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

Nicholas Molyneaux, Riccardo Scarinci, Michel Bierlaire

International Conference on Operations Research 2018

September 14^{th} 2018

Outline

1. Introduction
2. Proposed management strategies
   - Gating
   - Flow separators
3. Results
   - Gating results
   - Flow separators results
4. Conclusion & next steps

Introduction

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,
- ...

Context

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

Context

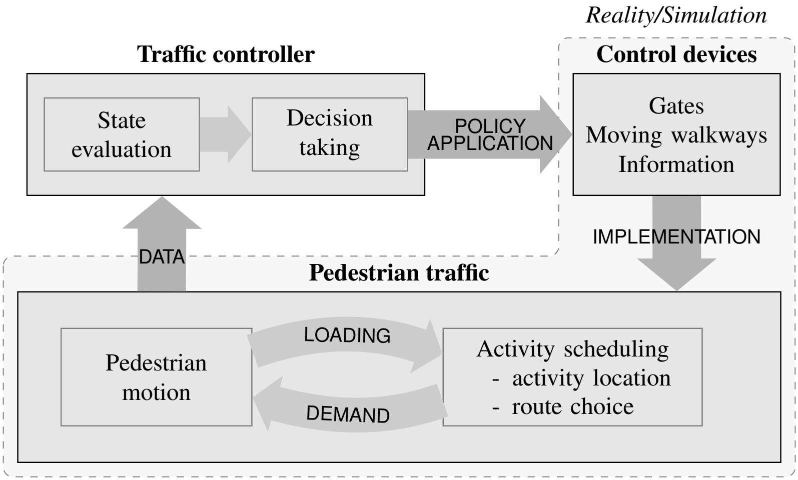
Some of the services available at the Lausanne (CH) train station...

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


Reality/Simulation
Traffic controller
State evaluation
Decision taking
POLICY APPLICATION
Control devices
Gates
Moving walkways
Information
IMPLEMENTATION
DATA
Pedestrian traffic
Pedestrian motion
LOADING
DEMAND
Activity scheduling
- activity location
- route choice

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 be studied.

Road traffic management

- Ramp metering
- Perimeter control
- Variable message signs
- Traffic lights
- ...

Proposed management strategies

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.

$\Downarrow$

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

$\Downarrow$

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.

$$\Downarrow$$

Count only "congested" pedestrians $\Rightarrow$ need threshold.

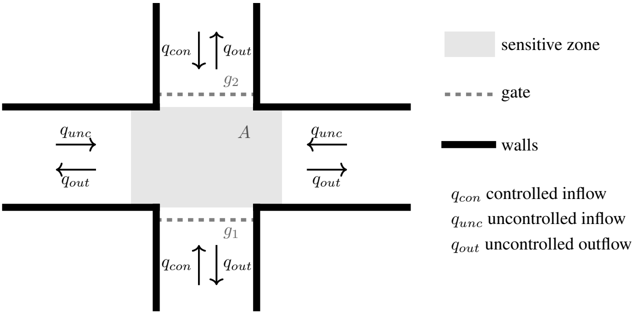
The indicator used is the following:

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".

Setup

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



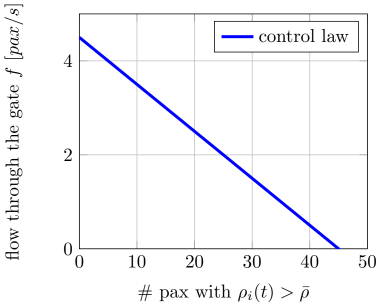
Control law

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.

⇓

Reduce this counter-flow to a minimum.

⇓

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

Setup

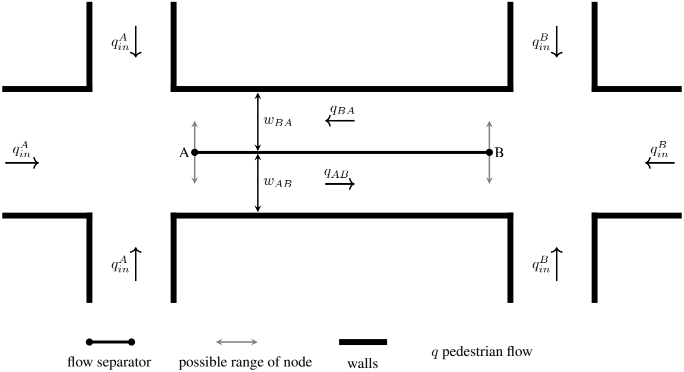


Figure: Schematic presentation of the devices used to separate the opposing flows. The inflow at each end determines the width available to each directed flow.

Width available for each direction is proportional to flows:

$$w_{AB} = \begin{cases} w \cdot f_{min,AB}, & \text{if } \dfrac{\sum q_{in,A}}{\sum q_{in,A} + \sum q_{in,B}} \leq f_{min,AB} \\ w \cdot f_{max,AB}, & \text{if } \dfrac{\sum q_{in,A}}{\sum q_{in,A} + \sum q_{in,B}} \geq f_{max,AB} \\ w \cdot \dfrac{\sum q_{in,A}}{\sum q_{in,A} + \sum q_{in,B}}, & \text{otherwise} \end{cases}$$

Results

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

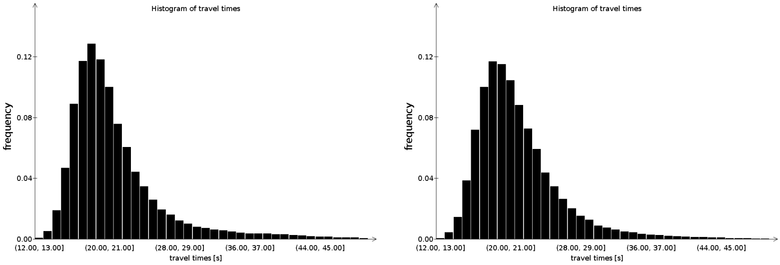
- Discrete event simulator combined with a
- disaggregate pedestrian motion model: NOMAD.

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

Results

Gating results

Travel times

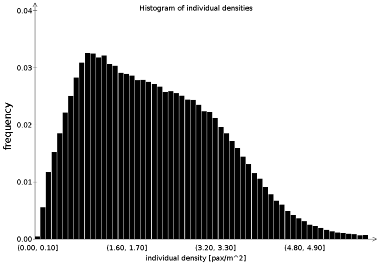


(a) Without gating (b) With gating

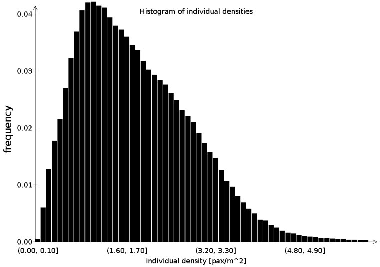
No significant difference in mean travel time: $21.04s$ VS $21.18s$
Reduction in travel time variance: $5.16s \rightarrow 4.41s$ (-14%)

- fewer people have long travel times

Individual density



(a) Without gating

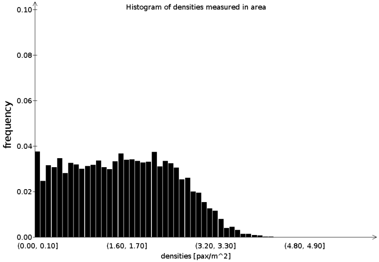


(b) With gating

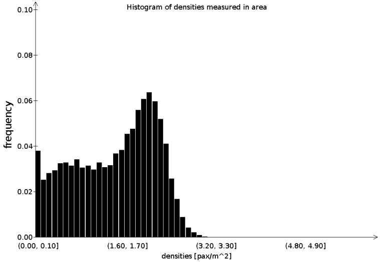
Decrease of

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

Average density



(a) Without gating



(b) With gating

Decrease of

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

Improvements

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

without increasing travel time.

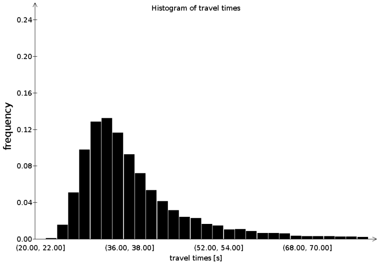
Open questions:

- complex distributions: mean and variance meaningful ?
- shape of the control law ?
- parameter calibration ?
- can travel time be improved ?

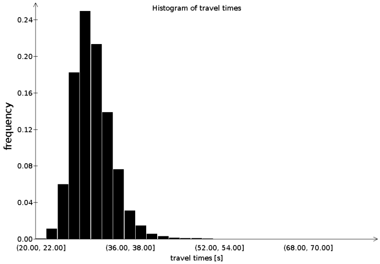
Results

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

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 ?

nicholas.molyneaux@epfl.ch

Acknowledgments

This research was performed as part of the TRANS-FORM (Smart transfers through unravelling urban form and travel flow dynamics) project funded by the Swiss Federal Office of Energy SFOE and Federal Office of Transport FOT grant agreement SI/501438-01 as part of JPI Urban Europe ERA-NET Cofound Smart Cities and Communities initiative. We thankfully acknowledge both agencies for their financial support.

ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE