Pedestrian management strategies for improving flow dynamics in transportation hubs

Nicholas Molyneaux, Riccardo Scarinci, Michel Bierlaire

17^{th} Swiss Transport Research Conference
Monte Verità, May $17^{th} - 19^{th}$ 2017

May 18^{th} 2017

Outline

1. Introduction
2. Management strategies
   - Hard strategies
   - Soft strategies
3. Simulation framework
   - Pedestrian movement models
   - Activity scheduling
   - Train induced flows
   - Key performance indicators
4. Case study
5. Conclusion
6. References

Comments after presentation

- Clarify my contribution: mgmt strategies and not mvmt model or act scheduling. Insist more on box structure.
- Framework which can be used with different codes
- Not spend too much time implementing
- Disaggregation process: when, how ? Agg seems ok from SF
- Add event based framework, would clarify I think.
- Event based with mesoscopic ?
- Really need define framework with plug/play structure.

Introduction

Context

- Strong increase in public transport demand
- All PT services require an infrastructure for pedestrians to use the services $\rightarrow$ transportation hubs
- When many different services arrive at the same time in the hub $\rightarrow$ pedestrian congestion

Motivation

- Congested infrastructures are uncomfortable for users and possibly dangerous
- Variability in pedestrian travel times makes schedule adherence challenging
- Goal: keep good LOS and decrease trip variability
- Some possible actions to accomplish this (not all are recommended!):
  - Decrease pedestrian demand
  - Spread the load over time & space
  - Management strategies
  - Improve dynamics
  - ...
- How to know which ones are effective, feasible or financially manageable ?

Motivation (ctnd)

- Need a framework for evaluating possible measures
- As many measures are expensive to put in place, a simulation framework should be available

$\Downarrow$

- Evaluate impact of management strategies for improving pedestrian flow dynamics

- Requirements
  - Management strategies
  - Pedestrian simulator
  - Measurement of impact

State-of-the-art

- Pedestrian movement models have been extensively covered in the past decade
- Activity scheduling models & route choice models exist for pedestrians
- but...
- Only some management/control strategies have been applied in transportation hubs
- Very few studies considering multiple strategies together

$$\Downarrow$$

- Develop a framework which uses management strategies as control variables for improving pedestrian dynamics

Management strategies

Management policies (control policies)

Many different elements can be considered:

- Direct flow control (barriers)
- Public transport schedule
- Moving walkways
- Businesses (shops)
- Information
- ...

Management strategies

Hard strategies

Direct flow control

What control strategies can be used for influencing the flows

- Restrict access to areas of infrastructure
- Block access to platforms until passengers have disembarked
- Create bi-directional flows using corridor separators
- Traffic lights

Moving walkways

How could moving walkways be used to control pedestrian flows?

- Control velocity
- Direction can be changed dynamically
- Control the number of people arriving (flow)

but...

- Heavy infrastructure
- User acceptance

Management strategies

Soft strategies

Information

What type and when can information be provided to passengers:

- The connecting train will wait for X minutes
- Inform passenger prior to arrival about the state fo the system
- Suggest next connection based on congestion (will miss planned connection)
- Screens to inform of congestion inside train station
- Occupancy inside PT vehicles

all these elements require modelling compliance

Guidance

- (Dynamic) floor markings
- Attractors/POI (shops, ticket machines, kiosks, etc)

Simulation framework

Framework

Goal: develop a simulation framework which can measure the impact of management strategies.

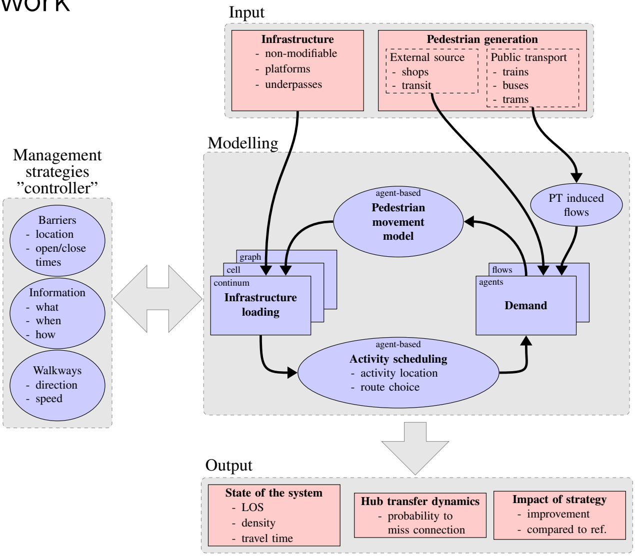
Components which are required:

- Input (data, pedestrian demand)
- Pedestrian movement model
- Activity scheduling model
- Controller for management strategies
- Output (results: density, travel times, etc)

$$\Downarrow$$

Supply-demand interaction

Framework


Input
Infrastructure
- non-modifiable
- platforms
- underpasses
Pedestrian generation
External source
- shops
- transit
Public transport
- trains
- buses
- trams
Modelling
PT induced flows
agent-based
Pedestrian movement model
graph
cell
continuum
Infrastructure loading
flows
agents
Demand
agent-based
Activity scheduling
- activity location
- route choice
Management strategies "controller"
Barriers
- location
- open/close times
Information
- what
- when
- how
Walkways
- direction
- speed
Output
State of the system
- LOS
- density
- travel time
Hub transfer dynamics
- probability to miss connection
Impact of strategy
- improvement
- compared to ref.

