Reducing variability in passenger transfer times with two management strategies (inside transportation hubs)

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Reducing variability in passenger transfer times with two management strategies
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Context

Pedestrians suffer from congestion just as vehicles do:

- increased travel time,
- excessive density.

Which in turn can make you:

- be late for your job interview,
- despise traveling in public,
- miss your connecting train or plane,
- ...

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Context

Higher capacity & faster PT services, to serve higher demand.
Context

Some of the services available at the Lausanne (CH) train station...

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Motivation

• Lack of comfort, hazardous situations, miss connections.

• How to prevent this? Some possibilities:
  – Decrease pedestrian demand (counter productive!)
  – Spread the load over time & space
  – Influence pedestrian’s routes
  – ...

• Simulation is needed to address the complexity of the problem

Goal: Integrate management strategies specific to pedestrian traffic within a Dynamic Traffic Management System (DTMS).
Framework

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Strategies

What specific measures can be considered to impact dynamics:

- Adjustments to the PT schedule
- Control access to specific areas ⇒ gates
- Change link travel time ⇒ moving walkways
- Prevent counter flow ⇒ flow separators
- Attract pedestrians to specific locations
Existing strategies

Pedestrian management
- Little research on dynamic strategies.
- Some static measures (design) have been studied.

Road traffic management
- Ramp metering
- Perimeter control
- Variable message signs
- Traffic lights
- ...
Proposed management strategies

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Proposed strategies

**Gating**
Prevent excess travel time in junctions.

**Flow separators**
Avoid counter flow in corridors.
Proposed management strategies

Gating
Objective

At corridor intersections, highly disordered flows takes place.

↓

Prevent too many individuals from crossing the intersection simultaneously (qualitative). → Prevent increase in travel time.

↓

What to measure? (quantitative)

• flow
• density
• speed
Density measurement

Some possibilities for measuring density:

**Pedestrian accumulation**
- snapshot
- sensitive to delimited area
- provides average values

**Voronoi based**
- snapshot
- expensive to compute
- provides individual values
- aggregation may be required

**Edie’s definition**
- average over time
- sensitive to delimited area
- provides average values
- strong physical interpretation
Density measurement

People with low densities are not problematic.

⇓

Count only “congested” pedestrians ⇒ need threshold.

The indicator used is the following:

For a density threshold $\bar{\rho}$,
for a given snapshot taken at time $t$,
count the number of individuals where $\rho_i(t) > \bar{\rho}$.

This gives a pedestrian-centric measurement (nearly) independent of any “zone”.

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Setup

The level-of-service must be measured and controlled inside area $A$.

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Control law

Parameters

- density threshold: $\bar{\rho}$
- uncontrolled flow: $f(0)$
- cut off value: $f(?) = 0$

Calibration based on:

- fundamental diagram
- distribution of individual densities
Proposed management strategies

Flow separators
Objective

Head-on-head “collisions” induce significant extra travel time.

\[ \downarrow \]

Reduce this counter-flow to a minimum.

\[ \downarrow \]

Dynamically allocate part of the available corridor width to each direction.
Setup

Figure: Schematic presentation of the devices used to separate the opposing flows. The inflow at each end determines the width available to each directed flow.

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Width available for each direction is proportional to flows:

\[
W_{AB} = \begin{cases} 
  w \cdot f_{\text{min},AB}, & \text{if } \frac{\sum q_{\text{in},A}}{\sum q_{\text{in},A} + \sum q_{\text{in},B}} \leq f_{\text{min},AB} \\
  w \cdot f_{\text{max},AB}, & \text{if } \frac{\sum q_{\text{in},A}}{\sum q_{\text{in},A} + \sum q_{\text{in},B}} \geq f_{\text{max},AB} \\
  w \cdot \frac{\sum q_{\text{in},A}}{\sum q_{\text{in},A} + \sum q_{\text{in},B}}, & \text{otherwise}
\end{cases}
\]
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Case study setup

Gating

- crossed shaped junction
- demand pattern:
  - sinusoidal for two directions
  - uniform for other two

Flow separators

- straight corridor
- shifted sine-shaped flows
Case study setup

- Discrete event simulator combined with a
disaggregate pedestrian motion model: NOMAD.

- Graph-based route choice (but no critical for now).
- Stochastic simulation → multiple runs.
Results

Gating results
**Travel times**

(a) Without gating  
(b) With gating

No significant difference in mean travel time: 21.04s VS 21.18s  
Reduction in travel time variance: 5.16s → 4.41s (−14%)  
- fewer people have long travel times
Individual density

(a) Without gating

(b) With gating

Decrease of

- mean density: $2.18\text{pax/m}^2 \rightarrow 1.82\text{pax/m}^2 \ (-16\%)$
- density variance: $1.22\text{pax/m}^2 \rightarrow 1.02\text{pax/m}^2 \ (-16\%)$
Average density

(a) Without gating

(b) With gating

Decrease of

- mean density: \(1.57 \text{ pax/m}^2 \rightarrow 1.42 \text{ pax/m}^2\) (\(-9.5\%\))
- density variance: \(0.93 \text{ pax/m}^2 \rightarrow 0.72 \text{ pax/m}^2\) (\(-22\%\))
Improvements

• less risk of gridlock.
• better level-of-service in the junction.

without increasing travel time.

Open questions:

• complex distributions: mean and variance meaningful?
• shape of the control law?
• parameter calibration?
• can travel time be improved?
Results
Flow separators results
Travel times

(a) Without flow separators

(b) With flow separators

Significant improvement in

- mean travel time: $37.86s \rightarrow 30.31s (-19\%)$
- travel time variance: $9.94s \rightarrow 3.39s (-66\%)$
Conclusion & next steps

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Conclusions

- Integration of two pedestrian control strategies in a DTMS.
- Gating improves the level-of-service and helps prevent gridlock.
- Flow separators significantly improves the travel time.

Next steps

1. Investigate more complex control laws (improvement ?).
2. Apply in more general context: train stations.
3. Model predictive control.
4. Simulation based optimization.
5. Dynamic control of accelerated moving walkways.
Thank you for your attention! Questions?

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