Global Positioning System (GPS)  
Automated Vehicle Location (AVL)  
Geographic Information System (GIS)  
and Routing/Scheduling System

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What is Global Positioning System (GPS)?

24 Satellites
6 planes with 55° rotation
Each plane has 4 or 5 satellites
20,200 km (12,600 mi) orbit
1 revolution every 12 hours
How does GPS determine your location?

Satellite Ranging: Measuring the distance from a satellite by measuring travel time of radio signals.
How Do We Know When the Signal Left the Satellite?

Signal generated from GPS satellite

Signal generated by GPS receiver

Distance = speed of light * latency in time
GPS Positional Errors

Positional errors in GPS are caused by:

- satellite orbit errors
- clock drift, onboard atomic clock accurate to within 40 billionths of a second
- signal delays caused by the atmosphere and the ionosphere
- Selective Availability (S/A), deliberate distortion of the GPS signals
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DGPS and WAAS

GPS
• 100 meters accuracy with Selective Availability on
• accuracy improved to 8 meters without S/A

DGPS – Differential GPS
• Corrects GPS error via a ground beacon receivers
• 6 meters accuracy

WAAS/Local – Wide/Local Area Augmentation System
• Developed by Federal Aviation Administration and the Department of Transportation for aviation purposes
• 3 meters accuracy vertically and horizontally
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Automated Vehicle Location System (AVL)

- First installation of AVL was at Chicago Transit Authority in 1968 using signpost and dead-reckoning technology.
- Today, GPS and wireless communication technology make Automated Vehicle Location (AVL) practical.
- AVL is a subsystem of the national Intelligent Transportation Systems (ITS) technology. Researches and demonstration projects were funded by the Intermodal Surface Transportation Equity Act (ISTEA).
How Do GPS and AVL Relate?

- GPS receiver calculates its position (latitude and longitude) and record the information at fixed time interval
- GPS transmitter transmits location and vehicle dynamic data to control center at prescribed interval
- Control center system disseminate and process data to customer specifications
- Software display filtered information on the screen with map layer
Categories of AVL User Functions

All AVL systems are “real-time”, the differences are when, what, and how often data are delivered to the end users

- As needed base: asset location
- Registration interval in minutes: service delivery, trucking industry, etc.
- Registration interval in seconds: fleet management system, public transportation, school transportation, etc.
Categories of AVL Systems for School Transportation

Passive AVL

• When:
  *end user download data at scheduled time*
  *(end of day, week)*

• What:
  *software defined vehicle dynamic information*

• How:
  *Infrared, serial port, etc.*

• Who are the end users:
  *transportation managements*
Categories of AVL Systems for School Transportation

 danmark Traveler Information System (ETA Paging System)

• When:
  \textit{pre-determined time before the bus arrive at stop}

• What:
  \textit{ETA or signal at predetermined time}

• How:
  \textit{wireless, phone, radio frequency}

• Who are the end users:
  \textit{parents}
Categories of AVL Systems for School Transportation

⇒ Advanced Public Transportation System (Vehicle Tracking System)
  • When: 
    system defined interval
  • What: 
    anything you can imaging
  • How: 
    wireless, radio frequency
  • Who are the end users: 
    transportation managements and/or parents
Costs of AVL System Components

✦ Hardware (\$\$)
  • GPS receiver/transmitter, antenna, data ports, power supply, ...

✦ Communication ($0 to \$$, monthly)
  • Cell, CDPT, burst, etc
  • private or public channel

✦ Software ($\$ to $$$\$ ?)
  • Digital map (update cost)
  • Intelligent algorithm to meet specifications
AVL Cost-Benefit Study: Willingness To Pay (WTP) Survey

- Surveys mailed to parents of 5000 WCPSS students
- Surveys sent to elementary, middle, and high school parents in each of 15 high school attendance boundaries
- Parents asked to complete survey for up to 4 of their children enrolled in WCPSS
- 1252 surveys returned (approx. 25%)
- 2274 useful records in database (1 record = 1 child)
- Useful information on approx. 1.8 children received in each survey
Advanced Traveler Information System (ETA Paging System)

- What cost parents considered “reasonable” to pay for paging service
Advanced Public Transportation System
(Vehicle Tracking System)
“if your child does not ride the school bus, would you allow him/her to ride if…”

**Paging Only:**
29% of all eligible students may shift to school bus

**Tracking Only:**
47% of all eligible students may shift to school bus

**Paging & Tracking:**
38% of all eligible students may shift to school bus

- 51% of (AU, SB) students may shift to school bus
- 31% of (AU, AU) students may shift to school bus

Source: Tori Rhoulac, PhD Dissertation, July 2003
Civil Engineering Dept. North Carolina State University
Possible Future Obstacle
Geographic Information System (GIS)

Coordination and analysis of information about a variety of “features” (parcels, houses, people, etc.), from a variety of sources, which share the same geographic space.
GIS in 1987
GIS Today

- Internet based data server
- Handheld GIS computer system
- GPS and PDA based interface to streamline data collection
- Commercial GIS data sources
Corporate GIS Data: Challenges

People
- Entrenched bureaucracies
- Turf protectionism

Technology
- Inter-agency network incompatibility
- Bandwidth

Competitions from private GIS data providers
Computer-Assisted School Bus Routing and Scheduling System
SBRSS

- Location of stops
- Passenger at stops
- Time at stops
- Time between stops
- Distance between stops
- Total bus route time
- Total bus route mileage
- etc…
AVL

- Where is the bus
- What direction is the bus traveling to
- What speed is the travel speed
- Where is stop
- How long is the stop
SBRSS

- Location of stops
- Passenger at stops
- Time at stops
- Time between stops
- Distance between stops
- Total bus route time
- Total bus route mileage
- etc…

AVL

- Where is the bus
- What direction is the bus traveling to
- What speed is the travel speed
- Where is stop
- How long is the stop
Integrated AVL Based SBRSS

- Did the bus make correct stop
- Is the bus following scheduled route
- Is the bus behind or ahead of schedule
- Did only eligible riders boarded at the stop
- Is the engine performing within tolerance
- Where is the bus
- What direction is the bus traveling to
- What speed is the travel speed
- Where is stop
- How long is the stop
- Etc, ...
Integrated AVL Based SBRSS
Customer Service Pyramid

You:
Bus 123 will run late

Driver:
Stuck in traffic at E Main St

T.D.:
Bus 123, Where are you?

Parents:
WHERE IS MY BUS?!!

You:
All routes completed, go home early

Parents:
Kids got home on time, great service!

T.D.:
Bus 123, 345 bypass E Main St.

Traffic Management:
Congestion at E Main St. expected delay 15 min.
Integrated AVL Based SBRSS

Travel Speed Refinement Cycle

Adjust bus route

Schedule bus route

Refine GIS travel data layer

Validate route path

Validate stop loc. & time

Adjust bus route

Schedule bus route

Refine GIS travel data layer

Validate route path

Validate stop loc. & time
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Crash at E. Main 10 min. delay

Illegal stop!

First stop 10 min. late
Change school transportation operating environment from “where is the bus?” to information management.
Keep the Big Picture in Mind