Combining speed adjustment and holding control for regularity-based transit operations

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Outline

• Introduction
• Control strategy formulation
• Application
• Results and analysis
• Conclusions
Introduction

Bus bunching
- Inefficient operation
- Require measures → control strategies

*Bus bunching (Source: Land Transport Guru)*
Introduction

Different types of control strategies:

• **Holding control**
  – Holding/delaying vehicle at control point stop
  – Simple, convenient
  – Increase waiting time onboard $\rightarrow$ longer generalized travel time

• **Speed adjustment**
  – Control by speeding up and slowing down the vehicle
  – Holding en-route $\rightarrow$ cost less
  – Less stable under conditions with more variability

• **Combined control strategies**
  – Potential improvements

This study:

• Combine the potential of holding control and speed adjustment
• Aim at improving regularity and reducing the waiting time onboard
• Impacts?
Control strategy formulation

• Rule-based control strategy

• Assumptions:
  1. Real-time communication between buses (event-based)
  2. Runs on dedicated lane
  3. Neglecting acceleration and deceleration effect
  4. Arrival time prediction based on the scheduled trip time
Control strategy formulation

- Headway reference
- Current position
- Network and transit system characteristics
- Operational constraints

State 1: Enter link
1. Arrival time prediction
2. Headway checking
3. Deriving speed advice

State 2: Enter stop
1. Arrival time prediction
2. Headway/early departure checking
3. Departure time advice
Application
Case study of Almere, the Netherlands

- Run by Keolis Nederland
- High-frequency bus operation (h = 5 min)
- Run on dedicated lanes
- Schedule-based holding control
- Consider 2 lines: M5 (16 Stops) and M7 (17 Stops)
- AVL and APC data April-May 2018

Scenario based on trip time scheduling:
- Scenario 1: Normal condition
- Scenario 2: Tighter schedule

Passenger activity in M5 and M7 (April-May 2019)
Application

- HOLDING CONTROL
  - Schedule-based holding control
  - Headway-based holding control
  - Different control point
  - Maximum holding time

- SPEED ADJUSTMENT
  - Different speed range

- SPEED ADJUSTMENT+
  - HOLDING
  - Different speed range

1. Coefficient of Variation (CoV) headway
2. Generalized travel time
Results and analysis
Scenario 1 – CoV headway

Proposed control strategy (SH):
- 11-63% regularity improvement compared to holding control
- 0-39% regularity improvement compared to speed adjustment-only (SA)

Factor affecting the effectiveness of SH:
1. Speed range
   - SH1 in Dir 2
2. Demand pattern
   - SA vs SH
Results and analysis

Scenario 1 – Generalized travel time

Proposed control strategy (SH):

- **0-4 minutes** longer generalized travel time than holding control

- **23-97%** average total holding time reduction (28–93 s) compared to holding control at all stops (EHALL)

- **1-31%** prolonged trip time (1-23 s longer) between stops compared to holding control
Results and analysis
Scenario 2 – CoV headway and generalized travel time

- Increase in irregularity
- Importance of arrival time prediction
- Example: Line M5 Dir 1 (-305%) and Line M7 Dir 2 (+61%)

- Longer generalized travel time for all strategies (7-9% longer)
Conclusion

• Combining strategies implies combining both the positive and negative attributes of each control
• Line characteristics determine the performance of each strategy
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Thank you!

Question?