

Passenger Counting Systems

DETAILS

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TCRP

SYNTHESIS 77

Passenger Counting Systems



A Synthesis of Transit Practice

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OF THE NATIONAL ACADEMIES

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TCRP SYNTHESIS 77

Passenger Counting Systems

A Synthesis of Transit Practice

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The need for TCRP was originally identified in *TRB Special Report 213—Research for Public Transit: New Directions*, published in 1987 and based on a study sponsored by the Federal Transit Administration (FTA). A report by the American Public Transportation Association (APTA), *Transportation 2000*, also recognized the need for local, problem-solving research. TCRP, modeled after the longstanding and successful National Cooperative Highway Research Program, undertakes research and other technical activities in response to the needs of transit service providers. The scope of TCRP includes a variety of transit research fields including planning, service configuration, equipment, facilities, operations, human resources, maintenance, policy, and administrative practices.

TCRP was established under FTA sponsorship in July 1992. Proposed by the U.S. Department of Transportation, TCRP was authorized as part of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). On May 13, 1992, a memorandum agreement outlining TCRP operating procedures was executed by the three cooperating organizations: FTA, the National Academy of Sciences, acting through the Transportation Research Board (TRB); and the Transit Development Corporation, Inc. (TDC), a nonprofit educational and research organization established by APTA. TDC is responsible for forming the independent governing board, designated as the TCRP Oversight and Project Selection (TOPS) Committee.

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Cover Figure: Ride connection passenger transfers from
TriMet bus to shuttle.

FOREWORD

Transit administrators, engineers, and researchers often face problems for which information already exists, either in documented form or as undocumented experience and practice. This information may be fragmented, scattered, and unevaluated. As a consequence, full knowledge of what has been learned about a problem may not be brought to bear on its solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem.

There is information on nearly every subject of concern to the transit industry. Much of it derives from research or from the work of practitioners faced with problems in their day-to-day work. To provide a systematic means for assembling and evaluating such useful information and to make it available to the entire transit community, the Transit Cooperative Research Program Oversight and Project Selection (TOPS) Committee authorized the Transportation Research Board to undertake a continuing study. This study, TCRP Project J-7, "Synthesis of Information Related to Transit Problems," searches out and synthesizes useful knowledge from all available sources and prepares concise, documented reports on specific topics. Reports from this endeavor constitute a TCRP report series, *Synthesis of Transit Practice*.

This synthesis series reports on current knowledge and practice, in a compact format, without the detailed directions usually found in handbooks or design manuals. Each report in the series provides a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems.

PREFACE

*By Donna Vlasak
Senior Program Officer
Transportation
Research Board*

The purpose of this synthesis is to document the state of the practice in terms of analytical tools and technologies for collecting transit ridership and other subsidiary data. It provides advice for transit agencies considering automatic passenger counter (APC) systems. Survey results include transit agency assessments of the effectiveness and reliability of their methodologies and of desired improvements. The survey was designed to emphasize APC systems; however, agencies using manual systems were also surveyed to gain an understanding of the reasons that new technologies have not been adopted. Detailed findings from six case studies characterize individual "best practice," as well as highlight problems common to APC implementation. An appendix summarizes APC implementation, including the percentage of vehicles equipped with APCs, hardware supplier, software supplier, and the procurement process for each agency.

This report was accomplished through a review of the relevant literature, a web-based survey of a cross section of transit agencies in North America, and telephone interviews conducted with key personnel at six transit agencies to profile innovative and successful practices and to explore ongoing issues. Surveys were received from 56 transit agencies; a response rate of 73%. Additionally, 45 agencies responded to a broad-based invitation to participate in the survey, for a total of 86 agencies. These 86 agencies range in size from having 10 to more than 2,000 buses in operation.

Daniel Boyle, Dan Boyle and Associates, San Diego, California, collected and synthesized the information and wrote the paper, under the guidance of a panel of experts in the subject area. The members of the Topic Panel are acknowledged on the preceding page. This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

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PASSENGER COUNTING SYSTEMS

SUMMARY TCRP Synthesis 29, published in 1998, summarized information from selected transit agencies regarding the benefits and pitfalls associated with various passenger counting technologies, as reported by users. The synthesis provided advice for agencies considering automatic passenger counter (APC) systems. At that time, manual passenger counting was the most prevalent technique in the transit industry.

This report documents the state of the practice in terms of analytical tools and technologies for measuring transit ridership and other subsidiary data. Results of a web-based survey of a cross-section of transit agencies in North America document tools and technologies used to count passenger boardings and alightings. Forty-one completed surveys were received from the 56 transit agencies approved by the panel for inclusion in the sample, a response rate of 73%. In addition, 45 agencies responded to an invitation to all American Public Transportation Association (APTA) members to participate in the survey, for a total of 86 transit agencies. Survey results include transit agency assessments of the effectiveness and reliability of their methodologies and of desired improvements. The survey was designed to emphasize APC systems, but agencies using manual systems were also surveyed to gain an understanding of why new technologies have not been adopted.

Key survey findings include the following:

- The most common reason to collect ridership and travel time data is to compile ridership data by route, although the majority of respondents also collect ridership and travel time data for more specific microlevel uses at the route segment or stop level. Tracking ridership changes, calculating performance measures, and adjusting schedules were the three most common uses of ridership and travel time data.
- A majority of respondents use a combination of automated and manual methods to collect ridership data. The most common combinations involve APC plus manual data collection and farebox plus manual collection. In many cases, an older technology is retained to test the validity of the new technology or for a specific purpose, such as National Transit Database reporting or data validation.
- Agencies that continue to collect ridership data manually cite cost as a reason, followed by low priority for automated data collection at the agency. Smaller systems (fewer than 250 peak buses) are more likely to continue to rely on manual data collection.
- Only a portion of most agencies' buses are APC-equipped; however, more than one-quarter of responding agencies have installed APCs on all buses. Nine of the 12 agencies that are 100% APC-equipped bought APCs as part of a broader intelligent transportation systems (ITS) purchase.
- Changes in professional staffing levels as a result of APC implementation were minimal in most cases: More than 70% of all agencies reported no changes or decreases in

staff levels. However, there were notable decreases in the size of traffic checking units. The case studies suggest that assigning analytical and maintenance staff specifically to the APC program is an important factor in successful implementations.

- The median reported capital cost per APC unit was \$6,638 among the 26 agencies responding. The median reported annual operating and maintenance cost per APC unit was \$600 among the 11 agencies responding. Cost data from the survey should be interpreted cautiously, as respondents varied in their ability to break down cost data (especially for older systems or for APC systems purchased as part of a larger ITS procurement).
- Processing APC data often requires changes to existing data systems, such as addition of global positioning system coordinates for stops and an updated or new bus stop inventory. A few agencies noted the establishment of defined interfaces between computerized scheduling software packages and APC or automatic vehicle location systems. For data storage and analysis, the most common changes were the addition of servers for data storage and new database software for analysis.
- Automated data validation programs, provided by the APC vendor, developed in-house, or purchased from a third party, can simplify the process of converting raw APC data into usable data. Agencies reported various thresholds for determining validity at the block or trip level.
- A majority of agencies rely on the hardware vendor for data processing and report generation software, but several indicated in-house software development or use of an outside vendor other than the APC vendor.
- Anyone who has been through the process of implementing a new technology knows that there is a “debugging” period. The debugging period, during which start-up problems are resolved, averages 17 months for APCs, identical to the finding of the 1998 synthesis, with a median of 18 months.
- The planning department is the most common location for management of the APC system, followed by the operations department. There is widespread involvement across departments in procurement of the APC system and use of the APC data. Downstream users typically access APC data electronically by means of standard reports, and 41% of agencies noted that downstream users could query the database directly.
- Implementation of APCs necessarily involves multiple departments within the transit agency. Positive aspects include improved communication among departments, greater value placed on ridership data, improved decision-making ability, greater responsiveness, and the ability to provide the needed data to end users. Difficulties include problems ensuring that assignments were completed, new demands for reports, low priority for APC equipment in the maintenance department, and unrealistic expectations regarding turnaround time and data quality.
- Implementation of APCs creates a need for training. A majority of respondents noted increased training needs in the areas of software/computer, analytical, and hardware skills. Only one-quarter of responding agencies reported no additional training needs.

The primary benefits of APCs included data disaggregated at the stop, segment, and trip levels; better quality of ridership data; availability of running time data to adjust schedules; and a better basis for decision making.

Problems encountered with the APC system included reporting software, data processing and analysis, data validation, and hardware problems. One-quarter of all respondents reported either no problems or only the usual start-up issues.

Results regarding agency satisfaction with the performance of its APC system in terms of counting passengers are positive: Eighty-five percent of respondents were very or somewhat satisfied. Forty percent were very satisfied, and 45% were somewhat satisfied.

Contract elements, procurement procedures, purchase of additional APC units, and the overall approach to APC implementation were the most frequently mentioned aspects of the APC process that transit agencies would like to change. Regarding procurement, stricter contractual requirements, purchase of a complete system through a single vendor, and changes to internal procedures were all important. Changes to the overall approach included being more informed about APC hardware and software choices, involving maintenance personnel at the start of the process, dedicating one or more technicians to work full time on APCs, completing the bus stop inventory before installation, and hiring a statistician to develop a methodology for passenger counting before vendor selection.

Almost three-quarters of all survey respondents that have implemented APC systems shared lessons learned from the process. Agencies focused on use and validation of the APC data, purchase and implementation, and ongoing agency maintenance in the discussion of lessons learned. Agencies offered lessons in many areas, but the emphasis on data systems and agency procedures suggests that these areas are critical to the success of APC implementation.

Major conclusions include the following:

- APCs provide a rich ridership and travel time database at a finer level of detail than farebox or manual counts, even for agencies with only a few APCs. The increased number of observations lends greater confidence to decisions regarding changes in service levels. An agency does not need APC units on all vehicles to establish a workable APC system, although installation of APCs on all vehicles produces a richer database and avoids vehicle assignment problems.
- An APC system does not work automatically. Successful agencies have developed procedures (in-house or through an outside vendor) to match APC data to bus stops, clean and validate data, generate standard reports, simplify the process of creating ad hoc reports, and flag potential hardware and software problems for the maintenance and information technology departments. The data processing and reporting software is the most important part of an APC implementation. Integration of APC data with existing agency databases, which may also be changing as a result of new technologies is challenging. Agencies' business practices and procedures may not be designed to make optimal use of available data.
- APC implementation is not simple, and the first year is the most difficult. There is a steep learning curve, particularly on the software side, and there are likely to be internal agency issues regarding responsibilities and priorities.
- Ownership of the APC system is important, as is collaboration across departments. The ownership part of the equation, in which one department assumes overall responsibility, ensures that the APC system receives priority, whereas the collaboration part works best when the lead department is attuned to the needs and procedures of other departments and can adjust to meet these needs. A good working relationship between the lead department and the maintenance personnel assigned to APCs is critical.

- Staffing presents a challenge, especially to small and medium-sized agencies. Successful implementations are characterized by close review of APC data as part of a quality assurance program, particularly in the first year when bugs are being worked out, and a dedicated maintenance technician or group of technicians who assumes primary responsibility for hardware issues. Agencies may not have the staff available or may not have staff with the right mix of skills.
- Transit agencies that have worked through the myriad issues associated with APC implementation cannot imagine life without APCs. These agencies reap the benefits of extensive and statistically valid data that are used with confidence to make important service-related decisions.

Findings from this synthesis suggest eight major areas for future study:

- In-depth investigation of critical factors to success. Are there optimal routines to match APC data to specific bus stops? What elements of a validation program are most critical to ensuring quality data? Which elements of reporting software are most useful, and what is the best way to create ad hoc query ability? How can APC data be integrated most usefully with existing agency databases? How can an agency “manage” the learning curve? Are there techniques to foster APC system ownership and collaboration? What if adequate staff is not available and added staff is not an option? How important is a strong commitment from senior management to the APC program?
- Exploration of various avenues to success. Both in-house and third-party approaches have been successful. Are there circumstances in which one is preferable to another? What is the state of the art in software packages? Ongoing developments within the transit industry, such as deployment of ITS technology, increased vendor attention to complete (hardware plus software) product packages, and a wider choice of hardware and software options (including off-the-shelf software), affect the answer to this question and suggest additional possibilities.
- Evaluation of data cleaning and validation techniques. This is an important barrier to success and is perhaps the major source of frustration to agencies that indicated dissatisfaction with their APC systems. Confidence in the accuracy of APC data is critical to their widespread use and acceptance within and outside the transit agency. Many agencies struggling with this step view it as a hardware problem, but its solution resides in considering both the hardware and the software used to clean and validate the data.
- More precise identification of factors preventing success and ways to overcome them. Data validation is not the only barrier to success. Broader hardware, software, and personnel issues need to be addressed and overcome, and a closer examination of successful strategies would serve the transit industry well.
- Exploration of new technologies that may improve APC data collection accuracy. As ITS technologies evolve, new hardware and software options that improve the accuracy of APC data are likely to emerge. What are the most promising options in this area?
- Investigation of alternative techniques, algorithms, and methodologies that can improve the state of the art of APC systems. As more agencies implement APC systems, the market for innovation grows larger. Using existing technology, what improvements can address the needs of transit agencies?
- Identification of business intelligence and data reporting tools that can be used with APC data. As data systems are integrated and downstream users begin to rely on APC data, new approaches and innovative analytical strategies can be expected. Additional

uses of APC data will continue to emerge as users become more knowledgeable and will affect data needs or the priority afforded to the APC system. Establishing a data warehouse can provide an opportunity to take advantage of many business intelligence techniques such as data mining.

- Institution of new methods of disseminating information on APC systems. This synthesis has provided a snapshot of the state of passenger counting systems in 2008. An APC forum or workshop, webinars on APC implementation and use of APC data, and an electronic mailing list devoted to APC-related issues are all possibilities to extend the findings of this report and to provide a continuing means for agencies to share information and learn from each other's experiences.

CHAPTER ONE

INTRODUCTION**PROJECT BACKGROUND AND OBJECTIVES**

TCRP Synthesis 29: Passenger Counting Technologies and Procedures, published in 1998, summarized information from selected transit agencies regarding the benefits and pitfalls associated with various passenger counting technologies, as reported by users. The synthesis provided advice for agencies considering automatic passenger counter (APC) systems. At that time, manual passenger counting was the most prevalent technique in the transit industry.

Since that time, improved technologies for boardings and alightings counts, reliable location detection, and data processing have entered the passenger counting marketplace. The use of APC technology has increased among transit agencies of all sizes, often in conjunction with automated vehicle location systems, improved fare collection systems, and the use of geographic information systems as an analytical tool. One result has been improved timeliness and reliability (because it is drawn from a larger sample) of the ridership data, which in turn has encouraged agencies to rely on and make greater use of the data.

The purpose of this synthesis is to document the state of the practice in terms of analytical tools and technologies for collecting transit ridership and other subsidiary data. Results of a web-based survey of a cross-section of transit agencies in North America document tools and technologies used to count passenger boardings and alightings. Survey results include transit agency assessments of the effectiveness and reliability of their methodologies and of desired improvements. The survey was designed to emphasize APC systems, but agencies using manual systems were also surveyed to gain an understanding of why new technologies have not been adopted.

This report includes a review of the relevant literature in the field, concentrating on material published since *TCRP Synthesis 29* in 1998. A final important element of this synthesis is the chapter documenting case studies, based on interviews with key personnel at selected agencies, to profile innovative and successful practices and to explore ongoing issues. Findings from all of these efforts are combined to summarize lessons learned, gaps in information and knowledge, and research needs.

TECHNICAL APPROACH

The approach to this synthesis included a literature review, a survey of transit agencies, and telephone interviews with six agencies selected as case studies. A Transportation Research Information Services search was conducted to aid the literature review.

The survey on passenger counting technologies was designed to elicit information on automated technologies. At the time of the last synthesis, manual data collection was the most common means of gathering information on ridership. Over the past 10 years, use of APCs has become more common. Manual passenger counting was well documented in the previous synthesis; therefore, this synthesis focuses on the state of the practice for nonmanual passenger counting systems, particularly APC systems.

Once finalized by the panel, the survey was posted and pretested by panel members and selected transit agencies. The pretest resulted in minor changes to survey logic and flow.

The sampling plan involved a “core” sample of transit agencies that have active passenger counting programs, have participated in similar studies, and have implemented or are considering APC systems. The core sample included 56 agencies. The project manager sent an e-mail with an attachment from the TCRP program manager explaining the importance of the survey and a link to the online survey site to each of the 56 agencies. In most cases, a known contact had been identified; otherwise, the e-mail was sent to the planning director or the general manager with a request to forward the message to the most appropriate staff member. Follow-up e-mails were sent approximately 2 and 4 weeks after the original contact to encourage response.

To guard against missing any agencies that are making interesting use of APCs and to ensure a broader sample, an identical e-mail message was sent to all APTA transit agency members inviting their participation in the survey. These agencies did not receive follow-up e-mails because of the sheer number of agencies.

Forty-one completed surveys were received from the 56 transit agencies in the core sample, a response rate of 73%.

Forty-five agencies responded to the broad-based invitation to participate in the survey, for an overall total of 86 transit agencies. These 86 agencies range in size from fewer than 10 to more than 2,000 buses.

Table 1 presents the distribution of responding agencies by size. Exactly half of all responding agencies operate fewer than 250 vehicles in peak service.

TABLE 1
TRANSIT AGENCIES BY SIZE

Vehicles Operated in Maximum Service No.	Agencies Responding	
	No.	%
Fewer than 250	43	50.0
250 to 999	32	37.2
1,000 or more	11	12.8
Total	86	100.0

Table 2 shows the distribution of responding agencies by FTA region. Regions IV, V, and IX led in terms of agencies responding. Figure 1 is a map of FTA regions.

TABLE 2
TRANSIT AGENCIES BY FTA REGION

FTA Region	Agencies Responding	
	No.	%
I	4	4.7
II	7	8.1
III	9	10.5
IV	11	12.8
V	17	19.8
VI	4	4.7
VII	1	1.2
VIII	2	2.3
IX	20	23.3
X	7	8.1
Canada	4	4.7
Total	86	100.0



FIGURE 1 Map of FTA regions.

ORGANIZATION OF THE REPORT

Following this introductory chapter, chapter two summarizes the findings of the literature review. Chapter three, the first of two chapters to present the results of the survey, focuses on reasons that transit agencies collect ridership and travel time data and the means by which data are collected and analyzed.

Chapter four discusses the responding agencies’ assessment of their APC systems. This chapter summarizes satisfaction with current methodologies, desired improvements, lessons learned, and advice for other transit agencies.

Chapter five reports detailed findings from each of the six case studies. Agencies were selected for the case studies for different reasons. Some approaches can be characterized as “best practices,” and others highlight problems common to APC implementation. All show a thoughtful response to the issues posed in implementing APC systems.

Chapter six summarizes the findings, presents conclusions from this synthesis project, and offers recommendations for further research. Findings from the surveys and particularly the case studies provide an assessment of strengths and weaknesses and likely future directions.

Appendix A presents a copy of the survey as it appeared online. Appendix B provides survey results by question. Appendix C lists all transit agencies participating in the survey. Appendix D summarizes APC implementation, including percentage of vehicles equipped with APCs, hardware supplier, software supplier, and procurement process, for each agency.

CHAPTER TWO

LITERATURE REVIEW**INTRODUCTION**

This chapter summarizes findings from a literature review related to transit ridership forecasting. A Transportation Research Information Services search was conducted to aid the literature review.

The literature review focuses on studies completed since 1998, when *TCRP Synthesis Report 29: Passenger Counting Technologies and Procedures* was published (1).

PREVIOUS SYNTHESIS

TCRP Synthesis 29 summarized information from selected transit agencies about benefits and problems associated with various passenger counting technologies, as reported by current users. It also presented advice for agencies considering each technology. Conclusions included the following:

- Procedures are more important than technology.
- Internal changes are necessary to ensure the success of new passenger counting technologies.
- Visiting and learning from other agencies before deciding on a new passenger counting technology are essential.
- Unnecessary customization should be avoided.
- A strong commitment from senior management is required.
- Active management of the passenger counting system is critical to success.
- Responsibilities must be clarified.
- Advanced passenger counting technologies offer several benefits, including more frequent data collection, analysis of ridership at finer levels of detail, greater timeliness and responsiveness, and lower cost. However, these benefits do not accrue automatically.
- There is no one perfect solution.

TCRP Synthesis 29 encompassed manual (paper and pencil) as well as automated data collection techniques. In 1998, APC systems were still in the early adoption phase in the United States. APCs have become more commonplace since 1998, and this report focuses on new developments in automated passenger counting within the transit industry.

GENERAL OVERVIEW OF AUTOMATIC PASSENGER COUNTERS

Several studies and articles have provided a sound overview of APC use and benefits. Baltes and Rey present results of a survey of North American transit systems related to APC usage, and summarize important issues for transit systems to consider (2). Rakebrandt summarizes the uses of APC data and reviews benefits and difficulties for transit systems (3). Jasmin and Vicente highlight the implementation of an intelligent transportation system (ITS) project at Metro in Los Angeles, noting that APCs allow service planners to use current data in making route and service decisions (4).

HOW AUTOMATIC PASSENGER COUNTER DATA ARE USED

Furth et al. (5) has conducted extensive research into the uses of APC data. Furth was the primary author of a comprehensive TCRP study that offered guidance on five subjects:

- Analyses that use automatic vehicle location (AVL)–APC data to improve management and performance;
- AVL–APC system design to facilitate the capture of data with the accuracy and detail needed for offline data analysis;
- Data structures and analysis software for facilitating analysis of AVL and APC data;
- Screening, parsing, and balancing automatic passenger counts; and
- Use of APC systems for estimating passenger-miles for National Transit Database (NTD) reporting.

