U.S. Department of Transportation

Automatic Passenger Counter Systems

The State of the Practice

June 1985

UMTA Technical Assistance Program

Automatic Passenger Counter Systems:

The State of the Practice

Final Report
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FOREWORD

Many transit operators have been frustrated in their attempt to implement systematic service evaluation systems because they have not been able to efficiently collect the required information. In response to these needs automated data collection techniques were developed in the last fifteen years. Today, more than twenty transit agencies in North America have implemented automated data collection systems. All of these applications use automatic passenger counters or APCs.

This report on APCs was prepared by the Lane Transit District in Eugene, Oregon. It evaluates the capabilities, cost and benefits of APCs and presents a broad range of detailed technical information on existing APC applications. We believe that this report will benefit transit agencies that are considering incorporating APCs into their data collection systems.

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PREFACE

This report was prepared by Lane Council of Governments for Lane Transit District, Eugene, Oregon. Funding for this study was provided by the Urban Mass Transportation Administration and the Oregon Department of Transportation.

This research into the applicability of APC techniques to Lane Transit District was made possible by the cooperative efforts of the participating transit agencies. Grateful acknowledgement is made to the following individuals for their generous contributions of time and information:

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Chapter One

Introduction

In recent years, concern for air pollution and depleting energy resources, gas shortages, gas prices, traffic congestion and parking shortages have created incentives for more people to ride the bus. The resulting change in demand for transit service has increased the importance of transit system surveillance. Growing fiscal pressures and a change in planning emphasis from capital intensive improvements to short-range transit efficiency actions further contribute to transit agencies' need for reliable indicators of how well the systems are performing. (Multisystems Interim Report. 1982).

To effectively evaluate system performance and identify potential improvements, public transit agencies require a significant amount of information. Collecting and evaluating this information is critical for an effective transit decision-making process. In general, there are three categories of data used by transit agencies:

(1) passenger loading profiles used to determine overloading and underutilization;
(2) time performance indicators used in route scheduling; and
(3) system performance indicators used by transit management.

This information is used at different levels of disaggregation for transit planning, scheduling, and management.

The methods employed by transit agencies to obtain information vary from agency to agency. The most common techniques include ride checks, point checks, and driver counts. These methods involve the use of manual data collection. The people performing these tasks are either retained on staff full-time or part-time or are hired and trained periodically as the need for data arises. The costs associated with manual methods are high, particularly for large agencies.

Several problems with manual data collection techniques have been identified by agencies. Primary among these are: poor reliability, low accuracy, operational problems, relatively high costs, and long turnaround time between observation and reporting of events (Multisystems Interim Report. 1982). In response to this need for more effective, reliable, and cost efficient data collection methods, automated data collection techniques were developed in the 1970's. Today, at least seventeen transit agencies in North America have implemented automated data collection systems. All of these applications use automatic passenger counters or APC.

Basically, APCs involve the use of electronic devices or "sensors" to detect transit passenger activity. Data on the number of passengers boarding and alighting (deboarding) the bus and the location of that activity are accumulated and stored in a microprocessor on-board the bus. These data are later transferred (either manually or automatically) to a central, stationary computer for data processing and report generation. Prior to the development of APCs, these tasks were performed exclusively by people. Today, many of the agencies using APCs have limited or discontinued manual data collection activities.

This study evaluates the capabilities, costs, and benefits of automated data collection techniques in collecting and analyzing ridership information essential to public transit planning and management. This evaluation presents a broad range of detailed and technical information on APCs which will be a resource for agencies researching alternative data collection techniques. In addition, the discussion on APC system implementation will benefit agencies planning a conversion from manual to automated data collection methods.

1.1 Background

The first automated information systems for transit agencies were designed to provide data in real-time for vehicle monitoring and emergency response. "Real-time" means that the time and location data are transmitted over the radio continuously while buses are on the road. As the buses move along their scheduled routes, their activity is displayed on screens in a central office. These systems are known as AVM or automatic vehicle monitoring systems.

Unlike AVM systems, APCs are report-oriented information systems used by planning, scheduling, marketing, and transit management. APCs count the number of passengers boarding and deboarding the bus and the time and location of that activity. APCs are "off-line" as opposed to "real-time" systems. This means that the data are analyzed and evaluated after a significant amount of data have been gathered, usually a one-day to a two-week sample. In contrast, AVM systems do not count passengers boarding and alighting the bus, but provide bus location and schedule adherence information for real-time monitoring by transit operations staff. In the late 1970's, automatic passenger counting capability was combined with vehicle monitoring capability in some systems. These combined APC-AVM applications are referred to as integrated systems.

APC system components can be divided into three categories: hardware, software, and personnel. A simplified illustration of the hardware is shown in Figure 1-1. The glossary of terms, included as Appendix 6.3, is a useful supplement to this diagram. Nine devices, some of which are optional, may be used in APC applications.

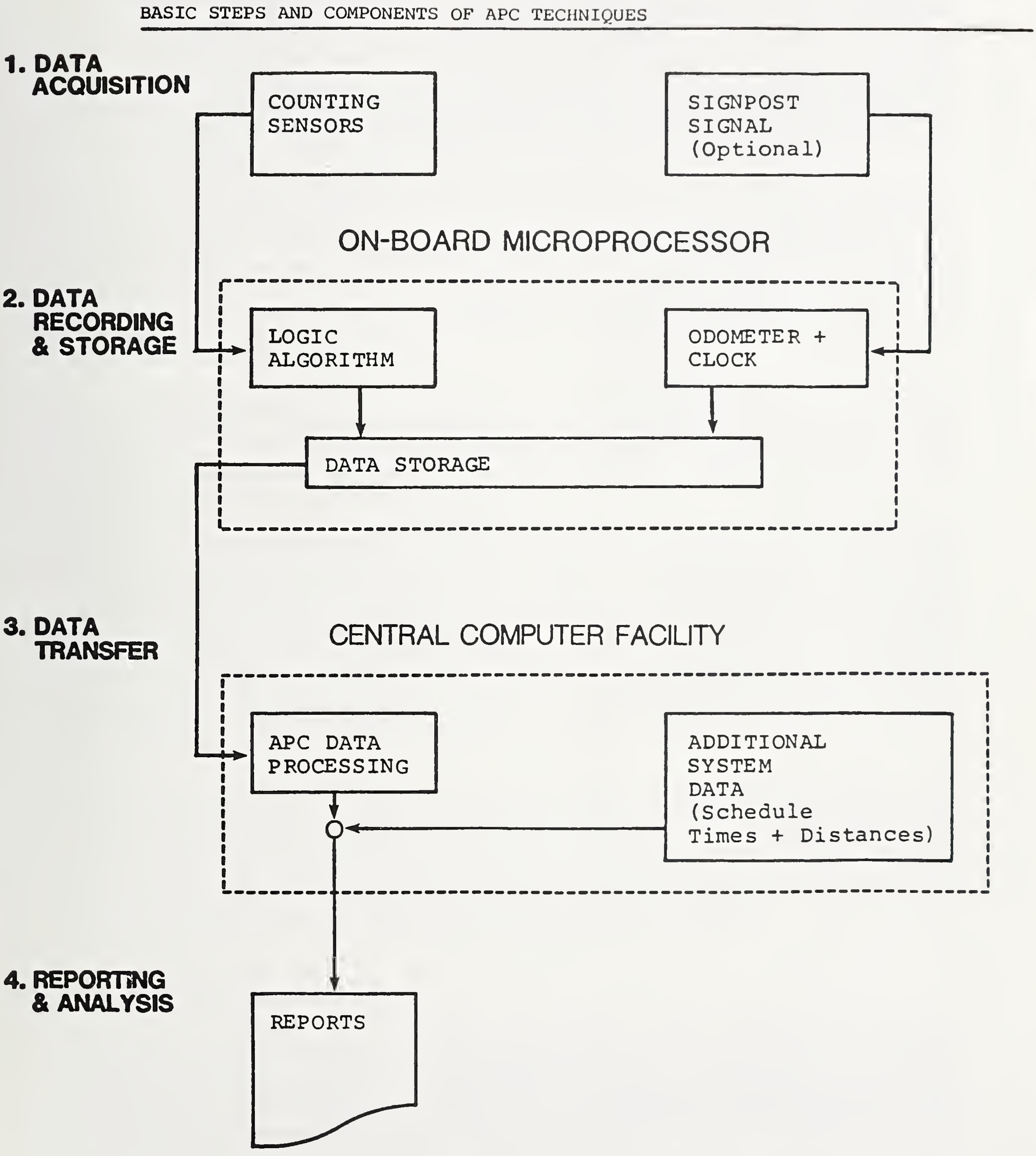
To gather data on passenger counts, the location of this activity, and the time of this activity, seven hardware components are required. Required equipment includes:

(1) counting sensors to detect passenger ons and offs;
(2) an odometer to calculate location of passenger activity;
(3) a clock to identify the time events occur (arrival at stops, dwell time, etc.);
(4) a microprocessing unit with a storage device to accumulate and store data on-board the bus;
(5) a power supply to convert, condition, and filter primary bus voltage to the data collection system (Lawerence and Zumwalt. 1984);
(6) a data transfer or retrieval device to transfer the data, either manually or automatically, from the bus to a central, stationary computer; and
(7) a stationary computer for data processing and report generation.

Optional hardware includes:

(1) door switches to register door opening and closing activity (used to control for counting when bus doors are closed); and

Figure 1-1: APC Hardware



Source: "An Assessment Of Automatic Passenger Counters". Multisystems Interim Report. 1982. Urban Mass Transportation Administration.

(2) signpost hardware (signposts, modems, and antennae or receivers) to either augment or substitute for the location referencing capability of odometer readings.

To produce useful reports, other information must be merged with APC data during data processing. The system flowchart in Figure 1-2 displays one software developer's (McEachern. 1981) version of APC data processing; it is presented as an illustration of the data typically required to create APC data files.

Module A in the diagram represents the initial editing and labeling of APC ("in-service") data. During this stage, the data are edited for inconsistenties in passenger counts, location data, and APC vehicle assignment information. Data are discarded when runs or parts of runs do not conform to known behavior of the transit system (ie: too many passengers carried or boarded at one stop, speed too high or too low at some point, distance traveled not appropriate). During this stage, the bus, route and run numbers of the APC vehicle assignments are appended to the APC data.

Module B edits the booking information which identifies the bus stop location (bus stop number, distance from previous stop, intersection closest to the stop, route, and any other information needed to identify the bus stop); and edits the data for miscellaneous data such as deadhead mileages. Deadhead mileage is the distance traveled by the bus either before or after it is in revenue service.

Module C edits schedule data, rejecting internal contradictions and conflicts with the in-service data on file. This is the first opportunity to determine automatically which runs did not take place or were truncated because of breakdowns. This module matches actual performance of the buses, by route and run, with the schedule by integrating the two files. This process is required to obtain schedule adherence data (McEachern. 1981). In addition to the editing tasks identified in Figure 1-2, this module formats and generates hard copy reports and archives the data for possible future statistical analysis and ad hoc reports. SPSS packaged software is most frequently used for report generation.

Personnel is the third component in an APC system. Transit agencies report that at least one full time person is needed to manage the APC project. Sometimes called an APC technician, this person is responsible for: hardware monitoring and diagnostics; coordinating APC vehicle assignments; devising a sampling plan; running the programs; entering the data defined above (schedule, bus stop, vehicle assignment, etc.); and overseeing general operation of the project. This person is sometimes responsible for data transfer as well.

1.2 Purpose And Objectives

Interest in automated data collection techniques usually stems from agencies' dissatisfaction with one or more aspects of their current data collection activity. For large agencies, the relatively high costs associated with manual methods most often create the incentive to investigate alternative approaches, such as APCs. For smaller agencies, the incentive is commonly potential access to more and better data on which to base decisions.

The purpose of this study is to investigate the viability of APC application at Lane Transit District in response to Lane Transit's need for more and better ridership, time, and system performance data. In addition to potential uses of

APC data by planning, scheduling, marketing and management, Lane Transit is interested in discovering the role APCs might play in the compilation of data for Section 15 reports. Section 15 reports are a requirement for federal funding through the Urban Mass Transportation Administration's (UMTA) grant program. This requirement mandates the collection and analysis of systemwide data at a 95% confidence level with ±10% tolerance (Bus Transit Monitoring Manual, Vol. 1. Multisystems. 1981). Several other issues of particular concern to Lane Transit planners include: APC hardware reliability and data accuracy; APC benefits and costs; APC system capabilities; APC system complexity; potential impacts of an APC system on current operations; and maintenance and personnel requirements.

Two objectives to be achieved through the research of APC systems in North America are:

(1) to determine the feasibility of APC implementation at Lane Transit District based on state-of-the-art APC technology, APC benefits, and APC costs; and

(2) to specify the system components which will satisfy Lane Transit's data needs (provided that APC implementation is recommended and that funding for the project is available).

1.3 Approach

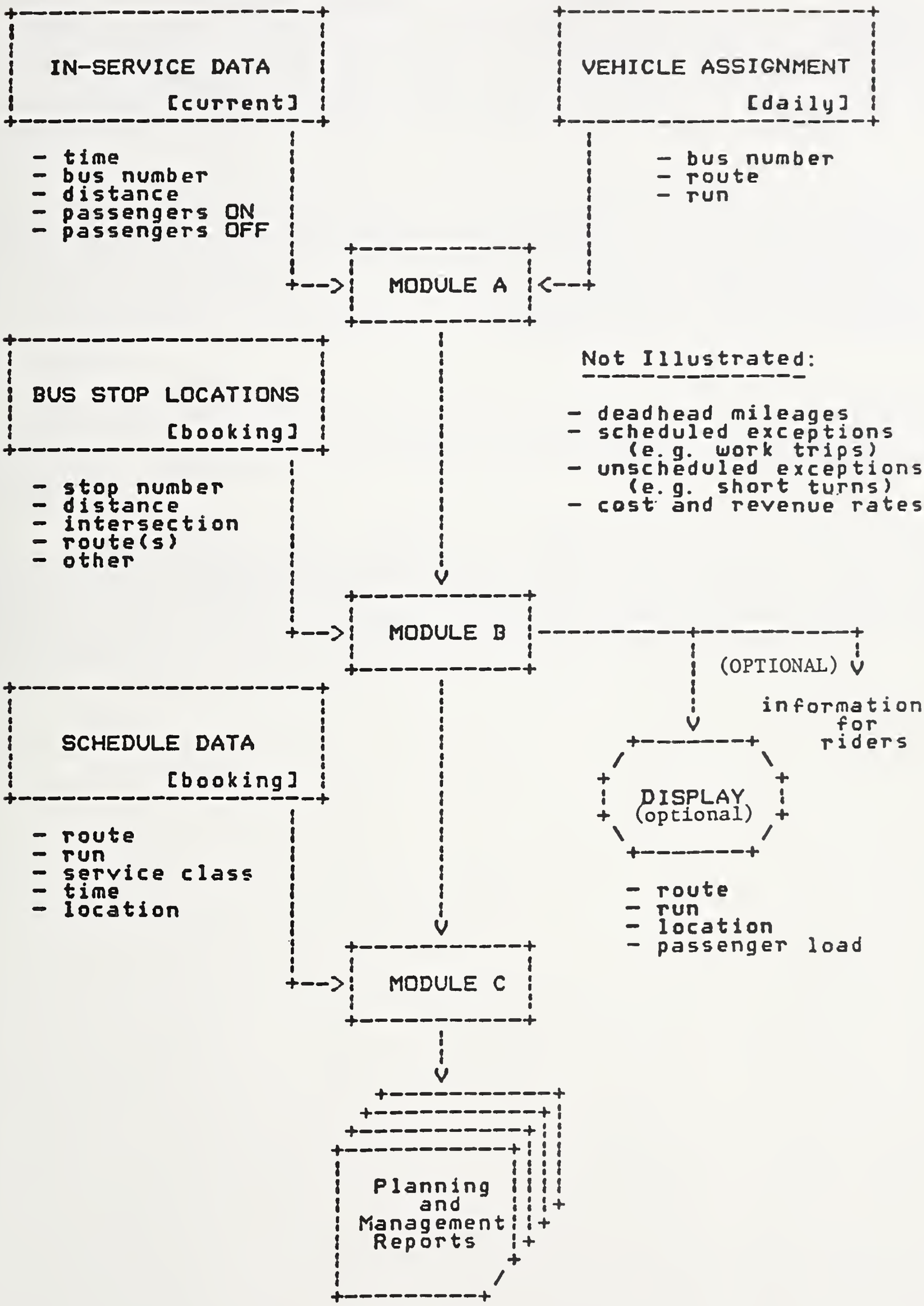
The information contained in this report was obtained from in-depth review of available APC documents and from detailed discussions with transit professionals, vendors, private consultants, and public agency personnel involved with APC use or study. The primary sources relied upon for agency-specific information were the transit professionals most closely associated with APC use at their agencies.

The research of APC applications consisted of five phases:

(1) Identifying APC user agencies;
(2) Surveying known APC user agencies;
(3) Visiting two sites with operational APC systems;
(4) Synthesizing survey responses into summaries on each agency; and
(5) Assessing the effectivness, benefits, costs, and special considerations involved in APC implementation.

APC user agencies were identified through a review of literature on automated data collection techniques. This information was supplemented through conversations with transit personnel over a period of six months. The agencies identified as APC users in this study do not represent the totality of APC agencies. APCs are used in Europe as well as in North America. European APC applications are not discussed in this study. Two other APC agencies excluded from this analysis are: Quebec City and Halifax, Nova Scotia. APC systems in these cities were not researched due to time constraints on this project. For additional information on current North American APC deployment, the reader is advised to contact the transit districts in these cities. Finally, due to the surging interest in APCs, many new applications of APC technology will likely be seen in the 1980's. Past, present, and future APC use is the topic of discussion in Chapter Two.

Figure 1-2: SYSTEM FLOW CHART FOR APC DATA PROCESSING



SOURCE: "Bus Transit Planning, Operations and Management", A Professional Short Course Transport Group, University of Waterloo; "An Introduction To Information And Control Systems", Neil V. McEachern, October, 1981.

A questionnaire (included as Appendix 6.2) was developed and mailed to known APC user agencies. The questionnaires were used as the basis for telephone interviews conducted with APC personnel. The information obtained from these interviews was summarized and the summaries were sent to the respective agencies for verification. These measures were taken to assure the accuracy of the information and to give the agencies the opportunity to edit and expand on the summaries.

To better understand how APCs function in actual applications, visits were made to Portland TRIMET and Seattle METRO transit agencies. The on-board equipment was demonstrated by representatives of these two agencies. These demonstrations were a valuable contribution to this research, lending conceptual significance to the capabilities of the hardware. The agency-specific information obtained from these site visits and interviews is summarized in the case studies in Chapter Three.

The specific applications of APC technology and uses of APC data are evaluated in Chapter Four. This chapter presents an assessment of the capabilities, effectiveness, benefits, costs, and special considerations involved in APC implementation.

Finally, in Chapter Five, major findings are summarized, special considerations are outlined, and recommendations are made regarding APC implementation at Lane Transit District. Although this recommendation is specific to this agency, the information contained in this chapter will benefit other agencies contemplating the implementation or expansion of automated data collection systems.

Chapter Two

APC Applications

The application of APC techniques in North America is limited to less than twenty agencies. Experience with the systems is also limited with the first APC project initiated in 1977. In addition to the APC agencies discussed in this study, APCs are used in: Halifax, Nova Scotia; Quebec City; and Europe. The application of APCs in these places was not investigated in this study.

In the search for APC applications, it was discovered that some agencies experimented with APCs in the 1970's and later decided to discontinue the projects. These pioneer projects (Early APC Experiments) are discussed breifly for purposes of comparison to fully implemented systems. Through this comparison, the importance of technological advances for system reliability is evident.

This discussion is followed by an introduction to the agencies currently using, testing, or contemplating use of APCs. APC applications or plans at these agencies are discussed as Implemented Systems, Demonstration Projects, and Potential Future Applications.

2.1 Early APC Experiments

Several agencies experimented with APCs in the mid and late 1970's, but decided not to implement APC systems. In 1977, an experimental program was initiated in Cincinnati, Ohio by General Motors. In 1981, the agency decided not to proceed with system implementation, and the project was moved to Windsor, Ontario. General Motors subsequently discontinued the APC portion of its operations.

Another pioneer project initiated in 1977 and later discontinued, the APC program in Edmonton, Alberta entailed prototype testing of two APC units. After testing, the program was discontinued primarily because of the high development and implementation costs.

Minneapolis/St. Paul Metropolitan Transit Commission (MTC) and the California Department of Transportation (CALTRANS) experimented with APCs in 1979. MTC purchased 44 dual beam systems. Due to contractual differences with the manufacturer, PRODATA, and the resultant non-delivery of on-board storage units, use of the system had always been limited. Since there was no mechanism for on-board storage, the drivers recorded count readings from display panels at designated points. Consideration was given to having drivers call in counts over the radio, but the agency decided this would create too much interference for the drivers. As a result, MTC does not use APCs as part of its on-going data collection program. (Multisystems Interim Report. 1982)

CALTRANS also experimented with APCs in 1979. A demonstration program was initiated with six small transit systems to determine the feasibility of APCs for small agencies. Another objective was to determine the role CALTRANS might play in assisting small agencies with data collection processes. Problems arose in coordinating the project and it was subsequently abandoned.

2.2 Implemented Systems

At least thirteen agencies in the U.S. and Canada have implemented or are implementing APC systems. Two of these applications are integrated systems which combine the real-time monitoring capability of automatic vehicle monitoring systems (AVM) with the off-line report capability of automatic passenger counting systems (APC). Table 2.1 displays the characteristics of these agencies according to: year of project initiation; total, peak and base fleet size; route structure; service area population; and number of APC buses.

From the data in this table, it is evident that APCs are applied to a variety of transit settings and that property characteristics are not determining factors in the application of APC technology. Five small agencies (with less than 200 buses in the fleet) and ten large agencies (greater than 500 buses in the fleet) have had some experience with APCs. Type of route structure also varies from complicated (combined radial, grid, and feeder trunk) to simple (radial). The service area populations of the agencies range from relatively small (less than 200,000) to very large (6 million). Note that all of these properties are peak-oriented (have high peak/base fleet ratios). The use of APCs for systematic sampling under these conditions demonstrates the applicability of APCs to peak-oriented transit systems.

Although the earliest APC implementations were at relatively large agencies, small agencies began APC projects within two years of the first applications in Seattle and Ottawa. The year of project initiation is not a valid indicator of APC capability or age since many of the earlier systems have been upgraded over time. These upgrades have been very costly for some agencies because extensive hardware retrofits and software modifications have been required. The increased versatility of modern systems and a phased approach to APC implementation help to minimize the marginal costs of upgrading the system over time. Phased implementation and other options available to reduce long-term project costs are discussed in Chapter Five.

The agencies in the first eleven cities listed in Table 2.1 have operational APC systems providing time, location, and ridership information for off-line reporting and analysis. This is not the primary objective of the systems in Los Angeles and Toronto. These cities use integrated APC-AVM systems with screen-oriented real-time service monitoring as the principal function. In Los Angeles, real-time monitoring takes precedence over off-line reporting. In Toronto, the APC system has no off-line reporting capability and all data, including passenger counts, are displayed on screens. Integrated systems are also used in Hull, Quebec and Rochester, New York (Deibel and Zumwalt. 1984). The APC-AVM applications in Hull and Rochester were not included in this research. For additional information on integrated systems, the reader is advised to contact the transit agencies in these cities.

Los Angeles' and Toronto's systems illustrate some of the special considerations involved in implementation and maintenance of integrated systems. Real-time monitoring (AVM) systems are designed primarily for operations control and emergency response. For this reason, AVM-APC buses are assigned continuously to specific routes. In order to consistently monitor the system in this manner, a higher percentage of the fleet must be AVM-equipped than is required for sole APC application.

Table 2.1: APC User Property Characteristics

	Began APC	Fleet Total	Fleet Peak	Fleet Base	Route Structure	Service Population (millions)	#APC Buses
APC Systems							
Seattle	1978	1069	915	450	Radial	1.3	116
Ottawa	1978	765	710	300	Radial, F.T.*	.5	66
Kalamazoo	1980	54	31	23	Radial	.2	20
London	1981	160	152	90	NA	.2	18
Windsor	1981	92	78	39	Modified F.T.	.2	27
Calgary	1982	683	435	155	Mainline, F.T.	.5	5
Portland	1982	631	424	228	Radial, Grid, F.T.	1.0	43
Columbus	1982	NA*	294	NA	Radial, F.T.	.9	20
Chicago	1983	2275	1950	995	Radial, Grid	3.7	6
Kitchener	1985	84	70	46	Radial	.2	20
Mississauga	1985	172	135	70	Radial, Grid, F.T.	.4	30
AVM-APC Systems							
Toronto	1978	2097	1621	710	Grid	2.1	100
Los Angeles	1980	2500	2100	1300	Radial, Grid, F.T.	6.0	200
APC Demonstrations							
Washington	1984	2000	1600	1200	Radial, Grid, F.T.	1.0	9
Denver	1984	745	620	326	Radial, Grid	NA	10

Notes:

1. F.T.= Feeder Trunk Route Structure
2. NA: Information not available

2.3 Demonstration Projects

It is common practice for agencies to conduct demonstration projects, usually six months to one year in duration, before deciding to proceed with full APC system procurement. These demonstrations are often part of a phased approach to APC acquisition and implementation. In some cases, the services of a system integrator or vendor are contracted for a specified time period to conduct on-site testing of the hardware and/or software. At some agencies, APC units were leased during the demonstration and later purchased. Other agencies purchased the equipment, usually a small number of units, during the demonstration phase and later expanded the systems.

The purposes of demonstration projects vary with the requirements of the agencies. Some of the common objectives of a demonstration project are to:

(1) perform accuracy and reliability testing on the hardware;

(2) increase familiarity with the hardware especially with installation and maintenance procedures and requirements;

(3) determine the feasibility of producing some or all of the hardware and/or software in-house (City of Calgary Report. 1983);

(4) minimize the long-term costs of hardware and software (Hardware retrofits and software modifications can be very costly. The purchase or lease of a few units in the early phases of the project reduces the amount of retrofitting that may be needed as the technology progresses. Also, data processing costs are significantly reduced with sample size. Since the software will be developed in the first year, a smaller sample is easier and less expensive to analyze while software routines are perfected.);

(5) help identify long-term hardware, software, and personnel needs; and

(6) allow for formulation of internal procedures (OC-TRANSPO, Ottawa).

At present, at least two agencies are conducting demonstration projects. Denver Regional Transportation District (RTD) and Washington Metropolitan Area Transit Authority (WMATA) have both contracted with APC vendors to conduct on-site testing of APCs. Summaries of the projects at these agencies are presented here as sample approaches to an initial APC project.

2.4 Denver Regional Transportation District (RTD) Demonstration Project

Interview with Jim Oliver, Manager of Schedules, RTD, Denver, Colorado

The Denver Regional Transportation District (RTD) proceeded with a six month APC demonstration project in November, 1984. The object of the demonstration is to test the accuracy and reliability of the hardware. Two firms were hired to demonstrate the relative effectiveness of different types of hardware. Pachena and Urban Transportation Associates (APC system suppliers) have each installed APC units on five buses and 10 signposts along routes. The equipment from Pachena was purchased by RTD; while the equipment from Urban Transportation Associates (UTA) was leased.

The objectives of the demonstration are:

(1) to determine if there are statistically significant differences between manual and APC counts; and

(2) to determine the magnitude of the differences and the statistical reliability of APC counts under the range of loading, passenger, environmental, and operating conditions normally experienced by RTD buses.

The tests compare APC performance to manual counts as well as comparing the performance of one system to the other. The results of the tests are not yet complete and both vendors have been doing a certain amount of "in the field" adjustments to improve the accuracy of their respective APC units. The estimated date of completion is around July, 1985.

To analyze and evaluate the test data, RTD has hired a consulting firm, IBI Group. The results will be analyzed in terms of the general feasibility of APCs and the relative effectiveness of the two systems now being tested.

RTD hires as many as 20 ride checkers during the year. Retaining good ride checkers is a problem especially since the checkers' job is an entry level position and thus has a high turn-over. For this reason, APCs are viewed as a favorable alternative to manual counts.

EVALUATION OF RTD'S APC SYSTEM

COUNTING SENSORS

Treadle mats, manufactured by Pachena, are installed on five buses. Infrared beams supplied by Urban Transportation Associates are installed on five buses.

ON-BOARD MICROPROCESSOR

Five buses contain Pachena microprocessors and five contain microprocessors supplied by Urban Transportation Associates.

LOCATION REFERENCING METHOD

A total of 20 portable signposts are used to reference location of data input. Ten signposts were purchased from Pachena and ten were leased from Urban Transportation Associates. These units are solar powered and no problems have been encountered with any of the signposts. The signposts are located as close as possible to specified time points along routes.

