Outline

1. Operations Data Needs and Availability
2. Farebox and Automated Fare Collection Systems (AFC)
3. Automatic Passenger Counter Systems (APC)
4. Automated Vehicle Location Systems (AVL)
5. Trip Time Analyzer
Extensive + Intensive Data

Extensive: farebox
• every trip, every day (weekends, too!)
• only a rough measure of passenger activity

Intensive: ride checks, point checks, surveys
• insight on a sample of trips
• expand using farebox data
  -- expand a survey by route, period
  -- apply load-boardings factors found in one day’s ride check

APC can be both extensive and intensive
Two Quality Loops: Real-Time and Planning

- Service Plan
- Operational control & Passenger info
- Transit Operation
- Analyze Performance
- Automated Data Gathering

Real time
Off-line
Off-Line Applications

- Monitoring service quality (several dimensions)
- Schedule improvements (running times, passenger flow)
- Match supply to demand
- Analyzing Bunching Effect
  -- late causes early; early causes late
  -- data on sequential buses
  -- integrate operations data with passenger counts
  -- operator differences
  -- dwell times
  -- traffic impacts (support TSP)
Traditional Farebox Data Problems

- Operator error and inattention
- Poor AFC system design
- Poor integration between AFC and other systems
- Lack of management use of data
Farebox can be your primary passenger counting tool, if …

You invest in Hardware:

- Card & transfer readers
- Link farebox to destination sign, on-board computer to segment trips, verify sign-in
- Transactional data

You invest in Software:

- Develop your own database
- Automate data screening, editing
- Integrate with schedule data, payroll, other data sources
Farebox can be your primary passenger counting tool, if …

You invest in Management:

• Someone responsible to check for data quality everyday
• Discipline, retraining for non-performing operators
• Priority in maintenance & servicing
• Manual verification counts

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Estimating Ridership from Revenue

Traditional approach because:

Revenue is Accurate
- on sampled trips: read it now or later
- annual, systemwide (but possibly not by route)

However:

Relationship to Ridership Is Variable
- pass use, transfers, discounts, etc., distort the ridership-revenue relationship
- “average fare” surveys become out-of-date
Transactional Farebox Data Innovations

Key is the ability to record and retain a transaction for each passenger with ticket ID

Transfer and Linked Trip (O-D) Data

• capture time and route of previous trip encoded on pass or transfer
• successful in NYC and CTA rail systems

Estimate load, passenger-miles

• transactional data with location stamp
• estimate alightings using symmetry
Automated Data for Off-Line Application: APC
Tied to on-board computer w/ nightly upload

- APC Analyzer converts sensor signals into counts
- On-board computer stores one record per stop
- Other events may also trigger records
- Nightly upload can be painless

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Passenger Detection Methods

- **Breaking light beam**
  - multiple beams (high/low; inner/outer pairs)
  - sturdy mount to prevent misalignment

- **Pressure sensitive mats**
  - some designs won’t work with low floor
  - footprint detection

- **Infrared (overhead)**
  - requires ambient temperature < body temperature

- **Image interpretation**
Event Records & Contents

• Stop record
  -- time door opened, closed
  -- location (GPS, odometer, etc.)
  -- on count, off count
  -- [maximum speed since last stop]
  -- [time at crawl speed with door closed since last stop]

• Other record types (contain time, location)
  -- speed threshold passed
  -- signpost or “virtual signpost” passed
  -- turn began/ended
  -- periodic (e.g., 10 s)
APC - Historic Uses

- **Mimic ride check analysis**
  - Route load profiles
  - Passenger-miles, NTD sampling
  - Running time distribution (limited)
  - On-time performance (limited)
APC - Historic Deficiencies

High cost, few vendors, short-life vendors
   -- Usually, only 10% of the fleet gets equipped

25% to 75% data recovery
   -- On / off imbalance, negative loads
   -- Route / schedule matching problems

End-of-line issues
   -- Zero-out load to prevent “drift”
   -- End-of-line operation is often irregular, hard to match
   -- Ons for next trip may begin before offs from previous are finished
Equipping 10% of the Fleet ...

- Logistical problems assigning equipped buses
- Not so bad for passenger count data ...
  -- Sufficient for NTD
  -- Superior to any checker force
  -- Adequate for conventional planning methods
- Barely adequate for scheduling data (running time, schedule adherence)
  -- 5% effective sample - each weekday trip sampled once a month
- Inadequate for detailed operations analysis
- Marginal cost of APC in integrated APC/AVL system is low
Automated Data for Real-Time Application: AVL Tied to Radio and Central Computer

Each bus polled in turn (Wide Area Network)

Polling interval

\[ \text{Polling interval} = \frac{\text{[unit poll time]}}{\text{[no. of buses]}} \times \frac{1}{\text{[no. of channels]}} \]

Ex: 0.5 s per poll

\[ \times 1000 \text{ buses} \times \frac{1}{4 \text{ channels}} = 125 \text{ s polling interval} \]

Variable polling interval possible
Problem of Polling Interval

- Analysis demands time at location; AVL gives location at (arbitrary) time of poll
  -- interpolation errors can be significant

- Too imprecise for efficient signal priority
  -- predict arrival time to within 5 s
  -- detect exit time to within 1 s
Location Method 1: GPS

- Interpret signals from 4+ satellites
- Low maintenance
- More $$ = more accuracy
  -- accurate clock
  -- differential correction
- Lose signal in tunnels canyons & tunnels
  -- re-radiate in subway tunnel
- Reflection (“multipath”) downtown: info deteriorates where you need it most
Other Location Methods

- Dead reckoning
  -- key backup system to complement GPS

- Odometer
  -- buses have electronic odometer/speedometer
  -- subject to calibration error, drift
  -- effective if route is known

- Signpost (broadcasts ID)
  -- positive location; useful at key points
  -- correct drift, calibrate odometer readings
  -- useless off-route
  -- maintenance hassle

- Combinations of methods
Poll Message Contents

- Time and Location
  -- GPS coordinates
  -- odometer reading (in “clicks”)
  -- ID of last signpost passed
  -- [odometer reading when signpost was passed]

- ID (bus / run / route / operator)

- Mechanical alarms

- Other info: possible, but longer message slows polling rate
• Security

• Crisis management (see big picture)

• Line management (limited)
  -- What actions can dispatchers take?
  -- Comparison to schedule often unavailable

• Off-line playback for incident investigations
AVL - Historic Deficiencies

- Data not stored for off-line analysis, except for playback (incident investigation)
- Often unmatched to vehicle route / schedule
- Always unmatched to operator schedule
Trip Time Analyzer
It’s APC without the passenger counter; it’s AVL without the radio

• Record location and time in on-board computer
• Record events such as door open/close, speed threshold passed, etc.
• Permits analysis of running time, delay, schedule adherence
• Dutch experience: Delft University with several transit agencies
• Equip 100% of the fleet
Observed Running Time by Scheduled Trip

**Gross and net route section times, mean, 85% and max values**

<table>
<thead>
<tr>
<th>Company:</th>
<th>Departure times</th>
<th>Dates: 2000/05/01 until 2000/05/26</th>
<th>Trips scheduled: 520 (Count)</th>
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<tbody>
<tr>
<td>Line: 1</td>
<td>From: Station NS From: 07:00 Mon Tue Wed Thu Fri Sat Sun Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Route: 1</td>
<td>To: Castilelaan Until: 12:00 4 4 4 4 0 20 Trips used: 427 (82%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Count | 14 15 19 17 16 17 16 12 18 18 18 18 16 18 17 18 16 17 |
|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
|       | 19     | 16     | 15     | 17     | 16     | 17     | 15     | 18     | 18     | 18     | 18     | 18     | 18     | 17     | 18     | 16     | 17     |

Source: Hermes (Eindhoven), generated by TriTAPT

**Figure 2. Observed running time by scheduled trip.**

Delays by Segment

![Graph showing individual delays, mean, 85%]

Source: Delft University, generated by TrnTAPT

Courtesy of the Transportation Research Board. Used with permission.

Figure 3. Delays by segment.

Schedule Deviation Along a Route

Individual punctuality deviations, 15%, mean and 85%

Company: USA_H28
Line: 1 From: Stop 1
Route: 1 To: Stop 41

Departure times: From: 08:00
Dates: 2003/03/31 until 2003/04/04
Total

Trips scheduled: 90
Trips used: 81 (90%)
Trips excluded: 0 (0%)

Early

Late


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Schedule Deviation Along a Route

Individual punctuality deviations, 15%, mean and 85%

<table>
<thead>
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<th>Company</th>
<th>Hermes</th>
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<tbody>
<tr>
<td>Line:</td>
<td>1</td>
</tr>
<tr>
<td>From:</td>
<td>Station NS</td>
</tr>
<tr>
<td>Until:</td>
<td>09:00</td>
</tr>
<tr>
<td>Dates:</td>
<td>Mon Tue Wed Thu Fri Sat Sun Total</td>
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<tr>
<td>2000/06/19 until 2000/06/23</td>
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</tr>
<tr>
<td>Trips scheduled:</td>
<td>60 (Count)</td>
</tr>
<tr>
<td>Trips used:</td>
<td>50 (83%)</td>
</tr>
<tr>
<td>Trips excluded:</td>
<td>0 (0%)</td>
</tr>
</tbody>
</table>