Simulation framework

Pedestrian movement models

Aggregate model (Network based)

Pedestrians are aggregated into flows, they are considered as a continuum.

+ No requirement of close interaction models
+ Lower computational cost
- Loose track of individual pedestrians

Disaggregate model (Social force model)

Pedestrians are considered individually

+ Fine control over pedestrian characteristics
+ Precise modelling of interaction (pedestrians and environment)
+ A pedestrian is "followed", dynamically update destination
+ Convenient for individual decision making (activity scheduling)
- Can be expensive to compute

Social force model

We decided to use the social force model (at least for now)

- activity choice $\rightarrow$ agent-based is conceptually easier
- can use parameters from literature
- result precision
- interactions with attractors/POI can be done
- calibration using specific data for case study will be considered

Simulation framework

Activity scheduling

Route choice

Utility maximization:

- highly customizable framework
- agent specific parameters
- generalized cost $\rightarrow$ multiple components

Some decisions agents can take:

- choose their route
- take a different PT service
- choose to buy a coffee (or something else)
- simply wait

Simulation framework

Train induced flows

Model

From PT vehicle to pedestrians: a disaggregation process

- PT vehicle based events
- Applicable to many different measurable quantities
  - flows: cumulated counts or arrival rates (y)
  - densities
  - occupation

$$\tilde{y} = \sum_{r,s} f(t; \gamma_{r,s}, t_{r,s}) + \varepsilon$$

with (r, s) a vehicle, f a function linking the vehicle to pedestrian quantities, $\gamma_{r,s}$ parameters specifying f, $t_{r,s}$ the vehicle arrival or departure time and ε the random error term

Simulation framework

Key performance indicators

How to measure change

To quantify the impact of a policy, indicators need to be defined:

- Travel time: slower travel times can indicate higher congestion
- Velocity: Deviation from a passenger's free flow speed
- Density: Higher densities can imply a lower LOS
- Transfer success: the fewer people miss their connection, the better

Case study

Lausanne's train station

Empirical tracking data on current Lausanne station:

- Detailed data which can be used for calibration.
- Train induced flows have been developed.
- Aggregate dynamics can be observed.
- Probabilistic fundamental diagrams can be characterized.

The new Lausanne station is considered for framework case study:

- Three pedestrian underpasses
- Shops
- Longer trains & platforms
- New metro line

Lausanne's train station

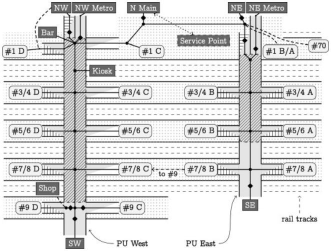


Figure: Current station, [Hänseler, 2016].

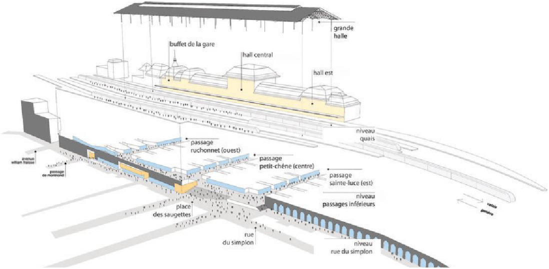


Figure: Future station, [SBB, 2017].

Conclusion

- Integrative framework with different components → flexibility.
- Ultimately, use as optimization tool for pedestrian infrastructure.

Next steps:

- Implement pedestrian movement model.
- Implement activity choice model.
- Controller formulation.
- Calibration ?

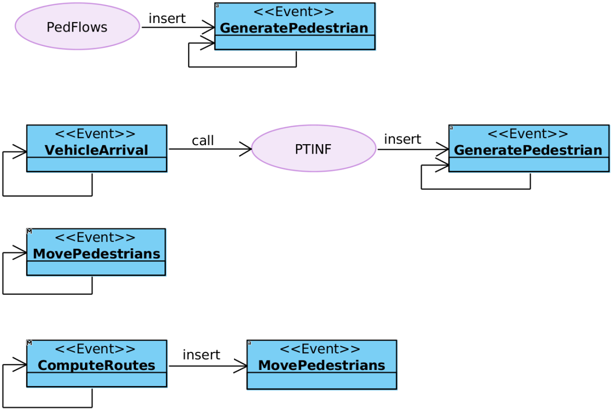
Thank you !

nicholas.molyneaux@epfl.ch

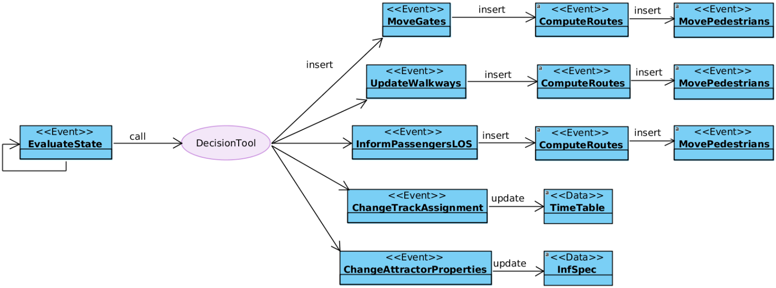
References

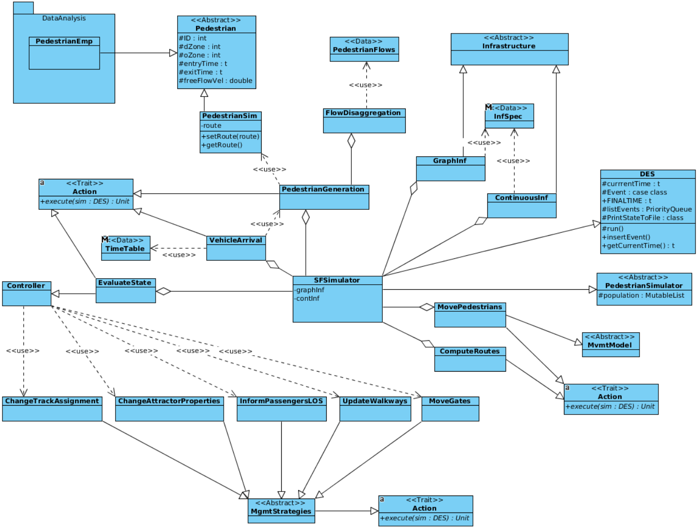
Hänseler, F. S. (2016).
Modeling and estimation of pedestrian flows in train stations.
PhD thesis, ENAC, Lausanne.

Pedestrian simulation events



Management strategy events

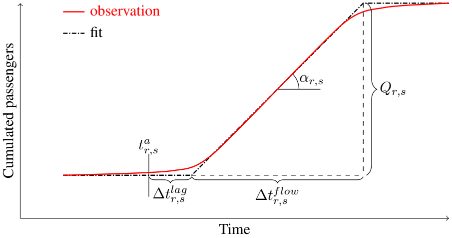



DataAnalysis
PedestrianEmp
<<Abstract>>
Pedestrian
#ID : int
#dZone : int
#oZone : int
#entryTime : t
#exitTime : t
#freeFlowVel : double
<<Data>>
PedestrianFlows
<<Abstract>>
Infrastructure
<<use>>
PedestrianSim
-route
+setRoute(route)
+getRoute()
FlowDisaggregation
<<Data>>
InfSpec
GraphInf
ContinuousInf
<<Trait>>
Action
+execute(sim : DES) : Unit
PedestrianGeneration
DES
#currrentTime : t
#Event : case class
+FINALTIME : t
#listEvents : PriorityQueue
#PrintStateToFile : class
#run()
+insertEvent()
+getCurrentTime() : t
<<Data>>
TimeTable
VehicleArrival
Controller
EvaluateState
SFSimulator
-graphInf
-contInf
<<Abstract>>
PedestrianSimulator
#population : MutableList
MovePedestrians
<<Abstract>>
MvmtModel
ComputeRoutes
ChangeTrackAssignment
ChangeAttractorProperties
InformPassengersLOS
UpdateWalkways
MoveGates
<<Abstract>>
MgmtStrategies

TRANS-FORM

Model - flow specification

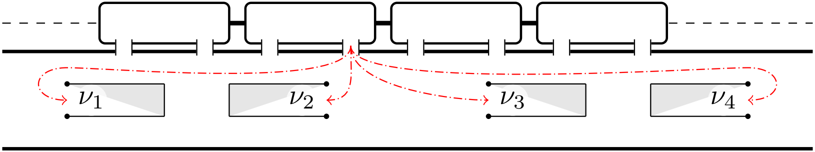
- Piecewise linear (PWL) function specifying the cumulated unloading flows



$$f = \begin{cases} 0 & \text{for} \quad t < t_{r,s} + \Delta t^{lag}_{r,s} \\ \alpha_{r,s} \cdot t & \text{for} \quad t \in (t_{r,s} + \Delta t^{lag}_{r,s}, t_{r,s} + \Delta t^{lag}_{r,s} + \Delta t^{flow}_{r,s}) \\ Q_{r,s} & \text{for} \quad t \geq t_{r,s} + \Delta t^{lag}_{r,s} + \Delta t^{flow}_{r,s} \end{cases}, \qquad \Delta t^{flow}_{r,s} = \frac{Q_{r,s}}{\alpha_{r,s}}$$

Model - route choice

- Pedestrians disembarking from trains choose an access ramp based on proximity, saturation and final destination
- A priori guess: longer train spread demand over all access ways whereas short trains concentrate demand in the closest access ways



Parameters

- For loading flows:
  - loading rate [ped/s]

- For unloading flows, train specific parameters:
  - unloading rate [ped/s]
  - disembarking passengers
  - dead time [s]

- Access way choice
  - logit model with travel time as utility