Controlling Pedestrian Flows Using a Dynamic Traffic Management System

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Outline

Introduction

Context

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

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Context

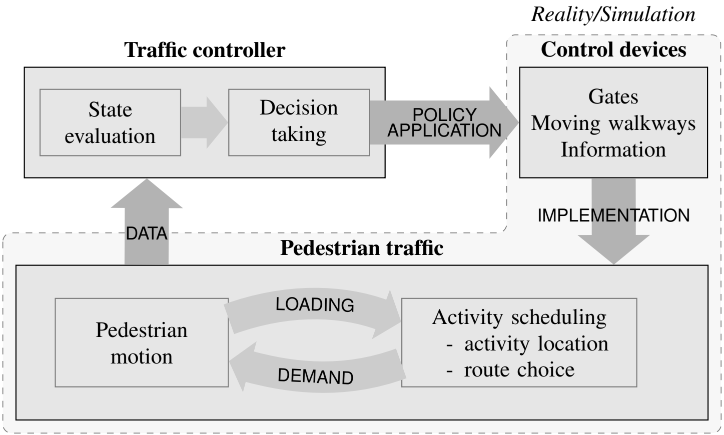
Some of the services available at the Lausanne (CH) train station...

Motivation

- Lack of comfort, hazardous situations
- How to ensure a satisfactory level-of-service & safety?
  - Decrease pedestrian demand (not recommended!)
  - Spread the load over time & space
  - Influence pedestrian's routes
  - ...
- Simulation is needed to address the complexity of the problem

Goal: **Design a framework to evaluate the impact of management strategies and to generate optimal control polices**

Framework


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

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 specific strategies.
- Some static measures (design) have be studied.

Traffic management

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

Perimeter control - Keyvan-Ekbatani et al. (2012)

- Exploit the properties of the MFD
- Develop process equation for "total time spent" and "total traveled distance".
- Calibrate PI controller based on simulation data from a city.

We will follow the same approach, except for pedestrian traffic.

Gating as a control strategy

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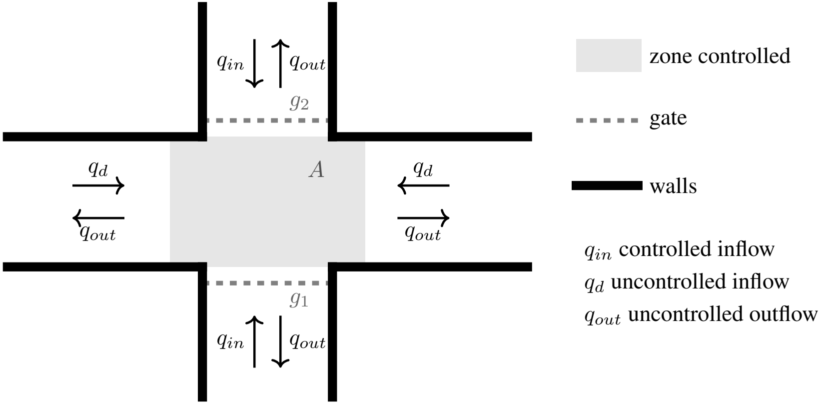
Setup

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



Process equation development

Conservation of pedestrians:

$$\frac{dN(t)}{dt} = q_{in}(t) + q_d(t) - q_{out}(t) \quad (1)$$

with:

- N is the number of people inside area A
- q_{in} **controlled** inflow
- q_d **uncontrolled** inflow
- q_{out} outflow

Two hypotheses

1. Hypothesis 1: A linear relation exists between outflow and *generalized flow* ($q_{out} = C_1 \cdot q_{e,gen}$).
2. Hypothesis 2: A pedestrian fundamental diagram exists.