Appendices to this TCRP study addressed needs, current practice, and potential in relation to the use of archived AVL–APC data and noted organizational barriers to successful use (6).

Furth et al. also examined critical factors in converting APC data into useful information (7). Several others have examined this subject, particularly in relation to performance monitoring. Hammerle et al. describe challenges faced by the Chicago Transit Authority in the use of APC and AVL data for service reliability indicators (8). Herrscher reports

on use of advanced technologies at the Orange County (California) Transportation Authority (9). Nokel and Schweiger describe the design and implementation of a monitoring system for passenger counts and delays and suggest implications for future projects of this nature (10). Bertini and El-Geneidy are among many transit researchers to examine TriMet's (Tri-County Metropolitan Transportation District of Oregon, Portland) innovative use of APC and AVL data to improve service quality and reliability (11).

Not surprisingly, APC data are extremely useful in identifying ridership impacts and passenger flows. Paliska and Kolene used APC and AVL data to evaluate the effects of unscheduled stops on ridership demand; any stop that was not associated with a known stop could be assumed to be unscheduled (12). Golani reports on the use of APC, AVL, and geographic information system (GIS) tools to define passenger flow on a bus route experiencing chronic delays (13). Strathman et al. analyzed the relationship between transit service headway deviations and passenger loads using TriMet's AVL and APC archived data, and show that excess loads are systematically attributable to headway deviations (14). Kimpel et al. found that APC data can be used for internal reporting and annual NTD reporting if there is widespread deployment of APC technology (15).

APC data have been useful in analyzing dwell time. Again using TriMet data, Dueker et al. report that passenger activity is an important determinant of dwell time (16). Rajbhandari et al. examine the impact of boarding and alighting passengers, the effect of standees, time of day, and service type on bus dwell time (17).

An exhaustive examination of the state of the art with regard to advanced public transportation systems (APTS) deployment noted that optimizing the data processing and reporting capabilities associated with an APC system may take years (18). Persistence is needed to cleanse and filter the data, verify route and trip attributes, and correct or remove anomalous data. Sharing data across departments is often hindered by lack of data consistency, continuity, and completeness. The report also notes state-of-the-art deployments that have overcome these issues.

AUTOMATIC PASSENGER COUNTING DATA AND MODELING

The reliability and sheer volume of APC data have encouraged researchers to use the data in modeling efforts. Several studies report on the use of APC data to develop a model to predict bus arrival times (19–21). Other researchers have used APC data to calibrate or validate travel models. One author notes that APC boarding data are far more reliable than data used to estimate the current set of boarding equations (22). Others note the benefits of an enriched transit data

set (23) and the use of APC and AVL data to develop better performing models (24).

DATA PROCESSING

As noted earlier, the ability to turn APC data into useful information is critical in realizing the benefits of APCs. Rucker provides examples of how APC data are processed for use in analyzing routes and schedules (25). Hammerle et al. describe methods developed at CTA to extract information for use in computing service reliability indicators (8).

DATA INTEGRATION

One of the challenges of new technologies, noted in the previous *TCRP Synthesis 29*, is the sometimes unexpected effects of their implementation on an agency's data systems. Bolden et al. (26) reported that interfaces between bus-related systems can be either unreliable or nonexistent, resulting in difficulty in coordinating data. The authors also note that agencies' business processes and procedures may not be designed to make optimal use of available data even when there is good technological integration (26).

Use of database management and GIS tools to analyze APC and AVL data has been cited by researchers (13, 27) as a means to make more complete use of the data. Although stand-alone APC systems collect a significant amount of valuable data, integration with data from AVL systems and other ITS applications enhance the overall usefulness of the data (28). Procuring APCs as part of a broader ITS system can reduce the overall cost of APC installation (29). In a report on a survey of eight transit agencies deploying ITS technologies, Jeng suggests that the integration of these technologies presents a challenge that goes beyond the technical realm. This paper also provides lessons learned in ITS deployment (30).

Within the transit industry, TriMet is generally acknowledged as one of the leading agencies in the use of APC data. As noted earlier, several researchers have focused on TriMet as an important case study in evaluating the use of APC data in conjunction with data from AVL systems and other sources (11, 14–16, 31).

IMPLEMENTATION OF AUTOMATIC PASSENGER COUNTING SYSTEMS

Marx and Bruun reported on a successful implementation of APCs as part of a broader ITS implementation at the Potomac and Rappahannock Transportation Commission (32). An interesting aspect of this report is that the benefits of advanced technologies do not accrue automati-

cally. At the Potomac and Rappahannock Transportation Commission, ITS efforts began in 1995, however full ITS functionality was achieved only in 2003 after the second procurement attempt. The report attributes success to more mature technologies; a turnkey project contract model; and refined, firm specifications based on both practical and academic experience.

Schweiger notes that the process of ITS implementation benefits from a consensus among a variety of project stakeholders regarding uses and benefits of new technologies (33). The author describes the challenges associated with stakeholders' input, from the selection of ITS components to the design of system functionality and from procurement to deployment.

Monahan et al. (34) document the implementation of APCs in conjunction with the deployment of ITS technologies at the Metropolitan Atlanta Rapid Transit Authority for the 1996 Olympic Games. The report summarizes the benefits of APCs and other ITS technologies and provides lessons learned (34).

Many of the implementation-related lessons address how to overcome obstacles. Furth et al. note that one key to APC usefulness is the automatic, routine conversion of the APC data stream into a database of accurate counts (7). In the CTA's experience, typical of many transit agencies, operational challenges included bus assignments (ensuring that an APC-equipped bus went out on the correct assignment), bus stop inventory (maintaining an up-to-date list with all stops accounted for), and undercounting on crowded trips (8).

RELATED TECHNOLOGIES

Most APC units count passengers by means of infrared beams. Older units used treadle mats mounted to vehicle steps. Sun et al. proposed video technology, including multi-object recognition, image segmentation, and feature matching, to count boardings and alightings (35). Navick and Furth explored the use of location-stamped farebox data to estimate origin–destination patterns and loads under the assumption that boardings and alightings are symmetrical on the return trip in the opposite direction (36). This approach has been used by transit agencies in Chicago and New York to estimate origin–destination patterns from farecard data (37, 38).

SUMMARY

Awareness of and experience with APCs are clearly greater now than in 1998 when the previous synthesis on this topic was published. At that time, the transit industry was in the latter stages of early adoption of this new technology. APCs are in more widespread use now, but issues remain in the areas of data integration and implementation.

A recent addition to the literature is a series of fact sheets related to transit technologies (39). These fact sheets summarize useful information on various technologies, including APCs. The next two chapters present the results of a survey of transit agencies regarding experiences with APCs. Survey results provide a snapshot of the state of the art as it exists today with regard to APCs.

CHAPTER THREE

RIDERSHIP AND TRAVEL TIME DATA COLLECTION AND ANALYSIS**INTRODUCTION**

This is the first of two chapters presenting the results of a survey of transit agencies regarding passenger counting technologies. The survey was designed to elicit information on automated technologies. At the time of the last synthesis, manual data collection was the most common means of gathering information on ridership. Over the past 10 years, use of APC systems has become more common. Manual passenger counting was well documented in the previous synthesis; therefore, this synthesis focuses on the state of the practice for nonmanual passenger counting systems, particularly APCs.

Forty-one completed surveys were received from the 56 transit agencies approved by the panel for inclusion in the sample, a response rate of 73%. In addition, 45 agencies responded to an invitation to all APTA members to participate in the survey, for a total of 86 transit agencies. These agencies range in size from fewer than 10 to more than 2,000 buses.

This chapter analyzes survey results related to the reasons that transit agencies collect ridership and travel time data and the means by which data are collected and analyzed. The introduction of new technologies such as APCs changes data processing and reporting requirements; these are analyzed in this chapter as well. Technological changes can also have organizational impacts, and these are also explored.

Chapter four discusses survey results related to the responding agencies' assessment of APCs.

WHY COLLECT RIDERSHIP AND TRAVEL TIME DATA

There are many reasons to collect ridership data. At the system level, ridership is an important measure of success for a transit agency. Federal and state funding agencies require ridership reports. At the route level, ridership provides a general indication of the level of demand. More detailed ridership data are used by service planners and schedulers to analyze performance and make changes to routes down to the trip and stop level so that service provided matches demand. Time-related data, often collected in conjunction

with ridership data, are used to monitor running times and schedule adherence.

Manual collection of ridership data is time-intensive and expensive, and typically would result in data for only a few days. An atypical event (increased congestion owing to a traffic accident or unusual weather) could skew the data. Use of automatic passenger counter (APC) systems creates a much richer database, with multiple observations for each trip. Issues regarding accuracy and analytical techniques are discussed later.

Table 3 summarizes survey responses regarding reasons for collecting data. The most common reason is compiling ridership by route, followed by tracking systemwide ridership totals. A majority of all respondents also collect data on ridership for more specific microlevel uses at the route segment or stop level. National Transit Database (NTD) reporting was the most common response in the "other" category and is reported separately in Table 3.

The percentages in Table 3 do not add up to 100% because multiple responses were acceptable. Any table in this report in which the sum of the percentages is greater than 100% reflects a survey question where multiple responses were allowed.

TABLE 3
PURPOSES FOR COLLECTION OF RIDERSHIP AND TRAVEL TIME DATA

Purpose	Agencies Responding	
	No.	%
Compile ridership by route	83	96.5
Track systemwide ridership totals	76	88.4
Compile boardings/alightings by stop	68	79.1
Monitor passenger loads at the maximum load point	64	74.4
Monitor schedule adherence and running times	56	65.1
Other	25	29.1
Total responding	86	100.0

Table 4 indicates how agencies use ridership and travel time data. Tracking ridership changes, calculating performance measures, and adjusting schedules were the three most common uses, each reported by more than 85% of all respondents.

TABLE 4
AGENCY USE OF RIDERSHIP AND TRAVEL TIME DATA

Use	Agencies Responding	
	No.	%
Assess changes in ridership	80	93.0
Calculate performance measures	77	89.5
Adjust schedules (add/delete trips, change headways)	75	87.2
Compile NTD reports	71	82.6
Revise routings	69	80.2
Determine locations for bus shelters and other facilities	63	73.3
Adjust running times/select or change timepoints	62	72.1
Other	8	9.3
Total responding	86	100.0

MEANS OF COLLECTING RIDERSHIP DATA

Table 5 addresses how agencies collect ridership data. A majority of respondents reported a combination of automated and manual methods. Twenty-one percent use manual methods only. Fourteen percent use APCs only, and 14% rely solely on some other automated means (fareboxes, turnstiles, and preprogrammed personal data assistants or other handheld data collection units).

Table 6 presents means of data collection by system size. A majority of respondents reported a combination of automated and manual methods. Smaller systems account for half of all agencies in the sample and are more likely to collect data manually or with some other automated method. Medium systems account for 37% of all agencies in the sample, and are much more likely to collect data by means of a combination of automated and manual methods. Large systems account for 13% of all agencies in the sample and use the various technologies in roughly the same proportion as all respondents.

Agencies using a combination of methods are of particular interest because these constitute a majority of all respondents. Figure 2 is a Venn diagram indicating the major

combinations (28 of the 44 combinations reported in Table 5) and including the number of agencies using only one means, also noted in Table 5. The top circle represents agencies using manual techniques, the bottom left agencies using APCs, and the bottom right agencies using fareboxes. The most common combinations involve APC plus manual (12) and farebox plus manual (8).

TABLE 5
MEANS OF RIDERSHIP DATA COLLECTION

Means	Agencies Responding	
	No.	%
Combination of automated and manual methods	44	51.2
Manual (paper and pencil) only	18	20.9
APCs only	12	14.0
Other automated methods (registering fareboxes, handheld units) only	12	14.0
Total responding	86	100.0

TABLE 6
MEANS OF RIDERSHIP DATA COLLECTION BY AGENCY SIZE

Technology	No. of Agencies			
	Total	Large	Medium	Small
Combination of automated and manual methods	44	6	23	15
Manual (paper and pencil) only	18	2	2	14
APCs only	12	1	5	6
Other automated methods (registering fareboxes, handheld units) only	12	2	2	8
Total responding	86	11	32	43

The variety of combinations in Figure 2 provides insight into the process of integrating new technologies into existing systems. In some cases, an older technology is retained to test the validity of the new technology. Agencies also retain older technologies for specific purposes, for example: NTD reporting or “official” systemwide ridership data collected through registering fareboxes. Several agencies noted problems with the accuracy or reliability of APC counts and thus have not transitioned to use of the new technology. Methods may also vary by mode, type of service, and type of vehicle.

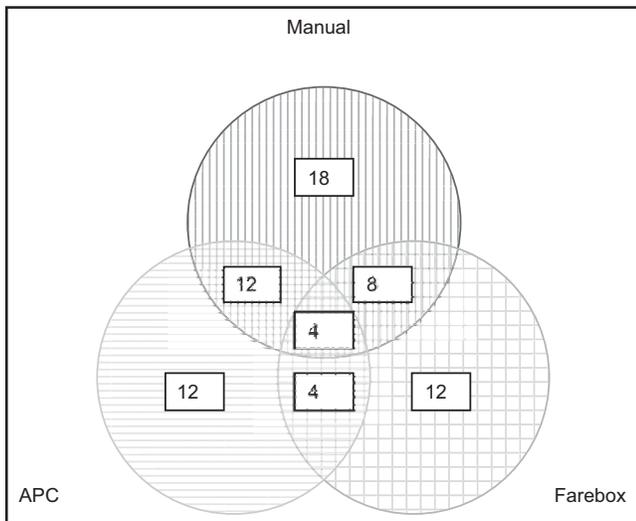


FIGURE 2 Combinations of automated and manual data collection techniques.

Agencies that continue to collect ridership data manually were asked for reasons why they have not switched to an automated technology. As Table 7 shows, cost is the most common reason, followed by low priority for automated data collection at the agency.

TABLE 7 REASONS FOR NOT SWITCHING FROM MANUAL TO AUTOMATED DATA COLLECTION

Reason	Agencies Responding	
	No.	%
Cost	10	71.4
Low priority at agency	6	42.9
Awaiting broader ITS purchase	4	28.6
Satisfied with manual data collection	4	28.6
Planning to change, but have not yet	4	28.6
Other	4	28.6
Total responding	14	100.0

USE OF AUTOMATIC PASSENGER COUNTERS AT TRANSIT AGENCIES

Given the inroads that APCs have made in the transit industry among agencies of all sizes, the remaining questions in the survey focused on APC installation and use of APC data. This section discusses types of equipment and percentage of fleet equipped with APCs.

The question of manufacturer was simpler to answer before integrated ITSs came on line. (For further informa-

tion, see Appendix D.) Only one agency reported the use of treadle mats, whereas APC installations were split between infrared beam and treadle mat in the 1998 synthesis.

Another difference is the universal inclusion of a global positioning system (GPS) element in the APC system. In the 1998 synthesis, by contrast, almost half of the APC systems were signpost-based. Interestingly, the majority of agencies with both APC and automated vehicle location (AVL) primarily use AVL time and location data. In many cases, the reason is that AVL is on all buses, whereas only a portion is equipped with APCs.

Almost half of all respondents indicated that their APC purchase was part of a broader ITS project. Among the “other” responses in Table 8 are differences by mode and stand-alone systems that have subsequently been (or will be) integrated with other ITS components.

TABLE 8 APC PURCHASE: STAND-ALONE OR PART OF A BROADER ITS PROJECT

Category	Agencies Responding	
	No.	%
Part of a broader ITS project	24	49.0
Stand-alone	16	32.7
Unsure	1	2.0
Other	8	16.3
Total responding	49	100.0

More than 80% of survey respondents noted that APC equipment was used only on buses. Four agencies use APCs on their light rail systems, three others are planning or beginning to implement APC on light rail, and one agency has installed APC on a heavy rail system.

Table 9 indicates the percentage of the agencies’ bus fleets equipped with APC. It is still the rule rather than the exception to install APCs on only a portion of the bus fleet and then rotate the APC buses among the various routes. However, more than one-quarter of responding agencies have installed APCs on all buses. Universal installation is more common as APC costs have come down, especially when APCs are part of a broader ITS purchase. Nine of the 12 agencies that are 100% APC-equipped bought APCs as part of a broader ITS purchase.

As many transit agencies have found, the planning and operations departments must work closely together on bus assignments when only some buses are APC-equipped. Introduction of APCs has resulted in changes in how buses are assigned. A typical arrangement is that service planners

or schedulers prepare a weekly list of blocks to be sampled and transmit the list to the operations department.

TABLE 9
PERCENTAGE OF BUS FLEET EQUIPPED WITH APCS

Percentage Range	Agencies Responding	
	No.	%
100	12	26.7
50 to 99	5	11.1
20 to 49	11	24.4
10 to 19	11	24.4
1 to 9	6	13.3
Total responding	45	100.0

Some agencies have automated the assignment process using APC system software to identify blocks for which no APC data have been collected. One agency noted that the operations department assigns APC buses randomly for the first half of a pick, and the software takes over this function for the second half to ensure that all blocks are sampled. However, only 16% of respondents reported use of an automated assignment process.

On average, 80% of daily APC assignments are completed as scheduled. This percentage varies from 40% to 100% among respondents. Anecdotal evidence suggests that the percentage of successfully completed APC assignments increases over time, as departments adjust to the new procedures.

The number of times each trip is surveyed in a given time frame varies with the percentage of APC-equipped buses. Clearly, APCs provide a richer ridership and travel time database at a finer level of detail than farebox or manual counts, even for agencies with only a few APCs. The increased number of observations lends greater confidence to decisions regarding changes in service levels.

Being rich in data provides clear benefits but can create its own challenges. How agencies process and manage the increased amount of ridership data is addressed in the next section.

AUTOMATIC PASSENGER COUNTING DATA: PROCESSING, VALIDATING, AND REPORTING

This section examines survey responses related to APC data processing, validation, and reports. The first step in data processing is to transfer the data from the APC unit. Table 10 indicates that data retrieval at the garage without a physical

connection and real-time dynamic or periodic remote retrieval of APC data are the most common methods. Some agencies in the “other” category use a combination of methods or use different methods by mode.

TABLE 10
MEANS OF APC DATA RETRIEVAL

Means of Retrieval	Agencies Responding	
	No.	%
At garage without a physical connection	23	48.9
Real-time dynamic or periodic remote retrieval	13	27.7
Direct download (probe) of APCs with a physical connection	4	8.5
Other	7	14.9
Total responding	47	100.0

An important step in APC implementation is to ensure that the data meet the specified level of accuracy. Most respondents reported a threshold for acceptance of the APCs at the 90% or 95% level of accuracy. Some were more specific, for example, with a confidence level of 90% that the observations were within 10% of actual boardings and alightings. A few agencies were even more specific:

Total boardings and alightings for a trip: maximum error of 10% for load along a trip and maximum error of 10% on no more than 10% of observations.

Passenger load accuracy should be +/- 5% at each stop and in 95% overall concurrence with manual passenger counts. The system is to identify the correct stop location 95% of the time with 100% of APC-generated stops being within +/- 1% of manually observed stops.

Stop-by-stop: for 85% of stops the ON or OFF count shall be correct; within +/- 1 person 90% of the time; and within +/- 2 persons 97% of the time. Overall, total Ons and Offs within +/- 5%.

For stops with 1–5 boardings, the APC count was to have an absolute error of 0 in 80% of the cases, of 1 in 90% of the cases, and of 2 in 95% of the cases. For stops with 6–10 boardings, the APC count was to have an absolute error of 0 in 50% of the cases, of 1 in 75% of the cases, and of 2 in 90% of the cases. For stops with 11 or more boardings, the absolute error was to within 10% in at least 90% of the cases.

Almost three-quarters of respondents (71%) indicated that they use their accuracy requirements on an ongoing basis. An FTA report notes passenger count accuracy in the 2% to 3% error range using APCs (18).

An important question regarding data accuracy is, Compared to what? Manual counts are typically used as the basis of comparison, as noted in the preceding examples, although

APC vendors and some users note correctly that manual counts are not 100% accurate. Table 11 reveals that comparison to manual counts is the most common technique to edit and validate APC data. However, agencies use a variety of methods to edit and validate data. Many validation techniques look for internal inconsistencies without reference to another data source to use as a comparison.

TABLE 11
METHODS TO EDIT AND VALIDATE APC RIDERSHIP DATA

Method	Purpose	Agencies Responding	
		No	%
Compare with manual counts	Accuracy	32	69.6
Look for unexplained variance across trips	Validation	27	58.7
Compare ridership totals across days for reasonableness	Validation	25	54.3
Rely on professional judgment of planners and schedulers	Validation	24	52.2
Use an automated program to analyze APC data	Validation	24	52.2
Compare ridership and revenue totals	Accuracy	18	39.1
Compare on/off totals by trip and adjust as needed	Validation	14	30.4
Other	Varies	7	15.2
Total responding		46	100.0

Automated data validation programs can make life much simpler for data analysts. These programs are provided by the APC vendor, developed in-house, or purchased from a third party. Agencies using third-party programs noted that they feature up to 36 validation routines with adjustable thresholds. Vendor software is not always transparent to the user, and it is important to understand how the validation checks work.

The most common test is to compare boardings and alightings. As Table 12 shows, agencies reported various thresholds for determining validity at the block or trip level. The table shows reported examples of validation tests, thresholds, and actions.

