Using Archived Stop-Level Transit Geo-Location Data for Improved Operations and Performance Monitoring

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Objectives

- Trends in transit technology
- AVL and APC
- BDS system and data archiving
- Preliminary route level analysis
- Other examples
- Conclusions and future research
Automatic vehicle location (AVL)

- Determination of vehicle location
  - Global positioning systems (GPS)
  - Signposts
  - Ground-based radio
  - Dead-reckoning
- U.S. transit agencies
  - 128 operational
  - 172 planned
Automatic passenger counters (APC)

- Count boarding and alighting passengers
  - Infrared beams
- U.S. transit agencies
  - 60 operational
  - 124 planned
## AVL/APC in the Bay Area

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<th>APC</th>
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Archiving AVL/APC Data

- AVL not designed with archived data in mind.
- Most AVL systems do not deliver data for off-line planning analysis.
- Transit agencies didn’t insist on it.
- APCs designed with archiving in mind.
- APCs often only in 10-15% of fleet.
- TriMet system driven by APC pays for itself in saved reporting costs

Source: TCRP H-28, Uses of Archived AVL-APC Data to Improve Transit Performance and Management.
About TriMet

- Serves 1.2 M population
- 575 mi²
- 62.8 M annual bus trips
- 206,600 daily bus boardings
- 95 bus routes
- 655 buses
- 8100 bus stops
- Also LRT, Paratransit
Performance measurement

- Measuring system performance is the first step toward efficient and proactive management.
- Increasing attention to transit performance
- Transit Capacity and Quality of Service Manual
  - Quantitative/qualitative
  - Passenger point of view
  - Linked to agency operating decisions
- NCHRP Performance Based Planning Manual
  - Accessibility
  - Mobility
  - Economic Development
- Improve reliability
  - Reduce variability of system performance
    - Delay
    - Travel time
  - Attract more riders
  - Reduce operations costs
  - Increase productivity
  - Link to service standards
In the past...

- Data collection more difficult
- Low temporal and spatial resolution
- “Many people to collect little data”
- Focus on limited, general, aggregate measures for external reporting
- Natural air conditioning
Today...

- Unlimited coverage and continuous duration
- Design, extract and test specific measures
- Actual system performance
- Data management/processing challenges
- Need for generating relevant measures
TriMet’s Bus Dispatch System

Navstar GPS Satellites

On-Board Computer

Doors
Lift
APC (Automatic Passenger Counter)
Overhead Signs
Odometer
Signal Priority Emitters

GPS Antenna

Radio System

Radio Antenna

Radio

Control Head

Memory Card

Garage PC’s
TriMet’s Bus Dispatch System

PCMIA Card

Control Head

Schedule deviation
Real Time Elements

Navstar GPS Satellites

Radio System

GPS Antenna

Radio Antenna

On-Board Computer

Radio

Control Head

Memory Card

Garage PC’s

Doors
Lift
APC (Automatic Passenger Counter)
Overhead Signs
Odometer
Signal Priority Emitters
Real Time Elements

Schedule Data → On-board Computer → GPS Location → Radio/Cellular Communications → 90 sec Updates

Dispatch and Control

Arrival Prediction
Archived Elements

Schedule Data → On-board Computer → GPS Location → APC/Lift → PCMIA Card

Event Data [Operator]
- Pass up Overload
- Traffic Delay
- Train/Bridge Delay
- Fare Evasion
- Graffiti/Vandalism

Stop Data [Automatic]
Event Data: Fare Evasion
Archived Elements

Schedule Data → On-board Computer → GPS Location → APC/Lift → PCMIA Card

Event Data (Operator)

Stop Data (Automatic)
- Scheduled
- Unscheduled
Stop Data

- **Arrive Time**
- **Door Open**
- **Dwell Time**
- **Door Close**
- **Leave Time**
- **Stop Location**
- **Rewritten Arrive Time (If Door Opens)**

**Timeline:**
- **15 Meters**
- **30 Meters**
## Stop Data

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- Route Number
- Vehicle Number
- Service Date
- Actual Leave Time
- Scheduled Stop Time
- Actual Arrive Time
- Operator ID
- Direction
- Trip Number
- Bus Stop Location
- Dwell Time
- Door Opened
- Lift Usage
- Ons & Offs (APCs)
- Passenger Load
- Maximum Speed on Previous Link
- Distance
- Longitude
- Latitude
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Route 14 Case Study
Route 14 Case Study

- 7.9 miles long
- 105 scheduled trips per weekday
- 64 scheduled stops
- 40-45 min scheduled trip time (mean 43.3, SD 2.7 min)
- 3-55 min headways (mean 11.4 min)
- Focus on two weeks April 1-12, 2002 [>1000 runs]
- Morning inbound from SE 94th/Foster to NW 4th/Hoyt
- Crossing Hawthorne Bridge
April 1 A.M. Inbound Trips
April 1 A.M. Inbound Trips
April 1 A.M. Inbound Trips
April 1 A.M. Inbound Trips
April 1: Two Inbound Trips
April 1: Two Inbound Trips

- **Trip 1290**
  - Badge 996 (28 yrs exp)
  - Median 1.2 min late

- **Trip 1295**
  - Badge 2606 (4 yrs exp)
  - Median 0.9 min late

- Two late departures
- One late, one early arrival

---

Graph showing distance (miles) vs time for two trips with different median lateness times.
April 1: Impact of Pax Load

---

Time

Distance (miles)

---

April 1: Impact of Pax Load

Trip 1290

Passenger Load

---

Distance (miles)

Time

---

April 1: Impact of Pax Load

Trip 1290

Passenger Load
On-time Performance

All "stops"
\[ n = 66,012 \]
\[ \text{Median} = 0.6 \text{ min Late} \]

32% Early
On-time Performance

TriMet Service Standard
[-1 min ➔ +5 min]
85% On-time
11% Early
4% Late
OTP vs. Time of Day
TriMet Operator Experience

$n = 3,249$
Mean = 9.8 years
TriMet Operator OTP

April 1-12, 2002
Route 14 Inbound
94 Operators
65,848 stops
TriMet Operator OTP

April 1-12, 2002
Route 14 Inbound
94 Operators
65,848 stops
Stop Level Performance

April 1, 2002
Stop No. 2606
Hawthorne/ 22nd Ave
Mean Headway 11:02 min
St. Dev. 7:10
Stop Level Performance

April 1, 2002
Stop No. 2606
Hawthorne/SE 22nd Ave
Mean Headway 11:02 min
St. Dev. 7:10
Route 14: Trip Time Model

\[ T = T_0 + aN_d + bN_a + cN_b \]

- \( T_0 \) = average nonstop trip time
- \( N_d \) = number of dwells
- \( N_a \) = passengers alighting
- \( N_b \) = passengers boarding
Dwell Time

Nonzero Dwells
n = 34,456
Mean = 13.3 s
SD = 20.3 s
Lift use = 232 times
Dwell Time vs. Passenger Movement

- Off: 28%
- On: 61%
- On + Off: 4%
- None: 7%

The chart shows a scatter plot of dwell time (in seconds) against passenger movement. The pie chart indicates the distribution of different passenger movement categories.
Boardings

n = 37,441
Mean = 1.33
SD = 2.45
Max = 37
Alightings

$n = 36,978$
Mean = 1.31
SD = 2.62
Max = 37
Dwell Time Model

Dwell Time = 5.94 + 2.87N_b + 0.96N_a

n = 24,995 [non-zero, no lift, APC = "G", no layover]
Boarding Only: Dwell = 6.03 + 4.27N_b
n = 15,357
Alighting Only: Dwell = 6.63 + 0.95N_a
n = 7,021
Nonstop Trip Time

\[ n = 30,036 \text{ links} \]

\[ \text{NSTT} = 15.3 + 191.2x \text{ (sec)} \]
Trip Time Model

\[ T = 1606 + 21.2N_d + 0.96N_a + 2.87N_b \]

\( N_d \) = number of dwells

\( N_a \) = passengers alighting

\( N_b \) = passengers boarding
Run Times: April 1-12, 2002

- $n=856$ trips
- Mean on = 40/trip
- Mean off = 40/trip
- Mean no. of dwells = 35/trip
Run Times: April 1-12, 2002

$n=856$ trips  
Mean=41.5 min  
SD=5.1 min
Run Time vs. Operator Experience

$n=856$ trips
83 operators
Run time/experience relationship (95% confidence)
Actual vs. Predicted Run Time

- **Actual Run Time** vs. **Predicted Run Time**

<table>
<thead>
<tr>
<th></th>
<th>Actual</th>
<th>Predicted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>41.5 min</td>
<td>41.6 min</td>
</tr>
<tr>
<td>SD</td>
<td>5.1 min</td>
<td>7.4 min</td>
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<tr>
<td>Veh-hrs</td>
<td>592</td>
<td>594</td>
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</tbody>
</table>

- **n=856**
Stop Consolidation Analysis

- Route 14 length 41710 feet, 64 stops
- Mean stop spacing 670 feet
- Consolidate stops to 1000 foot spacing—eliminate 10 stops
- Reduce trip time 21.2 sec per stop, save 3.5 min per inbound run
- 105 inbound trips per day → 6.1 hours savings ($60/hr +/-)
- Add ~9 trips using existing resources
- Improve mean headway 11.4 → 10.4 min
- Does it affect demand?
Boarding Area Improvement Analysis

- Streamlining program to reduce dwell time
  - Curb extensions
  - Nearside→farside conversion
  - Smart cards
- Mean boarding time estimated 2.87 sec
- Reduce boarding time by 1 sec at top ten locations
- Total of 1800 passengers boarded at these locations
- Save 30 min/day
Other Applications

Segment from Route 12
LANDUSE

- AGR
- COM
- FOR
- IND
- MFR
- PUB
- RUR
- SFR
- VAC
- Half mile service area
- Quarter mile service area

Passengers
- 0 - 31
- 32 - 79
- 80 - 184
- 185 - 354
- 355 - 727

[Map showing land use and passenger distribution]
Other Applications

- 1 census tract
- 0.25-mi buffers
- 38% of population
Transit Signal Priority

TSP Signals and Transit Corridors

April 2003
Transit Signal Priority

- Reduce run time and schedule variability
- 180 intersections complete, 100 more in 2003
- Emitter turned on if bus is >90 sec late
- Remains on until <30 sec late
- Green extension/red truncation
Transit Signal Priority

Run Time Distribution - PM Peak
Line 12 (Barbur - Sandy Blvd)

With Signal Priority
Before Signal Priority
Express Buses as Freeway Probes
Buses as Probes on Arterials
Buses as Probes on Arterials

Test Vehicle Run

Legend
- Signalized Intersection
- Bus Stop
Buses as Probes on Arterials
Buses as Probes on Arterials
Buses as Probes on Arterials

3D Speed Contours

- Test Vehicle
- Actual Bus
- Differences (Test Vehicle Speed - Bus Speed)

- Speed (mi/h)
- Time
- SW First Ave.
- Powell Blvd.
- SE 39th Ave.

6:00 AM → 9:30 AM
Buses as Probes on Arterials
Buses as Probes on Arterials

\[ \text{tt}_{\text{veh}} = 1.23 \text{ tt}_{\text{pseudo}} \]

\[ \text{V}_{\text{veh}} = 0.84 \text{ V}_{\text{pseudo}} \]
Buses as Probes on Arterials
Buses as Probes on Arterials

### EASTBOUND
- EB Probe: 2% Savings
- EB Bus: 9% Savings
- EB Hypothetical: 22% Savings

### WESTBOUND
- WB Probe: -6% Savings
- WB Bus: 27% Savings
- WB Hypothetical: 14% Savings

<table>
<thead>
<tr>
<th></th>
<th>EB Probe</th>
<th>EB Bus</th>
<th>EB Hypothetical</th>
<th>WB Probe</th>
<th>WB Bus</th>
<th>WB Hypothetical</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Before (sec)</strong></td>
<td>172</td>
<td>200</td>
<td>168</td>
<td>178</td>
<td>212</td>
<td>142</td>
</tr>
<tr>
<td><strong>After (sec)</strong></td>
<td>169</td>
<td>182</td>
<td>131</td>
<td>130</td>
<td>224</td>
<td>122</td>
</tr>
</tbody>
</table>
Discussion

- Other uses for the BDS data?
- Conclusions?
- Save all of your data!
- Ask for archiving capabilities
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- National Science Foundation
- Oregon Department of Transportation
- City of Portland
- Federal Transit Administration
More information

- Email: bertini@pdx.edu
- Web: http://www.its.pdx.edu
- TriMet data readily available.