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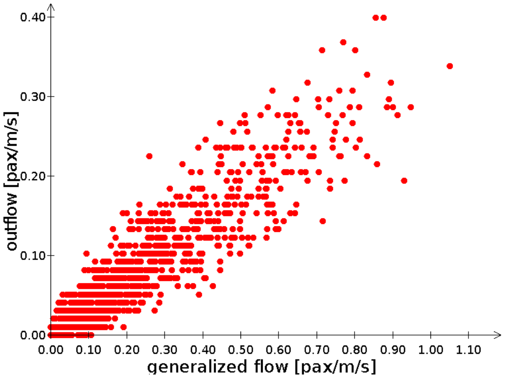
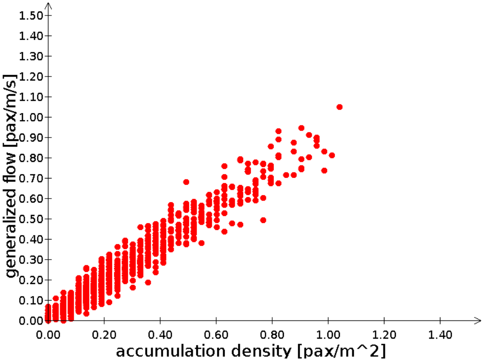
Hypothesis 1

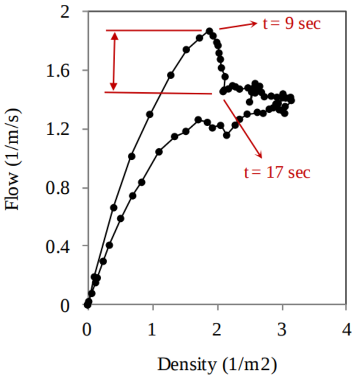


5 second intervals, based on tracking data in Lausanne

Hypothesis 2



(a) Tracking data



(b) Saberi and Mahmassani (2014)

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Process equation development (ctnd)

By exploiting both hypotheses and formulating the problem in terms of difference from steady state values, the process equation can be written as

$$\Delta\rho(k) = e^{-\frac{\Delta t \cdot F' \cdot C_1}{\omega_A}} \Delta\rho(k-1) + \frac{1}{F' \cdot C_1}\left(1 - e^{-\frac{\Delta t \cdot F' \cdot C_1}{\omega_A}}\right) \cdot [\Delta q_{in}(k-1) + \Delta q_d(k-1)] \quad (2)$$

From the process equation, a linear quadratic regulator is developed using standard methods of optimal control.

Flow separators

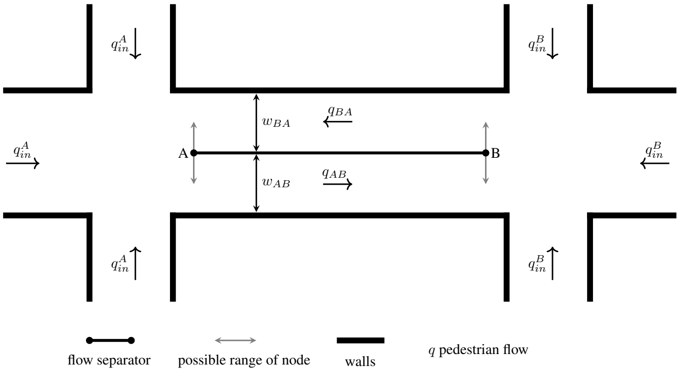

Figure: Schematic presentation of the devices used to separate the opposing flows. The inflow at each end determines the width available to each directed flow.

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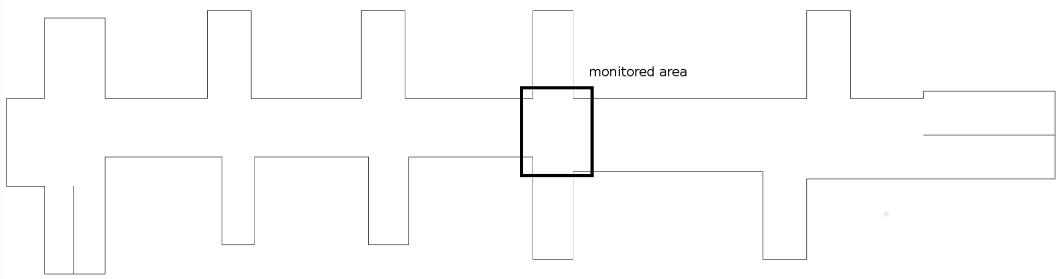
Width available for each direction is propotional to flows:

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

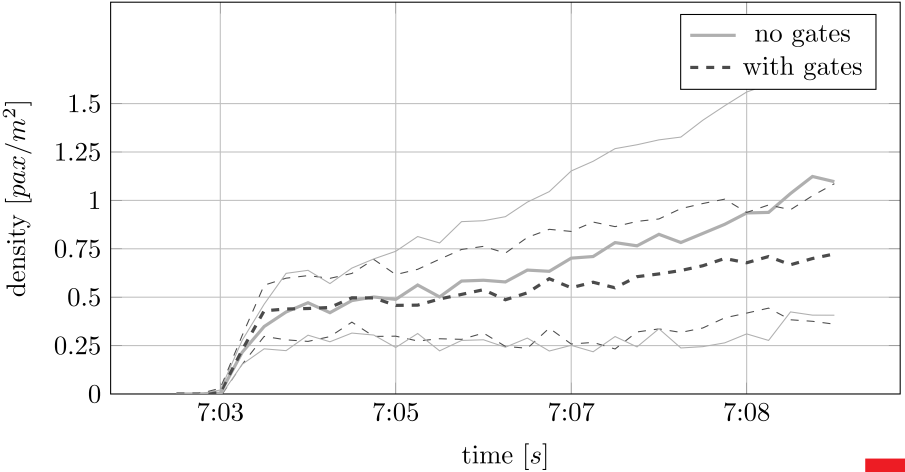
Results

Simulation setup

- Microscopic pedestrian simulator: NOMAD (Campanella, 2016)
- Route choice: shortest path
- Environment: Lausanne train station
- Demand: arrival of several trains
- Scenario: gates for avoiding excessive congestion


monitored area

Densities


no gates
with gates
1.5
1.25
1
0.75
0.5
0.25
0
density $[pax/m^2]$
7:03
7:05
7:07
7:08
time $[s]$

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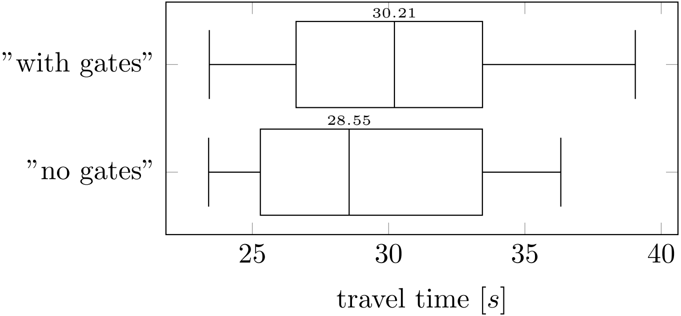
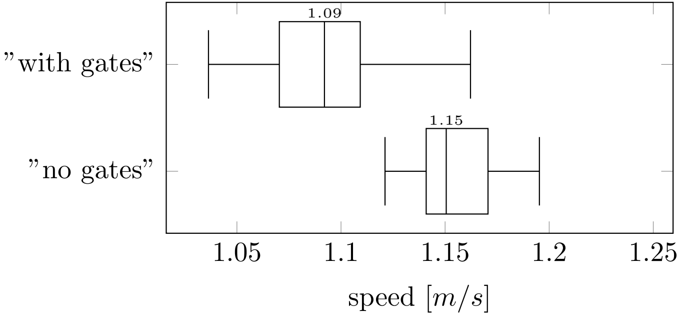
At what cost ?



Gates induce a increase of 5.8%[s] in travel times.

At what cost ?



Gates induce a decrease of 5.5%$[m/s]$ in speed.

Conclusion & next steps

Conclusions

- Assumptions have been verified thanks to empirical data.
- Usage of optimal control simplifies calibration.
- Decrease in density levels with very minor increase in travel times.
- Flow separators have potential to prevent counter flow.

Next steps

Short term

1. Run simulations and evaluate effectiveness of flow separators.
2. Use more advanced implementation of pedestrian simulator.

Long term

1. Implement accelerated moving walkways.
2. Model predictive control.
3. Simulation based optimization.

Thank you for your attention !

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Acknowledgments

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Keyvan-Ekbatani, M., Kouvelas, A., Papamichail, I., and Papageorgiou, M. (2012). Exploiting the fundamental diagram of urban networks for feedback-based gating. *Transportation Research Part B: Methodological*, 46(10):1393 – 1403.

Saberi, M. and Mahmassani, H. (2014). Exploring areawide dynamics of pedestrian crowds: three-dimensional approach. *Transportation Research Record: Journal of the Transportation Research Board*, (2421):31–40.