The following annotated version of one of the more detailed descriptions of APC data editing and validation in the survey is presented as an example:

The data collected by the APC buses and then matched to the stop/schedule data is stored in a DB2 database. We use a [Statistical Analysis System] SAS program to process this data, screen out “bad” data, and store the validated data in SAS datasets. The following tests are used to screen out “bad” data:

TABLE 12
EXAMPLES OF AUTOMATED VALIDATION PROGRAM RULES

Test	Threshold	Action
Boardings vs. alightings by block or by trip	5%	Discard block or trip data if exceed threshold
	10%	
	20%	
	30%	
Loads	Less than 0	Adjust boardings/alightings at heaviest use stops
Bus stop location	within 200 feet of actual bus stop	Flag stop data if exceed threshold
Actual vs. scheduled block miles/kilometers	10%	Discard data exceed threshold
Actual vs. scheduled block pullout/pull-in times	30 minutes	
	20 minutes	
Actual vs. scheduled trip start/end times	“significantly off-schedule”	
Observed vs. “expected” results at the route, block, trip, and stop levels	Not specified	Assign quality code to data
Geographic information vs. computerized scheduling software data	Look for match	Assign probable route/block
Block data	No data	Discard block data

1. If the ratio of ons/offers for a bus-date-block is less than 0.7 or greater than 1.3, then data for all trips operated by that bus-date-block are declared invalid.
2. If 0 ons and 0 offs are counted for a complete bus-date-block, then the data is declared invalid.
3. Multiple measurements for the same stop (when a bus opens its doors more than once at a stop, for example) are aggregated into a single record.
4. Data for trips measured by more than one bus on a single day (e.g., when an APC bus is traded off with another APC bus) are merged.
5. At route terminals at which layovers occur, all offs measured for the arriving trip and for the departing trip are assigned to the last stop of the arriving trip. All ons measured for the arriving trip and departing trip are assigned to the first stop of the departing trip.

6. Leaving loads are calculated for each stop. Special rules are used for open loop routes where passengers ride through a terminal.
7. Trip samples that have a mismatch between date and schedule type (as a result of stop matching errors) are eliminated from the database. This happens rarely, mainly for the first day of a booking that happens on the same day that a switch between standard time and daylight saving time occurs.
8. Trip samples that have large imbalances between total ons and offs are eliminated from the database.

Some agencies use APC data for NTD purposes. FTA requires manual checks annually to validate APC data for NTD submittal. The concept of manual validation of APC data as a one-time or periodic (every 3 years, for example) exercise is of interest to agencies as they become more confident in the accuracy of APC data.

The survey included a question on the percentage of raw APC data that is converted into useful information for service planners, schedulers, and others. The overall average is 74%, comparable to findings from 10 years ago, with a median value of 80%.

Processing APC data often requires changes to existing data systems. The majority of respondents reported the need to identify GPS coordinates for stops and to create or maintain a bus stop inventory. Several agencies had already done this for implementation of AVL or automated passenger announcements. A few agencies noted the establishment of defined interfaces between computerized scheduling

software packages and APC or AVL systems. Only one-quarter of all respondents indicated no changes to existing data systems.

For data storage and analysis, the most common changes were the addition of servers for data storage and new database software for analysis. Software development is discussed in greater detail later. More than 85% of respondents indicated that they archive APC data. The average and median length of time to keep APC data is 5 years, although four agencies indicate that they plan to keep archived data forever.

Table 13 describes type and frequency of routine APC reports. The most common type of report is boardings and alightings by stop, but all types of reports are generated by a majority of agencies that use APCs. Detailed (segment/stop level) ridership and scheduling-related reports are most likely to be generated as needed.

Table 14 indicates a variety of sources for data processing and report generation software. A majority of agencies rely on the hardware vendor, but several indicated in-house software development, and it was not uncommon for agencies to use an outside vendor other than the hardware vendor. More than 70% of agencies that used an outside vendor indicated that the process involved customization of the software to meet the agency's specific needs.

More than 90% of responding agencies indicated a capability to generate nonstandardized reports from the APC system. The most common method was for the end users to generate these reports, but one-quarter of agencies with this capability rely on the outside vendor for specialized report generation.

TABLE 13
TYPES OF REPORTS ROUTINELY GENERATED FROM APC DATA

Type	No. Agencies Responding	Frequency of Reports (percentage of agencies responding)					
		Annually	Quarterly	Monthly	Weekly	Daily	As Needed
Stop-level boardings and alightings	41	2	15	10	2	10	61
Route-level ridership	38	5	26	16	3	18	32
Route segment ridership	38	11	11	5	3	8	63
System ridership	33	9	15	27	—	21	27
Performance measures	33	6	27	12	3	12	39
Schedule adherence	32	—	16	13	—	16	56
Running times	31	—	13	3	3	13	68
Total responding	42	7	15.2				100

TABLE 14
DEVELOPMENT OF DATA PROCESSING AND REPORTING SOFTWARE

Source	Agencies Responding	
	No.	%
Hardware vendor	26	55.3
In-house, by end users of data	16	34.0
In-house, by information systems or computer services department	13	27.7
Another outside vendor	12	25.5
Other	3	6.3
Total responding	47	100.0

Anyone who has been through the process of implementing a new technology knows that there is a “debugging” period, during which start-up problems are resolved. The debugging period for APCs averages 17 months, identical to the finding of the 1998 synthesis, with a median of 18 months. There was a wide variation in responses to the debugging question, from 1 month to 5 years. Table 15 groups the responses by time frame. There were no significant differences by system size. Respondents involved on a day-to-day basis with APCs may have been more aware of problems and issues than others.

TABLE 15
LENGTH OF “DEBUGGING” PERIOD FOR APC IMPLEMENTATION

Time Frame	Agencies Responding	
	No.	%
Less than 6 months	3	9.7
6 to 11 months	4	12.9
12 to 23 months	8	25.8
24 months or more	6	19.4
Ongoing	10	32.3
Total responding	31	100.0

ORGANIZATION AND RESOURCE REQUIREMENTS

Organizational issues can affect the success of new technologies. Implementation of APCs and other ITS technologies fosters or requires integration and cooperation among departments that may have previously managed their data in isolation. This section explores organizational aspects of the purchase, management, and use of APC systems.

Interaction among data users, impacts on staffing levels and needs, and cost are all considered here. It should be noted, however, that costs reported by transit agencies varied depending on methods and assumptions used. In particular, it was difficult for agencies that purchased APCs as part of a broader ITS procurement to separate out the costs involved. The reader is cautioned that cost data are neither uniform nor complete.

Table 16 summarizes departmental involvement in management, purchasing, and use of APC systems. The planning department is the most common location for management of the APC system, followed by the operations department. The “other” responses related to management represent agencies where this responsibility is split among departments: planning and maintenance; maintenance and information technology (IT); operations, maintenance, and IT; planning and IT. Table 16 also shows widespread involvement across departments in procurement of the APC system and use of the APC data. Only one agency reported no downstream users of APC data.

In terms of data users, more than 80% of responding agencies reported electronic access to APC data through standard reports. Half of agencies indicated that hard copies of APC reports were available to data users, and 41% noted that data users could query the database directly.

TABLE 16
DEPARTMENTS INVOLVED IN AGENCY PURCHASE, MANAGEMENT, AND USE OF APC SYSTEMS

Department	% Involved in APC Purchasing Decision	% Primary Ownership of APC Management and Operation	% User of APC Data
Planning	90	42	91
Operations	62	20	73
Information services/computer services	67	16	14
Scheduling	57	7	82
Budget/finance	52	2	34
Maintenance	43	2	14
Marketing/market research	24	0	59
Senior management	N/A	N/A	52
Other	7	9	9
Total responding/percentage	42/100	44/100	44/100

N/A = not available.

Implementation of APCs necessarily involves multiple departments within the transit agency. Table 17 reports on the impacts of APC use on the transit agency. The most positive aspects of APC implementation included improved communication among departments, greater value placed on ridership data, improved decision-making ability, greater responsiveness, and the ability to provide the needed data to end users. Among other positive effects were better relations with external agencies and management's reaction to better reporting.

TABLE 17
EFFECTS OF INTERACTION AMONG MULTIPLE APC USERS

Effects	Agencies Responding	
	No.	%
POSITIVE		
Improved communications between departments	7	20.6
Greater value placed on ridership data	7	20.6
Better data leading to improved decision-making ability	5	14.7
Greater responsiveness to public/others	3	8.8
Ability to provide data to end users	3	8.8
NEGATIVE		
Difficulty with bus assignments	7	20.6
Constant/increased demands for new or reformatted reports	5	14.7
APC maintenance has low priority	4	11.8
Unrealistic expectations re: turnaround time and data quality (i.e., not perfect)	4	11.8
Total responding	34	100.0

The most frequently mentioned challenges to successful implementation and operation included problems ensuring that bus assignments were completed, new demands for reports, priority for APC equipment in the maintenance department, and unrealistic expectations regarding turnaround time and data quality. One respondent characterized maintenance personnel's attitude as very negative: APCs drain power from the bus batteries and take technicians' time away from important work.

Among other negative effects were concerns from operators and the union, tensions regarding data accuracy and processes for addressing missing data, frustrations regarding start-up problems, APC system vulnerability to communications problems, lack of commitment from all departments regarding maintenance of the data collection process, and unmet training needs.

Staffing levels for the passenger counting program are summarized in Table 18. Smaller systems were more likely to assign fewer people in each category. The survey also asked about changes in staffing associated with an APC program. More than 70% of all agencies reported no changes or decreases in staff levels in each of the categories in Table 18, with notable decreases in the size of traffic checking units. About one-quarter of respondents, none from small systems, indicated a minor increase (defined as one or two full-time positions) in maintenance staff, and 22% (consistent across systems of all sizes) reported a minor increase in professional staff.

Implementation of APCs does create a need for training. A majority of respondents noted increased training needs in the areas of software/computer, analytical, and hardware maintenance skills (Table 19). Only 24% of responding agencies reported no additional training needs.

TABLE 18
STAFF POSITIONS (FULL-TIME EQUIVALENTS) ASSIGNED TO CARRY OUT PASSENGER COUNTING PROGRAM

Category	Less than 1	1 to 1.9	2 to 3.9	4 or more	Don't Know	Total No. Responding
Managers/professionals	47.7%	29.5%	20.5%	2.3%	—	44
Support (e.g., equipment maintenance)	54.1%	27.0%	13.5%	5.4%	—	37
Clerical	72.0%	20.0%	—	—	8.0%	25
Traffic checkers	44.4%	11.1%	7.4%	29.6%	7.4%	27
Other	42.9%	—	14.3%	42.9%	—	7

NOTE: "Other" includes data retrieval, data editing/analysis/report writing, and ad hoc traffic checking personnel.

TABLE 19
TRAINING NEEDS ASSOCIATED WITH APC
IMPLEMENTATION

Skill	Agencies Responding	
	No.	%
Software/computer	29	69.0
Analytical	23	54.8
Hardware maintenance	23	54.8
Other	5	11.9
No training needs	10	23.8

As noted earlier in this section, cost data from the survey should be interpreted cautiously. Respondents varied in their ability to break down cost data (especially for older systems or for APC systems purchased as part of a larger ITS procurement). As one example, reported capital costs for the agency's APC system ranged from \$90,000 to \$40,000,000.

An attempt was made to standardize costs by asking the cost per APC unit installed. The average capital cost per APC unit was \$7,500. The median capital cost per APC unit was \$6,638, with 26 agencies responding.

Table 20 shows median capital cost and median capital cost per APC unit by number of vehicles with APCs. FTA's Transit Technology Fact Sheets (39) report a median cost of \$350,000 for an APC system, compared with the median in this sample of \$490,000.

Average annual operating and maintenance cost per APC unit was \$1,458. The median annual operating and maintenance cost per APC unit was \$600, with 11 agencies responding.

TABLE 20
APC MEDIAN CAPITAL COST AND MEDIAN CAPITAL
COST PER UNIT BY NUMBER OF VEHICLES EQUIPPED

No. of Vehicles with APCs	Median Capital Cost (\$)	Median Capital Cost per APC Unit Installed (\$)	No. Systems
Less than 100	200,000	7,500	13
100 to 400	500,000	2,700	7
Over 400	1,800,000	1,100	3
Total sample	490,000	6,638	26

NOTES: Three systems reported total cost only; three systems reported unit cost only. All three systems in the over-400 category had at least 1,450 vehicles with APCs.

SUMMARY

The most common reasons to collect ridership and travel time data are to compile ridership by route and to track systemwide ridership totals. A majority of all respondents also collect data on ridership and travel time for more specific microlevel uses at the route segment or stop level. Tracking ridership changes, calculating performance measures, and adjusting schedules were the three most common uses of ridership and travel time data.

A majority of respondents use a combination of automated and manual methods to collect ridership and travel time data. The most common combinations involve automatic passenger counter (APC) system plus manual data collection and farebox plus manual collection. In some cases, an older technology is retained to test the validity of the new technology. Agencies also retain older technologies for specific purposes, for example, National Transit Database (NTD) reporting or "official" systemwide ridership data. Several agencies noted problems with the accuracy or reliability of APC counts, and thus have not transitioned to use of the new technology. Methods also vary by mode, type of service, and type of vehicle.

Agencies that continue to collect data manually were asked why they have not switched to an automated technology. Cost is the most common reason, followed by low priority for automated data collection at the agency. Smaller systems (fewer than 250 peak buses) are more likely to continue to rely on manual data collection.

Nearly all agencies with APC systems use infrared beams, whereas APC installations split between infrared beam and treadle mat in the 1998 TCRP synthesis. Another difference is the universal inclusion of a GPS element in the APC system. Almost half of all respondents indicated that their APC purchase was part of a broader ITS project.

Only a portion of most agencies' buses are APC-equipped; however, more than one-quarter of responding agencies have installed APCs on all buses. Nine of the 12 agencies that are 100% APC-equipped bought APCs as part of a broader ITS purchase. The majority of agencies with both APC and automated vehicle location (AVL) primarily use AVL time and location data, typically because AVL is on all buses, whereas only a portion of the fleet is equipped with APCs.

Introduction of APCs usually requires a closer working relationship between the planning and operations departments. Typically, service planners or schedulers prepare a weekly list of blocks to be sampled and transmit the list to the operations department. Some agencies have automated the assignment process using APC system software to identify blocks for which no APC data have been collected. On

average, 80% of daily APC assignments are completed as scheduled.

Most respondents reported a standard for acceptance of the APCs at the 90% or 95% level of accuracy. Almost three-quarters of respondents indicated that they use these standards on an ongoing basis. An important question regarding data accuracy is, Compared to what? Manual counts are typically used as the basis of comparison.

APCs provide a richer ridership and travel time database at a finer level of detail than farebox or manual counts, even for agencies with only a few APCs. The increased number of observations lends greater confidence to decisions regarding changes in service levels. Being rich in data provides clear benefits but can create its own challenges. Processing APC data often requires changes to existing data systems, such as addition of GPS coordinates for stops and an updated or new bus stop inventory. A few agencies noted the establishment of defined interfaces between computerized scheduling software packages and APC or AVL systems. For data storage and analysis, the most common changes were the addition of servers for data storage, new database software for analysis, and network upgrades.

Automated data validation programs, provided by the APC vendor, developed in-house, or purchased from a third party, can simplify and streamline the process of converting raw APC data into usable ridership data. Agencies using third-party programs noted that they feature up to 36 validation routines with adjustable thresholds. Vendor software is not always transparent to the user, and it is important to understand how the validation checks work. The most common validation test is to compare boardings and alightings. Agencies reported various thresholds for determining validity at the block or trip level.

The percentage of raw APC data that is converted into useful information for service planners, schedulers, and others averages 74%, comparable to findings from 10 years ago, with a median value of 80%.

A majority of agencies rely on the hardware vendor for data processing and report generation software, but several indicated in-house software development or use of an outside vendor other than the hardware vendor. More than 70% of agencies that used an outside vendor indicated that the process involved customization of the software to meet the agency's specific needs. The most common type of report is boardings and alightings by stop. Detailed (segment/stop level) ridership and scheduling-related reports are most likely to be generated as needed, suggesting that the report process for these types of reports may not be automated.

More than 90% of responding agencies indicated a capability to generate nonstandardized reports from the APC

system. The most common method was for the end users to generate these reports, however one-quarter of the agencies with this capability rely on the outside vendor for specialized report generation.

Some agencies use APC data for NTD purposes. FTA requires manual checks annually to validate APC data for NTD submittal. The concept of manual validation of APC data as a one-time or periodic exercise is of interest to agencies as they gain confidence in the accuracy of APC data.

Anyone who has been through the process of implementing a new technology knows that there is a "debugging" period, during which start-up problems are resolved. The debugging period for APCs averages 17 months, identical to the finding of the 1998 synthesis, with a median of 18 months.

Implementation of APCs and other ITS technologies fosters or requires integration and cooperation among departments that may have previously managed their data in isolation. The planning department is the most common location for management of the APC system, followed by the operations department. There is widespread involvement across departments in procurement of the APC system and use of the APC data. Data users typically access APC data electronically through standard reports, and 41% of agencies noted that data users could query the database directly.

Implementation of APCs necessarily involves multiple departments within the transit agency. The most positive aspects of APC implementation included improved communication among departments, greater value placed on ridership data, improved decision-making ability, greater responsiveness, and the ability to provide the needed data to end users. The most frequently mentioned difficulties included problems ensuring that assignments were completed, new demands for reports, priority for APC equipment in the maintenance department, and unrealistic expectations regarding turnaround time and data quality.

Changes in staffing levels as a result of APC implementation were minimal in most cases: More than 70% of all agencies reported no changes or decreases in staff levels, with notable decreases in the size of traffic checking units. About one-quarter of respondents indicated a minor increase (defined as one or two full-time positions) in maintenance staff, and 22% reported a minor increase in professional staff.

Implementation of APCs does create a need for training. A majority of respondents noted increased training needs in the areas of software/computer, analytical, and hardware skills. Only one-quarter of responding agencies reported no additional training needs.

Cost data from the survey should be interpreted cautiously, as respondents varied in their ability to break down cost data (especially for older systems or for APC systems purchased as part of a larger ITS procurement). An attempt was made to standardize cost data by asking the cost per APC unit installed. The average capital cost per APC unit

was \$7,500. The median capital cost per APC unit was \$6,638, with 26 agencies responding. Average annual operating and maintenance cost per APC unit was \$1,458. The median annual operating and maintenance cost per APC unit was \$600, with 11 agencies responding.

CHAPTER FOUR

AGENCY ASSESSMENT OF AUTOMATIC PASSENGER COUNTER SYSTEMS

INTRODUCTION

This is the second of two chapters presenting the results of a survey of transit agencies regarding passenger counting. The previous chapter addressed the “nuts and bolts” of how agencies count passengers. This chapter’s focus is on agencies’ evaluations of automatic passenger counter (APC) systems. Specific topics include agency satisfaction with current methods, potential improvements, and lessons learned.

SATISFACTION WITH AUTOMATIC PASSENGER COUNTER SYSTEMS

Table 21 shows transit agency satisfaction with the performance of its APC system in terms of counting passengers. Most respondents are either very satisfied or somewhat satisfied with the performance of their APC system. Interestingly, 93% of agencies purchasing a stand-alone system were either very or somewhat satisfied, compared with 74% of agencies purchasing APCs as part of a larger ITS procurement. More than half of all stand-alone agencies were very satisfied, compared with 16% of agencies involved in a larger procurement.

TABLE 21
AGENCY SATISFACTION WITH APC SYSTEM
PERFORMANCE IN TERMS OF COUNTING PASSENGERS

Level of Satisfaction	Agencies Responding	
	No.	%
Very satisfied	16	40.0
Somewhat satisfied	18	45.0
Somewhat dissatisfied	2	5.0
Very dissatisfied	4	10.0
Total responding	40	100.0

Table 22 presents the primary benefits of APC for the agency. These represent responses to an open-ended question. The most frequently cited benefits included availability of data at a much finer level of detail (e.g., stop, segment,

and trip), improved quality of the data, and the availability of running time data for schedule adjustments.

TABLE 22
PRIMARY BENEFITS OF APCS

Benefit	Agencies Responding	
	No.	%
Finer level of detail (stop/segment/trip)	14	36.8
Quality of data	11	28.9
Running time data to adjust schedules	10	26.3
Better basis for decision making	6	15.8
Quantity of data	6	15.8
Timeliness of data	5	13.2
Total responding	38	100.0

Table 23 summarizes problems with the APC system, also representing responses to an open-ended question. The most frequently cited problems involved reporting, data processing, data validation, and hardware. One-quarter of all respondents reported either no problems or the usual start-up issues. There were no differences in problems encountered by system size or type of purchase (stand-alone vs. part of a larger ITS procurement).

TABLE 23
PROBLEMS ENCOUNTERED WITH THE APC SYSTEM

Problem	Agencies Responding	
	No.	%
None/usual start-up issues	10	25.6
Reports/reporting software	5	12.8
Data processing and analysis	4	10.3
Data validation	4	10.3
Hardware problems	4	10.3
Total responding	39	100.0

Respondents were asked, “If you could go back in time and change ONLY ONE aspect in the process of purchasing, installing, and using your APC system and associated methodology, what would you change?” Table 24 summarizes the results.

Improvements related to the procurement process and contract elements were most frequently mentioned. These included stricter contractual requirements (regarding accuracy, timely support, availability of spare parts, and timelines), purchase of a complete system through a single vendor, avoidance of purchase through a consortium, and changes to internal procedures.