DATA STORAGE

With the Pachena units, data are stored in solid state memory. With the UTA units, data are stored on cassette tapes. UTA APC data are later processed into reports. The data obtained from the Pachena units are displayed on the display pannel of a portable diagnostic unit. In this way, cumulative counts from the APC units are compared with manual counts for the same routes.

DATA TRANSFER

No data transfer or processing is performed with the Pachena units. In the UTA demonstration, tapes are replaced about once every two weeks by UTA personnel.

STATIONARY CPU AND SOFTWARE

Only the UTA project entails data processing and this is done at UTA offices on a PRIME mainframe computer.

REPORTS

No route analysis reports are required of the vendors as part of the demonstration. However, UTA will provide some reports in order to further demonstrate the usefulness of the system.

APC ACQUISITION AND FUNDING SOURCE

The demonstration projects were funded 100% by the district. Subsequent APC acquisition, if recommended, will be funded 80% by a federal capital grant and 20% by the agency. An RFP process was used to select the system integrators chosen for the demonstrations.

COSTS OF THE APC SYSTEM (For six month demonstrations)

Urban Transportation Associates:	$42,500 (to lease hardware and perform limited analysis on data)
Pachena:	$27,700 (to purchase, install and test hardware)
IBI Consultants:	$50,000 (to evaluate test results)

2.5 Washington Metropolitan Area Transit Authority (WMATA) Demonstration Project

Interview with Jim Robinson, Systems Engineer and APC Project Manager, WMATA, Washington, D.C.; and Tom Kowalski, Urban Transportation Associates

WMATA began experimenting with APCs in 1984 when it contracted with Urban Transportation Associates (UTA) to conduct a nine month test installation on nine buses. The APC units were leased from UTA during this time. Due to organizational restructuring at WMATA, the project was delayed and a three month extension was granted to the project.

This demonstration was initiated not only to demonstrate the capabilities of the hardware (including the capacity to collect stop-level data), but also to do some extensive analyses and to make recommendations. Five of the busiest and most challenging routes (having a high level of interlining and operating out of more than one garage) were chosen for the test. To date, route analyses have been performed on all but one of the routes and recommendations have been made, on the basis of the APC data, as to appropriate service levels (route changes, headway alignments, etc.) on the four lines analyzed.

The benefits and costs of APCs relative to the present manual data collection methods are of primary interest to the agency. WMATA currently employs 35 full-time salaried checkers to perform maximum load checks on all lines three times per year and on/off checks every two years. As part of the demonstration, counts on specified routes were recorded by both APCs and by WMATA staff riding the bus. These tests of the on-board equipment comparing APC data to ride check data revealed an APC accuracy at 98-99%.

Once all of the results of the tests are presented, the agency will make a determination as to the feasibilty of proceeding with system procurement. The systems engineer interviewed wrote the specifications for the APC demonstration. He is convinced that the technology is proven and believes that APCs are a valuable tool for transit agencies.

EVALUATION OF WMATA'S APC SYSTEM

COUNTING SENSORS

WMATA uses infrared beams supplied by UTA. Door switches are used to record door opening and closing events. The sensing devices are satisfactory in terms of accuracy and reliability. It was advised that the maintenance staff be instructed on the function of door switches to avoid accidental damage to the equipment during non-APC repair work.

ON-BOARD MICROPROCESSOR

The microprocessor, a Motorola 6800 unit, is physically located inside a PDU (portable data unit). An interface board is also located inside the PDU. This device interfaces the sensor data to the microprocessor and is a product of UTA and General Motors.

The PDU contains a clock (based on 24 hour time), and an odometer. Data input is activated whenever a bus enters and leaves a signpost field and when 256 seconds have elapsed since the last record was written. Each time a record is written, data are time and distance stamped. In this way, time and distance between stops are calculated. Reliability and accuracy of the units are satisfactory.

LOCATION REFERENCING METHOD

Motorola portable signposts are used to reference location of data input. The batteries for these units have a very short life and require replacement about once every two weeks.

According to the engineer, positioning the signposts is an art. He suggested placing one signpost at the maintenance facility, one at the start of the line, and one at each time point and layover point.

DATA STORAGE

Data are stored in a Datell unit on cassette tape.

DATA TRANSFER

Data are retrieved (tapes replaced) at least once every two weeks by UTA personnel.

STATIONARY CPU AND SOFTWARE

UTA performs a complete service for WMATA including data transfer and processing. The APC data are processed on UTA's PRIME computer and also fed directly into WMATA's minischeduler file on the agency's IBM mainframe.

REPORTS

When the analyses on all five lines are complete, UTA will have provided WMATA with a series of reports on each line. Based on these reports, UTA will recommend to WMATA appropriate service levels for these lines.

COSTS OF THE APC SYSTEM

Demonstration Project costs: $80,000 for the 12 month project

2.6 Potential Future Applications

APC use has expanded rapidly in the past few years and interest in automated data collection techniques is increasing in both the U. S. and Canada. Some APC agencies are conducting research (see, for example, Calgary Summary) prior to expanding their present systems to take maximum advantage of technological advances. These studies are usually part of a phased approach to APC implementation.

Some agencies with no prior APC experience are now conducting studies for their districts. This is the objective of a study soon to be conducted in Madison, Wisconsin. Madison Metro has prepared an RFP to solicit a consulting firm to conduct an "Automated Technology Study". The purpose of the study is: to evaluate Madison Metro's current radio and data collection systems; to assess available radio and automated data collection technology; to recommend cost effective improvements to Madison's present system; and to provide procurement assistance.

In addition to Madison, APC systems are being considered in Jacksonville, Tuscon, and Atlanta (Deibel and Zumwalt. 1984). Studies of APC technology are now either underway or contemplated in: Vancouver, B.C.; Miami, Florida; New Jersey; and Fresno County, California.

Chapter Three

APC Case Studies

The application of APC technology in North America today lacks uniformity in design. Technological advances, unique data requirements, resource considerations, environmental factors, and changing market conditions have influenced trends in APC deployment. As a result, application has been limited and highly specialized and each of the systems now in use is unique in at least one essential aspect.

Changing hardware and software technology has contributed to the specialized nature of APC applications. Earlier systems are being modified to add new capabilities as technological improvements are made, data needs change, and unanticipated needs are realized. The system components also vary due to varying levels of resources. Environmental factors such as rain and cold affect the reliability of certain types of hardware, further contributing to specialized application. In addition, some hardware manufacturers and software developers have left the market and new ones have entered over the years, adding to the diversity of the current application of APCs.

Due to this lack of uniformity, case studies provide the best indication of: the status of existing systems; the types of problems encountered by user properties; how these problems have been addressed; the benefits and costs of APCs; and the different approaches to APC system implementation. The case studies presented in this chapter represent all but a few of the APC systems currently in use in North America.

3.1 Seattle METRO

Interview with Tom Friedman, Senior Transit Planner, METRO, Seattle, Washington

METRO began implemention of an APC system in 1978 when Dynamic Control Corporation (DCC) equipped 56 buses with treadle sensor mats and CPUs. The system consists of stairwell mat switches, an odometer, an internal clock for deriving time and an on-board solid state storage capability. APCs are installed on 3 different bus types: MAN (articulated), AMG and Flyer. Some of the Flyers and articulated buses are equipped with Lift-U-Lifts.

In the early phases of the project, location was referenced using a time matching program. This method assumes that the bus is on time and produces a report displaying activity by locations based on where the bus was "supposed to be" at a specific point in time. Since buses do not always run on schedule, more accurate data was needed. METRO then purchased 250 signposts, manufactured by AVM Company, and installed them throughout the system. The major criteria for placement of signposts was the assurance that each APC bus receives at least two signpost signals per trip. New software was developed to process the additional data. This software involves the use of a computerized mileage template to produce a geographical representation of the route structure and automatically correlate counts to specific bus stops.

METRO has just begun to process the APC data with this new software system. At present, about 50% of the data are successfully logged. It is believed that once the software is refined, METRO will have access to route level and stop level data for scheduling, planning, and management applications for use both in real-time monitoring and off-line analysis and reporting.

In 1983, METRO contracted with Pachena, Inc. for 60 more APC units which brings the total to 116 or 12% of the fleet. METRO planners recommend this percentage as a guideline for properties. These systems will be completely installed by the summer of 1985.

EVALUATION OF METRO'S APC SYSTEM

COUNTING SENSORS

The DCC counters initially purchased by METRO in 1978 use treadle mats. These mats suffered from several design defects including water infiltration and bubbling. DCC is no longer in the APC business. The new mats, used to replace the DCC mats and supplied by Pachena in 1983, are manufactured by London Mat. These mats have worked well so far.

Because some types of buses, when equipped with wheelchair lifts, have only one step available for a treadle mat, a mat must be placed on the floor level at the front door. This has not been a problem for rear door sensors which are placed on the steps. No wheelchair counts are obtained at METRO by APCs.

ON-BOARD MICROPROCESSOR

The microprocessing unit is located on a partition behind the driver's seat. Unlike the DCC units, which lost stored data if the electrical system was disconnected, the Pachena unit contains an auxiliary battery which prevents the loss of stored data.

Another useful function of the Pachena unit is the capacity to record front and rear door activity separately. This feature allows more efficient monitoring of the equipment and detection of failures in the counting sensors.

Data collection is on-going as opposed to "triggered" by certain events. The following events are recorded:

* front and rear door opening
* front and rear door closing
* time at stops
* distance (odometer reading) at specific intervals to compute speed
* signpost code
* boardings and alightings
* dwell time
* mat switch diagnostic (every 12 hours, a record is generated reporting the number of times a switch is closed. This record helps to determine when a mat switch is failing.)

..........the date, device number, and header record are "stamped" to the data.

LOCATION REFERENCING METHOD

METRO initially purchased 250 AVM CO. signposts of which 226 were installed. The AVM signposts transmit coded radio signals received by a special antenna atop the bus. With this system, a bus enters and exits a signpost field with a radius of about 150', and the CPU records the signpost field entry and exit codes. The software used to process the data interpolates between the enter and exit mileage to derive location. All raw data locations are then adjusted by a scaling factor to produce a match with a template (contains detailed route information including schedule, bus stop, and time point data).

One option suggested by METRO planners is for the bus driver to manually enter location data by pressing a reset button at specific intervals. This method could be used in place of signposts at a considerable cost savings. In opting for this alternative, two considerations should be recognized: (1) the success of this technique highly depends on the cooperation and reliability of the bus drivers especially at high use stops where drivers are most likely to be distracted or preoccupied; (2) if signposts are eventually to be purchased, the most opportune time may be during implementation of the APC system since the costs of modifying an installed system for signposts are high and there may be a problem finding a compatible signpost system if installation of signposts is postponed. Alternatively, some APC systems contain an external connector to enable the system to be used with signposts and other capabilities that may be needed in the future.

DATA STORAGE

Data are stored on-board in a solid state record storage unit with a capacity up to 2000 stop records.

DATA TRANSFER

Data are retrieved with portable recording units. With the DCC system, data are transferred to cassette tape; with the Pachena system, data are transferred to 3 1/2 inch hard disks. Seven or eight buses can be fed into one tape. Data are retrieved twice a week by 2 employees who perform the task late at night as part of their regularly scheduled duties. Transfer takes about 1 minute per bus.

STATIONARY CPU AND SOFTWARE

METRO uses an IBM 3033 mainframe to develop, edit and run the APC programs. A PRIME 750 is used to send the data to the mainframe. Competition for use of the system has been a problem for the staff; but acquisition of a new computer (VAX 11/785) for various functions including the processing of APC data should remedy this problem.

METRO computer services division is developing the software to process the APC data. The software is written in RAMIS II and FORTRAN, and involves the use of templates to integrate the APC data with a geographical representation of all routes in the system. The geographical part of the system is called TRANSGEO which provides the capability for all route patterns to be coded onto a common base map (Census DIME file map). Bus zones, time points, and signpost locations are also coded on this base map. In addition, INGRESS, a relational data base system, will be used to retrieve APC information on the new VAX computer.

REPORTS

At present, METRO is in a transitional phase of APC development and successfully logs about 50% of the data. The time-matching software produced passenger load profiles by time of day in tabular and graphic format. With the new software, METRO hopes to have ready access to ad hoc reports as well as reports routinely used by planning, scheduling, and management.

In addition, the APCS will be used to: (1) assign METRO's fleet of articulated buses to routes where they will be the most effective; (2) compile Section 15 data; (3) plan and justify route changes; and (4) create, evaluate and adjust schedules and run times.

APC IMPACTS ON CURRENT OPERATIONS

METRO has worked extensively with operations and maintenance staff to insure that priority is given to APC vehicle assignments and maintenance of APC buses. For example, special parking lanes were assigned for the APC buses. Also, planning sends the hostler (the person who assigns vehicles to routes) a calender each week indicating which routes require sampling and which APC buses are available. The hostler makes the actual assignments based on this calender.

Cooperation between planning and maintenance is another important component of a successful APC program. At METRO, the planning staff notifies maintenance when they suspect from the data that there is a hardware problem.

METRO continues to use 8 full-time salaried point checkers to manually collect data. It is felt that the APC system has reduced the need to hire additional checkers even though the service level has grown almost 50% since the APC project was initiated.

APC ACQUISITION AND FUNDING SOURCE

METRO used a bid process to select a supplier of the APC system. In the 1983 purchase of APCs, Pachena, Red Pine Instruments, and Dynamic Controls were the 3 companies to respond. Pachena, the lowest bidder, was selected as they agreed to meet all specifications including a full 2 year warranty. The project was funded by an UMTA Section 3 capital grant.

COSTS OF THE APC SYSTEM

The costs below are for the AVM signposts initially purchased by METRO and for the new Pachena system.

CAPITAL COSTS

Counting Sensors (mats):	$ 1200 to $1700 per bus including wiring
Microprocessor:	$ 1500 per bus including wiring
Installation:	24 person hours per bus to install mats and microprocessor
Data Retrieval Unit:	$ 4000 to $5000 per unit
System Test/display Unit:	$ 1500 per unit
Signposts:	$ 300 per unit
Signpost Installation:	2 person hours per unit
Signpost receiver:	$ 1000 per unit
Signpost receiving antenna:	$ 200 per bus
Software Development:	2 person years to date

*OPERATING COSTS (Based on the original 56 APC units)

Hardware Maintenance:	.75 FTE
Data Analysis:	1 FTE

*Data processing costs and costs of replacement parts are not included.

3.2. Ottawa-Carleton Regional Transit Commission (OC TRANSPO)

Interview with Joel Koffman, Systems Planning Supervisor, Ottawa-Carleton Regional Transit Commission (OC TRANSPO), Ottawa, Ontario

Initially implemented in early 1978, OC TRANSPO's APC system is report-oriented for use in planning, scheduling, and management. Of a total 66 APC-equipped buses, 54 contain Prodata lightheads and 12 contain Red Pine lightheads. Red Pine, located in Ontario, manufactured the microprocessing units for the 66 buses. Of the 66 APC buses, about 60 produce good data on any given day. Hardware maintenance (both APC and non-APC related) and operational procedures such as problems associated with data transfer account for data loss on the remaining buses.

Overall, TRANSPO is enthusiastic about the potential and capabilities of APCs. The planners are satisfied with the accuracy of the data; and they would definitely repeat their APC experience. TRANSPO views APCs as cost-effective for two reasons:

(1) APCs replaced 7 of 8 salaried ride checkers. This was accomplished by attrition and alternate job placement.

(2) Every decision based on APC data to redirect service deployment improves operational efficiency and increases productivity.

Currently OC TRANSPO is upgrading the existing APC software and adding extra time utilization descriptive records to the on-bus unit output. These modifications will be completed by March, 1986. Although they have not ruled out the possibility of converting to an AVM system in the future, they believe the cost of equipping the total fleet with AVM hardware will be a major consideration.

EVALUATION OF OC TRANSPO'S APC SYSTEM

This evaluation applies to the current system which will be fully upgraded and operational by March, 1986.

COUNTING SENSORS

OC TRANSPO uses Prodata and Red Pine infrared counting sensors. Subsequent to TRANSPO's initial acquisition in 1978, Prodata stopped making the sensors. Red Pine then began to manufacture the light heads in order to facilitate sales of its microprocessors. Red Pine equipped 12 additional buses with counting sensors and microprocessors in 1982. These newer units were installed on articulated buses only. To accomodate the three doors on the articulated buses, a total of five passenger streams (or ten lightheads) per bus were required.

TRANSPO is very pleased with the sensors in terms of unit reliability. This planner contends that any errors in counting will have little impact on overall results as long as the errors are made consistently throughout the sample. Although high use stops are perceived to introduce some additional error, this is not considered to be consequential and is not of major concern at TRANSPO.

ON-BOARD MICROPROCESSOR

The microprocessors, or Passenger Counting Units (PCUs), are made by Red Pine. As a result of advances in technology, TRANSPO ended up with two somewhat different types of PCUs:

(1) The 54 microprocessors initially purchased at TRANSPO have only 4K byte storage capacity while the 12 newer units store up to 12K bytes;
(2) The newer units record dwell time and the older units do not.

The data recorded by the PCUs are: passenger boardings and alightings, relative-time stamps between stops, odometer readings, and dwell time (on the 12 newer units). Relative-time was prefered over real-time due to the fact that to obtain real time stamps, the clocks on all APC buses would need to be synchronized on occasion. Relative time stamps avoid the need for this task.

Data accumulated in the PCU are written to record at every odometer "click". Movement of the bus for fifty feet after stopping causes an odometer click provided that a significant event (passenger counts or idle time greater than one minute) has occured when the bus was stationary.

The PCU also flags memory space overflow when the storage capacity for time or distance is exceeded. The PCU accumulates distance data up to 2.6 miles and then resets the odometer to zero. Similarly, the clock is reset to zero after one hour has passed. In each instance, a record is written to signal the event.

The original 54 units were placed on the floor behind the driver's seat. There has been a problem with the plug connecting this "black box" to the power source being pulled out. To avoid this problem, the new units were placed behind and above the driver's seat.

LOCATION REFERENCING METHOD

The location referencing method employed at TRANSPO is the same method used at TRIMET in Portland. Location data is derived using a computer generated comparison of APC odometer readings with trip distance files. This method is not considered satisfactory due to the loss of an entire day's data if a bus deviates even slightly from its scheduled route.

To prevent the loss of data due to route deviation, OC TRANSPO plans to install 32 signposts and signpost receivers (on all 66 buses) and to modify existing PCUs (Passenger Counting Units) to process the signals. The signposts have been designed by Toronto Transit Commission. OC TRANSPO will begin by purchasing and field testing three signposts and receivers for 6 months in order to gain experience with signpost technology.

Signposts will be used to obtain route-level and route segment-level data. The system will have the capability to provide stop-level data as well should this level of disaggregation be desired in the future. OC TRANSPO intends to install the signposts to obtain at least one signpost reading on each round trip for every route in the system. The new system will thus have the capacity to accept with confidence data on a trip rather than a run basis. Calculations based on this reasoning resulted in a perceived need for 32 signposts in order to cover all 120 OC TRANSPO routes.

DATA STORAGE

The PCU on-board the bus uses a solid state memory device for storing data. The storage capacities of the two types of PCUs are 4K byte and 12K byte.

On-board storage of more than a day's worth of data is not desired at TRANSPO since it increases the risk of data loss and delays identification of equipment problems. This becomes particularly important if the problem occurs early during the first day of storage. For reasons discussed below, TRANSPO has switched to radio-link data transfer.

DATA TRANSFER

Until January, 1985, TRANSPO used portable recording units requiring manual operation to transfer the data onto diskettes. These units were used for diagnostics as well as data transfer. The transfer was performed by security guards at the end of each day. The security guard picked up the diskette unit and a blank diskette each night and took these to the APC buses which were lined up in a specified area. The unit was "plugged in" to the PCU and a light signaled when the transfer was complete. After all the data were retrieved, a microchip in the diskette unit sent a signal to the CPU to clear memory and begin a new counting day. Data transfer took about 20 seconds per bus.

OC TRANSPO found manual transfer unreliable. Very often APC data could not be retrieved because the bus was on a hoist, a substitute guard was on duty, security took precedence over APCs, etc. The guards eventually requested TRANSPO to hire a full time person to retrieve the data.

In response to this problem, TRANSPO switched to an automated radio transmission link via a special radio channel. Red Pine designed a modem which interfaces the microprocessor to the radio. OC TRANSPO data processing staff developed the software that controls the radio transfer link. The property tested one unit for 4 months and subsequently retrofitted the entire APC fleet. It took several months to fine tune the system. It is now fully operational and data are being extracted reliably every evening.

Transfer takes place as follows: At 10:00 each night, a retrieval program in the VAX stationary computer comes on line and signals bus #1 to respond if it is in the garage. Once a bus has been stationary for 30 minutes, the radio automatically switches to a special channel. The radio transfer is interactive. If a signal is too weak to be received, the VAX program requests a repeat signal. Once all of the data have been retrieved, the program signals bus #2 and so on. The data are stored in VAX files for processing. The software real-time stamps the data directly after they are transferred.

STATIONARY CPU AND SOFTWARE

In the early stages of APC development, TRANSPO leased time on Group Five's (a consulting firm in Ontario) PRIME computer to process APC data. In 1980, TRANSPO purchased a VAX 11/780 computer.

The software to process the APC data was initially developed by Group Five Consultants. This firm continued to work with TRANSPO in both minor software enhancement and software maintenance until 1983. At this point, OC TRANSPO made the decision to maintain the software in-house.

The planners see the main problem with processing the APC data as a data base management problem. The 3 software functions essential for processing the APC data are: (1) raw data validation and matching to prescribed schedules; (2) organizing, sorting and storing data files; and (3) formatting the output in such a way so that reports are generated which suit the needs of the individual users. TRANSPO planners believe the SPSS package can be used to label and format reports.

A total rewrite of the software is currently being performed by Systemware (see TRANSPO ASSESSMENT AND SUGGESTIONS). It is expected that, with this software, all of the processing required to validate and match data will be automatically done during the night.

In the morning, they expect to have access to validated data which have been correlated with route profiles. In addition, two reports should be available:

(1) A report identifying bus runs on which data were successfully retrieved during the night; and
(2) a diagnostic report pinpointing problems with either the hardware or schedule profiles.

One of the specifications in the RFP was that the software become the property of the province of Ontario for use by other properties.

REPORTS

Schedule data from a mini-scheduler software package by SAGE (a Toronto software firm) and data from a bus stop file (created by TRANSPO) are automatically correlated with the APC data to produce reports. The software by SAGE is an interactive schedule writing system.

With the current software, OC TRANSPO attempts to capture every run once during a sign-up (there are four sign-ups per year). The property has yet to capture all scheduled runs once in a sign-up period. Software does exist to crudely factor data to represent total scheduled service.

Another problem encountered at TRANSPO is that the software is designed so that ad hoc reports can be produced only on a semi-manual basis which requires much human effort. Also, the data base can be accessed only at the end of a sign-up when a quarter is complete.

APC IMPACTS ON CURRENT OPERATIONS

OC TRANSPO replaced 7 of 8 salaried ride checkers either through attrition or alternate job placement when APCs were installed. The planner believes the APC counts are more accurate than the checker counts due mainly to the fact that the job of checking is boring, routinized and unstimulating and, thus, checkers are likely to be less concerned about error. Also, the volume of data collected by APCs is much greater than could be obtained through former manual methods.

For operations, the impacts were numerous. Some of the most important consideartions were:

(1) the initial reassignment of parking lanes for APC equipped buses;
(2) the cooperation and coordination of the bus starter who makes driver-bus assignments;
(3) the cooperation of garage staff (electrical and body shop) to perform initial installation of equipment; and
(4) the cooperation of the garage electrical staff to assist in APC maintenance.

Bus drivers are not involved in any way with the APCs.

For planning, APCs have supplied access to more and better quality data. They now have more complete information on which to base decisions.

OC TRANSPO integrated the APCs gradually throughout the entire property so that each individual division "owned" its own piece of the project in terms of responsibilities. This created an amiable and cooperative atmosphere which lessened the impact of the APC project. For example, before an APC bus is put back on the road after being in the shop for repairs, an electronics specialist checks over the entire APC system to be sure it was not accidently damaged. There is considerable cooperation between planning and the electrical shop regarding APC maintenance.

TRANSPO ASSESSMENT AND SUGGESTIONS

In early 1984, TRANSPO made a careful assessment of its APC system and identified the following limitations restricting the usefulness of the APC system:

(1) Location data is inadequate;
(2) On-board microprocessors have different capabilities;
(3) Idle time, stop time, and traffic congestion data are not available as output from the on-bus microprocessor;
(4) Data transfer method is unreliable;
(5) The software is designed to allow only one sample of each bus run to be recorded during each 3 month booking period;
(6) The software will allow analysis reports on only an entire booking period (once every 3 months);
(7) The software will not produce ad-hoc reports between quarterly analysis, except on a semi-manual basis. The ad-hoc report that is available is very limited in scope;
(8) The present system of inputting missing bus runs is time consuming both in human and computer processing;
(9) The formatting of reports does not accommodate the needs of the users of the data;
(10) The procedure now used to create the run profiles with which the APC data are matched is cumbersome and rigid;

In response to #1 through #4 above, TRANSPO has contracted with Red Pine to upgrade the hardware; to make the system uniform; to modify the microprocessors to record signpost data and to analyze time utilization along each trip; and to design and manufacture a modem for use on-board the bus to allow radio transfer of the data. The installation of thirty-two signposts, manufactured by Electrocom (a Toronto firm) and designed by Toronto Transit Commission, is planned. At present, prototype testing is under way with three signposts and receiver units utilized with the new up-graded passenger counting units.

Conversion from a manual data transfer method to radio-link transfer is complete with the necessary hardware installed on all 66 buses. KVA Communications, a radio network consulting firm in Ontario, assisted with the overall design of the radio transfer.

To remedy the software problems, TRANSPO recently awarded Systemware a contract to design, develop, document, and implement applications software to process APC data and to produce reports. Development of this software will cost approximately $250,000 (in Canadian dollars) and will take about 18 months to complete (scheduled completion date is March, 1986).

Based on seven years of experience with APCs, the property suggests the following precautionary measures to cut long-term costs of APCs and to smooth APC implementation:

(1) The property should clearly identify its data needs from the outset (ie: desired level of accuracy, type and amount of data required, etc.).

(2) Strong support and directive from transit management for APCs from the project's inception will facilitate acceptance and integration of APCs.

(3) A 6 month pilot project is advised using about two prototypes leased or borrowed from a supplier or another property. A pilot project serves the following functions:

    (a) affords the property the chance to become familiar with the APC system;
    (b) allows for anticipation of future hardware needs;
    (c) provides an indication of software needs; and
    (d) allows for formulation of internal procedures.

(4) A thorough understanding of the hardware by planning division personnel is critical for the success of the APC project; and a large commitment of time and dedication is required on the part of staff directly involved with the APC system.

APC ACQUISITION AND FUNDING SOURCE

Red Pine was automatically awarded the contract to upgrade the hardware since this company was the original supplier.

TRANSPO used an RFP process to purchase the software. Systemware won the software contract because the company displayed the most thorough understanding of the specifications and presented the most viable options for meeting them. Systemware's fee was approximately $250,000.

The APC project has been and continues to be funded 75% through capital funds from the province of Ontario. The property provides the remaining 25% of the funds.

COSTS OF THE APC SYSTEM

Prices are based on the cost of the 12 units purchased in 1982. Figures are quoted in Canadian dollars.

CAPITAL COSTS

Counting Sensors (optics):	$ 400 per passenger counting stream
Microprocessor:	$ 3,300-3500 per bus
Installation:	2 person days/bus
Portable Transfer Device:	$ 5,000 per unit
Signpost Transmitter:	$ 1,200 per unit
Signpost Transmitter Installation:	not yet determined
Signpost Receiver:	$ 300 per unit
Signpost Receiver Installation:	not yet determined
Software Development	$250,000 SW development by Systemware
PCU modifications:	$ 300 per bus (for new upgraded system)
Conversion To Automated Radio Transmission:	$ 25,000 for pilot project $ 30,000 to retrofit 66 buses with modem (incl. instln.)

OPERATING COSTS

Hardware Maintenance:	$ 22,000 (Red Pine charges, replacement parts, and 1 FTE)
Data Processing:	1 FTE
Data Analysis:	2 FTE (users and report generation)

3.3 Kalamazoo Metro

Interviews with Bill Schomisch, Director, Kalamazoo Metro Transit, Kalamazoo, Michigan; and Chuck Richard, Project Manager, Michigan Department of Transportation (MDOT)

Metro's APC system was first implemented in 1980 when the Michigan Department of Transprtation (MDOT) and Metro contracted with General Motors Transportation Systems Center (GMTSC) for the purchase and demonstration of 20 APC units. The project, funded 100% by a state demonstration and development grant, was implemented in order to examine the applicability of APC techniques in the service monitoring programs of small transit properties in the state.

