations testing AVM systems for on-line route monitoring. General Motors (in cooperation with the city government and Queen City-Metro) has experimented with a signpost type AVM system in Cincinnati, Ohio. The system utilized an infrared beam counter and transmitted operational and ridership data. The second demonstration, sponsored by UMTA in Los Angeles, also uses a broad beam signpost AVM system; however, it utilizes a pressure sensitive treadle system for passenger counting. In addition, the Toronto Transit Commission has implemented an extensive system which provides continuous data on vehicle locations, schedule adherence, passenger activity and emergency status; data is displayed in real-time on controller's screens and reported off-line.

Recently, there has been considerable interest in using APCs as separate surveillance tools. The difference between this approach and AVM systems is that data are not transmitted instantly, but are stored on-board the bus on either magnetic tape or solid state memory. At a later time, the data are transferred to a central processing location for validation and analysis. The use of APC as a separate surveillance tool has been tested and implemented on an individual basis by several transit properties.

1.2 Objectives of this Assessment

Previous studies have focused almost solely on the accuracy of APCs in recording actual on/off passenger movements. Little, if any, attention has been paid to the integration of such automated techniques into an overall data collection program.

This assessment addresses this concern by examining all current applications of APC techniques utilized by transit properties throughout the U.S. and Canada. It concentrates on the off-line use of APC systems, noting, where appropriate, the increased capabilities and utility of combining such counters with real-time AVM systems.

To assess the various APC techniques which have been implemented and their integration with comprehensive surveillance systems, each of the current applications within the U.S. and Canada is examined. The major issues addressed in this assessment include:

- the number and type of counters currently in use;
- the specific data collected;
- the method of referencing individual stop or route segment data;
- the procedure for storing and transferring on-board data to a central processing location, and availability of data processing tools;
- a description of how the counters are used as part of the systemwide data collection program (e.g., used on only particular routes or rotated periodically throughout the system);
- the types of analyses for which APC data are used (e.g., simple ridership profile on the route or run level, or detailed boarding and alighting counts as well as schedule adherence at the stop level);
- the results of any tests which may have been performed on counter accuracy;
- an assessment of equipment reliability and maintenance requirements;
- the costs of purchasing, installing and using automated counters, and a comparison of these costs with manual techniques;
- the overall statisfaction among transit property staff regarding the role and use of the automated counters; and
- any future proposals and applications of automated techniques within an overall data collection program.

In addition, a comparison is made among the various techniques regarding costs, accuracy, reliability, turnaround time and overall satisfaction.

1.3 Study Approach

Preliminary information regarding the properties in North America who have implemented, or are planning to implement, APCs was obtained from personnel at the U.S. Department of Transportation (DOT)/Transportation Systems Center. An extensive literature search was also undertaken to trace the development of automated counter techniques.

Most of the information, however, was obtained via telephone discussions and follow-up with each of the operators currently using or designing APC techniques. Many of the operators also provided additional written materials on their data collection programs.

1.4 Organization of the Report

The purpose of this interim report is to describe the variety of automated counter techniques currently in use, assess the cost, reliability and effectiveness of these systems, and to examine their role within a comprehensive data collection program for transit system surveillance.

Chapter 2 defines each of the various hardware and software technologies currently utilized in automated passenger counter systems. This chapter discusses the types of counting sensors, logic units, data storage and transfer facilities, as well as processing and reporting programs which have been implemented.

Chapter 3 presents a summary description of current applications of APC techniques within transit properties throughout the U.S. and Canada. At least twelve transit systems have implemented automated counter programs.

In Chapter 4, APC systems are assessed on the basis of cost, accuracy, reliability and turnaround time.

In Chapter 5, the role of automated counters within surveillance programs of each operator is discussed through the overall mini case studies.

Finally, Chapter 6 concludes with a discussion of the potential role which APC systems might play in bus monitoring programs.

The primary objective of automatic passenger counters is to efficiently acquire accurate data on passenger activity and transit travel times. These data, which are essential for on-going planning and scheduling activities, may include boardings, alightings, passenger loads and vehicle running times. Automated techniques enable the reporting and analysis of these data in varying levels of detail (i.e., route, trip, route segment or bus stop).

Transit properites often differ regarding the specific data items which they consider in their service monitoring program. They place different emphases on the level of detail with which data are reported and analyzed. Due to these differences, a variety of APCs have been implemented.

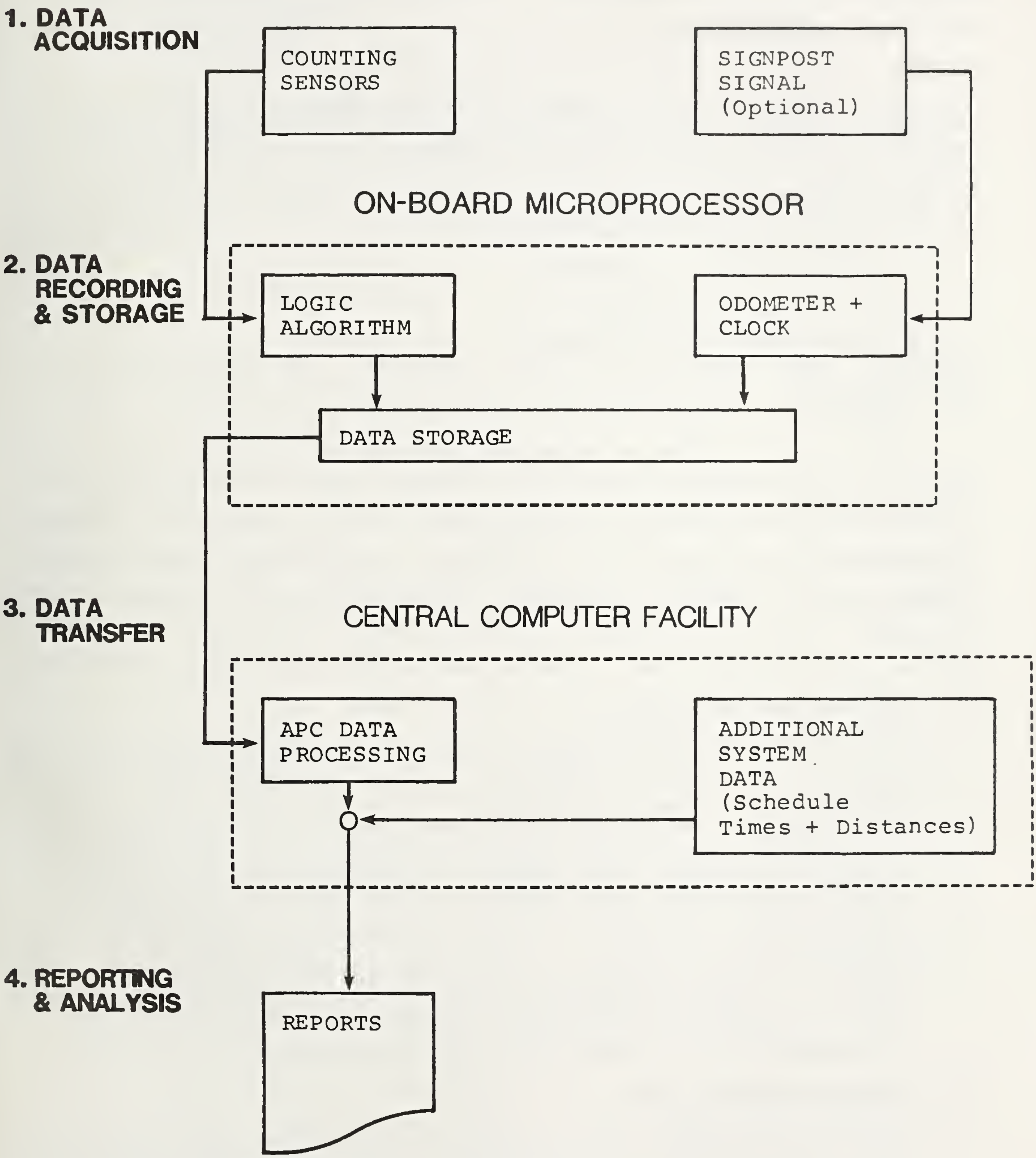
There are four basic steps in collecting and analyzing APC data which are common to all APCs (Figure 2-1). These include:

1. Data acquisition;
2. Data recording and storage (on-board);
3. Data transfer to a central computing facility; and
4. Reporting and analysis.

Several hardware and software components are used in these steps. First, counting sensors located at each doorway of the bus detect passenger activity. A data processing unit, located on-board the bus, uses a logic algorithm to translate the counts into boardings and alightings. Generally, these boardings and alightings are then stored in a way that permits easy stop-referencing of the counts. This is done through the recording of time or distance measurements, or from signposts (located at designated intervals

Figure 2-1

BASIC STEPS AND COMPONENTS OF APC TECHNIQUES



along the route) which transmit coded signals to the bus. After the data have been stored for a period of time (usually several days), some type of mechanism is used to transfer the information from the on-board processing unit to a central computing facility. Finally, the data are input to software packages and the desired reports are generated.

The remainder of this chapter describes these procedures in greater detail. The following components are examined:

- counters;
- on-board data processing units;
- location referencing methods;
- data transfer mechanisms; and
- reporting and analysis routines.

2.1 Counters

APCs count the number of passengers boarding and alighting a bus at each stop. A sensor device is installed at both the front and rear doors of the vehicle to detect passenger movement. These sensors must be able to count passengers bi-directionally (i.e., boarding and alighting). Many different sensor devices have been developed to detect passenger movement. These include:

Infrared beam interruption

This system projects at least two light beams horizontally across the bus doorways to a light-sensitive receiver. When the light beam is interrupted, a count is registered. This information is sent to a counting logic unit which identifies the direction of movement and number of passengers. The sequence in which the beams are broken determines the direction of movement. For example, a passenger boarding the bus first interrupts the beam closest to the door, then both beams simultaneously, then only the inner beam. Finally, neither beam is interrupted and a boarding count is recorded. In many cases, multiple beams are projected across the doorway in order to increase the detection ability of the sensors. The use of multiple beams allows more accurate identification of individual passengers during heavy boarding loads and helps prevent the inaccurate detection of extraneous objects (e.g., parcels and handbags).

Reflective infrared beam

Reflective techniques are very similar to the infrared interruption system except that they utilize a two beam device which both transmits and receives infrared light beams. Two beams of light are projected across the doorway of the bus. The reflectors are mounted on the opposite side of the doorway and transmit the light beams back to sensors which are located within the same unit as the light source. Thus, all of the "working" components are contained in a single device rather than two separate devices (i.e., a light transmitter and a receiver) as in the above infrared systems.

Treadle sensor mats

This system uses pressure sensitive mats which are installed on the two steps of each door on the bus. The mats contain pressure sensitive elements which are activited when a specified design weight is applied to the treadle. The logic processor is designed to produce a count whenever two steps are sequentially activated and to differentiate between boarding and alighting movements. Mats are sealed for protection from dust, moisture and other environmental factors.

Ultrasonic interruption sensors

While ultrasonic systems have been discussed in the research literature, no applications were discovered. Sonic beam sensors count passenger activity similarly to interruptable light beam sensors, except the sound energy is used as the medium in place of infrared light.

The installation of the counting sensors is considered one of the most important procedures in the development of a successful APC program. Experience in systems throughout North America has indicated that the accuracy of the boarding and alighting counts is highly correlated to the specific location of the sensor units within the doorway of the bus. This is particularly true of the infrared beam counters. Many operators note that the optimal location for the "outer" counter is as close to the skin (exterior) of the vehicle as possible, with the "inner" counter located closer to the end of the steps and the farebox.

At the same time, the units must be protected from vandalism, tampering and general abuse. Infrared sensors often become non-aligned as a result of excessive crowds, the doors changing position or slight collisions at the front end of the bus while taking turns. Treadle mats are also susceptible to damage from front-end collisions while the bus is turning, particularly on those vehicles equipped with low steps for wheelchair lifts.

As a result of possible damage to the sensors and non-alignment of the beams, careful attention must be given to the care and maintenance of the counting hardware. These issues, and the actual experience of properties using various APCs are discussed in greater detail in Chapter 4.

2.2 On-Board Data Processing Units

Counting sensors are connected to a microprocessing unit located on-board the bus. This microprocessing system serves several important functions. First, a logic algorithm is applied to inputs received from the counting sensors to produce counts of passengers and to identify direction of movement. Secondly, specific data items are recorded (e.g., boarding and alighting counts, time and distance measurements) when pre-defined events occur during the operation of the bus (e.g., arrival at a bus stop, beginning of schedule layover). These data are then stored in a facility on-board the vehicle until they are later retrieved and processed. Each of these functions of the microprocessor are discussed in greater detail below.

2.2.1 Counting Logic Algorithm

Before boarding and alighting counts can be recorded, inputs from the counting sensors must be interpreted. An algorithm installed in the microprocessing unit counts passenger volumes and direction of movement. For example, the algorithm utilized with treadle mat counting units records a count of one whenever the two steps in the doorway are activited sequentially. The direction of passenger movement (i.e., boardings and alightings) is dependent upon the order in which steps are activated. Similarly, algorithms used with infrared beam counters identify passage and direction by sequence of beam interruption.

Several potential sources of error exist during the activation of a count sensor and the interpretation of the logic algorithm. These include:

- inaccurately detecting direction and recording a boarding as an alighting, or vice versa;
- incorrectly counting a swinging arm or extraneous object (e.g., parcels, handbags) as a passenger;
- undercounting a large group of passengers while boarding or alighting;
- overcounting passengers who stand in the stairwell and move back and forth; and
- mistakingly counting a door opening or closing as a passenger boarding or alighting.

These potential errors can be minimized by the logic algorithm. For example, by disabling the counting sensors when the doors are closed, double counting of passengers in the doorway can be minimized. In addition, algorithms have been developed to compensate for detection of opening and closing doors.

In addition to passenger activity detection and interpretation, many microprocessing units also contain algorithms which are designed to identify failures in the passenger counting sensors.

2.2.2 Data Records

One of the most important functions of the microprocessing unit is to record specified data inputs. Actually, two types of data are obtained and stored by the APC units:

1. the passenger boarding and alighting counts and the vehicle arrival times which are the data objectives of the devices and would, otherwise, need to be collected using manual counting techniques; and

2. information which references the above data to a specific bus trip and to stop locations along the route of that trip.

The first type of data described here corresponds directly to the information observed and recorded by a transit "traffic checker" when performing a manual riding check. Such ride checks are immediately referenced as to vehicle trip and location since the checker manually notes information such as the run number, scheduled trip start time, and the bus stop location (address or code number) at which any passenger activity occurs. APC systems, on the other hand, do not have such an immediate, fail-safe capability for referencing the passenger count data by specific trip and bus stop location. Instead a variety of information is recorded which allows a series of computer programs to interpret the count and time data and reference the observation tc the appropriate trip and location.

The data generally recorded and stored by an APC system includes:

- passengers boarding and alighting at each stop;
- the time associated with the arrival at each stop where passenger activity occurs;
- one or more various trip and location referencing codes which might include:
  - a run, bus number or trip I.D. code (usually initialized once for an entire run or trip)
  - odometer readings for each stop where passenger activity occurs
  - a signpost-transmitted location code.

In order to efficiently accomplish the later data referencing processing task, each APC system includes different algorithms which automatically instruct the microprocessing unit to record specific data items. These algorithms are activated by a series of vehicle "events" which send a unique signal to the microprocessor to record certain data and/or record the type of event which occurred. For example, a vehicle event such as the arrival at a bus stop and the opening of the vehicle doors may instruct the microprocessor unit to record boardings, alightings, odometer readings, a time measurement, etc. For each event identified by the transit operator as important to route operation, the on-board microprocessor can be preprogrammed to record specified data observations. A list of location, distance or other operational events which may be utilized to activate data input include:

Door Opening	Data inputs may be recorded if either door is open for a specified length of time (e.g., one or more seconds). This event is generally used to signal the microprocessor to record passenger activity and time data.
Door Closing	Some properties may also be interested in recording the door closing in order to detect leave time and/or compute dwell time.
Begin of Idle	Data may be recorded when the bus has been idle for a specified time (e.g., one minute) without activating the door opening or closing event. Data recorded at this event can be useful in locating the vehicle in time and distance, since such idle events will generally correspond with layover points.
End of Idle	Data may be recorded when the bus has moved a specified distance after having been idle for a designated time (e.g., two minutes). This data helps identify time and distance when the vehicle is back in service.
Time and/or Distance Traveled without Stop	Data may be recorded at designated intervals (measured in time and/or distance) if the bus has been traveling without a stop. Such data records provide further interpretation of a vehicle's location, especially on routes with low passenger activity or long express segments.

(Optional) Signpost Detection — If the APC system utilizes signposts for vehicle location, data inputs are recorded when the signpost transmission is received. The unique ID code references the vehicle in time and distance. In addition, systems may record data at the loss of the signpost signal to provide additional locational information.

Memory Space Overflow — Data inputs may be recorded for internal system use in order to more efficiently record and store data. When the space in memory to record time, distance or passenger inputs is about to overflow and must be reset, a "flag" is recorded to reference this event, thereby signaling the analyst that some data has been deleted and accumulated totals should be adjusted.

