A Brief Summary of Real-time Bus Regularity Control
From a Simulation Study to Full-scale implementation

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Transport systems are inherently dynamic and stochastic

• Planning should also involve planning for the unplanned!

• Need for **proactive operations**

• Models to analyse service performance should represent
  • Sources of uncertainty
  • Interactions between system components
  • Adaptation strategies
Adaptation

- Service providers
  - Mitigate in the strategic and tactical planning phases
  - Control and management (preferably proactive)

- Service users
  - Day-to-day learning
  - Rerouting (preferably based on information)

- Involves predictions/expectations on future system states

- Role of Advanced Public Transport Systems

- Especially crucial in case of service disturbances/disruptions
Service unreliability: A vicious cycle
Example: Line 1, Stockholm

How can we improve regularity without compromising speed?
Strategic planning

Tactical planning

Real-time operations

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Real-time strategies

- Between stops
  - Speed adjustments
  - Transit signal priority
  - Overtaking

- At stops
  - Stop skipping/expressing
  - Holding/synchronizing
  - Short turning/deadheading
From idea to implementation

Idea generation
Understanding the problem

Analyses, lab/desktop tests and refinements

Field trial
Data collection

Analyses of field trial data

Implementation
From idea to implementation
From idea to implementation

Operator(s)

8:00  8:01

Analyses

Field trial

Analyses of field trial data

Implementation

Idea generation

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Analyses, lab/desktop tests and refinements

Data collection
From idea to implementation

- Operator(s)
- Application
- Research

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Implementation
A series of field experiments

- **RETT2**
  - Experiment – Line 1
  - Focus on regularity, decentralization

- **RETT3**
  - Experiment – Lines 1 and 3
  - No interlining, control center actions
  - Bus driver stress measurements
  - Led to its incorporation in the tendering process

- **RETT4**
  - Experiment – Line 4 (highest demand)
  - Additional measures – boarding, priority
  - Support full-scale implementation, including the development of an incentive scheme
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Define

- Define project objectives and identify opportunities
- Determine project scope, team, process, resources and timeline
- Set and quantify desired outcomes

Key aspects
- Problem description (causes not symptoms)
- Stakeholders involvement
- Identify and address barriers/risks
- Action plan
Line 4 Stockholm
Fact sheet

- **Route**: 31 stops along 12km, cross-radial inner-city line
- **Commercial speed**: 12.56 km/hr
- **Frequency**: 4-6 minutes all day long
- **Vehicle**: Articulated buses
- **Demand**: 65,000 passengers per day
Measure

- Evaluate and understand the current system state
- Identify and measure input and output variables
- Map relations between sub-processes

Key aspects
- Data collection plan and techniques
- Focus on performance variability
- Visualization
Estimating OD matrix from APC
15:00-18:00, 2014
Empirical performance evaluation

- Link related
- Operation & Control
- Stop related

Vehicle performance:
- Running time
- Reliability
- Dwell time

Vehicle times:
- Total trip time

Passenger times:
- In-vehicle time
- Waiting time
- Total travel time

Measure:
- APC / AFC
- AVL
- Demand Pattern

Monetary values:
- Measures
- Link related Operation & Control Stop related

Steps:
- Step 1
- Step 2
- Step 3

Monetary values:
- Measures
- Link related Operation & Control Stop related

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Analyze

- Determine the potential causes of quality problems
- Separate the sources of variability and their causes
- Deploy experimental, statistical and simulation tools

Key aspects
- Establish relations between system variables
- Identify variables and process to be targeted
Adaptive headway-control strategy

- Various strategies were evaluated using BusMezzo

- The most promising strategy
  - Try to remain in the middle with respect to the preceding and successive buses
  - Adjust your speed if possible
  - Disregard the timetable

\[
ET_{s,l}^k = \max \left( \min \left( ET_{s,l}^{k-1} + \frac{ET_{m,l}^{k+1} + SRT_{m,s} - ET_{s,l}^{k-1}}{2}, ET_{s,l}^{k-1} + \alpha h_{s,l}^k \right), AT_{s,l}^k + DT_{s,l}^k \right) \forall s \in S_l^k
\]
Decentralized headway control

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Simulation analysis

- Bus traffic simulation model development
- Represent sources of uncertainty
- Specify alternative control strategies
- Scenario design
- Performance analysis
Improve

• Design the solution
• Implement specific changes in the system to achieve the desired impact on system performance

• Key aspects
  • Pilot test the solution
  • Analyze carefully and systematically pilot results
  • Refine, Revise, Repeat
Line 4 Stockholm
Field experiment details

• Measures
  ✓ Introducing bus lanes on some line sections
  ✓ Cancelling 4 stops
  ✓ Running based on regularity
  ✓ Improving transit signal priority
  ✓ Allowing restricted boarding from the third door
  ✓ Street layout changes

• Period: 17-03-2014 – 19-06-2014
  • AVL (100%) and APC (15%) data
  • Compare with same period in 2013
Field experiments

Before
- Experiment design plan
- Control room training sessions
- Information campaign

During
- Supervising, monitoring, refining
- Feedback meetings
- Before-After analysis

RETT2
RETT3
RETT4
Before-After analysis
(One week before the experiment)
Before-After analysis
(One week after the experiment)
Better service regularity
Headway distribution

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Headway regularity evolution along the routes
...and excessive waiting time follows suit
More reliable fleet operations

Peak period

-9% Total running time
-3:26 Average trip time
-3:36 90th trip time

Significantly fewer extremely long trips

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Passenger time savings

- Average generalized travel cost 22:37 -> 14:19
Control

- Establish procedures to institutionalize the improvements
- Identify new problems and opportunities

- Key aspects
  - Continuously monitor system performance
  - Quantify the benefits of the project
Evaluation

- Excessive waiting time
- In-vehicle time
- Total travel time (1172->1056 sec)

- **Annual savings of 36.8 million SEK (3.87 million Euro)** for weekdays 7am-7pm
  - of which 2.76 million SEK are operational cost savings
Full-scale implementation

- Introduce regularity-driven operations along the service chain
  - Production planning
  - Daily operations
  - Control centre
  - Performance monitoring

- Design incentive scheme
- Reconsider business models

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Conclusion

• The latest procurement in Stockholm requires operating high-frequency bus lines based on regularity

• In fact, the bus operator, in consultation with the agency and the driver union, decided to continue with headway-based control and operations even before this was introduced into the contract

• New performance indicators and incentive schemes

• Systematic evaluation of the impact of bus improvement measures
  • both passenger and operator perspectives

• In addition to the improved reliability for both passengers and operators,
  • Removes the need to routinely negotiate timetables
  • Improves the working conditions for drivers
Questions? Ideas? Suggestions?

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