Although Metro is the only Michigan property to use APCs at the present time, the districts of Ann Arbor and Grand Rapids are now planning to conduct demonstration projects as a result of the perceived success of Metro's APCs. The recently developed RFP for Grand Rapids specifies a 6 month demonstration using 2 APC buses on one route. Ann Arbor is planning a similar approach.

Metro's APCs were completely installed in 1982. Subsequent to the initial installation, General Motors underwent an organizational restructuring and decided to drop the APC program. Two of GM's APC staff persons left GM and formed Urban Transportation Associates (UTA), a consulting firm in Cincinnati. UTA proceeded to service Metro's APCs.

Metro is a city Department of Transportation consisting of three divisions: Administration, Operations, and Maintenance. The report oriented APC system is primarily used and operated by Administration to serve planning functions. Initially, the APC data provided information on schedule adherence, route analyses, and productivity studies. They now include information for ridership reports as well. The information is used to: evaluate route performance; make schedule adjustments; improve system performance; evaluate alternative operating methods; and provide data for UMTA Section 15 reports.

In addition to these reports, APC data has served two critical functions at Metro:

(1) Prior to acquiring APCs, Metro did not use bus stops; patrons signaled for the bus. Metro used APCs to locate bus stops.

(2) In 1982, there was a $600,000 budget cut at Metro. The use of APC data facilitated route restructuring and service cutbacks which, according to those interviewed, were responsible for subsequent increased productivity.

These functions, along with elimination of ride checks, substantiate the cost effectiveness of APCs for this property. These benefits cannot long justify the monthly expense of UTA's services, however. For a fee of $2,700 per month, UTA provides: data processing; software design and development; software and hardware modifications needed to add report-generating capabilities; some hardware maintenance; and all final reports. Metro's goal is to become fully independent of UTA as soon as it purchases an IBM PC AT, and UTA modifies the software for use with this computer.

Overall, Metro and MDOT are enthusiastic about the success of the APC project, and the MDOT plans to repeat the APC experience at other properties in the state.

EVALUATION OF METRO'S APC SYSTEM

COUNTING SENSORS

Twenty buses, 37% of the fleet, are equipped with Honeywell dual beam infrared sensors. As is often the case with infrared beams (I-R beams), adjustments were required in positioning the sensors on-board the bus. In Metro's case, the lightheads were moved closer to the driver inside the fire extinquishing area by the glove compartment so that counting occurs on the top step. This move was necessitated by interference from hands holding on to the handrail and blocking counts.

Metro estimates that, as a result of these adjustments, accuracy improved from a previous 80-85% to the current 95-97%. Metro reports that, in some instances, accuracy is now 99%. Also, the number of people boarding or alighting at any one stop has never been a problem at Metro.

Metro is satisfied with the reliability of the sensors as well. Although maintenance of the sensors has not been a problem at Metro, repair work on the wheelchair lifts has indirectly created problems for the APCs. The wheelchair lifts have required considerable repair and, in the process of fixing them, APC wires and switches have been damaged. Due to minor hardware problems as well as normal daily preventative maintenance scheduling, about 10 of the 20 APCs are available on any given day.

ON-BOARD MICROPROCESSOR

The microprocessor, or portable data unit (PDU), is a Motorola 6800. Located on the partition above and behind the driver's seat, the PDU is attached via a cable to a power supply which is located on the floor behind the driver's seat.

The PDU contains an odometer, a clock, and logic algorithms to interpret counting sensor and signpost signals. A time stamp occurs whenever the bus passes a signpost and every 256 seconds. There are no records indicating that a bus has left a signpost field. Due to the lack of this function, Metro has saturated its routes with signposts in order to define location as precisely as possible.

The PDU provides data collection, validation, error detection and error correction. Data records include: passenger ons and offs, radio signpost identification, route location, coach door activities (wheelchair lift activity, front and rear door open, door close), time sequence, and accumulated odometer counts.

LOCATION REFERENCING METHOD

Metro uses 35 portable signposts made by Gould (now AVM) in Texas. The signposts are moved from one utility pole to another by simply climbing a ladder, removing the unit and banding it to another utility pole. The signpost codes in the units must be adjusted to represent the appropriate locations. These tasks each require about 5 minutes to complete.

The signposts are positioned at the end points of all runs and at beginning and end points for some routes. Additional signposts are placed on routes for which route segment-level data are desired. In this way, data are collected for the entire route structure.

The signposts use radio signal triangulation to transmit a coded signal with a field of approximately 300 feet to the receivers atop the bus. The signposts transmit a signal with very low frequency with the advantages that power demands are low and no FCC license is required.

Although Metro is satisfied with the equipment, a different type of maintenance procedure is desired. At present, when a signpost needs servicing, the installed unit is removed and one of the backups is put in its place. The down unit is then shipped to AVM for repairs. Metro would prefer that AVM send the diagrams and instructional repair manual to allow for in-house maintenance.

With the present hardware, only the signpost entry record is written; and there is no record to indicate when the bus left the field. No other signpost reading registers until the bus enters another field. The odometer sensors augment the signpost information to reference location. For present purposes, this method is deemed satisfactory, but Metro believes that the newer technique of recording signpost field entry and exit points and interpolating between the two points during data processing (see Seattle METRO) is probably a more precise method.

The signpost receivers, manufactured by Dorne and Margolin in Bohemia, New York, are about one inch thick and two feet long. They are encased in fiberglass and positioned horizontally atop the bus. The original units were of faulty design and allowed water infiltration. All of the original receivers were replaced and Metro has had no problems with the replacements.

DATA STORAGE

The PDU contains a Datell cassette recorder for data storage. With this system, cassette tapes could store a month's worth of data, but Metro retrieves the data more often to avoid delaying identification of equipment problems. Currently, the tapes are retrieved every two weeks.

There have been maintenance problems with the storage device. A local electronics firm worked on the units and some wrong connections were made. Also, the devices have a short life-span and after 3 years, some of the units are breaking down.

DATA TRANSFER

Data transfer is performed by dispatchers as part of their regularly scheduled duties. Once every two weeks, a dispatcher picks up an intialization device and blank tapes at the office and takes these to the APC buses. The data is first initialized by plugging the device into the PDU and punching a few numbers on the device. This attaches an updated time stamp to the data. The dispatcher then removes the initialized tape and replaces it with another prelabeled tape. The date, bus number and PDU ID# are written on the label. The process takes about 3 minutes per bus.

Metro is not satisfied with manual transfer of the data and would prefer automatic transfer. The property plans to phase out the initialization process and would like to convert to some form of automatic transfer in the future.

STATIONARY CPU AND SOFTWARE

Metro's APC data is currently processed on UTA's PRIME computer. The tapes are sent directly to UTA via Greyhound and the final reports are returned within one week. This "turn-around time" was specified by Metro in its RFP.

As noted earlier, Metro plans to purchase an IBM PC AT which will allow the property to process the data in-house as soon as the software is modified to function on the IBM.

REPORTS

Aside from the tapes, Metro supplies UTA with the following information in order to produce reports:

(1) a listing of daily vehicle assignments; and
(2) a checklist, completed when the data is retrieved, indicating any problems with the data or equipment.

Metro was originally supplied with monthly ridership, route analysis and schedule adherence reports, but, because this amounted to more data than current staff could handle, quarterly reports were requested for route analysis and schedule adherence. Ridership is still reported on a monthly basis. This approach is much more satisfactory. Mr. Schomisch commented that UTA's software is excellent and produces very sophisticated graphics with color available on request.

The reports are disaggregated to the system, route, and route segment level. Stop level data are available but this level of detail is neither necessary or desired at Metro.

APC IMPACTS ON CURRENT OPERATIONS

Prior to implementing APCs, Metro used hand counters with driver input; APCs are now used exclusively.

Hardware maintenance poses problems at Metro. Mr. Richard has, on occasion, worked on the hardware himself. He advised that the project requires a considerable amount of time and commitment; and that one person should be responsible at least half time for overseeing the APC equipment. He believes that many of the hardware problems could be avoided with adequate preventative maintenance.

APCs do not interfer with operations since the APC buses are simply rotated throughout the system all year long. This process provides a 33% sample which amounted to too much data generation. As a result, Metro reduced the number of APC coaches to 15 which was still considered excessive. Metro contends that 10 APC buses would be sufficient based on its data needs and the size of the property.

METRO ASSESSMENT AND SUGGESTIONS:

Metro would not change its counting sensors or signposts. As discussed earlier, the method of data storage and transfer could be improved. Otherwise, Metro is satisfied with its present system.

When asked what they would do differently if they were to purchase APCs today, those interviewed cited the following precautionary measures:

(1) Planning, Operations, and Maintenance need to work closely together in coordination of the project.

(2) Drivers should be made fully aware of the APCs and should not feel threatened by them in any way.

(3) A property should begin by using a prototype on one or two routes before implementing a full-scale project.

(4) A trained maintenance person should be retained on staff at least 1/2 time to monitor and service the APC hardware.

(5) The property should specify report formatting to suit the precise needs of the users of the data. These data needs vary from property to property.

APC ACQUISITION AND FUNDING SOURCE

Kalamazoo used an RFP process to purchase the hardware and for software support and report generation. The project was 100% funded by the state of Michigan through a Public Transit Demonstration Project.

COSTS OF THE APC SYSTEM

CAPITAL COSTS

Counting Sensors:	\$ 667 per bus
Microprocessor:	\$ 2890 per bus
Transfer Device:	\$ 2000 per initialization unit
Signposts:	\$ 300 per unit
Installation (bus and post):	\$ 2490
Signpost Receiver:	unknown
Software Development:	see below
Two year demonstration Project:	\$29680 for maintenance, spare parts, assistance \$17460 for data processing, report production \$ 8150 for training

OPERATING COSTS

*Urban Transportation Associates:	$ 2700 per month
Maintenance:	.5 FTE (recommended)

*Costs for UTA: to process data; modify hardware and provide some hardware maintenance; to modify programs for IBM compatibility; and to produce reports.

3.4 London Transit Commission

Interview With Gordon Arblaster, General Manager, and Darcy Clark, Director of Planning and Marketing, London Transit Commission, London, Ontario

In 1981, representatives of London Mat Industries approached London Transit with an offer to install counting algorithms in one of their "treadle step" equipped buses as part of a free six month demonstration. Forty of London Transit's 160 buses are equipped with automatic door opening devices called "treadle steps" which are activated when someone steps on the bottom step. As a safety measure, the bus must be at a complete stop and the driver must release a switch at the front of the bus in order for the device to work. Treadle steps at rear doors are optional equipment on General Motors buses. Front door treadles must be retrofit. London Mat Industries manufactures these devices.

Following the demonstration period, London Transit purchased additional mats and installed these on 18 buses. From the initial test installation to the present time, London Transit's APC system has consisted solely of treadle mats and digital display panels on the dashboards. No computers, signposts, or other data input or storage devices have ever been used at London Transit. When a survey is conducted on specific routes, the driver manually records counts from the display onto data sheets. This process requires manual manipulation and analysis of the data.

London Transit's approach to automated data collection is an incremental one. The property plans to try out system components "piece-by-piece" and to slowly integrate the system into transit operations and planning. For example, ride checks are still performed and bus drivers continue to play a role in data collection.

In terms of project implementation, there is some problem with coordination of the APC project. It was advised that a property encourage a high level of cooperation between planning and operations regarding the APCs. In addition, efforts should be made to allay the fears of drivers that their jobs are not threatened by this new technology.

During the past two years, the use of ride checks has increased from their use during the previous two years. This increase is due primarily to the rapidly declining accuracy level of the APCs. Initially, the property sought a 90% confidence level with plus or minus 10% tolerance. APC accuracy was, in some instances, 98% during the first two years. London Transit estimates that over the past two years, the APCs have deteriorated to about 20% accuracy. Harsh weather conditions over the past two winters are cited as the cause of the problem with the mats. Evidently, the electronic components in the mats are adversely effected by the calcium and salt products used to treat the snow, ice and slush. Also, melting snow infiltrates the mats and creates bad counts. London Mat Industries, located near London Transit, is working on the mats free of charge in an attempt to improve their design and marketability. Also, London Transit has installed heaters in the stairwells of 6 of the APC buses in an attempt to lessen the impact of the melted snow and ice on the mats.

A second, but less consequential, source of error is overcounting at high use stops. Although a large number of patrons boarding and alighting at one stop affects the accuracy of the counts, London Transit does not believe this error is sufficiently large to impact decisions that are based on the APC data.

Sizing the mats to fit different types of buses is another problem encountered at London Transit. London Transit intends to purchase only buses with a treadle rear door in the future in order to allow for expansion of APC use. At present, the property is waiting for London Mat to perfect the design of the mats so that they function in the harsh climate. Once the technology has improved, London Transit expects to expand its use of APCs. A critical first step in that process is for the property to identify what it expects from an automated data collection system and to decide what resources it is willing and able to commit to the project.

London Transit will continue to work with London Mat since this is a local company and very accessible for on-going maintenance of the counters. The mats were initially purchased from London Mat for this reason as well as because of the very low price. The complete cost including installation, wiring, and digital display was $400 per bus.

London Transit is 75% funded by farebox revenues. In 1984, there were 85 trips per capita and 20 million total passengers. The APC project was 75% funded by the province of Ontario and 25% by London Transit.

3.5 Transit Windsor

Interview with David Bjorkman, Transportation Scheduler, Transit Windsor, Ontario, Canada

Transit Windsor's APC experience began in 1981 when General Motors Corporation moved an APC system from Cincinnati, Ohio, to Windsor. The Cincinnati APC project, begun at Queen City Metro in 1977, was an experimental program sponsored by General Motors. The original project began at Queen City Metro in Cincinnati in 1977. Subsequent to moving the APC project to Windsor, General Motors decided to discontinue its APC operations. At that time, the APC system was fully installed at Transit Windsor.

The Queen City APC application was referred to as a "TIS" (Transit Information System) and was used for both real-time monitoring and off-line report generation. At Transit Windsor, data transfer is performed in real-time (buses are polled every 30 seconds via the radio and the stationary computer), but the Windsor system is used strictly for off-line report generation.

APCs are installed on 27 buses, one on an Orion and 26 on GM coaches. One full-time employee manages the APC project. The information is used to: create, evaluate, and adjust schedules and run times; plan and justify route changes; and monitor driver performance. Uses of the data are limited by a lack of software rather than hardware capability.

Transit Windsor is satisfied that its APC system functions according to original specifications. The property would definitely repeat its APC experience, taking advantage of technological innovations occuring in the past several years and making changes based on insights gained from the present system. Although APCs have not been cost-effective for the property in the past due to limitations imposed on the system by resource constraints, the system operator believes that a fully operational up-to-date APC system would be very cost-effective.

EVALUATION OF TRANSIT WINDSOR'S APC SYSTEM

COUNTING SENSORS

Transit Windsor uses PRODATA dual beam infrared sensors to count passengers boarding and alighting the bus. The lightheads require very minimal maintenance, but they must be kept free of dust. Transit Windsor has had to replace about two lightheads per year. The sensors will signal a count only when the object interrupting the infrared stream is greater than five inches wide. In this way, swinging arms and handbags are less likely to be counted as passengers.

Although some APC error is believed to be introduced at high use stops, the impacts of these errors on the summary data are considered inconsequential due to the fact that data are disaggregated to the route segment rather than the stop level. At the route segment level, errors are generalized and are thus less significant.

ON-BOARD MICROPROCESSOR

The microprocessing unit is a Motorola 6800 model. Transit Windsor is very pleased with the accuracy of the counts accumulated in the microprocessor. When compared with manual counts, the APC data are 98-99% accurate.

The microprocessor flags the data to indicate when counts were taken with the bus doors closed. These flags are later identified during data validation procedures. About 20% of the APC sampled trips must be discarded due to bad or inconsistent data. The system operator manually deletes trips with bad data. Data validation comprises a major portion of the system operator's responsibility. With conscientious data validation efforts, a high level of accuracy is achieved.

The microprocessing unit processes: counts from the infrared beams, odometer readings transmitted through special wiring linked to the bus transmission, and location reference communicated from an LSU or logic support unit. The LSU is a separate piece of hardware made by Motorola containing a location board which renders signpost information and bus ID# to the stationary computer. The location board contains a solid state short-term memory. The microprocessor and the LSU are very reliable and require minimal maintenance.

LOCATION REFERENCING METHOD

Windsor Transit uses a total of 43 signposts, made by Motorola, to reference location of passenger activity. Forty-one of these are fixed (permanent) and two are portable signposts. The portable are battery powered and the batteries have a very short life. These are used in special studies only. The fixed signposts are A.C. powered.

Both types are broad signposts transmitting coded radio signals periodically received by buses. The frequency is high and a license was required for their use. One of the major problems identified with the signposts has been that the radius of the signpost signal is too wide. In some cases, the signal is picked up by buses as far as 1500 feet away. As a consequence, location reference is sometimes vague and it is difficult to determine from the signpost code where the buses are located. To remedy this problem, the property has prepared an RFP to solicit a firm to solve the location problem either through hardware or software modifications.

Another signpost-related problem is the infiltration of moisture through the enclosure and the antennae (located inside the enclosure of the signpost transmitter).

DATA STORAGE

Since data are transferred to the stationary computer every thirty seconds, the short-term solid state memory in the LSU is sufficient to store the data on-board the bus.

DATA TRANSFER

Transit Windsor uses radio data transfer via a special radio channel. An interactive program in the stationary computer polls the APC buses every 30 seconds. Beginning with bus #1, all data accumulated within the last 30 seconds are transferred from the bus to magnetic tape in the stationary computer. This process occurs for 22 consecutive hours each weekday. On weekends, data are transfered on demand only.

Although the property is satisfied with this method in general, several problems have been experienced with it. For example, the voice function of the radio takes priority over data acquisition, particularly during peak service times. This is especially consequential since peak service data provides essential information for planning and scheduling.

A second problem with the data transfer process was caused by excessive draining of the battery on weekends by the data retrieval process. On Monday mornings, bus batteries were sometimes found to be too weak to run at full capacity. To solve this problem, a new schedule for data retrieval was devised which excludes weekend polling except upon special request.

STATIONARY CPU AND SOFTWARE

The computer used to process the APC data is a MODCOMP II minicomputer. This is a dedicated unit purchased with the APC system from General Motors. The unit is compatible with hard disk and magnetic tape. Data are automatically transferred from the buses onto the magnetic tape. The system operator later transfers the data onto disk. One of the problems with this computer is that it has only 2.5 megabytes of storage capacity. Once this limit is reached, new data are written over old data. As a result, data cannot be retained on disk for future analysis and ad hoc reporting. The data are stored on the magnetic tapes for 1.5 years, but transfer to the disk is necessary before data can be manipulated. This process requires considerable human effort.

General Motors developed the APC software. Since no programmer documentation was supplied, the APC programs cannot be updated or changed. Several programs must be run to take the raw APC data through all the stages necessary to produce reports. It takes a total of about eight hours to produce a report from raw APC data on one ten day sample. The functions performed by the software include: validating expected behavior on each instrumented vehicle; appending route numbers to the data; and appending vehicle assignment information to the data. From magnetic tape, a diagnostic report is accessed which displays passenger counts referenced by signpost codes. Schedule files must be updated manually five times per year during the five sign-up periods; these updates are processed with the APC data.

REPORTS

Transit Windsor's APC system produces the following reports:

(1) Passenger Loading Profiles: average passenger loads; maximum passenger loads; and number of standees.

(2) Time Performance: running times; percent on time (early/late); average speed between route segments; and schedule adherence.

(3) System Performance Indicators: passenger/kilometers; passengers per hour; and boardings per kilometer.

This information is disaggregated to the route segment level only. Data are distributed for the following time periods: totals for weekday, Saturday and Sunday; and time periods (a.m., p.m., mid, eve). Reports are presented in tabular format on-demand.

APC IMPACTS ON CURRENT OPERATIONS

Acceptance of APCs came slowly at this property so that manual data collection methods continue to be used in conjunction with the APC system. As APCs receive increasing support by the Transportation Department at Transit Windsor, limitation of manual methods is anticipated. These manual methods consist of driver counts and surveys conducted by students.

Manual data collection is used to augment and validate APC data. All routes are sampled by APCs in a rotating fashion within a three month period. The process is then repeated. Periodically, this schedule is interrupted and APCs are used to collect data on routes which are the subject of particular interest or controversy. The APC data are compared to data from driver counts and established statistics produced by the Finance Department.

For operations, APCs were initially perceived as a threat to drivers that their performance was being monitored. The system operator allayed these fears by emphasizing the positive benefits of APCs for operations and downplaying the monitoring capability of the system. For example, the two-way voice radio, purchased with the APC system, was cited as a benefit to drivers by opening lines of communication between the buses on the street and the central office.

A second issue with operations pertained to the assignment of APC buses. Non-APC servicing problems took priority over servicing of APC buses. The low priority of APCs relative to other operational considerations became evident. Again, the benefits of the APC system were emphasized. For example, attention was drawn to the fact the the two-way radio facilitates on-the-road servicing of disabled vehicles.

Finally, both operations and maintenance were affected by the bus battery drain caused by weekend polling of buses by the stationary computer to retrieve APC data. To remedy the problem, a new schedule for data retrieval was devised which excludes weekend polling unless absolutely required.

TRANSIT WINDSOR ASSESSMENT AND SUGGESTIONS

The conflicts arising over APCs at this property have subsided through cooperative efforts between the APC system operator and the various departments. Also, increased confidence in the APC data facilitated cooperation between the APC system operator and the planners. It should be noted that many of the problems experienced by this property could have been minimized if those involved were better informed from the outset. Lack of access to information on potential impacts can be attributed to the fact that APCs were a very new concept at the time this property adopted the technology.

Future plans for APCs at Transit Windsor include:

(1) increasing the disk capacity of the minicomputer. If the memory space capacity of the existing unit cannot be sufficiently enhanced, the property may consider purchasing a new computer for use with APCs.

(2) obtaining programmer documentation for the existing software so that it can be updated. An RFP is now being developed for this purpose.

(3) remedying the problem with the signpost field (see Location Referencing). Hardware and software solutions are being sought through an RFP process.

APC ACQUISITION AND FUNDING SOURCE

The APC project was funded 75% by the Ministry of Transportation and Communication of the Province of Ontario and 25% by Transit Windsor.

COSTS OF THE APC SYSTEM

A breakdown of system costs was not avialable. Total cost for the system was approximately $680,000 in 1980.

3.6 Calgary Transit

Interview with Abe Anwar, Scheduler, and Kieth West, Transportation Planner, Calgary Transit, Alberta

Calgary Transit began an investigation of APCs in 1980. From 1980 to 1981, a market search was conducted to identify and evaluate APC systems available in North America and Europe. During this time, an RFP was developed to select a system for a demonstration project.

The demonstration project, conducted by Group Five Consultants, commenced in April, 1982. The project was designed to obtain operating experience with the system by fully-equipping five buses and testing them for six months. After one six month extension, the demonstration was completed in May, 1983. Currently, Calgary Transit's APC system consists of the five original APC buses. An evaluation of the APC system conducted by the City of Calgary found the APCs acceptable for accuracy (less than 10% error ons/offs), but found reliability of the equipment unacceptable, requiring further testing. The property is conducting a market research study to obtain updated information on technological options available. Current plans are to expand the present system with twenty additional APC units.

Calagary Transit's APC system is report-oriented for use in planning and scheduling activities. In general, the APC data are used to:

* create, evaluate and adjust schedules and run times;
* plan and justify route changes;
* evaluate marketing strategies;
* estimate expected revenue;
* monitor driver performance;
* determine the location of bus stop facilities.

Use of APC data for these purposes has been limited by the small number of buses equipped with APCs. Three full-time checkers are retained on staff and these are Calagary Transit's primary data source. These checkers also perform APC data transfer which takes about two-to-three hours per day for one person.

The property is very much in favor of APC systems and would definitely repeat its APC experience. Calgary Transit's goal is to eventually acquire a systemwide passenger counting program, possibly capable of transferring data by radio signal to a central location.

EVALUATION OF CALGARY TRANSIT'S APC SYSTEM

COUNTING SENSORS

Red Pine infrared light heads are used to detect passenger activity. Two pairs of light heads were installed in the front door stairwell (to count both "ons" and "offs") and one pair in the rear door stairwell (to count "offs"). A set of light heads includes one transmitter and one detector.

The light heads are designed to operate when the bus doors are open. When the front door is open, the light heads are operating; when the front door is closed, the data are not transmitted to the data collection unit (DCU), containing the microprocessor. The rear door lightheads become operational when the rear door switch is operated. In this way, passengers standing in stairwells on overcrowded buses are not counted as boardings or alightings.

The initial design of the front doors was to connect the lightheads to a microswitch which operated the front stairwell dome light which supposedly became operational when the front doors were open. After it was discovered that the dome light comes on only if the bus headlights are operating, a modified microswitch was installed at the front doors.

Conditions which introduce error into the data include: small children held by an adult when boarding (not counted) and walking off the bus (counted); shopping bag or large parcel counted as a passenger; very quick movements; patrons passing each other on the stairwell; swinging arms; and standing in the stairwell when the doors are open. Of these, small children introduce the largest portion of the overall error.

Based on the evaluation of the system conducted by Calgary Transit, these errors are insufficient to have a significant impact on overall accuracy. The results of the test comparing APC with manual counts at this property concluded that the hardware achieves an acceptable level of accuracy.

Unit reliability was not considered acceptable, however, and considerable down time of the system was related to hardware problems such as: lighthead bracket adjustment; faulty lighthead; and reverse wiring. For this reason, a second market search will be conducted prior to purchasing additional hardware.

ON-BOARD MICROPROCESSOR

The Red Pine "data collection unit" (DCU) contains a Motorola 6809 microprocessor. The DCU is mounted to the modesty panel behind and above the driver's seat. The unit was positioned to the far left edge of the modesty panel to allow access for maintenance. The DCU is powered by the 12 volt bus battery. According to original design, whenever the bus was idle for 24 or more hours, the unit entered a low level state, consuming less power, and restored itself to full operation when the bus resumed movement. Restoring the unit to full operational capacity after it entered the low level state was not consistently possible. As a result, the DCU's were modified to eliminate the low level mode of operation. The property advises that the units be manually "powered down" if inoperable for more than fourteen days. The DCU contains spare batteries, but some of these were faulty. As a result, the batteries are checked constantly after two months of use.

The DCU receives signals from the counting sensors, the bus odometer, and from its own internal clock. Time is recorded as relative time (time since the DCU was last initialized) rather than absolute time (based on a 24 hour clock). When the data are transferred to diskette, the portable disk unit (which contains a more conventional 'clock') appends to the file the time of the transfer in days, hours, minutes, and seconds. The time of each event is then calculated during data processing routines. (see Data Transfer).

In addition to the above signals, the DCU will receive signpost codes and the software will process these, but the property does not now use signposts to reference location of data input.

LOCATION REFERENCING METHOD

The location of passenger activity is calculated manually from daily reports displaying time and distance stamped passenger counts at individual stops. Although summary statistical reports are not produced automatically by the present APC system, daily schedule sheets produced from the APC data are used for planning and scheduling evaluations.

DATA STORAGE

The DCU is capable of storing 8K bytes of read-write memory. The following events cause a record to be written to memory:

* Passenger activity and bus leaving the stop
* Time recorded minimum of every 60 minutes and at all passenger activity stops
* Distance recorded minimum of every 3.9 km and at all passenger activity stops
* No passengers or movement for one minute
* Bus leaves inactive stop after two minutes idle

When one or more of these events occur, the following information is stored in a 4 byte log:

* Time (in quarter minutes)
* Distance (in units of 50')
* Cumulative ons and offs
* Reason for the log

In addition to these records, every time on-bus data are transferred to diskette, they are preceded by a header record which contains: a 4 digit bus number (entered at the keyboard at the time of transfer), the last location in memory used on the bus, the time this data transfer started, and the elapsed time since the previous data transfer completed.

DATA TRANSFER

Data transfer is performed manually by maintenance personnel and checkers using portable disk units (PDU). Data are retrieved once a day. The maintenance personnel retrieve the data from the buses; the checkers transfer the data to the stationary computer.

The PDU is a small microprocessor-based computer with a telephone-like 12 character keyboard, a 4 digit display, and a floppy disk drive. It receives data from the buses through a quick-connect cable, initializes the DCU after data have been transferred, and transmits data to the stationary computer. The microprocessor in this unit is the Motorola 6809, the same as in the DCU.

The PDU draws its power from the DCU on the bus. In the office, when data are transferred to the stationary computer, the PDU is powered by a separate power supply provided as part of the system. For this transmission function, a key-driven ASCII terminal is attached and acts as the console.