2.2.3 Data Storage

After recording data inputs at specified vehicle events, the on-board microprocessor stores these data for later retrieval and analysis.[1] Two types of data storage techniques have been utilized within the industry: cassette tape and solid state memory. The storage capacity of those units which have been installed varies; however, cassette tape units generally have a significantly larger storage capacity than current solid state memory units. While all have the capability of storing at least 24 hours of data, actual capacity often ranges from three to fourteen days.

One of the major determinants in the choice of a storage technique is the available mechanism used to transfer the data from the vehicle to the central computing facility. Many properties wish to avoid human interaction in order to minimize the dangers of mishandling as well as to minimize the operating costs associated with the APC program. Mechanisms exist to automatically transmit the on-board data to a central computer facility (see Section 2.4), but currently these mechanisms are only compatible with a solid state on-board storage unit. Generally, however, no one type of storage device appears to offer any substantial advantages over another type.

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[1] In at least one U.S. system, however, data are not actually "stored", but rather, a cumulative on/off count is continually displayed (until reset) for recording by a driver or other transit system personnel.

2.3 Location Referencing Methods

Accurate vehicle trip and stop-referencing is one of the most important elements in the collection and analysis of APC generated data. Systems generally record time (through an internal microprocessor clock) and distance (using the vehicle odometer) measurements in conjunction with data on passenger activity. Individual trips and stops can then be determined by matching automated measurements with existing files of scheduled times and distances.

The individual run schedule time and stop-by-stop distance files can be used in two ways to reference APC data to a specific trip and bus stop (or route segment). For the first method, the bus is assumed to be "on time" at the beginning of each trip and any APC data recorded subsequently is referenced based on a computer-generated comparison of the APC odometer reading to the stop-by-stop distance file measured from the "start" location. Thus, if the bus is truly on time at the start of a trip, the referencing should be fairly accurate. (However, schedule adherence information is lost using this method since the analyses program assumes on-time performance to initialize the process.) A second method uses a computer program to search the APC records for bus layover intervals (i.e., begin and end of idle events). When a layover is detected within a specified "window" (e.g., ±15 minutes) of a scheduled layover, the program begins to reference individual vehicle trips and stops using the stop distance files and moving in both directions (i.e., before and after) from the layover record. In this way, the capability to analyze schedule adherence and route running times is maintained since the schedule files are used only to identify an initial bus layover point.

Some transit properties also use signpost identification systems for vehicle trip and stop-referencing. Signpost units are located at designated intervals along the route. They transmit coded signals which are recorded by the microprocessor receivers on-board the bus and stored with other data inputs. The recording of a signpost signal clearly marks the particular vehicle in space and time and allows easy referencing of all stop activity.

The following signpost identification technologies have been developed:

<u>Sharp Signpost</u> — Provides a precise position location at specific points (e.g., individual bus stops). Signals are transmitted through roadside narrow beam optical scanners, microwave transmitters or magnets imbedded in the road surface.

<u>Broad Signpost</u> — Provides area coverage within a designated range (e.g., over an entire route segment). Signpost units transmit coded radio signals periodically which are then received by buses within range. Thus, an APC unit might receive several signals from the same signpost while traveling along a particular route segment. Individual stop-referencing would require subsequent processing using specially developed software.

<u>Radio Frequency</u> — Systems provide precise position location at any point within the service area by means of computer analyzed radio signal triangulation. Technologies included VLF, pulse trilateration, AM phase lock.

The use of signposts does provide increased accuracy and often reduces the costs of stop-referencing and post-processing. The need for such a system is a function of the desired accuracy of referencing stop locations and of the availablility of detailed files which provide scheduled times and distances between bus stops.

2.4 Data Transfer Mechanisms

Some type of mechanism is required to transfer the data from storage on-board the bus (in either magnetic tape or solid state memory) to a central computing facility. While AVM systems automatically transmit data from the vehicle to the computer over a two-way radio, systems using only automatic counting units require the physical transfer of the data.

Two basic types of data transfer mechanisms have been developed:

- portable recording units (requiring manual operation); and
- automated retrieval systems.

The technique used by most operators is a portable recording unit. At designated times, transit system personnel (e.g., maintenance or security staff) enter the vehicle with the portable unit in order to retrieve the APC generated data. With APC equipment utilizing magnetic tape memory, this procedure usually involves pulling the used tape and replacing it with a fresh tape. With solid state memory, the portable recording unit is plugged into the microprocessor, retrieves the APC generated data, and stores it internally (e.g., diskette within the portable unit). At some later time, data recorded on the temporary storage medium (e.g., tape or diskette) are read into main computer memory.

An automated retrieval system is another data transfer technique which has recently been developed (although only in prototype forms to date). The automated systems minimize physical handling of the data. One automated technique utilizes an umbilical cable which may be inserted into the bus to facilitate data transmission directly to the computing facility. The cable data retrieval system can be located at the fueling island or a similar location. As a result, the transfer of the data, which is performed very quickly, can be implemented as a standard operating procedure. Another automated transfer technique utilizes infrared data transmission from the on-board unit to a receiving sensor. Data can then be transmitted to the receiving sensor and input to the main computer. The sensor may be located at the garage entrance or another convenient location where it can be utilized as part of normal bus "turn-in" operating procedures.

2.5 Reporting and Analysis Routines

The objective of any transit data collection program is to transform the data obtained into information which can be used effectively by transit operating managers. Once APC counts have been collected and transferred to a central computing facility, the raw data must be processed to provide useable management information.

The first processing step usually is related to referencing the vehicle trip and stop (or route segment) for each of the APC count records. In this first task, scheduled time and distance files are merged with the APC data files. APC generated time and distance data are matched with the schedule inputs in order to identify specific counts with the appropriate bus stop. For signpost referencing systems, a similar processing task is undertaken; in this case, a file which relates the signpost codes to specific locations, a schedule file, and the APC records are merged and edited to identify which observations "belong with" specific vehicle trips and stops. Once the APC data and schedule input files have been successfully merged, a completed master file listing APC data on a trip-by-trip or stop-by-stop basis is created and stored.

The APC data on ridership activity, times and schedule information stored in completed master files can be utilized to produce three general types of reports. These include:

- passenger activity;
- time performance; and
- performance indicators.

Reports on passenger activity may incorporate information on passenger loads (average or maximum) as well as boardings and alightings. Time performance reports may present several different data items including running times, schedule adherence, headway distributions and dwell times. In addition, many transit properties combine the APC generated data and other schedule and financial data to produce a variety of performance indicators. A wide range of such measures are utilized within the industry including passenger miles, passengers per hour, revenue/cost ratios, revenue miles/vehicle miles, etc.

Each of these reports can be generated for several different levels of detail. Reports can vary on the basis of both spatial and temporal disaggregation. For example, Table 2.1 presents several different spatial and temporal levels of detail which can be analyzed and reported using the APC generated data. The level of detail differs from property to property primarily as a result of different emphases incorporated within service monitoring programs. There is a clear tradeoff between level of detail and level of expenditure. If a transit property should decide to analyze time and count data at the stop level, there are additional expenditures for acquiring more accurate counting sensors, greater utlization of the APC units in order to obtain larger samples, and more extensive software required to accurately stop-reference data. Therefore, while the APC system may be capable of reporting and analyzing the data in great detail (e.g., for each bus stop), each property must make the decision whether or not the disaggregation is worth the added cost.

Table 2.1

LEVELS OF DETAIL INCORPORATED IN APC GENERATED REPORTS

SPATIAL DISAGGREGATION

- System total
- Division or garage total
- Route level
- Driver run or vehicle block
- Bus Trip
- Route segment
- Bus stop

TEMPORAL DISTRIBUTION

- Totals for weekday, Saturday, Sunday
- Time periods (AM, MID, PM, EVE)
- Hourly
- 15-minute periods during peak traffic hours

CHAPTER 3: NORTH AMERICAN APPLICATIONS OF APC TECHNOLOGY

Since the mid 1970s, several U.S. and Canadian transit properties have implemented APC systems. At this writing, additional systems are in the process of installing or acquiring APC units. As discussed in the previous chapter, each transit property has a relatively unique program of service monitoring, planning and scheduling, and often consider different types of data and levels of detail in their surveillance, analysis and reporting procedures. Consequently, APC systems have been designed to serve a variety of functions.

This chapter presents a description of the automated counter technology implemented in U.S. and Canadian properties. The different systems are examined in terms of the number of APC equipped buses and the types of counter and signpost (if applicable) components utilized. Specific methods used to store data on-board the bus, to transfer it to the central processing location, and to accurately stop-reference counts and time measurements are discussed. Further discussion of the objectives and roles of APC systems in the context of the properties overall data collection systems is contained in Chapter 5.

3.1 Characteristics of Current APC Systems

Twelve North American properties are now operating or are about to implement APC systems (Table 3.1). These properties can be grouped into three categories:

1. automated vehicle monitoring (AVM) systems (3);

2. operational APC systems (non-AVM) (2); and

3. new APC systems (7).

Table 3.1

APC SYSTEMS IN NORTH AMERICA

	Number of Units	Type of Counter	Implementation Date
AVM SYSTEMS			
Windsor (formerly Cincinnati)	27 Counters 37 Signposts	Pro-Data Dual Beam	1981 (1977-1981)
Los Angeles	200 Counters 500 Signposts	Dynamic Control Treadle Mats	1980
Toronto	100 Counters 16 Signposts	Dual Beam (self-designed)	1976
OPERATIONAL APC SYSTEMS			
Ottawa	49 Counters (16 new units anticipated)	Pro-Data Dual Beam (Paul Isaacs Infrared Beam)	1978-79 1982 (new systems)
Seattle	56 Counters (acquiring 250 signposts)	Dynamic Control Treadle Mats	1978
NEW APC SYSTEMS			
Calgary	5 Counters (demonstration)	Paul Isaacs Infrared Beam	1982
CALTRANS	25 Counters (obtaining 65 units from LA)	Dynamin Multiple Beam	1979 (purchase) 1982 (implementation)
Columbus	6 Counters 8 Signposts	Pro-Data Dual Beam	1982
Kalamazoo	20 Counters 30 Signposts	Honeywell Dual Beam	1982
Minneapolis/ St. Paul	44 Counters	Pro-Data Dual Beam	1979 (purchase)
Portland	50 Counters	Paul Isaacs Infrared Beam	1982
Quebec City	3 Counters (10 new units)	Pro-Data Dual Beam (Paul Isaacs Infrared Beam)	1980 1982 (new systems)

Three types of counting sensor technologies have been used (i.e., dual infrared beam, multiple infrared beam and treadle mats), although the dual beam counters have proven most popular with eight systems in use (or proposed) at this date. Half (six) of the current systems use or plan to use signpost location referencing technology.

The earliest applications of APC techniques were in coordination with comprehensive automated vehicle monitoring systems. In Cincinnati, Ohio, General Motors Transportation Systems Division experimented with an AVM system that utilized infrared beam counters. Signposts, located at schedule timepoints, transmitted location code signals to passing buses. At frequent intervals, raw data collected on the bus were sent over the radio to the computer for processing. (The full Cincinnati system has been moved recently to Windsor, Ontario.) In 1976, the Toronto Transit Commission designed and installed 100 dual beam counter units and 16 signposts as a part of its overall AVM surveillance program. They have also been experimenting with treadle mats due to dissatisfaction with the accuracy of the beam counting logic. Finally, an UMTA-sponsored demonstration in Los Angeles has implemented a broad beam signpost AVM system that utilizes pressure sensitive treadle mats for passenger counting. The 200 units have been used exclusively on four heavily patronized bus lines.

Two transit properties have extensive experience with APCs which are used to collect passenger data and store it for later processing. The Seattle Metro installed a treadle mat system on 56 buses in early 1978, and is installing signpost identification systems in 1982. OC Transpo in Ottawa, presented as a detailed case study later in this report, installed 49 dual beam counters in 1978-79 and is acquiring 16 more units in 1982.

Three U.S. systems have more recently installed, or are planning to acquire, automated counter units. The State of Michigan is sponsoring a demonstration in Kalamazoo. Twenty buses have been equipped with dual beam counters and 30 signposts have been installed for stop-referencing. The purpose of the demonstration is to examine the applicability of APC techniques in the service monitoring programs of a small transit system within the State. Tri-Met in Portland, Oregon, is implementing 50 dual beam units in 1982. Tri-Met made the decision to initiate an operational program after two years of experience with two prototype units. The Central Ohio Transportation Authority (COTA) in Columbus, Ohio, has made a rather unique arrangement. A consultant has been contracted for a fourteen-month period to provide six dual beam counters and eight portable signposts, collect data on all routes and bus runs, and generate detailed reports appropriate for route planning activities.

The Metropolitan Transit Commission (MTC) in Minneapolis/St. Paul purchased 44 dual beam systems in 1979. However, due to contractual difficulties with the manufacturer (and the resultant non-delivery of on-board storage units), use of these systems has been limited. While the existing units do display on-board the bus a cumulative count of ons and offs, no mechanism for data storage is available. Drivers are required to record count readings at designated points in order to use the counters. MTC considered establishing a system in which drivers call in data over the radio at specified locations; however, it has not yet been tried because of operational difficulty with such frequent communications, particularly during peak periods. Since these problems have not been resolved, MTC does not use the counters as part of their ongoing data collection program.

In 1979, CALTRANS began a demonstration program with six small transit systems in the State (Bakersfield, Golden Gate Transit, Montebello, Monterey, Sacramento and Santa Cruz) by acquiring 25 multiple beam counters. CALTRANS is currently also negotiating for the acquisition of 65 units originally purchased for Los Angeles. The purpose of the test is to determine whether the APC technique was practical for small properties. Another objective is to determine what role CALTRANS may have in assisting small systems in data collection. Currently, all hardware (i.e., 25 units) has been installed and processing software is being developed in Sacramento. Several problems have developed and delayed the demonstration. The direction and scope of the demonstration is now being re-evaluated.

Four other Canadian cities have some experience with the implementation of APC systems. In Calgary, five infrared beam counter units are currently being installed on a demonstration basis. In Quebec City, 13 units are being used in a systemwide monitoring program to identify "problem" routes which may require more detailed manual data collection to identify appropriate service changes. One APC unit is currently being tested by the London, Ontario, transit system in order to determine if a full-scale program should be developed. In Edmonton, Alberta, two prototype APC units were developed in 1977-78 but, after testing, the program was discontinued primarily because of high development and implementation costs.

3.2 Methods of Data Storage, Transfer and Referencing

The majority of the APC systems utilize solid state memory data storage components (Table 3.2). The storage capacity of the APC units generally ranges from three to fourteen days with the magnetic tape units currently having significantly greater storage capability. Solid state memory is preferred by most properties because of their desire to minimize human error, possible mishandling or other damage. Magnetic tape is often viewed as more susceptible to these potential damages since the storage medium must be directly handled by operating personnel, although there is no evidence that the properties using tape have encountered significant problems.

Most APC properties currently transfer the on-board data to a central computing facility with some form of portable recording unit. At designated intervals (e.g., every night or once every three nights), an employee enters the vehicle in the garage, plugs the portable unit into the on-board storage facility, and makes the transfer. At a later time, data are transmitted from the portable recorder to the central computing facility. The Columbus and Kalamazoo systems (each using magnetic tape memory) have established transfer procedures which simply require "pulling" the "used" cassette tape from the bus, and reloading the bus with a new cassette.

A few APC properties have developed mechanisms for automatically transmitting data via a communication link with the bus at the garage or fueling station. For example, the CALTRANS demonstration retrieves data from the bus storage facility by inserting an umbilical cable into a connector on the bus while it is in line at the fueling station. Data are automatically transmitted to the computing facility over telephone lines in approximately fifteen to twenty seconds.

Portland is introducing a retrieval system which transmits data from bus storage to sensors located at the garage entrance through an infrared communications link. At the end of each day, the bus pulls in and data are automatically transmitted in approximately two seconds. The bus is required to pull into this location at the garage every day as part of the standard procedure to "pull" the farebox. Consequently, data transfer is accomplished

Table 3.2

METHODS OF APC STORAGE, TRANSFER AND REFERENCING*

	Method of Data Storage	Method of Data Transfer	Method of Stop Referencing
OPERATIONAL APC SYSTEMS			
Ottawa	Solid State	Portable Unit	Extensive schedule files matched with counts
Seattle	Solid State	Portable Unit	Match schedule time and APC recorded times (acquiring signposts)
NEW APC SYSTEMS			
Calgary	Solid State	Portable Unit	No stop-referencing capability at this time
CALTRANS	Solid State	Transmission at Garage	Extensive schedule files matched with counts
Columbus	Magnetic Tape	Portable Unit	Match distance files, aided by signposts
Kalamazoo	Magnetic Tape	Portable Unit	Match distance files; aided by signposts
Minneapolis/ St. Paul	No Storage Capability	No Transfer	Drivers manually record stop and APC count from display
Portland	Solid State	Transmission at Garage	Extensive schedule files matched with counts
Quebec City	Solid State	Portable Unit	No stop-referencing capability at this time

* AVM systems not included in table since storage, transfer and referencing capabilities are not required for AVM technologies.

quickly, automatically (no human interaction), and as a step in standard operations. This system was designed by Tri-Met to deliberately eliminate human error and minimize mechanical difficulties. This completely automated system is not yet in place, so it is impossible to determine its reliability in regular use.

As shown in Table 3.2, a few properties have developed processing routines which automatically match APC count, time, and distance data with existing files on scheduled times and distance measurements for each stop by route, run and trip. This procedure requires that extensive files of each scheduled trip be maintained which list times and distances between each stop and layover point. Two other properties (Columbus and Kalamazoo) match APC count data with scheduled time and distance files; however, the location identification and referencing process is complemented by signpost input data.

Seattle Metro currently uses a manual system that identifies trips and stops on the basis of scheduled time. Printouts are generated for each route and run which list scheduled times and APC observed times. It is assumed that the bus is on schedule and that the stops match the time point. Metro is acquiring signposts in 1982. It is believed that the signposts will increase the accuracy of matching stops.

At the present time, Calgary and Quebec City do not have stop-referencing capability. A decision has not been made in the Calgary Transit APC Demonstration on the most appropriate referencing technique. Consideration is being given to signposts and different time and distance data files. In Quebec City, there is interest only in using the automatic counters to collect route level data. An optional attachment is being introduced for the on-board unit which can be initiated by the driver at specified locations. This capability allows referencing at selected points for use in special surveys or other data collection efforts.

CHAPTER 4: ASSESSMENT OF APC TECHNIQUES AND APPLICATIONS

This chapter assesses the current APC applications on the basis of four technological factors: accuracy, equipment reliability, data turnaround time and cost. When available, actual operating data are presented. In other cases, more qualitative assessments have been made based on detailed discussions with operating personnel.

4.1 Accuracy

Most assessments of automated counter techniques have concentrated almost exclusively on the issue of counter accuracy. Previous analyses have conducted tests which collect both manual and automated counts on board the same vehicle. Findings generally emphasize that APCs may be accurate in a comparison with the manual check within some percentage (e.g., 85%, 90%) in terms of total boardings and alightings, or that APC data may be accurate within ±2 passengers at the bus stop level a certain percentage (e.g., 90%, 95%) of the time.

While these are important issues, there has not been much consideration given to the implications of these varying degrees of accuracy on the utility of count data for service monitoring and planning purposes. For example, what is the real significance of an APC boarding count being within 90% accuracy (in comparison with manual boarding counts) as opposed to 80%? This is especially germane when the counts may only be collected once every four months and may not be "typical" of route performance simply due to the day-to-day variation in ridership activity. As with manual data collection techniques, the implications of selecting desired accuracy levels must be carefully considered. The use of the data and the increased cost of obtaining more accurate data must be weighed in selecting appropriate accuracy levels and, consequently, data collection methods.[1]

This section of the report addresses these issues relating to counter accuracy. First, the results from accuracy tests presented in the research literature are presented. Findings from tests performed by several transit properties operating APC units are then discussed.

4.1.1 Research

In 1979, an evaluation of three commercial passenger counter systems (one treadle mat system and two infrared beam systems) was conducted to assess their potential performance for the Los Angeles AVM system.[2] Accuracy and environmental tests were conducted in the laboratory and on-board an operating transit bus. Test data indicated that the counter which incorporated treadle mats exhibited superior counting performance over the two infrared beam systems (Table 4.1). In general, all three counter systems were more accurate on boarding counts as compared to alighting counts. Also, all three systems tended to undercount passenger activity rather than overcount.

In March of 1982, UMTA, through the U.S. DOT Transportion Systems Center, sponsored a task to conduct a limited-scale accuracy field-test with the intention of providing an indication of the relative performance of APCs and on-board manually-taken ride checks. The test covered a range of boarding conditions on routes exhibiting from 1 to 12 passengers boarding at any given stop. The field test was conducted on five properites: Seattle, Minneapolis/St. Paul, Columbus, Kalamazoo and Los Angeles. The counter technology used on three of the five properties was a dual infrared beam; on the remaining two properties, pressure sensitive treadles (mats) were tested.

The results of the field test did not indicate a significant difference in performance between the APCs and the on-board ride checkers. A summary analysis of a composite sample of approximately 8600 transactions yielded the

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[1] The reader is referred to the Bus Transit Monitoring Manual for a detailed discussion of the desired accuracy for bus monitoring programs.

[2] Balaram, A., G., Gruver, H., Thomas, "Evaluation of Passenger Counter System for an AVM Experiment, Volume 1: Technical Report," Gould Information Identification, Inc., Fort Worth, Texas, February 1979.

Table 4.1

SUMMARY OF LA/GOULD PASSENGER COUNTER ACCURACY TESTS

Summary of Boarding Errors

Measure of Accuracy	Treadle Mat Dynamic Control	Multiple Beam Dyniman	Dual Beam Pro Data
Percentage of Errors That Were Overcounts	21.02	31.16	23.08
Percentage of Errors That Were Undercounts	78.98	68.84	76.92
Percent Correct Counts	92.65	91.02	78.83

Summary of Alighting Errors

Measure of Accuracy	Treadle Mat Dynamic Control	Multiple Beam Dyniman	Dual Beam Pro Data
Percentage of Errors That Were Overcounts	45.99	31.52	44.67
Percentage of Errors That Were Undercounts	54.01	68.48	56.32
Percent Correct Counts	90.08	81.53	79.56

Source: Balaram, A., G., Gruver, H., Thomas, "Evaluation of Passenger Counter System for an AVM Experiment, Volume 1: Technical Report," Gould Information Identification, Inc., Forth Worth, Texas, February 1979.

following results: the APCs were in absolute agreement with "truth"[1] for 78% of the transactions compared to 86% for the on-board ride checkers; with a variance of ±1, the APC's performance was 95%, compared to 96.5% for the ride checkers.

In terms of total passenger counts for a sample size in excess of 20,000,[2] the data acquired using APCs was 94.2% of the "truth" compared to 96% for the on-board ride checkers. Two factors are of significance when considering the results:

1. The on-board ride checker results can be considered a "best effort" since it was known that these results would be compared with two other sources: the "truth" and the APCs. (Even so, there was a wide range in performance among the on-board ride checkers); and

2. No special maintenance or tuning was performed on the APCs in preparation for the field test. In at least one instance, no such effort had been made within 18 months.

4.1.2 Operator Experience

Most APC transit properties have undertaken "loose" accuracy checks and concluded that counters seem accurate enough for their purpose. On the other hand, few properties have implemented extensive accuracy testing through comparisons of APC-generated counts with manual counts.

In the Winter of 1978-79, Seattle Metro undertook a series of accuracy tests on both standard and articulated buses equipped with automatic counters. As shown in Table 4.2, the treadle mat counters were found to be extremely accurate. For example, standard bus accuracy is 98% for boardings and almost 94% for alightings. These accuracy measures are even higher when examined on the basis of stop records being within ±1 or ±2 of manual counts. These findings seem somewhat consistent with the 1979 Los Angeles AVM study which found that the treadle mat counters were highly accurate. On the standard buses, test results also confirm previous findings that counters seem

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[1] The "truth" was defined as a team of individual checkers (one to monitor each door) acting independently of the third who was "the" on-board ride checker for the purposes of comparison with the APC units.

[2] The data from which these statistics were derived precluded the possibility of including bus stops at which more than 12 passengers boarded or alighted.

Table 4.2

SEATTLE ACCURACY TESTS (Winter 1978/79)

		STANDARD BUS	ARTICULATEDS
N(# Tests)		20	22
# Stops per Test	$\bar{X}$	132.4	74.5
	S	38.0	23.4
TRIP ACCURACY			
% Accuracy on	$\bar{X}$	98.0	94.0
	S	2.1	2.6
% Accuracy off	$\bar{X}$	93.8	94.8
	S	2.8	2.4
STOP ACCURACY			
% 0 On	$\bar{X}$	93.0	88.4
	S	2.4	4.8
Off	$\bar{X}$	88.0	88.6
	S	3.2	5.2
% $\pm$ 1 On	$\bar{X}$	98.4	97.7
	S	1.2	1.9
Off	$\bar{X}$	96.3	97.5
	S	3.2	2.2
% $\pm$ 2 On	$\bar{X}$	99.3	99.1
	S	0.8	1.0
Off	$\bar{X}$	98.8	99.4
	S	0.8	1.1

Note: $\bar{X}$ equals the mean
S equals the standard deviation

more accurate for boarding measurements than for alightings. It is interesting to note that the articulated test results do not agree with this finding. While there is a slight tendency toward more accurate measurement of alightings, accuracy levels are generally identical. In ongoing operation, Metro has found that about 80% of the boardings and alightings totals for a full day bus operation are within 10% of each other (the standard established for retention use of the APC data in Seattle).

The London Transit Commission in London, Ontario, Canada has been experimenting with one APC equipped bus using pressure sensitive treadle mats. During the Winter/Spring of 1982, a series of accuracy tests were performed. In March 1982, peak hours were surveyed for one week by two checkers who manually recorded passengers boarding and alighting at each stop and recorded the count from the APC equipment. Accuracy was compared on the basis of number of passengers boarding at the front door, alighting at the front door and alighting at the rear door (Table 4.3). Tests concluded that front door "on" and rear door "off" APC counts were very accurate in comparison with manual checks, 93.9% and 97.6%, respectively, while front door "off" counts exhibited 84.8% accuracy. The APC units tended to overcount on rear door alightings. The test results present accuracy data separately for stops with relatively low passenger activity (1 to 5 boardings or alightings) and high passenger activity (6 to 10 boardings or alightings). Findings indicate that at stops with high passenger activity, APC counts are 100% accurate within ±1 of the manual count. At stops with low passenger activity, APC counts were 98%-100% accurate within ±2 of the manual counts.

Accuracy tests were also performed in Cincinnati as part of the evaluation of the transit information system (Table 4.4). The Cincinnati results differed from previous findings in that alighting counts were more accurate than boardings (in most other tests, boardings are more accurately measured). The Cincinnati results are consistent, however, in that the APCs tended to undercount.

During the Winter of 1980-81, MTC in Minneapolis/St. Paul, performed accuracy tests on its APC-equipped buses. Because MTC did not have a complete set of APC equipment on their buses (no on-board memory), the automated count data was tabulated by drivers reading off the counter at the end of each trip. These numbers were then compared to the manual count data on a trip and

Table 4.3

LONDON, ONTARIO ACCURACY TESTS (March 1982)

	Front Door Boardings	Front Door Alightings	Rear Door Alightings
Average Weekday Total Count			
% Accuracy	93.9%	84.8%	97.6%
Stop Level Accuracy			
1-5 Passenger Activity	(83 stops)	(50 stops)	(100 stops)
% Error 0	86.7%	70.0%	97.0%
% Error ±1	98.8%	94.0%	99.0%
% Error ±2	100.0%	98.0%	100.0%
6-10 Passenger Activity	(10 stops)	(1 stop)	(10 stops)
% Error 0	70.0%	0.0%	70.0%
% Error ±1	100.0%	100.0%	100.0%

Table 4.4

CINCINNATI ACCURACY TESTS

N = 33 Trips

Total number of ONS = 1826

Total Number of OFFS = 2009

TRIP ACCURACY

% Accuracy ON	87%
% Accuracy OFF	90%

STOP ACCURACY[1]

% 0 Accuracy ON	81%
% 0 Accuracy OFF	85%

[1] Tests results not presented for accuracy at stop level within ±1 or ±2; results only presented for perfect accuracy at stop.

run basis. As a result of this methodology, no stop level analyses were possible. As shown in Table 4.5, the accuracy of APC boarding counts is extremely high. On the other hand, the accuracy of alighting counts appears low. The difference is particularly evident when one examines the percentage of runs and trips which are within ±15% accuracy. As with previous test results, the MTC data indicate that the automated counters tend to undercount rather than overcount passenger activity.

In the MTC test results, the fact that the accuracy of boarding counts is so high seems to indicate that the counting sensors themselves are performing extremely well. However, the significant difference between boarding and alighting accuracy may be due to the location of the sensor in the rear stepwell or some other minor flaw. Experiences in other APC properties have shown that sensor location for infrared beam counters is a major determinant in count accuracy. Even a slight movement of the light beam sensor (also referred to as lighthead) toward the "skin" of the bus can yield substantial improvements in count accuracy.

In addition to altering the location of counting sensors, there are other measures which can be taken to compensate for differences in boarding and alighting accuracies. In cases like the MTC where there is a systematic error resulting in undercounts of alighting activity, these data can be factored by the boarding count on a trip or run basis in order to yield matching and consistent counts. For example, OC Transpo in Ottawa, Ontario, calculates and applies such a factor within their analysis and reporting software. For individual APC equipped vehicles, the software calculates the systematic undercount of alightings (from the previous days data) and computes a factor which is then applied to the count.

Generally, then, the available data have shown that APC data obtained from properly installed and cared for units are reasonably accurate, especially when boarding counts alone are considered.

4.2 Equipment Reliability

An issue of special concern which transit operators frequently raise when discussing APC technology is the reliability and durability of the counting sensor hardware, the on-board microprocessing unit,

Table 4.5

MINNEAPOLIS/ST. PAUL ACCURACY TESTS

N_r = 31 Runs

N_t = 118 Trips

TOTAL SAMPLE ACCURACY

% Accuracy ON	95.4%
% Accuracy OFF	85.7%

RUN ACCURACY

% Accuracy ON	93.3%
% Accuracy OFF	83.6%
ON Count	90% of runs within ± 15% accuracy
OFF Count	49% of runs within ± 15% accuracy

TRIP ACCURACY

% Accuracy ON	96.7%
% Accuracy OFF	87.7%
ON Count	90% of trips within ± 15% accuracy
OFF Count	58% of trips within ± 15% accuracy

and electrical connections. Transit properties are not able to utilize 100% of the data potentially collected with APC equipment. Operators report that only 85-90% of APC units are in working order at any given time and, of these, only about 80% produce acceptably accurate readings on specific bus runs. In some cases, there have been mechanical problems which have hampered effective utilization of the counting technology. Most properties have been able to overcome these technical difficulties; however, there remains skepticism regarding the reliability of the APC equipment. Only one operational system (Seattle Metro) was able to provide an estimate of the continuing equipment availability. In Metro's case, 35-36 (90%) of their 40 operating units are generally in working order on any given day. For those in working order, Seattle Metro generally has to discard approximately 20% of the individual vehicle trip readings because of "bad" or inconsistent data. This section addresses the reliability issue by examining typical mechanical malfunctions and the various actions taken to solve them.

In general, problems of equipment reliability experienced by North American transit properties which have implemented APC programs can be grouped into the following categories:

- sensor malfunction or non-alignment;
- electrical disconnections;
- odometer readings; and
- environmental factors.

4.2.1 Sensor Malfunction

In Los Angeles, the treadle mats with counting sensors were originally installed on the first and second steps of the stairwell at both the front and rear door of the bus. The mat on the first step was often damaged or destroyed when buses turned close corners and hit the curb. To minimize damage, the installation procedures were changed and the mats were moved to the second step and the platform. This alteration successfully minimized the problem. In addition, Los Angeles experienced difficulty when mats tended to "set" on the stairwell; that is, after time the mats occasionally settle in over the treadle pins. As a result, treadle pins are not activated and passenger counts not registered. This malfunction can be corrected by replacing the mat and resetting the treadle pins.

The major difficulty with infrared beam counting sensors concerns maintaining the proper alignment of the paired units of lightheads at each doorway. Improper alignment of the two lightheads simply means that the light source is being emitted, but is never received and therefore no counts are registered. Front-end collisions may damage or change the alignment of the lighthead sensors. The location of the sensor units within the doorway also makes them highly susceptible to general abuse and movement by crowded passengers. In addition, counting units may fall victim to vandalism on-board the bus. To minimize these problems, the counting sensors require frequent monitoring and inspection in order to identify and correct problem units.

4.2.2 Electrical Disconnections

Buses have an extensive series of electrical connections weaved throughout the frame of the vehicle. The electrical wiring complicates APC installation procedures and often requires special body work to insert the wires and connectors for the APCs. Electrical disconnections or other malfunctions occasionally occur. For example, Seattle Metro experienced difficulty when its data dump operation would unexpectedly "hang up". Maintenance personnel originally thought it was a noise spike from the bus electrical system. After examination, it was discovered that one of the electrical sockets merely had a bad connection. As a result, what was originally feared as a major electrical problem turned out to only require a few dollars for a new connecting socket. Clearly, there have been other instances where APC applications have experienced more extensive electrical malfunctions. One interesting note concerns the Los Angeles automated counter units. At one time they were having difficulty on chair lift installations because cables running under the mats on the floor were being "guillotined" by wheelchairs.

4.2.3 Odometer Readings

Another equipment problem is inaccurate odometer readings. Odometer readings are required to stop-reference count data. Inaccuracies of the odometer readings can produce distance calibration errors. Odometers are extremely sensitive measuring devices. Several properties mentioned problems experienced with distance calibration. For example, CALTRANS and OC Transpo in Ottawa, Ontario, have both observed variation in odometer readings. OC Transpo keeps a record of distance calibration accuracy for each APC equipped bus and introduces a correcting factor which is applied to the distance measurement in the software processing.

4.2.4 Environmental factors

Environmental factors can impact the accuracy and reliability of counting sensors. For example, Seattle Metro has problems with leaking and water penetration in their treadle mats. While the mats have been redesigned, there are still some linkage problems, particularly on the lower mats. Seattle operating personnel feel that the major defect is the design of the mats, in that they do not "hold' strongly in place on the step.

Infrared beam sensors are also susceptible to environmental factors, particularly cold weather, ice and snow. OC Transpo in Ottawa, Ontario, experienced malfunction problems with sensors, particularly lightheads located closest to the "skin" (exterior) of the vehicle, as a result of ice produced by the extreme cold weather. The problem was solved by redirecting the flow of warm air from a nearby heater vent toward the lighthead. The added warmth has been extremely helpful in minimizing the problem.

Another environmental problem is light reflections. OC Transpo observed that boarding and alighting counts are extremely inaccurate when APC buses are traveling directly into the sun, particularly in early AM and late PM periods. On the other hand, passenger counts are excellent when the vehicle is moving away from the sun. They have observed that vinyl clothing (e.g., raincoats, parkas) or other shiny objects reflect light and interrupt the operation of the light beam counting sensors.

There are a number of specific actions which can be taken to minimize problems with equipment reliability. First, preliminary testing of the equipment can help avoid potential technical difficulties. Many of the successful automated passenger counter programs started with a few prototype units before they introduced the total system. For example, Portland, Ottawa, Quebec City and Calgary all gained experience with prototype units and worked out the technical "bugs" before defining desired equipment and performance specifications. In addition, these properties shared information and were able to learn from others' mistakes.

Proper installation techniques can also minimize reliability problems regarding beam alignment. For example, the appropriate location of the sensor, protective brackets, hidden wiring, and secure doors can protect the lightheads from vandalism and general abuse.

Finally, monitoring of the equipment and its performance can be critical to effective utilization of the APC technology. Several transit operating personnel stated that it is important to develop a close working relationship among the APC supervision personnel, maintenance, body shop and electrical staffs. While it is clear that APC equipment needs a degree of special attention, which other vehicle subsystems generally do not require, the APC properties believe that equipment reliability and maintenance needs do not pose major obstacles to the successful operation of an APC system. On the other hand, greater industry acceptance of APC technology appears to hinge on an improvement (and solid documentation of this improvement) in the operational reliability of such systems.

4.3 Data Turnaround Time

One of the major concerns regarding the collection of transit operating data is the turnaround time between observation and analysis. Transit managers, planners and schedulers often require quick analysis of current data on ridership activity and time performance. The objective of any data collection program is to assemble this information in an efficient manner. AVM systems are designed to transmit operating data over real time to enable instantaneous analysis. Both APC and manual systems, on the other hand, store this information for later processing and analysis.

The APC technique appears to be superior to manual data collection regarding turnaround time. APC data is read directly from on-board storage into the central computing facility. Software is then used to generate the desired reports and analyses. Manually collected data, on the other hand, requires assembling all ride and load count sheets, keypunching and, finally, reading the data into software packages.[1] A significant time savings can be achieved with an APC system. In fact, several properties currently utilizing manual data collection programs have experienced excessively long turnaround times (e.g., up to a year) between observation and data reporting and analysis. SCRTD in Los Angeles is currently experiencing this problem. The longest delay in the typical process includes the time for data validation, editing and keypunching.

Specific information on data turnaround times for APC applications is limited. Little information was discovered on direct comparisons between turnaround times of APC and manual data collecton programs. However, interviews with operating personnel from properties implementing APC techniques did provide insights on turnaround time.

The average turnaround time at Seattle Metro is between five to six days. A portion of this time includes a day or two during which the data is stored on-board the bus in solid state memory. Due to manpower and APC scheduling conflicts, it sometimes takes two to three weeks to provide the information requested from a transit manager and the generated analyses. Despite these

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[1] A recent improvement in this area which can be incorporated into manual collection programs is the development of a number of hand-held data collection devices which are calculator-like instruments into which checkers can input observed data which is then stored and (later) automatically dumped into a central computer.

minor time lags within the data collecton program, Seattle personnel noted that this turnaround time represented a major improvement over the manual system previously utilized.

OC Transpo in Ottawa, Ontario, assembles all APC generated data into a series of management reports at the end of each quarterly service period. OC Transpo also assembles data from APC observed bus runs for spot analyses for purposes of short-term planning and scheduling. APC count and time data are transferred from on-board storage to the central computer facility on the day following data collection. A series of automated processing procedures then separate each bus run into individual trips and segments. Finally, stop-by-stop listings of APC count data are produced and become available for spot analyses one or two days after the initial observation.

Metro Transit in Kalamazoo specified within their contract with the APC vendor a maximum of a one-week turnaround time from "pulling the data tapes" from on-board storage to generation of reports. At the present time, all data processing is undertaken at the vendor's computing facility. Operating personnel at Metro Transit stated that turnaround time may be reduced significantly if the processing capability is maintained in-house rather than off-site. Nevertheless, the current one-week turnaround represents a significant time savings over the manual system.

4.4 Costs

An obviously critical step in the assessment of automated passenger counters is to examine the costs of acquiring and operating such systems. This discussion considers two major aspects of APC cost factors: (1) the actual costs experienced by North American APC applications are listed and examined; and (2) costs of APC systems are compared with the costs of manual data collection programs (on a hypothetical basis).

4.4.1 Identification of APC Costs

The costs of acquiring and operating APC systems have been dissagregated into discrete cost components. These major cost components, divided into expenditures for hardware and software, include:

1. Hardware

- Equipment

  - counting sensors (lightbeams, treadle mats, etc.)
  - on-board microprocessors
  - signposts
  - transfer mechanisms

- Installation

- Maintenance

2. Software

- Development of Analysis and Reporting Software

- File Creation and Updating

  - vehicle assignments
  - scheduled times and distances

- Operating Costs

  - editing and validation
  - processing
  - analysis and reporting

4.4.1.1 Hardware Costs

In general, hardware costs listed under the heading of equipment are clearly identified by transit properties utilizing APC techniques. Installation and maintenance costs, on the other hand, are not as straightforward. The counting sensors and microprocessor units require monitoring of the data and occasional readjustment. While significant amounts of manpower are required for these tasks, the corresponding costs are often not identified.

The costs of acquiring and operating APC systems (for both hardware and software) vary significantly among transit properties. Several different types of systems have been implemented in order to serve a variety of data analysis and reporting functions. Consequently, the costs of these systems also differ, depending upon the type of information desired and the accuracy required. In addition, APC hardware costs cannot be easily estimated because the market for such equipment is so small. Manufacturers of APC components have come and gone over the past decade and virtually every procurement has involved "tailor-made" specifications. As a result, there are few, if any, "off-the-shelf" components currently on the market or in production.

It is difficult to make meaningful comparisons of these costs among systems. One reason for this difficulty is the relatively large time lag between the acquisition dates of equipment. As shown in Table 4.6, at least 12 APC systems have been implemented in North America, and several APC hardware units have been purchased between 1976 and 1982. Simply due to inflation, a comparison between 1976 and 1982 costs can be misleading. Second, and more importantly, these costs naturally vary because of the different capabilities included within each system.

There is also a wide range of costs for counting sensors and on-board microprocessors. When examining both of these components in terms of one unit cost per bus, early APC systems (before 1981) range from $2,000-$3,500, while the more recent systems range from $2,500-$4,000.

The estimated cost of the signposts used in the Cincinnati AVM were approximately $450 per unit. The new APC system in Kalamazoo is using signposts which cost an estimated $300 per unit. In addition, Seattle Metro reports that new signposts cost approximately $300 per unit. While the actual cost of the signpost unit is not very high, there are additional expenditures regarding the need for receivers on the on-board microprocessor which can receive and record signals from the signpost.

Not much information was available on the costs of APC transfer mechanisms. Data, stored on-board the bus on magnetic tape or solid state, must be transferred to the central computing facility. In Kalamazoo the portable data recorder was priced at $2000 per unit. For the more recent Canadian properties, portable transfer units were priced at $5000-$6000 per unit.

There are also additional costs associated with portable transfer mechanisms (for both tape or solid state storage mediums) which involve the labor required to enter each vehicle, retrieve the cassette/read in stored data, and initialize the new cassette or solid memory component. Data transfer may be performed by maintenance or security personnel performing their routine duties. For example, in Ottawa it is standard procedure for security personnel to enter each vehicle late in the evening and retrieve data with the portable recorder unit. Each morning, all the diskettes collected

Table 4.6

APC HARDWARE COSTS

	Equipment*					
	Counting Units	On-board Micro-processor	Signposts	Transfer Mechanisms	Installation	Maintenance
AVM Systems						
Cincinnati	$700	N.A.	$450/ unit	-	$315/bus $400/post	$36000 annual
Los Angeles	$2000 (total cost/bus)		N.A.	-	N.A.	N.A.
Toronto	$300	N.A.	N.A.	-	N.A.	N.A.
OPERATIONAL APC SYSTEMS						
Ottawa	$600-750	$3000-$3500	-	$5000/ unit	2 mandays/ bus	$20,000 annual
Seattle	$2800 (total cost/bus)		$305/ unit	N.A.	$500/bus $50/post	N.A.
NEW APC SYSTEMS						
Calgary	$4000 (total cost/bus)		-	$6000/ unit	N.A.	N.A.
CALTRANS	$2000 (total cost/bus		-	N.A.	N.A.	N.A.
Columbus	(Total Contract of $31,000 equaling $135 per peak bus)					
Kalamazoo	$667	$2890	$300/ unit	$2000/ unit	$2490/bus and post	$29680 annual
Minneapolis/ St. Paul	$750	$2500	-	-	N.A.	N.A.
Portland	$2587 (standard bus) $3559 (articulated) (total cost/bus)			$3880/ unit	$641/bus	N.A.
Quebec City	$3200 (total cost/bus)	-	-	$5000/ unit	$350/bus	N.A.

* Equipment costs are presented as follows: counters and on-board microprocessor costs may be presented separately as cost per equipped bus or collectively as total cost per equipped bus; signpost and transfer mechanism costs are presented on a per unit basis.

the previous evening are placed in the main administrative office and are available for input to the computer. In Portland, Oregon, the data retrieval system has been designed to minimize human interaction by transmitting data from the bus to sensors located at the garage. This system is priced at $3880 per unit; however, the installation costs are substantial (over $7000 per unit at the garage). Of course, only a limited number of these units need to be purchased based on the number of operating divisions at which APC buses will be based.

Regarding installation, costs in older systems range from $300-$500 per bus, while the more recent APC systems range between $500-$750 per bus. In addition to the construction of supporting brackets and placement of the counting sensors and on-board microprocessor, there is a great deal of wiring which must be placed in the vehicle. Throughout North American APC applications, a variety of installation arrangements have been undertaken. Some properties install the units in-house, using their own maintenance, electrical and body shop personnel. In some cases, the vendor selling the equipment is also hired to install it, or independent contractors may be hired. Seattle Metro first installed mat units in-house (with some assistance from the vendor) before they decided to contract with a local firm.

There seems to be a high economy of scale regarding the actual time required for installation. With experience, the process can be streamlined significantly. For example, in Kalamazoo, the first unit took 1½ weeks (using 2-3 people per day), while the last four units were all installed in 1 week.

APC equipment also needs constant monitoring and readjustment. While a significant amount of manpower is attributed to these tasks, often the corresponding costs are not specifically identified and allocated to the APC budget. In Kalamazoo, the annual maintenance budget (including spare parts) for 20 units and 20 signposts is approximately $30,000. Cincinnati budgeted $36,000 annually for maintenance.

At the 1979 Passenger Counter State-of-the-Art Conference, part of the discussion addressed maintenance expenditures. One APC manufacturer suggested that the norm within the electronics industry was an expenditure of 0.5% to 0.75% of the initial capital costs as a budget for monthly maintenance expenditures. Therefore, it was suggested that perhaps 1.5% (per month of initial capital cost) should be used as the budgeted maintenance costs for APC systems since they had to operate in a hostile rather than a protected environment.[1] To examine this budget estimate, an analysis was made of the Cincinnati AVM budget.[2] Based on expenditures for on-board equipment totaling $202,390, the maintenance budget ($36,000) equaled 17.8% of capital cost on an annual basis, or exactly 1.5% on the monthly basis. Signpost maintenance, on the other hand, was budgeted at an annual expense of 3.2% of capital cost. An examination of the Kalamazoo budget found that monthly maintenance was estimated at 2.6% of capital expenditures.

4.4.1.2 Software Costs

While hardware is used to collect the data, the software is used to assemble, edit, analyze and report the data. Because of the large amounts of data generated and the complexity of the processing routines, software development and operating costs often exceed expenditures for hardware components. In many cases, the software costs are not well documented and may be underestimated.

Total software costs incorporate three basic components: software development; file creation; and operating costs. Report writing is not included as a major cost component because the major software efforts involve data validation, editing, sorting, and the merging of APC and schedule files.

Through contacts with transit operating personnel, expenditures for software development in a few APC applications were obtained. These estimated costs range between $150,000 and $250,000. For example, OC Transpo in Ottawa, Ontario, spent approximately $250,000 on initial software development. In addition, another $25,000 was spent to incorporate new analysis and reporting capabilities within the existing software. These new capabilities include programming revisions to accommodate articulated buses and to compute dwell times as well as ons/offs for the individual doors on the vehicles. Calgary, Alberta, is currently developing an APC demonstration project. Estimated costs

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[1] Documented in the "Minutes of the Passenger Counter State-cf-the-Art Conference Conducted at SCRTD Headquarters in Los Angeles on Wednesday, December 12, 1979," Prepared by John B. Schnell, American Public Transit Association, Washington, D.C., December 1979.

[2] Bevilacqua, O., et al., "Evaluation of the Cincinnati Transit Information System (TIS), DeLeuw, Cather and Co., San Francisco, CA, August 1979.

for initial software development range between $150,000 and $200,000. At Seattle Metro it was estimated that 1.5 person-years were spent on software development. Other properties (e.g., Columbus and Kalamazoo) utilize APC systems with software and analysis packages which were developed previously by the vendor (although these properties do specify additional capabilities in order to incorporate individual reporting requirements). No development cost estimates are available for these applications.

Accurate stop-referencing of the count data is enhanced significantly by merging APC data with schedule time and distance files. This is often accomplished as a procedure within the computerized data processing system. The schedule data inputs attempt to recreate the time and distance travelled (including deadheading and layovers) by each bus run in the system. As a result, there are significant costs associated with the creation and updating of these files.

Despite the significance of the costs for creation of schedule files, most transit properties contacted did not have documentation of expenditures for these tasks. In fact, only one property provided a cost estimate. OC Transpo in Ottawa, Ontario, indicated that the creation of a schedule file cost an estimated $40,000.

Finally, software costs include the expenditures for processing, editing and reporting data. These ongoing costs tend to range between $50,000 and $70,000 annually in the APC programs implemented to date. Once again, specific processing cost estimates were only obtained from a few properties. Ottawa spends approximately $60,000 per year in processing and editing. Kalamazoo estimated annual expenditures of $61,500 for data processing and software maintenance. Seattle Metro reports approximately $12,000 per year in processing costs; however, many of the editing and stop-referencing tasks are performed manually. Portland Tri-Met, which has not yet implemented its APC program, provided an annual estimate of between $60,000 and $70,000.

4.4.2 Comparison between APC and Manual Data Collection Costs

In general, APC techniques are used by transit systems to facilitate the collection of useful, accurate data in a cost-efficient manner. The conventional method of data collection used by most transit properties involves the use of traffic checkers to perform point (or load) checks, riding checks, and/or the collection of boarding counts by the bus operator. To make a valid assessment of automated counter techniques, it is necessary to compare APC costs with typical expenditures for manual data collection programs.

Most transit systems are not able to furnish good estimates of their costs for manual data collection. In general, such programs are not treated as separate budget items, but are included as part of the overall scheduling and service planning expenditures. Also, it is difficult to isolate these data collection costs when transportation, marketing, accounting, and other personnel are collecting and assembling selected data items as part of their overall job responsibilities.

Few of the transit properties who have implemented APC techniques were able to provide detailed comparisons between the current budget and previous expenditures for manual data collection. One reason that direct comparisons are often difficult is that the APC system is generating much more data than previously collected with manual checkers.

COTA in Columbus, Ohio, awarded a $31,000, six-month contract to a consulting firm to collect, process and report data for each run in the system. While a direct comparison is not available, one COTA representative stated that a similar effort attempted manually in-house would cost in excess of $200,000 and most likely would not be completed within the same six-month time period.

In Ottawa, Ontario, OC Transpo previously employed eight full-time traffic checkers, with an annual cost of $160,000 for the manual monitoring program. OC Transpo currently operates 49 APC equipped buses, and is in the process of equipping 16 more vehicles. The current staff consists of two people who are now responsible for other administrative duties, but do occasionally perform trailing checks or load counts. OC Transpo believes that the APC system paid for itself in its first two years of operation. In addition, they believe that much more useful data is being collected and reported than was possible with the manual program.

Since there have not been many direct comparisons, an analysis was made of typical expenditures for APC and manual programs. Major cost components within a budget for manual data collection programs generally include the following:

- manpower needed to collect data on-board buses or on the street;
- administrative or supervisory tasks (e.g., the detailed scheduling of checker work assignments);
- data preparation (coding and keypunching of completed forms); and
- data processing, editing and reporting.

The first item can be compared with the hardware costs associated with automated counter techniques. While APC systems require an initial expenditure for purchase of equipment (and corresponding installation and maintenance costs) to collect data, manual checker programs require the payment of annual salaries to staff members who perform checking duties. Both APC and manual programs require a significant amount of administrative and supervisory time and cost. The last two items directly relate to the software costs of automated counter techniques. A substantial amount of data is generated and must be processed. APC systems do not require coding and keypunching of count data since these data are automatically transferred from the vehicle to computer memory via magnetic tape or diskette. On the other hand, once the data are keypunched, processing costs for manual data may be less than for APC systems. APC processing costs are higher because the APC data must be stop-referenced through the use of schedule files and edit count data. Manually collected data are already stop-referenced on the checker form.

The largest cost item in manual data collection budgets is the manpower needed to collect data on-board buses or on the street. Manual checking programs and practices vary substantially across the industry in terms of labor costs and work policies.[1] Checker costs depend greatly on the ability

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[1] See Interim Report #1, Data Requirements and Collection Techniques, Bus Transit Monitoring Study, prepared for UMTA by Multisystems, Inc. and ATE Management and Services Co., Inc., April 1979.

of management to assign personnel to odd shifts and have the same personnel perform varied data collection duties.

In the first phase of the Bus Transit Monitoring Study, a range of checker requirements were estimated (assuming statistically-based sampling) for typical bus system sizes.[1] The (full-time) traffic checker requirements shown in Table 4.7 are based on the assumption that a sample of trips on every route in the system is monitored four times a year. (If less frequent monitoring is desired, these requirements can be reduced proportionally.) Generally, the low ends of the ranges given in Table 4.7 represent cases where reliable operator data are available; the upper ends of the ranges represent the cases where drivers do not collect boarding data.

This analysis has undertaken a cost comparison between manual and automated data collection techniques. The comparison examines costs of the different data collection programs (APC and manual) for a transit property with 750 peak buses. The estimation of costs for the manual program utilizes the range of number of traffic checkers required as shown in Table 4.7; that is, manual costs assume a range of 8-15 full time checkers.

The cost comparison for a property with 750 peak buses incorporated APC costs which assume a range of 8-15 buses equipped with automated counters. The assumption is made in the analysis that both manual and APC systems can collect approximately the same quantity and quality of transit data using the same number of units (either checkers or APC equipped buses). This assumption is based on several findings of this assessment. For example, APC accuracy tests performed by researchers and transit operators conclude that automated systems generate reasonably accurate data in comparison to manually collected data. In addition, information obtained from APC operators has provided insight regarding the quantity of information generated using automated techniques. While a checker is limited to an eight hour day, five days a week, an APC equipped bus can theoretically collect passenger data twenty-four hours a day, seven days a week. Due to equipment reliability, maintenance and accuracy considerations, however, operators are not able to utilize 100% of the data potentially collected with APC equipment. Generally, of the APC

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[1] Attanucci, J., I. Burns and N. Wilson, <u>Bus Transit Monitoring Manual, Volume I: Data Collection Program Design</u>, Multisystems, Inc., prepared for Urban Mass Transportation Administration, Washington, D.C., August 1981.

Table 4.7

TYPICAL CHECKER STAFF REQUIREMENTS FOR BUS SYSTEMS OF DIFFERENT SIZES ASSUMING STATISTICALLY-BASED SAMPLING

Peak Buses	Off-Peak Buses	Average Daily Service Hours	Number of Traffic Checkers Required
25	22	12	1/4 - 1
50	40	12	1 - 2
100	70	14	1-1/4 - 4
300	215	15	3 - 7
500	250	16	6 - 13
750	470	17	8 - 15
1000	600	18	10 - 19
2000	1100	19	20 - 38

Source: Attanucci, J., I. Burns and N. Wilson, Bus Transit Monitoring Manual, Volume I: Data Collection Program Design, Multisystems, Inc., prepared for Urban Mass Transportation Administration, Washington, D.C., August 1981.

units available to a property, only 85-90% are in working order at any given time and, of these, only about 80% produce acceptably accurate readings on specific bus runs. Thus, it can be assumed that a typical APC unit installed on a vehicle used for twelve hours a day will, on the average, obtain the same amount of useable data as a traffic checker assigned for eight hours.

Table 4.8 presents the different unit costs employed in the comparison between manual and APC systems for a transit property of 750 peak buses. The APC hardware and software costs employ ranges of expenditures actually experienced by APC properties of that size. Administrative requirements and manual personnel costs are also derived from actual North American APC applications and from industry averages. Software costs for manual data collection systems were obtaind using professional judgement and experience. For example, the study team is currently undertaking a comprehensive software development effort as part of the Bus Transit Monitoring Study. The study

Table 4.8

DOCUMENTATION OF COST ESTIMATES

MANUAL CHECKING PERSONNEL	• Checkers - $23,000 annual salary for 5 years
APC HARDWARE	• APC Equipment - on-board equipment at $4,000/unit - 150 signposts at $450 per unit - 2 transfer mechanisms at $4,000 per unit
	• APC Installation - $600 per on-board unit - $100 per signpost
	• APC Maintenance - 18% of capital cost for on-board equipment, annually for 5 years

SOFTWARE		Manual	APC
	• Software development	$100,000	$250,000
	• File creation and update	$ 32,000	$ 70,000
	• Processing costs for	$2,500/month for 5 years	$5,000/month for 5 years

ADMINISTRATION & SUPERVISION	• Manual - 1½ employees at $23,000 annual salary for 5 years
	• APC - 2 employees at $23,000 annual salary for 5 years

team is currently spending approximately $125,000 for software development to analyze both ride and point checks as well as driver boarding counts.

In general, the cost estimates used in the analysis can be considered conservative in favor of the manual technique; that is, lower estimated costs were applied to the manual system while higher estimated costs were applied to the automated counter system. The comparison considers the costs accrued over a five-year period. Consequently, manual costs incorporate checkers salaries (and benefits) over the five-year period and APC costs incorporate the initial purchase expenditure, installation, and maintenance costs (assuming a five-year useful life); both manual and APC system costs include software development and ongoing processing costs.

The results of the cost comparison for a property with 750 peak buses, presented in Table 4.9, indicate that an automated counter system is less costly than a manual data collection program of comparable size.[1] On an annual basis, the analysis estimates manual costs of $274,900 to $435,900 for 8 to 15 checkers, respectively, and APC system costs of $211,900 to $223,400 for 8 to 15 APC equipped vehicles, respectively. In terms of annual cost per unit, manual system costs are estimated at $34,400 for 8 checkers and $29,100 for 15 checkers, while APC per unit costs are estimated at $26,500 for 8 units and $14,900 for 15 units.

In addition to the difference in costs beteween manual and APC techniques, note the decreasing cost per APC unit as the number of APC equipped vehicles increases. The decreasing marginal cost is primarily because software development and processing costs make up the major expenditures, and these costs tend to increase at a decreasing rate for additional units. The significance of the marginal cost is illustrated when one notes that the annual cost of utilizing one additional checker equals approximately $23,000 while the annual cost of utilizing (installing and monitoring) one additional APC equipped bus equals approximately $6,000.

The approach used in the development of the cost analysis for the transit property with 750 peak buses has also been used to develop a cost comparison between manual and APC systems for properties of different sizes. Unit costs for manual personnel and APC hardware acquisition, installation, and maintenance are the same for different size properties as for the property with 750 peak buses. Administrative and supervisory personnel requirements change proportionally with varying property size. The estimation of software costs for both manual and APC systems, on the other hand, does not change in strict linear proportion with the size of the transit property or with the number of APC equipped buses. There is a relatively high initial start-up cost for software development and file creation which is difficult to minimize, even with small properties and few APC units. In addition, large properties with many APC units experience significantly higher processing costs as the volume of data increases and the processing routines become more complex.

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[1] Note that discount and inflation rates were not utilized in the calculation of annualized costs.

Table 4.9

COMPARISONS BETWEEN APC AND MANUAL COSTS - ESTIMATES OVER A FIVE-YEAR PERIOD

TYPE OF COST	MANUAL PROGRAM (8-15 Checkers)	APC SYSTEM (8-15 Equipped Buses)
TOTAL CHECKER PERSONNEL COST	$920,000-$1,725,000	
TOTAL APC HARDWARE		$261,900-$319,300
Equipment		
- onboard units	$32,000-$60,000	
- signposts		$67,500
- transfer		$8,000
Installation		$12,300-$16,500
Maintenance		$89,600-$114,800
TOTAL SOFTWARE	$282,000	$620,000
Software Development	$100,000	$250,000
File Creation and Update	$32,000	$70,000
Processing Costs	$150,000	$300,000
ADMINISTRATION & SUPERVISION	$172,500	$230,000
5-YEAR TOTAL COSTS	$1,374,500-$2,179,500	$1,059,400-$1,116,800
ANNUAL COSTS	$274,900-$435,900	$211,900-$223,400
ANNUAL COST PER UNIT	$34,400-$29,100	$26,500-$14,900

The comparison of costs for manual and APC data collection programs (Table 4.10) indicates that, for most sized properties, APC systems can be less costly than manual techniques. When costs are accrued over a five year period, the high "up-front" costs for APC hardware and software development are lower than the ongoing costs for manual checker salaries and benefits. The analysis indicates, however, that for those transit properties below 100 peak buses (utilizing less than 4 checkers or APC units), the difference in costs between the two data collection techniques is minimal.

Table 4.10

COST COMPARISON FOR DIFFERENT SIZE TRANSIT PROPERTIES

Peak Buses	Number of Traffic Checkers Required*	Number of APC Equipped Buses*	Annual Costs** Manual Program	Annual Costs** APC Program	Annual Costs per Unit** Manual Program	Annual Costs per Unit** APC Program
25	1	1	59,000	82,000	59,000	82,000
50	2	2	86,000	84,000	43,000	42,000
100	4	4	142,000	121,000	36,000	30,000
200	6	6	201,000	142,000	33,000	24,000
300	7	7	227,000	149,000	32,000	21,000
500	13	13	385,000	196,000	30,000	15,000
750	15	15	436,000	223,000	29,000	15,000
1000	19	19	532,000	245,000	28,000	13,000
2000	38	38	$1,027,000	$398,000	$27,000	$10,000

*Assumes the maximum number of units (checkers or APC buses) required as stated in the Bus Transit Monitoring Study.

**Assumes the costs accrued over a five-year period (discount rates were not applied to annualized costs).

It should be noted that this cost comparison indicates that APC data collection programs generally require lower annual operating costs and higher capital expenditures than manual data collection programs. When considered on the basis of total data collection costs for a 750 bus property over a five-year period, approximately 93% of the manual program expenditures come out of the operating budget, in comparison with an estimated 56% of APC system costs.

CHAPTER 5: APC's ROLE IN OVERALL SURVEILLANCE PROGRAMS

Perhaps the most important characteristic of APC systems is the role they play in a property's overall data collection program. This chapter presents a summary of the objectives of current North American APC programs and reports on the current and planned use of these systems. This chapter concludes with a case study of the APC program in Ottawa, Ontario, the only North American property which currently depends almost entirely on APC techniques to supply their service planning data needs.

5.1 The Objectives of North American APC Programs

A variety of data collection, service monitoring and performance evaluation programs have been implemented by properties utilizing automated counting techniques. Some incorporate the APC generated data into comprehensive route profiles which are periodically updated and evaluated. Other properties use the automated counters to collect data for scheduling and planning purposes on an "as needed" basis, with little or no systematic approach.

As shown in Table 5.1, most properties utilize the automated counters as a service monitoring tool. Ottawa, Portland and Kalamazoo each periodically rotate APC units throughout their transit system in order to collect data on a sample of each route and bus run. For example, Ottawa attempts to observe each run in the system once every three months to correspond with each of the four service planning periods in a year. Several properties, on the other hand, do not make an attempt to systematically monitor the system. In Seattle the system has expanded considerably, and "demand has outgrown supply" for automated counters. Consequently, they are only available for use on specific data requests. However, these usually center around analyses for

Table 5.1

OBJECTIVES OF AUTOMATED COUNTER PROGRAMS

	% of Fleet APC Equipped	Purpose	Types of Analyses	Most Disaggregate Level of Detail
OPERATIONAL APC SYSTEMS				
Ottawa	8	Service Monitoring	Ridership, Times and Performance Indicators	Stop
Seattle	7	Special Studies	Ridership	Run
NEW APC SYSTEMS				
Calgary	1 (8% planned)	Service Monitoring	Ridership, Times and Performance Indicators	Stop
CALTRANS	N.A.	State Demonstration	Ridership, Times and Performance Indicators	Stop
Columbus	3	One time development of route profiles	Ridership and Performance Indicators	Run
Kalamazoo	40	Service Monitoring	Ridership Times and Performance Indicators	Route Segment
Minneapolis/ St. Paul	5	Special Studies	Ridership	Run
Portland	8	Service Monitoring	Ridership Times and Performance Indicators	Stop
Quebec City	3 (5% planned)	Service Monitoring	Ridership	Run

their four-month service periods. Minneapolis/St. Paul also had originally intended to monitor all runs with APC equipment; however, their contractual difficulties have made this impossible. Columbus, Ohio, is currently using automated counters to generate extensive loading profiles on each route and run in the system on a one-time basis.

Most properties (Ottawa, CALTRANS, Kalamazoo and Portland) examine passenger activity, time measurements and a set of performance indicators. Passenger activity is assessed in terms of boardings, alightings and loads, while time measures often include schedule adherence, running times and dwell times. A wide variety of performance indicators may be generated (e.g., passengers/hour, passenger miles, etc.) if related schedule and financial data are available. Two transit properties, Seattle and Columbus, are primarily interested in passenger activity and not time measurement data. Their approaches tend to emphasize more of a service planning than scheduling orientation.

APC-generated data are examined at various levels of detail depending upon the purpose and types of analyses undertaken. These levels of detail range from the route to vehicle assignment (or bus run) to route segment to bus stop level. Several properties do disaggregrate count and time data down to the stop level, although the extent to which any thorough analyses are undertaken at this level is unclear. The actual number of boardings, alightings and loads at a particular location along the route must be considered within some upper and lower bound of accuracy.[1] This is due to the inherent variability of transit operations and passenger activity, as well as to potential inaccuracies of automated technologies.

Some of the properties contacted have little, if any, confidence in stop level data. The Kalamazoo system, equipped with signposts for accurate location referencing, only disaggregates data down to the route segment level. Currently, Columbus and Seattle do not examine automated counts below the vehicle assignment, or bus run, level. However, Seattle plans to undertake more detailed analyses after acquiring signposts. It is of interest to note that none of the systems currently equipped with signpost technology (and its increased accuracy in stop-referencing) attempt to consider stop level detail in their analyses of APC data.

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[1] It should be noted that this holds true for count data collected manually by checkers as well as mechanically by automated counters.

5.2 The Role of APC Programs in Selected Cities

The transit authorities in Seattle, Columbus, Kalamazoo, Portland, Calgary and Quebec City are examined in this section to examine more closely the role of APC systems within the overall data collection programs.

Seattle

Seattle Metro adopted a set of service evaluation criteria in 1977. While several performance measures are considered, most short-range planning and scheduling decisions are based on passenger performance (passengers per bus hour, passengers per trip), loading standards, and schedule adherence. There are separate schedule adherence and passenger performance standards for each route for peak and midday service periods.

Prior to 1977, only peak load counts were used to collect monitoring and evaluation data. With the development of the evaluation criteria, it was determined that these counts alone were inadequate as the sole data collection technique. A decision was made to collect ride check data and that counters were the most cost-effective technique. One other event stimulated the switch to APC technology. A plan adopted in 1973 mandated that a designated number of passengers had to be carried by 1980 within a specified budget constraint (in terms of labor hours). Therefore, management felt the need to acquire accurate ridership data while minimizing manpower utilization.

Originally, Seattle Metro intended to use the automated counters as a general service monitoring tool. Metro planned to rotate the vehicles equipped with APCs to record data on every bus run every four-month service period. However, the transit system in Seattle has experienced substantial growth and the demand for automated counters has outstripped supply. As a result, the APC units are currently only used to respond to requests for data on specific routes or runs. In general, these data requests coincide with route planning analyses undertaken for their service period changes. Metro has maintained the same level of peak load point checking which was conducted before the APC program was initiated for basic scheduling decisions.

APC-generated data are primarily used to examine ridership activity loads on the route or run level. Examples of the APC data analysis performed by Metro are shown in Figures 5-1 and 5-2. Currently, APC-generated data are stop-referenced by time matching; where it is assumed that the bus is on

Figure 5-1
SEATTLE METRO LOAD PROFILE REPORT

VEHICLE ASSIGNMENT 149/ 3 WEEK DAY
WEDNESDAY MAY 19, 1982
COACH NUMBER 1249 PROCESS DATE (05/25/82) 13 44 PCU DEVICE 26

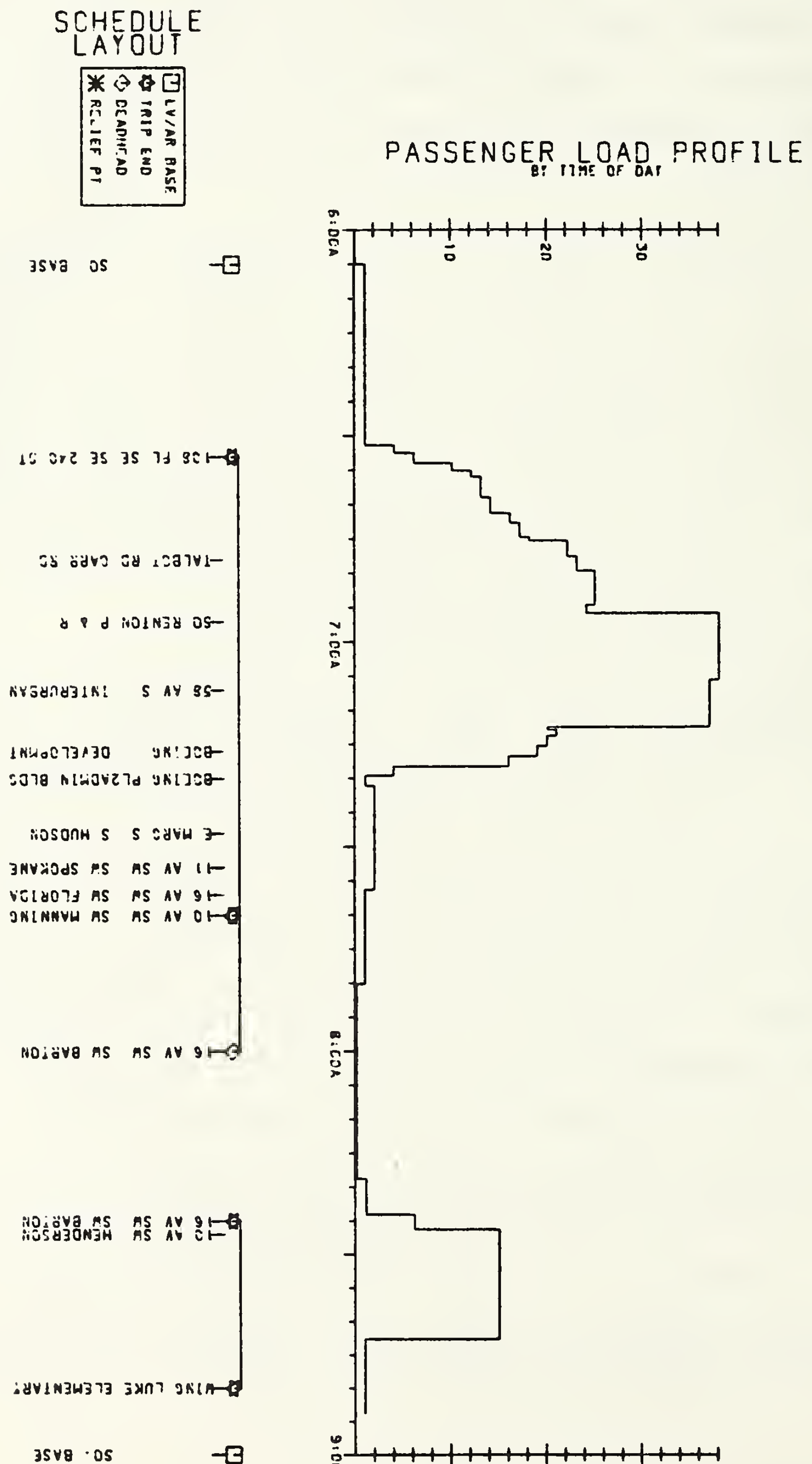


Figure 5-2

SEATTLE METRO TIME-MATCH REPORT

AUTOMATIC PASSENGER COUNTER
D E T A I L TIME MATCH R E P O R T

JOB APC525A4 BR2-C126 - M E T R O PAGE 1
PROCESS DATE (05/25/82) 10:44

VEHICLE ASSIGNMENT 149/ 3 WEEK DAY
WEDNESDAY MAY 19, 1982
COACH NUMBER 1249 (26)

LOCATION	SCHED ARR TIME		ACCUM MILES	DOOR OPEN	DOOR SHUT	TIME AT STOP	PSGR LOAD	RIDERS OFF	RIDERS ON	LEG DIST	LEG SPEED	ACCUM ONS	ACCUM PSGR MILES	ACCUM PSGR HOURS
			0.0	6:04A	6:05A	1:00	0	0	1	0.0	0.	0	0	0.0
SO. BASE	6:05A	PULL OUT •••••••												
			12.17	6:24A	6:31A	6:24	1	0	3	12.17	37.	1	0	0.0
			12.27	6:31A	6:31A	:10	4	0	0	0.10	17.	4	0	0.0
			12.35	6:32A	6:32A	:21	4	0	2	0.08	15.	4	1	0.0
108 PL SE SE 240 ST	6:33A	START TRIP- 149001030												
			12.66	6:33A	6:33A	:18	6	0	4	0.31	16.	6	2	0.2
			13.10	6:34A	6:35A	:10	10	0	2	0.44	27.	10	6	0.3
			13.28	6:35A	6:35A	:20	12	0	1	0.18	21.	12	8	0.4
			14.51	6:38A	6:39A	:09	13	0	1	1.23	25.	13	23	1.1
			15.47	6:41A	6:41A	:12	14	0	2	0.96	29.	14	[illegible]	1.5
			16.12	6:42A	6:42A	:08	16	0	1	0.65	31.	16	45	1.9
			16.50	6:44A	6:44A	:14	17	0	1	0.38	12.	17	51	2.5
			16.59	6:45A	6:45A	:14	18	0	4	0.09	20.	18	53	2.5
			17.34	6:47A	6:47A	:10	22	0	1	0.75	21.	22	68	[illegible]
TALBOT RD CARR RD	6:48A													
			18.40	6:49A	6:49A	:11	23	0	2	1.06	34.	23	92	4.2
			19.81	6:54A	6:55A	1:11	25	1	14	1.41	17.	25	126	6.3
SO RENTON P & P	6:57A													
			24.05	7:05A	7:05A	:11	38	1	0	4.24	26.	39	232	12.7
58 AV S INTERURBAN	7:07A													
			26.10	7:12A	7:12A	:24	37	17	1	2.05	18.	39	356	14.8
			26.51	7:13A	7:14A	:13	21	1	0	0.41	25.	40	364	17.0
			26.68	7:15A	7:15A	:10	20	1	0	0.17	8.	40	368	17.7
BOEING DEVELOPMNT	7:16A													
			27.08	7:16A	7:17A	:14	19	3	0	0.40	17.	40	375	18.2
			27.45	7:18A	7:19A	:19	16	12	0	0.37	18.	40	380	18.5
			27.65	7:19A	7:21A	1:32	4	3	1	0.20	12.	40	381	18.6
BOEING PL2ADMIN BLDG	7:20A													
E MARG S S HUDSON	7:28A													
11 AV SW SW SPOKANE	7:33A													
			32.52	7:36A	7:36A	:20	2	1	0	4.87	19.	41	386	18.9
16 AV SW SW FLORIDA	7:37A													
16 AV SW SW MANNING	7:40A	E N D TRIP												
16 AV SW SW MANNING	7:40A	••START DEADHEAD												
			37.56	7:50A	8:19A	28:43	1	1	1	5.04	22.	41	386	18.9
16 AV SW SW BARTON	8:00A	••••END DEADHEAD												
			37.89	8:19A	8:24A	4:13	1	0	5	0.33	19.	42	386	18.9
16 AV SW SW BARTON	8:25A	START TRIP- 586007940												
			38.48	8:26A	8:26A	:16	6	0	9	0.59	18.	47	389	19.0
19 AV SW HENDERSON	8:27A													
			43.93	8:42A	8:43A	:37	15	14	0	5.45	20.	56	465	22.6
WING LUKE ELEMENTARY	8:50A	E N D TRIP												
			47.70	8:52A	8:53A	:54	1	0	0	3.77	24.	56	465	22.8
			47.71	8:53A	8:54A	1:00	1	1	0	0.01	36.	56	465	22.8
SO. BASE	9:00A	PULL IN •••••••												

••• WARNING ••• TIME MATCHING ASSUMES BUS IS ON TIME.
PASSENGER LOAD IS THE LOAD ARRIVING AT A STOP.
DISTANCE AND SPEED REFER TO THE LEG SINCE THE PREVIOUS STOP.

schedule and the location is determined by matching APC recorded times to schedule times at bus stops. As a result of this referencing procedure, data on schedule times cannot be analyzed. Schedule adherence data are still collected by traffic checkers at peak load points. Signposts at major time points are programmed to be implemented in 1982. Using these signposts, schedule adherence and running time analyses using APC data will be possible.

Metro personnel estimate that an effective (i.e., periodic monitoring of all routes for several days at least three times a year) service monitoring program requires that 11% of the fleet (approximately 85 buses) be APC equipped. Currently, 7% of the fleet (56 buses) are equipped with automated counters. While they would like to acquire more automated counter equipment in order to properly sample runs for service monitoring, funding constraints may defer that action for some time.

Columbus

COTA in Columbus, Ohio, has contracted with a consulting firm to undertake a fourteen-month data collection effort utilizing APCs. The general (ongoing) COTA data collection program collects load counts using point checks and undertakes passenger surveys. The consultant is to collect data on each run in the system in order to develop complete route profiles. The APC effort is intended to develop (on a one-time basis) a detailed data base for each route and run in the system by time period for weekdays, Saturdays and Sundays.

The route and run level profiles contain data on loads, ridership activity and performance indicators (e.g., ons/offs, loads, passenger miles, passengers/hour, passengers/mile, etc.). At least two weekdays were initially sampled for each run in the system and selected routes were chosen for further sampling which included the analysis of route segment ridership patterns.

According to a COTA representative, this "one-time" development of the comprehensive route profile is being undertaken with the APC technology at significant cost savings compared to the manual checker program. Because of these savings, COTA personnel mentioned that they are considering using the same APC approach to periodically monitor service and update profiles.

Kalamazoo

Metro Transit in Kalamazoo, Michigan, is using the APCs as a general monitoring tool to develop comprehensive route, run and trip profiles. Metro Transit is primarily interested in two types of reports:

1. Total passenger activity (including loads, ons/offs); and

2. Schedule adherence (including running time, schedule adherence, revenue/vehicle time, dwell time).

Reports are presented by route, segment and time period.

Twenty buses are equipped with APC equipment, representing approximately 40% of the entire fleet. The equipped vehicles are regularly rotated throughout the system (i.e., on the average, any given route is being monitored four out of every ten days). APC-generated data are then assembled over a defined "transit operations time span". These time intervals, defined by the planner as a period during which the environment remains relatively fixed, may include weekdays, weekends, a specific day of the week (e.g., Mondays), or quarterly service periods (e.g., summer, fall), etc. Data collected by the automatic counters and stored in the data base can then be retrieved and reported for specified routes or segments in terms of these defined time spans. For example, load and schedule adherence characteristics can be presented for Route 1 on an average weekday.

The Kalamazoo application is generally interested in analyses of trip level data, disaggregated by route segments (between signposts) which are generally between one and three miles in length. The system does have the capability to output stop level data or analyze smaller segments, if desired. The fact that nearly 40% of the bus fleet is APC equipped implies that a substantial amount of data is collected on the trip level. Sampling considerations have not been incorporated into the Kalamazoo data collection and service monitoring program to reduce data storage and processing costs.

Portland

Tri-Met in Portland, Oregon, plans to implement an APC program in 1982, equipping 50 buses with APC units. Tri-Met planners intend to use APCs as a service monitoring tool by periodically rotating APC units throughout the system as well as by making special counts of routes when necessary.

Portland's current data collection program utilizes boarding counts collected by drivers, peak load counts collected by traffic checkers and trailing checks conducted by road supervisors. Each quarter, drivers record boardings by fare type on each route over a period of nine consecutive days -- five weekdays, two Saturdays and two Sundays each quarter. The data are compiled to produce average weekday, Saturday and Sunday operating statistics. The following statistics are produced for each route by time period:

- originating passengers
- average fare
- revenue
- costs
- revenue/cost
- # transfers
- cost/total passengers

Two considerations stimulated a move towards automated data collection at Tri-Met. First, new advanced design buses equipped with darkly tinted windows have been put into service in increasing numbers during the last several years. The tinted windows make point checks virtually impossible to perform under certain lighting conditions and difficult under the best conditions. Second, the property is about to institute a "self-service," off-vehicle fare system, so that driver counts would be less useful than in the past since revenue information would be eliminated.

After two years of experience with two prototype APC units, Tri-Met made the decision to implement a full-scale automated data collection program. The automatic counters are intended to be used as an ongoing service monitoring tool to provide time and ridership data for planning and scheduling purposes. There is interest in very detailed analyses at the route, run, trip and stop level to evaluate ridership activity, running time and schedule performance.

Calgary

Calgary Transit is currently implementing a demonstration project with 5 APC units. In 1983, they propose to have up to 50 buses equipped with APCs. Once the APC demonstration is complete, Calgary Transit would like to equip a full 10%, or 60-65 buses of the total fleet (600-650 buses). At the present time, Calgary is collecting, planning and scheduling data with a staff of five full time manual checkers. The manual staff primarily collects load counts. Planning and scheduling personnel have not been satisfied with this data collection program as a result of its poor accuracy and the infrequency of obtaining count data. In addition to planning and scheduling, the Finance Department has expressed interest in utilizing more accurate total passenger data for revenue and deficit allocation. There are currently four service periods per year; the APC program intends to collect data on each run in the system once in each quarterly service period.

Since the demonstration is just getting underway, the complete set of reporting and analysis routines has not been specified. However, it is proposed that a series of management reports on a quarterly, annual and as-needed basis be generated. The quarterly reports will be grouped into three major headings: passenger activity, time performance and performance indicators. Examples of potential passenger activity reports include:

- passenger summary tables (boardings and average distance);
- peak period bus occupancy across screenlines; and
- peak period load at the maximum load point (list all routes, identifying the 10 "best" and 10 "worst" performers).

Quarterly reports on time performance include the following:

- schedule adherence and average speed (list all routes, identifying the 10 "best" and 10 "worst" performers); and
- peak period schedule adherence.

A variety of productivities and performance indicators are proposed for inclusion in the quarterly reports. These include:

- vehicle usage summaries (e.g., vehicle-kilometers, revenue-hours);
- passenger-kilometer summary tables (e.g., passenger-km/revenue-km);
- cost and revenue summaries (e.g., cost/passenger-km, cost/revenue-hour); and
- revenue/cost ratios.

Calgary also proposes to generate annual reports which may indicate seasonal variation in boardings, passenger-kilometers, revenue-kilometers and revenue/cost ratios. In addition, it is planned to have the capability to produce several reports on an as-needed basis. These include:

- stop-by-stop run listings;
- weekday variations in boardings;
- passenger load and headway at specified locations;
- passenger load and headway within specified route segments; and
- boardings and alightings within specified districts.

Quebec City

Quebec City Community Transit will have 13 APC equipped buses in 1982 (they initially implemented 3 units in late 1980). A total of 20 buses will be equipped with APCs in 1983. The 20 units will constitute approximately 5% of the bus fleet (400 buses). Quebec City hopes to use the counters in order to collect ridership and time data on a "typical" weekday once each month, and a "typical" Saturday and Sunday once every two months. The route level data will be utilized for various planning, scheduling and reporting purposes.

In addition to utilizing the data for ongoing planning and scheduling, the APCs will provide input for the Route Performance Evaluation Process. This activity incorporates route level APC data and performance indicators in order to identify substandard routes. Following the identification of problem routes, manual checkers will undertake detailed analyses and special surveys. Quebec City currently has a staff of six full time checkers; there are no plans to eliminate these positions as a result of the introduction of automatic counters.

5.3 OC Transpo in Ottawa, Ontario: A Case Study

OC Transpo began operating an automated data collection program in 1978-79, utilizing 49 APC equipped buses (approximately 6% of the fleet). In 1982, 16 additional APC equipped vehicles will be introduced. The automatic counter program was implemented in order to facilitate ongoing service monitoring. Currently, data is recorded on each of the 1100 daily bus runs once every quarter.

In 1978, before implementation of the automatic counter program, OC Transpo collected operating and performance data by conducting point checks and ride checks as well as by undertaking passenger surveys. The manual data collection system utilized eight traffic checkers at an annual cost of $160,000. Today, all of the traffic checker positions have been eliminated.

The impetus for the APC system came as planning personnel became interested in developing a systematic service monitoring and performance evaluation system. They were not satisfied with the manual method of data collection and the infrequency of performance measurements. The level of accuracy of the data was questionable, and the manual system was only capable of indicating major trends in ridership activity and system performance. The proposed automated monitoring program was to be capable of detecting detailed changes in running and loading characteristics as well as in various level of service standards. The new service monitoring program was considered particularly important in light of the substantial growth which the transit property had been experiencing, and was expecting to continue to experience.

Table 5.2 presents service and operating characteristics which exhibit the tremendous growth of OC Transpo prior to 1978. The substantial increase in service kilometers, hours and ridership precipitated the perceived need for a more systematic monitoring program. The sometimes unreliable and infrequent nature of the data previously collected by the system was inadequate for the required performance monitoring and planning activities. Since 1978, the Ottawa property has continued to experience growth; however, the rate of increase has stabilized. As a result of satisfaction with the APC program and continued growth of the transit system, OC Transpo is adding 16 more APC units in 1982.

The remainder of this section specifically addresses the incorporation of the APC program within the OC Transpo data collection and service monitoring system. First, the discussion addresses how the APC program is operated and the types of reports which are produced. Secondly, the ways in which the generated data and information are utilized by OC Transpo planners are addressed.

Table 5.2

OC TRANSPO OPERATING CHARACTERISTICS

	1972	1974	1976	1978	1980
Service Area Population	413,000	435,000	460,000	475,900	486,600
Service Area (KM^2)	207	220	380	380	380
Annual Unlinked Trips (10^6)	46.943	63.231	78.147	90.836	97.424
Average Ridership - Weekday	127,000	169,250	210,059	241,486	260,344
- Saturday	79,000	85,520	111,461	126,473	138,144
- Sunday	24,000	24,000	26,965	31,041	40,200
Annual Rides Per Capita	91	111	134	145	153
Total Fleet	368	515	674	786	760
Annual Kilometrage (10^6)	14.999	25.652	33.929	39.436	44.523
Revenue/Total Cost	0.84	0.58	0.52	0.52	0.51

Source: "Orientation Report", OC Transpo, Ottawa-Carleton Regional Transit Commission, Ottawa, Ontario, Canada, 1981.

5.3.1 Operation of the OC Transpo APC System

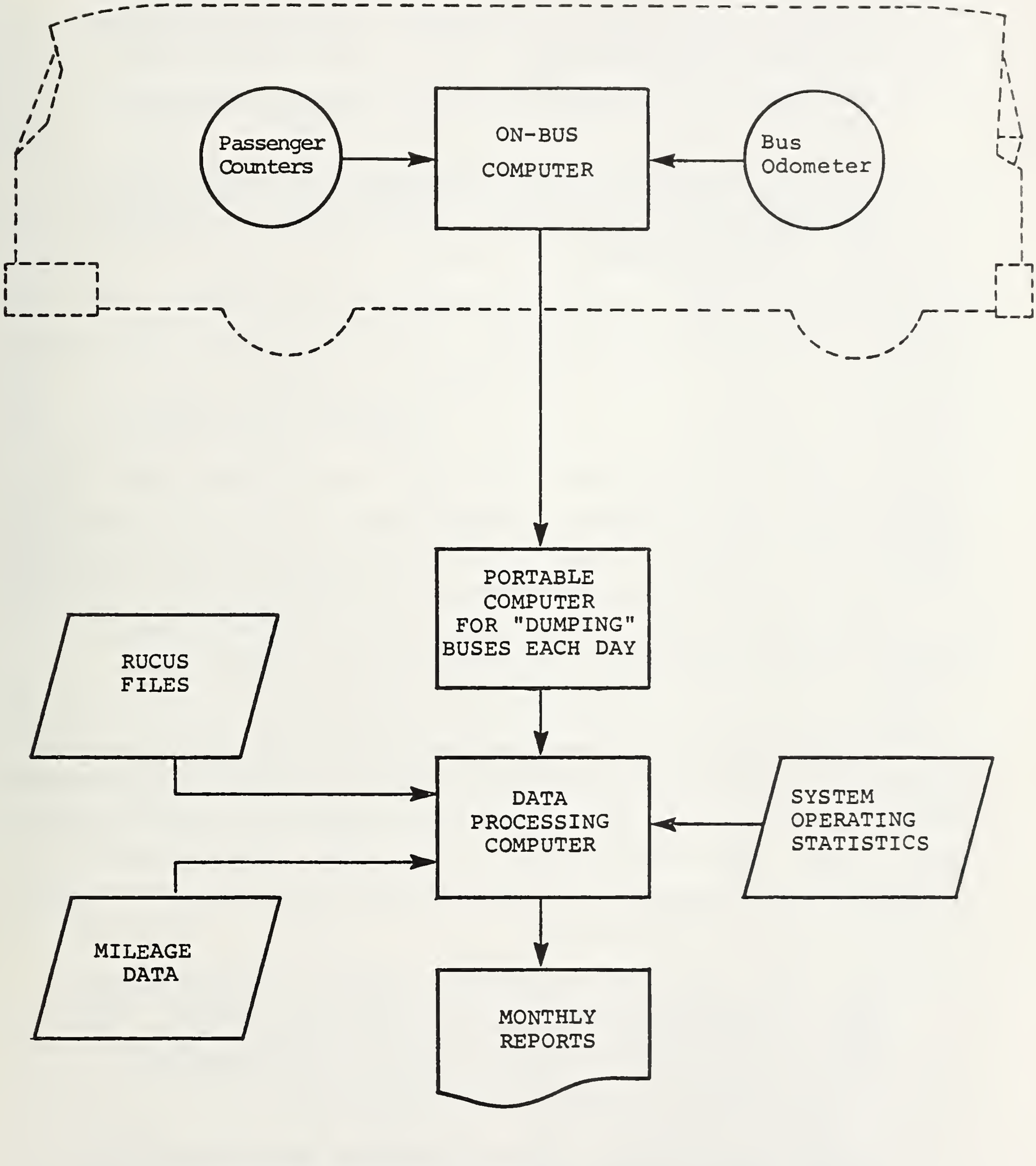
The automated data collection system (Figure 5-3) consists of three major elements:

- counting sensors and microprocessors on-board buses;
- transfer of this information into a computerized data base in combination with schedule time and distance files; and
- a software system capable of merging data files and generating performance reports.

Buses equipped with APCs are periodically rotated throughout every route and run in the system. Operating personnel attempt to record a valid count on each of the 1100 daily bus runs once every quarter. All of the bus runs on a particular route are not necessarily scheduled for APC counts on the same day. By design, run data are compiled from several days in an attempt to reflect average system performance. For example, a recorded count in the spring quarter for a route with ten bus runs may have two runs with counts from March, five runs from April and three runs from May.

Figure 5-3

OC TRANSPO DATA COLLECTION SYSTEM



Source: Bonsall, John A., "OC Transpo Data Collection System", Ottawa-Carleton Regional Transit Commission, Ottawa, Ontario, September, 1978.

Data is transferred daily from the on-board microprocessor to the central computer and edited for validity. The editing process detects any errors within the data base. A hierarchical correction procedure is then applied, including in order:

1) corrections for the known tendency to overcount passengers alighting at the rear door;

2) corrections for violations of the rule "no more passengers can alight at a stop than were on-board the bus"; and

3) if, after the above corrective operations, there still exists a discrepancy (i.e., an imbalance of boardings and alightings) at the end of the day, it is eliminated by reclassifying boarding and alighting passengers.

OC Transpo has been unable to successfully collect APC count data on all 1100 daily bus runs during each quarter. OC Transpo personnel report that no more than 70% of the runs have been recorded in one quarter. The lower than anticipated completion rate is due to mechanical malfunctions or beam alignment problems, large inaccuracies in counts, or physical mishandling of the data in the transfer process. In order to present count data for the complete set of bus runs in the system, the counts for runs not recorded are estimated. This estimation process is undertaken by extrapolating count data from the runs immediately before and after the missing run at the stop level. As a result, boarding and alighting counts are constructed by stop for the missing run by averaging ridership activity observed for similar runs.

At the end of each quarter, count data are assembled for all bus runs. The APC-generated data are not stop-referenced in the file but contain counts, odometer readings and time readings. To obtain stop-referencing, files which represent the entire bus system in terms of distance and time measurements must be input. These schedule files are then merged with APC data files to identify the stop locations for the APC count data. The information required to identify stop locations includes:

- A file for each route and run containing the scheduled arrival times or departure times from every node in the network. These nodes are normally time points, and include garage nodes. The system is able to accept RUCUS trip data for this information.

- A file of distances between stops along every route.

- A deadhead distance file to provide distances between any terminal timepoint and/or garage between which buses operate in non-revenue service.

- A general exception file to incorporate all variations to the standard runs such as school trips and hospital detours, etc.
- A "starter sheet" file which links actual bus numbers to particular routes and runs.

The final product is a master file containing both schedule and observed data for all routes and runs in the transit system. OC Transpo personnel estimate that it takes approximately three weeks each quarter to update all of the schedule files.

After the master file, containing both scheduled and observed data, has been completed, management reports are produced. A variety of reports are generated each quarter by the automated data collection system. In general, four types of management reports are produced: ridership activity; time performance; performance indicators; and screenline bus occupancy. Examples of these reports are shown in Figures 5-4 through 5-7.

5.3.2 Utilization of the APC Data

The APC-generated data is used for spot check analyses or "troubleshooting" before the master file is completed and management reports are produced at the end of each quarter. However, such intermediate analyses do require manual manipulation of the count data.

Service modifications are developed as a result of analyses of the information generated by the APC data collection system. Proposed modifications are normally developed by the Operations Planning Department and reviewed by the Service Review Committee, which has members drawn from the Transportation, Planning, Public Relations, and Marketing Departments. Service modification proposals selected by the staff and the Review Committee are then sent to the members of the Commission for their approval. The information and reports generated by the APC system have been quite helpful as documentation for the Committee and for public hearings.

OC Transpo has no systematic approach to evaluating the APC-generated performance indicator data in order to identify "substandard" routes or to flag "violations" of current service policies. While there is no systematic evaluation of route level performance, OC Transpo has recently developed a set of Corporate Policies and Objectives. These objectives, derived from the Region's Official Plan, do specify standards which should be met by the

Figure 5-4

OC TRANSPO: LOAD PROFILE REPORT

OTTAWA-CARLETON REGIONAL TRANSIT COMMISSION

PAGE 3

PUBLISHED ON 08 JUN 79

B U S   R I D E R S H I P   D A T A   S Y S T E M

EASTBOUND LOAD PROFILES FOR MARCH 1979

				TIME PERIODS					MORNING PEAKS		EVENING PEAKS	
ROUTE	PASSENGER LOAD AFTER LEAVING			04:01 06:30	06:31 09:30	09:31 15:30	15:31 18:30	18:31 04:00	HOUR	QUARTER HOUR	HOUR	QUARTER HOUR
002	5407 ... GOLDEN	BYRON	MINIMUM	7	0	2	1	2	2	10	7	3
			AVERAGE	7	9	13	13	11	12	19	14	17
			MAXIMUM	7	28	43	30	17	28	28	25	30
			# OF BUSES	1	14	17	13	5	6	2	5	2
	5406 ... HOLLAND	WELLINGTON	MINIMUM	0	5	2	5	5	10	16	6	35
			AVERAGE	0	16	13	15	11	19	28	20	35
			MAXIMUM	0	40	27	35	17	49	40	35	35
			# OF BUSES	0	16	17	14	5	6	2	5	1
	5405 ... PRESTON	SOMERSET	MINIMUM	0	6	11	7	5	12	25	9	56
			AVERAGE	0	21	20	23	17	23	32	30	56
			MAXIMUM	0	56	32	56	26	39	39	56	56
			# OF BUSES	0	16	17	14	5	6	2	5	1
	5511 ... QUEEN	OCONNOR	MINIMUM	0	8	17	9	5	8	25	21	23
			AVERAGE	0	21	28	28	24	31	41	35	28
			MAXIMUM	1	56	52	51	39	56	56	51	33
			# OF BUSES	3	15	18	13	6	5	2	4	2
	5610 ... MONTREAL	ST.LAURENT	MINIMUM	3	10	13	11	6	10	13	27	25
			AVERAGE	7	23	28	33	27	23	22	37	44
			MAXIMUM	12	49	54	56	41	44	31	55	56
			# OF BUSES	3	12	18	13	8	7	3	5	3
	5605 ... NATIONAL	RESEARCH	MINIMUM	3	2	11	7	4	9	14	18	18
			AVERAGE	3	9	20	21	19	10	14	26	22
			MAXIMUM	5	14	34	37	24	14	14	37	25
			# OF BUSES	2	5	5	9	5	3	1	4	2
	5614 ... NATIONAL	RESEARCH	MINIMUM	10	3	6	6	12	3	34	40	40
			AVERAGE	10	19	20	17	15	16	34	40	40
			MAXIMUM	10	34	47	49	25	34	34	40	40
			# OF BUSES	1	6	14	4	4	5	1	1	1
	4605 ... SHOPPERS	CITY EAST	MINIMUM	2	0	4	0	1	0	6	11	11
			AVERAGE	6	8	12	13	11	11	13	20	19
			MAXIMUM	19	20	27	29	23	20	20	28	28
			# OF BUSES	2	12	19	12	9	5	2	5	3

Figure 5-5

OC TRANSPO: SCHEDULE ADHERENCE REPORT

OTTAWA-CARLETON REGIONAL TRANSIT COMMISSION

PAGE 3
PUBLISHED ON 08 JUN 79

B U S R I D E R S H I P D A T A S Y S T E M

EASTBOUND SCHEDULE ADHERENCES FOR THE PERIOD MARCH 1979

VALUES GIVEN ARE MINUTES PRECEDING (-) OR FOLLOWING (+) SCHEDULE TIMES

ROUTE	TIME POINT (CODE + NAME)				TIME PERIODS 04:01 06:30	06:31 09:30	09:31 15:30	15:31 18:30	18:31 04:00	DAILY 04:01 04:00
2	5407 ..	GOLDEN	BYRON	EARLIEST	+0	-8	-12	-13	-15	-15
				LATEST	+4	+0	+1	+2	+0	+8
				AVERAGE	+3.50	-1.36	-6.61	-4.92	-9.00	-4.62
				STANDARD DEVIATION	0.71	4.63	4.03	4.57	5.10	5.16
				NUMBER OF BUSES	2	14	18	13	5	52
	5406 ..	HOLLAND	WELLINGTON	EARLIEST	+0	-1	-5	-6	-1	-6
				LATEST	+3	+9	+1	+4	+1	+9
				AVERAGE	+3.00	+1.60	-2.71	-1.64	+0.00	-0.81
				STANDARD DEVIATION	0.00	2.50	1.61	2.97	1.00	2.86
				NUMBER OF BUSES	1	15	17	14	5	52
	5405 ..	PRESTON	SOMERSET	EARLIEST	+0	+0	-5	-4	-2	-5
				LATEST	+0	+0	+2	+7	+1	+8
				AVERAGE	+0.00	+2.31	-1.71	-0.21	-0.20	+0.08
				STANDARD DEVIATION	0.00	2.09	1.72	2.94	1.30	2.69
				NUMBER OF BUSES	0	16	17	14	5	52
	5511 ..	QUEEN	OCONNOR	EARLIEST	+0	-6	-11	-12	-7	-11
				LATEST	+5	+4	+0	+4	+0	+5
				AVERAGE	+3.00	-1.07	-5.61	-3.50	-5.86	-3.47
				STANDARD DEVIATION	2.00	2.81	2.99	1.87	1.35	3.80
				NUMBER OF BUSES	3	15	18	12	7	55
	5610 ..	MONTREAL	ST.LAURENT	EARLIEST	-3	-4	-6	-7	-6	-7
				LATEST	+2	+4	+3	+9	+1	+9
				AVERAGE	-0.33	-1.08	-2.94	-2.17	-2.78	-2.19
				STANDARD DEVIATION	2.52	2.15	2.65	4.22	2.82	3.01
				NUMBER OF BUSES	3	12	18	12	9	54
	5605 ..	NATIONAL	RESEARCH	EARLIEST	-2	-3	-5	-6	-7	-7
				LATEST	+0	+0	+1	+9	+4	+8
				AVERAGE	-1.50	-2.40	-2.60	-1.19	-1.00	-1.76
				STANDARD DEVIATION	0.71	0.55	2.30	4.47	3.94	3.13
				NUMBER OF BUSES	2	5	5	8	5	25
	5614 ..	NATIONAL	RESEARCH	EARLIEST	-1	-2	-7	-7	-6	-7
				LATEST	+0	+4	+7	+0	+0	+7
				AVERAGE	-1.00	-0.43	-1.92	-2.75	-5.00	-2.37
				STANDARD DEVIATION	0.00	1.99	1.45	2.99	1.41	3.02
				NUMBER OF BUSES	1	7	11	4	4	25
	4606 ..	SHOPPERS	CITY EAST	EARLIEST	-4	-6	-9	-10	-11	-11
				LATEST	+6	+9	+7	+7	+3	+9
				AVERAGE	+2.33	-0.36	-2.11	-3.75	-5.33	-2.41
				STANDARD DEVIATION	5.51	4.92	4.52	4.59	4.00	4.82
				NUMBER OF BUSES	3	11	19	12	9	54

Figure 5-6

OC TRANSPO: PERFORMANCE INDICATOR REPORT

OTTAWA-CARLETON REGIONAL TRANSIT COMMISSION

PAGE 1
PUBLISHED ON 08 JUN 79

B U S R I D E R S H I P D A T A S Y S T E M

VEHICLE USAGE SUMMARY BY ROUTE FOR THE PERIOD MARCH 1979

	VEHICLE KILOMETERS (TIME PERIODS)					DAILY	VEHICLE HOURS (TIME PERIODS)					DAILY
ROUTE	04:01 06:30	06:31 09:30	09:31 15:30	15:31 18:30	18:31 04:00	04:01 04:00	04:01 06:30	06:31 09:30	09:31 15:30	15:31 18:30	18:31 04:00	04:01 04:00
001	147.0	533.4	980.4	514.7	188.7	2372.2	7.5	30.5	58.7	28.0	8.8	134.3
002	164.0	433.0	672.6	362.0	272.4	1904.0	8.3	35.3	42.7	13.1	14.1	113.5
003	186.2	339.4	877.5	611.1	270.5	2284.7	7.5	17.3	42.1	29.0	12.3	108.3
004	192.8	381.9	815.6	434.2	185.6	2010.1	8.2	20.7	43.0	21.6	8.3	101.9
005	29.8	98.2	208.1	99.7	95.7	531.4	1.3	6.3	11.9	5.8	5.8	31.0
006	29.7	90.4	214.5	171.3	0.0	505.9	1.0	5.7	13.0	9.4	0.0	29.0
007	128.1	501.9	551.2	459.3	27.5	1668.0	5.4	30.2	34.1	25.8	1.0	96.6
008	49.8	215.6	424.3	187.1	106.5	983.3	2.8	15.1	29.8	12.5	6.3	66.5
009	7.2	78.8	0.0	117.9	0.0	203.9	0.3	2.9	0.0	4.0	0.0	7.3
010	0.0	242.4	0.0	52.2	0.0	294.6	0.0	8.8	0.0	1.7	0.0	10.5
011	5.3	256.0	45.4	212.4	7.4	526.5	0.3	7.6	1.3	6.7	0.2	16.1
012	0.0	65.6	15.2	77.1	0.0	157.9	0.0	1.9	0.4	2.4	0.0	4.7
014	0.0	83.0	0.0	97.4	0.0	180.4	0.0	2.2	0.0	2.2	0.0	4.5
015	29.7	163.9	20.7	145.0	0.0	359.3	0.8	4.8	1.0	4.8	0.0	11.5
016	13.9	122.7	91.0	214.3	0.0	442.0	0.5	3.3	4.9	5.6	0.0	14.3
017	0.0	248.4	15.2	103.6	0.0	367.2	0.0	7.3	0.5	2.8	0.0	10.7
018	7.4	203.4	40.0	278.1	1.8	530.7	0.4	7.2	2.2	9.6	0.0	19.4
019	17.2	169.7	0.0	110.3	22.2	319.4	0.4	4.6	0.0	2.7	0.5	8.2
020	0.0	151.3	9.3	109.5	0.0	270.1	0.0	4.9	0.9	4.0	0.0	9.8
021	0.0	159.1	5.5	52.9	0.0	217.5	0.0	5.2	0.3	1.9	0.0	7.3
022	0.0	33.3	0.0	0.0	0.0	33.3	0.0	1.2	0.0	0.0	0.0	1.2
023	82.2	183.5	36.9	169.8	0.0	472.5	1.8	6.5	1.4	4.8	0.0	14.6
024	60.9	231.5	30.7	177.0	0.0	500.0	1.6	7.9	0.8	5.2	0.0	15.5
025	52.8	325.4	91.7	237.6	0.0	707.5	1.5	10.0	3.9	7.7	0.0	23.1
026	56.1	220.1	24.9	198.7	28.9	528.7	1.4	6.4	1.1	6.6	0.6	16.1
027	73.3	383.3	42.6	537.0	18.1	1054.3	2.1	10.7	1.6	13.9	0.4	28.7
028	0.0	86.6	0.0	59.7	0.0	146.3	0.0	2.7	0.0	1.8	0.0	4.5
029	13.1	155.2	0.0	88.0	0.0	256.4	0.4	5.1	0.0	2.9	0.0	8.5
030	54.5	128.6	258.8	128.6	273.4	843.9	1.6	6.0	12.1	5.9	12.4	38.1
031	0.0	115.3	69.3	125.4	0.0	310.0	0.0	4.6	3.4	6.7	0.0	14.7
032	16.8	61.7	125.0	58.1	135.4	397.0	0.6	3.0	6.1	2.8	6.4	19.0
034	0.0	162.0	87.2	228.5	0.0	477.7	0.0	6.2	3.6	9.8	0.0	19.6
037	97.9	226.6	0.0	278.3	28.1	631.0	2.4	6.4	0.0	6.4	0.5	15.6
039	0.0	140.8	31.5	173.3	4.4	350.0	0.0	4.1	2.0	5.5	0.1	11.7
040	1.9	137.8	53.4	48.4	0.0	241.5	0.1	6.7	2.5	3.1	0.0	12.4
041	33.0	86.7	101.7	86.7	99.6	407.8	1.3	5.7	6.7	5.4	6.2	25.4
042	0.0	53.7	25.9	15.6	0.0	95.2	0.0	1.7	1.7	0.7	0.0	4.1
043	0.0	52.1	0.0	82.6	0.0	134.7	0.0	1.8	0.0	2.5	0.0	4.3
044	0.0	41.2	0.0	53.0	0.0	94.3	0.0	1.2	0.0	1.9	0.0	3.1
045	0.0	17.1	0.0	11.8	0.0	28.9	0.0	0.9	0.0	0.3	0.0	1.3

Figure 5-7

OC TRANSPO: SCREENLINE SUMMARY REPORT

OTTAWA-CARLETON REGIONAL TRANSIT COMMISSION

PAGE 1
PUBLISHED ON 13 JUN 79

B U S R I D E R S H I P D A T A S Y S T E M

INBOUND BUS OCCUPANCY ACROSS SCREENLINE DURING THE PERIOD MARCH 1979

P E A K S U M M A R Y

S/L	LOCATION CODE	NAME	AM PEAK: 06:31 09:30	AM PEAK: PEAK HOUR	AM PEAK: PEAK HOUR VOLUME	AM PEAK: PEAK QUARTER HOUR	AM PEAK: PEAK QUARTER HOUR VOLUME	PM PEAK: 15:31 18:30	PM PEAK: PEAK HOUR	PM PEAK: PEAK HOUR VOLUME	PM PEAK: PEAK QUARTER HOUR	PM PEAK: PEAK QUARTER HOUR VOLUME
21	4405 - BRONSON	SUNNYSIDE	293	07:16-08:15	158	08:01-08:15	52	175	16:16-17:15	113	16:31-16:45	59
	4509 - ST.PAULS	UNIVERSITY	128	08:01-09:00	97	08:01-08:15	30	51	15:01-16:00	51	15:16-15:30	15
	5406 - HOLLAND	WELLINGTON	509	07:16-08:15	199	07:16-07:30	65	427	15:01-16:00	222	15:46-16:00	71
	5502 - PARK	CARLING	817	08:31-09:30	382	08:46-09:00	143	672	15:16-16:15	354	15:16-15:30	135
	5510 - BEECHWOOD	MCKAY	278	07:46-08:45	136	08:31-08:45	64	272	15:46-16:45	177	16:01-16:15	92
	5536 - HANNAH	MONTREAL	466	07:16-08:15	231	07:46-08:00	104	166	15:46-16:45	114	16:01-16:15	41
	5569 - RIDEAU	FRIEMAN	170	08:16-09:15	95	08:16-08:30	37	116	15:46-16:45	83	15:46-16:00	41
	5610 - MONTREAL	ST.LAURENT	209	08:01-09:00	138	08:46-09:00	53	171	16:16-17:15	[illegible]	16:16-16:30	47
	TOTALS FOR S/L 21		2870	08:01-09:00	1240	08:31-08:45	365	2050	16:01-17:00	[illegible]	16:01-16:15	390

transit system as a whole. Beginning in 1982, an annual report will be produced which uses APC data to formally assess the achievement of the stated objectives.

In addition, the official plan of the Regional Municipality of Ottawa-Carleton established the basic transportation goals of the municipality. These goals generally state that the public transit system should attract a high proportion of both peak and off-peak travel. In order to determine the modal split between automobile and transit travel, annual traffic and vehicle occupancy counts are conducted by municipal staff at predetermined screenline locations. Screenline bus occupancy counts are collected and reported by the APC system in a format which is compatible with the municipal screenline reports. Collection of transit load data with the APC system has reduced the labor required for the counts and increased accuracy significantly. The APC system also provides more frequent measurement at a greater number of screenlines than was possible under the previous system.

In addition to providing information for service monitoring and annual reporting, the automatic counters are also used for special studies and unique data collection efforts. For example, OC Transpo is participating in a demonstration of articulated buses and an honor-fare system. The effort, sponsored by the Ministry of Transportation and Communications of Ontario, is currently scheduled for implementation in the Fall or Winter of 1982. APCs are being used to collect "before" and "after" operating data for use in the evaluation. Eleven of the twenty-one new articulated buses will be equipped with APC units.

In addition to the introduction of the new articulated vehicles, an honor fare program is being introduced on an experimental basis on two bus routes. Of the data items required for the evaluation, the measures of dwell time and passenger activity by door have not previously been reported and required new software development. In order to collect data which can be used in the evaluation of both events (articulated buses and honor fare), the following data collection schedule has been established:

TIME FRAME	OPERATING CONDITIONS	DATA REPORTS
Before	- No Honor Fare - Standard Vehicles - Current Schedule	- Dwell Time - Door Activity - Schedule Adherence - Boarding Passengers - Load Profiles
Before	- No Honor Fare - Standard/Artics Mixed - Current Schedules	- Same as above
After	- Honor Fare - Standard/Artics Mixed - Current Schedules	- Same as above
After	- Honor Fare - Artics Only - New Artic Schedule	- Same as above
After	- Honor Fare - Artics Only - Amended Artic Schedule	- Same as above

Dwell time is the time between the first door is opened and the last door is closed. As shown in Figure 5-8, dwell time information is presented for categories of passenger activity (e.g., 1-4, 5-8, 9-12, etc.). At this time, the APC system only presents boardings and alightings for the entire vehicle, not individually for each door. Passenger activity patterns by door will be examined in the articulated bus demonstration. Figure 5-9 presents an example of a report proposed to present this information.

APCs were also used to evaluate OC Transpo's schedule information system, referred to as "560". The system is designed to provide riders, calling from their homes, the scheduled arrival time of the next two buses at a designated bus stop as well as a status report on a particular route. The "560" information system is currently in place throughout OC Transpo's entire service area, operating 24 hours a day, 7 days a week.

APC equipped buses were used to assess the impact of the "560" system on ridership. Impact was measured in two ways:

1) Growth in transit ridership was compared between a specified portion of the "560" test area and a similar control area. Both are bedroom communities located several kilometers from the CBD with approximately 3000 households.

Figure 5-8

OC TRANSPO: DWELL TIME REPORT

OTTAWA-CARLETON REGIONAL TRANSIT COMMISSION

B U S   R I D E R S H I P   D A T A   S Y S T E M

ACTIVITY AND DWELL-TIME REPORT FOR PERIOD OCTOBER 1980

ROUTE	LEVEL OF PASSENGER ACTIVITY		* -------- DWELL TIME (SECONDS) BY TIME PERIOD				------ *	DAILY
			04:01 06:30	06:31 09:30	09:31 15:30	15:31 18:30	18:31 04:00	04:01 04:00
002	1 - 4	LOWEST	0	4	4	4	4	4
		HIGHEST	0	4	4	4	4	4
		AVERAGE	0.00	4.00	4.00	4.00	4.00	4.00
		NUMBER OF STOPS	0	42	90	35	26	193
	5 - 8	LOWEST	0	7	7	7	7	7
		HIGHEST	0	7	7	7	7	7
		AVERAGE	0.00	7.00	7.00	7.00	7.00	7.00
		NUMBER OF STOPS	0	23	51	32	22	128
	9 - 12	LOWEST	0	11	11	11	11	11
		HIGHEST	0	14	14	14	14	14
		AVERAGE	0.00	12.39	12.54	12.41	12.13	12.39
		NUMBER OF STOPS	0	28	70	36	45	179
	13 - 16	LOWEST	0	18	18	18	18	18
		HIGHEST	0	18	18	18	18	18
		AVERAGE	0.00	18.00	18.00	18.00	18.00	18.00
		NUMBER OF STOPS	0	7	24	8	5	44
	17 - 20	LOWEST	0	21	21	21	21	21
		HIGHEST	0	21	21	21	21	21
		AVERAGE	0.00	21.00	21.00	21.00	21.00	21.00
		NUMBER OF STOPS	0	5	13	6	9	33
	21 - 24	LOWEST	0	25	25	25	25	25
		HIGHEST	0	28	28	28	28	28
		AVERAGE	0.00	26.33	26.12	26.50	25.81	26.18
		NUMBER OF STOPS	0	9	16	12	11	49

Figure 5-9

OC TRANSPO: ARTICULATED BOARDING REPORT

B U S   R I D E R S H I P   D A T A   S Y T E M

PUBLISHED ON 110781

NUMBER: 1

DOOR USAGE PATTERNS FOR THE PERIOD DECEMBER 1981

04:01 - 06:30								06:31 - 09:30								09:31 - 15:30							
ALL-DOORS		DOOR-1		DOOR-2		DOOR-3		ALL-DOORS		DOOR-1		DOOR-2		DOOR-3		ALL-DOORS		DOOR-1		DOOR-2		DOOR-3	
ONS	OFFS	ONS	OFFS	ONS	OFFS	ONS	OFFS	ONS	OFFS	ONS	OFFS	ONS	OFFS	ONS	OFFS	ONS	OFFS	ONS	OFFS	ONS	OFFS	ONS	OFFS
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	29	15	7	7	15	15	7	95	103	29	37	37	29	29	37	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	2	2	0	0	2	2	0	87	93	27	33	33	27	27	33	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	18	6	6	6	6	6	6	87	93	27	33	33	27	27	33	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	89	91	29	31	31	29	29	31	5	7	1	3	3	1	1	3
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	45	45	15	15	15	15	15	15	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	71	73	23	25	25	23	23	25	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	91	86	32	27	27	32	32	27	0	0	0	0	0	0	0	0
		41%	23%	17%	54%	41%	23%			33%	34%	35%	32%	33%	34%			20%	43%	60%	14%	20%	43%

2) Growth in transit ridership was compared between routes which only provide service in the "560" area and similar routes not servicing the "560" area.

The availability of APC data, in this case, provided an easy way to tabulate "before/after" data by varied geographical limits.

CHAPTER 6: CONCLUSIONS

This assessment of more than a dozen current applications of APC technology has reviewed a number of issues which should be carefully considered by any bus transit properties investigating the utility of APC systems. Perhaps most important of those is the realization that the technology currently exists to adequately count passengers and record time-related bus performance data with little or no direct human interaction. It should be noted, however, that some technological improvements are still desirable. For example, the possibility of linking the collection and storage of passenger revenue data from newly designed electronic fareboxes to APC data should be investigated. Also, it is clear that operators contemplating the use of APC equipment should be keenly aware of related "software" needs (i.e., broadly defined in terms of the potential use of APC techniques, as well as potential data processing requirements).

Transit managers should be extremely careful to define just what might be expected from APC data collection techniques so that equipment and data processing needs can be anticipated in advance of any decision to proceed with a new data collection program. If nothing else has been learned to date, experience has shown that a number of current APC users initially underestimated the time and effort required to implement and maintain automated data collection systems. A general lack of prior information and the need to use unproven equipment sometimes resulted in the "trial and error" efforts in installing equipment and maintaining it, much higher than expected data editing and processing costs, and the underutilization of available equipment capabilities. Fortunately, much can be learned from the experiences of current APC technology users. Any operator contemplating a move to APC data collection would do well to contact the properties listed in this report.

A number of specific considerations should be reviewed in planning for the initiation of an APC system. These include:

- Both of the major types of APC units currently in use (infrared beams and treadle mats) perform satisfactorily; in general, the treadle mats have been found to be slightly more accurate, but they have seemed to require more maintenance and may need to be replaced more frequently than comparable infrared units.

- The accuracy of the APC units now in use is adequate for most purposes to which the data are put; data from a recent UMTA test showed the APC units to be remarkably close to counts taken by a human ride checker.

- For medium to large-size bus properties (those with more than about 100 buses), the cost of an APC system compared favorably to manual (ride check) data collection costs over the long run; however, since different equipment and data collection techniques will provide different types of data (and data detail), a property should perform a careful cost analysis prior to moving forward with any new program.

- While the use of APC signposts for location referencing may reduce the overall cost of the post-processing needed to get the raw APC data into useable form, recent developments by Portland Tri-Met indicate that an odometer-linked referencing system may provide an equivalent level of accuracy in stop-referencing.

- It is extremely important for potential APC users to define in detail the potential uses of APC data; these uses will impact the design of the data recording and counting algorithm internal to the APC counter units, as well as the extent of the data processing development which will be necessary to produce fully useable reports. A careful anticipation of the full range of potential uses and required data reports will undoubtedly reduce the overall cost of implementing a new system.

- Potential users of APC equipment should be aware of the need to carefully install and maintain the equipment; pre-planning should include the discussion and agreement on interdepartmental responsibilities, and all involved should fully understand the need for the APC data and the importance of regular, careful attention to ensure that the system operates to its fullest capability.

In addition, more attention should be paid to sampling issues with regard to the planning and use of APC technology. Initially, the number of APC units to be ordered should be based on a detailed design of an on-going data collecton program[1] (several pilot units might actually be

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[1] See Bus Transit Monitoring Manual, Volume 1: Data Collection Program Design.

purchased or leased to help monitor a number of routes prior to the major procurement in order to calculate route data variances to be used in estimating route and system sampling rates). Once the necessary units have been obtained, it is important to determine individual line sampling rates so that all line data obtained are of comparable accuracy levels (rather than just having equal sample sizes). APC equipment also offers the advantage of allowing an operator to determine seasonal variation in line performance during the first several years of use, thus allowing a better determination of the number of times a year an individual line should be monitored.

More can still be learned about the use and capabilities of APC technology. With the initiation of fully-supported operational programs in Portland, Kalamazoo, and Seattle, the information available regarding the potential problems and opportunities related to automated surveillance techniques will grow significantly in the next several years. While APC technology and its creative use may not be the "magical solution" to the bus transit monitoring dilemma, it offers one more option which operators can seriously consider to more effectively satisfy their data collection needs.

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* U.S. GOVERNMENT PRINTING OFFICE: 1982 381-428/2321

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DOT-I-82-43

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