Transit Service Reliability

- Impacts of unreliability
- Causes of unreliability
- Reliability Metrics
- Real-Time Control Strategies

Impacts of Unreliability

- Passenger impacts
  - Longer wait times
  - Need for trip time reliability buffer
  - Higher loads (uncomfortable and slow rides)
- Agency impacts
  - Increased costs
  - Reduced ridership and revenue
  - Reduced operator morale
  - Public and political problem
  - Reduced effective capacity

Causes of Unreliability

- External
  - Traffic and traffic signals
  - Demand
  - Incidents (e.g. medical emergency)
- Internal
  - Equipment failure
  - Insufficient resources
  - Poor operations planning
  - Lack of supervision and control
  - Human driver behavior

Transit Service Delivery as a Business Process


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Data-Driven Reliability Management

- Automated Data Collection Systems (AVL, AFC, APC) make it easier to measure reliability
- Automated scheduling systems make it easier to revise schedules
- Improved communications makes it easier to adjust operations plans in real time

Reliability as a Performance Measure

- Reliability is not the only service dimension of value
  - Speed/trip time
  - Productivity
- Reliability means different things
  - To different customers
  - On different services
- A single measure of effectiveness focused on reliability may lead to poor decisions
  - ... but ...
- We do need to measure performance with respect to reliability

Reliability on Low Frequency Service

Most customers time their arrival at stops/stations based on expected service departure times (e.g. schedule)
- On-time performance is critical, for example:
  - 1 minute early to 5 minutes late
  - 0 minutes early to 3 minutes late
  - 0 minutes early to 1 minutes late
- Little interaction between successive vehicles
- Real-time information is changing this
  - Poorly understood
    - In what manner?
    - To what extent?
    - What are the implications?

Reliability on High Frequency Service

- Most customers do not time their arrival at stops with service departures
- Expected wait time depends on mean and variance of headways
- Punctuality is not so critical
- Extensive interaction between successive vehicles:
  - Vehicle bunching
  - Long gaps
  - ... but ...
- High frequency routes can have branches and short route variants, so many customers may still behave like those on low frequency routes
- Schedule control is much easier than headway control
Reliability Buffer Time

High Frequency Service, Closed Fare System
- use tap-in and tap-out times to measure actual station-station journey times
- characterize journey time distributions measures such as Reliability Buffer Time (at O-D level)

\[
RBT = 95^{th} \text{ percentile travel time} - \text{median travel time}
\]

additional time a passenger must budget to arrive late no more than 5% of the time

Reliability Metrics - Rail

- Aggregate to line level by distinguishing between normal and incident days

Reliability Metrics - Bus

In contracted service delivery context, need to distinguish between:
1. Contractor performance: measure against contracted service expectations
2. Performance as seen by passenger

If service is unreliable, the passenger doesn't care whether the problem was caused by traffic or poor operator behavior, but the authority must be sure which caused the problem.
Reliability Metrics - Bus

Challenge to measure passenger journey time because
- (typically) no tap-off, just tap-on
- tap-on occurs after wait at stop, but wait is an important part of journey time

Strategy to use
- Infer destinations using trip-chaining (ODX)
- Use AVL to estimate
  - average passenger wait time
  - based on assumed passenger arrival process
  - actual in-vehicle time

Preventive Strategies
- Reserve fleet of drivers and vehicles
- Exclusive bus lanes
- Traffic signal priority
- Route design strategies: shorter routes, less stops
- Schedule planning
- Supervision

Reliability Management Strategies

Preventive
- Maintain normal service; robust operating plans
- Reduce probability of problems occurring

Corrective
- Return to normal service once problems arise
- Minimize impact on passengers

Impact of Schedules

Critical decisions
- Cycle time/half cycle time: impacts cost and terminal departure reliability
  - Allocation of time between running and recovery time
- Time Points: impacts cycle time and/or recovery time, reliability along route and passenger trip time
  - Number and location
  - Schedule at each time point
Impact of Schedules

Traditional scheduling approach
- Set half cycle time so that 90-95% of vehicle departures are on time
- Set time point scheduled times at 65 percentile of observed running times

... but ...
- This doesn't recognize the feedback between scheduled time and operating speed
- It is not sensitive to the ratio of passengers on board versus passengers waiting at time point and further down route

Corrective Strategies

- Supervision, operations control
- Holding: schedule-based vs. headway-based
- Transit Signal Priority
- Deadheading
- Expressing
- Short-turning
- Use of reserve vehicles

Holding Strategies

- Schedule adherence
- Scheduled headway adherence
- Threshold headway adherence
- Headway regularity (even headways)
- Optimization (rolling horizon)
  - Models passenger costs explicitly
    - Trade-off between waiting time and in-vehicle time
  - Reduces excessive holding
    - Avoids holding full vehicles
    - Prevents unnecessary reduction of effective capacity
  - Potentially considers operating constraints
    - Excessively late drivers

Rolling Horizon Optimization: Static vs. Dynamic Inputs
**Optimal Holding with Dynamics**

**Dynamic Running Time Functions**
- Dynamic Demand Functions
- Current System State

**Optimization Model**
- Optimum Holding Times to Minimize Cost

**Performance Model**
- Predicted System Evolution (e.g., vehicle trajectories)

**Cost Model**
- Mean-Passenger Cost

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**Optimal Holding with Dynamics**

\[
\text{minimize} \quad \frac{W_V + \theta S W_S}{P} \\
\text{subject to} \quad \text{vehicle movement constraints} \quad \text{passenger activity constraints} \\
0 \leq h_{v,s} \leq h_{s}^{\text{max}} \quad \forall v \in V \quad \forall s \in S
\]

**Rail Operations Control: Decision Factors**

- **Level of service**
- **Passenger impact**
- **Capacity constraints**
- **Uncertainty and manageability**
- **Safety**
- **Crew management**
- **Energy management**
- **Rolling stock management**
- **Infrastructure maintenance**

- These factors can trigger service control interventions or place constraints on interventions performed for other reasons
- Conflicts between objectives are frequent
- Service control can cause unreliability!
- How can we best coordinate and integrate these objectives and constraints?


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Three Levels of Control Problems

- **Routine disturbances** few minutes deviation from schedule
  - speed adjustment
  - dwell time adjustment (selective holding)
  - terminal recovery

- **Short-term disruptions** 5-30 minute blockages
  - holding
  - short-turning
  - expressing

- **Longer-term disruptions** >30 minute blockages
  - single-track reverse direction operations
  - replacement bus service around blockage

State of Practice in Operations Control

- Advances in train control systems help minimize impacts of small incidents
- Major disruptions still handled in individual manner based on judgment and experience
- Little effective decision support for controllers
- Simplistic view of objectives and constraints in model formulation
- Substantial opportunities for more effective models

Disruption Response Strategies

MBTA Green Line Headway Dispatching

**Current Operations**

- Trains dispatched by on-site inspectors following the schedule

**Headway Dispatching Pilot**

- Decision support tool delivered on touchscreen tablet
- Even headway dispatching, with constraints
- Contains vehicle and driver information