Additional APCs and differences in approach also ranked highly. “Approach” is a catch-all category that includes being more informed about hardware and software choices, involving maintenance personnel at the start of the process, dedicating one or more technicians to work full time on APCs, completing the bus stop inventory before installation, and hiring a statistician to develop a methodology for passenger counting before vendor selection. Testing, different choices of hardware, and enhanced training were also mentioned by more than one respondent.

LESSONS LEARNED FROM SURVEY RESPONSES

Approximately 40% of all survey respondents and 73% of agencies that have deployed APCs shared lessons learned from the implementation and use of APC systems. The lessons learned can be grouped into nine broad categories plus three miscellaneous categories (respondents had a lot to say!), as shown in Table 25. Lessons regarding data processing and use led the list of topic areas, followed by purchase and implementation, data validation, and maintenance.

Responses are presented by category below.

TABLE 24
ONE IMPROVEMENT TO THE APC PROCESS

Improvement	Agencies Responding	
	No.	%
Contract and procurement	8	25.0
Additional APCs	7	20.6
Approach	7	20.6
Testing	4	11.8
Hardware	3	9.4
Training	2	5.6
Total responding	32	100.0

TABLE 25
LESSONS LEARNED FROM SURVEY RESPONSES

Category	Agencies Responding	
	No.	%
Data processing/use/reporting	14	41.2
Purchase/implementation	9	26.5
Data validation	7	20.6
Maintenance	7	20.6
Staff/resource needs	5	14.7
Time frame	5	14.7
Testing	5	14.7
Experience of peers	4	11.8
Training	4	11.8
Other: procedures	6	17.6
Other: staff/management	3	20.6
Other: APC system inputs	2	17.6
Total responding	34	100.0

Survey Responses: Data Processing, Use, and Reporting

- Pay attention to post-processing capabilities.
- Concentrate on the soft side of the system—this is where success is really achieved.
- Listen to and tailor reports for system users (planners, schedulers, management).
- Ensure that staff monitors the system and understands how to use the data.
- Ensure that staff is capable and comfortable analyzing and using APC data.
- Find out how valuable the canned reporting software is, and be prepared to buy a good program and hire or use people in your agency to develop a program.
- Be sure that the system purchased has good reporting capabilities and can balance loads in a statistically valid manner.
- Purchase reporting and analysis software on the front end.
- Develop report generation software internally if the agency has staff with the right skill sets; having an internal capability to modify or generate new report is very beneficial.
- Ensure that the software program provides required analysis.
- Think long-term, and ensure that data structures can be integrated with downstream applications.
- Be sure that the system purchased has good software with diagnostic capabilities.

- Understand uses and limitations of the data, depending partly on how many APC units are deployed.
- Realize that software issues are part of APC growing pains.

Survey Responses: Purchase and Implementation

- Buy APC software and hardware from the same vendor—life is much easier.
- Be aware that a stand-alone APC system (i.e., not part of a larger ITS system) is best.
- Do not implement until software is ready.
- Realize that more is always better when it comes to APC units to maximize the degree to which significant data levels can be aggregated over time for specific routes.
- Realize that an APC program can be successful with 10% of the buses equipped with APCs.
- Specify standards for accuracy of both counts and passenger-mile calculations as a disqualifying factor for acceptance in the request for proposals.
- Focus on equipment acceptance standards.
- Work with a company that can deliver the total proven package.
- Calibrate units as part of the standard operating procedure before implementation.

Survey Responses: Data Validation

- Conduct an ongoing manual versus machine validation program.
- Maintain manual staff for periodic manual checks to validate data.
- Understand the error rate of manual counts before expecting 100% accuracy from machines.
- Make sure the data are validated.
- Ensure all data are correct.
- Maintain a manual method or develop some other method to cross-check the data before eliminating manual method.
- Do not assume that calibration testing will occur: Go out and verify the counts for yourself.

Survey Responses: Maintenance

- Involve maintenance early and find people who can handle troubleshooting of APC equipment.
- Dedicate a maintenance person to the APC system.
- Ensure timely maintenance on the basis of good diagnostics produced by or derived from the collected data.
- Plan on extra maintenance staff.
- Realize that hardware issues are part of APC growing pains.
- Develop a maintenance plan upfront.
- Identify malfunctioning equipment and to transmit this information to maintenance personnel in a timely

fashion by means of vendor equipment diagnostic data files and reports.

Survey Responses: Staff and Resource Needs

- Make sure your staff has or gets the required resources and knowledge—APCs don't automatically work.
- Include a hardware technologist on the APC staff to coordinate new bus installations and ensure that all buses are counting properly.
- Consider staff abilities when planning for any new system.
- Do not expect miracles without very responsible and involved "owners" of the APC system.
- Plan on extra staff in the short term and for maintenance.
- Be sure to have at least one dedicated full-time staff person to support the APC system.
- Dedicate one full-time maintenance person to the APC system.

Survey Responses: Time Frame

- Make sure that the organization knows that APC implementation cannot be done in a year—it takes about 3 years to work out all the bugs.
- Be patient.
- Prepare for the long haul; counters are not as easy to install as people think.
- Realize that start-up time is longer than stated.
- Expect growing pains associated with APCs.

Survey Responses: Testing

- Do not always believe what vendors tell you.
- Test every single aspect of the system before acceptance.
- Do exhaustive testing of the APC system.
- Focus on testing.
- Do not let a vendor tell your management that its system will get 100% of the data.

Survey Responses: Experience of Peers

- Always try to find other agencies that have this new equipment and ask about their experience before deciding to purchase.
- Contact and visit other agencies and bring a cross-functional team with you to see how they use APCs.
- Seek advice from peers using the same or similar equipment.
- Visit other properties and learn from them.

Survey Responses: Training

- Make sure that your staff gets the needed knowledge of the system through training.
- Make sure that qualified staff are trained to monitor the system and use the data.

- Realize that good upfront training is needed.
- Train, train, and train again.

Survey Responses: Other—Procedures

- Establish and track bus assignment procedures to identify any problems.
- Make sure a crosssection of the fleet is APC-equipped.
- Provide online assignment instructions to dispatchers to ensure correct assignments.
- Realize that integration with scheduling software is a major factor in how the system will work.
- Get prior FTA approval to use APC data for National Transit Database (NTD) reporting.
- Realize that other agencies took their lumps in getting approval of APC data for NTD, so you should not have to do the same.

Survey Responses: Other—Staff and Management

- Realize that some employees are not so open to change.
- Do not get rid of all traffic checkers; they are needed for other purposes such as NTD.
- Realize that ongoing support from upper management is important.

Survey Responses: Other—APC System Inputs

- Make sure bus stops have correct GPS coordinates and route inventories are accurate.
- Understand the data requirements for stop matching and establish a system to generate the required data before implementation.

SUMMARY

This chapter has described agency assessments of automatic passenger counter (APC) systems. Findings include the following:

- Results regarding agency satisfaction with the performance of its APC system in terms of counting passengers are positive. Forty percent were very satisfied, and 45% were somewhat satisfied.
- The primary benefits of APCs included data disaggregated at the stop, segment, and trip levels; better quality of ridership data; availability of running time data to adjust schedules; and a better basis for decision making.
- Problems encountered with the APC system included reporting software, data processing and analysis, data validation, and hardware problems. One-quarter of all respondents reported either no problems or the usual start-up issues.
- Contract elements, procurement procedures, purchase of additional APC units, and the overall approach to APC implementation were the most frequently mentioned aspects of the APC process that transit agencies would like to change. Stricter contractual requirements, purchase of a complete system through a single vendor, and changes to internal procedures were all important. Changes to the overall approach included being more informed about hardware and software choices, involving maintenance personnel at the start of the process, dedicating one or more technicians to work full time on APCs, completing the bus stop inventory before installation, and hiring a statistician to develop a methodology for passenger counting before vendor selection.
- Almost three-quarters of all survey respondents that have implemented APC systems shared lessons learned from the process. Agencies focused on use and validation of the APC data, purchase and implementation, and ongoing agency maintenance in the discussion of lessons learned. Agencies offered lessons in many areas, but the emphasis on data systems and agency procedures suggests that these areas are critical to the success of APC implementation.

The following chapter describes findings from six case studies that explore issues related to APC implementation and use in greater detail.

CHAPTER FIVE

CASE STUDIES**INTRODUCTION**

Survey results provide an excellent overview of the major issues regarding automatic passenger counter (APC) system procurement, implementation, and use. Following a review of these results, six agencies were selected as case study sites. Personnel directly involved with APC deployment and use agreed to be interviewed by telephone. In some cases, more than one person at an agency either participated in the interviews or reviewed the draft summary of the case study. The case studies are intended to provide additional details on innovative and successful practices as well as on issues related to APCs.

The selection process for case studies had several criteria: (1) to include transit agencies of various sizes in different parts of the country, (2) to include agencies that have achieved success in the use of APCs, and (3) to select agencies with varied levels of reported satisfaction with APCs so that ongoing issues can be better understood. More than two-thirds of responding agencies offered to serve as a case study and, as shown by examples from non-case-study respondents in chapters three and four, these agencies offered very interesting responses based on their experiences. The six agencies chosen do not necessarily consider themselves as examples of best practices, but together they provide a representative overview of the state of APC system use.

The six case study agencies are

- OC Transpo (Ottawa–Carleton Regional Transit Commission), Ottawa, Ontario, Canada
- RTD (Regional Transportation District), Denver, Colorado
- NFTA (Niagara Frontier Transportation Authority), Buffalo, New York
- RTC (Regional Transportation Commission of Washoe County), Reno, Nevada
- Metro Transit, Madison, Wisconsin
- TriMet (Tri-County Metropolitan Transportation District of Oregon), Portland, Oregon

The case studies summarize survey responses and interview observations from each agency. The introduction to each case study includes a basic description of the system, with data taken from FY 2006 NTD reports or provided

directly by the agency. The interviews explored issues raised by the survey responses in greater depth. OC Transpo and TriMet also served as case studies for the previous TCRP synthesis on this topic.



OC TRANSPO (OTTAWA–CARLETON REGIONAL TRANSIT COMMISSION), OTTAWA, ONTARIO, CANADA

OC Transpo was a case study for *TCRP Synthesis 29* and is a long-time user of APC systems with more than 25 years' experience. OC Transpo was formed in 1973, but has a history dating back to the 1870s under different names. The agency serves an area with a population of 778,000 and operates 832 peak buses out of a total fleet of 991 buses. Annual ridership is 95.6 million (as of 2007). The Transitway, a dedicated system of bus-only roadways, provides an exclusive rapid transit link across much of Ottawa's urban area.

The agency originally relied on a signpost-based APC system, however it is now moving to GPS. Earlier version APC equipment had no GPS capability, however now GPS is built into all new APC hardware purchased since 2000. The switch to GPS "virtual" locations, replacing the on-street signpost "fixed or hard" locations, has greatly improved APC locational accuracy. To gain further benefits of GPS, the operating software still needs to be updated. OC Transpo has plans to migrate to new software that is more mainstream and provided by a supplier that has other transit clients. The current software is customized and used only by OC Transpo; therefore, the agency pays the full cost of any upgrades and has no recourse if the company decides to

redeploy staff to other projects or even to discontinue supporting the product altogether. The agency sees strong benefits in using hardware and software provided by the same supplier. The possibility of being a part of an APC user community that shares a common product, and its cost, is very appealing.

Ninety buses, slightly less than 10% of the OC Transpo fleet, are equipped with APCs. Each scheduled trip is sampled three times on average during each of the quarterly booking periods. Spread spectrum radio is used to download data at the garage. Spread spectrum radio has a limited range, but is constantly polling and will find a bus entering the garage and download APC data. Data are then moved to a central computer for processing. Automated downloading is simple, low cost, reliable, and low maintenance. Buses continue to collect and store data for at least 2 to 3 days; therefore, no information is lost during rare system problems that cause automatic downloading to fail.

OC Transpo has not employed traffic checkers since the APC system went online in the early 1980s. Current staffing needs include 3.5 positions: an APC supervisor, an APC analyst, a hardware technologist, and a part-time student from one of the local universities who assists with equipment maintenance. Estimated replacement cost for capital equipment is \$600,000 (\$525,000 to purchase hardware plus \$75,000 for installation) and \$225,000 for software. Estimated annual operating and maintenance cost is \$315,000.

The hardware technologist is a key position. This person has excellent rapport with other employees in the garages and also with the vendors. The hardware technologist maintains the APC system and oversees all work on the bus (union mechanics must do any work on the bus itself).

The part-time student position, APC technician, may be unique to OC Transpo and is extremely useful. The agency tries to hire a first- or second-year student who will stay on the job for 2 to 3 years. He (or most recently, she) usually works nights and weekends when the hardware technologist is not at work. She can perform preventative maintenance, troubleshoot and identify problems with APC units as they come in for the night or are parked on weekends, and communicate her findings electronically to the hardware technologist, who then arranges for a union mechanic to correct the problem.

OC Transpo uses internally developed software to assist in managing the sampling program to ensure that all trips are sampled. The program looks for trips and runs that have not been sampled, identifies these runs to have an APC bus assigned the following day, and transmits the information to the bus starter's screen in the garages. The bus starter assigns buses to operators, and it is very important that the requested

APC assignments appear in real time on their working screen. Even with this system, however, some assignments are still not completed as scheduled. The biggest of the agency's three garages is where most of the assignment problems occur, owing in large part to overcrowded conditions that make it difficult to park the APC buses in a separate area. A new bus garage is being constructed and is expected to lessen problems with assignments not being properly completed. Even so, the assignment process works better now than it did 10 years ago.

The agency plans to implement new APC software by 2010, with benefits including GPS identification of bus stops, more accurate trip and stop matching, increased data throughput, enhanced data quality, and improved hardware maintenance through the use of maintenance management tracking software. Another less tangible benefit of integrated hardware and software is establishing a good, solid product with excellent technical support that will lessen the current reliance on the two staff members who have been the source of all APC knowledge within the agency. This will allow for a smoother transition on their retirement.

Although there was initially a steep learning curve regarding training in the use of the APC system, APCs are now a part of the fabric of the agency. Most planners and managers who use passenger count data have never used anything other than APC data.

There are now many good APC suppliers offering complete packages of hardware and software, as opposed to the early 1980s when OC Transpo cobbled together its first system. Using a single supplier for hardware and software should greatly improve an agency's ability to get APCs up and running. All new OC Transpo bus purchases are prewired for APCs. This significantly reduces the installation time for new hardware or moving equipment from bus to bus. It also allows greater flexibility in the selection of which buses to equip.

The validation techniques have not changed over the past 10 years. Critical factors analyzed in the validation of APC data include the balance between boardings and alightings at the trip level, total trip distance, stop recognition, and start–end times. These same parameters will be used after the software change, with an expectation of improved stop-level accuracy through the use of GPS.

Bus itineraries are now seen as more accurate. Until recently, OC Transpo had a separate bus stop file for the APC system, but now APC taps into and uses the bus stop inventory in the scheduling and information systems' database. Customer service and other departments also use this inventory, resulting in quick discovery and correction of any errors and enhanced accuracy.

APC data are more important than ever for OC Transpo's planners and managers, who rely on them as the primary input to all planning decisions covering, for example, route planning, bus stop usage, shelter justification, long-range plans, and transit priority strategies. Like all transit agencies, OC Transpo is under added scrutiny to ensure that it spends public funds wisely. Performance standards are an important tool in this regard, but performance measures depend on ample and accurate ridership data.

The use of APC data for scheduling purposes took longer to gain acceptance. All OC Transpo buses are now "smart buses," equipped with mobile data terminals and GPS, and will provide running time data for schedules because it provides a 100% sample compared with the 10% sample for APC. APC data will supplement these data because they can provide detailed time utilization information such as dwell times at stops.

If OC Transpo could go back and change only one thing, it would purchase a complete system from a single APC vendor. Of course, this was not an option when APCs were introduced in Ottawa, but today there are several proven suppliers of hardware and software systems.

Lessons learned include the following:

- Do not expect miracles overnight. It may take up to 3 years to fully implement, get the procedural bugs out, and have all internal staff accept and adjust to working with APC. It cannot be done in a year. Make sure that the organization, including management, knows and accepts this.
- Buy APC software and hardware from the same vendor. Life is much easier. Before buying, talk to users of APC systems and find out why their system succeeded or failed.
- Concentrate on the "soft side" of the system—this is where real success is achieved. An example is an automated bus assignment program that both determines assignments for tomorrow and reports on how well the assignments were made. It is important to measure this so those responsible for operational assignments (e.g., bus starters at OC Transpo) know when there are problems.
- Include a hardware technologist on staff responsible for coordinating new bus installations and also ensuring that all existing APC buses are counting properly. This involves an ongoing program of rotational on-board checks (manual vs. machine). OC Transpo also employs a part-time technology student on a year-round basis. The student works off-hours (weekends, very late at night), which works well with school schedules and is also when most buses are in the garages. The student checks count accuracies and carries out minor adjustments on the bus. The agency hires a first- or

second-year student who then stays with OC Transpo for approximately 3 years.

- Listen to planners, schedulers, and management; they are the real clients of the APC staff. Tailor reports to what they want, both content and format-wise.
- Involve fleet/equipment staff early in the process. It is important that they are on board, understand the importance of the system, and fully accept it.
- Promote the system as a planning tool that benefits both union and nonunion stakeholders. This can be done through demonstrations or talks with all parties. It is important that the union realizes the system will not be used for disciplinary reasons.
- Adapt to shifts in planning interests. The increased concern over budgets has made weekend sampling as well special service new hot spots for planners. APC must, more than ever before, ensure adequate coverage of these service types.
- Realize that implementing a successful APC system is a large undertaking that shouldn't be underestimated. It could stand on its own and not be viewed as an "add-on" to a larger system such as a real-time monitoring system. If possible, the contract for the system should be with the APC supplier and not a system integrator who subcontracts the work to the APC supplier.
- After implementation, include a line item in the agency budget for improvements and enhancements to the APC system to meet the needs of the clients as they gain more experience with using the data. Several case studies have noted similar ongoing enhancements. Improvements and enhancements can involve both hardware and software.



RTD (REGIONAL TRANSPORTATION DISTRICT), DENVER, COLORADO

The RTD is a public agency created in 1969 by the Colorado General Assembly to develop, operate, and maintain a mass transportation system in the 2,326 square mile district, which includes all or parts of eight counties. The agency serves an area with a population of 2.6 million and operates 921 peak buses out of a total fleet of 1,060 buses. A significant portion of service is contracted to private operators. RTD operates light rail service with 57 peak vehicles. Annual ridership is 86.6 million, including all services operated (FY 2006). In downtown Denver, RTD offers frequent service on the 16th Street Transitway/Mall.

RTD has established a very successful ridership tracking program using APCs on 20% of its bus fleet. RTD purchased its APC system in 2004. At the beginning of the process, the agency realized that getting the data was only half the program. RTD needed a way to analyze and report the data. Its survey of other agencies using APCs indicated that this element seemed to be lacking in many cases.

RTD's first important step was to purchase software for data analysis at the same time as it purchased APCs. RTD uses Ridecheck Plus to analyze ridership data.

The second important step was to realize that an effective ridership analysis program using APC data requires a substantial amount of support. There would be a learning curve, plus the usual problems that arise when implementing a new technology. Training was a critical aspect of the program. RTD also needed to get the support staff in place.

One of the first support team activities was to decide how to assign buses to ensure a comprehensive ridership database with all trips surveyed within a given pick (or run board, to use RTD's terminology). It was clear to RTD that this would involve more than a person making a list and sending it to someone else. The service development staff sat down with garage supervisors to discuss the current vehicle assignment process and how APC assignments could fit into the current process. The operations division made revisions to a draft assignment process to make it work in the garages, and service development then arranged to transmit APC assignments to the operations division.

Once the assignment process was agreed on, service planning then focused on back-office aspects such as tracking data as they came in, planning the next set of assignments, and quality assurance in general. These activities have become routine and semiautomated.

The collaborative nature of this effort was an important factor in its ultimate success. An important factor was the understanding that operations was most interested in schedule adherence data because the division was accountable for this. The Ridecheck Plus system is able to accept data collected on a laptop by road supervisors (separate from the APC system) to analyze on-time performance. Service development set up a system in which operations collects field data on flash drives and turns these in to service development, which then uploads the data for validation and analysis.

The APC system has been incrementally improved over the past several years and is now the primary source of data for ridership and running time analysis. However, the flexibility of the Ridecheck Plus software helped to encourage collaboration and acceptance of the APC system. Support of upper management and the board of directors also helped.

RTD is a large system, and setting up the entire APC system took a lot of work. The first year of APCs required extensive troubleshooting, as problems were identified and solved and as staff moved up the learning curve. The second year saw considerable improvement. After 3 years, service planning staff has confidence in the data and has developed the means to use it fully. Staff still finds oddities or problems—this is, after all, a very complex process—so vigilance and technical support are constants. Service planners are also identifying enhancements to the software in terms of reports and validation procedures. The vendor is creating a query to address Furth et al.'s suggestions regarding crowding (5) as one example.

Training played an important role in APC implementation. Service development has overall responsibility for the APC system, and staff needed to understand the workings of both the APC system and the report software.

RTD arranged for training for all service development staff, and a specific staff member specializes in a particular area, such as APC monitoring, reporting using Ridecheck Plus, or the overall data processing function. Broad staff training emphasized an understanding of the reports, including how to generate a report and how to use filters. Technical training to support Ridecheck Plus was modest; instead, service development established tech support with the vendor's program manager for an annual fee.

On the maintenance side, the vendor trained RTD's electronic technicians, who troubleshoot APC equipment to the unit level. Defective units are removed and sent to the vendor for repairs on a unit cost basis. The end result is that hardware maintenance is carried out by expert technicians; specialists oversee APC data, software applications, and all data processing; and all service development staff understands the use of APC data.

Ridecheck Plus has the capability to display APC ridership data in a geographic information system (GIS). This ability is extremely useful in preparing presentations for the board of directors or for public meetings. Ridecheck Plus includes extremely detailed reports (e.g., running time by direction between time points) for internal use. Over time, RTD has identified which reports are most useful for specific purposes and has generated enhanced reports to meet specific agency needs.

Using APCs on the light rail system introduced new challenges. A train is not a bus, but rather (for the purposes of APC data) a combination of buses. Given that not all light rail vehicles are APC-equipped, RTD factors the data from an individual vehicle according to how many APC vehicles were included in the train set. RTD assumes random placement of the assigned APC-equipped car(s) in a consist, allowing for use of a simple expansion factor to calculate train loads.

Over the 3-year period since APCs were introduced, service development staff have achieved a high confidence level in the data and the analyses and have conveyed this to others inside and outside the agency. There is a clear understanding that comprehensive, in-depth ridership and running time data are now being used, and that data analysis is more rigorous. The agency and the board understand that the APC system combined with GIS has enabled service changes to be easily and quickly depicted on a map to aid in making decisions.

RTD is very satisfied with the performance of its APC system. The primary benefit is extensive and statistically valid data produced by the system, which in turn provide a sound basis for service development and maintenance.

RTD characterizes problems with the system as typical start-up issues. The process is very complex: The agency is taking data from its computerized scheduling system and on-board bus and light rail systems, making wireless data transfers, and building or revising complex databases to store and analyze the data. Extensive troubleshooting is inevitable under these circumstances. RTD staff from various departments worked together with the hardware and software vendors over a period of several years to develop an accurate and reliable passenger counting system.

If RTD could go back and change only one thing, it would purchase additional APC units. Its ongoing efforts have shown that, with effort and dedication, a robust APC program can be developed with APCs on only 20% of the fleet.

RTD provides an excellent example of successful APC implementation using third-party software. Lessons learned include

- Purchase reporting and analysis software on the front end at the same time that APCs are purchased. The validation and reporting capabilities of the third-party software used by RTD were a huge part of RTD's successful implementation of its APC system.
- Quality assurance of both data and reporting is key to acceptance by service planning and scheduling staff, and the public. Staff support and validation and maintenance procedures are critical for quality assurance.
- Ownership of the system is important, as is collaboration with other departments within the agency and with the vendors. Ownership ensures that the APC system does not "fall between the cracks," and collaboration builds support for the system.
- Successful implementation takes time. Introduction of new technologies, integration of complex data systems, and identification and resolution of problems do not happen overnight.



NFTA (NIAGARA FRONTIER TRANSPORTATION AUTHORITY)—BUFFALO, NEW YORK

The NFTA is the transit operator in the Buffalo–Niagara region in western New York State. The agency serves an area with a population of 1.2 million and operates 280 peak buses. NFTA also operates light rail service with 23 peak vehicles. Annual ridership is 23.8 million, including all services operated (FY 2006).

NFTA first considered APCs in the mid-1990s, when its board of directors expressed interest in their use. The subject arose again in 2000, at a time of declining ridership. APCs offered the means to obtain detailed ridership data and thus be able to identify exactly where the greatest use of transit was occurring. NFTA specified that APCs be included in its bus procurement. The APC system was implemented in 2001 after considerable testing, in which the counts proved to be very accurate. NFTA had implemented a talking bus system the previous year, so GPS data and the bus stop inventory had already been prepared and tested. NFTA added a process to share those data with the APC system.

The implementation went smoothly, but it took 2 years of tweaking to ensure that the system worked under all circumstances for all NFTA routes. The APC vendor performed (and continues to perform) post-processing data validation using proprietary software. In general, APC information is compared with the schedule for accuracy. Some agencies preload the schedule information on board vehicles, but post-processing works well at NFTA. APC implementation was accompanied by minor staff adjustments.

Most routine processing issues were resolved by 2005. NFTA developed many report requests, and noted slow turnaround by the APC vendor. The customized reports did not always exactly match NFTA's request. NFTA eventually built an entire suite of reports in Statistical Package for the Social Sciences, the software used by the APC system, although it would have preferred a different platform with greater capabilities.

In 2005, NFTA began investigating the ability of using APC data for NTD reporting. There was very little information on this at the time. NFTA saw many places where things could go wrong with this process. NFTA realized that passenger-mile calculations were fraught with difficulties. First, the APC system uses GPS differential to calculate distance, and it does not produce correct results. Second,

passenger-miles are calculated by multiplying load times distance. Passenger load calculations are a weak link in the APC system. To NFTA, the inability to use APC counts for NTD reporting is an important shortfall. The APC vendor is considering alternative ways to address distances between stops, but the major stumbling block is the passenger-mile calculations.

NFTA uses APC data in its in-house monthly reports. Management and in-house users are very pleased. Route ridership and productivity figures are reported for every schedule change. APC data are used to justify adding, deleting, and adjusting service.

APC data are also used for detailed running time analysis. The computer-aided dispatch (CAD)/automated vehicle location (AVL) system only measures by timepoint, whereas APC data are available at each stop. AVL uses a large geographic buffer because the system is used for other purposes such as changing headsigns and NFTA prefers to err on the side of caution for passenger-related functions. NFTA designed a routine to move APC running time data into the computerized scheduling software package. The bus stop database does not reside in the computerized scheduling software but is a separate Access file.

NFTA is pleased with post-processing tests for data validity. The agency discards 10% to 15% of the raw APC data based on confidence calculations, but is confident in the remaining data. To date, data have never been assigned to an incorrect block. Adjustments are also made in post-processing to try to deal with load accuracy.

In any one signup period, the APC system provides 15 to 20 samples of each trip. Staff review and discard outliers. The sheer amount of data is self-validating.

Interestingly, system ownership is split between the planning and maintenance departments. Downstream users receive reports, but the data are very well filtered within the department. A set of reports goes to the Surface Transportation Committee of the board. Planners are sometimes frustrated by inaccurate load totals and the occasional time issue (e.g., if the operator takes layover before or after the assigned location, running times for the preceding and subsequent segments can be incorrect). Users are generally happy. Working relationships between departments have improved, as have relationships with outside agencies. A greater value

is also placed on APC ridership data because of their accuracy and level of detail.

NFTA has concluded that deployment of APC vehicles will always be an issue in need of constant supervision. To date, 90% have been deployed correctly, but the percentage has not increased as the number of APC-equipped buses has risen from 57 to 160 (approximately 40% of the fleet). Constraints in the garage, some personnel issues, and mechanical issues all contribute to the problem. All APC buses have cameras, and requests for camera buses can conflict with APC assignments. Other APC-related issues include evolving demands for new reports and a lack of understanding that even APC data are not 100% accurate all the time.

APCs are being installed on light rail. The decision was made to equip all rail vehicles because a single roundabout and few crossovers can make it difficult to ensure that a specific car is in a specific place at a specific time.

NFTA is mostly satisfied with the performance of its APC system in terms of counting passengers. The primary benefit is the amount of data available, up to 80 samples per trip per year compared with one sample every other year with manual checking.

NFTA encountered several problems in implementation of the APC system, and describes a painful growing process until it got the system tailored to its service and needs. Passenger counting is very accurate, but the unreliability of passenger-mile calculations, which precludes use of APC data for NTD reporting, is an unresolved issue. Bus assignment is still problematic, but the reasons for this are external to the APC system.

If NFTA could go back and change only one thing, the agency would include a passenger-mile accuracy requirement in the request for proposals (RFP).

Lessons learned include the following:

- Require vendors to meet NTD reporting accuracy (95% confidence and +10% precision levels) in the RFP as a disqualifying factor for acceptance of the system.
- Specify accuracy requirements for both boardings and alightings and passenger loads.
- Test every aspect of the system, despite vendors' claims that things work, before accepting it.



RTC (REGIONAL TRANSPORTATION COMMISSION OF WASHOE COUNTY), RENO, NEVADA

RTC was formed in 1979 as a result of legislation approved by the Nevada legislature. RTC operates public transportation service in the cities of Reno and Sparks and in unincorporated areas of Washoe County. The service area has a population of 253,000. RTC operates 62 peak buses. Annual ridership is 9.0 million, including all services operated (FY 2006).

RTC started the process of purchasing ITS equipment with a special earmark in the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). The agency had always lacked current passenger data by stop. RTC used to do a full system count every 3 years, but it was typically only one day per route. The idea of purchasing APCs had a lot of appeal throughout the agency. The central motivation was to have real-time, always current ridership data at a very detailed level.

At the beginning of the procurement process, RTC staff traveled to other agencies to see examples of APC systems first hand. After hearing from one agency's maintenance department how side-mounted beams were frequently bumped out of alignment by passengers, RTC opted for overhead sensors. The process was helped because the APCs were no longer cutting-edge. Agencies like TriMet (Portland, Oregon) offered a model for APC implementation. RTC purchased its APC system as part of a broader ITS procurement in 2002.

RTC highly recommends going to other agencies to see how APCs work in the real world. Even honest and well-meaning vendors do not always inform clients of all potential problems. For example, after implementation RTC found that the APC units were counting but were not meeting the specifications for accuracy. The solution was for the APC manufacturer to prototype each bus, that is, calibrate the units for

each vehicle type based on how fast the doors opened. The workings on the units are based on door-opening logic in the programming, a fact that was never considered.

The importance of the door-opening logic also affects subsequent use of APCs. If APC units are included as part of the original equipment manufacture, then a unit cannot be switched to a different type of bus without reprogramming. The APC manufacturer can do the reprogramming if it has a prototype, but it is an added cost. When RTC introduced articulated buses, the manufacturer had to create a new prototype that addressed the third door.

It is important to test how the software on the analyzer works when introduced into service. A test in a controlled non-revenue-service environment such as a bus garage will not reveal everything an agency needs to know. The validation process was interesting. RTC compared the APC data with manual counts during an on-board survey by connecting a laptop to the analyzer, so that the surveyor could see what the analyzer was counting at each stop.

RTC used a standard of 90% accuracy for boardings and alightings. The agency found that accuracy varied by bus type: Vehicles with narrow doors achieved an accuracy level of 97%, and vehicles with wide doors had a 93% accuracy level. A wide-door vehicle allows riders to board more quickly, however passenger bunching affects the accuracy of counts at busy stops.

RTC retrieves APC data from each bus when it pulls into the garage at the end of the day by means of a wireless download. Interlines can create problems, and bus detours result in unidentified stops. RTC has adopted a policy of reprogramming stops for detours that will be in effect for at least 1 month. Route and stop information are housed within the computerized scheduling software, which is accessed by the ITS/APC database.

Introduction of APCs results in training needs. There are two basic categories of training requirements: hardware and software.

Hardware training for maintenance personnel is essential. RTC has two master technicians who specialize in electronics on its maintenance staff. These master technicians are the troubleshooters for ITS-related issues. RTC cautions that the involvement of too many mechanics in APC maintenance creates its own problems. Although all maintenance personnel are trained in basic APC maintenance, the master technicians are responsible for all nonroutine issues.

Software training for planning and other staff who will use APC data is focused on the use of databases. The ITS system at RTC stores data in a Structured Query Language (SQL) server database. Canned reports are available but

do not always meet the agency's needs. RTC worked with the manufacturer before implementation to create customized reports. It was not possible to anticipate all the types of desired reports, especially because the availability of so many data through APCs leads to ideas and requests for different reports. Staff versed in SQL programming can create needed reports and thus make maximum use of APC data.

RTC also notes the need to scrutinize canned reports in terms of parameters and data used. For example, a canned schedule adherence report may or may not use the same definition of "on time" as the agency does. There is a need to have staff resources, time, and knowledge to make sure the report represents the actual situation.

RTC is moderately satisfied with its APC system. The APCs function well once they are installed and tested, and the data are very useful. Post-processing functions, particularly the ability to customize reports, need improvement. RTC designed customized reports before implementation, but reporting is an iterative process. Enhanced data availability and accuracy have spurred new report designs that better meet the needs of RTC.

The major benefits of APCs for RTC include detailed passenger activity at the stop level and running time data at the route segment level. The data provide a dependable basis for service and scheduling decision as well as the ability to respond to passenger requests for stop amenities such as shelters and benches.

APC-related issues at RTC include the ease and functionality of post-processing and reporting procedures, inability to shift an APC unit to a different type of bus without reprogramming the door-opening logic, and the need for hardware and database training to make full use of APCs.

When RTC began to explore APCs in the context of a broader ITS purchase, there were fewer APC vendors. If the agency could change one thing, it would explore APC capabilities across manufacturers, particularly in the areas of hardware–software interface and post-processing procedures.

Lessons learned include the following:

- APCs do not automatically work once installed. Agencies need lots of resources and knowledge on the hardware (electronics) and software (database) sides.
- Delegate primary responsibility for APC upkeep and trouble-shooting to a single maintenance group or person with knowledge of electronics and the equipment being used. Involve the maintenance department early on in the process.
- Test everything in real-world conditions. Do not always believe what the vendor tells you.
- Reports can be misleading—do not assume the data on the report are what you are looking for.

METRO TRANSIT—MADISON, WISCONSIN

Metro Transit provides public transportation services in the city of Madison, Wisconsin, and surrounding communities. The combined service area had a population of around 280,000 in the 2000 Census. Metro operates 167 peak buses when the University of Wisconsin and the public schools are in session. Annual ridership across all services is 12.3 million (FY 2006).

Metro Transit purchased APCs in 2004 as part of an upgrade of its radio system. Metro purchased an ITS-type package, with voice and data communication capabilities and computers, GPS, and mobile data terminals on board each bus. APCs were a marginal cost in the scope of the entire procurement, and 40 APC units were installed on approximately 18% of Metro's fleet.

The primary benefit of purchasing APCs as part of a larger procurement is that the GPS component and the entire data structure are included. A disadvantage was perhaps a more limited selection of APC technologies because the prime contractor for the radio system had a preferred set of APC subconsultants with whom it had worked in the past.

Metro has never been completely satisfied with the functioning of the APC units. The system uploads raw data (unadjusted counts by bus number, with only positional coordinates and a time stamp) to a database, where this information is then automatically processed overnight. The system correlates the raw data with route, block/trip, and



stop data and produces adjusted boarding and alighting data at the stop level.

The first problem is errors within the APC technology. Boardings and alightings do not balance on any given trip, resulting in incorrect loads. A second problem that contributes to the first is that the system is set up to parse data that may have occurred “off-route.” Every trip is programmed as a series of stop intervals. As a trip progresses, the system calculates distance traveled and constantly confirms adherence to the preprogrammed compass headings and proximity to the coordinates for the next stop. Distances, stop coordinates, and compass headings were populated by driving a staff car. Data errors, odometer problems, or excessive lane changes can result in mismatches from the preprogrammed adherence guidelines, which can result in the bus falling back into an “off-route” status. The system will disregard the raw APC data collected during any period of time the bus was either correctly (owing to actual detour) or mistakenly (as a result of data mismatch) in this “off-route” status.

One solution to load issues is to “zero out” the load at the end of each trip. Metro schedules a fair amount of interlines and loop routes, and in many cases passengers remain on the bus at the “end” of a trip. Another issue with interlining is that it becomes more challenging to collect a single day’s data on a given run. Some core routes may have up to 20 blocks providing trips. This issue is exacerbated by the geography of Madison. There is a narrow isthmus between two lakes, with three primary corridors that buses use to access the downtown and university campus. This results in a network structure where multiple routes provide service along these three trunk corridors. Metro is not able to get a single-day 100% count at a given stop on one of these three trunk corridors.

Metro has only been able to find effective use for its APC data at the stop level. Each trip serving a given bus stop is assumed to have an APC bus assigned on at least a few days within a pick (typically 90 days). An external reporting process is used to calculate the average number of boardings and alightings at each stop for each trip, and then to sum these averages for all the trips serving this stop over the course of a day for a total count of daily boardings and alightings by stop. The resulting data are used primarily within the agency to provide an order of magnitude type of comparison of passenger activity by stop.

Overcoming the various issues with APC data is a challenge. As is the case at many small and medium-sized agencies, limited staff resources affect what can be done. APCs are just one of many ITS-related projects that Metro has implemented in recent years, and staff has had limited opportunity to dedicate the time needed to iron out the problems. Planning staff recognizes the benefits of

additional APC units to enhance the ridership database, but this argument is difficult to make if staff is not completely satisfied with the underlying quality of the data produced by the existing APC units. On the other hand, staff also struggles with how much effort to dedicate to generating other outputs from the APC data, given the limited fleet of APC buses available for data collection, and the complications described earlier regarding the complex scheduling requirements.

Overall, Metro is moderately dissatisfied with the performance of its APC system in terms of its ability to deliver usable data on passenger counts. The primary benefit to date is a general picture of boarding and alighting trends at the bus stop level. Problems include inaccuracies in boarding and alighting counts across an entire trip, which lead to inaccurate loads, and lost data owing to the inability to maintain route adherence correctly. The latter problem often results from detours or other unusual operating circumstances, such as special events, but can also stem from insufficient or inaccurate route data programming.

If Metro could go back and change only one thing, the agency would go into the process with a better understanding of potential pitfalls. The request for proposals for the ITS procurement included a requirement for 95% accuracy in the APC units, and the prime contractor has subsequently been on-site addressing various issues. More staff involvement and attention in the testing and acceptance phases would have been useful, but staff limitations played a role here as well. The primary lesson learned is to set better equipment acceptance standards and testing.



**TRIMET (TRI-COUNTY METROPOLITAN
TRANSPORTATION DISTRICT), PORTLAND, OREGON**

TriMet was a case study for *TCRP Synthesis 29* and is a long-time user of APCs. TriMet began operation on December 1, 1969. In 1975, the agency began operating Fareless Square in downtown Portland, 2 years before the opening of the transit mall. The Banfield light rail line began service in 1986, and the light rail system now has four lines. TriMet serves an area with a population of 1.3 million and operates 526 peak buses and 81 peak light rail vehicles. Annual ridership is 101.6 million (2006).

Over the past 25 years, the agency’s IT staff has sought to develop new and innovative applications of APC data. A fairly large IT staff and a strong analytical staff that has worked together with APCs for a long time have been two

positive factors in TriMet's success. The addition of a CAD/AVL system several years ago improved the passenger counting program by greatly enhancing and simplifying the ability to identify bus stops.

TriMet is a good example of an agency that developed its own analytical software, mainly because nothing of that sort existed when it first implemented the APC system. The in-house program is driven by block-level and stop-level data, which are then matched to the schedule and the bus stop. The bus stop matching program can identify and flag a location with no matching stop and assign the data to the nearest bus stop. This capability was developed in the early days when stop matching relied on odometer data and continues to be useful in many circumstances today.

Approximately 75% of the bus fleet is equipped with side-mounted APCs. The integrated APC/AVL system collects data every time a bus passes a stop or opens its doors. Data upload occurs in the garage through PCMCIA (Personal Computer Memory Card International Association) cards that are removed from the buses by operators and placed into a networked computer by station management personnel. This older technology has its challenges. It is difficult to obtain new 1-megabyte cards. Today 1-gigabyte cards are common, but the data transfer takes much longer with the larger cards. The data retrieval and processing automatically happens every night and data are available the next day.

Overhead APC units are installed on light rail vehicles. The APC database treats rail like bus, except that adjustments are made if only one car in a two-car train is equipped with APCs. The Oracle database contains all the scheduling information needed to make these adjustments. APCs transmit data wirelessly, but sometimes the overnight transmission does not happen and data are not available the next day. The next generation of APC for the bus fleet is likely to use overhead beams.

TriMet did use a program that randomly assigned APC-equipped vehicles to specific blocks, but no longer does so. The Service and Performance Analysis manager will check periodically that all blocks have been scheduled for APC within a given pick. All new buses have APCs, but only about 30% of the oldest buses in the fleet are APC-equipped. All buses collect AVL data, therefore arrival and departure times at stops are always available. Specific requests for an APC bus assignment are occasionally made, usually for a low-frequency low-ridership route that is under consideration for discontinuation or service adjustment.

The overnight data processing includes automated programs to ensure that the beams are working correctly, to match data to schedules, and to validate boarding and alighting totals. The validation program checks that boarding and alighting totals differ by no more than 10% and adjusts for negative loads. Any suspect data are removed from the system, resulting in

approximately 80% of the raw APC data being used for analysis. A recent study indicated that APC counts are accurate at a confidence level of 95% and an error of +5%.

Previously, TriMet would balance loads by block, but now the program adjusts loads at the trip level. Boardings and alightings are averaged, and adjustments are made at stops with the greatest passenger activity. Loads are zeroed out at the end of the line if the bus lays over for at least 5 minutes. This condition allows for non-zero end loads on through trips. The balanced loads are used only for load-related analyses; stop-level analyses use the actual APC counts.

In-house programs also address other data anomalies. For example, if a bus lays over before its designated layover location, running time and load data are not registered correctly. TriMet developed a routine to use time-stamp information from the AVL system to correct the data. Another routine associates boardings at a layover point with the following trip and alightings with the previous trip. IT staff has developed these and similar routines to address the data oddities that have been observed over 25 years.

All APC and AVL data reside in an Oracle database maintained by the IT department. Scheduling and payroll data are integrated into this database. The open nature of the database provides access to a wide variety of data and its inclusiveness encourages innovative analysis. TriMet is currently examining factors contributing to absenteeism among bus and light rail operators and is able to explore a number of hypotheses related to loads and on-time performance through the database.