In the office, the PDU incorporates a number of commands which allow, for example, a directory to be printed of the bus data on disk, the disk to be initialized for reuse, the raw data to be printed directly on the ASCII terminal, etc. In the field, the PDU can be continually connected to the DCU so that the contents of the various registers in the DCU can be displayed at will (passengers on and off by door, distance travelled, etc.).

Hardware problems with the PDU include: faulty battery charger connections, faulty cable connection, and faulty floppy disk.

STATIONARY CPU AND SOFTWARE

APC data are processed on the City of Calgary's IBM 380 mainframe computer. A modem is used to access the city computer from the transit office. The transfer of APC data via the modem is a slow process, sometimes taking an hour to dump one day's data from five APC buses.

The software, supplied by Group Five Consultants, consists of Group Five SUNDAY catalogue procedure and the TRANSMIT program. The purpose of the software is to produce a simple listing of the data produced on a daily basis.

During the first six months of the Demonstration Project, data collection and functioning of the software was monitored by the city and by Group Five Consulting, which used a data route connection from Ottawa. Calgary's Data Processing Services Department (DPSD) assisted in installing the software on Calgary Transit's Spring Gardens Complex computer in 1983. DPSD also assisted in tailoring the Group Five software to Calgary's computer system.

The software incorporates an algorithm which ensures that output indicates that the bus returns to the garage empty and that at no time do more passengers alight than were on the bus as a stop was approached.

REPORTS

As stated earlier, no summary statistics are reported with the APC system at Calgary. A daily report is produced which displays the time, distance travelled, passenger ons/offs, and cumulative time, distance and count data. Passenger load is also displayed (passenger ons - passenger offs). The data are corrected for on-off dispcrepancies and other inconsistencies. These corrected data are displayed in the daily reports.

APC IMPACTS ON CURRENT OPERATIONS

The phased approach to APC implementation at Calgary Transit has helped to minimize the initial impacts often accompanying a transition to automated data collection methods. The project has been divided into four phases:

Phase I - Market Search
Phase II - Systems Analysis
Phase III - Demonstration Project
Phase IV - System-wide Implementation

Prior to each acquisition of APC hardware and software, the property conducts a market search to identify system improvements resulting from technological advances. By this means, the staff is made aware of new APC capabilities and potential system improvements. Also, the maintenance and training requirements associated with APC use are identified during each phase without incurring the costs of a full system. This approach is particularly beneficial from a project management perspective. By phasing in APCs, this new technology is integrated slowly throughout the different divisions allowing time for adjustment.

CALGARY TRANSIT ASSESSMENT AND SUGGESTIONS

The City of Calgary Transportation Department issued an evaluation report on its APC project in June, 1983. Much of the information contained in this summary is taken directly from that evaluation. After a thorough examination of the hardware, software, and system accuracy and reliability, this report concluded that Calgary's APC system produces an acceptable level of accuracy; but that the reliability of the hardware was not acceptable. The recommendation was to purchase 20 additional APC units following a market search to address the reliability issue.

Calgary Transit believes that APCs produce quite valuable data. They recommend that technological improvements be studied so that hardware and software problems may be minimized and good reports can be produced for future planning and studies.

APC ACQUISITION AND FUNDING SOURCE

The demonstration project supplier was selected via an RFP process. Funding for phases I through III was shared between the City of Calgary and the Province of Alberta.

COSTS OF THE APC SYSTEM

Summary of Demonstration Project Expenses* (one year duration)

CAPITAL COSTS

Counting Sensors:	$ 750 per bus
Microprocessor:	$ 3,000 per bus
Installation (DCU and Sensors):	$ 800 per bus
Portable Disk Unit:	$ 6,000 per unit
Signposts:	NOT APPLICABLE
Installation (bus and post)	NOT APPLICABLE
Signpost receiver:	NOT APPLICABLE
Software Development:	$ 3,000

OPERATING COSTS

Repair/Adjustment:	$ 4,383
Planning Staff:	$13,280

OTHER COSTS

Calibration:	$ 1,600
Software Documentation:	$ 3,000
Travel Expenses (Consultant):	$ 788
Data Processing Costs:	$ 3,200
Dataroute to Ottawa:	$ 4,628

*Does not include Phases I, II, or IV

3.7 Portland TRIMET

Interview with Doug Allen and Karen Eckert-Barcus, Scheduling Technician/Analyst, TRIMET, Portland, Oregon

TRIMET began implementation of its APC system in 1982 when Red Pine Instruments equipped 40 buses with APCs. TRIMET uses an information APC system which is report-oriented for planning and scheduling. Once the system becomes fully operational, the APC data will be used to create, evaluate and adjust schedules and run times; to plan and justify route changes; and to report on ridership. Once some of the articulated buses are equipped with APCs, the data will also be used for Section 15 reporting.

Due to the lack of software necessary to produce reports, there is very limited use of boardings and peak load information. Three factors have delayed the development of the software needed to process the APC data: (1) design problems with the counting sensors; (2) lack of on-site support services from the supplier to resolve hardware problems; and (3) limited staffing of the APC program.

The passenger sensors, consisting of infrared multiple beams, were a new design and suffered from design defects allowing water damage and other conditions which produce unreliable counts. The responsibility for both software development and hardware maintenance of the APCs at TRIMET rests almost completely with the two Schedule Department employees interviewed. Due to the continuous demands of the hardware, they spend a great deal of their time tracking down APC buses and fixing or monitoring APC equipment instead of developing the software. They devote almost all of their time to the APC project and they suggested that a third person is needed temporarily until additional software has been implemented and hardware problems are fully resolved. The contract with the supplier includes a consulting budget, and this budget is not expended when the manufacturer does not come on site. The considerable cost savings to TRIMET of maintaining the system in-house is offset by the slower progress made in the APC program. Of the 43 buses now equipped with APCs, 36 are operational at any given time.

EVALUATION OF TRIMET'S APC SYSTEM

COUNTING SENSORS

TRIMET uses infrared multiple beam sensors located about 40 inches above the bottom step just inside the front and rear doors. Proper alignment of the lighthead pairs is critical in order for the counting function to work. TRIMET has not done sufficient testing to determine if the sensors are in the most optimal location.

TRIMET is not very satisfied with the sensors: the original design allowed water damage; the beam distribution does not produce the most reliable counts; wiring terminals or some other connectors are needed to ease replacement; and placement of the lightheads can create problems such as requiring the removal of stanchions where they interfere with the sensors and cause poor counts.

Heavy dust accumulation on the lightheads has interrupted the counts. The sensors must be kept free of dust and other obstructions in order to function.

TRIMET uses APCs on its lift equipped buses, but it does not monitor lift usage with the counters.

ON-BOARD MICROPROCESSOR

The microprocessor on-board the bus is located on the floor behind the driver's seat. This unit was also manufactured by Red Pine Instruments. Counts are recorded only when the bus doors are open. The following events are recorded:

* begin idle (no bus motion for more than 1.5 minutes)
* end idle
* time and distance if bus goes 1.2 miles without stopping
* bus passing a data retrieval unit
* time and distance if bus sits for one hour without moving
* bus stop with passenger activity

The following data are stored by the CPU:

* passenger boardings and alightings
* vehicle departure times from stops
* time between stops (relative time and not actual time is stored; the data are time stamped when retrieved; the processing routines convert the relative time, eg -1.7 or -3 hrs., into actual time)
* distance between stops

For each event, distance traveled since the last event and the type of event are recorded.

Although there are high use stops, distribution of ridership is does not appear to be the major factor in the accuracy of APC data at TRIMET. According to TRIMET, APC error more likely stems from the behavior of each individual passenger than from large numbers of people boarding or alighting at one stop.

About 20% of the counts are lost. The reasons for data loss are, in order of importance:

1. Vehicle does not complete its run as scheduled (does not meet tolerance for time and mileage);
2. Improper or unknown assignment imformation (eg. two different buses both claim to be on the same run);
3. Counter error;
4. Mileage file error.

The CPU does not identify failures in the sensors. The software compensates for differences of less than 15% between total daily boardings and alightings. Data with over 15% differences are discarded. Memory space overflow is handled by processing routines.

Aside from occasional vandalism, the only problem encountered with the microprocessor has been the loss of data when the battery is disconnected during bus maintenance and repair.

LOCATION REFERENCING METHOD

At TRIMET, location is referenced by means of a computer generated comparison of APC odometer reading with trip distance files. In addition, a computer program searches APC records for bus layover intervals and compares them with computer stored trip files. This method seems to work well in separating individual trips. The software needed to produce stop level data and time points has not been developed; so, it is not yet known whether or not this method will be successful in achieving those results.

There are three reasons why APC data will not match the schedule data input by the RUCUS file:

* wrong driver input (when drivers radio in train #)
* buses traded during the day
* inaccurate mileage files

The advantages of this method are that no signposts or signpost location files, and no software processing of signpost data are required. The disadvantages are that: distance files require a great deal of manual maintenance to keep them up to date; and reroutes for construction and bus trades require special manual input (otherwise, the count data are rejected).

DATA STORAGE

A solid state memory unit allows automatic transfer of the data. This unit has a 12K byte capacity (about three full days of counts).

DATA TRANSFER

TRIMET uses automated retrieval systems at 3 garages. As part of the normal, daily routine, whenever an APC bus returns to the garage and stops for a parking lane assignment, an infrared sensor/transmitter "beams across" all available count data with no human involvement. The transfer of one full day of counts takes two seconds. The only maintenance of the retrieval unit is repair when a unit has been struck by a bus. Problems with this method of data transfer are: occasional hardware failure and lack of access to the retrieval unit due to construction detours, other vehicles, etc.

STATIONARY CPU AND SOFTWARE

Raw data are transferred from the retrieval units via modems to a minicomputer with disk drive. Each work day, more or less, counts are sent to an IBM mainframe, with hundreds of users and hundreds of terminals, for further processing. This hardware was already available to TRIMET for other uses and it is not a dedicated unit.

The software performs validation checks against expected behavior on each instrumented vehicle; appends route numbers to the data; and appends vehicle assignments. Current schedule files (including mileage) from the RUCUS system must be created and entered on a regular basis. However, this is a virtually automatic process (schedules are not entered separately for the APC system).

Software complexity is not a problem for users of the system who have computer skills and are familiar with the APC system. The programs are written in FORTRAN and COBOL and can be run with simple instructions. Considerable familiarity with APCs is necessary for modifying the programs, however, and there is a trade-off between complexity and lack of flexibility. Although the software developed so far at TRIMET is not very complex, it has limited capability. For example, useful reports for transit functions are limited to trip by trip summaries such as total boardings or maximum load. Trip segments or individual stops are not currently reported.

TRIMET is developing the software in-house. The analysts view this as advantageous since in-house software development allows interfacing with the existing RUCUS system and the ability to become experienced with the hardware at the same time as the software is being developed. 1.5 person years have been spent on software development so far at TRIMET.

REPORTS

At present, TRIMET's APC system produces one type of report which includes data on average boarding rides, average deboardings, and maximum load on each scheduled trip. System total, route level, and totals for weekdays, Sat. and Sun. are also available. This report is produced five times a year at the end of each sign-up period.

Once the system is fully operational, TRIMET planners hope to have access to the following reports produced from the APC data:

* maximum passenger loads
* route profiles
* boardings per trip
* boardings per hour
* peak load point
* total boardings per route for entire system
* running time between time points

.....and the following levels of detail:

* system total
* route level
* route segment
* individual bus stop
* bus trip
* sign up
* totals for weekdays, Sat and Sun

.....and presented in tabular format periodically.

Most reports are produced periodically by scheduling staff. Basic data files are available for further manipulation by users with computer skills. Only manual integration of APC data with other information (ie: census data) is now possible; and, at present, APC data cannot be accessed for ad hoc reports.

APC IMPACTS ON CURRENT OPERATIONS

Trips are uniformly sampled during each of the five annual signup periods. Each day, a random sample of trips is drawn from a pool of trips which have been sampled the least so far, taking into account allowable fleet type.

For the scheduling division, the main impact of APCs is in terms of extra personnel to operate the system. TRIMET estimates the following costs in time to obtain schedule information once the software is in place and the system is fully operating:

2 hrs/day processing + 1 hr/day maintaining data file + 1 hr/day running programs + 2 hours week preparation for next week's assignment + miscellaneous tasks = 1 full-time person to obtain scheduling information.

Aside from scheduling, other divisions affected by the APC system are operations and maintenance. The APC equipped buses must travel on specified routes, involving operations. Also, the APC equipped buses get priority for repair when broken down for non-counter reasons, involving maintenance.

To date, APCs have not been cost effective for TRIMET, but the property has high hopes for the future. Four to five full-time positions occupied by traffic checkers have been eliminated. Thus, there has been some cost saving to date. However, the savings from reallocating underutilized service cannot yet be attributed to the counters. Planners and schedule writers do review the summary counts, and the system is thus beginning to be utilized.

TRIMET would do it again. In the near future, they plan: (1) to switch to a better door sensor design (a few other components are being retrofitted under warranty to cure minor design defects); (2) to equip 10 more buses; (3) to enhance software to extract running time information; and (4) to refine location referencing technique and software to obtain route segment data.

APC ACQUISITION AND FUNDING SOURCE

TRIMET used an RFP process and Red Pine was the only company to submit a proposal. Red Pine supplied the complete system with some options and carried a 1 year warranty as in specifications. TRIMET's APC system was funded by an UMTA grant.

COSTS OF THE APC SYSTEM

CAPITAL COSTS

Counting Sensors:	\$ 622 per bus
Microprocessor:	\$2158 per bus
Installation:	\$ 288 per bus
Transfer device:	\$5000 per unit
Stationary CPU:	\$7000 for extra disc drive in minicomputer \$ 300 per modem (2 extra purchased for APCs)
Miscellaneous:	\$ 258 per bus (wiring, brackets, etc.)
Software Development:	2.5 person years (1.5 spent so far)

OPERATING COSTS

Hardware Maintenance:	0.5 FTE
System operation/software maintenance:	1.0 FTE

3.8 Central Ohio Transit Authority (COTA)

Interview with Sue Litzinger, Project Manager, COTA, Columbus, Ohio

COTA's APC system was first implemented in 1982 when Urban Transportation Associates (UTA) was awarded a contract to conduct a demonstration project. Under the original contract, COTA leased 6 dual beam counter units and 8 portable signposts from UTA. UTA collected data on all routes and bus runs and provided COTA with detailed reports for route planning activities.

During this demonstration period, signposts were not used except to collect location data for special studies. These experiences proved less than successful due to the unreliability of the portable signposts. The most useful type of report provided to COTA during this time was a time period report. For a particular route or a particular run, the data showed the number of boardings for different time periods. This report was produced every trimester (once every 4 months). Daily totals and interim reports were also supplied.

COTA is now in the process of installing a new system, recently purchased from UTA. The system consists of 20 APC buses (one will be kept as a spare and used for diagnostics) and 50 signposts. The new system will have greater capacity for data collection and report generation. In the past, UTA managed and operated the entire system, ie. data retrieval, data processing, report generation, etc. With the new system, COTA will be responsible for everything except creation of the data files. UTA will continue to process the raw APC data and produce the data files for COTA at a cost of $2031 per month.

In the past, the APC data were used to plan and justify route changes and for UMTA Section 15 reporting. In addition to these functions, the data will now be used for scheduling, to adjust run times, to evaluate marketing strategies, and to determine fleet needs. The data will <u>not</u> be used to monitor driver performance; and there are no plans to interface APCs with the automatic farebox collection system.

COTA is enthusiastic about the APC system as is evident from its recent acquisition of APCs. In spite of the on-going costs for UTA to create and manage the data base, COTA believes APCs are cost effective. That is, the benefits derived from the additional information supplied by the APCs justify the expenditures. At present, there are no plans to become fully independent of UTA and it is possible that UTA will always process COTA's raw APC data.

EVALUATION OF COTA'S APC SYSTEM

COUNTING SENSORS

The original sensors were Prodata dual beam lightheads (I-R beams). The recently purchased sensors are Honeywell infrared beams. The sensors are located at the top of the front and rear door stairwells. Positioning and alignment of the sensors was not a problem because these adjustments had been made during the leasing program.

Fifteen of the APCs were installed on the long (40 foot) buses and five were installed on the short (35 foot) buses. There have been some problems getting the APCs to function properly on the short buses. UTA and COTA's Maintenance Department have identified and solved these problems.

COTA is very satisfied with the accuracy and reliability of the sensors. COTA is now in the process of testing to get some estimated figures on accuracy at low and high use stops. The results to date are very satisfactory.

The only problems associated with the I-R beams are that the reflectors get scratched and the lightheads needed replacement after 4 years. Given the nature of the environment in which they operate and the type of equipment, COTA believes these conditions are to be expected, however.

ON-BOARD MICROPROCESSOR

The microprocessor, inside the PDU or portable data unit, is located under the driver's seat. This unit contains an odometer, a clock, and a modem which translates the signpost signal from the receiver to a cassette tape.

Data input is activated by door switches which signal when doors close. All data accumulated from the last data input are written to record when the front or rear doors close. It was recently discovered that counts accumulate in the PDU when the doors are closed and the bus is moving. Thus, if someone is standing or moving in the stairwell between stops, counting takes place. The next time the doors close this activity is written to record.

Data is written to tape whenever a bus enters and leaves a signpost field and when 256 seconds elapse since the last record was written. Each time a record is written (data input), data are time and odometer stamped. The time stamp is based on a 24 hour clock. By this means, time and distance between stops are calculated.

"On-off discrepancies" are common and, in most cases, more alightings than boardings are recorded. This discrepency is reduced by lighthead adjustment and is not a major concern. In the past, COTA has used only the "on" counts because the data were used to determine the number of passengers boarding the bus by time of day. Data with on-off discrepancies exceeding 10% have been discarded during processing routines. Now that COTA plans to use the data for scheduling, APCs will be used to derive maximum load counts and some adjustment algorithm will be used in the processing routines (not the microprocessor) to set the load equal to zero and compensate for on-off discrepancy at the end of every trip.

The microprocessor has been very reliable. There have been some problems with the link between the microprocessor and the cassette storage unit, however. UTA has resolved this problem.

LOCATION REFERENCING METHOD

COTA uses 50 Motorola signposts to reference location. Forty of these are "permanent" and ten are "portable". The A.C. powered permanent signposts tap into the power source of the traffic control boxes (TCB). These devices are enclosed in small grey boxes that blend in with and are attached to the TCB. In order to install these boxes and to use the power supplies, permission was sought from the local jurisdictions. COTA had no problem in obtaining their permission.

The portable signpost is a small grey box attached to a second grey box containing the battery. These devices are strapped to utility poles by a band

and are easily transferred from one pole to another. The portable devices are very unreliable and require a great deal of maintenance. Also, the batteries have a very short life and need constant replacement. To resolve these problems, UTA is installing solar panels in the portable signposts. The permanent signposts are very reliable and require minimal maintenance.

Both types of signpost are broad signposts transmitting coded radio signals periodically received by buses within a radius of 150 feet. The frequency is 173.4 Hz which is close to the frequency of a local radio station. There have been no interferences from outside signals. COTA will receive an FCC license to operate the signposts.

COTA initially experienced some problems with the signposts and receivers (also made by Motorola). She receivers need to be fine tuned. Some of the receivers pick up signpost signals as far as 500 feet away while others do not receive the signals at all. Although each bus is now consistently receiving signpost signals, fine tuning is still needed so that each bus will receive the signal at about the same range. COTA suggests that 200-300 feet is probably the optimal range, but the critical issue is for there to be no variation in the ranges as this affects the locational accuracy of the schedule adherence data.

The signposts are positioned at major transfer points and major time points and are spaced an average of 2 to 3 miles apart. For express routes, they are placed at the downtown end only. COTA has many interlining routes and there are an average of 4 signposts per route. In the future, COTA plans to have a signpost at the end of major lines.

COTA will use the signposts for route and route segment level data, and will not reference individual stops.

DATA STORAGE

Data are stored in a Datell cassette tape unit in the PDU. The data are retrieved once a week. Longer storage is possible but not desired due to the hazards associated with long term storage (see OC TRANSPO summary and others).

DATA TRANSFER

Data transfer is a two step process. First, the cassette tapes are replaced and the PDU's (portable disk units) are initialized (see Kalamazoo case study) by an automated systems technician, hired full-time to monitor APCs. The technician schedules the buses into the garage one day a week to retrieve the data and to check on the hardware. When the tapes are retrieved, an audit is performed to obtain measures on the status of the hardware, ie. the number of times the doors opened, the number of boardings.

Secondly, the tapes are sent to UTA where another transfer takes place. The cassettes are inserted into a Kennedy tape drive one at a time. This machine transfers the data onto a 9 track tape. The process is very slow, taking 20 minutes for each cassette.

COTA would prefer automatic transfer of the data, but this option was not researched or considered during the acquisition process.

STATIONARY CPU AND SOFTWARE

UTA will continue to create the data base for COTA at a cost of about $2000 per month. Three days after UTA receives a tape, it will send COTA some preliminary information: diagnostics and daily totals. Within 10 days, UTA will send all the data files on both diskette and 9 track tape.

The data processing by UTA will include matching route-run assignments and correlating APC data with bus schedule and scheduling data. In addition to the cassettes, COTA will supply UTA with the following information and updates:

* locations of signposts
* distances between stops
* outstation and instation times (to delete garage time)
* Rucus trip file
* vehicle assignments

In addition, COTA will append route and run numbers to the data. One disadvantage of this arrangement is that the data base cannot be manipulated by COTA for exceptional analyses. As a clause in its contract, UTA will accomodate new data base needs as "special requests" for a negotiable fee. COTA budgeted $3400 per year for special requests.

To generate reports, COTA will use SPSS PC packaged software on its IBM XT computer. All reports will be preformatted. COTA will also have access to Ohio State University's (OSU) PRIME. UTA will send the 9 tracks for use on the PRIME. OSU has a color plotter and a high speed printer. This system will be used with the APCs to produce special reports.

REPORTS

COTA expects the new software to provide the following information:

(1) Passenger loading profiles: average and maximum passenger loads; load as a percent of seated capacity; time with standees; standees as a percent of seated capacity; and distance travelled with standees.

(2) Time performance: running time; arrival time; departure time; layover time; percent on time; minutes early/late; run time between time points; schedule adherence; and dwell times.

(3) Performance indicators: passenger miles; passengers per hour; boardings per mile; and boardings per hour.

Data will be available on the route and route segment level and for vehicle blocks and bus trips. All data will be available for time periods, weekday and weekend totals, monthly totals, and sign-ups. Reports will be routinely produced periodically with some data reported every two weeks.

APC IMPACTS ON CURRENT OPERATIONS

APCs' major impact at COTA has been in the MIS (Management Information Services) Division. In that division, a full time person was hired to assign APC buses, to monitor APC performance, to conduct the data transfer, and to communicate with UTA on the status of APCS. In addition, a project manager spends .5 FTE coordinating the APC program.

Although MIS is the only division directly involved with the APC project, other divisions such as marketing, service development, and scheduling request information on specific routes and route segments. These requests are made to the technician who communicates the assignments to the vehicle line-up people. These people report back later in the day with an account of exactly where the APC buses were during the day. The technician keys this information into a D-Base II program and gives the diskette to UTA periodically. UTA has an assignment algorithm that matches the date and bus number with the assignment information on the diskette.

Drivers have never been involved in the data collection process at COTA, and they do not take part in the APC system. COTA continues to use manual data collection (ride checks) in conjunction with APCs in recognition of the most efficient application of each data collection resource.

Planning, Maintenance, and Operations cooperate on the APC project and there are positive and open lines of communication between the APC technician and these departments.

COTA ASSESSMENT AND SUGGESTIONS

Based on past experience, COTA views the APC project as more cumbersome than complex. For example, when a change is made to a route, considerable recoding is necessary. Also, ad hoc reporting requires a great deal of effort on UTA's part. (UTA has extensively modified the software since its original development by General Motors.)

There have been problems with the tapes not being properly demagnetized and new data were read over old data. UTA edited the data but additional editing was done by COTA on occasion.

COTA offers the following suggestions for a property to follow prior to implementing an APC system:

(1) The property should identify its needs and determine how APCs will satisfy these needs.
(2) When writing specifications for APCs, the property should present exactly what it expects the vendor to supply.
(3) Logic to ensure that counting does not take place while the doors are closed and when the bus is moving should be built into the microprocessor as a safeguard against overcounting.
(4) The property must understand that the APC software is as crucial to the success of the APC system as the hardware.

APC ACQUISITION AND FUNDING SOURCE

COTA used an RFB (request for bids) process to solicit vendors for its APCs. There were two bids, one of which was unresponsive to the specifications. The project was funded 80% by an UMTA Capital Grant and 20% by COTA.

COSTS OF THE APC SYSTEM

1983 14 month demonstration:	
	$ 60,000 (Includes cost of: leasing hardware to equip 6 buses; access to 8 signposts; all hardware maintenance, data processing, data transfer, and report generation.)
1984 Purchase of APC System:	

CAPITAL COSTS

Sensor Set:	$ 26,300 (Includes I-R sets, door switches, antenna, odometer, installation and wiring for 20 buses)
Portable Data Units:	$102,585 (For 21 PDUs including installation)
Signposts: (including installation)	$ 64,000 (For 40 A.C. signposts) $ 14,000 (For 10 portable signposts)
Initialization Unit:	$ 2,500 (For one unit)
Training and Material:	$ 4,000 (For manuals, guides, documents, and training)
Software:	$ 38,930 (Includes 2 copies of SPSS PC; report generating command files; and copies of Fortran software used to create data base (COTA requested these programs in order to safeguard its investment))
Total Capital Cost:	$252,315 (Total initial cost for system)

OPERATING COSTS*

1983-1984:	$ 6,000 per month (paid to UTA for continued leasing of equipment and report generation between the end of demonstration and the beginning of new system.)
Aug.-Dec. 31, 1984:	$ 6,000 per month (to UTA for data transfer, maintenance, data processing, and report generation on new system)
1985:	$ 2,031 per month (to UTA for data processing, editing, and creation of data files including transfer to 9 track tapes.)

1983-1985 Personnel: .5 FTE Project Manager

1 FTE APC Specialist

*Operating costs also include data processing machine time and human effort. These costs are likely to be less for COTA than for some systems since the data base is not created in-house at COTA.

3.9 Chicago Transit Authority (CTA)

Interview with Lynn Ritter, APC Specialist, CTA, Chicago, Illinois

CTA began implementation of an APC system in the summer of 1983 with a five month demonstration project integrated by Urban Transportation Associates (UTA). At the end of the demonstration, funding was approved by the Authority to lease the equipment and continue the services of UTA. Capital funding for the first phase of implementation and purchase of a complete APC system has recently been approved.

During the demonstration and leasing periods, 6 buses were equipped with APCs at one of the nine CTA garages. Because of the very small APC sample relative to the size of the property, no adjustments were made to the size of the manual data collection force (28 people) because of the APCs. The reports produced by APCs were designed to meet the specified data needs of the property. There are five sign-ups or "picks" per year and specific routes were sampled for each report requested from UTA for each pick. Generally, sampling would be concentrated on a single route during a pick enabling a set of reports to be produced for a route analysis.

UTA's services to CTA are similar to UTA's services in the past to COTA in Columbus, Ohio (see COTA Summary). CTA leased the equipment used during the demonstration and will now purchase the software and additional hardware from UTA. Because the decision to go ahead with APC acquisition is a very recent one, the specifications for the system have not yet been developed. Plans are to equip 270 buses, or 11% of the total fleet, with APCs over a period of several years.

CTA's APC system is report-oriented for planning and scheduling. Approximately 1.5 FTE in planning are spent managing the APC project. Generally, APC data are used at CTA to:

* create, evaluate and adjust schedules and run times
* plan and justify route changes
* section 15 reporting
* respond to non-standard inquiries such as questions regarding passenger activity at particular stops.

CTA is satisfied with the performance of its APC system and would repeat its APC experience. The major problem with APCs encountered by CTA has been related to unit reliability. Much time and effort has been expended working with UTA to resolve some of the reliability problems. In addition, the age (9 years) and poor health of the buses equipped with APC hardware contribute to the down time of the APC system.

EVALUATION OF CTA'S APC SYSTEM

COUNTING SENSORS

The hardware was supplied by UTA and the make and manufacture was not known at the time of the interview. The sensors are reflective dual infrared beams. The reflectors are located on the modesty panel. The light heads are on the dashboard at the front of the bus and on a bracket mounted to the front of the rear door. Door switches are also used to assure that counting takes place only when the doors are open. CTA is very satisfied with the reliabilty and accuracy of the sensors.

ON-BOARD MICROPROCESSOR

The make of the microprocessor is a PROLOG 6800; but name of the manufacturer was not known. The following events cause records to be written:

* front and rear door opening and closing
* signpost field entry and exit
* time stamp every 256 seconds if no other event occurs

Most of the hardware problems relate to the power supply needed by the microprocessor. The buses have 12 volt electrical systems. The way the unit is currently designed, a slight deterioration in the bus battery power results in the loss of microprocessor initialization. When this occurs, no data is recorded until the microprocessor is manually reinitialized.

Failures in the sensors are detected via a portable diagnostic unit which plugs into the microprocessor and displays the front and rear door counts. This unit is used for testing of the equipment as well. Sensor and microprocessor failures may also be detected in the diagnostic step of data processing.

Passenger boardings and alightings referenced by location are the data stored by the microprocessor. In addition, the driver fills out a trip ticket for all runs indicating what routes that bus has taken that day. The information from these tickets is later key punched into a data file for matching with the APC data.

LOCATION REFERENCING METHOD

CTA uses Motorola signposts to reference location of data input. Currently 450 signposts are installed on all routes. The reason that CTA has so many signposts is because the signposts are used for emergency response as well as APCs. In fact, the signposts had already been in place, some as early as 1970, before APCs were implemented at CTA.

The signposts are broad signposts transmitting coded radio signals periodically received by buses within range. Most of the signposts operate on A.C. power and have little or no maintenance requirements. Maintenance is contracted out.

DATA STORAGE

Data are stored on-board the bus on cassette tape.

DATA TRANSFER

Data transfer at CTA is performed by the vendor at least once every two weeks. Portable units are used to initialize the microprocessor. During transfer, the tapes are replaced, the unit is initialized, some diagnostics are done on the hardware, and the sensors are tested. The entire process takes about 20 minutes per bus. The simplicity of the process is considered an advantage of manual transfer. However, the time delay between observation and reporting of events is a major disadvantage. To overcome this disadvantage, tapes can be changed on a weekly basis.

STATIONARY CPU AND SOFTWARE

At present, CTA's APC data are processed on UTA's PRIME computer. Once CTA is independent of UTA, the data will be processed on CTA's Sperry UNIVAC 1100 mainframe computer. CTA will need to purchase equipment to translate the data from the cassettes to magnetic tapes. Both data file creation and report generation will be performed on the UNIVAC. The software will be purchased from UTA and will include the data base program and the command files for SPSSX.

Software costs are estimated at between $100,000 and $200,000. Although a breakdown of the software costs was not available, the cost of the modifications needed to convert the software from PRIME to UNIVAC use is expected to be the most expensive element in overall software costs. The costs of the translation have not yet been identified by UTA.

In addition to the APC data, the driver trip ticket data, end of line adjustment information and data on the number of feet between stops must be entered for stop level data. Finally, an automated schedule file, developed in-house, is used to match schedule information with APC data.

REPORTS

UTA currently supplies CTA with reports produced from the following APC data:

PASSENGER LOADING PROFILES

* average passenger loads
* maximum passenger loads
* load/capacity
* route profiles
* maximum load points and locations
* boardings by stop
* alightings by stop

TIME PERFORMANCE

* running times
* signpost field enter and exit
* layover time
* minutes early/late
* average speed between time points
* schedule adherence

These reports are produced mostly on-demand with a few reports produced routinely for scheduling. The APC system is capable of disaggregating these data to the system, route, bus trip, route segment and bus stop level. Potential temporal distribution of the data can be for seasons or sign-ups, monthly, weekday, Saturday and Sunday, time periods and 15 minute periods during peak traffic hours. CTA has received reports at all of these levels except monthly totals which have not been requested. Graphics are seldom requested and reports are usually in tabular format. In additon, diagnostic reports on the status of the hardware are supplied four times per month to CTA.

APC IMPACTS ON CURRENT OPERATIONS

Because such a small portion of the fleet has been equipped with APCs to date and because so much of the work is performed by UTA, the impacts of APCs have yet to be fully realized. The addition of 1 FTE for APC coordination and management and another .5 FTE for assistance have been the most immediate impacts noted so far.

CTA ASSESSMENT AND SUGGESTIONS

Leasing a few units was advised for a beginning APC implementation to discover how well APCs fit into the operations of the transit district. Slow, careful, incremental implementation was also advised.

APC ACQUISITION AND FUNDING SOURCE

Funding for the demonstration project came from CTA's operating budget. UTA was chosen to perform the demonstration project. They had provided CTA with an unsolicited proposal in 1982. The concept of a passenger counting system that integrated hardware and software such as the system proposed by UTA was deemed a project worth testing. UTA was found to be the only vendor in the APC industry offering the integrated hardware/software system.

The property is currently funding the lease program. The planned acquisition of the system will be funded 20% by local match and 80% by UMTA.

COSTS OF THE APC SYSTEM

Demonstration Project:	$ 40,000 for five months
Leasing:	$ 1,700 per month per bus for lease, maintenance, and report generation
Estimated Cost of Purchase:	
On-Board Equipment:	$ 8,000 per unit
Estimated Software:	$100,000-$200,000

3.10 Kitchener Transit

Interview with Vince Mauceri, Senior Transportation Planner, Kitchener Transit, Ontario, Canada

Kitchener is now in the process of implementing an APC system. The expectation is that the system will be operational by the end of June, 1985. Twenty buses are being equipped with APCs. Of these, Kitchener will operate up to 17 at any given time. The APC system will be report oriented for planning and scheduling. APC data will be used to create, evaluate, and adjust schedules and run times; to plan and justify route changes; to evaluate marketing strategies; to determine fleet needs; to monitor driver performance; to determine location of bus stop facilities; to monitor schedule adherence; to determine location or removal of bus shelters; and to perform cordon counts.

Kitchener has contracted with Systemware, Inc. and Sigma Star Research and Consulting Corporation to develop the software to process the APC data. Mississauga Transit, another Ontario property, also has contracted with this company for software development. Although both Kitchener and Mississauga Transit Properties will have the same software and will use the same computer (VAX minicomputer), they will use different on-board equipment. This arrangement is part of an experiment planned by the Province of Ontario in an attempt to obtain software which will have uniform application to all properties in the province.

Kitchener planners believe the APCs will be cost effective by virtue of their replacing 15-20 ride checkers, saving the property about $18,000 annually. They contend that the APC system should more than pay for itself over a two year period. Plans for the future include expanding the APC system to include real-time monitoring capability and acquiring signposts within two to three years.

EVALUATION OF KITCHENER'S APC SYSTEM

COUNTING SENSORS

Kitchener will use treadle mats manufactured by London Mat Industries. These mats are being installed on the two steps at the front and rear stairwells.

Kitchener staff will perform the actual installation of the mats. The supplier will train the maintenance staff in the proper installation and maintenance of the equipment.

ON-BOARD MICROPROCESSOR

The microprocessors are manufactured by Pachena Scientific and Industrial Electronics Inc., British Columbia. They will be mounted on the floor or modesty panel behind the driver. The following events will be recorded by the unit:

* passenger ons and offs
* front and rear door opening and closing
* time between stops (24 hour clock) for vehicle arrival times
* distance between stops (odometer readings to reference location)
* memory space overflow

* idling events
* record of date and time of last data retrieval
* built-in PCU (Passenger Counting Unit) identification attached to the bus number (if possible)

Failures in the passenger counting sensors will be identified through use of a portable testing unit supplied with the PCU. The microprocessor on-board the bus will transmit a signal to the portable testing unit when data are in error due to hardware failure (see Data Transfer).

LOCATION REFERENCING METHOD

Kitchener plans to use a computer generated comparison of APC odometer reading to stop by stop distance files to reference location of passenger activity. With this technique, a computerized schedule file, Bus-Sched, is compared with the distances recorded by the microprocessor. Because the system is not yet implemented, no assessment of the method at Kitchener is available. Refer to TRIMET summary for more information on this approach.

DATA STORAGE

The portable data unit contains a solid state memory device which has a storage capacity of up to 128K bytes.

DATA TRANSFER

Kitchener plans to use a cable retrieval system located inside the garage in the service fueling area. The device consists of a standard cable with an RS-232 connector. While vehicles are being serviced late at night, a serviceman will plug the cable with the RS-232 into the APC unit located on the modesty panel behind the driver's seat. Once the data have been transferred to the central computer, an LCD display on the microprocessor unit located on the bus will indicate whether a successful or unsuccessful transmission was made.

STATIONARY CPU AND SOFTWARE

Data collected by the APCs will be processed by a Digital Equipment Corporation (DEC) VAX 11/750 minicomputer, purchased in 1984 from Plessey Peripheral Systems Canada, Ltd. The total purchase included the VAX, two dot matrix printers, four terminals, one console printer/terminal, one tape drive, the VMS operating system, 450 MB disk, and Fortran and Basic compilers.

In addition to processing APC data, the computer will be used for several other functions such as: scheduling, runcutting, statistical analysis, spread sheet applications, advertising inventory, financial planning, etc.

In order for the APC to produce useful reports, it is necessary to extract "vehicle block" data from the computer scheduling package, Bus-Sched. The file created by this software is integrated with the APC data to reference location.

Software functions of the stationary computer include:

* validation checks against expected behavior on each instrumented vehicle;
* appending route numbers to the data;
* appending vehicle assignment information;
* appending run numbers.

The software is being developed by the joint efforts of Kitchener and Mississauga Transit properties with the assistance of Systemware Inc. and Sigma Star Corporation, both of Toronto. The software is 100% funded by the Province of Ontario. All source code will be supplied to the properties upon completion of the software development. Planners perceive the software as easy and inexpensive to update as it is written in Fortran-77.

REPORTS

Kitchener expects the APC system to produce the following reports:

LOADING PROFILES

* average passenger loads
* maximum passenger loads
* load/capacity
* route profiles
* maximum load points
* boardings by stop
* alightings by stop

TIME PERFORMANCE

* running times
* layover time
* percent on time
* minutes early/late
* schedule adherence
* headway distributions
* dwell times

PERFORMANCE INDICATORS

* passengers per hour
* passengers per Kilometre
* boardings per hour
* revenue/cost ratios
* deficit per passenger
* cost per passenger

This information will be made available for system totals, route level, driver run, bus trip, route segment and bus stops; and will cover time periods ranging from 15 minute periods to monthly and quarterly reports. Reports will be presented both routinely and on demand in tabular format. Graphic capability will be added at a later date. Kitchener's APC system will not have the capability to integrate APC data with other data (ie. survey data, etc.). Additional software or a commercial data retrieval package would be required to perform this task. However, the APC data could be used in conjunction with surveys to establish sample rates, population sizes, etc.

APC IMPACTS ON CURRENT OPERATIONS

As the APCs have not yet been implemented at Kitchener, the impacts cannot realistically be assessed. The current data collection techniques used at Kitchener involve annual on/off surveys for all routes (100% sample of all runs and trips) for a typical weekday using 15-20 ride checkers. Interestingly, this method is considered very reliable and accurate (verified by farebox revenues), yet Kitchener planners believe the APC technique will be an improvement over manual methods.

APC ACQUISITION AND FUNDING SOURCE

The APCs were acquired through a tender and bid process. Three bids were received. The hardware was 75% funded by the Province of Ontario and 25% by the property. The software was funded 100% by the Province.

COSTS OF THE APC SYSTEM

Note: all costs quoted are in Canadian funds as of August, 1984

CAPITAL COSTS

*Counting Sensors	$ 18,413 (for 20 buses)
*Microprocessor	$ 34,092 (for 20 buses)
Transfer Device	$ 1,150 (one device)
**Stationary Computer	$189,000 (see Section B.6 for details)

* Installation costs not available

**The stationary computer was purchased over a year prior to the acquisition of APCs and is used for several other functions in addition to APCs.

OPERATING COSTS

APC system is maintained by supplier.

Counting Sensors	2 year warranty
Microprocessor	$ 1,490 per year
Transfer Device	$ 150 per year

All other expenses unknown

3.11 Mississauga Transit

Interview with Norman Dodd, Manager Transit Planning, Mississauga Transit, Ontario, Canada

Mississauga has recently purchased an APC system consisting of counting units and microprocessors for thirty buses (twenty 40 foot and ten 60 foot buses). The hardware will be installed in April, 1985. The software will be developed by the joint efforts of Mississauga's computer staff and personnel from Systemware, an Ontario software firm. Systemware's consulting fee will be reduced in exchange for the use of Mississauga's mainframe computer. Software costs to the property are also lessened by splitting 25% of the costs with Kitchener Transit.

In general, Mississauga Transit will use the APC data to:

* create, evaluate and adjust schedules and run times
* plan and justify route changes
* evaluate marketing strategies
* estimate expected revenue
* determine fleet needs
* provide schedule adherence data
* determine location of bus shelters
* provide transit trip generation data
* provide information on terminal passengers (shopping centers, subways, Government rail commuter train service evaluations, etc.)
* obtain performance indicator statistics
* calculate revenue/cost ratio
* conduct five-year forecasting studies

As this property has yet to implement an APC system, this summary examines Mississauga's plans for future implementation including the types of reports it expects the system to produce.

EVALUATION OF MISSISSAUGA TRANSIT'S APC SYSTEM

COUNTING SENSORS

Mississauga Transit has purchased London Mat treadle mats to count passengers. The mats will be installed by Ontario Bus Industries, a Mississauga company. The mats will be placed on two steps with splits for two streams at all doors. The choice of mats over beams was based on the experiences of Ottawa (beams) and Toronto (mats) Transit Commissions.

ON-BOARD MICROPROCESSOR

APC Industries of London, Ontario, a subsidiary company of London Mat Industries, manufactured the microprocessor. This unit time tags and date tags the data, records an odometer reading, accumulates passenger counts (boardings and alightings), and records dwell time and door opening and closing. The door opening activates data input. When the memory space is filled, a flag indicates this event to identify when and where data were lost.

LOCATION REFERENCING METHOD

Mississauga will use a computer-generated comparison of APC odometer reading to stop by stop distance files to reference location of data input.

Section B.4: DATA STORAGE

The microprocessor uses a solid state memory device to store APC data. The storage capacity is 16K bytes.

DATA TRANSFER

Mississauga plans to use an automated retrieval system to transfer data from the bus to a stationary computer. The method will be a cable data retrieval system located at the fueling island. Transfer should be completed within 60 seconds. Data will be passed through a hand wired cable to the host computer once each day as the bus is fueled. The cable will be made in-house by Mississauga Transit.

STATIONARY CPU AND SOFTWARE

The host CPU is a VAX 11/780. For APCs there will be one terminal in the fueling area and one in the Planning Department. An interactive program will transfer the data from the fueling area to the stationary computer. The VAX was not purchased for use with the APCs and it is used for a number of other data processing tasks.

The software will be developed as a joint effort between Mississauga's computer technicians and personnel from Systemware. In addition to creating data files and formatting APC data into reports, the software will serve the following functions:

* validation checks against expected behavior for each instrumented vehicle;
* append route numbers to the data;
* append bus stop numbers (replacing 'distance' measurement with 'true' location);
* append vehicle assignment;
* append run number.

In addition to the files necessary to perform these functions, other information which must be input into the processing routines are any exceptional conditions such as bus change offs, short turns, schedule changes, etc.

REPORTS

The reports Mississauga expects its APC system to produce include all passenger loading profiles, time performance, and system performance indicators specified in the survey. Mississauga has specified that these data be available for the system, route, bus trip, route segment, and bus stop levels. Cordon area and screenline crossings have also been specified. Monthly totals, totals for weekday, Saturday and Sunday, time periods, and 15 minute periods during peak traffic hours should be produced. Both tabular and graphic (including color) formats will be available periodically and on-demand.

Other information needed to produce these reports include a data bank containing stop-to-stop and route distances, mini-scheduler files, and bus data (see STATIONARY CPU section).

APC IMPACTS ON CURRENT OPERATIONS

Current data collection activities at Mississauga include the following:

* bi-annual screenline count program
* standing counts as required (usually one day only)
* on/off counts as required by route
* bi-annual total system on/off survey
* waybill data (driver counts of revenue and transfer passengers) by route (APC will check these data)

Mississauga expects APCs to reduce field staff work, including screenline counts of passengers and to provide pre-signup data for route review studies that might not otherwise be collected. Also, the property expects APCs to probably increase confidence in the data used for route reviews.

Future plans are sketchy as yet but the property does not plan to equip more than 25% of the fleet and will consider the use of microwave signposts in the future.

APC ACQUISITION AND FUNDING SOURCE

The APC hardware was tendered and the contractor was chosen on four criteria:

* lowest price
* qualifications
* proximity in case of problems, spares, etc.
* that counting algorithms were compatible with step mat sensors

A one year warranty on all hardware was required. The acquisition was funded 75% by the Province of Ontario and 25% by the property. 25% of the software cost was split with Kitchener Transit in Ontario.

COSTS OF THE APC SYSTEM

On-Board Hardware:

Total Cost:	$3,700-$5,300 per articulated bus
	$2,740-$4,110 per 40' GMC

3.12 Toronto Transit Commission

Interview with Rick Thompson, Design Engineer, Plant Department, Toronto Transit Commission, Ontario

Toronto's APC experience began in 1978 as part of an AVM test system (Automatic Vehicle Monitoring System). The project involved equipping 100 buses with AVM and passenger counting hardware. In 1981, the property discontinued using the passenger counters but continued to operate the AVM system for real-time vehicle monitoring. An additional 150 buses were equipped with AVM hardware in 1982 and the system became fully operational at one division in September, 1984. Toronto is presently developing a plan for city-wide implementation of the AVM system.

Accuracy and reliability of the APCs were the two major considerations in determining the viability of the passenger counting system. The original 100 buses were equipped with APCs custom made by Transduction Ltd. This company no longer manufactures or supports this product. After extensive testing of the hardware, the property determined that the accuracy of the data did not meet specified accuracy levels, particularly at high use stops (six or more passengers boarding or alighting at one stop). For this reason, the APC portion of the AVM system was discontinued.

Due to the fact that the APC project was never fully operational (since the required accuracy was never met), the passenger count data were used in real-time monitoring only. The real-time monitoring function of the AVM system has taken priority over the off-line information function of the AVM system.

APC-related problems found during testing were associated mainly with activity at high use stops. For this reason, the property has decided to implement APCs at off-peak times (weekends). At the request of the planning department, 150 buses will be equipped with passenger counters. The property is now in the process of writing specifications to purchase the APC units. This project will operate separately from the AVM system.

EVALUATION OF TORONTO TRANSIT COMMISSION'S APC SYSTEM

COUNTING SENSORS

Infrared beams, manufactured by Transduction Ltd., were used in the initial APC installation on 100 buses. The reliability of the hardware and the accuracy of the data were too low to meet the property's specified criteria.

Specified accuracy levels for both boardings and alightings were:

	Error	Percent of the Time
For 1-5 people	0	70
	±1	95
	±2	99
For 6-10 people	0	40
	±1	90
	±2	95
For 11 or more	within 10%	90% of the time

Testing generally showed acceptable accuracy levels for 1-5 people boarding or alighting at one stop, but six or more people at one stop could not be accurately counted within these parameters using infrared sensors.

In 1982, the property began experimenting with treadle mats manufactured by London Mat. Although the mats proved to be more accurate than the beams, accuracy at high use stops was unacceptable using the mats as well. At present, the property has exhausted all testing with the mats and plans to write specifications to equip 150 buses with APCs. This system will be used to obtain off-peak samples on weekends and evenings only.

ON-BOARD MICROPROCESSOR

For the initial testing (using the beams), the microprocessor in the AVM unit on the bus accumulated count data and a modem transmitted these data through the radio to the central computer. The AVM units were manufactured by Unified Technologies Inc. (no longer in business). The microprocessor used in conjunction with testing of the mats was supplied by London Mat and designed by Dynamic Controls. These units were interfaced with the AVM units for radio transmission to the central computer.

The passenger counting function of the system was event-driven. That is, passenger counting occurred only when bus doors were open. Events recorded by the APCs were: door opening and closing, distance between stops, and signpost codes. None of the APC buses were lift-equipped. The AVM unit contains a clock to detect time, a separate odometer (a sensor attached to the right front wheel) and an algorithm to interpret signpost codes.

The equipment was maintained in-house. The Transportation Department identified passenger counting problems from the screen (in real-time) and passed this information on to the Maintenance Department.

LOCATION REFERENCING METHOD

Toronto uses sharp signposts at precise locations at specific points along routes. These units are microwave transmitters. When a vehicle receives a signpost transmission, the AVM unit will reset the AVM odometer to zero. About 45 signposts are installed with an average of about 2-3 signposts per route.

Generally, the signposts were placed at three mile intervals or at branch locations. At least one signpost reading is obtained per bus trip.

The signposts are A.C. powered (tap into the city power supply). They have no notable maintenance requirements and their performance is considered satisfactory. The signposts were designed by Toronto Transit Commission and manufactured by Electrocomm, a local firm.

DATA STORAGE

Since the AVM system transfers data in real-time, there is no need for on-board storage of the data. The AVM units do contain short-term solid state memory for storage prior to transfer.

DATA TRANSFER

As part of the AVM system, the data are transferred to the central computer in real-time through designated radio channels. Every six seconds, each bus is polled by the program in the central computer. This information is displayed on screens for use mainly by the Transportation Department.

STATIONARY CPU AND SOFTWARE

With the AVM system, a Data General Nova minicomputer is used to process the data. This unit was purchased with the AVM system and it is a dedicated unit.

Although report software was developed for use in off-line reporting of the passenger count data, it was never used due to the inaccuracy of the data. All software related to the AVM system and report software was developed in-house by computer services technicians. At present, an automated minischeduling system, booking information, etc. are on file and are incorporated with the AVM data during data processing.

Although the exact arrangements have not yet been made, it appears likely that the APC data generated from the new counting units will be processed on the property's IBM mainframe. There is report generating software available on the IBM. This software is presently used to produce reports from manual counts. This report software will be used with the new APC system.

REPORTS

AVM reports have been available since the system became fully operational in September, 1984. APC reports were not generated from Toronto's AVM system.

APC IMPACTS ON CURRENT OPERATIONS

The APC system was initially installed as part of an AVM project. The real-time monitoring function took priority over the off-line information system. Since the passenger counters did not pass the test for acceptable accuracy, they were never used to collect data for off-line reporting. For this reason, the APCs have not had any impacts on current operations.

APC ACQUISITION AND FUNDING SOURCE

Toronto used an RFP process to select a supplier for its AVM system. The project was funded 75% by the Province of Ontario and 25% by the Metropolitan Government.

COSTS OF THE APC SYSTEM

CAPITAL COSTS

For AVM:	$5000 per vehicle for total hardware for AVM (includes APC) in 1978.
Installation	2 person days each unit
Signpost receiver:	$ 350 per unit

OPERATING COSTS

Maintenance:	.2 FTE

3.13 Southern California Rapid Transit District (SCRTD)

Interview with Louis Cherene, Senior Planner, SCRTD, Los Angeles, California

SCRTD's passenger counting system, first implemented in 1980 as a demonstration project funded by UMTA, is a prototype system intended as an ongoing APC evaluation program. This APC system functions in real-time for screen-oriented monitoring (AVM or "Automatic Vehicle Monitoring") and off-line for report generation. The APCs are used to obtain information, both real-time and off-line, on four of the 200 routes. Off-line, APC data are used primarily for scheduling; on-line, the APC system monitors vehicles for performance and emergency response.

SCRTD's APC system was fully operational in 1982. After that year, interest in the system waned and the hardware and software deteriorated. SCRTD identifies the problem both organizational and hardware-related. Other transit functions have taken priority over data collection activities. Providing bus service for the Special Olympics is one example of a non-APC priority. Also, maintenance of APCs has come second to maintenance of the voice radio system which operates through a separate radio channel from the AVM. As a result, about 30% of the sensors are presently malfunctioning. Many of the signpost batteries need to be replaced as they approach their five year shelf life.

Due to these and other problems with the APC system, there is presently very little confidence in APC data at SCRTD. APC data are available only for about 40% of the trips. Occasionally, this percent will be as high as 70% on individual lines. For this reason, SCRTD continues to employ 34 full time salaried ride checkers. The APC time performance data are compared with manually collected data for accuracy and to distribute the checker counts along routes and route segments.

In response to the many and varied problems encountered with APCs at SCRTD, the property has hired a specialist to evaluate and upgrade the APC system as part of a new Transit Radio System (TRS). Funds for the project will be apportioned for hardware improvements and software development. SCRTD is now in the process of evaluating and recommending needed improvements to the AVM subsystem. Plans for the future include equipping 100% of the fleet with new radio transmitters as part of an improvement in both the TRS and the AVM systems and the improvement of the existing service analysis software developed by Multisystems, Inc.

EVALUATION OF SCRTD'S APC SYSTEM

COUNTING SENSORS

At SCRTD, 200 buses are equipped with APCs. Of these, 17 are articulated. Ten-to-twenty buses are equipped with infrared beams and the rest contain mats. The mats were made by London Mat Industries; the beams were made by Red Pine.

Common problems associated with the sensors are damage to the mats caused by wheelchairs and during repair of wheelchair lifts, and beam wires being cut when other maintenance of the bus is performed. Due to such conditions, about 20-30% of the data are discarded during processing routines due to bad or inconsistent counts. An additional consideration is the on-off discrepancy common to APC counts. At SCRTD, on-off discrepancy is resolved to 5% of the data. That is, when the discrepancy between boardings and alightings exceed 5% of the counts for a particular run, the data for that run are discarded. This percentage is low in comparison to other properties, most of which compensate for discrepancy up to 10-15% of the data.

ON-BOARD MICROPROCESSOR

The microprocessor was supplied by AVM, Inc. The manufacturer of the unit was not known. The microprocessing unit used at SCRTD accumulates counts and location data; but it does not write records to tape or store data on-board the bus. These functions are performed during data transfer (see DATA TRANSFER).

The microprocessor contains a clock which time tags data according to a 24 hour clock, an odometer to register distance and a signpost signal receiver.

LOCATION REFERENCING METHOD

SCRTD uses signpost readings to reference location of data input. A total of 900 signposts are presently installed. Of these, 400 are located on the routes currently surveyed by APCs. The others were left in place to locate off-route vehicles and random route vehicles. SCRTD pays the City of Los Angeles $25,000 per year for the privalege of hanging these signposts.

These signposts, manufactured by AVM, Inc., are broad beam, battery powered signposts. They function by transmitting coded signals within an 800 foot radius. The on-board receiver accepts the three strongest signals. The signposts are positioned approximately on every other block and there are about 8 signposts per mile on the four main routes in the system. The only problem with the hardware is that the batteries need to be replaced after five years. Also, it is necessary to reset the codes after batteries are replaced.

DATA STORAGE

Data are not stored on-board the bus (see DATA TRANSFER).

DATA TRANSFER

Data transfer is performed by an interactive computer program which communicates with the APC buses via a special radio channel. An AVM program in the DEC 11/60 minicomputer taps into the radio computer and operates two polling base stations. The DEC contains two disk drives and a tape drive. Every 40 seconds, data are transmitted from the microprocessor on-board the bus to the 11/60 and processed. These data are displayed on screens for real-time monitoring and, at the same time, written on disk.

Every morning, the data stored on disks are processed and written on magnetic tape. These tapes are then converted and read onto an IBM 3083 system for service analysis. These data include:

* line identification
* date
* direction of bus
* headers of time points
* trip summary (which labels the bus #, run #, trip #, branch, bus type, number of boardings and alightings, etc.)
* time points which are numbered from 1 to 19 including schedule data (minutes early/late), number of miles past time point that signpost signal was received, cumulative boadings and alightings, maximum load, etc.

STATIONARY CPU AND SOFTWARE

The stationary computer is located in the central transit station. This is the DEC 11/60 minicomputer purchased specifically for use with the AVM system. The DEC is a dedicated unit with consoles for use in real-time monitoring.

Data file creation and report generation take place in the DEC. Every week, a new tape is mounted and the old tape is stored in the tape library. Although data for a full month could be stored on one tape, tapes are replaced weekly in order to more effectively monitor the system. Due to library space constraints and to the huge volume of APC data collected, these tapes are stored for one quarter and then moved to warehouse storage.

The software used to process the APC data for service analysis (off-line) is located in an IBM mainframe. Multisystems, Inc. has been contracted to develop software which will accurately generate and format data files and reports.

REPORTS

At present, daily and weekly reports are produced by the APC system. Daily reports indicate whether the data are good, identify hardware failures and other equipment problems, and produce the summaries described above (see DATA TRANSFER). As noted above, use of APC data for service analysis has been limited and these reports are not routinely produced by SCRTD's APC system. Efforts are underway to use service analysis software and APC data to update schedules on two lines.

APC IMPACTS ON CURRENT OPERATIONS

The impacts of APCs are primarily felt by Telecommunications and vehicle maintenance personnel. For example, because the AVM system competes with the voice radio for transmission of information, the APCs come into conflict with the service monitoring and vehicle response functions for which Telecommunications personnel are primarily responsible. Special efforts were required to assign APC-equipped buses to monitored lines. As a result, APC data has been spotty over an extended period of time. These organizational problems are cited as the greatest impediment to the success of SCRTD's APC program.

SCRTD ASSESSMENT AND SUGGESTIONS

Many of the difficulties encountered at SCRTD directly relate to the integration of the APCs with a real-time monitoring system. This problem is analogous to the more common problem with data transfer using security guards. When APCs come into conflict with traditional transit functions which are essential to every day operations, the functionality and success of the APC system are threatened. In the case of SCRTD, the APC system was neglected over the years. As a result, a large investment in time and money resources is now being made to restore the system to its former level of functioning.

The primary purpose of the APC Prototype operated by SCRTD is to ascertain the technical feasibility of such a system and to identify its value for both real time control of vehicle service and off-line analysis of service data. The present system is providing Telecommunications, Operations, Planning, and Scheduling personnel with ample experience to intelligently evaluate alternative features of the new Transit Radio System.

APC ACQUISITION AND FUNDING SOURCE

SCRTD's APC system was funded by an UMTA section 6 grant as a demonstration project in 1980. An RFP process was used and the contract was awarded to AVM, Inc., the system integrator.

COSTS OF THE APC SYSTEM

The costs of SCRTD's APC project were not available at the time of the interview.

Chapter Four

Assessment Of APC Techniques

Like many recent innovations, automated data collection techniques have introduced a wide range of possibilities for gaining knowledge about operational systems. Ideally, the types and volumes of data APCs make available to transit agencies form the basis for more informed decisions and, consequently, contribute to increased operational efficiency and improved service to the public.

A variety of factors come into play in the assessment of APCs in light of this ideal. For large transit agencies, the relative cost of APCs when compared to manual methods may be the deciding factor. For small agencies, the benefits of APCs are seen chiefly in the types and amounts of data the systems provide. For all transit agencies, the intended uses of APC data should be identified in the first phase of an evaluation of APCs. This identification of data needs is also a critical step in writing specifications for an APC system.

For these reasons, this assessment begins with a discussion of intended uses of APC data. This is followed by an analysis of APC system components, including accuracy and reliability issues. The benefits of APCs are discussed next and reports are included which illustrate the capabilities of existing systems. Costs of APCS are the topic of discussion in the next section, followed by a perscription for APC system implementation. The issues and concerns revealed in these discussions are summarized in the final section of the chapter.

4.1 Intended Uses Of Data

Agencies need to evaluate their data needs and identify intended uses of the data before deciding to implement an APC project. This requirement applies both to agencies studying the feasibility of APCs and to agencies planning a conversion to automated techniques. The evaluation of data needs is especially important for small transit agencies since the cost-effectiveness of APCs is less precisely defined for small properties than for large properties. This evaluation should consider the following:

(1) the adequacy of current methods in collecting needed data (This consideration implies an evaluation of current methods in terms of their effectiveness in providing a sufficiently large sample from which to make inferences about the true performance of the system.);

(2) data presently collected manually that might be obtained more efficiently using automated data collection methods (This issue implies that present methods be evaluated in terms of effectiveness, benefits, and costs; and that a comparison be made between present methods and automated techniques); and

(3) classes of data needed but not presently collected; the purposes for obtaining this information now; and the objectives this additional information is likely to serve. (Desired accuracy level and sample size are a function of the uses to which data will be put. It is thus important to consider the reasons for needing particular information in deciding whether or not the data should be collected, how much to collect, and what is the best method to use.)

The intended uses of the APC data by current user properties are displayed in Table 4.1. The uses of data by APC-AVM properties (Toronto and Los Angeles) are not included in this table since the priority uses of these systems are vehicle monitoring and emergency response rather than off-line reporting. London Transit was also excluded since this APC application consists solely of treadle mats; data recording and analyses are performed manually.

Because all of the agencies interviewed are now undertaking APC system modifications, intended rather than present uses of APC data from upgraded or fully installed systems are listed in Table 4.1. All of those interviewed plan to use the data obtained by the APC systems for scheduling and route planning activities; and all of the U.S. properties plan to use APC data for Section 15 reporting. Half of those interviewed plan to use the data to: evaluate marketing strategies; determine fleet needs; and determine the location of bus stop facilities. None of the U.S. properties plan to use APC data to estimate expected revenue or monitor driver performance.

The "other" uses of data included on this table were not part of the original survey, but were mentioned by some agencies during the interviews. It is likely that more agencies plan to use APC data for these purposes.

4.2 APC System Components

APC systems collect and analyze data on transit passenger activity, time, and location. The success of APC systems in accomplishing these tasks is contingent on synergism of three essential system components: hardware, software and personnel. Each of these components plays a vital role in the quality of overall system performance.

4.2.1 APC HARDWARE

There are both essential and optional hardware components in current APC systems. Essential components are:

* counting sensors: either treadle sensor mats or infrared beams to detect passenger boarding and deboarding activities;

* data collection units: commonly referred to as either system controllers, PDU (portable data units), or DCU (data collection units), to accumulate and record counts, time, and location data (contains a microprocessor, clock, odometer sensing unit, an interface board, and a storage device);

* a power supply to convert, condition and filter primary bus voltage to the data collection system.

* data retrieval units: either automatic (radio-link, infrared, or cable) or manual (cassette or PDU (portable disk units)) devices used to retrieve data from on-board the buses and transfer to the stationary computer; and

Table 4.1: Intended Uses Of APC Data[1]

Uses Of Data	Number of Responses
* Create, evaluate and adjust schedules and run times	10
* Plan and justify route changes	10
* Evaluate marketing strategies	5
* Determine fleet needs	5
* Determine location of bus stop facilities	5
* Prepare Section 15 reports	5
* Estimate expected revenue	3
* Monitor driver performance	3
* Other:	
* Report on ridership	2
* Respond to non-standard inquiries	2
* Conduct cordon/screenline and/or area counts	2
* Provide transit trip generation data	2
* Obtain performance indicator statistics for route group analysis	2
* Conduct 5 year forecasting studies	2

Missing Cases: 3
(This information was not obtained for Toronto, Los Angeles, or London Transit Agencies)

Notes:

1. Intended rather than actual use is included in this table. Currently, all properties are modifying their APC systems. The listings here reflect the intended use of data obtained from new or upgraded systems.

* stationary computer: either a mainframe, minicomputer, or microcomputer to process APC data and produce reports.

Optional devices include:

* door switches: to monitor or control counting when bus doors are closed; and

* signposts: to transmit signal to the on-board data collection unit (via special signpost antennae atop the bus) to identify bus location.

The hardware used in implemented systems is displayed in Table 4.2. A full description of these devices, their use, and relative advantages and disadvantages can be found in the individual case studies in Chapter Three. To summarize from Table 4.2: infrared beams are used more frequently than treadle sensor mats; automatic data retrieval is more common than manual data transfer; and minicomputers are the most popular size stationary computer.

These frequencies generally make sense given the special considerations involved in APC use. Although slightly less accurate than mats, beams have lower initial and replacement costs. Also, wheelchairs and water infiltration cause damage to the mats. The reliability of the beams is good as long as the lightheads are kept free of heavy dust accumulation and are properly installed and aligned. Mats may be a better option on buses without lifts in relatively dry climates.

The choice between automatic and manual data retrieval depends on the agency's resources and the availability of staff to perform the transfer. Automatic transfer has higher initial and installation costs; while manual transfer involves the use of human labor. Manual transfer works best when it does not interfere with the routine operations of the agency. When data retrieval is a second priority of the person doing it (e.g. security guard, driver, etc.), data transfer is less reliable since this is not this person's primary responsibility. Manual transfer does work well when properly trained, dependable individuals are assigned this as a priority task. Note that solid state memory in the data collection unit is required for automatic data retrieval.

There are also factors to consider in choice of specific retrieval method. Radio-link transfer may require the use of a dedicated radio channel; infrared transfer cannot be performed if the bus is on a hoist or there are construction detours at the site; and cable transfer has yet to be tested. With regard to manual retrieval, both cassette tape and PDU require the use of a retrieval device. The principal difference between these two manual methods is that with cassettes it may be neccessary to transfer the data to disk for use on the stationary computer; and this can be a time-consuming process. At least one manufacturer is now phasing out cassette retrieval.

Minicomputers have several advantages which may be an indication of why they are used more frequently than other size computers for APC data processing.

Table 4.2: APC Hardware Used In Implemented Systems

	Counting Sensor		Data Retrieval Device		Stationary Computer		
	Beams	Mats	Automatic	Manual	Mainframe	Mini	Micro
APC SYSTEMS							
Seattle		X		PDU + Cassette		VAX	
Ottawa	X		Radio			VAX	
Kalamazoo	X			Cassette	PRIME	IBM*	
London		X	None		None		
Windsor	X		Radio			MODCOMP	
Calgary	X			PDU	IBM		
Portland	X		Infrared		IBM		
Columbus	X			Cassette	PRIME		IBM*
Chicago	X			Cassette	UNIVAC		
Kitchener		X	Cable			VAX	
Mississauga		X	Cable			VAX	
AVM-APC SYSTEMS							
Toronto	X	X	Radio		IBM		
Los Angeles	X	X	Radio			DEC	
Total	9	6	7	5	5	7	1

Notes:

1. Kalamazoo plans to purchase an IBM PC AT to process APC data. At present, UTA processes the data and produces reports for this agency.

2. COTA in Columbus, Ohio uses an IBM XT to generate reports. Data files are created for COTA on UTA's PRIME computer.

These advantages include:

(1) both data file creation and report generation can be performed on the same computer;
(2) minimcomputers allow greater flexibility than mainframes since they can be interfaced with mainframes and micros; and

(3) if minicomputers are used as dedicated units, there is less competition for use of the system, reducing the impacts of APCs on other operations.

Whichever device is selected, choice of a computer already in use with APC programs will reduce software costs by avoiding the expense of modifications. Modifying software from one computer make to another comprises a major portion of overall software expense.

In addition to the hardware included in Table 4.2, a system controller is required to accumulate and store data on-board the bus. This device is sometimes referred to as a data collection unit (DCU) or a portable data unit (PDU). The system controller receives and records the signals transmitted by the sensors, the odometer and the signposts. It contains a clock which stamps the data when significant events occur (such as passengers boarding or receipt of a signpost signal).

Signposts and door switches are optional devices which improve the accuracy and reliability of the data. Door switches either monitor or control counts with bus doors closed. Signposts transmit a coded radio signal to the buses, via special antennae atop the bus, to either substitute for or augment odometer readings to identify location. This can be done in one of three ways depending on the signpost, system controller and software capabilities:

(1) upon receipt of the signal, the system controller resets the odometer to zero; or

(2) the system controller records signpost field entry and exit points and the software later interpolates between these points to calculate location; or

(3) the system controller records precise location of vehicle from coded radio signal at specific locations.

Refer to the case studies in Chapter Three for detailed discussions on these three methods.

4.2.2 APC SOFTWARE

Due to the large volume of data generated by APCs and to the complexity of processing routines, software development and processing costs frequently exceed the expenditures for hardware. In addition, as with hardware components, the cost of APC software is a function of the level of detail and sample size desired by the user property. For these reasons, special efforts were made in this study to explore ways to minimize software expenditures. Separate processing routines are required to perform the two discrete software functions necessary to process APC data:

(1) data file creation; and

(2) report generation.

Of the two processes, data file creation is much more complex, time consuming, and costly. Fortran programs are used to create data files. The first step involves merging schedule files with APC data to calculate location. Next, these data are validated, edited, sorted, and stored in files on either disks or tapes or both. For a property comparable in size and service area population to Lane Transit (with a total of about 80 buses), it takes about three days to create a data file from two weeks of data from 15 to 20 buses.

The second software function, report generation, is a relatively simple procedure. Packaged software, usually SPSS PC or SAS, is used to access APC data files, perform analyses, and format reports. One aspect of report generation which will incur some cost, although not a major one, is writing the command files for use with the software. The cost of this task is unknown. The only other costs associated with report generation are the computer and labor costs of running the programs. About one day per month is required in human effort to perform this task.

Table 4.3 groups the current approaches to APC data processing by hardware and software vendor or supplier. These approaches represent three software development options:

(1) software support contracts;
(2) in-house software development; and
(3) software acquisition

<u>Software Support Contracts</u>

Many APC properties have contracted with private consulting firms for on-going software support. Part or all of the data processing is done by the firm using the firm's facilities. Often, a consulting firm becomes involved either in demonstration projects or during initial installation of permanent systems.

Kalamazoo Metro (Michigan) and COTA (Columbus, Ohio) are two properties which have taken this approach to data processing. At Metro, cassette tapes are sent to Urban Transportation Associates (UTA), a private consulting firm, once every two weeks. Within one week from the date the tapes are received, UTA sends the final reports requested by Metro. Kalamazoo is now in the process of purchasing an IBM PCAT to process the data in-house. The software will be purchased from UTA.

Although UTA has performed similar services for COTA in the past, currently the report generation step is being conducted by COTA on its microcomputer. COTA also has access to a mainframe which it plans to use for larger jobs.

Table 4.3: Hardware and Software Applications

Supplier/Vendor		
Hardware	**Software**[1]	**Properties**
Urban Transportation Associates (UTA)	UTA	Kalamazoo Columbus Chicago
Red Pine Instruments	Group Five In-house Group Five	Ottawa Portland Calgary
Pachena	In-house Systemware and Sigma Star	Seattle Kitchener
General Motors[2]	General Motors	Windsor
APC Industries	Systemware and In-house	Mississauga
AVM Systems Inc.	Multisystems	Los Angeles
Unified Technologies Inc. and Transduction Ltd.[2]	In-house	Toronto

Notes:

1. Initial software development only is listed here.

2. These companies are no longer in the APC business.

Software Support Contract Cost:

Kalamazoo Metro:	\$ 2,700 per month (includes some hardware maintanence and software modifications)
COTA:	\$ 2031 per month (data files provided on disks and 9 track tapes)
Annual range:	\$24,000-\$32,400

<u>In-house Software Development</u>

Four transit agencies have fully or partially developed their APC software in-house: Portland, Seattle, and Toronto have undertaken full development, and Mississauga is in the process of developing software with Systemware, a private consulting firm in Ontario. Based on the experiences of these properties, in-house development requires at least two years to complete. This approach has worked best when the services of computer technicians are available locally. These services may be housed within the agency or they may be obtained on a contract basis from within the local area. Nearby universities and technical schools may prove to be a valuable resource for programmer assistance and software development.

In-house Development Cost:

TRIMET:	1.5 person years to date
METRO:	2 person years to date

<u>Software Acquisition</u>

Final options are to request proposals for software development contracts, or to obtain the software from another property and modify as necessary to match the data needs and hardware facilities of the agency. Modifying programs comprises the major portion of acquired software expense. For this reason, agencies can minimize software costs by purchasing software which is designed to be used with the same type of stationary computer they have available for APC use.

In existing applications, software costs ranged from \$3000 for very rudimentary software with limited capabilities to \$250,000 for very sophisticated software. One software developer estimated the price of software to create data files within the range of \$15,000-\$60000, with the precise price depending on the extent of modifications required. These estimates do not include the cost of the SPSS or SAS software to generate reports. Also, command files must be written to create a systems file from these two files.

Software Acquisition Cost:

Data Base software:	\$15,000-\$ 60,000
Actual Prices Paid:	\$ 3,000-\$250,000

4.2.3 PERSONNEL

Personnel is a key component of an APC system, but one which is frequently underestimated by user properties. The implementation, coordination, monitoring, and management of an APC project are time-consuming processes. The complexity of APC system operation, as demonstrated in the procedures discussed in section 4.6 (APC System Implementation), mandates that agencies make strong commitments to APC projects. The assignment of a specialist to the project facilitates integration of the system into on-going transit operations. This person is a critical link between the request for information and the production of reports.

The tasks performed by the specialist include: managing the vendor; monitoring the equipment; diagnosing hardware problems; assuring the assignment of APC buses to specified routes; enterring and processing data; updating schedule files; and running the programs to produce reports. At some agencies, the APC specialist is responsible for data transfer as well. Based on their experiences, user properties advise that at least one full-time person is needed to coordinate an APC project. At agencies which lack the resources to make this commitment, long delays in achieving operational status of the APC system have resulted.

A second personnel requirement of APC systems is the assignment of one person from .2 to .5 FTE (full-time equivalent) to APC maintenance. It is important that at least one person in the maintenance department be knowledgable about APC hardware to assure long-term maintenance of the equipment. This is especially important for agencies located a great distance from their suppliers. It has also been advised that the maintenance department become involved from the beginning of the project when the hardware is first installed. In this way, the agency is able to replace worn or defective parts over time. The agency should specify training requirements in an RFP to facilitate these processes.

4.3 Accuracy and Reliability Issues

In general, properly installed and well maintained APC systems are capable of accurately and reliably providing ridership, schedule adherence, and system performance data. Almost all of the properties interviewed expressed satisfaction with the accuracy of their APC data, but they were less satisfied with the reliability of the hardware.

Appropriate data accuracy levels depend on the intended uses of the data. The relative satisfaction of the agencies with the accuracy of their data is thus determined by the extent to which agencies believe APC error will influence decisions based on the data. APC data accuracy has been tested by a number of agenices, consultants, and suppliers (see, for example, UMTA 1982; National Research Council 1984; City of Calgary 1983).

APC data accuracy issues are summarized as follows:

1. Under conditions where manual checkers have been aware that their performance was being evaluated, tests comparing the accuracy of manual counts to APC counts have concluded that there is no significant difference in the relative accuracy. In tests conducted by individual properties comparing APC data to data obtained by either management staff or revenue information, the accuracy of APC data was demonstrated at between 98-100% within ±1.

2. Studies have shown treadle mats to be slightly more accurate than infrared beams in counting passengers. Although more factors influence the accuracy of beams than of mats, this accuracy difference is significant only when beams cannot meet the specified accuracy levels of individual properties.

3. Major factors affecting the accuracy of both types of counting sensors are: children carried on-board and walking off the bus; people passing on stairwells; and people standing in stairwells. Two types of error are introduced by these conditions: error in total counts and error in passenger load counts. Passenger load is the number of people on-board the bus at any given time.

4. Since APCs tend to count boardings more accurately than deboardings, some properties have used total boardings, boardings per hour, and boardings per mile as indicators of productivity and system performance.

5. "On-off discrepency", or the difference between boarding and deboarding counts, must be take into account when APCs will be used to obtain maximum load counts, maximum load points, and load as a percent of capacity. There are at least three measures which can minimize the impacts of the conditions causing on-off discrepencies:

   (a) door switches can be used to control or monitor counts taken when bus doors are closed;

   (b) buses with narrow stairwells allowing passage of only one passenger stream at a time can be APC equipped; and

   (c) software routines can identify trends in the occurrence of on-off discrepency and assign weights to boardings or deboardings at specific points to compensate for observed differences.

6. At most properties, differences between ons and offs that amount to more than 10-15% of the counts for runs are not tolerated and these data are discarded. When this procedure is used, it should be applied to the lowest feasible level of disaggregation to minimize the amount of data lost.

7. The accuracy of location data presented the greatest difficulty for some user properties. Signposts can significantly increase the accuracy of location data especially when the signposts are used at major time points and end points of trips. Systems using signpost techniques which reset the APC odometer to zero at specific intervals have accurate location referencing. Other systems which record the signpost field entry and exit codes and use software to interpolate between the two points to derive location have also been successful, but more sophisticated software is required for this method.

8. APCs are capable of disaggregating to the bus stop level; but this level of disaggregation is often not desired because the volumes of data are overwhelming and because the costs of obtaining stop-level data outweigh the benefits.

Reliability issues with APC hardware are summarized as follows:

1. Most properties report that unit reliability is a problem; but, the general concensus is that proper system maintenance, monitoring and operational procedures significantly improve the reliability of the hardware. APC transit personnel are quoted as saying: "these systems require alot of babysitting"; "the data are as good as people make them"; "these systems do not run by themselves, especially in the beginning"; and "a large commitment of time is required to get these systems up and running and functioning properly."

2. Major reliability issues of mats are: damage caused by wheelchairs; damage caused during repair of wheelchair lifts; and water infiltration. To minimize these affects: mats can be used on buses with no wheelchair lifts; mats can be placed on the first step and floor level; maintenance personnel can be trained in the function of APC hardware and wiring; and stairwell heaters can be used to decrease the impacts of water and melting snow and ice.

3. Major reliability issues of the beams are: improper lighthead alignment preventing the completion of the light stream; passenger hands on stanchions blocking the streams; dust accumulation on the lightheads or reflectors preventing light transmission or reception; lightheads being knocked out of alignment by passengers; and scratched reflector surfaces. These issues can be resolved by proper bus and APC maintenance and monitoring procedures and by optimal positioning and installation of the lighthead pairs and reflectors.

4.4 APC Benefits

APCs are viewed by user properties as a powerful tool for transit planning, operations, and management. Although properties are quick to caution about the need to approach APC implementation slowly and to realistically assess the required commitment of resources, almost all of the properties stated without hesitation that they would repeat their APC experiences.

The expansion of APC applications to six additional North American properties within the last three years attests to the general viability of the technique. The value of APCs for small properties is evidenced in Michigan's plans to apply APCs to three additional small transit districts in the state. The Michigan Department of Transportation's decision to implement APCs at these properties was based on the perceived cost-effectiveness of the APC project at Kalamazoo, Michigan, a property comparable in size and service area population to Lane Transit District.

APC benefits are realized both in the short and long run. In the short run, APCs reduce the need for manual data collection activities; in the long run, when an APC system is fully operational, this need is completely eliminated. In addition, unlike manual data collection techniques which require time and money commitments for training, supervising, and periodic hiring of part-time workers, APCs are autonomous and continuously available. Although some operational costs are associated with the use of APCs, studies comparing manual to automatic data collection methods have found that the on-going costs of manual methods exceed the on-going costs of automated techniques for comparable data collection efforts.

Other APC benefits are more difficult to quantify, but nevertheless contribute to the overall cost-effectiveness of APCs. One such benefit is the significant reduction in turn-around time between observation and reporting of events. Very long turn-around times are usually associated with manual data collection techniques. With APCs, reports can be produced within one week from the time observations are made.

Because automatic counting systems efficiently generate accurate data on passenger activity by location and time, APCs demonstrate their most immediate effects in transit planning. For planning, APCs provide access to a much larger pool of information to assess the current and future needs of the transit population. For example, APCs provide on-going and ready access to data on passenger loads, route profiles, and load as a percent of capacity. With the use of APC technology, this information can be available on a daily, weekly, monthly, or quarterly basis. Access to this information is an important asset in locating bus stops and bus shelters and in devising route restructuring strategies. An indirect benefit of APCs could be the increased public support for route changes based on more complete data obtained from APCs.

For scheduling activities, the time performance reports generated by APCs provide valuable indicators on how well time schedules match on-the-road conditions. Based on APC data, schedules can be changed to more accurately reflect actual arrival and departure times. Service improvements resulting from APC data also have the indirect benefit of improving public relations and increasing public support for the transit district.

APC benefits are particularly evident in the use of APC information by transit management. The APC benefits most frequently cited by user properties are increased productivity and revenue saved by taking buses off non-productive routes. With APCs, system performance indicators such as passenger miles, passengers per hour, boardings per hour, and boardings per mile, are reported both routinely and on demand for specified time periods. The productivity reports produced from these data are valuable indicators of the system and route performance. The cost savings realized from access to this information can be significant. For example, one property estimates that for every bus taken out of the system, the property saves about $178,000 per year in operating expenses. This estimate does not include capital costs of the bus.

In addition, many properties use APCs to collect and analyze data to fulfill UMTA Section 15 reporting requirements. Due to the high level of accuracy required by Section 15 (95% confidence at ±10% tolerance) for systemwide data, the costs of manually collecting these data are high. A fully operational APC system can perform this task as part of a normal daily routine at minimal additional cost to the property.

Potential benefits of automated data collection techniques are their applications in marketing and policy setting activities. The application of APCs to marketing has been limited because the more immediate applications discussed above have received priority. One property is now developing a marketing strategy based on APC data by integrating it with survey and census data. Similarly, the use of APC data in setting long term transit goals has been limited. Again, this is due primarily to the fact that it is relatively new technology. It is conceivable that APCs will play a valuable role in these endeavors in future applications.

4.4.1 REPORTS

APC data on ridership, time, and location are used to produce three types of reports:

(1) Passenger loading profiles used to identify overloading and underutilization;

(2) Time performance reports used for route scheduling; and

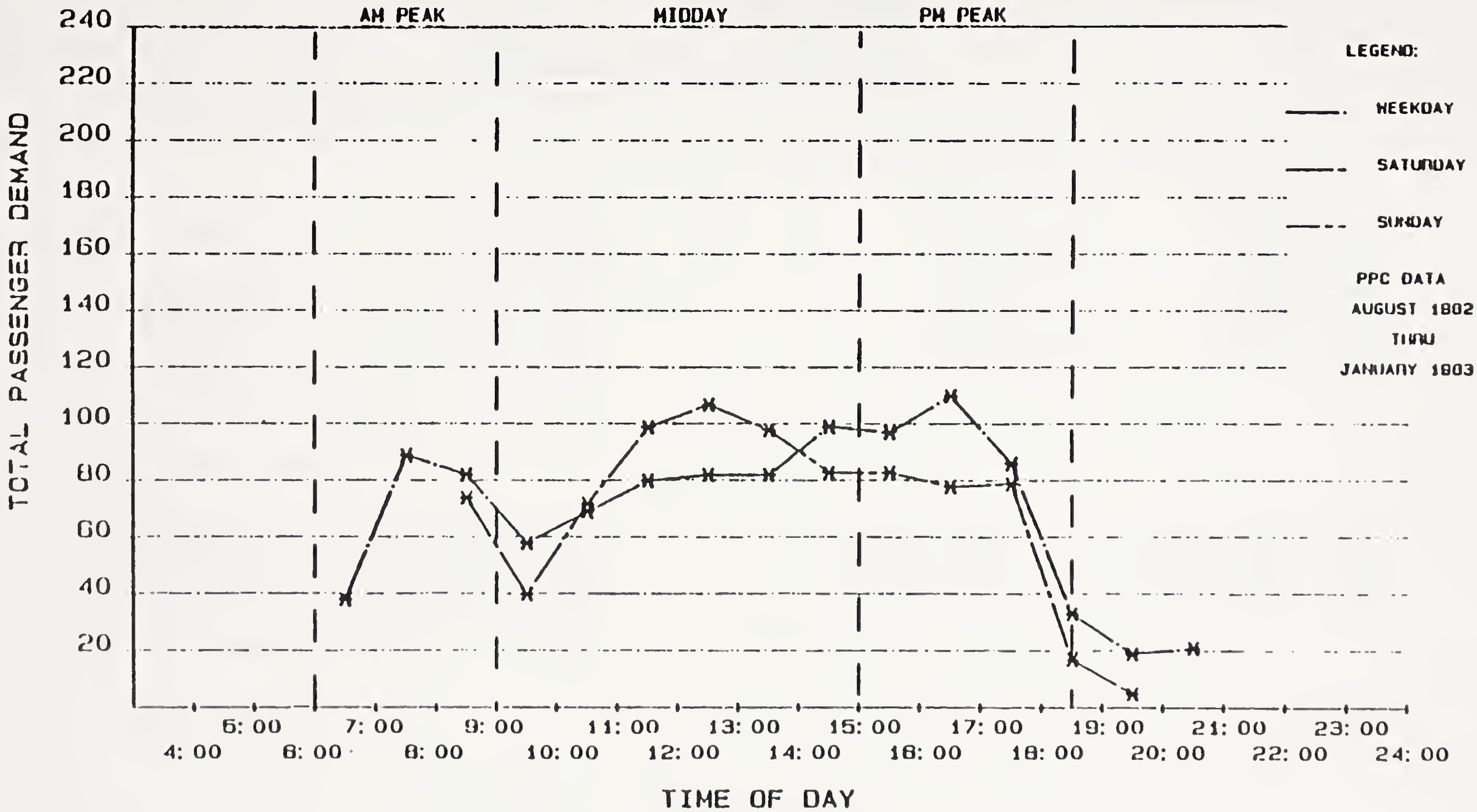
(3) System performance indicators used for transit management.

These reports can be produced for different time periods ranging from 15 minute periods to quarterly or seasonal reports. They are presented in both graphic and tabular format. APC data can be incorporated with survey data for trend analyses, but additional programs are needed for this purpose. The sample reports on the following pages serve as examples.

KALAMAZOO METRO TRANSIT SYSTEM

RT #1 WESTNEDGE

TOTAL DAILY ROUTE DEMAND PLOT



URBAN TRANSPORTATION ASSOCIATES

SCHEDULE DEVIATION REPORT FOR SCHEDULING DEPARTMENT
FOR 01-09-79

JAN 10,1979 PAGE 0001

LINE 041 EARLY THRESHOLD MN:SS 01:00 LATE THRESHOLD MN:SS 10:00

RUN 01 DIVISION 02 BUS NUMBER 7200

DIRECTION NORTHBOUND

TIMEPOINT (DEVIATED)	TRIP NUMB		THIS RUN SCHEDULE DEPART HR:MN:SS	THIS RUN DEPARTURE DEVIATION MN:SS	REMARKS		PREVIOUS RUN SCHEDULE DEPART HR:MN:SS	PREVIOUS RUN DEPARTURE DEVIATION MN:SS		FOLLOWING RUN SCHEDULE DEPART HR:MN:SS	FOLLOWING RUN DEPARTURE DEVIATION MN:SS
ALVARADO/PICO	1070		06:00:30	+01:33			05:39:30	0:00		06:28:30	0:00
MONTANA/LIBERTY			06:20:00	+01:45			06:00:00	0:00		06:40:00	0:00
ALVARADO/6TH	1080		07:23:30	+01:45			07:12:30	0:00		07:31:00	0:00
ALVARADO/PICO	1090		08:33:30	-11:30			08:20:30	+02:00		08:47:00	0:00
ALVARADO/6TH			08:40:30	-13:30			08:27:30	+02:30		08:53:30	0:00
DRIVER NUMBER 6407											
ALVARADO/6TH	1150	13:50:00	13:50:30	+01:45		13:35:00	13:35:30	0:00	14:04:00	14:04:30	0:00
DIRECTION SOUTHBOUND											
ALVARADO/BEVERLY	1070	06:26:00	06:26:30	+01:30		06:05:00	06:05:30	0:00	06:46:00	06:47:00	0:00
ALVARADO/6TH		06:29:00	06:29:30	+02:00		06:08:00	06:08:30	0:00	06:49:00	06:49:30	0:00
ALVARADO/PICO	1080	07:53:00	07:53:30	-11:30		07:42:00	07:42:30	-06:15	08:03:00	08:03:30	0:00
BANDARB/FIGUEROA		08:09:00	08:17:00	-05:30		07:58:00	08:04:00	-01:30	08:19:00	08:30:00	0:00
BANDARB/FIGUEROA	1150	14:40:00	14:54:00	+01:30		14:25:00	14:42:00	0:00	14:55:00	15:09:00	0:00

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SOURCE: GOULD, Inc.

****
ROUTE ANALYSIS REPORT
****

KALAMAZOO METRO TRANSIT
ROUTE 1
WESTNEDGE
SOUTH

NO. WEEKDAY SAMPLES FOR
NOV 1982

SCHED DEPT TIME	BLK NO.	SEGMENT 1 MICHIGAN/ROSE FOREST/WESTNEDGE ON	OFF	RUN TIME	MAX LOD	SEGMENT 2 FOREST/WESTNEDGE DENWAY/WESTNEDGE ON	OFF	RUN TIME	MAX LOD	SEGMENT 3 DENWAY/WESTNEDGE SOUTHLAND MALL ON	OFF	RUN TIME	MAX LOD	SEGMENT 4 MICHIGAN/ROSE SOUTHLAND MALL ON	OFF	RUN TIME	MAX LOD	SEGMENT ON	OFF	RUN TIME	MAX LOD	ON	OFF	RUN TIME	MAX LOD
5:50A	1	8	8	6	8	14	14	9	10	11	11	9	11	0	0	0	0								
6:20A	2	6	6	5	6	7	7	6	7	6	6	5	6	0	0	0	0								
6:45A	1	8	8	6	8	14	14	9	13	11	11	11	11	0	0	0	0								
A 7: 6A	11	0	0	0	0	0	0	0	0	0	0	0	0	5	5	4	5								
7:15A	2	6	6	6	6	7	7	7	7	5	5	5	5	0	0	0	0								
A 7:35A	11	0	0	0	0	0	0	0	0	0	0	0	0	4	4	3	4								
7:45A	1	9	9	7	9	14	14	9	14	10	10	8	9	0	0	0	0								
8:15A	2	6	6	6	5	7	7	7	5	6	6	6	5	0	0	0	0								
8:45A	1	8	8	7	5	13	13	9	12	10	10	9	6	0	0	0	0								
9:15A	2	7	7	7	7	7	7	7	7	6	6	6	6	0	0	0	0								
9:45A	1	8	8	8	8	12	12	8	12	10	10	10	10	0	0	0	0								
10:15A	2	7	7	7	7	7	7	7	7	7	7	7	6	0	0	0	0								
10:45A	1	8	8	8	8	13	13	10	11	10	10	10	9	0	0	0	0								
11:15A	2	5	5	5	5	7	7	7	7	5	5	5	3	0	0	0	0								
11:45A	1	8	8	8	7	13	13	9	11	11	11	10	10	0	0	0	0								
12:15P	2	6	6	6	6	7	7	7	7	6	6	6	5	0	0	0	0								
12:45P	1	8	8	8	8	14	14	12	12	10	10	10	6	0	0	0	0								
1:15P	2	7	7	7	7	7	7	7	6	6	6	4	4	0	0	0	0								
1:45P	1	9	9	9	9	13	13	10	13	10	10	9	9	0	0	0	0								
2:15P	2	6	6	6	6	7	7	6	7	6	6	5	5	0	0	0	0								
2:45P	1	8	8	7	8	13	13	11	12	9	9	9	6	0	0	0	0								
3:15P	2	6	6	6	6	7	7	7	7	6	6	5	4	0	0	0	0								
3:45P	1	8	8	8	7	12	12	9	11	9	9	9	4	0	0	0	0								
A 4:15P	12	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	1								
4:15P	2	7	7	7	6	7	7	7	4	6	6	5	5	0	0	0	0								
A 4:45P	12	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1								
4:45P	1	9	9	9	9	14	14	13	12	10	10	10	5	0	0	0	0								
5:15P	2	7	7	7	7	7	7	7	7	6	6	5	5	0	0	0	0								
A 5:20P	12	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	2								
5:45P	1	8	8	7	7	13	13	9	12	10	10	10	7	0	0	0	0								
6:15P	2	7	7	7	6	7	7	7	6	7	7	6	6	0	0	0	0								
B 6:45P	1	4	4	4	4	4	4	4	3	4	4	4	3	0	0	0	0								
B 7:15P	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0								
B 7:45P	1	4	4	4	3	4	4	4	4	4	4	3	3	0	0	0	0								
B 8:15P	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0								

GM TRANSPORTATION SYSTEMS
TRANSIT INFORMATION SYSTEM

****
ROUTE PRODUCTIVITY REPORT
****

KALAMAZOO METRO TRANSIT
ROUTE 1
WESTNEDGE
NORTH

WEEKDAY AVERAGES FOR
NOV 1982

TIME PERIOD TOTALS

TIME PERIOD	TOTAL ON	TOTAL OFF	NO. OF VEH. TRIPS	SEAT-MILES	SEAT-HOURS	PASS.-MILES	PASS.-HOURS	LOAD* FACTOR	OCCUP** FACTOR
AM PEAK 6: 0A- 8:59A	98	46	8	1502.0	90.9	449.4	30.9	29.9	34.0
MID DAY 9: 0A- 2:59P	173	136	12	2320.3	157.5	782.8	62.3	33.7	39.5
PM PEAK 3: 0P- 5:59P	83	108	9	1518.4	94.0	458.8	34.7	30.2	36.9
NIGHT 6: 0P-10: 0P	26	25	8	956.7	51.3	182.4	14.4	19.1	28.0
ALL DAY 5: 0A-10: 0P	380	315	37	6297.4	393.8	1873.4	142.2	29.7	36.1

*LOAD FACTOR = PASS.-MILES/SEAT-MILES X 100%
**OCCUP FACTOR = PASS.-HOURS/SEAT-HOURS X 100%

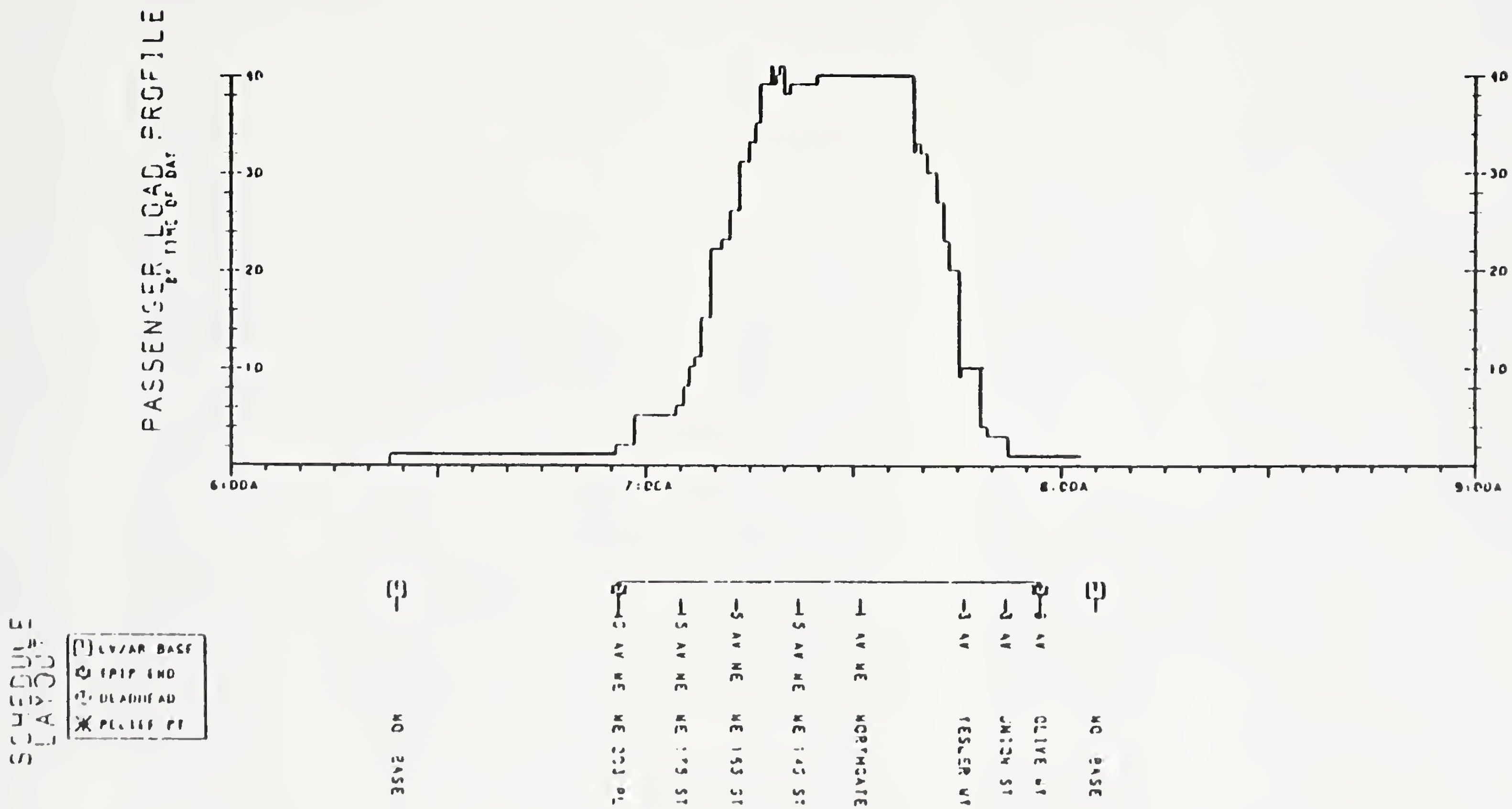
KALAMAZOO ROUTES

HISTORICAL RIDERSHIP SUMMARY
AUGUST 1982 -- JANUARY 1983

WEEKDAY

ROUTE	RUN	DATE	VEH	ON	OFF	PASS-MILES	PASS-HOURS	DAILY MILES	DAILY HOURS	TRIP LNTH	TRIP HURN	PASS PER MILE	PASS PER HOUR	VEL (MPH)	LOAD FACTR	MAX LOAD	MIN LOAD	AVG LOAD	SEAT MILES
		09/30/82	1030	369	413	791	58	181.6	13.6	1.8	.14	2.3	30.4	13.4	.115	26	0	5	6938
		10/10/82	1035	376	437	691	51	185.5	13.6	1.6	.12	2.4	32.1	13.6	.103	18	0	4	6678
		10/19/82	1035	371	439	618	47	166.5	12.3	1.4	.11	2.6	33.7	13.5	.103	16	0	4	5994
		10/21/82	1025	335	412	636	47	186.6	13.8	1.5	.11	2.2	29.9	13.5	.075	17	0	4	6718
		11/09/82	1011	307	441	740	58	181.1	13.8	1.7	.13	2.4	32.0	13.1	.113	20	0	5	6520
		11/11/82	1030	345	393	841	64	181.4	13.8	2.1	.16	2.2	28.5	13.1	.129	19	0	5	6530
		11/29/82	1031	364	445	659	48	183.1	13.7	1.5	.11	2.4	32.5	13.4	.100	20	0	4	6592
		11/30/82	1027	370	428	840	65	184.7	13.0	2.0	.15	2.3	31.0	13.4	.126	19	0	5	6649
		12/02/82	1015	360	420	817	63	177.3	14.2	1.9	.15	2.4	29.6	12.5	.120	24	0	5	6383
		12/23/82	1017	210	266	612	42	183.3	13.7	2.3	.16	1.5	19.4	13.4	.093	23	0	3	6399
		01/04/83	1019	377	455	601	45	181.8	13.7	1.3	.10	2.5	33.2	13.3	.092	21	0	4	6545
		01/10/83	1031	356	425	652	52	181.7	13.7	1.5	.12	2.3	31.0	13.3	.100	24	0	4	6541
		01/13/83	1017	307	457	547	43	182.0	13.7	1.2	.09	2.5	33.4	13.3	.083	18	0	4	6552
		02/03/83	1029	416	482	662	54	182.4	13.7	1.4	.11	2.6	33.2	13.3	.101	22	0	5	6566
		02/04/83	1015	403	457	818	65	180.2	13.7	1.8	.14	2.5	33.4	13.2	.126	23	0	5	6487
	MEAN			357	409	930	71	178.0	13.7	2.4	.18	2.3	30.1	13.1	.144	22.4	M	5.7	6437
	STDEV			45	54	1015	76	14	0			0	4	1	.149	10	M	5	
MEAN				374	423	1346	103	170.4	13.4	3.1	.24	2.5	31.7	12.6	.219	20	M	8	6035
STDEV				39	78	1709	143	32.0	.6	4.5	.3	3.3	6.7	2.3	.203	20.3	M	11.0	1338
MAX				631	844	8244	617	194.7	14.2	20.8	1.5	30.1	76.0	14.2	1.274	77.0	M	40.0	7016
MIN				210	262	107	30	20.0	10.7	.1	.0	1.5	17.4	2.5	0.0	13.0	M	3.0	0.0
VALIDN				78	78	77	78	77.0	78.0	77.0	78.0	77.0	78.0	77.0	78.00	78.0	0.0	78.0	78.0
SUM				29101	33005	*****	8024	13120	1042	247	19.0	228	2530	980.3	16.39	2214	M	638	*****

VEHICLE ASSIGNMENT 477/ 6 WEEK DAY
FRIDAY JUNE 11, 1982
COACH NUMBER 1305 PROCESS DATE 10/02/82 14 16 PCU DEVICE 13



4.5 APC Costs

There are two cost factors to consider in assessing the cost-effectiveness of APCs: total cost and relative cost. Table 4.4 displays the total cost of an APC system consisting of on-board equipment for 20 buses, a minicomputer, 50 signposts, including all installation, wiring, miscellaneous costs and software acquisition costs. These estimates are based, whenever possible, on direct quotes from suppliers. Otherwise, a range of costs is presented which is based on the prices of the most recently purchased systems. The large disparity between the low and high estimates is due to the costs of the various hardware options and to the wide range in software costs. The individual case studies contain separate sections on cost, and the reader is referred to Chapter Three for more information on the individual costs of system components.

In Table 4.4, direct costs include capital costs of hardware and software and annual costs of data processing and personnel. The total capital cost of an APC system (including all wiring and installation costs) with 20 APC buses, 50 signposts, mini-computer, and software to create data files ranges from $165,300 to $284,300. Total annual costs include personnel, spare parts, and data processing costs. Although annual costs tend to vary from property to property, the personnel requirements in Table 4.4 are the minimum needed for an effective APC system.

Note from Table 4.4, that the capital cost of an APC system is highly sensitive to software costs, especially for small properties. For small transit agencies, software costs can exceed all other capital costs of the system combined. The most extensive improvements in APC technology have been in software rather than hardware modifications. With few exceptions, the hardware used in current applications is very similar to the technology employed in the earliest APC applications. In contrast, major advances have been made in software design.

The second cost factor to consider is the cost of APCs relative to current data collection methods. This comparison should be based on comparable data collection efforts. APCs generally provide more and better quality data than has been gathered using past manual techniques. The level of effort is determined by the data needs of the individual property. Aside from data needs, other factors enter into the analysis including: peak fleet size; the number sign-ups per year; the type of method currently used; the number of people employed to collect data; and the number and type of APC system components. These factors are displayed for current APC user properties in Table 4.5. Although no analysis of these variables has been performed for the purposes of this study, this table illustrates one means of making this comparison.

Figure 4-1 displays the relative costs of APCs. This comparison was made by Deibel and Zumwalt in 1984. According to the analysis performed by these authors, for large transit agencies, which utilize a large checker staff, the annual cost of APCs approximates the annual cost of checker salaries alone. When based on comparable data collection efforts, their analysis reveals that APCs are significantly more cost-effective than manual methods for large properties.

Since many small transit agencies rely on smaller sample sizes and often do not retain permanent checker staffs, cost-effectiveness of APCs for small agencies is more a function of the agencies' perceived data needs. These agencies should compare the benefits of APC data (including both direct and indirect benefits) to the costs.

Table 4.4: Estimated Total Costs Of APC Acquisition And Implementation

Fixed Costs	Low Estimate	High Estimate
On-board equipment (20 buses) (counter and door sensors, DCU, signpost antennae including installation and 2 year warranty)	$ 76,300	$136,300
Signposts (50) (including installation and 2 year warranty)	$ 64,000	$ 64,000
Data Retrieval Device	$ 4,000	$ 14,000
Minicomputer	$ 6,000	$ 10,000
Software Acquisition[1]	$ 15,000	$ 60,000
Total Fixed Costs:	**$165,300**	**$284,300**
Annual Costs		
APC Technician[2]	1 FTE	1.5 FTE
APC Maintenance[3]	.2 FTE	.5 FTE
Data Processing	NA	NA
Training, manuals, spare parts	NA	NA

Notes:

1. Includes only the cost of programs to create data files.
2. Assumes project supervision will be performed by existing staff.
3. Maintenance will increase as the system ages.

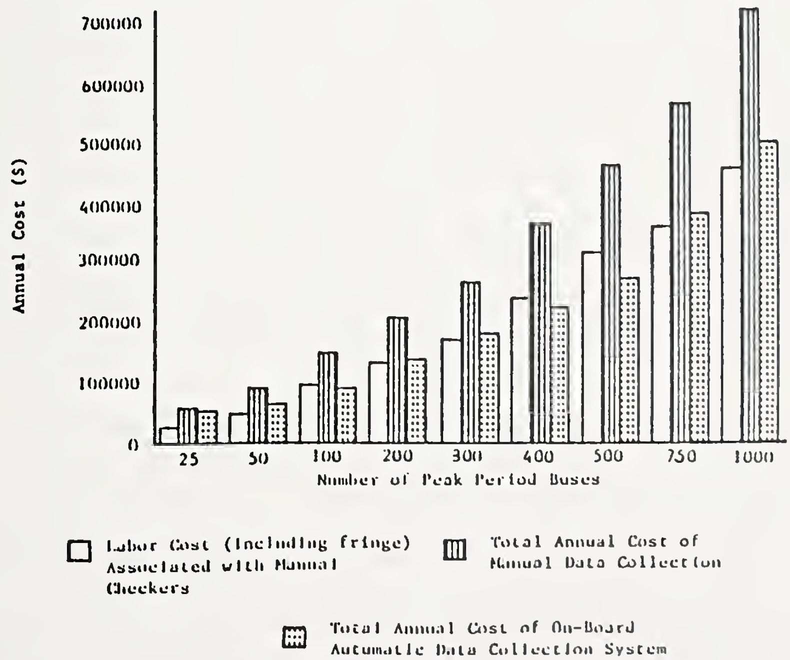
Table 4.5: Comparison Of Manual To Automatic Data Collection Methods

	Property Characteristics		Manual Methods		APC Methods	
	Peak Fleet	#Sign-ups Per Year	Number	Type	#APC Buses	#Signposts
APC SYSTEMS						
Seattle	915	3	8	Ride checker	116	226
Ottawa	710	4	8	Ride checker	66	32
Kalamazoo	31	NA[1]	NA	Driver counts	20	35
London	152	NA	NA	Driver counts	18	0
Windsor	78	4	NA	Driver counts	27	43
Calgary	435	NA	3	Checker	5	0
Portland	424	5	5	Ride checker	43	0
Columbus	294	3	4	Ride checker	20	50
Chicago	950	5	28	Checker	6	450[2]
Kitchener	70	NA	20	Checker	20	0
Mississauga	135	NA	NA	NA	30	0
AVM-APC SYSTEMS						
Toronto	1621	NA	NA	NA	100	45
Los Angeles	2100	NA	34	Checker	200	900

Notes:

1. NA: Information not available or not applicable
2. Chicago uses signposts for emergency response as well as APCs.

Figure 4-1: Comparison Of Manual And Automated Data Collection Costs



Source: "Modular Approach To On-Board Data Collection Systems". Lawrence E. Deibel and Barbara Zumwalt, Mitre Corporation, McLean, Virginia. For the National Research and Development Program. Report 9. 1984

4.6 APC System Implementation

The first question agencies must address is whether or not to implement an APC system. The response should be based primarily on an evaluation of the agency's data needs. This evaluation should identify intended uses of the data. If an agency decides to implement an APC system, it can base its APC functional requirements on these specified data needs. Figure 4-2 suggests uniform functional requirements for APC systems. These requirements were proposed by the Canadian Urban Transit Association (APC Functional Requirments Definition. 1983) in an effort to encourage uniformity in the design of APC systems.

In deciding the appropriate number of buses to APC-equip, agencies need to consider several factors including: intended uses of the data; fleet size; route structure; and average expected down time of the system. Generally, routes need to be sampled about five times during a sign-up to obtain an adequate three day sample; but experience with the system over time will provide additional information on both data needs and appropriate sample size. Incremental hardware acquisition is advised to allow identification of unanticipated data needs and a realistic assessment of adequate sample size. Another advantage of incremental hardware acquisiton is that it minimizes up-front capital costs of the system. A general rule adopted by many agencies is to equip 12% of the fleet. The rough estimate derived from this rule can be used to assess the long-term costs of the system.

In making individual estimates of sample size, agencies need to take the average down time of the system into account. Although this varies from property to property, many agencies report that about 80% of the vehicles are available on any given day. Because the age and condition of APC buses affect the down time of the system, newer buses in good condition should be APC equipped.
Operational procedures have been one of the biggest impediments to successful APC implementation. For some properties, there have been problems assigning buses to routes and/or verifying APC bus assignments. This type of problem is particularly evident in cases where APCs interfere with other transit functions. For example, bus driver or security guard involvement in APCs has not proven very reliable since these employees have responsibilities which take priority over APC data transfer or monitoring. Also, at agencies where APCs have been viewed by drivers as a threat, sabotage of the hardware and a lack of driver cooperation have resulted.

APC system implementation and operation are complex processes, requiring a large commitment of time. The flow chart in Figure 4-3 (City of Calagary Report. 1983) provides a clear indication of the degree of human involvement in APC systems and the complexity of the data collection process. This flow chart illustrates the need for both interdepartmental cooperation and a project coordinator (APC specialist discussed in section 4.2.3). At Calgary, at least five departments are involved in the process: schedules, planning, maintenance, dispatching, and electric systems. Although this process and the participating departments vary from property to property, the involvement of dispatching, planning (including scheduling), and maintenance is necessary for all systems. Interdepartmental cooperation is essential for successful APC implementation, and the system works best when all departments (planning, maintenance, dispatching, etc.) have a stake in the outcome of the project. Cooperation may be elicited, especially when resistance is anticipated, by the strong support of transit management and by the use of incentives.

Figure 4-3 also illustrates the complexity of APC systems, emphasizing the need for a project coordinator. For example, there are several steps involved just in the deployment of APC coaches to their assigned routes. Seattle uses a calender system for this purpose. This system is illustrated in Figure 4-4. The calender is prepared by planning on a weekly basis and sent to dispatching where the actual assignments are made. To create this calender, it is necessary to determine which routes to sample for a given time period, day, and season. The system must also take into account the number of times routes need to be sampled to estimate between-day, within-day, and seasonal variation. The data must be validated and some routes may need to be resampled. These are just a few of the steps required to obtain adequate samples. Yet, this element represents only a part of the overall data collection process.

4.7 Summary

Many APC systems have achieved the objectives originally established by the user properties and the majority of the transit agencies interviewed stated that they would repeat their APC experience. APCs have been used by small as well as large properties and type of route structure is not a factor influencing the application of APC systems. All of the properties using APCs are peak-oriented systems.

The status of existing APC systems is displayed in Table 4.6. All properties in Table 4.6 are currently undertaking either initial APC installation or system modifications. These modifications are fully explained in the case studies in Chapter Three and the reader is advised to refer to this chapter for a complete description of these systems. This information is summarized in Table 4.6 to provide an easy reference for the reader and to illustrate the tendency of user properties to expand and modify their APC systems over time.

In sum, there are a variety of hardware and software options open to transit agencies contemplating or planning a conversion to automated data collection techniques. Choice of system components is a function of the agency's data needs and resources. Because these conditions vary from property to property, agencies should conduct their own analyses based on their perceived data needs, available resources, present methods, and property characterisitics. The benefits, costs and operational considerations outlined in this chapter can serve as a guide for these analyses.

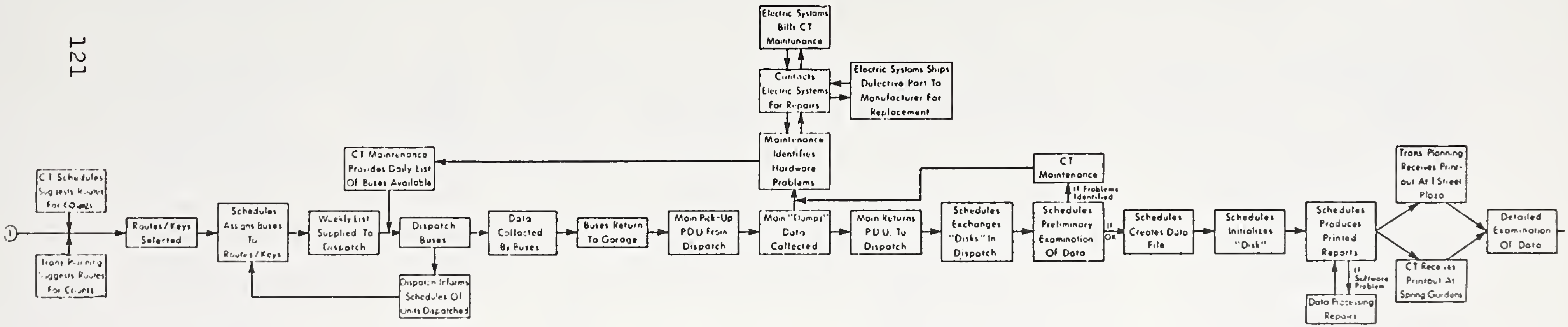
Successful implementation of an APC system requires a high level of interdepartmental cooperation, carefully designed procedures, and a large commitment of time on the part of transit agency staff directly involved with the project. The level of commitment made to the project is a key factor influencing the successful and timely operation of the system. If agencies are unable to commit sufficient resources, including personnel, to the project, more time will be needed for the system to become fully operational.

AUTOMATIC PASSENGER COUNTING SYSTEM

- **Data Acquisition**
  - Sense Door Activity
  - Sense Passenger Movement
  - Sense Odometer Pulses
  - Sense Signpost Signal
- **Data Recording**
  - Record Door Opening/Closing
  - Record Passenger Ons
  - Record Passenger Offs
  - Record Distance
  - Record Time
- **Data Transfer**
  - Transfer to Storage Media
  - Transfer Data to CPU
- **Data Processing**
  - Create Schedule File
  - Merge Raw APC Data
  - Edit APC Records
  - Produce APC Master File
  - Produce APC Reports

Figure 4-2: AUTOMATIC PASSENGER COUNTING SYSTEM FUNCTIONAL BREAKDOWN
Source: "APC Uniform Functional Requirements Definition". Canadian Urban Transit Association. 1983

Figure 4-3: Automated Data Collection Process



DATA COLLECTION PROCESS
FLOWCHART - Automatic Bus
Passenger Counting Program

CITY OF CALGARY -- TRANSPORTATION DEPARTMENT

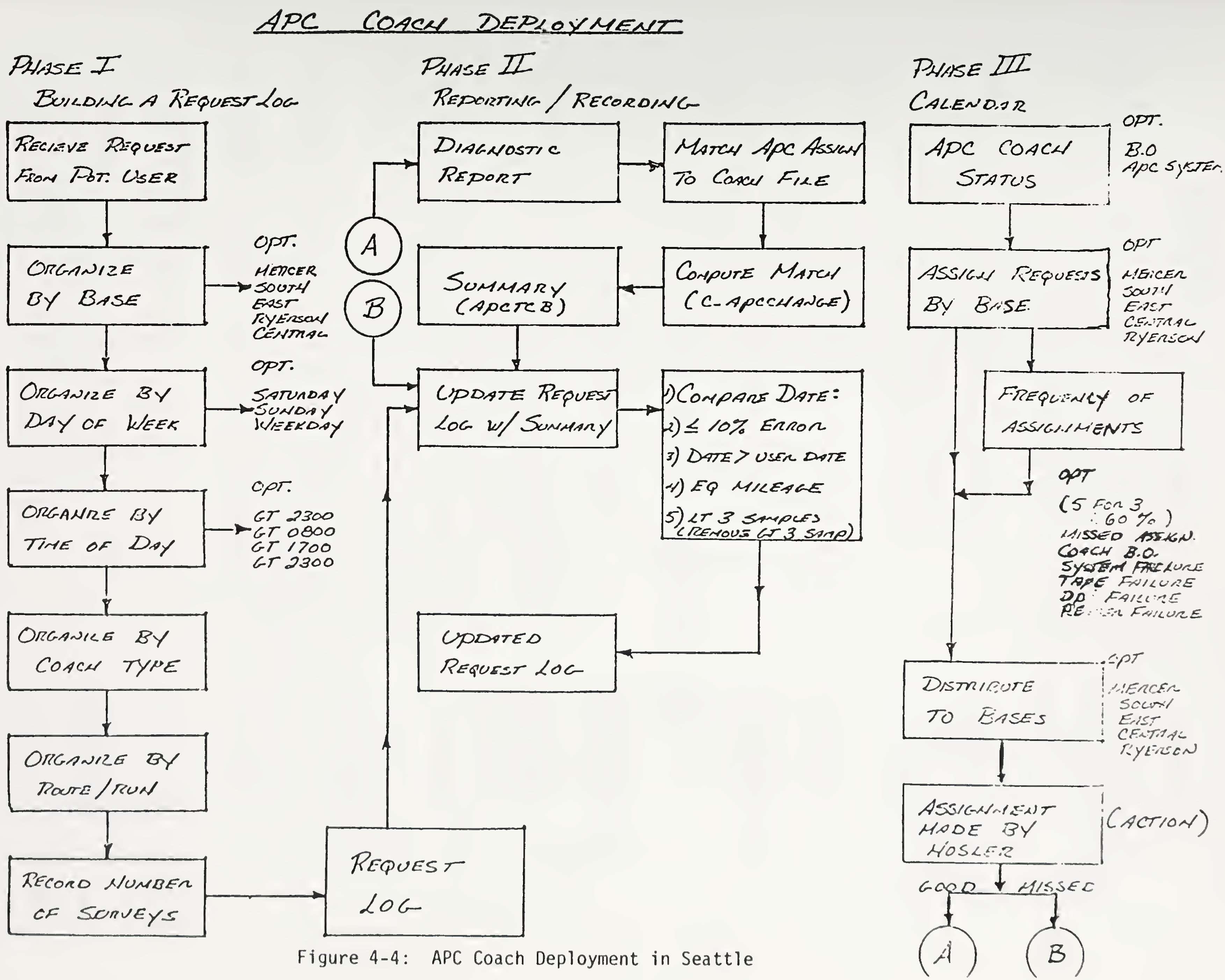


Figure 4-4: APC Coach Deployment in Seattle

Table 4.6 : Modifications Of Existing APC Systems

	Implementation Year	Modification	Status
APC Systems			
Seattle	1978	Equip 60 more buses	Installed; Expect Completion Sum '85
		Software Development for stop-referencing	Completed
Ottawa	1978	Upgrade hardware	In progress
		Install 32 signposts	Testing 3 prototypes
		Manual to radio-link transfer conversion	Hardware installed
		Software development	Expect completion 3/86
Kalamazoo	1980	Purchase IBM PC AT	
		Purchase software to process APC data in-house	In progress
London	1981	Improve treadle sensor mats	In progress
		Expand APC system	Long-range goal
Windsor	1981	Increase disk capacity	Planning
		Obtain programmer documentation	RFP
		Remedy signpost problem	RFP
Calgary	1982	Equip 20 more buses	Market study
		Equip total fleet	Long-range goal
Portland	1982	Switch door sensor design	Planning
		Repair sensors under warranty	In progress
		Equip 10 more buses	Planning
		Software enhancement	In progress
Columbus	1982	Install 20 APCs and 50 signposts	In progress
Chicago	1983	Begin first phase of APC acquistion and implementation	Funding approved
		Equip 270 buses	Long-range goal
Kitchener	1985	APC hardware and software installation and implementation	In progress
Mississauga	1985	APC system implementation	In progress
AVM-APC Systems			
Toronto	1978	Equip 150 buses	Writing specifications
Los Angeles	1980	Evaluate present system	Hired specialist
		Upgrade hardware	Evaluating
		Enhance software	Evaluating
		Equip 100% fleet with radio transmitters	Planning

Chapter Five

Conclusions And Recommendations

Use of APC techniques in North America has been limited, with less than twenty transit agencies having operational APC systems. The duration of APC use in North America has also been limited, beginning in 1978 in Seattle and Ottawa. Furthermore, all of the researched systems installed since 1978 are now being expanded or modified to increase cababilities or improve reliability.

APC hardware and software are capable of accurately and reliably collecting and analyzing data on transit passenger counts, running times, and location. Hard copy reports on overloading and underutilization conditions, schedule adherence, and system performance indicators can be produced by APC systems. Data turnaround time can be less than one week.

For these reasons, many transit agencies would do well to implement APC systems. This general conclusion does not apply to all agencies, however, since the applicability of APCs to individual transit agencies depends on a variety of factors. Of these, intended use of the data is the most important. Other critical issues are: APC system components, data accuracy and reliability, cost-effectiveness, and implementation. The following conclusions address major concerns related to each of these factors. These conclusions are followed by recommendations on APC implementation at Lane Transit District.

Conclusions

1. The decision to convert to automated data collection techniques should be based on a careful evaluation of an agency's data needs. The intended uses of the data should be the overriding consideration in both the decision to implement an APC system and the specifications for an APC system.

2. Appropriate sample sizes and accuracy levels are determined by the intended uses of the data. For example, properties using APC systems in conjunction with real-time monitoring systems (AVM) have high accuracy standards for location data since the data are primarily used for operations control and emergency response.

3. The majority of properties surveyed expressed satisfaction with the accuracy of their APC data. The accuracy of location data presented the greatest difficulty for some user properties. Signposts can significantly increase the accuracy of location data especially when the signposts are used at major time points and end points of trips.

4. Most properties report that unit reliability is a problem; but, the general concensus is that proper system maintenance, monitoring and operational procedures significantly improve the reliability of the hardware.

5. The most extensive improvements in APC technology have been in software rather than hardware modifications. With few exceptions, the hardware used in current applications is very similar to the technology employed in the earliest APC applications. In contrast, major advances have been made in software design.

6. Fortran programs are often used to create data files; and SPSS packaged software is frequently used to access data files and generate reports. Software modifications needed to convert the Fortran programs for use on different host computers comprise a major portion of the software costs.

7. Programmer documentation is needed to modify and enhance the software over time. Well written users' manuals facilitate use of the system.

8. Personnel is a key but often underestimated component of an APC system. Minimal personnel requirements reported by APC properties include at least one full time person to manage and coordinate the APC project and at least one person half-time to maintain the hardware.
Transit personnel are quoted as saying: "these systems require alot of babysitting"; "the data are as good as people make them"; "these systems do not run by themselves, especially in the beginning"; and "a large commitment of time is required to get these systems up and running and functioning properly."

9. The capital cost of an APC system is highly sensitive to software costs, especially for small properties (100 peak buses or less). For small transit agencies, software costs can exceed all other capital costs of the system combined.

10. The cost-effectiveness of APCs is determined by comparing the benefits of the system to the costs and by comparing the costs of current data collection methods to APC costs. The comparison of APCs to current methods must be measured by comparable data collection efforts.

11. Some of the costs and benefits of APCs are difficult to quantify; and indirect benefits as well as direct benefits of the system should be identified.

12. Depending on the extent and expense of current data collection efforts, APCs can be significantly more cost-effective than manual methods. For large agencies with permanent checker staffs, APCs approximate the costs of checker salaries alone. For small agencies (less than 100 peak buses), the cost-effectiveness of APCs is less precisely defined. Individual agencies need to determine whether the benefits (including indirect benefits) of APCs justify the costs.

13. The functional requirements of an APC system depend on the data needs and resources of individual properties. For example, APCs are capable of disaggregating to the bus stop level; but this level of disaggregation is often not desired because the volumes of data are overwhelming and because the costs of obtaining stop-level data do not outweigh the benefits.

14. Operational procedures have been one of the biggest impediments to successful APC implementation, particularly when other transit functions have taken priority over APCs. Thus, interdepartmental cooperation is essential for successful APC implementation. The system works best when all departments (Planning, Maintenance, Operations, and Management) have a stake in the outcome of the project.

15. APC systems are strongly affected by technological change. When hardware becomes obsolete, spare parts may be unattainable or difficult to find. The costs of retrofits necessitated by product obsolesence are minimized by incremental hardware acquisition.

16. At transit agencies where drivers have suspected that APCs were monitoring their performance, sabotage of the hardware and a lack of driver cooperation have resulted.

17. Type of bus is not generally a factor in the success of APC systems. However, equipping buses with wide doorways (allowing passengers to pass each other on the stairwells) should be avoided; Articulated buses are more costly to APC equip than standard buses due to the need for sensors at the third door.

18. The availability of APC buses is affected by non-APC maintenance and repair as well as APC maintenance and repair. The age and condition of APC-equipped buses affect the down-time of the system.

Recommendations

1. Lane Transit should conduct a thorough evaluation of its data needs prior to making a final decision to implement an APC system. This evaluation should involve interviewing representatives of appropriate departments at Lane Transit (such as planning, operations, management, finance, marketing, etc.) to identify the types and amount of information needed by each department. This evaluation should be followed by an assessment of present data collection techniques in light of their cost-effectiveness in providing current and newly identified data.

2. Assuming that data needs are identified in #1 which cannot be met effectively by Lane Transit's current methods, Lane Transit should proceed with phased implementation of an APC system. This recommendation is based on the conclusion that, given the need for the volumes and types of data APCs are capable of generating, transit agencies can benefit significantly from the use of APC systems.

3. Lane Transit should develop an APC implementation plan which details a phased implementation process best suited to the agency's personnel, operational, and policy characteristics. The plan should include the following:

   (a) A procedure to disseminate information on APCs, their use, and the roles of the separate departments in the implementation scheme. This may be in the form of an APC committee whose members represent all of the departments within the agency. Each department should feel "ownership" of the system and play a responsible role in the implementation process.

   (b) Clear guidelines identifying the changed procedures in traditional operations brought about by implementation of APCs. In cases where APCs interfere with routine operations, sufficient time for adjustment should be allowed.

   (c) A scheme to enlist the cooperation of all departments. Where resistence is anticipated, incentives can be used to facilitate cooperation. Special efforts should be made to assure drivers that APCs will not be used to monitor their performance.

(d) The assignment of at least one full-time person to the project. If agency resources prohibit the hiring of additional staff and present staff is inadequate to meet this requirement, the agency should anticipate a longer time frame for the system to become fully operational.

(e) Hardware specifications written in fine detail. The specifications should describe: the functional and physical requirements of the hardware; performance standards; warranty requirement; a provision for training on the installation and maintenance of the system including user and repair manuals; and a request for total price quotes including all wiring, cables, brackets, and, if appropriate, installation costs. If possible, the hardware should be installed by Lane Transit maintenance staff in order to increase the agency's competency in long-term system maintenance.

(f) Phased APC implementation proceeding with the purchase or lease of one or two units and signposts in the first year. From these units, more information will be provided on which to base decisions about future purchases.

4. The RFP should be sent to suppliers or vendors for review prior to the formal process of requesting proposals. Suppliers have stated a preference for editing RFPs in order to provide more realistic expectations of the hardware. For the agency, this step will provide additional information on the available systems.

5. With regard to software development, Lane Transit should simultaneously explore three options:

   (a) Purchasing software designed for use on the host computer Lane Transit intends to use for APC data processing;

   (b) Gaining access to programs already developed by or for other transit agencies. If available programs are incompatible with Lane Transit's host computer, modifications can be made either in-house or locally; and

   (c) Pursuing in-house software development or contracting out software development to a local firm or the University of Oregon.

6. Based on user experience, in-house development is a time-consuming process, taking more than 2 person years to complete. This cost, once known, should be compared with the cost of software acquisition. These costs pertain only to the Fortran programs needed to create data files and the command programs needed for SAS or SPSS to access these files and generate reports. (Lane Transit already has access to SPSS and SAS packages.)

7. Programmer documentation and a user's manual should accompany the APC software.

8. Since the condition and age of the buses affect the down-time of the APC system, newer buses in good condition should be APC-equipped.

9. If Lane Transit intends to APC-equip different types of buses in the long-run, the initial installation in the first implementation phase should include each type of bus that will eventually be APC-equipped. If feasible, buses with wide stairwells should not be APC-equipped; and, if articulated buses will be APC-equipped, the additional expense of equipping articulated buses should be accounted for in cost estimates of the system.

Chapter Six

Appendices

Appendix 6.1

APC Hardware Suppliers and Software Developers

Automatic Passenger Counting Systems, Ltd.
635 Newbold Street
London, Ontario, Canada N6E 2T8
TELEX 064-7557

Gandalf Data Limited
Gandalf Plaza
9 Slack Road
Nepean, Ontario, Canada K2G 0B7
613-225-0565

Group Five Consulting Limited
1215 Rooney's Lane
Ottawa, Canada K1H 7Y6
613-521-4413

London Mat Industries, Ltd.
P.O. Box 292 Station B
London, Ontario, Canada N6A 4V8
519-681-2980

Pachena Scientific and Industrial Electronics Inc.
7966 Winston Street
Burnaby, B.C., Canada V5A 2H5
604-420-2023

Red Pine Instruments, Ltd.
RR 1
Denbigh, Ontario, Canada K0H 1L0
613-333-2776

Systemware
425 Mount Pleasant Road
Toronto, Ontario, Canada M4S 2L8
416-481-9480

Urban Transportation Associates
7111 Hamilton Hills Drive
Cinncinati, Ohio 45244
513-232-5283

Appendix 6.2

SURVEY OF AUTOMATIC PASSENGER COUNTER USERS

GENERAL INFORMATION ON PROPERTY AND APC USE

Date of Interview____________

Name of Transit System____

Address____

____
city state zip

Name of Contact Person_____________________ Phone Number_________

Division_____________________ Title___________________________

Division's Functions:

Names of other personnel involved with APC program:

Names Title/Division Phone No. APC Involvement

* What is the size of your transit system in terms of fixed route service?

Total number active vehicles including spares________
Base fleet size_________ Peak fleet size________

* What is the size of the population serviced by your system?______

* How is ridership distributed along routes? (ie: do most routes have a major bus stop, or is ridership spread evenly along most routes?) If there are high use stops, how do you perceive APC error at these STOPS?

* How many buses are equipped with APCS?____________
number of buses

* Of these, how many are operational at any given time?__________

* If APCS are installed on different bus types, is type of bus a factor in the success of the system? Explain:

* On the average, how many person hours does your division spend using the APC data and/or equipment? ___________FTE

* In general, for what purposes do you use APC information or equipment?

()Create, evaluate and adjust schedules and run times
()Plan and justify route changes
()Evaluate marketing strategies
()Estimate expected revenue (farebox accountability)
()Determine fleet needs
()Monitor driver performance
()Determine location of bus stop facilities
()Section 15 reporting
()Other (Describe:)

* Generally, which type of APC system do you use?
() Information System: report-oriented for planning and scheduling
() Control System: screen-oriented operating in real-time.
() Integrated System: combined information and control system.

* (If integrated system is used) To what extent does competition for use of the system create problems or conflicts? How have you resolved or do you plan to resolve these problems?

* Are you satisfied with your present system? In general, what, if any, changes would you make or are you planning to make to your present system?

COUNTING SENSORS

* What type of sensors do you use? (make, source, date of purchase, etc)

* What types of APC COUNTERS do you use?
()Infrared beam interruption
    ()dual beams
    ()multiple beams
()Reflective infrared beams
()Treadle sensor mats
()Ultrasonic interruption sensors
()Other (please describe in detail)

* Where are these counters located on the bus? (describe exact location)

* What are the maintenance requirements of these sensors?

* How do you feel about this equipment? If you were to purchase the counters today, what would you do differently after having had some experience with the present sensors?

ON-BOARD MICROPROCESSING UNIT AND FUNCTIONS

UNIT AND ALGORITHM:

* What type of microprocessor do you use on-board the bus? (Describe make, source, and date of purchase)

* What functions are performed by the counting algorithm of this unit? (e.g. time tags, date tags location and passenger data, etc.)

* Discuss electronic operation and maintenance requirements and costs:

* What type of errors have you encountered with the sensors or the interpretation of the logic algorithm?

* Do the algorithms of this unit identify failures in the passenger counting sensors? How is this accomplished?

* Are errors minimized or avoided by other means? Discuss:

* How much of the individual vehicle trip readings must be discarded due to bad or inconsistent data?

DATA RECORDS:

* What types of data are obtained and stored by the APC Unit?

()passenger boarding counts
()passenger alighting counts
()vehicle arrival times
()location reference
()run, bus number, trip I.D. code initialized for entire run or trip.
(Describe:)

* How is data input activated? ("A" if activates data input)

* Which of the following events are recorded? ("R" if recorded)

door opening, front and rear?___________
door closing, front and rear?__________
begin of idle______
end of idle_______
time between stops______
distance between stops_______
signpost detection______
memory space overflow_______
lift action for handicapped____________
(Describe how this operates)

()other (please describe in detail)

Comments:

LOCATION REFERENCING METHOD:

* How do you reference location of data input?
()computer generated comparison of APC odometer reading to stop by stop distance file
()computer program to search APC records for bus layover intervals, ie: begining and end of idle events
()signpost identification systems for vehicle trip and stop-referencing
()other (please describe in detail)

* Discuss maintenance requirements:

* Are you satisfied with this method? Discuss:

DATA STORAGE:

* What type of data storage mechanism does this unit use?

  ()cassette tape
  ()solid state memory
  ()bubble memory
  ()radio
  ()infra-red
  ()other

* What is the storage capacity of this unit?________bytes

* Are you satisfied with this method? Discuss:

* Is this method compatible with automatic transfer of on-board data to a central computer facility?

* Discuss make, source and date of purchase of microprocessing unit:

* Discuss level of satisfaction with on-board CPU (What, if anything would you do differently if you purchased this unit today?):

DATA TRANSFER DEVICE AND PROCESS

* What type of data transfer mechanism do you use?

  ()portable recording units requiring manual operation
  ()automated retrieval systems
    ()cable data retrieval system; indicate where located, ie: fueling island, etc.
    ()infrared data transmission to receiving sensor; indicate where located, ie: garage, etc.

  ()radio transfer

  ()other (describe:)

* How many of these devices do you use for APCS?________

* Discuss maintenance requirements:

* Discuss make, source, and date of purchase:

* How does data transfer take place? Describe step by step process:(How often is it done, who does it, how much time is involved, how is it done? etc.)

* (If manual transfer used) what are the costs, errors, and/ or problems associated with this method?

* Are you satisfied with this method? Discuss:

SIGNPOST INFORMATION

* (IF signpost is utilized) Which type of signpost method do you use?
()sharp signpost: at precise locations at specific points
()roadside narrow beam optical scanners
()microwave transmitters
()magnets imbedded in road surface
()other (describe in detail)

()broad signpost: transmitting coded radio signals periodically received by buses within range
()with software to reference individual stops (please describe software)*

()radio frequency: computer analyzed radio signal triangulation
()VLF
()pulse triangulation
()AM phase lock
()other (describe in detail)

()other (describe in detail)

* How many signposts have you acquired?__________

* Number of miles apart_______

* Number per route______

* Discuss maintenance requirements:

* Did incorporating signposts require modification of the on-board unit to accomodate additional data? If so, what costs did this incur? To what extent did this increase the level of complexity for the user?

* Comments on this method and equipment:

  Are you satisfied with equipment? If not, why not?

  Discuss source, make, and date of purchase of signposts

STATIONARY CPU HARDWARE AND SOFTWARE

HARDWARE:

* What type of stationary CPU do you use with the APC system at a central location? Is this a dedicated unit? What users can access data from this CPU? Are terminals used with a main processing unit? how many? Is system interactive?

* Did you purchase this unit for use with APC system or was it already at your disposal for other purposes?

* Discuss source, cost and time of purchasing this unit and terminals:

SOFTWARE:

* Describe software functions of central computer:
()validation checks against expected behavior on each instumented vehicle
()append route numbers to the data
()append bus stop numbers (replacing 'distance' measurement with 'true' location)
()append vehicle assignment
()append run number
()other (describe:)

* What other information must be created and/or entered on a regular basis for the software to operate? ie: schedule changes, etc.

* How complex are APC programs to run and update or change?

* What steps do you recommend to deal with over-complexity?

* How did you obtain software for the CPU? (was it developed in-house; did you purchase canned programs; where? make, etc.)

* What are the advantages of the means you chose to obtain software? (ie: if purchased, how reliable is the source for updating or obtaining additional packages or programs? If in-house, are costs of up-dating software and training users lessened? discuss:)

* Describe costs and pattern of purchase of this software:

APC GENERATED REPORTS

* What reports are produced from the APC data on ridership activity?

()PASSENGER LOADING PROFILES (overloading and underutilization)
- ()average passenger loads
- ()maximum passenger loads
- ()load/capacity
- ()route profiles
- ()maximum load points
- ()boardings by stop
- ()alightings by stop
- ()number of standees
- ()time with standees
- ()standees as a percent of seated capacity
- ()other (describe)

()TIME PERFORMANCE (for route scheduling)
- ()running times
- ()arrival times
- ()departure time
- ()layover time
- ()percent on time
- ()minutes early/late
- ()average speed between time points
- ()schedule adherence
- ()headway distributions
- ()dwell times
- ()other (describe)

()PERFORMANCE INDICATORS (for management)
- ()passenger miles/kilometers
- ()passengers per hour
- ()boardings per mile/km
- ()boardings per hour
- ()revenue/cost ratios
- ()revenue miles/vehicle miles
- ()other (describe)

* What levels of detail are incorporated in your APC generated reports?

  () SPATIAL DISAGGREGATION:
    ()system total
    ()division or garage total
    ()route level
    ()driver run or vehicle block
    ()bus trip
    ()route segment
    ()bus stop
    ()other (describe)

  () TEMPORAL DISTRIBUTION
    ()season
    ()sign up
    ()monthly totals
    ()totals for weekday, Sat, Sun
    ()time periods (AM, MID, PM, EVE)
    ()hourly
    ()15 minute periods during peak traffic hours
    ()other (describe)

  REPORT PRESENTATION
    ()tabular
    ()graphical - color?
    ()exception
    ()on-demand
    ()periodic
    ()other (define)

* What information is needed to produce these reports? How do you obtain this information? How is it input into the APC data file or otherwise integrated into the program? (e.g computerized schedule data used to time match APCs data with schedule, etc.)

* How easily can these reports be accessed for further data manipulation?

* How can APC data be integrated with other information (ie: census data, bid documents, origin and destination studies, etc.)?

* Can APC data be accessed for AD HOC reports? How is this done? Describe cost and source of additional software procured for this purpose:

APC IMPACTS ON CURRENT OPERATIONS

* What type of route structure do you have?
  ()radial ()grid ()feeder trunk ()other (Describe:)

* Describe current data collection techniques you use. Do you use a sampling plan? How do you determine an appropriate sample size? what is the level of accuracy and reliablilty you seek to achieve with your current techniques?

* To what extent has the use of the APC system forced you to alter your data collection process? Was this an advantageous change? If not, how would you suggest this alteration be avoided in the future?

* How is the APC system monitored for accuracy? What have you learned from your experience with APC equipment in terms of accuracy and reliability of the data obtained from the system you now use and from other systems you have used in the past?

* How have APCs effected other transit functions (ie: scheduling, interlining, maintenance, etc.)?

* Have APCs been cost effective for your property?

* Would you do it again?

* What are your plans for future use of, additions to, or modifications of your present APC system? discuss:

BACKGROUND ON APC PURCHASE

* How did you select your contractor? On the basis of price only (bid)? Or did you base your decision on qualifications as well as price (RFP or RFQ)? How many responses did you receive? Did you have separate bids per item or did you purchase a complete system at one time?

* Did you require a warranty for all items? how long?

* Would you be willing to send us a copy of your RFP for review?

* How did you secure funding for your APCS purchase?

* Notes on other uses of data from other divisions using the APC system:

COSTS OF APC SYSTEM

HARDWARE

EQUIPMENT:

Counting Sensors______________per unit ______________total purchase
Date of purchase____________

On-board microprocessor_____________per unit _____________total purchase
Date of purchase____________

Signposts____________per unit ______________total purchase
Date of purchase____________

Transfer Device_______________per unit _____________total purchase
Date of purchase____________

Central Processing Unit (Stationary)_________________total cost
Date of purchase______________

* Did you purchase this computer for use with APCS?

* If you purchased these items as a package, what was the total cost of your complete system?_______________ How does this break down per item? Estimate:

INSTALLATION (Cost or person hours as applies):

Counting Sensors__________________per unit
()In-house ()contractor ()supplier ()other

Microprocessing Unit________________per unit
()In-house ()contractor ()supplier ()other

Signposts______________________per unit
()In-house ()contractor ()supplier ()other

Transfer Device__________________per unit
()In-house ()contractor ()supplier ()other

Stationary CPU____________________
()In-house ()contractor ()supplier ()other

ANNUAL MAINTENANCE (cost or person hours):

Counting sensors________________average

On-board microprocessor________________average

Signposts________________average

Transfer Device_____________average

Stationary CPU_______________average

* How is your system maintained?
()In-house ()contractor ()supplier ()other

* Comments on maintenance costs:

SOFTWARE

Development of analysis and reporting software________________

( )In-house ( )contractor ( )supplier ( )other

File creation:

vehicle assignments___________
scheduled times_____________

File update:

vehicle assignments___________
scheduled times_____________

Other Software Costs: Describe

Appendix 6.3

Glossary

Alighting: deboarding

APC (Automatic Passenger Counter): Hardware and software used in automatically collecting and analyzing data on passenger counts, running times, and bus location for transit planning, scheduling, and management.

Counting sensors: electronic devices that transmit a signal to the data collection unit when passengers board and deboard the bus. Infrared beams and treadle sensor mats are the most commonly used counting sensors.

Data Collection Unit (DCU): device used to collect and store data on-board the bus. DCU contains a microprocessor, a clock, and location board or other unit to receive and interpret signpost code and odometer readings.

Lighthead: transmits light beam to either a reflector or a receiver in infrared counters.

Location referencing: general term defining methods of locating the bus for schedule adherence data (ie: signposts reference location of passenger activity).

Off line reporting: Data are examined in hard copy reports sometime after the events occur. APC applications are off-line information systems.

Portable Data Unit (PDU): DCU (Data Collection Unit).

Portable Disk Unit (PDU): device used to retrieve data from the on-board storage unit.

Property: Transit agency.

Real-time Monitoring: Monitoring bus activity on screens in "real-time", or "as it occurs". AVM or Automatic Vehicle Monitoring Systems operate in real-time.

Relative time: the time elapsing since the most recent event (as opposed to absolute time, or time of day based on a 24 hour clock). For example, relative time may be recorded as ±10 minutes. The interpretation is "±10 minutes since the bus has passed a signpost, picked up passengers, etc."

Signpost: devices which transmit radio signals to the data collection units on-board the bus via special signpost antennae located atop the bus. Signposts are used to identify bus location.

System Controller: DCU (see Data Collection Unit).

Treadle sensor mat: electronic components installed under the stairwell mats on buses. Passengers are counted as either boarding or deboarding depending on the sequence in which they step on the mats (ie: "first step-second step" sequence = deboarding).

Turnaround time: the time it takes for data to be collected, analyzed and presented.

Appendix 6.4

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