Use of Automated Vehicle Location and Passenger Counters in Planning and Scheduling at Pace Suburban Bus

Tunde Balvanyos, Ph.D.
Bus Rapid Transit Coordinator
Pace Suburban Bus
550 W. Algonquin Road
Arlington Heights, IL 60005
Tel: (847)-228-2389
Fax: (847)-228-2330
tunde.balvanyos@pacebus.com

Ben Owen
Service Restructuring Coordinator
Pace Suburban Bus
550 W. Algonquin Road
Arlington Heights, IL 60005
(847) 228-2391
(847) 228-2330
ben.owen@pacebus.com

INTRODUCTION

Transit agencies are under increasing pressure to provide higher-quality service and higher service levels at lower costs. Improved decision making and effective use of new and existing technologies are essential to meeting this challenge.

Pace operates buses in the 6 county suburban area surrounding Chicago, IL covering 3500 square miles of mostly low density suburbs and exurbs as well as satellite cities, such as Aurora, Joliet or Elgin. Pace serves 234 suburban municipalities. On an average weekday Pace serves approximately 133,000 riders. Effectively providing transit services to this large, low density, disperse, multi-jurisdictional area is further complicated by significant funding constraints. Within this complex operating environment, Pace strives to provide reliable service to its customers with the limited resources available. Reliable, timely data is essential to enable the agency to make informed decisions regarding the allocation of its scarce resources effectively.

In 2004, Pace started operating the Intelligent Bus System (IBS). IBS consists of an Automated Vehicle Location (AVL) system with CAD display for dispatchers and Automatic Passenger Counter (APC) equipment on 20 percent of Pace's bus fleet.

IBS collects an enormous amount of data. The volume of data can be overwhelming or helpful to dispatchers, agency management, and planners in making informed decisions about allocating resources to efficient use. Pace has been aggressive in making the maximum use of the data generated from IBS to better operate and manage its bus system. Analyzing archived data enables Pace to identify problems qualitatively and quantitatively, as well as to recognize trends in the data.

The following case studies serve to illustrate how Pace has used AVL and APC data in planning to make informed decisions:

1. Pace planned to discontinue an express route to Chicago but reconsidered its plan after community opposition. The APC data enabled Pace to develop a revised plan which focused service on the stops and time of day with the greatest demand.
2. Pace used AVL data in a study to increase service reliability by rescheduling 26 routes at Pace's South Division garage.
3. Pace's planners use AVL and APC data in their every day planning activities.

APC DATA UTILIZED TO ADDRESS COMMUNITY CONCERNS

Route 835 – Southwest Suburban Chicago Express provided all-day weekday bus service to supplement limited rush hour-only commuter rail service between Orland Park and downtown Chicago. In 2005, Metra, the regional commuter rail agency, completed a project to double-track the rail line. Upon completion of this project Metra announced plans for all-day rail service. In response to the increased rail service, Pace proposed to discontinue all Route 835 service. When the proposed elimination of the bus route was released to the public, some Route 835 customers objected, primarily because they would have lost direct access to portions of downtown Chicago not serviced by the rail line. After a review of the APC data showed that much of the demand was concentrated at a few stops and at specific times, Pace agreed to reconsider its discontinuation plan. In March 2006, Pace implemented a revised service plan for reduced Route 835 service which both met the ridership demand and reduced the per-rider subsidy (see ***Figure 1***).

The availability of the APC data enabled Pace to make an informed decision. An analysis of the data revealed that the three innermost suburban Metra stations – Oak Lawn, Chicago Ridge and Worth – and courtesy stops between them accounted for 94 percent of inbound boardings and 87 percent of outbound alightings. Consequently, Pace elected to eliminate the segment of the route beyond Worth Metra station to Orland Park/179th St., which had light ridership. Additionally, the number of trips was reduced, particularly in the morning rush hour and off-peak periods, to correspond to the busiest travel times:

Table 1. Former and Current Schedule of Route 835

	Former schedule		**Current schedule**	
	Trips	Buses	Trips	Buses
AM peak inbound	11	8	4	4
Midday	4	2	--	--
PM peak outbound	5	5	4	4
Evening outbound	2	2	--	--

The revised service continued to provide a one-seat ride between high-ridership suburban locations and downtown Chicago during peak commute times.

The route truncation shortened scheduled end-to-end travel times by up to 35 minutes (to 61-69 minutes inbound and 71 minutes outbound from 92-96 minutes and 82-106 minutes respectively). Furthermore, as part of the route restructuring, Pace cut deadhead times significantly (from 30 minutes to 6 minutes). In all, the former service operated 1,373 vehicle miles and 56 vehicles hours per day at $3,528 per day (2005) while the restructured route operates 256 vehicle miles and 14 vehicles hours per day at $784 per day (2006). Pace was able to avoid split shifts by interlining the new trips as well as employing part time operators on some of the trips.

In summary, APC data enabled Pace to reschedule bus service on Route 835 by cutting 74% of the trips and 78% of the costs while continuing to serve almost 90% of the previous riders.

REGIONAL RESTRUCTURING PROJECT USES AVL AND APC DATA

Pace is currently restructuring service in much of the southern and southwestern portions of its service area through its South Cook County – Will County Initiative (SCC-WCI). The project entails a comprehensive analysis and redesign of service based on advanced market research, analysis of APC and AVL data; input from advisory committees, municipalities and townships concerning area development and transit needs; and extensive public input. Service types will include those outside of Pace's standard repertoire, such as flex routes and general-public dial-a-ride services. In addition, Pace is working on strengthening its trunk route network. Pace is engaging in this planning exercise to improve service levels and operating efficiencies in the short term and to develop mid and long term growth plans.

AVL Data Used in Attempt to Increase Service Reliability

When service deviates from schedule, costs are incurred by both the passengers through increased overall trip time (including waiting time) and the transit agency through unscheduled overtime and lost revenue due to lost patronage. Unreliable service also erodes public support and confidence in the transit system as effective means of transportation. AVL data enables transit planners to see bus operation on individual routes, including actual trip run time, and the mean and the variability of trip run time.

Before Pace IBS was implemented, on time reliability data was collected manually by Bus Operations staff. Once a month, 36 people in one rush hour performed manual data collection at selected locations around the system. This time consuming, expensive, incomplete collection sampled only a tiny proportion of Pace's vast system requiring extrapolation to routes for which there were no data. Under this system, Pace fixed route on-time performance was considered to be generally satisfactory.

In 2005, Pace developed a system that used IBS data to evaluate fixed route on-time performance. Now, utilizing information provide by IBS, on time performance is reported for every vehicle for whole trips (for both departure and arrival), as well as for every segment. This more complete, much larger dataset enabled an accurate and timely evaluation of on-time performance at every time points. It served to uncover service performance problems not previously known.

In September 2005, Pace had begun working on the SCC-WCI program, a project to evaluate and restructure fixed route service operated by three Pace Divisions – South, Southwest, and Heritage. Schedule adherence improvements were determined to be a key goal, as measured by IBS. The initial focus was on Pace South, the division with the poorest on-time performance.

In the spring of 2006 Pace initiated the Existing Schedules Efficiency Review Project for its South Division using AVL data. This project addressed schedule efficiency and on-time performance issues for the 26 fixed routes operated from this garage. Pace evaluated and revised the run times and recovery time requirement using Hastus ATP.

The objectives of the project were to:

- Develop a sound method for addressing the run time and recovery time requirements inherent in Pace operations in the South Division area, including dealing with issues such as extensive at-grade railroad crossings;
- Develop revised run times and recovery times to improve schedule reliability, robustness and efficiency.

Pace developed a method for the evaluation and calibration of run times and recovery time requirements that met Pace policy and operating conditions. The following steps led to revised schedules for the division:

1. Existing service levels and schedule structures were analyzed to establish existing performance.
2. Pace established policies for on-time performance; this served as input into Hastus ATP.
3. Planners used the Hastus ATP iterative process to generate new run time periods and durations to arrive at the proposed schedules, blocks and runs. Existing schedule structures were used to benchmark the revised schedules.

The primary goal was to improve operating efficiencies and route performance while implementing the revised run times and recovery time requirements. All existing labor contract provisions (e.g. contractual recovery time requirements, interlining) and scheduling practices (e.g. time transfers) were met.

Data Preparation

Six months of South Division AVL data was imported into Hastus ATP. The run time records, imported into Hastus ATP, were based on departure to departure times, except between the 2nd to last and last timepoints, in which case departure to arrival was used. Any records where the schedule adherence deviation was greater than 2 hours (at either the 'from' or 'to' timepoint) were not imported into Hastus ATP. Also, any records where vehicles were changed mid trip were thrown out - only run times between pairs of timepoints that were operated by the same vehicle were imported. In addition, atypical observations (such as those on days with unusual weather or traffic conditions, or data for July 4th) were discarded.

In addition, loaded run time measurements that significantly deviated from others were deactivated in Hastus ATP, so as not to distort statistical calculations. (Such significant deviation could be caused by mechanical problem or an unusual event.) Hastus ATP displays inactive (unused) data as circles, not dots (see ***Figure 2***).

Figure 2 shows Hastus ATP's display of all run time data points for a run time link. Run time link is defined as any two time points on a route. These two time points need not be adjacent. The top graph on ***Figure 2*** shows run time data for a route between its two terminals. The bottom figure shows run time data for a segment (between the second and third timepoints) of this route. Data points line up vertically because Pace runs low frequency service on this route. If frequency were higher the data display would appear more like a cloud of dots.

Run time periods are represented by horizontal segments of the line. The run time durations are shown in relation to the duration scale on the left side of the graph. Vertical segments of the line marking the start and end of each period are shown in relation to times of the day – giving the hours associated with each run time period – along the top of the graph.

Existing Performance

Existing run time periods were imported into Hastus ATP. Hastus ATP calculated the proportion of trips that were completed on or within scheduled run time duration. This number is displayed under the horizontal line of each time period (in white color).

Pace Policies

In order to use Hastus ATP to generate new run time periods and durations, company policies of on-time performance need to be specified for the program. On-time performance policy should balance the needs of both the driver and the passenger. There should be enough run time so that the driver can complete the trip on time driving safely. However, run time should not be more than needed since passengers prefer fast trips. Essentially, run time balances schedule adherence and speed.

Pace has defined on time performance such that if a bus is no more than 5 minutes late or 1 minute early it is considered on time. On most of its routes Pace runs infrequent service (15 or 30 minute frequency). At this frequency, passengers arrive to stops in clusters, just prior to scheduled departure (not randomly). If a bus runs 5 minutes early on a 30 minutes frequency and a passenger arrives to the stop 2 minutes before scheduled departure, the passenger would have to wait 32 minutes. Therefore, Pace wants to avoid early departures from time points by scheduling for 55th percentile run time. That is, buses should complete their journey within scheduled run times 55% of the time.

Recovery time is used to balance trip time. Recovery time is used to ensure that at least 90% of trips arrive prior to their next scheduled departure. Recovery time was determined by setting an end-to-end run time, including recovery time, at the 90th percentile; taking the difference between this time and the 55th percentile run time defines the minimum recovery time. This would mean that operators of 55% of the trips will have the whole recovery time as break, 35% will arrive during recovery time and 10% will arrive beyond the recovery time and have to start the return trip immediately yet already late. In this last case, the effect of being late would be carried over to the next trip.

Building New Schedules

The Hastus ATP generated run time periods and durations aid in scheduling, but they are not results of an optimization tool. Planners analyzed the Hastus ATP-generated graphs that showed both the old and the revised schedule and manually adjusted the run time durations and periods where needed. The tool-generated information is a statistical and visual aid to planners; the new schedule generation is a highly iterative process that heavily relies on planners' experience.

First, whole trips were analyzed. End-to-end run time budget and recovery time for each run time period were established. Second, run time for individual segments between adjacent time points were analyzed and adjusted. (Recovery time is not calculated for segments, only for the whole trip.) Planners, relying on years of personal experience, then adjusted the allowed run time duration and period for each segment individually while maintaining end-to-end trip time for the trip. Generally, segments at the beginning of the trip would be tighter, while segments at the end of a trip would be slightly looser. This exercise produced the new set of segment run times for all time periods, which then were fed to Hastus for updating route schedules and building new run cuts.

While the Hastus ATP tool allows for different types of analysis of the data, Pace did not analyze the effect of driver behavior (even though IBS data would allow disabling data points that belong to any given driver). Schedule robustness to railroad crossing delays were addressed through the newly established recovery times.

Results

Based on the work with the Hastus ATP tool, Pace built a new preliminary schedule for South Division routes. This schedule was preliminary because certain operational issues were not yet addressed, such as transfers with Pace routes operated from other garages or transfers with other services, such as Metra trains.

Based on work completed, the estimated annual cost of the proposed improvements was about $700,000. The proposed adjustments would require 33 additional Weekday vehicle hours, 14 additional Saturday vehicle hours, 23 additional Sunday vehicle hours and 4-6 additional buses. The potential to offset these costs by reducing late pull-ins and unscheduled overtime was not promising.

Part of this additional expense was due to the fact that many routes simply needed longer run time to complete their trips. In many cases, scheduled run times had not been adjusted in years to reflect increased traffic congestion. Run time changes often impact cycle times and existing headways. In this case, Pace schedules were rewritten to observe existing half-hourly pulses at two transit centers despite extended cycle times. In addition, trips were scheduled to arrive for pulses at transit centers based on the 90th percentile run time to protect connections; this sometimes substantial time cushion was not included in the original schedule.

The other part of this additional expense, however, was due to a significant policy change that Pace tried to make. Pace desired to change policy with regard to interlining, intending to eliminate as much interlining as possible so that freight train disruptions on one route did not affect others. In the South Division routes regularly cross freight train lines. These trains do not operate on a regular schedule. A freight train can disrupt operation for up to an hour.

The conclusion of this study was that this project is to be reintegrated with the SCC-WCI. Results of the South Division study are being integrated into scheduling where applicable. In addition, it has become clear that by evaluating on-time performance at every time point, Pace judges its on-time performance using a more stringent criteria than most other US transit agencies.

AVL AND APC DATA IN DAILY PLANNING ACTIVITIES

The last case study shows how AVL and APC data can help save resources without elaborate planning studies. Pace has made ArcGIS available to all its planners and coded additional functionalities to ArcGIS to enable planners to query archived AVL and APC data bases from their desks. With training and easy, immediate access to data, planners have started using AVL and APC data in their every day work.

Route 547 provides service from Elgin Terminal and Metra Station to the northwest residential areas of Elgin. Most of the route is a one way loop, with 23 minutes run time scheduled with 7 minutes of recovery time. The service operates every half hour. A regular trip scheduled to leave Elgin Terminal at 3:15 PM is scheduled to leave the time point at Wing Street & McLean Blvd. at 3:31PM. On school days, an additional trip is scheduled to leave Kimball Middle School at 3:30pm, which is about 1 minute away from the Wing Street & McLean Blvd. time point, and follows the standard routing to Elgin Terminal. Since the two trips are so close, it was questioned as to whether both trips were needed or the regular trip could serve the school as well.

Planners and supervisors observed low ridership on these trip. Their observation was confirmed by fare box data of these trips. Analysis of archived APC data for the school year showed passenger activity stop-by-stop: on average 12 people rode on the school trip, and average passenger load on the regular trip was 6. This investigation showed that the regular trip could accommodate the passenger load of the school trip without difficulty. Next, analysis of archived AVL data for the same time period showed that the 3:15 PM regular trip, which is scheduled to arrive at the Elgin terminal at 3:38PM, consistently arrived at 3:39 PM. A field trip showed that diverting the regular trip to the school would add only 1 minute to this segment's run time.

Based on this information, Pace has proposed a new schedule for route 547. The school trip has been discontinued. The 3:15 PM regular trip has been diverted to the school. This trip's run time was lengthened by 1 minute reducing recovery time to 6 minutes. This 1 minute was added to the segment that now includes a diversion to the school. All other trips remained the same.

Without the AVL and APC data, the only way to gather data to answer the planner's question would have been to send out planners to count the number of passengers and record arrival times over some period of time. Pace would have collected data on only a few days and hoped that these were representative of the entire school year. Today, planners' observations are greatly augmented by data collected automatically and continuously. Planners have easy access to a large data base with known accuracy. Planners can continually evaluate routes to improve efficiency and service quality. Their decisions are now based on much more information, made with more confidence, and in much shorter time.

CONCLUSION

The implementation of the Intelligent Bus System has enabled Pace to obtain AVL and APC data. Pace has recognized the value in the data. Instead of being overwhelmed by the amount of data, Pace has proactively integrated the use of the data into its decision making process. Pace is training its planners, dispatchers, and managers in how to use the data. The examples in this paper illustrated that Pace is using AVL and APC data to make informed decisions in planning and scheduling.

The first case study about the Southwest Suburban Chicago Express showed that APC data was used to adjust service to better match demand. This case also shows that using APC data to adjust service does not in itself lead to savings. How much saving can be realized depends on other factors, for example, the agency's labor laws or possibilities for interlining.

South Division case illustrated how valuable reliable data can be. AVL data allowed planners to see route on-time performance (actual run times), while tools, such as Hastus ATP, enabled planners to analyze this data, and build "what if" scenarios. But this case study is cautionary as well. The agency's definition of on-time performance will determine to what degree "on-time" service is. The agency's policies (such as those about interlining) affect the available solutions, and therefore, the resources needed to reach set goals. Pace has learned a great deal about what is actually happening on the streets, what the impact of its definition of on-time performance is and the magnitude of resources that would be needed to improve service to 90% on-time trip departure standard at just one division.

Beyond the large scale restructuring projects, empowered by easy access to reliable AVL and APC data, planners are using the data in their regular work. This significant change in how Pace conducts its business has improved Pace's decision making process and, thus, enabled Pace to make informed decisions about efficient allocation of its resources.

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FIGURE 1 Route 835 with APC Data.

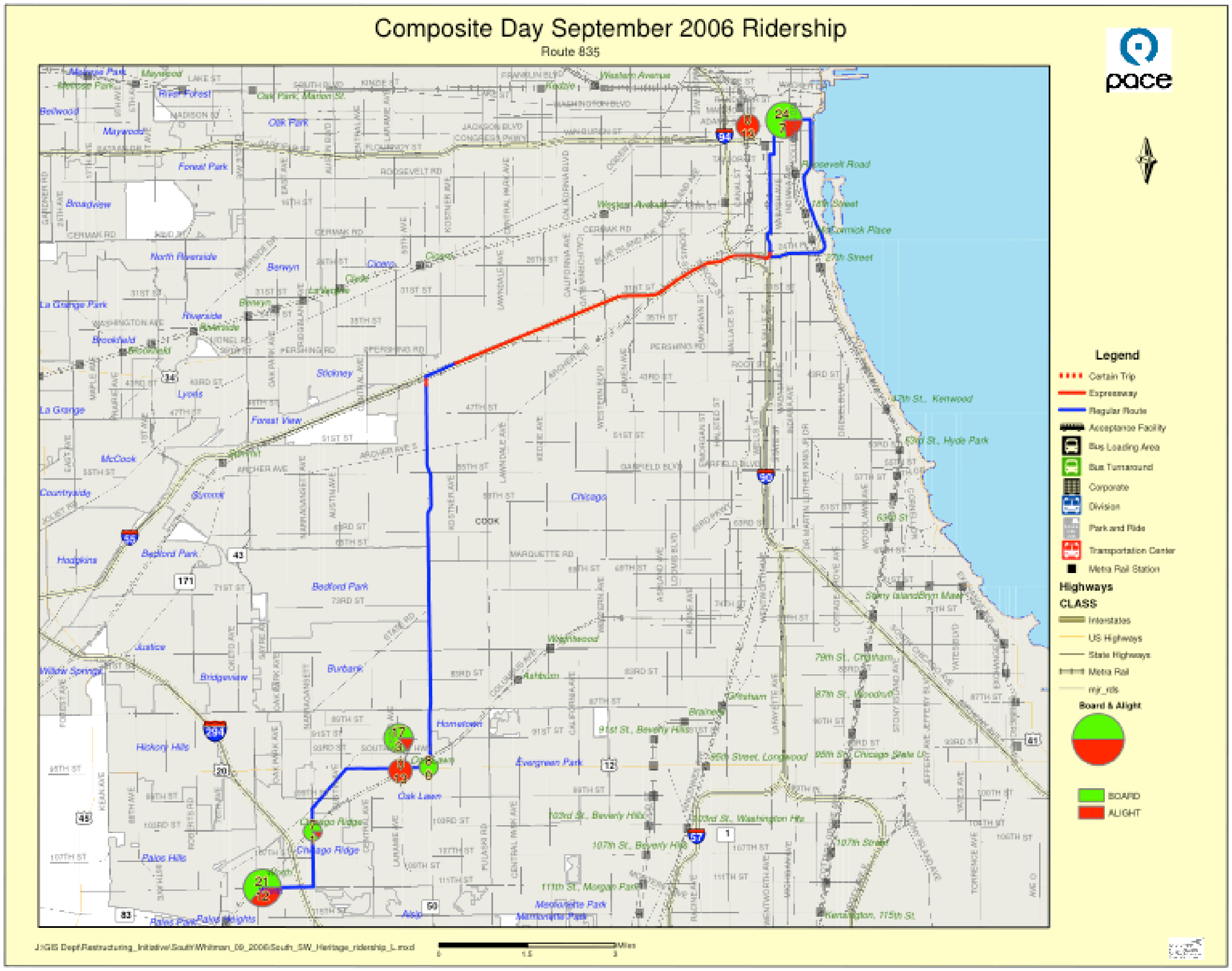

FIGURE 9 Hastus ATP Runtime Graph for a Route and a Segment of the Route