Use of APC data for NTD reporting is a topic of great interest. TriMet keeps a separate database to calculate loads as an input to the passenger mile calculations required for NTD. The reason is that the standard validation program adjusts for negative loads, which biases the load estimate upward. TriMet works with James Strathman from Portland State University to ensure that any errors in APC boardings and alightings are random. FTA approved TriMet's use of APC data for NTD in 1986, but has since changed its procedures and requires annual validation of APC data, with a minimum sample of 100 trips. FTA granted TriMet a waiver for its most recent NTD report, but the agency is conducting manual validation this year. TriMet would prefer to see a periodic validation requirement of every 3 to 5 years instead of an annual requirement for NTD reporting.

Maintenance of APC units is the responsibility of electronic technicians in the maintenance department. Originally, when TriMet had less than 60 APCs and no AVL, TriMet had one project manager/technician to perform the equipment maintenance and data programming/processing requirements. With the increasing number of electronic components on the buses, additional technicians have been hired

and the APC system is only one of their responsibilities. The maintenance director understands the importance of APCs for the agency, but repairs can take longer than expected.

TriMet is very satisfied with the performance of its APC system. The primary benefits are a large amount of statistically valid ridership data, greater confidence in the accuracy of the data, and no need for ride checkers.

TriMet has such a long history (25 years) with APC data that it has been able to address all the problems encountered. For example, the agency noted that it took about a year to work out all issues in the integration of APC and AVL databases. The system works very well and there is a high degree of confidence in using the data. Because of this history and the current state of affairs, TriMet was hard pressed to answer the question of what it would go back and change if it could.

TriMet provides an excellent example of successful APC implementation using internal software developed by its IT

department in conjunction with data users. Lessons learned include the following:

- Check and validate all data.
- Develop accurate and reasonable techniques to balance loads. Load data are often the weak link in an APC system.
- Develop routines to address end-of-trip data. Consider where and when to zero out loads and handle other anomalies that can arise at the end of the trip.
- Realize that a close working relationship with the information technology department is essential. TriMet's success was aided by a large IT department that has developed and refined data processing and reporting procedures.
- Use the open architecture of the agency's Oracle database and integrate with the computerized scheduling software to access a wide variety of data. TriMet relies on this extensive database as it continues to develop innovative analytical and reporting techniques.

CHAPTER SIX

CONCLUSIONS AND SUGGESTIONS FOR FUTURE STUDY**INTRODUCTION**

This chapter summarizes findings and presents conclusions from this synthesis project, and offers suggestions for future study. Findings from the surveys, particularly the case studies, provide an assessment of factors contributing to the success or failure of automatic passenger counter (APC) system implementation. The chapter is organized in five sections:

- Automated Passenger Counting (APC) Implementation
- APC data: Processing, Reporting, and Validating
- Agency assessments of APCs
- Lessons learned
- Conclusions and areas of future study

The further research needs offered here attempt to place the study findings in a larger context of how APC use might evolve at transit agencies.

AUTOMATIC PASSENGER COUNTER IMPLEMENTATION

- The most common reason to collect ridership and travel time data is to compile ridership by route, although the majority of respondents also collect ridership and travel time data for more specific microlevel uses at the route segment or stop level. Tracking ridership changes, calculating performance measures, and adjusting schedules were the three most common uses of ridership and travel time data.
- A majority of respondents use a combination of automated and manual methods to collect ridership data. The most common combinations involve APC plus manual data collection and farebox plus manual collection. In many cases, an older technology is retained to test the validity of the new technology or for a specific purpose: for example, National Transit Database (NTD) reporting or data validation.
- Agencies that continue to collect ridership data manually cite cost as a reason, followed by low priority for automated data collection at the agency. Smaller systems (fewer than 250 peak buses) are more likely to continue to rely on manual data collection.

- More than 90% of respondents indicated that their APC systems included a global positioning system element. Almost half of all respondents reported that their APC purchase was part of a broader intelligent transportation systems (ITS) project.
- Only a portion of most agencies' buses are APC-equipped; however, more than one-quarter of responding agencies have installed APCs on all buses. Nine of the 12 agencies that are 100% APC-equipped bought APCs as part of a broader ITS purchase.
- Most respondents reported a standard for acceptance of the APCs at the 90% or 95% level of accuracy for passenger boardings and alightings, and almost three-quarters of respondents indicated that they use these standards on an ongoing basis. Manual counts are typically used as the basis of comparison.
- Changes in professional staffing levels as a result of APC implementation were minimal in most cases: More than 70% of all agencies reported no changes or decreases in staff levels. However, there were notable decreases in the size of traffic checking units. About one-quarter of respondents indicated a minor increase (defined as one or two full-time positions) in maintenance staff, and 22% reported a minor increase in professional staff. The case studies suggest that assigning analytical and maintenance staff specifically to the APC program is an important factor in successful implementations.
- The median reported capital cost per APC unit was \$6,638 among the 26 agencies responding. The median reported annual operating and maintenance cost per APC unit was \$600 among the 11 agencies responding. Cost data from the survey should be interpreted cautiously, as respondents varied in their ability to break down cost data (especially for older systems or for APC systems purchased as part of a larger ITS procurement).

AUTOMATIC PASSENGER COUNTER DATA: PROCESSING, VALIDATING, AND REPORTING

- Processing APC data often requires changes to existing data systems, such as addition of GPS coordinates for stops and an updated or new bus stop inventory.

A few agencies noted the establishment of defined interfaces between computerized scheduling software packages and APC or AVL systems. For data storage and analysis, the most common changes were the addition of servers for data storage and new database software for analysis.

- Automated data validation programs, provided by the APC vendor, developed in-house, or purchased from a third party, can simplify the process of converting raw APC data into usable ridership data. Agencies reported various thresholds for determining validity at the block or trip level.
- The percentage of raw APC data that is converted into useful information averages 74%, comparable to findings from 10 years ago, with a median value of 80%.
- A majority of agencies rely on the hardware vendor for data processing and report generation software, but several indicated in-house software development or use of an outside vendor other than the hardware vendor. Detailed (segment/stop level) ridership and scheduling-related reports are most likely to be generated as needed, suggesting that the reporting process for these types of reports may require intervention in defining parameters.
- More than 90% of responding agencies indicated a capability to generate ad hoc, specialized reports from the APC system. The most common method was for the end users to generate ad hoc reports, but one-quarter of agencies with this capability rely on the outside vendor for specialized report generation.
- Some agencies use APC data for NTD purposes. FTA requires manual checks annually to validate APC data for NTD submittal. The concept of manual validation of APC data as a one-time or periodic exercise is of interest to agencies as they gain confidence in the accuracy of APC data.
- Anyone who has been through the process of implementing a new technology knows that there is a “debugging” period. The debugging period, during which start-up problems are resolved, averages 17 months for APCs, identical to the finding of the 1998 synthesis, with a median of 18 months.
- The planning department is the most common location for management of the APC system, followed by the operations department. There is widespread involvement across departments in procurement of the APC system and use of the APC data. Downstream users typically access APC data electronically through standard reports, and 41% of agencies noted that downstream users could query the database directly.
- Implementation of APCs necessarily involves multiple departments within the transit agency. Positive aspects include improved communication among departments, greater value placed on ridership data, improved decision-making ability, greater responsiveness, and the ability to provide the needed data to end users.

Difficulties include problems ensuring that assignments were completed, new demands for reports, low priority for APC equipment in the maintenance department, and unrealistic expectations regarding turn-around time and data quality.

- Implementation of APCs creates a need for training. A majority of respondents noted increased training needs in the areas of software/computer, analytical, and hardware skills. Only one-quarter of responding agencies reported no additional training needs.

AGENCY ASSESSMENTS OF AUTOMATIC PASSENGER COUNTING SYSTEMS

- The primary benefits of APCs included data disaggregated at the stop, segment, and trip levels; better quality of ridership data; availability of running time data to adjust schedules; and a better basis for decision making.
- Problems encountered with the APC system included reporting software, data processing and analysis, data validation, and hardware problems. One-quarter or all respondents reported either no problems or only the usual start-up issues.
- Results regarding agency satisfaction with the performance of its APC system in terms of counting passengers are positive: Eighty-five percent of respondents were very or somewhat satisfied. Forty percent were very satisfied, and 45% were somewhat satisfied.
- Contract elements, procurement procedures, purchase of additional APC units, and the overall approach to APC implementation were the most frequently mentioned aspects of the APC process that transit agencies would like to change. Regarding procurement, stricter contractual requirements, purchase of a complete system through a single vendor, and changes to internal procedures were all important. Changes to the overall approach included being more informed about APC hardware and software choices, involving maintenance personnel at the start of the process, dedicating one or more technicians to work full time on APCs, completing the bus stop inventory before installation, and hiring a statistician to develop a methodology for passenger counting before vendor selection.

LESSONS LEARNED

- Almost three-quarters of all survey respondents that have implemented APC systems shared lessons learned from the process. Agencies focused on use and validation of the APC data, purchase and implementation, and ongoing agency maintenance in the discussion of lessons learned. Agencies offered lessons in many areas, but the emphasis on data systems and agency

procedures suggests that these areas are critical to the success of APC implementation.

- The Ottawa-Carleton Regional Transit Commission (OC Transpo) (Ottawa, Ontario, Canada) was a case study for the previous TCRP synthesis on passenger counting and has been using APC data for more than 25 years. It is an example of an APC system developed in-house over a number of years that works extremely well. The agency has assigned staff to support the program and has developed bus assignment, reporting, and maintenance procedures to overcome problems. OC Transpo continues to adapt and refine APC use.
- The Regional Transportation District (RTD) (Denver, Colorado) provides an example of successful APC implementation using third-party software. RTD purchased reporting and analysis software at the same time that the APC system was purchased. Clear identification of responsibilities, close collaboration with maintenance and other departments from the outset, training for all staff using APC data, and emphasis on quality assurance are the major factors contributing to success.
- The Niagara Frontier Transportation Authority (NFTA) (Buffalo, New York) case study provides an example of an agency that developed its own in-house reporting capabilities in response to dissatisfaction with the vendor's reports. NFTA is also interesting in that system ownership is split between the planning and maintenance departments. All issues have not been resolved, even after 2 years of tweaking, but management and in-house users are pleased with the monthly ridership reports. Use of APC data to justify service changes is a standard practice.
- The Regional Transportation Commission of Washoe County (RTC) (Reno, Nevada) is an example of the introduction of APCs as part of a broader ITS procurement. RTC involved maintenance personnel at the outset and continues to focus on collaboration. RTC is still working through post-processing issues, but already uses APC data for service-related decisions.
- The Metro Transit (Madison, Wisconsin) case study is typical of the stage in many APC implementations where there is no confidence in the APC data at any level other than stop-level boardings and alightings. Potential solutions involving revisions of the bus stop inventory and route itineraries are known but are difficult to implement with limited staff resources. In turn, the lack of extensive useful APC data makes it hard to justify added resources.
- The Tri-County Metropolitan Transportation District of Oregon (TriMet) (Portland, Oregon) was also a case study for the previous TCRP passenger counting synthesis and is an example of successful APC implementation using in-house analytical software. Its success over the past 25 years was aided by a large information technology department that has developed

and refined data processing and reporting procedures and integrated APC data with other agency databases. The agency paid close attention to balancing loads in a statistically reliable fashion and addressing other data anomalies. The open architecture of the agency's database and the integration with the computerized scheduling software resulted in the ability to access a wide variety of data and generate innovative analyses.

CONCLUSIONS AND AREAS OF FUTURE STUDY

- APCs provide a rich ridership and travel time database at a finer level of detail than farebox or manual counts, even for agencies with only a few APCs. The increased number of observations lends greater confidence to decisions regarding changes in service levels. An agency does not need APC units on all vehicles to establish a workable APC system, although installation of APCs on all vehicles produces a richer database and avoids vehicle assignment problems.
- An APC system does not work automatically. Successful agencies have developed procedures (in-house or through an outside vendor) to match APC data to bus stops, clean and validate data, generate standard reports, simplify the process of creating ad hoc reports, and flag potential hardware and software problems for the maintenance and information technology departments. The data processing and reporting software is the most important part of an APC implementation. Integration of APC data with existing agency databases, which may also be changing as a result of new technologies, is challenging. Agencies' business practices and procedures may not be designed to make optimal use of available data.
- APC implementation is not simple, and the first year is the most difficult. There is a steep learning curve, particularly on the software side, and there are likely to be internal agency issues regarding responsibilities and priorities.
- Ownership of the APC system is important, as is collaboration across departments. The ownership part of the equation, in which one department assumes overall responsibility, ensures that the APC system receives priority, and the collaboration part works best when the lead department is attuned to the needs and procedures of other departments and can adjust to meet these needs. A good working relationship between the lead department and the maintenance personnel assigned to APCs is critical.
- Staffing presents a challenge, especially to small and medium-sized agencies. Successful implementations are characterized by close review of APC data as part of a quality assurance program, particularly in the first year when bugs are being worked out, and a dedicated maintenance technician or group of technicians who

assumes primary responsibility for hardware issues. Agencies may not have the staff available or may not have staff with the right mix of skills.

- Transit agencies that have worked through the myriad issues associated with APC implementation cannot imagine life without APCs. These agencies reap the benefits of extensive and statistically valid data that are used with confidence to make important service-related decisions.

Findings from this synthesis suggest eight major areas of future study:

- *In-depth investigation of critical factors to success.* Are there optimal routines to match APC data to specific bus stops? What elements of a validation program are most critical to ensuring quality data? Which elements of reporting software are most useful, and what is the best way to create ad hoc query ability? How can APC data be integrated most usefully with existing agency databases? How can an agency “manage” the learning curve? Are there techniques to foster APC system ownership and collaboration? What if adequate staff is not available and added staff is not an option? How important is a strong commitment from senior management to the APC program?
- *Exploration of various avenues to success.* Both in-house and third-party approaches have been successful. Are there circumstances in which one is preferable to another? What is the state of the art in software packages? Ongoing developments within the transit industry, such as deployment of ITS technology, increased vendor attention to complete (hardware plus software) product packages, and a wider choice of hardware and software options (including off-the-shelf software), affect the answer to this question and suggest additional possibilities.
- *Evaluation of data cleaning and validation techniques.* This is an important barrier to success and is perhaps the major source of frustration to agencies that indicated dissatisfaction with their APC systems. Confidence in the accuracy of APC data is critical to its widespread use and acceptance within and outside the transit agency. Many agencies struggling with this step view it as a hardware problem, but its solution resides in considering both the hardware and the software used to clean and validate the data.
- *More precise identification of factors preventing success and ways to overcome them.* Data validation is not the only barrier to success. Broader hardware, software, and personnel issues need to be addressed and overcome, and a closer examination of successful strategies would serve the transit industry well.
- *Exploration of new technologies that may improve APC data collection accuracy.* As ITS technologies evolve, new hardware and software options that improve the accuracy of APC data are likely to emerge. What are the most promising options to achieve improved count accuracy, enhanced data quality, and reliable data location matching?
- Investigation of alternative techniques, algorithms, and methodologies that can improve the state of the art of APC systems. As more agencies implement APC systems, the market for innovation grows larger. Using existing technology, what improvements can address the needs of transit agencies?
- *Identification of business intelligence and data reporting tools that can be used with APC data.* As data systems are integrated and downstream users begin to rely on APC data, new approaches and innovative analytical strategies can be expected. Additional uses of APC data will continue to emerge as users become more knowledgeable and will affect data needs or the priority afforded to the APC system. Establishing a data warehouse can provide an opportunity to take advantage of many business intelligence techniques such as data mining.
- *Institution of new methods of disseminating information on APC systems.* This synthesis has provided a snapshot of the state of passenger counting systems in 2008. An APC forum or workshop, webinars on APC implementation and the use of APC data, and an electronic mailing list devoted to APC-related issues are all possibilities to extend the findings of this report and to provide a continuing means for agencies to share information and learn from each other’s experiences. The TCRP panel for this project strongly supports this initiative.

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ACRONYMS

APC	automatic passenger counter
APTA	American Public Transportation Association
APTS	advanced public transportation systems
AVL	automatic vehicle location
CAD	computer-aided dispatch
CTA	Chicago Transit Authority (Chicago, Illinois)
FTE	full-time equivalent
GIS	geographic information systems
GPS	global positioning system
IT	information technology
ITS	intelligent transportation systems
MARTA	Metropolitan Atlanta Rapid Transit Authority (Atlanta, Georgia)
NFTA	Niagara Frontier Transportation Authority (Buffalo, New York)
NTD	National Transit Database
OC Transpo	Ottawa–Carleton Regional Transit Commission (Ottawa, Ontario, Canada)
PCMCIA	Personal Computer Memory Card International Association
PRTC	Potomac and Rappahannock Transportation Commission
RFP	request for proposals
RTC	Regional Transportation Commission of Washoe County (Reno, Nevada)
RTD	Regional Transportation District (Denver, Colorado)
SAS	Statistical Analysis System
SPSS	Statistical Package for the Social Sciences
SQL	Structured Query Language
SSR	spread spectrum radio
TCRP	Transit Cooperative Research Program
TRIS	Transportation Research Information Services
TriMet	Tri-County Metropolitan Transportation District of Oregon (Portland, Oregon)

APPENDIX A

TCRP SYNTHESIS SURVEY: PASSENGER COUNTING TECHNOLOGIES

TCRP Passenger Counting Systems

1. Default Section

1. Today's Date

Date MM / DD / YYYY

/ /

2. Respondent Name

3. Respondent Title

4. Agency Name

5. Agency size

Small

Medium

Large

6. Respondent telephone number

7. Respondent email address

2. PURPOSES

8. For what purposes are ridership data collected and used at your agency? (check all that apply)

Track system-wide ridership totals

Compile ridership by route

Compile boardings/alightings by stop

Monitor passenger loads at max load point

Monitor schedule adherence and running times

Other (please specify)

TCRP Passenger Counting Systems

9. How does your agency use the data collected? (check all that apply)

- Calculate performance measures
- Adjust schedules (add/delete trips, change headways)
- Adjust running times/select or change timepoints
- Revise routings
- Assess changes in ridership
- Determine locations for bus shelters and other facilities
- Compile NTD reports

Other (please specify)

3. TECHNOLOGIES

10. How does your agency collect ridership data?

- Automatic passenger counters
- Automated methods other than APCs, such as handheld data collection units or registering fareboxes
- Manually (paper and pencil)
- A combination of automated and manual methods

4. TECHNOLOGIES - Manual

11. If your agency collects ridership data manually, what are the reasons that you have not switched to an automated technology? (check all that apply)

- Cost
- Satisfied with manual data collection
- Data collection/analysis procedures fully developed and tested
- Awaiting broader ITS purchase that will include APC
- Tried APC in the past but it didn't work out
- Low priority at the agency

Other (please specify)

5. TECHNOLOGIES -Combination

TCRP Passenger Counting Systems

12. If your agency uses a combination of manual and automated methods, please describe how each method is used.

6. TECHNOLOGIES - Automated other

13. If other automated methods are used, please describe these.

7. TECHNOLOGIES - APC

14. What APC equipment does your agency use (including sensor type – infrared, treadle,etc.), and who is the manufacturer?

15. Does your agency's APC system include a GPS element?

- Yes
 No
 Don't know

16. What percentage of your agency's bus fleet is equipped with APC?

- 100%
 Less than 100%

If less than 100%, enter percentage below

8. TECHNOLOGIES - APC Sample

17. If APC equipment is not on all buses, who prepares the daily assignments of APC buses by route and trip?

18. Is the assignment process automated within the APC software system?

- Yes
 No
 Don't know

TCRP Passenger Counting Systems

19. What percentage of daily assignments are completed as scheduled?

20. How often within one year is a particular weekday trip successfully counted, on average?

9. TECHNOLOGIES - APC Counts

21. Is APC equipment used on any modes other than bus?

- No, only bus
- Yes, light rail
- Yes, Other (please specify)

22. Is your agency's APC system a stand-alone system, or is it part of a larger project?

- Stand-alone system
- Purchased as part of a larger ITS project
- Don't know
- Other (please specify)

23. If your agency also has an AVL system, is there a preferred source for time-based information at timepoints?

- Yes, we primarily use APC time data
- Yes, we primarily use AVL time data
- No preference: either is acceptable
- we do not have an AVL system

10. APC DATA: PROCESSING, MANAGING, VALIDATING

24. What standards did your agency use for the initial acceptance of APC (e.g., level of accuracy)?

25. Does your agency use these standards on an ongoing basis?

- Yes
- No

TCRP Passenger Counting Systems

26. How does your agency transfer ridership data from the APC units?

- Direct downlink (probe) of APCs with a physical connection
- Retrieval of APC data at garage without a physical connection
- Real time dynamic or periodic remote retrieval of APC data
- Other (please specify)

27. Please describe what steps are taken to edit and validate APC ridership data. (check all that apply)

- Compare ridership and revenue totals
- Look for unexplained variations across trips
- Compare ridership totals across days for reasonableness
- Rely on the professional judgment of planners/schedulers
- Use an automated program to analyze APC data
- Compare on/off totals by trip and adjust as needed
- Compare with manual counts
- Other (please specify)

28. If your agency uses an automated program to analyze APC data, please describe it briefly in terms of what it looks for and how it decides the validity of the data.

11. APC DATA: VALIDATING NTD

29. Are any special steps required to validate ridership data for NTD reporting purposes?

- Yes
- No
- We do not use APCs to collect NTD data

12. APC DATA: MEANS OF VALIDATING NTD DATA

30. Please describe how your agency validates APC data for NTD purposes

13. APC DATA: USING

TCRP Passenger Counting Systems

31. What proportion of raw APC data collected at your agency is converted into useful information that can be used by service planning, scheduling, and other departments?

32. Were any changes required for existing agency data systems to provide the data needed for APCs to work? (check all that apply)

- Yes, creating or updating the bus stop inventory
- Yes, identifying GPS coordinates
- No changes required
- Yes, Other changes (please specify)

33. Were any changes required for existing agency data systems or software to store and analyze APC data?

- No
- Yes (please specify)

34. What types of reports are routinely generated from APC data? Please also indicate the approximate frequency for each type of report.

	Annually	Quarterly	Monthly	Weekly	Daily	As needed
System ridership	<input type="radio"/>					
Route-level ridership	<input type="radio"/>					
Route segment ridership	<input type="radio"/>					
Stop-level boardings/alightings	<input type="radio"/>					
Performance measures	<input type="radio"/>					
Schedule adherence	<input type="radio"/>					
Running times	<input type="radio"/>					
Other (specify below)	<input type="radio"/>					

If other, please specify

TCRP Passenger Counting Systems

35. How did your agency develop data processing and report generation software (check all that apply)?

- In-house, by information systems or computer services department
- In-house, by end users of data
- Through the hardware vendor
- Through another outside vendor
- Other (please specify)

36. If software was developed through an outside vendor, did the process include customization or modification of the software to meet the agency's specific needs?

- Yes, extensive customization
- Yes, moderate customization
- Yes, minor customization
- No
- Not applicable

14. APC DATA: REPORTS AND IMPLEMENTATION

37. Does your agency have the capability of generating ad-hoc, specialized ridership reports from the APC system (check all that apply)?

- Yes, through information services or computer services department
- Yes, through the outside vendor
- Yes, directly by end users
- No

38. Does your agency archive APC data for previous year comparisons or future analytical needs?

- No
- Yes

If yes, how long do you keep APC data in the archives?

TCRP Passenger Counting Systems

39. Most new technologies require an implementation or "debugging" period in which agencies become familiar with the new equipment and start-up problems are ironed out. If your agency implemented APC within the last five years, how long did this period last (in months)?

15. ORGANIZATION AND DATA INTEGRATION

40. Which departments were involved in the decision to purchase APCs at your agency? (check all that apply)

- Planning
- Scheduling
- Budget/Finance
- Operations
- Information Services/Computer Services
- Maintenance
- Marketing/Market Research
- Other (please specify)

41. Which department takes primary ownership of management and operation of the APC system?

- Planning
- Scheduling
- Budget/Finance
- Operations
- Information Services/Computer Services
- Maintenance
- Marketing/Market Research
- Other (please specify)

TCRP Passenger Counting Systems

42. Which departments are downstream users of APC data? (check all that apply)

- Planning
 - Scheduling
 - Budget/Finance
 - Operations
 - Information Services/Computer Services
 - Maintenance
 - Marketing/Market Research
 - Senior Management
 - No downstream users
 - Other (please specify)
-

16. ORGANIZATION AND DATA INTEGRATION: Downstream users

43. How do downstream users access APC data? (check all that apply)

- Hard copy
 - Electronically via standard reports
 - Electronically via dynamic queries
 - Other (please specify)
-

17. ORGANIZATION AND DATA INTEGRATION: Interaction

44. If there are multiple users of APC data, please describe the interaction among the different groups and any synergy or tensions/conflicts that have arisen. Examples could include: greater value placed on ridership data; better working relationships between departments; difficulties in ensuring that daily assignments are completed successfully; demands for new and/or reformatted reports

18. RESOURCE REQUIREMENTS

TCRP Passenger Counting Systems

45. How many staff positions (full-time equivalents) are assigned to carry out your agency's passenger counting program?

	Less than 1 FTE	1-1.9 FTEs	2-3.9 FTEs	4 or more FTEs	Don't know
Managers/Professionals	<input type="radio"/>				
Support (e.g., equipment maintenance)	<input type="radio"/>				
Clerical	<input type="radio"/>				
Traffic Checkers	<input type="radio"/>				
Other	<input type="radio"/>				

If other, please specify

46. Has the APC program resulted in changes in number of staff? Consider a change of more than 2 FTEs a "major" change.

	Major decrease	Minor decrease	No change	Minor increase	Major increase
Professional staff	<input type="radio"/>				
Support staff	<input type="radio"/>				
Clerical staff	<input type="radio"/>				
Maintenance staff	<input type="radio"/>				
Traffic checkers	<input type="radio"/>				
Other	<input type="radio"/>				

If other (please specify)

47. Has the APC program resulted in changes in training needs for staff?

- No
- Yes, in software/computer skills
- Yes, in analytical skills
- Yes, in hardware maintenance skills
- Yes, in other skills (please specify)

19. RESOURCE REQUIREMENTS: Cost

48. What is the capital cost associated with your agency's passenger counting program? For capital costs, list approximate purchase cost and year purchased. If multiple purchases were involved (e.g., bus one year, rail the next year), list bus information in the boxes and add other information in the next question. You do not need to use a dollar sign; enter a number for each box

Overall cost

Cost per APC unit

Year purchased

TCRP Passenger Counting Systems

49. Add any additional information on capital costs here.

50. What is the annual operating/maintenance cost associated with your agency’s passenger counting program? If multiple purchases were involved (e.g., bus one year, rail the next year), list bus information in the boxes and add other information in the next question. You do not need to enter a dollar sign; enter a number in each box.

Overall cost

Cost per APC unit

51. Add any additional information on annual operating/maintenance costs here

20. ASSESSMENT

52. How satisfied has your agency been with the performance of its APC system in terms of counting passengers?

Very satisfied Somewhat satisfied Somewhat dissatisfied Very dissatisfied

Satisfaction level

53. What have been the primary benefits of APC for your agency?

54. Have there been any problems encountered with the APC system?

55. If you could go back in time and change ONLY ONE aspect in the process of purchasing, installing, and using your APC system and associated methodology, what would you change?

56. Please describe any “lessons learned” that would benefit other transit agencies that are considering changes to their passenger counting methods.

TCRP Passenger Counting Systems

57. Is there another transit system that you suggest we contact for this synthesis project? If you know of a contact at that system, please list the name also.

58. Would you be willing to participate further as a case study, involving a telephone interview going into further detail on your forecasting methodology, if selected by the TCRP panel for this project?

Yes

No

21. END

This concludes the survey. Thank you for participating. Please contact Dan Boyle at dboyle34@pacbell.net if you have any questions or comments

APPENDIX B

TCRP SYNTHESIS SURVEY RESULTS

PASSENGER COUNTING SYSTEMS

RESPONDENT INFORMATION

1. *Date:*
2. *Name of Respondent:*
3. *Title of Respondent:*
4. *Agency Name:*
5. *Agency Size (note: this was entered after survey responses were received, based on FY 2006 NTD data)*
 - Small (<250 peak buses) _____ 43 50.0%
 - Medium (250–1,000 peak buses) _____ 32 37.2%
 - Large (1,000+ peak buses) _____ 11 12.8%
6. *Respondent Telephone Number:*
7. *Respondent E-mail Address:*

PURPOSES

8. *For what purposes are ridership data collected and used at your agency? (check all that apply)*
 - Track system-wide ridership totals _____ 76 88.4%
 - Compile ridership by route _____ 83 96.5%
 - Compile boardings/alightings by stop _____ 68 79.1%
 - Monitor passenger loads at max load point ___ 64 74.4%
 - Monitor schedule adherence and running times _____ 56 65.1%
 - Other (please describe): _____ 25 29.1%

Other includes: NTD reporting; ridership by fare category; ridership by trip; ridership by route segment; service evaluation/performance reports; prioritization for bus shelters; evaluation of business initiatives; identify discrepancies in bus stop database; forecast equitable placement of vehicles; specific counts related to employer bus pass programs and targeted demographic analysis; develop screenline counts; model and estimate origin-destination patterns; monitor pricing and fare patterns; monitor individual driver performance in such categories as on-time performance and excessive layover; passenger miles and rural service statistics; calculate variances compared to farebox data; determine where additional resources are warranted; estimate revenue and help determine cost-sharing arrangements with other agencies; ridership by time period; ridership by direction; answer inquiries from businesses re passenger activity at stops near potential development sites; route productivity; contract-specific requirements with universities.

9. *How does your agency use the data collected? (check all that apply)*
 - Calculate performance measures _____ 77 89.5%
 - Adjust schedules (add/delete trips, change headways) _____ 75 87.2%
 - Adjust running times/select or change timepoints _____ 62 72.1%
 - Revise routings _____ 69 80.2%

- Assess changes in ridership _____ 80 93.0%
- Determine locations for bus shelters and other facilities _____ 63 73.3%
- Compile NTD reports _____ 71 82.6%
- Other (please describe): _____ 8 9.3%

Other includes: revenue calculation for third-party services (e.g., to universities); evaluation of demand from passengers using mobility devices and potential for additional service or wheelchair stations on the bus; fare modeling and pricing analysis; growth projections and marketing.

TECHNOLOGIES

10. *How does your agency collect ridership data?*

- Automatic passenger counters _____ 12 14.0%
- Other automated methods such as handheld data collection units or registering fareboxes _____ 12 14.0%
- Manually (paper and pencil) _____ 18 20.9%
- A combination of automated and manual methods _____ 44 51.2%

11. *If your agency collects ridership data manually, what are the reasons that you have not switched to an automated technology? (check all that apply, then you are finished)*

- Cost _____ 10 71.4%
- Satisfied with manual data collection _____ 4 28.6%
- Data collection/analysis procedures fully developed and tested _____ 1 7.1%
- Awaiting broader ITS purchase that will include APC _____ 4 28.6%
- Tried APC in the past but it didn't work out ___ 1 7.1%
- Low priority at the agency _____ 6 42.9%
- Other (please specify) _____ 6 42.9%

Other includes: planning to change but have not yet (4); lack of staff time and expertise to maintain additional data and electronic systems; GFI fareboxes damaged by Hurricane Katrina.

12. *If your agency uses a combination of manual and automated methods, please describe how each method is used.*

- APC plus manual _____ 12 29.3%
- Farebox plus manual _____ 8 19.5%
- APC plus farebox _____ 4 9.8%
- APC plus farebox plus manual _____ 4 9.8%
- APC plus handheld devices _____ 2 4.9%
- APC plus farebox plus handheld _____ 2 4.9%
- Handheld plus manual _____ 2 4.9%
- AMTD plus AVL plus APC _____ 1 2.4%
- APC plus handheld plus manual _____ 1 2.4%
- AVL plus farebox plus manual _____ 1 2.4%

- Farebox plus farecard plus manual _____ 1 2.4%
- Farebox plus handheld _____ 1 2.4%
- Farebox plus manual plus on-board survey ____ 1 2.4%
- Farebox plus on-board survey _____ 1 2.4%

13. *If other automated methods are used, please describe these.*

Responses include: investigating APCs; registering fareboxes as our primary means; fareboxes and turnstiles used for most ride counting, supplemented by APCs, farecards, handheld devices, and video; APCs plus registering fareboxes; drivers manually pressing a button for non-pass riders plus pass swipes; registered turnstile entries; APCs as supplemental; farebox counts; farebox and handheld units; palm pilot with portable GPS capabilities; PDAs.

14. *What APC equipment does your agency use (including sensor type—infrared, treadle, etc.), and who is the manufacturer?*

All except one use infrared. See Appendix E for manufacturers.

15. *Does your agency's APC system include a GPS element?*

- Yes _____ 47 94.0%
- No _____ 3 6.0%

16. *What percentage of your agency's bus fleet is equipped with APC?*

- 100% _____ 12 26.7%
- 50%–99% _____ 5 11.1%
- 20%–49% _____ 11 24.4%
- 10%–19% _____ 11 24.4%
- 1%–9% _____ 6 13.3%

17. *If APC equipment is not on all buses, who prepares the daily assignments of APC buses by route and trip?*

- Planning/service planning _____ 8 30.8%
- Operations _____ 5 19.2%
- Randomly assigned _____ 3 11.5%
- Schedules _____ 3 11.5%
- APC staff _____ 2 7.7%
- Data collection _____ 2 7.7%
- Other _____ 3 11.5%

Other includes: randomly unless special needs, then senior planner; UTA software; randomly for first half of booking, then planning technician with computer program.

18. *Is this process automated within the APC software system?*

- Yes _____ 6 16.2%
- No _____ 29 78.4%
- Don't know _____ 2 5.4%

19. *What percentage of daily assignments are completed as scheduled?*

Average is 80%. Range is from 40% to 100%.

20. *How often within one year is a particular weekday trip successfully counted, on average?*

Responses vary widely, from once a year to nearly every day.

21. *Is APC equipment used on any modes other than bus?*
- No, only bus _____ 42 85.7%
 - Yes, light rail _____ 4 8.2%
 - Yes, other (please describe) _____ 3 6.1%

Other includes: heavy rail; at two light rail stations; light rail procurement in process

22. *Is your agency's APC system a stand-alone system, or is it part of a larger project?*
- Stand-alone system _____ 16 32.7%
 - Purchased as part of a larger ITS project _____ 24 49.0%
 - Don't know _____ 1 2.0%
 - Other (please specify) _____ 8 16.3%

Other includes: light rail stand-alone, bus as part of ITS; APCs preceded AVL, but now integrated; some are stand-alone, others part of ITS; smaller legacy stand-alone system being replaced by new integrated system; mostly stand-alone but gets GPS from DRI talking bus; also purchased Ride Check Plus software; currently stand-alone but capable of downstream integration.

23. *If your agency also has an AVL system, is there a preferred source for time-based information at timepoints?*
- Yes, we primarily use APC time data _____ 3 6.1%
 - Yes, we primarily use AVL time data _____ 28 57.1%
 - No preference: either is acceptable _____ 9 18.4%
 - We do not have an AVL system _____ 9 18.4%

APC DATA: PROCESSING, MANAGING, VALIDATING, AND USING

24. *What standards did your agency use for the initial acceptance of APC (e.g., level of accuracy)?*
- 85% _____ 1 3.0%
 - 90% _____ 8 24.2%
 - 95% _____ 13 39.4%
 - 97% _____ 1 3.0%
 - 95% + 10% _____ 2 6.1%
 - 95% + 5% _____ 1 3.0%
 - Varies by level _____ 7 21.2%

25. *Does your agency use these standards on an ongoing basis?*
- Yes _____ 30 71.4%
 - No _____ 12 28.6%

26. *How does your agency transfer ridership data from the APC units?*
- Direct downlink (probe) of APCs with a physical connection _____ 4 8.5%
 - Retrieval of APC data at garage without a physical connection _____ 23 48.9%
 - Real-time dynamic or periodic remote retrieval of APC data _____ 13 27.7%
 - Other (please specify) _____ 7 14.9%

Other includes: combination of real-time and wireless; radio; PCMCIA card for bus, wireless for light rail; diskettes; WLAN.

27. Please describe what steps are taken to edit and validate APC ridership data. (check all that apply)

- Compare ridership and revenue totals _____ 18 39.1%
- Look for unexplained variations across trips__27 58.7%
- Compare ridership totals across days
for reasonableness _____25 54.3%
- Rely on the professional judgment of
planners/schedulers _____24 52.2%
- Use an automated program to analyze
APC data _____24 52.2%
- Compare on/off totals by trip and adjust
as needed _____14 30.4%
- Compare with manual counts _____32 69.6%
- Other (please specify) _____7 15.2%

Other includes: automated program, users identify anomalies, and ongoing manual counts; examine data quality score for each chunk of APC data; use a business intelligence solution with pre-set tolerances, compare with farebox, and spot-check against manual counts; compare to farebox; none on a regular basis; compare with video counts; exception reports from daily diagnostics.²⁸If your agency uses an automated program to analyze APC data, please describe it briefly in terms of what it looks for and how it decides the validity of the data.

See summary table below for examples of validation tests, thresholds, and actions.

Test	Threshold	Action
Boardings vs. alightings by block and/or by trip	5%	Discard block or trip data if exceed threshold
	10%	
	20%	
	30%	
Loads	Less than 0	Adjust boardings/alightings at heaviest use stops
Bus stop location	Within 200 feet of actual bus stop	Flag stop data if exceed threshold
Actual vs. scheduled block miles/kilometers	10%	Discard if data exceed threshold 15,000
Actual vs. scheduled block pull out/pull in times	30 minutes	
Actual vs. scheduled trip start/end times	20 minutes “significantly off-schedule”	
Observed vs. “expected” results at the route, block, trip, and stop levels	Not specified	Assign quality code to data
Geographic information vs. computerized scheduling software data	Look for match	Assign probable route/block
Block data	No data	Discard block data

29. Are any special steps required to validate ridership data for NTD reporting purposes?

- Yes (describe below) _____17 32.7%
- No _____5 9.6%
- We do not use APCs to collect NTD data ____30 57.7%

30. Please describe how your agency validates ridership data for NTD reporting purposes.

Responses include: follow FTA guidelines; software developed by consulting statistician; manual validation; reasonable checks and management review; use APC data in very limited fashion for NTD; compare with farebox data.

31. *What proportion of raw data collected by APCs at your agency is converted into useful information that can be used by service planning, scheduling, and other departments?*

Average 74%; median 80%; range 10% to 100%.

32. *Were any changes required for existing agency data systems to provide the data needed for APCs to work? (check all that apply)*

- Yes, creating or updating the bus stop inventory _____ 23 53.5%
- Yes, identifying GPS coordinates _____ 25 58.1%
- Yes, other changes (please describe below) ___ 13 30.2%
- No changes required _____ 12 27.9%

Other includes: complete rewrite of ridership estimation program for APCs (previously for farebox data); have route changes as far in advance as possible; automated bus assignments; bus stop inventory and GPS coordinates previously developed for another application, but needed to share with APC system; updating schedules and formatting for use with APC system; creating a template of stops, signposts, and timepoints for each bus; creating bus routes for the system to track; created defined interfaces with computerized scheduling software package; formalize bus stop change procedures; create schedule file; internal program developed to import schedule data.

33. *Were any changes required for existing agency data systems to store and analyze APC data?*

- Yes (please specify) _____ 19 46.3%
- No changes required _____ 22 53.7%

Changes include: data storage changes; switch to Oracle database and in-house software to clean and schedule-match APC data; separate server; additional server; scrap vendor-supplied matching software and write our own; hardware and network connections to host APC software and data servers; installation of hardware and related software; new servers; developing reports and GIS access; in-house application to correlate APC data with bus stop database; purchased Ridecheck Plus, vendor software incapable of generating needed reports; vendor software unable to analyze data or perform diagnostic tests to validate data and make needed adjustments; new servers for data storage; third-party solution being considered to address this issue; new servers and vendor-supplied software as part of larger ITS program; network upgrade; installation of SPSS; integrated database; whole new large software package as part of AVL purchase; separate server; creation of Crystal Reports queries/reports for additional analysis.

34. *What types of reports are routinely generated from APC data? Please also indicate the approximate frequency for each type of report.*

	Annually	Quarterly	Monthly	Weekly	Daily	As needed
System ridership	9.1%	15.2%	27.3%	--	21.2%	27.3%
Route-level ridership	5.3%	26.3%	15.8%	2.6%	18.4%	31.6%
Route segment ridership	10.5%	10.5%	5.3%	2.6%	7.9%	63.2%
Stop-level boardings/alightings	2.4%	14.6%	9.8%	2.4%	9.8%	61.0%
Performance measures	6.1%	27.3%	12.1%	3.0%	12.1%	39.4%
Schedule adherence	--	15.6%	12.5%	--	15.6%	56.3%
Running times	--	12.9%	3.2%	3.2%	12.9%	67.7%
Other (please specify)	--	20.0%	20.0%	--	--	60.0%

Other includes: ridership for special events (rail); ad hoc request response within 24 hours; manual means still primary for generating reports; percentage of trips sampled and how often during current schedule; daily trip-level information; report by bookings instead of by quarter and include linked-trips estimate each year.

35. *How did your agency develop data processing and report generation software?*

- In-house, by information systems or computer services department _____ 13 27.7%
- In-house, by end users of data _____ 16 34.0%
- Through the hardware vendor _____ 26 55.3%
- Through another outside vendor _____ 12 25.5%
- Other (please specify) _____ 3 6.3%

Other includes: plan to use another outside vendor; occasional help from IT department; in-house by a technical person hired to support end users of the data; hardware vendor or end users; part of hardware package; two outside programs; user developed for farebox, computer services department test-processing for APC data.

36. *If software was developed through an outside vendor, did the process include customization or modification of the software to meet the agency's specific needs?*

- Yes, considerable customization _____ 5 10.6%
- Yes, moderate customization _____ 12 25.5%
- Yes, minor customization _____ 4 8.5%
- No _____ 8 17.0%
- Not applicable _____ 18 38.3%

37. *Does your agency have the capability of generating ad hoc, specialized ridership reports from the APC system?*

- Yes, through information services or computer services department _____ 16 35.6%
- Yes, directly by end users _____ 29 64.4%
- Yes, through the outside vendor _____ 11 24.4%
- No _____ 4 8.9%

38. *Does your agency archive ridership data for previous year comparisons or future analytical needs?*

- Yes _____ 35 85.4%
- No _____ 6 14.6%

38a. *If yes, how long do you keep APC data in the archive?*

Average and median length is 5 years.

39. *Most new technologies require an implementation or "debugging" period in which agencies become familiar with the new equipment and start-up problems are ironed out. If your agency implemented APC within the last five years, how long did this period last?*

- Less than 6 months _____ 3 9.7%
- 6–11 months _____ 4 12.9%
- 12–23 months _____ 8 25.8%
- 24 months or more _____ 6 19.4%
- Ongoing _____ 10 32.3%

Average (excluding ongoing) is 17 months; median is 18 months

ORGANIZATION AND DATA INTEGRATION

40. Which departments were involved in the decision to purchase APCs at your agency? (check all that apply)

- Planning _____ 38 90.5%
- Scheduling _____ 24 57.1%
- Budget/Finance _____ 22 52.3%
- Operations _____ 26 61.9%
- Computer Services/Information Services ____ 28 66.7%
- Maintenance _____ 18 42.9%
- Marketing/Market Research _____ 10 23.8%
- Other (please specify) _____ 3 7.1%

Other includes executive/senior management.

41. Which department takes primary ownership of management and operation of the APC system?

- Planning _____ 19 42.3%
- Scheduling _____ 3 6.8%
- Budget/Finance _____ 1 2.3%
- Operations _____ 9 20.5%
- Computer Services/Information Services ____ 7 15.9%
- Maintenance _____ 1 2.3%
- Marketing/Market Research _____ 0 0.0%
- Other (please specify) _____ 4 9.1%

Other includes combinations of: IT, maintenance, and operations; maintenance and IT (joint department); planning and maintenance; planning and IT

42. Which departments are downstream users of APC data? (check all that apply)

- Planning _____ 40 90.9%
- Scheduling _____ 36 81.8%
- Budget/Finance _____ 15 34.1%
- Operations _____ 32 72.7%
- Computer Services/Information Services ____ 6 13.6%
- Maintenance _____ 6 13.6%
- Marketing/Market Research _____ 26 59.1%
- Senior management _____ 23 52.3%
- No downstream users _____ 1 2.3%
- Other (please specify) _____ 3 6.8%

Other includes: transit priority group within city government; local businesses, Federal and local governments, Board of Directors, local government planners

43. How do downstream units access APC data? (check all that apply)

- Hard copy _____ 22 50.0%
- Electronically via standard reports _____ 35 79.5%
- Electronically via dynamic queries _____ 19 43.2%
- Other (please specify) _____ 8 18.2%

Other includes: reports run by APC staff and e-mailed to users with 24-hour turnaround; GIS tools; Ridecheck Plus; schedulers and planners can run dynamic queries; still working out the process.

44. *If there are multiple users of APC data, please describe the interaction among the different groups and any synergy or tensions/conflicts that have arisen. Examples could include: greater value placed on ridership data; better working relationships between departments; difficulties in ensuring that daily assignments are completed successfully; demands for new and/or reformatted reports*

POSITIVE

- Improved communication between departments 7 20.6%
- Greater value placed on ridership data _____ 7 20.6%
- Better data leading to improved decision-making ability _____ 5 14.7%
- Greater responsiveness to public/others _____ 3 8.8%
- Ability to provide data to end users _____ 3 8.8%

NEGATIVE

- Difficulty with bus assignments _____ 7 20.6%
- Constant/increased demands for new/reformatted reports _____ 5 14.7%
- Low priority for APC maintenance _____ 4 11.8%
- Unrealistic expectations re turnaround time and data quality _____ 4 11.8%

RESOURCE REQUIREMENTS

45. *How many staff positions (full-time equivalents [FTEs]) are assigned to carry out your agency's passenger counting program?*

	<1 FTE	1-1.9 FTEs	2-3.9 FTEs	4+ FTEs	Don't Know
Managers/professionals	47.7%	29.5%	20.5%	2.3%	--
Support (e.g., equipment maintenance)	54.1%	27.0%	13.5%	5.4%	--
Clerical	72.0%	20.0%	--	--	8.0%
Traffic checkers	44.4%	11.1%	7.4%	29.6%	7.4%
Other (please specify)	42.9%	--	14.3%	42.9%	--

Other includes: data retrieval person; data editing and analysis plus report production; traffic checkers ad hoc.

46. *Has the APC program resulted in changes in number of staff? Consider a change of more than 2 FTEs a "major" change.*

	Major Decrease	Minor Decrease	No Change	Minor Increase	Major Increase
Professional staff	--	2.8%	72.2%	22.2%	2.8%
Support staff	3.1%	--	81.3%	12.5%	3.1%
Clerical staff	3.1%	6.3%	87.5%	3.1%	--
Maintenance staff	--	--	71.9%	28.1%	--
Traffic checkers	20.0%	28.6%	48.6%	--	2.9%
Other (please specify)	10.0%	--	70.0%	10.0%	10.0%

Other includes: we needed more IT support and maintenance at first; data retrieval person; eliminated two positions in Treasury branch; but it should!

47. *Has the APC program resulted in changes in skill levels required by staff?*

- Yes, in software/computer skills _____ 29 69.0%
- Yes, in analytical skills _____ 23 54.8%
- Yes, in hardware maintenance skills _____ 23 54.8%
- Yes, in other skills (please specify) _____ 5 11.9%
- No _____ 10 23.8%

Other skills include: learning how to use the data properly, what it is good for, and its limitations; we have had APCs for so long, it is part of our ongoing fabric; training for operators

48. *What is the capital cost associated with your agency’s passenger counting program? For capital costs, list approximate purchase cost and year purchased. If multiple purchases were involved (e.g., bus one year, rail the next), list bus information in the boxes and add other information in the next question. You do not need to use a dollar sign; enter a number for each box.*

- Overall cost: _____
- Cost per APC unit: _____
- Year purchased: _____

Cost data from the survey should be interpreted cautiously. Respondents varied in their ability to break down cost data (especially for older systems or for APC systems purchased as part of a larger ITS procurement). As one example, reported capital costs for the agency’s APC system ranged from \$90,000 to \$40,000,000.

The average capital cost per APC unit was \$7,500, with a range from \$450 to \$26,700. The median capital cost per APC unit was \$6,638, with 26 agencies responding. See below for breakdown (Table 21 in Chapter 3).

APC Median Capital Cost and Median Capital Cost per Unit by Number of Vehicles Equipped

No. Vehicles with APCs	Median Capital Cost (\$)	Median Capital Cost per APC Unit Installed (\$)	No. Systems
< 100	200,000	7,500	13
100 to 400	500,000	2,700	7
> 400	1,800,000	1,100	3
Total sample	490,000	6,638	26

NOTES: Three systems reported total cost only; three systems reported unit cost only. All three systems in the over 400 category had at least 1,450 vehicles with APCs.

49. *Add any additional information on capital costs here.*

See above.

50. *What is the annual operating/maintenance cost associated with your agency’s passenger counting program? If multiple purchases were involved (e.g., bus one year, rail the next), list bus information in the boxes and add other information in the next question. You do not need to use a dollar sign; enter a number for each box.*

- Overall cost: _____
- Cost per APC unit: _____

Cost data from the survey should be interpreted cautiously. Respondents varied in their ability to break down cost data (especially for older systems or for APC systems purchased as part of a larger ITS procurement).

Responses regarding annual operating and maintenance costs also showed a huge variation, from \$0 (everything is under warranty) to \$15,000,000. Average annual operating and maintenance cost per APC unit was \$1,458, with a range from \$0 to \$6,500. The median annual operating and maintenance cost per APC unit was \$600, with 11 agencies responding.

51. *Add any additional information on operating/maintenance costs below.*

See above.

ASSESSMENT

52. *How satisfied has your agency been with the performance of its APC system in terms of counting passengers?*
- Very satisfied _____ 16 40.0%
 - Somewhat satisfied _____ 18 45.0%
 - Somewhat dissatisfied _____ 2 5.0%
 - Very dissatisfied _____ 4 10.0%
53. *What have been the primary benefits of APC for your agency?*
- Finer level of detail (stop/segment/trip) _____ 14 36.8%
 - Quality of data _____ 11 28.9%
 - Running time data to adjust schedules _____ 10 26.3%
 - Better basis for decision making _____ 6 15.8%
 - Quantity of data _____ 6 15.8%
 - Timeliness of data _____ 5 13.2%
54. *Have there been any problems encountered with the APC system?*
- None/usual start-up issues _____ 10 25.6%
 - Reports/reporting software _____ 5 12.8%
 - Data processing/analysis _____ 4 10.3%
 - Data validation _____ 4 10.3%
 - Hardware problems _____ 4 10.3%
55. *If you could go back in time and change ONLY ONE aspect in the process of purchasing, installing, and using your APC system and associated methodology, what would you change?*
- Contract/procurement _____ 8 25.0%
 - Additional APCs _____ 7 20.6%
 - Approach _____ 7 20.6%
 - Testing _____ 4 11.8%
 - Hardware _____ 3 9.4%
 - Training _____ 2 5.6%
56. *Please describe any “lessons learned” that would benefit other transit agencies that are considering changes to their passenger counting methods.*
- Data processing/use/reporting _____ 14 41.2%
 - Purchase/implementation _____ 9 26.5%
 - Data validation _____ 7 20.6%
 - Maintenance _____ 7 20.6%
 - Staff/resource needs _____ 5 14.7%
 - Time frame _____ 5 14.7%
 - Testing _____ 5 14.7%
 - Experience of peers _____ 4 11.8%
 - Training _____ 4 11.8%

- Other: procedures _____ 6 17.6%
- Other: staff/management _____ 3 20.6%
- Other: APC system inputs _____ 2 17.6%

57. *Is there another transit system that you suggest we contact for this synthesis project? If you know of a contact at that system, please list the name also.*

Various responses.

58. *Would you be willing to participate further as a case study, involving a telephone interview going into further detail on your forecasting methodology, if selected by the TCRP panel for this project?*

- Yes _____ 28 68.3%
- No _____ 13 31.7%

APPENDIX C

LIST OF PARTICIPATING TRANSIT AGENCIES

PASSENGER COUNTING SYSTEMS

1. Albany, N.Y.	Capital District Transportation Authority
2. Allentown, Pa.	Lehigh and Northampton Transportation Authority
3. Ann Arbor, Mich.	Ann Arbor Transportation Authority
4. Anoka, Minn.	Anoka County Transit
5. Arlington, Ill.	PACE
6. Atlanta, Ga.	Metropolitan Atlanta Rapid Transit Authority
7. Austin, Tex.	Capital Metro
8. Baltimore, Md.	Maryland Transit Administration
9. Bay City, Mich.	Bay Metropolitan Transportation Authority
10. Blacksburg, Va.	Blacksburg Transit
11. Boone, N.C.	AppalCART
12. Boston, Mass.	Massachusetts Bay Transportation Authority
13. Bremerton, Wash.	Kitsap Transit
14. Bryan, Tex.	Brazos Transit District
15. Buffalo, N.Y.	Niagara Frontier Transportation Authority
16. Burlington, Vt.	Chittenden County Transportation Authority
17. Butler, Pa.	Butler Transit Authority
18. Calgary, Alberta	Calgary Transit
19. Champaign–Urbana, Ill.	Champaign–Urbana Mass Transit District
20. Chicago, Ill.	Chicago Transit Authority
21. Cincinnati, Ohio	Metro/Southwest Ohio Regional Transit Authority
22. Cleveland, Ohio	Greater Cleveland Regional Transit Authority
23. Colorado Springs, Colo.	Mountain Metropolitan Transit
24. Columbus, Ohio	Central Ohio Transit Authority
25. Dallas, Tex.	Dallas Area Rapid Transit
26. Davis, Calif.	ASUCD Unitrans
27. Dayton, Ohio	Greater Dayton Regional Transit Authority
28. Delano, Calif.	City of Delano
29. Denver, Colo.	Regional Transportation District
30. Duluth, Minn.	Duluth Transit Authority
31. Elk Grove, Calif.	e-tran
32. Eugene, Ore.	Lane Transit District
33. Fairfield, Calif.	Fairfield-Suisun Transit
34. Fresno, Calif.	Fresno Area Express
35. Fort Myers, Fla.	Lee County Transit
36. Gainesville, Ga.	Hall Area Transit
37. Hartford, Conn.	Connecticut Transit
38. Honolulu, Hawaii	City and County of Honolulu Department of Transportation
39. Houston, Tex.	Metropolitan Transit Authority of Harris County
40. Ithaca, N.Y.	Tompkins Consolidated Area Transit
41. Jacksonville, Fla.	Jacksonville Transportation Authority
42. Knoxville, Tenn.	Knoxville Area Transit
43. Lancaster, Calif.	Antelope Valley Transit Authority
44. Las Vegas, Nev.	Regional Transportation Commission of Southern Nevada
45. Livermore, Calif.	Livermore/Amador Valley Transit Authority (WHEELS)
46. Louisville, Ky.	Transit Authority of River City
47. Madison, Wis.	Metro Transit, City of Madison
48. Milwaukee, Wis.	Milwaukee County Transit System
49. Minneapolis, Minn.	Metro Transit

50. Muskegon, Mich.	Muskegon Area Transit System
51. Nashville, Tenn.	Nashville Metropolitan Transit Authority
52. New Orleans, La.	Regional Transit Authority
53. New York, N.Y.	MTA New York City Transit
54. Newark, N.J.	New Jersey Transit
55. Newark, N.J.	Port Authority of New York and New Jersey
56. Oakland, Calif.	Alameda–Contra Costa Transit District (AC Transit)
57. Orange, Calif.	Orange County Transportation Authority
58. Orlando, Fla.	Lynx
59. Ottawa, Ontario	OC Transpo
60. Oxnard, Calif.	Gold Coast Transit
61. Peoria, Ill.	QC Metrolink
62. Port Angeles, Wash.	Clallam Transit District
63. Portland, Ore.	Tri-County Metropolitan Transit District of Oregon
64. Providence, R.I.	Rhode Island Public Transit Authority
65. Redondo Beach, Calif.	Beach Cities Transit
66. Reno, Nev.	Regional Transportation Commission of Washoe County
67. Rockville, Md.	Montgomery County Ride On
68. Salem, Ore.	Cherriots–Salem/Keizer Transit
69. San Diego, Calif.	San Diego Association of Governments (SANDAG)
70. San Francisco, Calif.	San Francisco Municipal Transportation Agency
71. San Mateo, Calif.	SamTrans
72. Santa Cruz, Calif.	Santa Cruz Metropolitan Transit District
73. Santa Monica, Calif.	Santa Monica’s Big Blue Bus
74. Seattle, Wash.	King County Metro Transit
75. State College, Pa.	Centre Area Transportation Authority
76. Syracuse, N.Y.	CNY Centro, Inc.
77. Tacoma, Wash.	Pierce Transit
78. Tallahassee, Fla.	Star Metro
79. Toledo, Ohio	Toledo Area Regional Transit Authority
80. Topeka, Kans.	Topeka Metropolitan Transit Authority
81. Toronto, Ontario	Toronto Transit Commission
82. Washington, D.C.	Washington Metropolitan Area Transit Authority
83. West Covina, Calif.	Foothill Transit
84. Wilmington, Del.	Delaware Transit Corporation
85. Winnipeg, Manitoba	Winnipeg Transit System
86. Woodbridge, Va.	Potomac and Rappahannock Transportation Commission

APPENDIX D

AGENCIES AND AUTOMATIC PASSENGER COUNTER MANUFACTURERS

Table D1 lists transit agencies with automatic passenger counter (APC) systems, the size of the agency as measured by the number of peak vehicles in service, and the percentage of vehicles equipped with APCs, hardware supplier, software supplier, and procurement process. All information except for agency size is taken directly from survey responses. National Transit Database 2006 data were used to determine system size: Small agencies have fewer than 250 peak vehicles, medium agencies have between 250 and 1,000, and large agencies have more than 1,000.

TABLE D1
AGENCIES AND APC MANUFACTURERS

Agency/City	Size	% APC Vehicles	Hardware Supplier	Software Supplier	Procurement
AC Transit/Oakland, Calif.	Medium	10	UTA IRIS through Orbital	Hardware vendor	UTA stand-alone Orbital part of larger ITS
Ann Arbor TA/Ann Arbor, Mich.	Small	52	Red Pine	Outside vendor	Part of larger ITS
Blacksburg Transit/Blacksburg, Va.	Small	100	ATC	Outside vendor	Part of larger ITS
Calgary Transit/Calgary, Alberta	Medium	12	Infodev	Infodev	Infodev
CDTA/Albany, N.Y.	Medium	25	INIT	Mobile Statistics INIT In house	Part of larger ITS
Capital Metro/Austin, Tex.	Medium	23	UTA	In house UTA	Stand-alone
LYNX/Orlando, Fla.	Medium	20	UTA	In house UTA	Stand-alone, capable of downstream integration
CNY Centro/Syracuse, N.Y.	Small	6	N/A	Hardware vendor	Part of larger ITS
COTA/Columbus, Ohio	Small	15	UTA	UTA	Stand-alone
Champaign–Urbana MTD/ Champaign–Urbana, Ill.	Small	100	INIT	In house INIT Outside vendor	Part of larger ITS
Cherriots–Salem/Keizer Transit/ Salem, Ore.	Small	45	Digital Recorders	N/A	Stand-alone
DART/Dallas, Tex.	Medium	3	UTA	UTA	Stand-alone
Delaware Transit Corp/Wilm- ington, Del.	Medium	5 (test status)	Orbital	In house	N/A
Duluth Transit Authority/ Duluth, Minn.	Small	50	Siemens Transit Master	Siemens Transit Master	Part of larger ITS
Foothill Transit/West Covina, Calif.	Medium	100	N/A	Crystal Reports Business Objects software In house	Part of larger ITS
Fresno Area Express/Fresno, Calif.	Small	25	Red Pine through Siemens	Siemens In house	Part of larger ITS
GCRTA/Cleveland, Ohio	Medium	25	Red Pine through Conti- nental/ Siemens	Crystal Reports Software	Part of larger ITS
Greater Dayton RTA/ Dayton, Ohio	Medium	15	Siemens Red Pine	Siemens	Part of larger ITS

TABLE D1 (Continued)
AGENCIES AND APC MANUFACTURERS

Agency/City	Size	% APC Vehicles	Hardware Supplier	Software Supplier	Procurement
King County Metro/Seattle, Wash.	Large	15	IVT	In house	Stand-alone
Lane Transit District/Eugene, Ore.	Small	100	IRIS	In house	Part of larger ITS
MARTA/Atlanta, Ga.	Medium	100	Pine Box IRIS	In house	New fully integrated replacing legacy stand-alone
MBTA/Boston, Mass.	Large	10 of pilot garage	UTA	SPSS (UTA) In house	Stand-alone
Metro Transit/Minneapolis, Minn.	Medium	14	Red Pine through Continental/ Siemens	In house	Part of larger ITS
Metro Transit/City of Madison, Wis.	Small	18	N/A	In house	Part of larger ITS
MetroLINK/Peoria, Ill.	Small	100	INIT	INIT	Part of larger ITS
MTA of Houston and Harris County, Texas	Large	100	INIT	INIT Outside vendor In house	Bus: part of larger ITS Light rail: stand-alone
Milwaukee County Transit System/Milwaukee, Wis.	Medium	8	Infodev	Infodev In house	Stand-alone
MTA NYCT/New York, N.Y.	Large	Pilot	IRIS through Siemens Transit Master	N/A	Part of larger ITS
NFTA/Buffalo, N.Y.	Medium	40	UTA INIT (not yet in service)	UTA In house	Stand-alone, but GPS from DRI talking bus system
OC Transpo/Ottawa, Ontario	Medium	10	Infodev	Outside vendor	Stand-alone
OCTA/Orange, Calif.	Medium	< 100	IRIS through Orbital	In house	Stand-alone
Pace/Arlington, Ill.	Large	40	Red Pine	In house	Part of larger ITS
RTC Washoe County/ Reno, Nev.	Small	100	Siemens	Outside vendor In house	Part of larger ITS
RTC of Southern Nevada/Las Vegas, Nev.	Medium	50	N/A	In house	Part of larger ITS
RTD/Denver, Colo.	Large	20+	INIT	Ridecheck Plus	Software purchased with hardware
RIPTA/Providence, R.I.	Medium	10	UTA	UTA	Stand-alone
SamTrans/San Mateo, Calif.	Medium	40–50	Iris through Orbital	Orbital	Part of larger ITS
San Francisco MTA/San Francisco, Calif.	Medium	10	UTA	UTA	Stand-alone
SANDAG/San Diego, Calif.	Medium	25	IRIS	Ridecheck Plus	Part of larger ITS
Santa Monica's Big Blue Bus/Santa Monica, Calif.	Small	100	N/A	In house	Part of larger ITS

TABLE D1 (Continued)
AGENCIES AND APC MANUFACTURERS

Agency/City	Size	% APC Vehicles	Hardware Supplier	Software Supplier	Procurement
SORTA/Cincinnati, Ohio	Medium	3	UTA	UTA	Stand-alone
TheBus/City and County of Honolulu, Hawaii	Medium	24	UTA Infodev IRIS Clever Devices	UTA Outside vendor	Part of larger ITS
TriMet/Portland, Ore.	Medium	75	Bus: Red Pine Light rail: IRIS	In house	Originally stand-alone; integrated with AVL
Winnipeg Transit System/Winnipeg, Manitoba	Medium	15	Infodev	In house	Stand-alone
WMATA/Washington, D.C.	Large	100	Cubic	In house	Part of larger ITS

NOTE: N/A= Not Available; ITS = intelligent transportation systems; GPS = global positioning system; AVL = automatic vehicle location; SPSS = Statistical Package for the Social Sciences; UTA = Urban Transportation Associates; IRIS = iris-GmbH. See the website <http://www.apc-irma.biz/>; INIT refers to itself as init Innovations in Traffic Systems. see the website <http://www.initusa.com/>; DRI is DRI Corporation, see the website <http://www.digrec.com/>; IVT is Integrated Vehicle Technologies

Abbreviations used without definition in TRB Publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI-NA	Airports Council International-North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	Air Transport Association
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation