

**RAIL APC VALIDATION AND SAMPLING FOR NTD  
AND INTERNAL REPORTING AT TRIMET**

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**ABSTRACT**

This paper presents findings from an evaluation of the accuracy of automatic passenger counters (APCs) on TriMet's light rail vehicles. APC boarding and alighting counts were compared to manually recorded counts. Overall, the APCs tended to under-count boardings and over-count alighting alightings. Thus, correction factors will be needed in using APC-recovered data for national transit database (NTD) and internal reporting. The paper also describes the sampling procedures employed by TriMet for NTD and internal reporting, in which sampled trips are linked to archived APC data records.

## INTRODUCTION

Automatic passenger counters (APCs) are included among the advanced technologies collectively known as Transit ITS, and are rapidly gaining favor among US transit providers. A Volpe Center (1) national survey of advanced technology deployment found that 60 transit providers had operational APC systems in 2002, with another 124 providers planning acquisition. The number of operational APC systems in 2002 represented a 445% increase over the number reported in a 1995 Volpe Center survey.

With an approximate 25-year history in the transit industry, APC technology has evolved to become more mechanically reliable and accurate. The integration of APC and automatic vehicle location (AVL) technologies has also resulted in a great improvement in the locational referencing of APC data, which had previously been problematic (2). For example, prior to the deployment of AVL technology, TriMet stop-referenced its APC data by first attempting to identify time breaks associated with layovers and then attempting to match APC data records to stops using odometer information. Data for entire trips and sometimes trip-blocks were lost when layovers could not be identified. Coupled with losses related to equipment malfunctions and data screening, losses related to the inability to stop reference the APC data resulted in a final data recovery rate of about 25% (3). Following AVL implementation at TriMet, each APC stop data record is now spatially referenced and the final data recovery rate has improved to about 75% (2).

Passenger data recovery with APCs is very cost-effective compared to traditional manual data collection methods (4). This data supports a variety of service planning and scheduling activities, especially when combined with vehicle running time data from AVL systems (5).

One common activity requiring passenger data is annual National Transit Database (NTD) reporting activity. NTD reporting must adhere to given statistical precision and sampling requirements (6). Strathman and Hopper (3) and Kimpel et al. (7) have developed methods that satisfy these requirements using APC data from TriMet's bus system, substituting for manually collected data.

NTD and internal reporting can also be supported by passenger counts derived from revenue and farebox data, coupled with periodic on-board passenger surveys. However, the increasing variety of fare media and payment options in the transit industry has eroded the reliability of these alternatives, and this may be one reason why APC deployment has grown so rapidly.

TriMet also provides light rail service but, until recently, their rail fleet lacked APC technology. They have thus relied on manually collected data for NTD reporting for that mode. With recent expansion of their light rail system, TriMet has added 18 vehicles to their rail fleet, which now totals 95 vehicles. TriMet plans to specify APC systems in all future rail car acquisitions, and the agency expects to have 28 APC-equipped rail vehicles in service by the end of the 2005 fiscal year.

The purpose of this paper is two-fold. First, we report on an evaluation of the accuracy of passenger activity counts of the new rail APC units. As we reported previously (7), systematic differences between APC and base reference counts can be used to determine correction factors for APC boarding and alighting data. Second, using archived APC passenger activity data, we design a sampling method to satisfy NTD reporting requirements.

The remainder of the paper is organized as follows. In the next section we explain the research design for evaluating APC accuracy, and the associated data collection process. This is followed by an analysis of the differences between APC and manually collected boarding and alighting data. A sampling approach is then presented, with archived APC data used to illustrate the process for determining NTD sample size requirements. The final section of the paper includes discussion and conclusions.

### ASSESSING APC ACCURACY: RESEARCH DESIGN

The APC units in TriMet's rail vehicles use infrared beam technology to count boarding and alighting passengers. The technology consists of Infrared Motion Analyzer (IRMA) 3rd Generation APC units manufactured by iris-GmbH. The IRMA sensors include both a passive and an active infrared component allowing for the registration of the thermal radiation of passengers and the reflection of the emitted infrared radiation from persons. The sensors register the signals of moving persons, and transmit these signals to an onboard computer, which calculates the number of persons entering and leaving per door at each stop. This is the same technology employed in TriMet's bus fleet and is increasingly favored throughout the industry. The rail application differs from bus, however, due to differences in door widths. Bus door widths allow only single file passenger movements, and APC infrared beams project horizontally to record boarding and alighting activity. Rail car door widths are wider, allowing simultaneous boarding and alighting passenger movements. Thus on rail cars, APC beams project vertically and can record passenger boarding and alighting activity in double file form. These differences suggest that the rail environment involves greater complexity with respect to passenger counting, with correspondingly greater potential for recording errors. To date, however, the literature on APCs has not reported accuracy statistics for this type of application.

In the present analysis, accuracy is defined in terms of the systematic difference between passenger boarding and alighting counts recorded by APC units and the corresponding counts recorded manually by a ride checker. Because the APC units and the ride checker are "observing" the same events, their counts can be interpreted as a paired sample in testing for systematic differences (8). Thus, the difference between the APC and ride checker counts can be calculated for each observation, and the standard deviation of this difference can be used to construct a confidence interval and test for systematic differences (i.e., bias). The relevant confidence interval for the difference between APC and manually recorded passenger counts is defined as follows:

$$\Delta = D \pm t_{.5\alpha} [S_D \div \sqrt{n}], \text{ where} \quad (1)$$

$\Delta$  = the difference in the population means;

$D$  = the difference in the sample means,

=  $1 \div (n-1) \sum_n (P_{APC} - P_{RC})$ , where  $n$  is the sample size,  $P_{APC}$  are the APC passenger counts, and  $P_{RC}$  are the ride checker passenger counts;

$t_{.5\alpha}$  = the critical two-sided t distribution value at the  $1 - \alpha$  level of confidence;

$SD$  = the standard deviation of the APC – RC count differences.

The rail vehicles contain three sets of doors on each side. Stations provide passenger access to vehicles from one side only, and thus each stop can generate three boarding and three alighting observations.

In previous work (7), the authors employed on-board cameras to recover the reference passenger counts for comparison with the APC counts. It was believed that this approach would result in less measurement error than would be the case with on-board ride checker crews. Previous research has established that measurement error is associated with ride checker passenger counts (9). Although the light rail vehicles in this study are equipped with cameras, the authors found that their positioning prevented a clear view of passenger movements through the six sets of doors on each vehicle. Recognizing the concerns about measurement error by standard ride checkers, one of the authors took on that task and recorded the reference passenger counts for this study. Whether this person's conscientious effort yielded more accurate manual counts than what would have been produced by team of regular ride checkers is unknown. One would expect that a single observer would provide for more consistent recording of passenger activity, if not more accurate, than the multiple observer alternative.

### **ASSESSING APC ACCURACY: DATA RECOVERY AND ANALYSIS**

The passenger count data were recorded from a random sample of mid-day and evening peak trip segments on trains containing APC units. Trains generally consisted of two vehicles, with the exception being single vehicle trains providing airport service. The ride checker recorded the train number, stop location, and boarding and alighting passengers per door. Events where no passenger activity occurred for a given door were not recorded as observations. Data was recovered Between February 2 and March 11, 2004. Passenger activity was recorded for 722 passenger movement events. An event is defined as passenger movement through a given door. A typical stop can involve three passenger movement events, depending on passenger flows and volumes.

Trip, stop and door identification were also recorded with the manual passenger counts. This enabled a direct matching of manual passenger count events with the APC counts of those same events drawn from TriMet's data archive. In other words, there was a manually-recorded and an APC-recorded observation of boardings and alightings for each passenger movement event in the sample.

Relevant statistics comparing APC and manually recorded passenger counts are presented in Table 1. The first pair of columns compares mean boardings per door as recorded by APCs and the ride checker, respectively. Overall, the mean APC boarding count is slightly lower than the corresponding ride checker count. Mean boardings per door are also somewhat greater when the sampled vehicle is the rear car of a train compared to the front car location. Boardings are also somewhat lower through the middle door of the vehicle compared to the outside doors. Comparisons are also reported for high passenger volume observations, where the sum of boardings and alightings is greater than or equal to five, versus low passenger volume events. This delineation was based on the objective of including a sufficient number of observations (144, or about 20% of the sample) for statistical testing, although a limited number of peak period events can involve substantially greater passenger volumes. The breakdowns for door position and passenger volume are included for subsequent accuracy tests.

(Table 1 about here)

The middle pair of columns in Table 1 report mean alightings recorded by APCs and the ride checker. In contrast with boardings, APCs generally tend to over-count

alightings compared to the ride checker's recording. Also, alightings tend to be greater for inside doors than outside doors.

The final pair of columns in the table report the differences in mean boardings and alightings. Asterisks denote instances where the differences in means were found to be statistically significant at the 95% confidence level. Overall, APCs were found to significantly undercount boardings (-5.4%) and significantly over-count alightings (6.9%). Since boarding and alighting data are used to calculate passenger loads and passenger miles, this result indicates that APC-generated data would tend to systematically understate those respective values by about 12%. Thus, correction factors will be needed to adjust for systematic errors in the APC boarding and alighting counts. The relative magnitude of the system-level rail APC correction factors would be substantially greater than those previously developed by the authors for bus APC applications (7). The absolute values of the system level correction factors reported above are nearly four times greater than the counterpart bus APC correction factors in the case of boardings and nearly seven times greater in the case of alightings.

The bottom row of the table contains results for the airport light rail line. This line was singled out to assess whether systematic counting biases existed in circumstances where passengers with baggage were boarding and alighting. The systematic differences between APC and manual counts of boardings and alightings on the airport line did not differ significantly from the other lines in the system. However, it should be noted that airport line observations did not include the airport terminal stop, where anecdotal reports indicate potential boarding and alighting activity related to security screening activity. In this case, the issue is not whether the APC counts are accurate, but the extent to which the recorded activity represents the actual movement of passengers. Additional work will be needed to determine if a correction factor for this particular stop is needed.

As the table shows, the presence and magnitude of systematic error tends to vary with respect to door location and passenger volume. Inside doors are not found to be subject to bias, while the systematic APC boarding under-counts (-7.0%) and alighting over-counts (11.0%) for outside doors are fairly substantial. The design layout of the outside doors required a different installation of the APC units, and this may have contributed to the biased counts for these doors versus the inside doors. Count bias associated with passenger volume is somewhat mixed, with more substantial under-counting of boardings (-8.7%) occurring with heavy volumes and more substantial over-counting of alightings (7.7%) occurring with light volumes.

Application of correction factors for boardings and alightings eliminates systematic counting errors, which ensures that corrected APC passenger counts are accurate. Following correction, only random error remains, which reflects the precision of the APC counts. For a given level of statistical confidence, precision can be determined from the standard deviations of the differences between the APC and manual counts. A breakdown of the systematic and random error components for vehicle boardings and alightings is presented in Table 2. In this case, random error was determined at the 95% level of confidence and standard deviation values (from the sample) of .70 and .60 for boardings and alightings, respectively. As the table shows, systematic error is larger than random error for both boardings and alightings. Thus, elimination of systematic error through correction will yield a substantial improvement.

(Table 2 about here)

### **NTD SAMPLING CONSIDERATIONS**

Sampling requirements for Federal Transit Administration (FTA) annual reporting are described in UMTA Circular 2710.1A (6). The guidelines presented in the Circular are based on sample estimates achieving a precision of  $\pm 10\%$  at the 95% level of confidence. The procedure recommended in the Circular is based on a simple random sample of trips over the year, with allowance for selection of a given number of trips per day.

As Furth et al. (10) have noted, there are logistical inconveniences associated with data collection in trip-based sampling schemes. For example, deployment of ride checkers would be facilitated if round trips or blocks of trips could be used as the sampling unit. Thus, Furth et al. (10) designed a cluster sampling approach to recover passenger data from blocks of trips. Their approach accounts for the fact that trips within blocks are correlated (i.e., not independent), resulting in the need to sample a larger number of trips to achieve a given level of statistical precision. They contend that the costs of sampling more trips are more than offset by the savings in data collection costs from assigning rider checkers to blocks of trips.

By design, passenger data collection with APCs occurs in clusters of trips in conjunction with a subject vehicle's service assignment. These trips can be thought of as super-clusters, and sampling depends on the extent of APC deployment in the bus fleet and vehicle assignments. Most transit agencies with APC technology have limited deployment to 10-20% of the vehicles in their fleets, although with declining unit costs over time, the level of deployment has been expanding (1).

With limited APC deployment, implementation of a sampling plan for recovering passenger data depends on an agency's ability to coordinate assignment of APC-equipped buses to randomly sampled trip blocks. Strathman and Hopper (3) designed a cluster sampling plan for recovery of Section 15 (now NTD) passenger data for TriMet. At that time, APCs were installed on about 9% of TriMet's bus fleet. Implementation of their sampling plan depended on the ability of fleet managers at the agency's three garages to schedule APC-equipped vehicles to trip blocks randomly selected by the analyst responsible for Section 15 reporting. Section 15-related vehicle assignment requests often competed with service planning-related requests and other logistical considerations. After several frustrating years of sporadic vehicle assignments, TriMet reverted back to manual data collection for NTD reporting.

With the declining cost of APC technology, TriMet decided in the mid 1990s to specify APCs in all new bus acquisitions. APC deployment has subsequently expanded and now covers about 70% of their bus fleet. The vehicle assignment problems that plagued their earlier efforts to implement an APC-based sampling plan for Section 15 reporting were no longer pertinent with such extensive deployment. A new sampling plan drawing on archived trip level passenger data was developed to take advantage of extensive APC deployment (7). Beginning in 2003, TriMet has used APC data to meet its reporting requirements.

## NTD SAMPLING FOR RAIL REPORTING

The sampling approach developed by Kimpel et al. (7) for NTD reporting of TriMet's bus system passenger data provides the base reference for developing a rail sampling plan. The bus system sampling plan employs the following steps: 1) sample size determination; 2) random selection of sample trips; 3) data archive query to match sampled trips to APC data.

Sample size determination is governed by the precision requirements for NTD reporting, namely  $\pm 10\%$  at the 95% level of confidence. Using passenger miles per trip as an example, the annual sample of trips needed to meet the NTD reporting standard is defined as follows:

$$n = [(1.96 * S_{pm}) \div (.1 * X_{pm})]^2, \text{ where} \quad (2)$$

$n$  = the number of trips to be sampled;

1.96 = the critical two-tailed t distribution value associated with the 95% level of confidence;

$S_{pm}$  = the sample standard deviation of passenger miles per trip;

$.1 * X_{pm}$  = one-tenth of the mean passenger miles per trip (i.e., the target precision level).

The values for the sample standard deviation and mean can be drawn from previous years data, and it would be prudent to inflate the standard deviation value somewhat to ensure that the current year's sample achieves the precision target. Also, the sample size should be determined using the passenger variable with the greatest coefficient of variation (i.e., the standard deviation divided by the mean), since the necessary sample size for this variable will then be more than sufficient to meet the precision target for other variables. For TriMet, the variable with the greatest coefficient of variation is passenger miles per trip.

From TriMet's 2003 NTD report the relevant values for the passenger mile standard deviation and mean per trip are 360.47 and 417.13, respectively. Given these values, Equation 2 indicates that an annual sample of 287 trips, or 24 trips per month would be needed to achieve the precision target. Increasing the monthly sample to around 30 trips should provide a sufficient number of trips to meet the precision target.

The next step involves the sample selection of trips. At TriMet, a random selection is drawn from the monthly roster of scheduled trips. The final step involves a query of TriMet's data archive to link sampled trips to valid APC trip records. For bus system reporting, the APC data archive is queried to determine if a given sampled weekday trip corresponds to a valid APC record of that trip for any weekday in the given month. For example, if the randomly selected trip happened to be the 5:07 pm outbound trip on the Route 14 Hawthorne on Wednesday, July 21, the database query would seek an APC record of that trip for any weekday in the month of July. The same approach is used for sampled Saturday and Sunday trips. This approach provides a match for about 95% of sampled trips. Where a direct match cannot be made between the sampled trip and the APC data archive, the query iterates to adjacent trips to find a match. This step is consistent with the procedure recommended in Circular 2710.1A for dealing with missed pull-outs from sampled trips.

Presently, the deployment of APCs is more limited in TriMet's rail fleet than its bus fleet. This will improve with the planned addition of more APC-equipped rail cars, but the question is whether the existing deployment is sufficient to use the same sampling

approach to recover rail passenger data for NTD reporting as is currently used for the bus system.

To assess this question, a series of 200 independent samples of 50 trips each was drawn from the June 2004 light rail system schedule. For each sample, the archived rail APC database was queried to link the sampled trips to valid APC trip records for the month of June. The test was limited to a single month, given that June 2004 was the first full month of data recovery for the new APC-equipped rail vehicles. The sample size of 50 trips is about 40% larger than necessary, compared to the monthly sampling rate used in TriMet's 2003 NTD report.

Over the 200 replications, about 44 of the 50 sampled trips were directly matched to valid APC trip records (see Figure 1). Seventy five percent of the replications yielded direct matches for 43 or more sampled trips. This direct match rate is about 8% lower than what has been achieved for bus trips. However, the month in question also witnessed disproportionate use of APC-equipped rail cars on the new Interstate Light Rail Line to monitor passenger activity during the line's start-up phase.

The trip match rate achieved in this example exceeds Furth's (11) recommended threshold for annual sampling and NTD reporting. He concludes that NTD reporting can be satisfied with a minimum APC fleet penetration of 15% and a corresponding sampling approach that involves assigning APC-equipped vehicles to recover passenger data from each scheduled trip at some point during the year. Whether this level of APC penetration is also sufficient to support service planning and other internal activities is not clear. It is doubtful that investments in APC technology can be rationalized solely on the basis of the avoided costs of manual data collection for NTD reporting. For example, prior to switching to APC data for NTD reporting, TriMet spent about \$50,000 per year for manual data collection. Presently, their capital cost per vehicle for APC units is about \$1,000. Thus a \$50,000 capital outlay for APCs would only yield 8% penetration in their bus fleet of 634 vehicles. This indicates that the cost effectiveness of APC investments will depend on the ability of the technology to support multiple activities, and there is little that is currently known about what threshold level of penetration is required in that context. TriMet is currently planning for 100% APC penetration in its rail and bus fleet by 2009 (12).

(Figure 1 about here)

## **SAMPLING FOR MONTHLY INTERNAL REPORTING**

While the sampling approach described above is capable of satisfying NTD annual reporting requirements, TriMet is also interested in generating monthly estimates of passenger activity at the system level. Under standard sampling approaches this would require a substantially larger number of trip observations to achieve the same level of precision. However, the existence of archived APC data has allowed the agency to develop a monte carlo-type sampling scheme for bus route passenger activity reporting that results in a much higher level of precision and reliability (7). TriMet has used this method since 2003, when it replaced a revenue-based method that had become increasingly unreliable with the expansion of fare and payment options.

The gains from the monte carlo sampling approach is based on the central limit theorem, which demonstrates that the distribution of a sample statistic (such as mean boardings) is much more compact than the distribution of that same phenomenon in the

general population. Another benefit is that the sample statistic is known to be normally distributed even when the parent population distribution is non-normal (8). In addition to the improvement in statistical efficiency, the monte carlo sampling approach provides a measure of insurance against the alternative possibility that a single random sample with a large number of observations would produce an unreliable estimate in a given month, given the incomplete APC coverage of scheduled trips.

The monte carlo sampling procedure follows the same steps described in the previous section, but then iterates to produce about 300 samples per month, with each sample containing 1,000 trips. The passenger activity reported is the grand mean calculated from the means of the constituent samples. The gain in precision from this approach can be seen in the contrasting confidence interval formulas for passenger boardings from a simple random sample versus the iterative approach. For a simple random sample of size  $n$ , the confidence interval is defined as

$$\mu_B = X_B \pm t_{\alpha/2} * S_B \div \sqrt{n}, \text{ where} \quad (3)$$

$\mu_B$  = mean boardings in the population of trips;  
 $X_B$  = mean boardings from the simple random sample;  
 $S_B$  = the standard deviation of boardings.

In contrast, the confidence interval from the monte carlo sample is defined as

$$\mu_B = {}^G X_B \pm t_{\alpha/2} * {}^G S_B \div n, \quad (4)$$

where the superscript G the grand mean and mean standard deviation derived from the iterated trip samples. The main difference in Equation 4 is in the divisor. Rather than dividing the standard deviation by the square root of the sample size, as for a simple random sample, the divisor for a monte carlo sample is the sample size itself. This clearly shrinks the confidence interval (and improves precision) at an exponential rate with respect to the size of the sample.

Statistics from TriMet's 2003 NTD report for light rail passenger boardings can be used to illustrate the precision gains from the monte carlo sampling approach. In this case the sample size is 437 trips, with mean boardings of 70.35 per trip and a standard deviation of 45.3. By Equation 3, the 95% confidence interval from this sample is  $\pm 4.25$  boardings and the associated precision is  $\pm 6.0\%$ . Assuming the grand mean and standard deviation are equivalent to their simple random sample counterparts, the corresponding confidence interval for a monte carlo sample would be  $\pm 0.20$  boardings and an associated precision of  $\pm 0.30\%$ . Thus the monte carlo approach results in an approximate 95% reduction in the range of the confidence interval. Even with a monthly sampling rate of 30 trips, the precision of monthly estimates of boardings per trip from a monte carlo sample would be  $\pm 4.4\%$ , versus  $\pm 24.0\%$  from a simple random sample.

## CONCLUSIONS

In this study, TriMet's rail APC units were found to systematically under-count passenger boardings and over-count alightings. Without correction, this would lead to an under-reporting of unlinked passenger trips and an even greater under-reporting of passenger miles. The inaccuracies observed in the rail setting were greater than those previously reported by the authors for buses. This may reflect differences in bus and rail door widths. In the case of rail the APC units must record simultaneous boarding and alighting passenger movements, while the narrower spaces on buses limit passenger flows to single file movements. The lower rail accuracy may also be a consequence of

installation differences of the APC units, given that counts from outer doors of the rail vehicles were systematically less accurate than counts from the middle doors.

More generally, there are several issues that are relevant to the subject of APC accuracy that were not addressed in this study. First, accuracy may be affected by such factors as weather and temperature. Second, as Furth (11) notes, “drift” can erode accuracy over time, necessitating periodic assessment and adjustment of correction factors.

It was determined that the trip sampling and APC data archive query procedure currently employed by TriMet for NTD reporting of bus passenger activity can be extended to the rail setting. Compared to the bus sampling procedure, the likelihood of matching sampled rail trips to archived APC records was found to be only slightly lower.

The introduction of AVL technology in the late 1990s resulted in a substantial improvement in the locational referencing of APC data at TriMet. As a result, data losses have been greatly reduced in comparison to the situation observed by Strathman and Hopper (3). In addition, more extensive deployment of APC units in the vehicle fleet has broadened the coverage of archived APC data to the point where ex post sampling and database queries can be employed to satisfy NTD and internal reporting activity. This has eliminated the problems previously encountered in efforts to assign APC-equipped vehicles to sampled trips. Extensive deployment of APCs also precludes the need to rotate vehicles to ensure coverage of scheduled trips.

More extensive APC data recovery has also allowed the development of an ex post monte carlo sampling and database query procedure for internal monthly reporting of passenger activity at TriMet. This iterative approach has resulted in a substantial improvement in the precision of boarding estimates. Thus for internal monthly reporting of passenger activity, where precision targets are stricter than those required for the NTD, TriMet has switched to APC-based estimates from revenue-based estimates.

With respect to accuracy issues, this paper has limited its focus on the raw door-level passenger counts recovered by APCs. However, it should be recognized that accuracy can also be affected, both positively and negatively, by post-recovery data screening and processing activity. For example, TriMet screens its bus APC data and deletes trip block records where the aggregate difference between boardings and alightings exceeds 10%, which should improve accuracy. For the data that passes through this initial screen, another post-recovery data processing activity involves load balancing. Load balancing corrects for the remaining differences in boarding and alighting counts to “zero out” passenger loads, usually at the trip block level. Furth (11) has found that commonly-used load balancing approaches can result in error propagation when applied at the block level, and has recommended an alternative that zeroes out loads at the trip level for service with conventional layovers and accounts for carryover loads for interline-type service.

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**FIGURE 1 Frequency distribution of direct matches of sampled rail trips and archived APC trip records, June 2004 (sample size = 50; replications = 200).**

**TABLE 1 Passenger Activity Descriptive Statistics**

		Boardings Per Door		Alightings Per Door		Differences (APC – Manual)	
Variable	n	APC	Manual	APC	Manual	Boardings	Alightings
All Events	722	1.59	1.68	1.54	1.44	-0.09*	0.10*
Rear Car	174	1.79	1.96	1.32	1.28	-0.17*	0.04
Front Car	154	1.45	1.55	1.44	1.35	-0.10	0.09*
Inside Door	378	1.45	1.50	1.62	1.57	-0.05	0.05
Outside Door	344	1.75	1.88	1.44	1.30	-0.13*	0.14*
High Volume	144	3.74	4.09	3.45	3.28	-0.35*	0.17
Low Volume	578	1.06	1.08	1.06	0.98	-0.02	0.08*
Airport Line	325	1.68	1.74	1.84	1.71	-0.07	0.13*

\* Asterisk indicates that the difference is statistically significant.

**TABLE 2 APC Error Composition**

Category	Systematic Error (%)	Random Error (%)
Boardings	5.36	5.11
Alightings	6.94	4.38

**FIGURE 1** Frequency distribution of direct matches of sampled rail trips and archived APC trip records, June 2004 (sample size = 50; replications = 200).

