BusMezzo
Dynamic Transit Operations and Assignment Model

Modelling approach and applications

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Key model capabilities (I)

- **Traffic dynamics.** Each individual vehicle is affected mesoscopically by traffic conditions on links and at intersections.

- **Transit operations.** Sources of uncertainty such as traffic dynamics, flow-dependent dwell times and propagation of delays through vehicle scheduling are modeled explicitly. A library of holding control strategies is available.
Key model capabilities (II)

- *En-route passenger decisions.* Each individual passenger takes a sequence of travel decisions based on his/her expectations which are based on service provision, real-time information (if applicable) and past experience (when using iterative network loading). A library of real-time information provision alternatives is available.
Key model capabilities (III)

- **Disruptions.** Simulating unplanned partial capacity reductions on network links.

- **Day to day learning.** Performing an iterative network loading where individual travelers gain experience about service attributes, including waiting times, on-board crowding and the reliability of real-time information.
BusMezzo developers

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Oded Cats, BusMezzo Intro, July 2018
Modelling approach
Modelling philosophy

• Modelling public transport system dynamics
• Multi-modal metropolitan public transport networks
• Represent sources of uncertainty
• Adaptation of both supply and demand agents
• Enable modelling the effects of ITS

Implementation approach
• Object-oriented programming
• Integrated with a mesoscopic traffic simulation
• Modular, range of applications
• Research tool
Model development evolution

- Public transport supply
- Dynamic route choice
- Information, reliability, congestion, disruptions
- Day-to-day learning
Agent-based, bottom-up order

- Emergence of global spontaneous order from numerous interdependent local decisions
- Adaptive behavior
- System dynamics
- Examples
  - Ecology, biology
  - Social networks
  - Market dynamics
  - Crowd management
  - Travel patterns
Dynamic assignment

Travel Behavior

Travel choices

Network performance

Travel time
Reliability
Crowding
Positioning Agent-based DTA

- Schedule-based
- Frequency-based
- Agent-based

Supply vs. Demand

- Macro vs. Micro

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Modelling framework

Service Planning

Traffic Dynamics & Transit Operations

Dynamic Loading

Automated Data Collection

Real-Time Prediction

Control Centre

Day-to-day

Within-day

Fleet

Passenger Assignment

Traveler Decisions

Traveler Perception

Traveler Strategy

Traveller Population

Transit Performance

Network

Service Planning

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Object-oriented framework

Legend:
- Subclass
- One to one relationship between object classes
- One to many relationships between object classes

PRIVATE VEHICLE
- Follows
- Loads

TRANSIT VEHICLE
- Follows
- STEERS
- Loads

VEHICLE

CONTROL CENTRE

DAY
- Has

LINE
- Has

TRANSIT ROUTE

ROUTE

PATH

OD

TRIP

TRAVELLER
- Arrives

USER GROUP

Legend:
- Subclass
- One to one relationship between object classes
- One to many relationships between object classes

Follows
- Assigns

Has
Network representation

- **Transit vehicle trajectory**
  - Ride
  - Queue
  - Dwell
  - Recover

- **Traveller trajectory**
  - Walk
  - Wait
  - On-board
Demand modelling

- Poisson arrival process
- Non-compensatory rule-based choice-set generation process
- En-route decisions
  - Assess the attributes of each available path
  - Calculate the joint utility (Logsum) of the bundled paths
- Path: outcome of successive decisions
Range of model applications

**Strategic**
- Evaluating network alternatives
- Network robustness analysis

**Tactical**
- Reliability of timetable design
- Transfer synchronization

**Operational**
- Real-time control strategies
- Disruption management

Networks: Stockholm, Amsterdam, BRT Haifa
Reliability and Control

Real-time Information

Network Resilience

Congestion

Applications
Congestion

or when $\text{VOC} = 0.8$ is not good enough
How can the value of reduced congestion be quantified?
Evaluation of congestion effects

On-board crowding → Increased perceived in-vehicle time

Denied boarding → Increased waiting time

Reduced service reliability → Increased total travel time
Appraisal of Increased Capacity

- Crowding factor in static/dynamic model: +3%/+120%
- Value of increased capacity: underestimated in static models
Reliability

or when the average headway is hardly experienced
From Research to field implementation

**Modeling** - Transit operations simulation model, BusMezzo

**Validation** - Tel-Aviv case study

**Evaluation and Optimization** - Real-time holding strategies for Stockholm case study

**Demonstration** - Field trial

**Implementation** - Full-scale operations
Example: Preferential measures

- Line 4 in Stockholm, 4-6 minutes headway 65k passengers per day
- Field experiment of bus lanes, stop consolidation, regularity-based operations, allowing boarding from the rear-door,…
- Objective: measure impacts on modal share, accessibility, equity and satisfaction
- Data: AVL and APC
Simulation results

1 min boarding
3 min control
2 min physical
Information

or when passengers do not have perfect knowledge
Impacts of Information

Path choice

Performance

Prediction

Provision

Perception
Passengers’ Response to Service Reliability and Travel Information
Final distribution of credibility coeff.  

Example: evolution of credibility coeff. 

\[ \alpha_{j,n}^{\lambda}(d + 1) = (1 - \kappa_n^\alpha) \star \alpha_{j,n}^{\lambda}(d) + \kappa_n^\alpha \star \left( \left( \frac{t_{j,n}^{e(\lambda)}(d)}{t_{j,n}^{\alpha}(d)} - 1 \right) + 1 \right)^\nu \]
Vulnerability

or when passengers can not execute their pre-trip plan
Capturing disruption dynamics

- Static model: underestimation of disruption effects
- En-route decisions, imperfect information
- Both passengers and operators can respond to disruptions

*Spill-over*—secondary effects caused by either supply processes or passenger rerouting

*Upstream*—vehicles progress until they queue upstream of the link closure

*Downstream*—can reconsider and revise their travel decisions

*Stranded passengers*—on-board passengers are unable to alight and have to wait until the service is restored
Model applications

- Flow (re-)distribution model (route choice)
- Modelling disruptions (capacity, frequency)
- Identifying critical links (network indicators)
- Modelling adaptation strategies (ex-ante, ex-post)
- Measuring the impact (connectivity, robustness)
Normal operations

Passenger trip-loads

Disruption (D4)

Travel time distribution

Impacts of information provision

Change in flow/capacity
The road ahead

or what are we currently working on
On-going developments (I)

- **Real-time control strategies** [ADAPT-IT; Giorgos, David, Hend]
  - Extending the toolkit
  - Scaling-up to corridors and networks

- **Real-time transfer management** [TRANS-FORM; Menno, Flurin]
  - Interfacing with railway scheduling optimization and hub pedestrian flow models
  - Transfer synchronization control

- **On-demand services and hybrid PT** [SMART, iQMobility; David, Jonas]
  - Combined fixed-flexible operations and passenger assignment
  - Optimal allocation of automated buses
On-going developments (II)

- Passenger on-board and station platform crowding [CROWD; Melina]
  - Passenger metro car and platform section choices
  - Congestion propagation

- Real-time crowding information [Arek, Rafal]
  - Prediction and dissemination alternatives
  - Impacts on equilibrium conditions

- User adaptation under uncertainty [MyTRAC; Sanmay]
  - Robust route choice making
Relevant references (I)


Relevant references (II)


Relevant references (III)


