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U.S. Department
of Transportation
**Urban Mass
Transportation
Administration**

Automated Passenger Counting Systems
Synopsis of Working Group Meeting

Prepared by:
Transportation Systems Center

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UMTA Technical Assistance Program

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Synopsis of Working Group Meeting

Transportation Systems Center
March 23 - 25, 1982

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INTRODUCTION

A working group meeting to review the status of Automatic Passenger Counting Systems (APCS) was held at the Transportation Systems Center (TSC) in Cambridge, Massachusetts on March 23-25, 1982. The meeting was held as part of the APCS Technical Assistance Program carried out by TSC and sponsored by the Urban Mass Transportation Administration's (UMTA) Office of Bus and Paratransit Systems. Invitations were extended to transit agencies currently using APCSs and APCS suppliers. Several transit agencies actively contemplating use of APCSs and consulting firms working with APCS-using agencies also participated.

The principal objective of the meeting was to explore the issues relevant to full and effective use of APCSs, in light of the resurgent interest in automated data collection as a vital element in improving transit system productivity and service. The topics addressed were:

1. The state-of-the-art of APCS, and current U.S. and Canadian deployment;

2. The utilization of APCS data for transit systems management and reporting;

3. The relative accuracy of APCS and manual data collection methods, and the specification of APCS accuracy requirements;

4. The feasibility of establishing guidelines for uniform specification of functional requirements and modular levels of functional capability;

5. Identification of low-risk incremental improvements to enhance the utility of existing APCSs.

Prior to the working group meeting, TSC contracted with several of the APCS transit agencies to conduct limited field assessments of the comparative accuracy of their APCSs and typical manual data collections methods; the results to be presented for discussion at the meeting.

In attendance were representatives from: Minneapolis/St. Paul Metropolitan Transit Commission (MTC); Cincinnati Queen City METRO; Kalamazoo METRO Transit System; Seattle METRO; Metropolitan Atlanta Regional Transit Authority (MARTA); New York City Transit Authority (NYCTA); Southern California Rapid Transit District (SCRTD); Greater Vancouver Regional District Transit Department; Toronto Transit Commission (TTC); Central Ohio Transit Authority (COTA); Michigan DOT; New York State DOT; Dynamic Control; Vapor/Almex; ATE Management Services; Urban Transportation Associates; Group Five Consultants; Hickling-Partners Inc.; and Multisystems Inc. The meeting was chaired by Vivian J. Hobbs and Paul J. Poirier of TSC.

This report provides a brief background on Automated Passenger Counting Systems followed by a synopsis of the material covered at the APCS Working Group Meeting.

BACKGROUND

Collection of data on ridership and schedule adherence is fundamental to transit system productivity: that is, optimum use of labor and capital expenditures, operational efficiency and the provision of effective bus service. The information derived from such data is used by transit managers to:

- create, evaluate and adjust schedules and run times;
- plan and justify route changes;
- assign particular bus types (e.g. articulated);
- evaluate marketing strategies (e.g. fare incentives);
- estimate expected revenue (farebox accountability);
- determine fleet needs;
- and, in some cases, monitor driver performance.

Additionally, as part of the recent "Urban Mass Transportation Industry Uniform System of Accounts and Records and Reporting System" (Section 15), the Federal Government has required the reporting of "service-consumed" (ridership) data. These data are the only primary indicators of user benefits that are currently collected under the Section 15* program.

Historically, ridership and service data have been collected manually by "ride checkers" on board the buses or "point-checkers" stationed along a route. Many transit properties maintain a staff solely for this purpose, others contract for data collection services, use planning or other in-house staff as needed, or do without such data entirely.

In order to be meaningful, data should be collected along several, or all routes for multiple days encompassing different time periods, weekends, seasons, etc. It should be collected systematically, and frequently enough to capture changes. This can be costly when carried-out manually.

*Section 15(a) of the Urban Mass Transportation (UMT) Act of 1964, as amended. ...to provide data that meets "the needs of individual public mass transportation systems, Federal, State and local governments, and the public for information on which to base planning for public transportation services, and shall contain information appropriate to assist in the making of public sector investment decisions at all levels of government..."

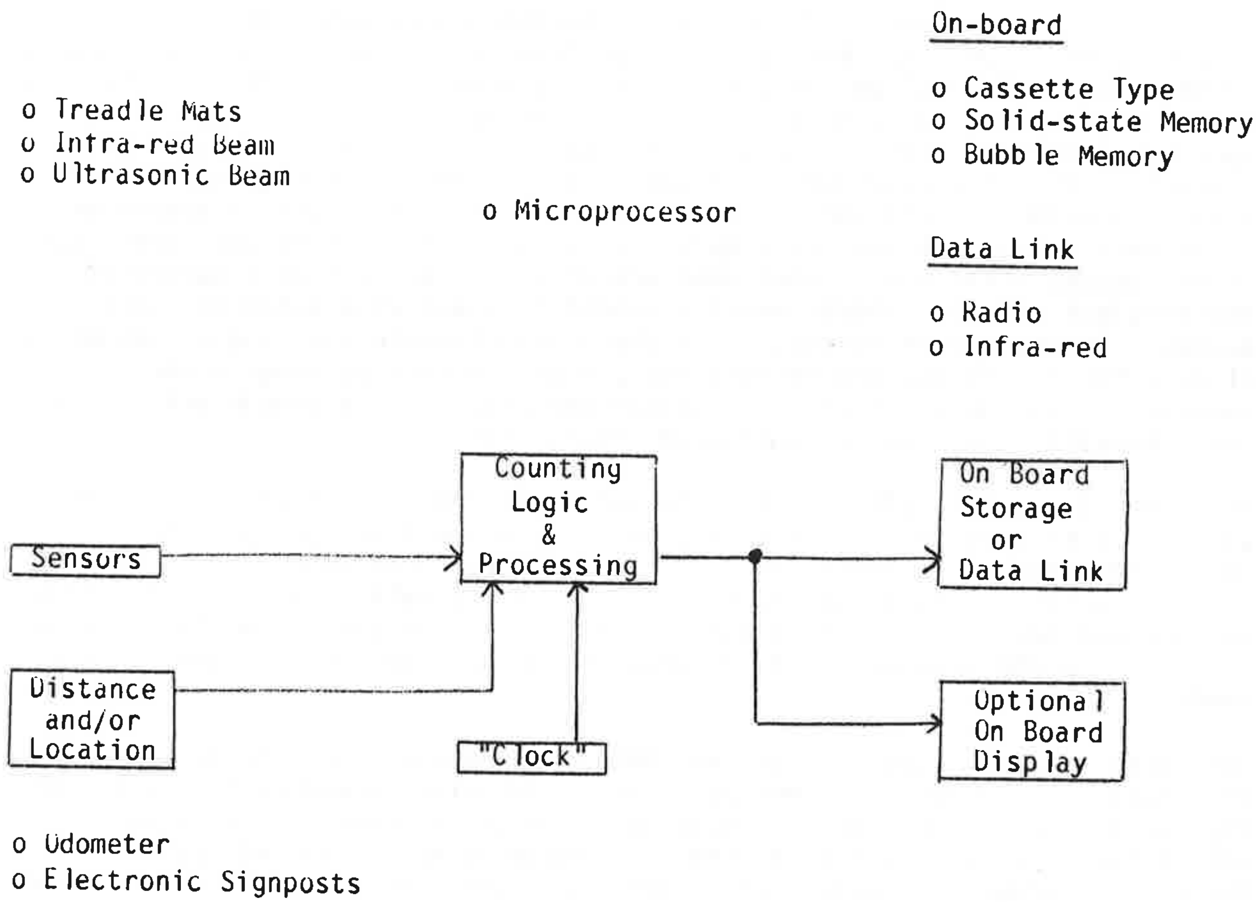
The fact that it is a costly operation often precludes frequent or systematic data collection, and the time lag between collection of data and the production of useful reports is often great. The reliability and accuracy of manually collected data is affected by a number of factors. The data can be biased because a driver will often alter his/her performance when a ride-checker is on-board the bus. The performance of manual data collectors varies from individual to individual. Errors creep into the data due to loss of concentration: i.e., on and off counts may be transposed exaggerating apparent load conditions; data may estimated, not recorded, or possibly "fudged". Standing passengers can obstruct the view, causing miscounts or missed location correlation. Ride checkers may be distracted by passengers' appearance or by questions or complaints addressed to them because they appear to be company officials. Point checkers on the street can be thwarted by smoked-glass windows, and/or weather conditions, and distracted by other duties. Errors can be introduced in the manual transferring and manipulation of data for reporting; and because the job of counting passengers and recording location and time is a tedious one, experienced people are hard to keep, resulting in frequent untrained observations.

The general economic climate, funding cuts, and reduced operating subsidies will force transit properties to adjust service and fares and/or otherwise modify operating practices. If these changes are to be made in an informed fashion, contributing to the system's productivity rather than deteriorating service and operations, and if the effects of various service or fare changes on ridership and revenue are to be understood, thorough and reliable data is needed.

Automated Passenger Counter Systems (APCS) overcome many of the deficiencies of manual data collection, they offer an opportunity to reduce the costs and improve the reliability and ultimate accuracy of ridership and service information. At the same time, the significantly more detailed data and thorough coverage available through APCSs provides the data base for creative analysis and tuning of resources and services not previously possible with normal manual data collection and reduction efforts.

APCSs are distinct from, and do not require, the sophisticated trappings of an Automatic Vehicle Monitoring (AVM) system, although they may be included as an integral part of an AVM system to provide the "management information" benefits. Real-time vehicle monitoring and control are not provided by APCSs. Typically, data are stored on-board the vehicle, retrieved periodically (e.g., once/week) via computer-readable devices, and processed by computer into specific information reports as needed.

A simplified block diagram of an automated passenger counting unit is shown below.



SIMPLIFIED BLOCK DIAGRAM OF AUTOMATED PASSENGER COUNTER SYSTEM

The systems presently in use employ either infra red beams or pressure sensitive mats as sensing devices.

The infra red beam sensor consists of an array of two or more transmitter receiver pairs situated on opposite sides of the stairwell which are used to detect the presence of a sufficiently large mass and determine the direction of its motion. The beam array functions best when mounted at an appropriate height in the stairwell and as close to the "skin" of the bus as practicable.

The pressure sensitive mat sensor consists of stairwell treads designed and fabricated to incorporate one or more pressure sensitive electrical switches which span the tread. Two or more mats are used to detect the presence of a sufficiently heavy mass and determine the direction of its motion. The mats function best when installed on the first and second steps.

Counting logic coded into a microprocessor unit is used to determine the number of passengers boarding or alighting based on the sensor information. The simplest counting logic sequence might be as follows: "presence" sensed by the first sensor only, followed by "presence" sensed by the first and second sensor simultaneously, followed by "presence" sensed by the second sensor only, and the sequence being completed when "presence" is not sensed by either sensor. Directivity (passenger boarding or alighting) is determined by which device senses "presence" first.

Count data, if it is to be stored on board, must be time-stamped inferring the requirement of a "clock".

Distance and/or location data is necessary for effectively correlating count data to specific bus stops or other key locations. Distance data is acquired using an odometer;and location data, an option, requires the use of sign posts or similiar devices.

WORKING GROUP PARTICIPANT REPORTS:

STATUS OF U.S. AND CANADIAN SYSTEM DEPLOYMENT

Tom Geehan of Hickling Partners presented a summary report of "Review of Passenger Counting Systems" which Hickling Partners had prepared under contract to the Greater Vancouver Regional District (GVRD). During the discussion which followed, Tom:

- o Recommended that early emphasis should be placed on analyzing the requirements and objectives of the specific APCS in terms of what is needed for an effective management information system, since hardware costs are small in contrast to the cost of necessary software development.

- o Supported the advisability of specifying uniform requirements for APCS hardware.

Figure 1 depicts the status of United States and Canadian deployment of Automated Passenger Counter Systems (APCS) as determined by the Hickling Partners report as of March, 1982 and supplemented by TSC inquiries.

UNITED STATES	SUPPLIER	# OF BUSES EQUIPPED AND TYPE OF SYSTEM
Columbus	Urban Transportation Associates	6 dual beam* (leased)
Kalamazoo (Michigan DOT)	General Motors	20 dual beam
Los Angeles (AVM)	Dynamic Control	200 treadle mat + 100 treadle mat (planned)
	Dyniman	65 multiple beam (removed)
Minneapolis/St. Paul	Prodata	44 dual beam
Portland	Isaacs Associates**	50 dual beam (on order)
Sacramento, Monterey & 4 others (CALTRANS)	Dyniman	35 multiple beam
Seattle	Dynamic Control	56 treadle mat
CANADA		
Calgary	Group Five/Isaacs	5 dual beam (initial demo)
London	London Mat (Vapour Canada)	1 treadle mat + 30 treadle mat (planned)
Ottawa	Group Five/Prodata/Isaacs	50 dual beam + 30 dual beam (planned)
Quebec	Group Five/Isaacs	3 dual beam + 10 dual beam (planned)
Toronto	In-house development (contractor assisted)	treadle mat 100 dual beam (150 add'l planned)
Windsor	General Motors	27 dual beam

* dual & multiple beam refer to infra red

**Isaacs Associates is now "Red Pine Instruments Ltd." and their infra-red units have been changed to four-beam light heads.

APCS
U.S. & CANADIAN DEPLOYMENT
(MARCH 1982)

FIGURE 1

APCS TRANSIT AGENCY EXPERIENCE AND DATA UTILIZATION

In order to establish a common level of understanding for subsequent discussion, the attendees who participated in the accuracy field assessment were asked to: give a brief history of their APCS experience; describe their APCS hardware; discuss how the data is gathered, processed and utilized; comment on maintenance and reliability issues; assess management reactions; estimate cost savings (if any); and indicate any planned or desired systems improvements.

Minneapolis/St. Paul - Metropolitan Transit Commission

Ray Neetzel of the MTC of Minneapolis, St. Paul, related the MTC's use of and experience with APCS to date. The MTC acquired the on-board hardware for 44 International PRODATA dual beam infra-red systems in late 1977 and early 1978. The original plan envisioned polling the on-board units via the existing radio link, however the supplier has not yet delivered the PR812 units that would make this possible; consequently the only means to acquire data is by having the driver transcribe the counts from a display mounted on the operator's panel. The MTC, then, has not pursued the development of software for handling data automatically.

Despite the lack of automated recording and processing, the MTC has made some limited use of the on-board systems. The drivers fill out trip sheets which have been modified to include APC data (on/off totals) at selected stops. Fifteen to twenty minutes are required to process the APCS data from a trip sheet. The information has been used by the planning department for late night and weekend trips, thereby reducing overtime costs for data collection. As an example an estimated 300 - 400 hours of night and weekend overtime was saved over an 8-month period. APCS data has been used to adjust headways, and to modify routes. On occasion, the information has been used to substantiate driver contentions of constrictive schedule design. It is anticipated that APCS data would also be useful in supporting route changes at public hearings.

The MTC employs in-house ride checkers and also contracts for ride-check services. They do not foresee eliminating the in-house ride checker staff as a result of APC use (maintaining a variable fare structure requires fare breakdown information which is not currently possible with existing APCSs) but the potential for a meaningful reduction in ride checker costs is recognized. MTC's present policy is to conduct two ride-checks per route per year; each ride-check requires three days. A "fully automated" APCS at the MTC would greatly facilitate acquiring and processing data. Schedule changes could be made as often as every 4 weeks on some routes; since 20 - 30% of system is so called extra-board work.

Operationally the original plan envisioned 44 systems: This was based on 1 system for each bus assigned to the largest route in each of 4 garages - (10 buses for each of the 4 major garages with a 10% allowance for spares). A number of systems have been cannibalized for parts; as a result the buses having operational counters are rotated through each of the garages.

Since the APCS network has never been fully realized due to the lack of the PR812 multiplexing units, there is insufficient experience to evaluate reliability in a meaningful way. However, for the limited APCS use, equipment failures, other than fuses, were estimated to be no more than one every 6 months per system. Cooperative drivers have been instrumental in prompt identification of system malfunctions and failures. Other than that, the APCSs are checked once a month during their use. Vandalism has not been a problem.

Ray deemed the APCS accuracy as acceptable and not an issue. The MTC considers the on-board count as an important data point and ultimately would want to develop a means to effectively acquire it automatically.

Seattle METRO

Tom Friedman recounted the history of APCS's at the Seattle METRO.

The METRO took delivery of 56 APCSs with treadle mat sensors from Dynamic Control in late 1977. The system consists of stair-well mat switches plus door switches, an odometer, an internal clock for deriving dwell time and an on-board solid state record storage capability for up to 1500 bus stops (a portable cassette unit is used to dump the data approximately twice a week; this is done by the same person who recovers the tachographs.)

Seattle has units installed on three different bus types: MAN (articulated), AMG and Flyer. Some of the Flyers are equipped with Lift-U-Lifts.

Of the 56 systems approximately 42 are operational at any given time (they have cannibalized where necessary). Most of the failures have been associated with the mats. The initial failures were attributed to an inadequate seal; the replacement mats are experiencing a different problem: the rubber develops bubbles attributed to fatigue. This does not present an immediate functional problem but it poses a safety problem, the solution to which creates a functional problem for the APCS. To remove the bubble, maintenance personnel have been known to drive a screw through the mat into the stairwell. This process renders the mat functionally inoperable. The failure rate on the bottom front mat is the worst (approximately 50% over a 15 month period). Replacement costs for existing mats are approximately $300 - $350 per mat plus labor for installation (about 1 1/2 hours). Seattle is presently considering London mats as a possibly less expensive and perhaps more reliable replacement - about $100 per mat. These costs were contrasted (via comment from another attendee) with a relatively reliable and easy to install infra-red beam unit whose cost was said to be in the range of $200 per pair. METRO also initially experienced some problems with the micro-processor "hanging-up". This was resolved by first replacing the socket with one having greater insertion force and, for insurance, modifying the software to monitor and reset when the "hung-up" condition is detected.

The Seattle APCS data is automatically preprocessed to create a "coach" file which is time and date stamped. Then, using an interactive terminal, a data analyst selects records to separate data according to vehicle assignment and run number, because this latter process is not presently an automated function.

The data is then filtered to discern illegitimate count conditions such as negative load or passengers on board a bus returning to the garage. If the difference in on/off counts exceeds 10%, the data is discarded. For less than a 10% difference, a reconciliation scheme referred to as a "Propensity for Error" routine is used. This adjusts the counts by adding or subtracting one from the bus stops where the most activity occurred (therefore the largest propensity for error) until the total ons equal the total offs. Schemes which relied on passenger boarding rates and random adjustments were previously tried but ultimately rejected.

Computerized schedule data is used to time match APCS data with schedule. The data is presented in a table or in a plotted profile. This process is only useful if the bus is approximately on-time, otherwise insufficient location resolution make it difficult to adequately correlate the data automatically. The resolution of the odometer is probably sufficient but variations introduced by driver habits, temperature as it affects tire inflation, tire load as it effects tire deflection, short turns, detours, etc. preclude effectively using only the odometer for distance referencing. Approximately 30% of the data is currently discarded due either to logical inconsistancies as described above or the inability to adequately correlate counts with specific stops; this could be reduced significantly with better location data.

Recognizing these limitations, and the amount of cumulative error which can be introduced when servicing long routes, METRO does not currently rely on computer-derived trip information; which means data processing is not yet fully automated. To correct this deficiency 250 sign posts are being acquired which will be installed 2 - 4 miles apart, 2 - 3 per route. (Incorporating signposts requires that the on-board units be modified to accomodate additional data.) The sign post data together with odometer data will be used in conjunction with a computerized mileage template during processing to automatically correlate counts to specific bus stops.

In addition, METRO plans to modify the firmware to include an "idle" record and intends to expand the on board storage capability beyond the present 1500 bus stop limit to 2000.

A fully automated technique for transferring the data from the on-board storage to the central computing facility would be preferred in the future; i.e., eliminating the portable cassette process.

The METRO APCS data is used to produce management reports which specify intersection, dwell time, on/off counts and cumulative statistics. One of the uses has been in assigning METRO's rapidly growing fleet of articulated buses to routes where they will be the most effective. The APCS is routinely used to compile Section 15 data, and for evaluations which previously relied on a manually-acquired standing load criteria (having compared APCS data with point checkers Seattle discovered that the point checker method (i.e., counting only at peak load points) resulted in the total ridership being underestimated by as much as 50%. METRO has effectively supported scheduling and route change proposals at public hearings using reports based on APCS data.

The METRO fleet presently at about 1000 buses is expanding rapidly. With 10% of the fleet instrumented with APCS equipment (it's less than 5% currently) it is judged that the required tri-annual ride checks which typically last 5 days could be accomplished at reduced costs, and with a high degree of confidence.

This judgement is based on the existing favorable cost/benefit situation associated with maintaining and operating 56 systems. The cost elements based on 56 systems, include a data analyst 3/4 time, an electronics technician 1/3 time, replacement components, and computer time as well as the original capital costs. The savings feature a potential reduction in the checker staff translating into $150K per year, and $50-60K per year savings in developing the Section 15 data.

The management response to APCS at METRO is seen as enthusiastic. Reports are currently produced on a demand-responsive basis but will gradually evolve to a systematic basis as additional software is developed and hardware improvements are incorporated.

METRO has a dedicated tax as a source of funding.

Kalamazoo Metro Transit

Chuck Richards of Michigan D.O.T. and Bill Schomisch of the City of Kalamazoo Metro Transit summarized the status of APCS deployment in Kalamazoo. Michigan D.O.T. is sponsoring a demonstration project in Kalamazoo through 2/83. The demonstration hardware consists of 20 dual beam infra red systems installed on GM lift-equipped buses in use with a network of 30 sign posts. The data is stored on board the bus on a cassette which has the capacity to store 10 - 14 days of data.

Metro Transit, a relatively small fleet - 73 buses, plans to rotate the instrumented vehicles throughout the system to survey the entire system as many as 17 times a year to produce performance standards (cost/hour, passengers/hour, schedule adherence, etc). Metro Transit Management is judged to be committed to and supportive of APC's and anticipates using APC data to define and defend route and service changes. Kalamazoo does not presently have designated bus stops (making correlation of data difficult even with sign posts), APC data will be used to establish designated bus stops.

GM, the equipment supplier is no longer in the APCS business; therefore Metro Transit is applying for a grant to convert the GM developed software for use on an in-house computer prior to expiration of their contract with GM.

As yet, no meaningful equipment reliability data exists at Kalamazoo; although the one notable problem that was encountered did emphasize a maintainability feature: it required only 1 1/2 days to replace all 30 sign posts.

Kalamazoo would like to eliminate the operational inconvenience of having to initialize the on-board system after the bus's electrical system has been powered down, e.g., when the battery has been pulled during vehicle maintenance (this is apparently not an uncommon occurence).

Kalamazoo plans to continue with APCS beyond the completion of the demonstration in 1983.

Columbus - Central Ohio Tranist Authority (COTA)

Keith Armstrong and Tom Kowalski of Urban Transportation Associates, (UTA) who have an APCS service contract with the Central Ohio Transit Authority (COTA) in Columbus reviewed the COTA experience.

COTA contracted with UTA to demonstrate APCS. The contract consists of leasing hardware for 6 buses and 9 portable signposts along with the means and expertise to process and analyze data. The hardware is referred to as portable; however items for which the cost to install or remove exceeds the value of the item (such as sensors, cabling, door switches and the odometer) are installed on a permanent basis.

The UTA system is of GM design, a slightly earlier version of the Kalamazoo system. The resolution of the distance measurement is 2.6 feet. However, the accuracy in odometer measurement is subject to the same limitations as Seattle. The accuracy of the location reference is a function of sign post location and distance tuning (distance tuning is a function of the amplitude of the transmitted signal). UTA has added back-up batteries to the GM design for the on-board electronics which eliminate the need to reinitialize the system when the vehicle's battery is pulled during vehicle maintenance.

Due to a 30% increase in ridership, UTA will survey the entire system to produce route ridership profiles with recommended schedules.

To date, the emphasis at COTA has been on total ridership as opposed to stop-by-stop. In general total ridership decisions require only coarse data, e.g., over 50 - add a bus, below 30 - subtract a bus etc. For example, a consistent observation of fifty standees during a given time period on a route might suggest the addition of a bus for that interval. Conversely, thirty empty seats could justify the removal of a bus. Alternatively, headways may be adjusted over the day to better service the demand. As a result of UTA's analysis of a particular route it was recommended that the number of buses on that route be reduced from 7 to 6 during the peak hours, resulting in a savings of approximately $64K/year.

UTA presents data to COTA management on a route segment basis (hourly summaries for each run). UTA maintains that data on a stop-by-stop basis is overwhelming to the typical user. Data at the bus stop level is retained but is only reported on an exception basis.

The next phase at COTA will be to examine route segments as a function of time, as schedule adherence and assignment of run times is considered an important use of the APCS data. For example, analyzing data for a given run for more than the customary 3 - 5 days, which is easily done with an APCS due to the abundance of data, allows a scheduler to fine tune the schedule. Experience gained at COTA indicates that an important element in this overall process is having good time/position data during free running intervals of the route where tolerances are most easily adjusted. This infers installing sign posts at or near those critical locations.

A problem which becomes apparent when the number of APCS systems is limited (such as it is at COTA where there are only 6 systems), is that of getting an APCS-equipped bus assigned to a specific route. Some 15 - 25% of the time it has not been possible to assign an instrumented bus to a desired route.

The front and rear door counts are recorded separately making individual sensor malfunctions easy to detect. No serious problems have been found with the infra red sensor. The microprocessor, location receiver and counting sensors are checked every 7 - 10 days when the cassettes are changed and the system is reinitialized.

Los Angeles - Southern California Regional Transit District (SCRTD)

Ken Bray, an on site representative for TSC at SCRTD, highlighted the experience at Los Angeles.

SCRTD has 200 Dynamic Control treadle mat systems in use in conjunction with an AVM system. The experience there has been clouded by mat reliability problems similar to those experienced by Seattle METRO but on a larger scale. The SCRTD installation differs from that in Seattle. Seattle has mats on the first and second steps resulting in better accuracy. SCRTD has a mat on the second step and the platform. Originally the mats now on the platforms were on the first steps, but they were being damaged when the driver pulled into curbs. The cost of replacement and the rate of damage prompted a decision to move the mats to the platform. SCRTD is also looking into the possibility of replacing the current mats with a less expensive, more durable design.

In the SCRTD AVM system the vehicle is polled on a time basis. There are instances when the bus is being polled during a transaction after having missed one or more pollings. This produces uncertainty as to the location of the counts. In this instance, software is used to distribute the on/off counts among the 2 or more bus stops in question. The present operation precludes obtaining data which can be easily and reliably correlated on a stop by stop basis.

Toronto - Toronto Transit Commission (TTC)

The TTC was not a participant in the accuracy assessments, but did attend the working group meeting. Milan Pristupa was invited to comment on the TTC system. The TTC has an AVM-type system with approximately 100 buses currently instrumented with infra-red sensors. The goal is to equip the entire fleet of

1800 buses with APCSs. Accuracy is an issue with TTC since they plan to use the on-board count to make short-turn decisions with their AVM systems in real-time. There is a further requirement to achieve better accuracy for transactions involving 5 - 10 passengers boarding/alighting, since the extensive transit system in Toronto has numerous transfer points where boardings/alightings in the 5 - 10 range are frequent.

General Comments

General views which were expressed during the discussion on experience and data utilization are summarized below:

o Drivers should not be disciplined as a direct result of information derived from APCS data - doing so produces resentment of the APCS leading to poor driver cooperation. Rather, supervisors should be alerted to problems and independently substantiate them, especially if discipline is contemplated. On the other hand, when the APC data indicates extra driver effort, they should be commended.

o Drivers perform differently when contract renewals are being negotiated or when ride check personnel are on board. Therefore, APCS's are a distinctly more reliable source of unbiased data than manual methods of data collections.

o The potential of an APCS for improving effectiveness and efficiency of transit operations has barely been tapped.

o The chief institutional barrier to exploiting APCS is the reluctance of scheduling staffs. It is useful to analyze data in new ways and perhaps apply non traditional methodologies to take full advantage of all the information which is available through the use of an APCS.

o To ease the transition for schedulers, effort should be directed at producing graphic or tabular results which can be easily related to a traditional perspective.

o Good location/distance data is essential to the full automation of APCS data processing; odometers and schedules or route templates alone do not appear to be adequate for computer-based location resolution on systems with close bus stops and potential schedule deviations due to detours and/or adverse traffic conditions.

o Accuracy requirements should be based on the types of decisions which a transit property plans to make using the data.

o Regional workshops should be scheduled on a regular basis for sharing ideas, information and perhaps resources.

o UMTA should act as catalyst for technology sharing, information dissemination and concept development. Production of standard systems or "packages" probably cannot satisfy all situations due to the myriad of conditions peculiar to individual agencies.

TRANSPORTATION SYSTEMS CENTER (TSC) STUDY OF APCS ACCURACY

In order to develop a perspective on the issue of passenger counting accuracy, TSC contracted with several APCS-equipped transit agencies to conduct a limited comparative field assessment of the relative accuracies of the present practices in ridership data collection, both manual and automatic (See Appendix A for statement of work).

For this assessment, the typical on-board ride-checker data and the APCS data were to be compared to a "true" value determined by an independent "team" of counters stationed one per door. To assure the integrity of the test, it was specified that there should be no collaboration among the "team" members to reconcile data, nor should there be any communication regarding count data between the "truth" team and the on-board ride-checker. (A single on-board ride-checker normally monitors all doors - all transactions).

Ride checks to measure accuracy were conducted at the following transit agencies having APCSs: Minneapolis/St. Paul (MTC); Columbus, (COTA); Seattle, (METRO); and Kalamazoo, (METRO TRANSIT). These agencies employed APC systems with treadle-mats or dual beam infra-red sensors. Sacramento, one of the agencies selected by CALTRANS to demonstrate a "multiple" beam system was invited to participate but was unable to complete arrangements in the desired time frame. Los Angeles (SCRTD) was also invited to report on data acquired with the APCS portion of their AVM systems, although no formal contractual arrangements were made. Ken Bray, the TSC representative at SCRTD presented some accuracy results which were discussed at the meeting. However, ambiguity in the correlation of counts to stops introduced by the AVM polling algorithms limited the sample size and precluded including the results in the tables which follow.

Since the field assessments were designed to compare the relative accuracies of manual and automatic methods of ridership data collection, and specifically not to attempt to compare the accuracy of one APC system with another, the results will be reported here in composite form. Discussion will be on a "case" basis.

Although each transit property was operating from the same statement of work, significant variation occurred in the manner in which the assessment was conducted. These variations are substantial enough to preclude any meaningful comparison of one APC system with another. In addition, it was apparent from the presentations of individual results from each transit property that the outcome was somewhat influenced by the circumstances of the experiment. Composite data are presented in Tables 2 - 4.

Case 1 was conducted over a period of 4 days; consisted of almost 2,700 boardings/alighting events and generated a total on/off passenger count in excess of 6,400. Several groups of ride checkers were contracted from a local survey company who had previous experience in passenger counting, and received an additional 2 hours of training concerning the specifics of this test. Three buses were used to collect the data. In this case, the APCS out-performed the ride-checker for boardings; the ride-checker performed better for alightings.

Case 2 was conducted for 8 days during a 14-day period; consisted of approximately 2,200 boarding/alighting events; and generated a total on/off passenger count of almost 6,000. The ride checkers were experienced checkers who are employed by the transit property in this capacity. Most of the data was collected using one bus and the same group of ride checkers. In this case, the ride checkers out-performed the APCS for both boardings and alightings. The ride-checker results were significantly higher in this case than in any other.

Case 3 was conducted over a 4-day period; used 3 groups of ride checkers; consisted of approximately 2900 boarding/alighting events; and generated a total on/off passenger count in excess of 10,000. The ride checkers were contracted on the basis of having had prior experience performing ride checks. A total of 5 buses were used to collect data over the duration of the task. In this case the ride checker clearly out-performed the APC for boardings but was just slightly better for alightings.

Case 4 was conducted over a 3-day period; used 2 groups of ride checkers; consisted of approximately 1,950 boarding/alighting events; and generated a total on/off passenger count of almost 5,000. The ride checkers had no prior experience. They were trained for one day which included an on board trial run. Two buses were used to collect the data.

The case 4 transit property experienced difficulties in the data reduction process and inconsistancies in the data which suggested problems in the data collection effort. Feeling, therefore, that their stop-by-stop analysis was an unreliable indicator, they performed an analysis based on total counts which is presented in Table 1. Although these abridged results cannot be used to interpret accuracy on the basis of various numbers of boardings and alightings, they do show that, at least in this case, the "truth" reference was not sufficiently dependable. Case 4 data is not included in the composite results of Tables 2 - 4 which were derived from stop-by-stop data.

In reviewing Tables 2 - 4 the following factors should be kept in mind:

- Although, for the purposes of comparison, "truth" was defined to be the observations of a special team of ride-checkers, each dedicated to recording transactions at a single door, it was obvious from the raw data in several cases that the "truth" was in error (i.e., "truth" recorded no counts on or off when both the APCS and the manual ride checker recorded activity). For the sake of consistency, these "errors" were counted against the APCS and/or ride-checker. It can be assumed from this that the accuracy performance of both the APCS and the ride-checker may be slightly better than the data would indicate.

- Because for these assessment tests, the normal ride-checker was aware that his/her data was being compared to two other sources of data (the truth-team and the APCS), it can be assumed that he/she would be particularly conscientious, thereby biasing the ride-checker performance higher than that which might be obtained in typical data collection efforts.

- o There were no special efforts made to "tune" the performance of the APCSs used in the accuracy assessments; they were used in the "as-is" condition.

The tables will indicate that the ride checkers performed generally better than the APC's. However,an analysis of the individual data sets indicated that the ride-checker accuracy for one of the transit agencies (case 2) was significantly better than that of the other agencies causing the composite ride-checker performance to be skewed somewhat higher than might otherwise be the case.

All of the data supported the premise that ride checkers count boardings more accurately than alightings. Standing loads typically will obstruct the ride checkers view of the rear door where passengers may be alighting. In the case of the dual beam infra-red APC's, the alighting accuracy was less than that for boardings, but just the opposite was true for the treadle mats.
The raw data indicated a wide variation in ride checker accuracy from day to day, and among the individual ride checkers which would give lie to the assumption that manual data collection is intrinsically accurate. In one of the cases, the variation in ride-checker performance was examined. The results suggested that the accuracy of the ride checkers was influenced by a number of factors: e.g., standing loads, volume of activity at a bus stop, concentration as a function of the duration of a shift, distractions from passengers, educational background and motivation. Typically the errors consist of missed counts, transposition/juxtaposition of on/off counts, attribution of counts to the wrong bus stop, etc.

APCSs, on the other hand, do not suffer from these fundamental limitations of human beings. There should be little variation in day to day performance (short of detectable evidence that a malfunction exists), yielding a greater degree of repeatability, and thus a reliable level of accuracy.
In addition to the field assessments of APCS and manual accuracy, an effort was made to evaluate the comparative accuracy of manual data collection performed with and without the aid of a lap-held data entry device. To this end, Queen City Metro in Cincinnati was asked to conduct a field assessment employing E.Z. Data units. Delays in negotiating the contract permitted only a scaled-down effort in order to meet the schedule restriction imposed by the meeting. The resulting limited sample size was not sufficient to produce a conclusive result.

However, ATE Management Services (supplier) discussed and demonstrated the data entry device at the meeting. It is reasonable to conclude that an on-board ride checker using such a device could produce more reliable data than a ride checker using a pen and clip board; the records would be automatically time-stamped (making it difficult to alter data) and input validation steps would minimize the possibility of keying-in wrong data or transposing boarding and alighting information. Even more attractive is the fact that the system, like an APCS, is designed to transmit the data directly to a computer (in this case via telephone link), thereby eliminating time-consuming and error-prone manual data transcription and reduction. But, unlike APCSs, lap-held data entry devices do not eliminate the need for and the cost of having a ride-checker on-board the bus nor the attendant biasing influences that the presence of a ride-checker can have on the performance of the driver.

					"Truth" TEAM			RIDE-CHECKER			APCS		
Day	Coach	Start Load	End Load	Expect Diff. (Off-On)	On	Off	Diff	On	Off	Diff	On	Off	Diff
1	A	20	2	18	380	392	12	419	400	-19	413	414	1
	B	22	1	21	434	445	11	405	358	-47	394	407	13
2	A	32	0	32	378	426	48	411	422	11	377	424	47
	B	17	0	17	423	441	18	418	422	4	374	402	28
3	A	31	3	28	400	426	26	376	379	3	398	437	39
	B	16	0	16	383	492	109	384	496	112	439	458	19
TOTAL	A	83	5	78	1158	1244	86	1206	1201	-5	1188	1275	87
TOTAL	B	55	1	54	1240	1378	138	1207	1276	69	1207	1267	60
TOTAL		138	6	132	2398	2622	224	2413	2477	64	2395	2542	147
% Difference Between On and Off					8.5%			2.6%			5.8%		

TABLE 1

CASE 4 TOTAL PASSENGER COUNTS SUMMARY

		NO COUNT ERRORS (100% ACCURACY)		COUNT ERROR = ±1		COUNT ERROR = ±2		COUNT ERROR = ±3		COUNT WAS 100% ACCURATE OR WITHIN ±1
NUMBER OF PASSENGERS BOARDING/ ALIGHTING	NUMBER OF OBSERVATIONS	% OF TIME	% ACCURACY	% OF TIME	% ACCURACY	% OF TIME	% ACCURACY	% OF TIME	% ACCURACY IS EQUAL TO OR LESS THAN	% OF TIME
1	4108	91.8	100	7.6	0.0	0.4	0.0	.2	0.0	99.4
2	1926	88.3	100	7.6	50.0	3.9	0.0	.1	0.0	95.8
3	977	83.4	100	11.9	66.6	2.4	33.3	2.3	0.0	95.3
4	517	79.9	100	13.7	75.0	3.9	50.0	2.5	25.0	93.6
5	285	75.1	100	15.1	80.0	4.9	60.0	4.9	40.0	90.2
6	208	82.2	100	13.9	83.3	3.8	66.6	.1	50.0	96.1
7	143	70.6	100	18.9	85.7	2.1	71.4	8.4	57.0	89.5
8	122	68.0	100	22.1	87.5	5.7	75.0	4.2	62.5	90.1
9	84	66.7	100	22.6	88.8	6.0	77.7	4.7	66.6	89.3
10	71	57.7	100	21.1	90.0	12.7	80.0	8.5	70.0	78.8
11	49	73.5	100	16.3	90.9	4.1	81.8	6.1	72.7	89.8
12	32	65.6	100	12.5	91.6	9.4	83.3	12.5	75.0	78.1

TABLE 2

COMPOSITE RIDE CHECKER RESULTS

		NO COUNT ERRORS (100% ACCURACY)		COUNT ERROR = ±1		COUNT ERROR = ±2		COUNT ERROR = ±3 OR MORE		COUNT WAS 100% ACCURATE OR WITHIN ±1
NUMBER OF PASSENGERS BOARDING/ ALIGHTING	NUMBER OF OBSERVATIONS	% OF TIME	% ACCURACY	% OF TIME	% ACCURACY	% OF TIME	% ACCURACY	% OF TIME	% ACCURACY IS EQUAL TO OR LESS THAN	% OF TIME
1	4101	87.4	100	12.0	0.0	0.5	0.0	0.1	0.0	99.4
2	1913	80.8	100	16.2	50.0	2.9	0.0	0.1	0.0	97.0
3	970	73.8	100	21.1	66.6	3.4	33.3	1.7	0.0	94.9
4	518	62.7	100	26.8	75.0	6.2	50.0	4.3	25.0	89.5
5	285	61.4	100	26.3	80.0	7.4	60.0	4.9	40.0	87.7
6	208	60.6	100	26.9	83.3	7.2	66.6	5.3	50.0	87.5
7	142	48.6	100	31.7	85.7	9.8	71.4	9.9	57.0	80.3
8	119	41.2	100	34.4	87.5	13.4	75.0	11.0	62.5	75.6
9	82	42.7	100	32.9	88.8	14.6	77.7	9.8	66.6	75.6
10	70	45.7	100	27.1	90.0	12.8	80.0	14.4	70.0	72.8
11	47	53.2	100	25.5	90.9	17.0	81.8	14.3	72.7	78.7
12	32	53.1	100	31.2	91.6	12.5	83.3	13.2	75.0	84.3

TABLE 3

COMPOSITE APCS RESULTS

NUMBER OF PASSENGERS BOARDING/ ALIGHTING	Number Of Observations	% of Time No count Errors		% of Time Count was Within ±1		% of time Count was Within ±2		% of time Count Error was Equal to or Greater than 3	
		APCS	R/C	APCS	R/C	APCS	R/C	APCS	R/C
1	4100	87.4	91.8	99.4	99.4	99.9	99.8	0.1	0.2
2	1900	80.8	88.3	97.0	95.8	99.9	99.7	0.1	0.3
3	970	73.8	83.4	94.9	95.3	98.3	97.7	1.7	2.3
4	515	62.7	79.9	89.5	93.6	95.7	97.5	4.3	2.5
5	285	61.4	75.1	87.7	90.2	95.1	95.1	4.9	4.7
6	208	60.6	82.2	87.5	96.1	94.7	99.9	5.3	0.1
7	140	48.6	70.6	80.3	89.5	90.1	91.6	9.9	8.4
8	120	41.2	68.0	75.6	90.1	89.0	95.8	11.0	4.2
9	80	42.7	66.7	75.6	89.3	90.2	95.3	9.8	4.7
10	70	45.7	57.7	72.8	78.8	85.6	91.5	14.4	8.5
11	45	53.2	73.5	78.7	89.8	95.7	93.9	14.3	6.1
12	32	53.1	65.6	84.3	78.1	96.8	87.5	13.2	12.5

*Note that ride checker performance is probably biased high, since the ride checkers were aware that their results were being compared to two other count sources.

TABLE 4

COMPARISON OF
APCS AND RIDE-CHECKER*
ACCURACY
(Composite Data)

WORKING GROUP DISCUSSIONS:

Specification of Accuracy for an APCS

Due to the importance of mutually understanding what we mean by "accuracy" when communicating with one another and with the manufacturers, a first attempt was made to reach a consensus in defining a format for specifying accuracy. The preliminary format is presented in Table 5. If agreement could be reached as to the value of the various accuracy parameters it would have significant benefit not only to the manufacturers but to the users as well.

In the interim, when specifying values for the accuracy parameters, it was agreed that it would be wise to give consideration to what is attainable using existing technology, and the specific requirements for accuracy dictated by the planned use of the data. Specifying more accuracy than is reasonably needed, if it exceeds what is presently available "off-the-shelf", will result in R&D costs and possibly a limited interest on the part of the established supplier industry.

The feasibility and/or cost of acceptance testing against accuracy requirements is significantly affected by the sample size that is specified. Specifying high confidence levels (large sample size) will result in large costs to conduct acceptance tests, and/or the supplier may be forced to inflate quotes to insure that most contingencies can be covered. Due to what the suppliers perceive as an uncertain market, they may be reluctant to expose themselves to the risks associated with new development, or to incur the cost of preparing a competitive proposal that includes budgetary estimates covering acceptance testing contingencies.

It is important to consider what will be used as a reference against which the accuracy of the APCS will be evaluated during acceptance testing. The supplier will have a vested interest in the "accuracy" or dependability of that reference; i.e., if ride checkers are to be used to establish the "truth", the experience and capability of the ride checkers will affect the accuracy of the "truth".

It was agreed that it is worthwhile to continue pursuing a uniform guideline on how accuracy should be specified and evaluated; and that a proper forum to do so would be via an APTA subcommittee.

Uniform Modular Functional Requirements

In considering the use of APCSs, transit agencies are concerned about the availability and stability of suppliers in order to ensure long-term product support. Suppliers, on the other hand, are concerned with the existence of a market and the ability to develop a reasonably standard product line in order to make a sufficient profit to remain in business.

I. Total On/Off Count $\pm a\%$ Based on a total passenger boarding count >2500 but not to exceed 5000

II. Stop-by-Stop:

When the Number of Passengers Boarding is	The Specified Minimum Sample Size b_i is:	The Minimum Value of C_i* is	The Minimum Value of $\frac{C_i + d_i}{b_i}$ is:	The Minimum Value of $\frac{C_i + d_i + f_c}{b_i}$ is:
1	b_1	c_1	e_1	g_1
2	b_2	c_2	e_2	g_2
3	b_3	c_3	e_3	g_3
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
n	b_n	c_n	e_n	g_n

* c_i = the number of observations where the APCS agrees with the reference

d_i = the number of observations where the APCS differs with the reference by ± 1

f_1 = the number of observations where the APCS differs with the reference by ± 2

Table 5

STRAWMAN FORMAT FOR SPECIFYING APCS ACCURACY REQUIREMENTS

(continued)

III.	On Board Count $\pm h\%$	Based on a pseudo-random selection and average of j samples; at least 1/3 of the samples shall be for on board counts as observed by the reference, of ≤ 10 and at least 1/3 for counts ≥ 10 but ≤ 25.
		or
	For an Actual on Board Count of	The maximum allowable variation in count as derived by the APCS based on r** pseudo randomly selected observations
	5-10	k
	11-20	l
	21-30	m
	31-40	p
	41-50	q

** the r observations shall be selected prior to the cumulative on/off counts for a given APCS having exceeded x

Table 5 (continued)

STRAWMAN FORMAT FOR SPECIFYING APCS ACCURACY REQUIREMENTS

Until recently, the market for APCSs in the transit industry has been very limited, consisting primarily of large and/or particularly innovative transit agencies. Additionally, since individual transit agencies have, of necessity, pursued the use of APCS essentially in the R&D mode, specifications have been set-forth in such a manner as to make each transit property's system unique in some way; thereby precluding the suppliers from establishing a standard product. Consequently, suppliers have come and gone creating an unstable environment for the nurturing of an APCS market.

The recent growth of interest in the application of APCSs to improve transit system efficiency and effectiveness, spurred on by a tight economy and reduced operating subsidies, has provided the stimulus to find a way out of this support vs market dilemma. This issue was taken-up at the working group meeting.

It was generally agreed that uniformity in APCS requirements specification on the part of the transit industry would go a long way towards fostering a stable supply industry and encouraging a more widespread use of APCSs as a management tool. It was further agreed that functional requirements and APCS systems could probably be organized into modular levels of capability. This would permit a transit property to select a level of capability (and cost) most suitable to its needs, while also allowing suppliers to develop a fairly standard product line with a reasonable number of configuration options. It was also pointed-out that it is a costly process to both supplier and buyer to provide individual variations on the output of an APCS microprocessor control unit either in format, sequence, or types of records produced, when transit agencies need, and are asking for, essentially the same information. A standard set of data records could probably be identified in a standard format for each modular level of capability. A transit property could avail itself of a subset of the data records provided at the particular modular level it selects, if it does not choose to process all of the information available. Format incompatibilities with any pre-existing data processing facilities could be easily handled through software pre-processing of the records in question; as would be the case with any other kind of off-the-shelf data acquisition equipment, rather than having each customer requiring costly engineering development changes to existing APCS microprocessor firmware. Software developed especially for processing the APCS data would, of course, be designed to handle the standard formats. An added advantage might be that applications software developed for use with a particular suppliers standard APCS product could conceivably be useful and transferrable to more than one transit property, thus reducing individual software development costs. It was concluded that enough APCS experience now exists in the transit industry to effectively address this matter. The essence of what is required to standardize control unit functions is a consensus on the format, sequence, and content of data records, and the conditions which must be satisfied for the system to generate distance and "idle" records. A preliminary effort was made to define a strawman for such a standard set of records (Table 6).

Other areas in need of attention in terms of settling on a reasonable set of options are the methods and procedures for initialization of the on-board units, and for data storage and retrieval. These too can affect the design of the microprocessor control unit.

The working group felt that a continued effort should be made to address these issues, perhaps through an APTA committee composed of APCS users, potential users, and suppliers.

Data	Record Types
	Header
	Idle
	Event
	Distance

DATA ITEM	RECORD PARAMETERS	STORAGE REQUIREMENTS
1	Type	N
2	PCU ID	NNNN
3	date	MM DD YY
4	Front on counter	NN
5	Front off counter	NN
6	Front door dwell time (in seconds)	SSS
7	rear on counter	NN
8	rear off counter	NN
9	rear door dwell time (in seconds)	SSS
10	distance	MMM.MM
11	sign post location	LLLL
12	time of day	HH MM SS

Data record content:

Record Type	Data Items
Header:	1, 2, 3, 10, 11, 12
Idle:	1, 10, 12
Event:	1, 4, 5, 6, 7, 8, 9, 10, 11, 12
Distance:	1, 10, 11, 12

Required storage (in hex characters): 64K

TABLE 6

STRAWMAN FOR DATA RECORDS STANDARDS

SUMMARY OF WORKING GROUP RESULTS/CONCLUSIONS

Data Utilization

- The full potential of APCS data for transit management has barely been tapped. APCSs can provide much more data than that which is traditionally gathered by manual methods. Innovative uses of this increased information-base will evolve as experience is gained. Creative use of the abundant APCS data is the current challenge.

- Accurate location information is essential if fully automated screening and processing of APCS data is desired.

- Software development costs are generally the predominant cost of implementing an APC system. Front-end planning should carefully consider to what uses the data will be put; i.e., what type of decisions will be made and what kinds of information reports will be necessary to support those decisions, so that software requirements can be clearly defined.

- APCS suppliers do not generally supply data processing software. If in-house capabilities do not exist, the transit property should give as much attention to the selection of software services as they do to hardware.

- Scheduling staffs are sometimes reluctant to accept APCS data due to a perceived threat of change to their traditional thinking, and/or misconceptions about the relative accuracy of manual versus automatic passenger counts. Sensitivity to these issues can forestall implementation difficulties. Reluctance may be mitigated by demonstrating how APCS information can be used by a scheduler to enhance his/her effectiveness.

Accuracy

- No counting method, either automatic or manual, is likely to provide 100% accuracy under all possible field conditions.

- APCS accuracy is reasonable and generally acceptable to the using transit agencies. The exceptions appear to be AVM-equipped systems having a high incidence of transfer points (multiple boarding or alightings in the five, ten or greater range) desiring to make real-time decisions based on the instantaneous on-board passenger count (e.g., short-turning a bus). Since count errors (of one or two) are more frequently encountered under high transaction conditions, it was suggested that the on-board count is not sufficiently reliable to confidently make such unconfirmed decisions in real-time. However, acceptable accuracy (other than 100%) for this situation was not defined. If the existing technology truly fails to meet the specification, a property faced with this requirement will have to weigh the costs of developing equipment to achieve the defined accuracy against the costs of using other system facilities (e.g., radio, or special software reasonableness tests) to validate on-board counts when a decision is contemplated.

- APCS accuracy is comparable to the accuracy obtained through on-board ride-checkers.

- APCS accuracy is sensitive to the location, mounting and maintenance of the sensors.

- APCS accuracy is a function of the sophistication of the counting algorithms and the number of discrete sensors employed.

- When automatically processing APCS data, software filters and reasonableness checks tailored to the specific operational environment should be employed to screen-out obvious inconsistencies, thereby optimizing the accuracy and utility of the data.

- When specifying accuracy requirements for an APCS, the transit property should consider the cost, feasibility, and the method of acceptance testing against the requirement.

- Specification of accuracy beyond that available with existing systems implies an R&D effort.

Feasibility of Uniform Modular Requirements

- Uniform modular requirements, at some level, are necessary to encourage a stable supply industry - to assure the future of APCSs as a commercially available product with all the necessary support (parts, repairs, replacements, etc.)

- Sufficient experience now exists in the transit industry to address the establishment of uniform functional requirements and a modular approach to APCS design.

- Transit agencies should avoid specifying "unique" system features, formats, or requirements if possible, since they are likely to incur additional costs, could possibly result in an R&D effort with its attendant risks, and might limit the response from the established supplier industry.

Aspects of System Design/Engineering

- Ideally, the APCS system should not require driver involvement.

- There is a need to improve mat reliability and/or reduce costs.

- Development of less expensive signposts is desirable.

- Development of a fully automated technique for transferring the data from the APCS to the computer is a vital link in facilitating use of APCS data. Manual data/retrieval is inconvenient especially if there is more than one bus garage and/or if there isn't a scheduled time each day when the buses would be available for this purpose.

General

- Interest in the implementation of APCSs to improve transit system productivity and service is growing.

- The following options have been exercised by transit agencies for automating data collection and analysis:

  - Bought automated aids for manual ride checks, e.g., lap-held data entry devices

  - Bought APCS service, e.g., lease of APCS equipment and data processing/data analysis services

  - Bought available APCS equipment and separate computer hardware/software development services

  - Bought available APCS equipment and developed software in-house

  - Developed custom APCS equipment and software in-house, supplemented via directed contract

- While APCSs can be implemented in conjunction with an AVM system (real-time automatic vehicle monitoring and control), they are not limited to an AVM-like environment, and should therefore, be distinguished from AVM for purposes of discussion to avoid misunderstanding.

- Procedures for quantifying costs and benefits of using APCS versus manual methods of data collection need to be developed and disseminated.

- Guidelines are needed on development of sampling plans and determination of the number of APCS units to satisfy the data needs of individual agencies.

- Positive APCS experience should be demonstrated and publicized.

- UMTA should continue to foster and support use of APC systems.

APPENDIX

STATEMENT OF WORK
(FOR ACCURACY STUDY DATA COLLECTION)

1.0 Objective

The objective of performing this passenger counting task is to establish the relative accuracies of all the present practices. It is therefore essential that no attempt be made by the people involved in the counting process to correlate data with one another, the automatic passenger counter, or if applicable, the lap held entry device. For the purpose of providing a reference for this comparison and in the absence of absolute data, a passenger counting team will be used as the standard to which the other practices are to be compared.

2.0 Collect passenger data per the following:

2.1 Route Selection - The ridership profile of the route to be selected for the ride check shall conform, to the maximum extent practicable, to these basic characteristics:

2.1.1 There shall be a range of 50-75 percent of the total number of stops at which boardings occur where the typical number of passengers boarding ranges from 1-3.

2.1.2 There shall be a range of 10-25 percent of the total number of stops at which boardings occur where the typical number of passengers boarding ranges from 4-6.

2.1.3 There shall be a range of 5-25 percent of the total number of stops at which boardings occur where the typical number of passengers boarding exceeds 6.

2.1.4 There shall be a comparable number of transactions (±25%) where the values specified for 2.1.1, 2.1.2, & 2.1.3 are applicable to alightings.

2.1.5 The daily average passenger boarding count during the morning and afternoon peak ridership periods shall be at least 500.

2.2 Approach - The approach is to use two buses each with an on-board crew of 3 or 4, and one enroute spot checker per both buses. The passenger count shall be performed during the peak ridership periods along a route as suggested by the above criteria. The number of days required to complete the ride check will be determined by the daily average and the objective of attaining a total of 2500 passenger boardings total. (If possible, the same two buses shall be used for the duration of the task.)

2.2.1 Crew - To the maximum extent practicable, changes in the crew or assignments within the crew shall be avoided for the duration of the task.

2.2.1.1 Two members in each of the on-board crews shall function as a team; one shall monitor and record the boardings/alightings at the front door, and the other shall perform this task for the rear door. Each will be responsible for recording his/her own comments and pertinent observations. Both members of the team will be responsible for recording the time, for verifying/recording the bus stop designation and noting any unscheduled transaction.

2.2.1.2 The third/fourth members (in the absence of an APCS, a fourth crew member is assigned to operate a lap held entry device) of each of the on-board crew, functioning independent of the team and not conversing with either the team, or the bus driver, or each other concerning the data, shall be responsible for monitoring and recording data for both front and rear doors, the time, verifying the bus stop designation, recording comments or any pertinent observation such as an unscheduled transaction, and any other tasks a 'ride checker' is normally required to do that relates to data which can be derived from APCS data.

2.2.1.3 The remaining crew member shall be assigned as the enroute "spot checker" and shall be stationed at 10 predetermined bus stops and be responsible for recording the bus stop designations, the bus number, the time and an estimate of the number of passengers on board when the bus leaves as well as the number of passengers boarding and alighting at that particular stop. This data will be subsequently correlated to data collected on board.

2.2.1.4 If applicable and in the absence of a data recorder for the Automatic Passenger Counting System (APCS) or equivalent capability, the bus driver or an additional crew member, functioning independent of the other crew members and not conversing with the other crew members concerning the data, shall be assigned to record the count as indicated by the APCS.

2.2.2 Data Logging

2.2.2.1 Procedures for recording data - The raw data shall be recorded using indelible ink; all changes in the data shall be commented and initialled by the contract coordinator. All alightings and boardings by crew members or the bus driver shall be recorded in the comments section by the crew member responsible for the door through which they passed.

2.2.2.2 Information Content - The raw data sheets shall provide as a minimum the information contained in the attached sheets. If approved existing sheets may be modified for the purpose of this passenger counting task. Prevailing weather conditions and temperature should be noted.

2.3 Training/Experience/Qualifications

2.3.1 On-board crew members - All on-board crew members shall be experienced counters or receive no less than one day of on-the-job training performing at an acceptable level prior to the actual counting task. It is recommended that the more experienced counters be assigned to the position which monitors and records data for both doors.

2.3.2 Enroute "spot checker" - The "spot checker" shall be someone who has functioned in this capacity for at least 6 months.

3.0 Process the passenger count data per the following:

3.1 Comparison of the APCS or lap held entry device and the team of counters - Using the values obtained by the team of counters as a reference, totalize and tabulate (see Tables I-IV) the number of bus stops for which 1 person boarded, 2, 3, ..., etc.; then for each of the totals, provide the data obtained from the APCS or the lap held entry device for these same bus stops and indicate the number of transactions where the APCS (also the lap held entry device) and the team agreed on the count, differed by +1, -1, +2, -2, +3, -3, ..., etc. Process the alighting data in the same manner.

3.2 Comparison of the independent counter and the team of counters - Process the data obtained by the independent counter in the same manner as that for the APCS or the lap held entry device.

3.3 Comparison of the enroute "spot checker" with the team of counters - Compute the on-board count for the predetermined bus stops based on the initial count and the subsequent on/off transactions, and make a direct comparison on a per bus stop basis with the estimates or observed and recorded by the enroute "spot checker" from a wayside vantage point.

4.0 Test results report - Prepare a test results report which contains as a minimum the ridership profile for the selected route, the raw data, and the data as processed per Paragraph 3.0. Summary results graphs shall be included which collectively depict the relative overall accuracy for each of the methods used. See attached Figures 1-4 for required format.

5.0 Delivery/Schedule - The final test results report shall be delivered to TSC prior to 2/26/82.

FRONT DOOR MONITOR

RAW DATA SHEET

DATE: | RUN #: | BUS #:

BUS DRIVER: | COUNTER: | ROUTE #:

START TIME: | STOP TIME: | INITIAL NUMBER OF PASSENGERS ON BOARD:

BUS STOP DESIGNATION	FRONT ON	FRONT OFF	COMMENTS

REAR DOOR MONITOR

RAW DATA SHEET

DATE: RUN #: BUS #:

BUS DRIVER: COUNTER: ROUTE #:

START TIME: STOP TIME: INITIAL NUMBER OF PASSENGERS ON BOARD

BUS STOP DESIGNATION	REAR ON	REAR OFF	TIME	COMMENTS

FRONT & REAR DOOR MONITOR

RAW DATA SHEET

DATE: RUN #: BUS #:

BUS DRIVER: COUNTER: ROUTE #:

START TIME: STOP TIME: INITIAL NUMBER OF PASSENGERS ON BOARD:

BUS STOP DESIGNATION	FRONT ON	FRONT OFF	REAR ON	REAR OFF	TIME	COMMENTS

APCS

TABLE I

NUMBER OF PEOPLE BOARDING	NUMBER OF OBSERVATIONS	NUMBER OF BUS STOPS FOR WHICH THERE WAS AGREEMENT	DIFFERENCES +1	-1	+2	-2	+3	-3	+4	-4	+5	-5	$>\lvert\pm 5\rvert$ COMMENT
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13-20													
21-30													
31-40													
>40													

APCS

TABLE II

NUMBER OF PEOPLE ALIGHTING	NUMBER OF OBSERVATIONS	NUMBER OF BUS STOPS FOR WHICH THERE WAS AGREEMENT	DIFFERENCES +1	-1	+2	-2	+3	-3	+4	-4	+5	-5	>|±5|	COMMENT
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
11														
12														
13-20														
21-30														
31-40														
>40														

ON BOARD 'RIDE CHECKER'

TABLE III

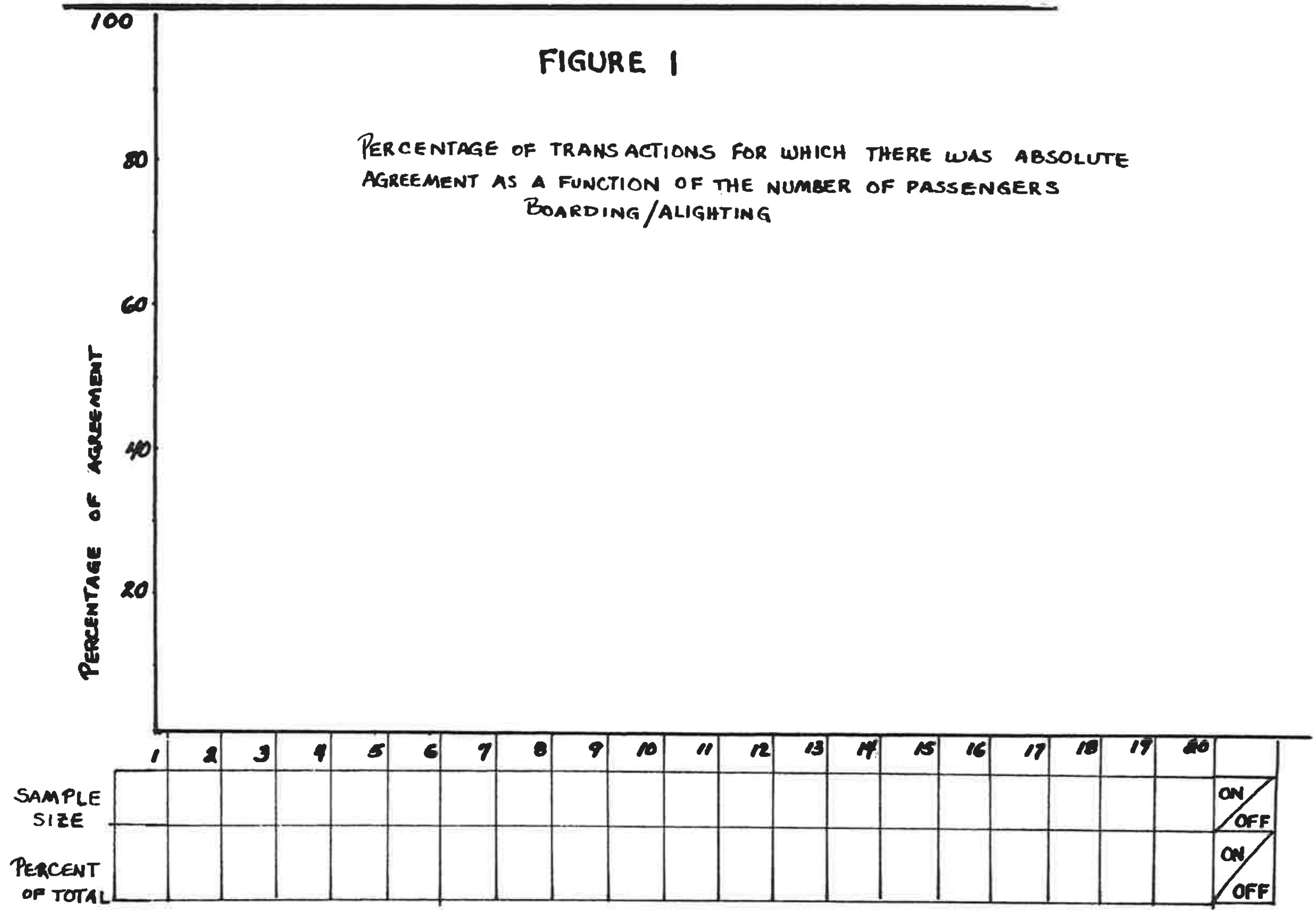
NUMBER OF PEOPLE BOARDING	NUMBER OF OBSERVATIONS	NUMBER OF BUS STOPS FOR WHICH THERE WAS AGREEMENT	DIFFERENCES +1	-1	+2	-2	+3	-3	+4	-4	+5	-5	>|±5| COMMENT
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13-20													
21-30													
31-40													
>40													

ON BOARD 'RIDE CHECKER'
TABLE IV

NUMBER OF PEOPLE ALIGHTING	NUMBER OF OBSERVATIONS	NUMBER OF BUS STOPS FOR WHICH THERE WAS AGREEMENT	DIFFERENCES +1	-1	+2	-2	+3	-3	+4	-4	+5	-5	$>\lvert\pm5\rvert$ COMMENT
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13-20													
21-30													
31-40													
>40													

FIGURE 1

PERCENTAGE OF TRANSACTIONS FOR WHICH THERE WAS ABSOLUTE AGREEMENT AS A FUNCTION OF THE NUMBER OF PASSENGERS BOARDING/ALIGHTING

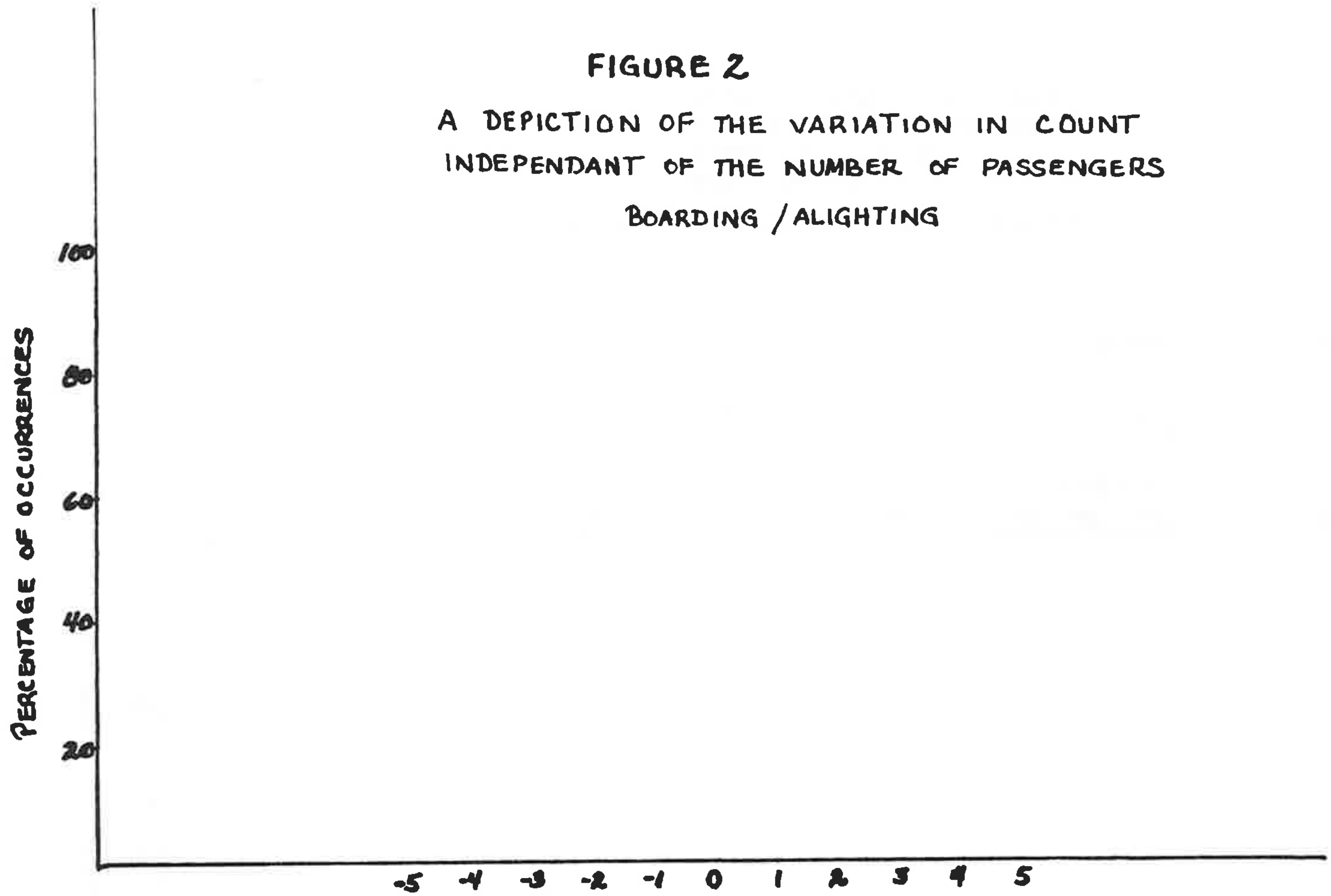


NUMBER OF PEOPLE BOARDING/ALIGHTING

- △ APCS BOARDINGS
- ○ APCS ALIGHTINGS
- × 'RIDE CHECKER' BOARDINGS
- □ 'RIDE CHECKER' ALIGHTINGS

FIGURE 2

A DEPICTION OF THE VARIATION IN COUNT INDEPENDANT OF THE NUMBER OF PASSENGERS BOARDING / ALIGHTING

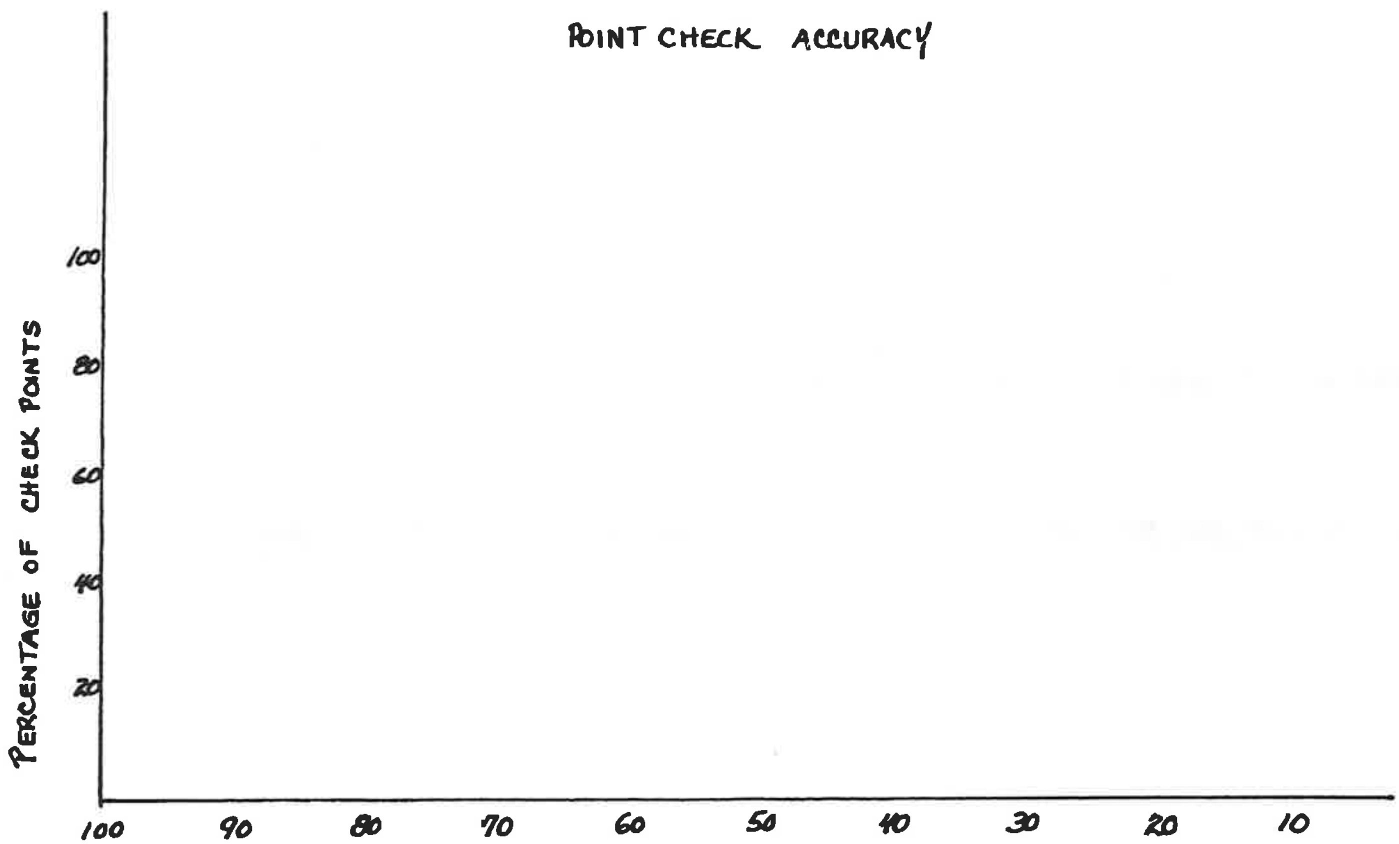


DIFFERENCE IN COUNT AS INDICATED OR OBSERVED BY:

- Δ APCS BOARDINGS
- O APCS ALIGHTINGS
- X 'RIDE CHECKER' BOARDINGS
- □ 'RIDE CHECKER' ALIGHTINGS

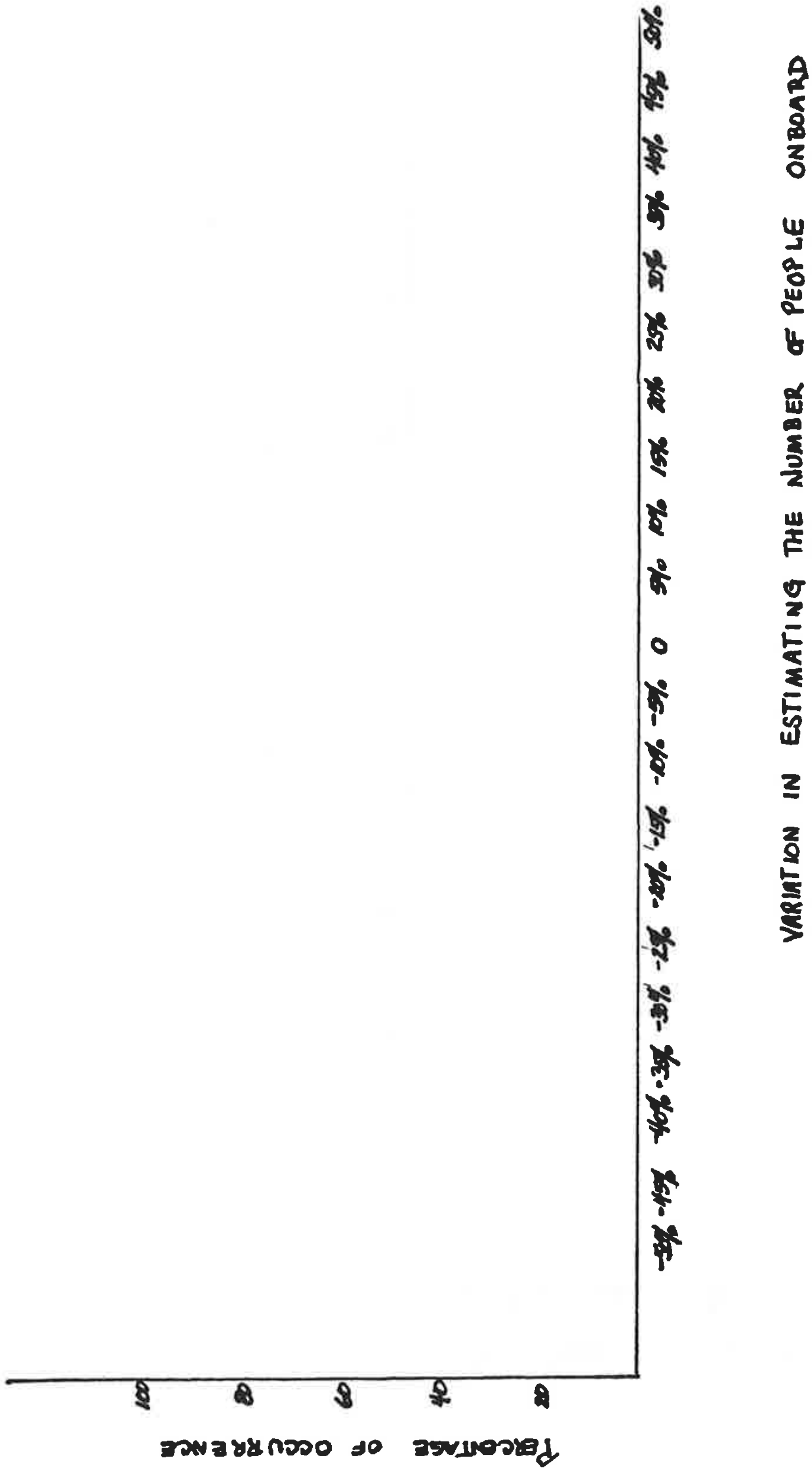
FIGURE 3

POINT CHECK ACCURACY



ACCURACY OF ESTIMATE (%)

FIGURE 4



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