Nørreport

Grontmij | Carl Bro and Legion real-time 3D simulation model of the Station

General Overview and Conclusions
Contents

1. Introduction to Pedestrian Simulation from Legion
2. Scenario Definition for Norreport
3. Inputs required for the project
4. Demand Definitions Spreadsheet
5. The Simulations
6. Understanding Fruin Level of Service (LoS)
7. The Output maps
8. The Results
9. The Conclusions
10. More possibilities with the Software Services
Legion Overview
The Legion Suite comprises three applications:

- Model Builder
- Simulator
- Analyser

and Legion 3D
Simulation
The Model Builder brings the inputs together

Venue Layout

Model Builder

Operational Information

Pedestrian Demand

Activities and Routes
The architectural plans of the space require adaptation to reflect a pedestrian’s view. This is done by:

- removing non-obstacle lines
- introducing missing obstacles
Demand data inputs have a quantitative component...

The quantitative component – **how many** people use the space, and at what rate of entry over the simulated period

- **Demand data defines:**
  - Quantity of pedestrians and their rate of arrival
  - Their origins, destinations and interim activities

- **Data can be input to the model in a number of ways:**
  - Population in a defined area of the model at the simulation start, e.g. a seated crowd
  - Manually created flow rate, or pulse, within the model
  - Data imported from spreadsheets or text files

A demand “origin-destination” matrix should be prepared to cover all possible combinations
... and a secondary, qualitative component

The qualitative component –the *types* of people using the space, which can influence characteristics such as speed or personal space

- Entities have varying preferences – for example
  - Walking speed
  - Personal space
  - Luggage allowance
  - etc…

- These distributions are taken from measurements of real people

- User-defined distributions can also be added

- Data available about the types using a space can affect the *distributions* used
- *Different colours* can also help highlight *different types* moving through a model
The ONLY product based on real measurements

Graphs show unimpeded walking speeds on flat ground and up / down stairs
The ONLY software to pass independent validation tests
Pedestrian attributes: physical space

Human body cross section approximately an ellipse
Figure: S. Pheasant, Bodyspace Anthropometry (1988)

Incompressible area:
Distributions of parameters by ethnicity, sex, age, etc. exist

Note the **Perceived Density Level** is defined as follows:

“Each entity has a personal space so count the number of people in their personal space”
Fundamentals of Pedestrian Decision Making

- Personal Preferences
- Awareness of circumstance (waiting, stairs)
- Objectives
- Awareness of time
- Memory
- Perception of others behaviour
- Negotiation with others
- Physical constraints
- Synchronisation

Dissatisfaction
- Frustration
- Inconvenience
- Discomfort
Spatial information is also required to define activities, and routes between activities.

- Architectural drawings do not provide information about the *operation* of a space, such as queuing areas, waiting areas, and pedestrian routes.

- Entities require additional *contextual* information about the space.

- This information is added to a model using *Spatial objects*. 
Activity objects define the nature & location of activities, Route Map objects define routes

Spatial objects can be:

- **Activity objects** that provide *origins* or *targets* for entities to move *from* or *towards*, or perform an action *within*.

- **Route Map objects** that provide *navigational information* for entities during their passage between activity objects.
The Analyser enables interrogation of the results

What are the average boarding and alighting times?

What densities are experienced at the base of the stairs?

What is this person’s perceived time through the station?

How long will this person actually take to exit the station?

How long does it take to clear the platform?

What is the flow at the top of the stairs?

What is the impact of altering furniture/retail on the station concourse?

What is the new density at the gateline?
Confidential

Outputs can be Maps, Graphs, Tables or Raw Data
In summary

- **Model Builder**
  - CAD data (.dx, .dwg, .dgn)
  - Demand Data (.csv)
  - Operational Data
  - Model File
    - Import demand data and obstacles
    - Introduce activity and route map objects
    - .LGM

- **Simulator**
  - Model Export (.ORA)
  - Simulation Results (.RES)
  - Run simulations and record results
  - The results from the Modelling, Simulation and Analysis can be saved for viewing with A Legion Viewer

- **Analyser**
  - Analysis Repository
  - Play and analyse recorded simulations
  - Produce maps, graphs and tables
  - Output images, data and video for presentation materials
  - .ANA

**FINAL Output**

- .LGV
Norreport Scenario’s modelled

1. Base Case Works as normal – AM and PM Peaks at 15 minute intervals

2. Close off Regional Right Half of platform – E1 AM and PM Peak at 15 minute intervals

3. Close off Regional Left Half of platform – E2 AM and PM Peak at 15 minute intervals

4. Therefore 6 simulations carried out for the above

5. Temporary staircase provided in the centre of the platform for passengers on regional trains to get to the S-train and the Metro
Nørreport station
Modemisering / Kn 14
September 2009

Forslag B
Etape 2

Flow diagram
Forslag B - Etape 2

- Adgang til RE-perron
- Hovedtrappen
- Golbærgsgade-trappen
- Trappe fra Metro
- Metro afstigning
- Elevator til RE-perron
- Midlertidig trappe
- Trappe til RE-perron
-aeldeen plateau og RE-perron
- Elevator mellem godseplan og RE-perron
- Elevator mellem godseplan og Metro
- Escalator mellem S-tog og Metro
- Hovedtrappen
- Trappe til S-togsperron
- Elevator til S-togsperron
- Vendersgade-trappen
- Nordtrappen mellem godsperron og S-tog
Norreport Scenario’s modelled

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5. Temporary staircase provided in the centre of the platform for passengers on regional trains to get to the S-train and the Metro
Temporary staircase provided in the centre of the platform for passengers on regional trains to get to the S-train and the Metro.
# Input - AM demand

## OD matrix

<table>
<thead>
<tr>
<th>O/D</th>
<th>S-train</th>
<th>Re-train</th>
<th>Metro</th>
<th>Street</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-train</td>
<td></td>
<td>77</td>
<td>2,832</td>
<td>2,652</td>
<td>5,561</td>
</tr>
<tr>
<td>Re-train</td>
<td>82</td>
<td></td>
<td>315</td>
<td>712</td>
<td>1,110</td>
</tr>
<tr>
<td>Metro</td>
<td>3,642</td>
<td>379</td>
<td></td>
<td>1,137</td>
<td>5,158</td>
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<tr>
<td>Street</td>
<td>2,943</td>
<td>739</td>
<td>981</td>
<td></td>
<td>4,663</td>
</tr>
<tr>
<td>Sum</td>
<td>6,667</td>
<td>1,195</td>
<td>4,128</td>
<td>4,502</td>
<td>16,493</td>
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</table>

## Arrival distribution

<table>
<thead>
<tr>
<th>20 min Warm up</th>
<th>07:00 - 07:20</th>
<th>07:20 - 07:35</th>
<th>07:35 - 07:50</th>
<th>07:50 - 08:05</th>
<th>08:05 - 08:20</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20%</td>
<td>23%</td>
<td>30%</td>
<td>23%</td>
<td>23%</td>
</tr>
</tbody>
</table>

(NOTE: - the warm up is allow the station to fill up with people)
### Input - PM demand

#### OD matrix

<table>
<thead>
<tr>
<th>O/D</th>
<th>S-train</th>
<th>Re-train</th>
<th>Metro</th>
<th>Street</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-train</td>
<td>72</td>
<td></td>
<td>2,660</td>
<td>2,491</td>
<td>5,223</td>
</tr>
<tr>
<td>Re-train</td>
<td>77</td>
<td>296</td>
<td></td>
<td>669</td>
<td>1,042</td>
</tr>
<tr>
<td>Metro</td>
<td>3,420</td>
<td>356</td>
<td>921</td>
<td></td>
<td>4,844</td>
</tr>
<tr>
<td>Street</td>
<td>2,764</td>
<td>694</td>
<td></td>
<td>4,380</td>
<td></td>
</tr>
<tr>
<td>Sum</td>
<td>6,262</td>
<td>1,123</td>
<td>3,877</td>
<td>4,228</td>
<td>15,489</td>
</tr>
</tbody>
</table>

#### Arrival distribution

<table>
<thead>
<tr>
<th>20 min Warm up</th>
<th>15:40 - 16:00</th>
<th>16:00 - 16:20</th>
<th>16:20 - 16:40</th>
<th>16:40 - 17:00</th>
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</thead>
<tbody>
<tr>
<td>20%</td>
<td>32%</td>
<td>37%</td>
<td>32%</td>
<td></td>
</tr>
</tbody>
</table>
Input – Demand Definitions

1. Demand definitions in one Tabbed spreadsheet

2. Definitions of assumptions e.g. On AM Tab
   a) Street entrances
   b) 25% stamp ticket at the yellow stamp machines
   c) Arrival of trains defined for Metro and S-train

3. On Re-train Tabs (AM and PM)
   a) Boxed items show train arrivals for arrival distributions for simulation times
   b) Other assumptions – passenger arrival distributions, dwell time

4. On S-train Tab
   a) Shows shared destinations for passengers i.e. Passenger going too Hellerup S can choose a C B or E train
   b) Takes into account that certain trains go to similar destinations i.e. C_T3 2.02% and BxA_T3 6.31% of people will take both trains

This provides a true definition of how the whole station works
Norreport Simulations

Colours for pedestrians represent where they are going as follows:

- Blue – People travelling to street level
- Red – People heading for the Metro
- Green – People heading for S-Train
  * Note remain this colour then change as they get onto the platform as they decide on their final destination on the S-train
- Orange – People heading for Regional trains
  * Note remain this colour then change as they get onto the platform as they decide on their final destination
Fruin level of service standards

It is not desirable to design pedestrian environments upon maximum capacity, but on a desired pedestrian level of service that allows sufficient space for a pedestrian to:

- Walk at a relaxed walking speed
- Bypass slower pedestrians
- Avoid conflicts with oncoming or crossing pedestrians
- Interact visually with surroundings

<table>
<thead>
<tr>
<th>FRUIN Level of Service area occupancy standards</th>
<th>Persons per square meter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walkways</td>
<td>A</td>
</tr>
<tr>
<td>&lt; 0.31</td>
<td>0.31 to 0.43</td>
</tr>
<tr>
<td>Queuing</td>
<td>&lt; 0.83</td>
</tr>
<tr>
<td>Staircases</td>
<td>&lt; 0.54</td>
</tr>
</tbody>
</table>

| Fruin LoS Walkways                           | Good practice guidelines                                      |
| LoS Persons/sq.m                             |                                                             |
| A < 0.31                                     |                                                             |
| B 0.31 to 0.43                               | General concourse areas                                      |
| C 0.43 to 0.72                               | General platform and interchange areas                       |
| D 0.72 to 1.08                               |                                                             |
| E 1.08 to 2.17                               | Boarding and alighting areas, queue zones                    |
| F > 2.17                                     | Stair and escalator boarding areas                           |

Source: Pedestrian Planning and Design, John J. Fruin, 1987
## Fruin level of service standards

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Normal walking speed can be freely selected &amp; slower pedestrians can be easily overtaken. Crossing conflicts can be easily avoided.</td>
</tr>
<tr>
<td>B</td>
<td>Sufficient space to select normal walking speed and overtake in primarily one-way flows. Where counter flow or cross flows exist minor conflicts will occur, slightly lowering average walking speeds and potential volumes.</td>
</tr>
<tr>
<td>C</td>
<td>Restricted ability to select normal walking speed &amp; freely pass others. High probability of conflict where crossing movements &amp; counter-flows exist. Conflict avoidance requires frequent adjustment of walking speed &amp; direction. Flow is reasonably fluid, however considerable friction &amp; interaction between pedestrians is likely to occur.</td>
</tr>
<tr>
<td>D</td>
<td>Restricted walking speed; overtaking slower pedestrians is difficult. Counter-flows &amp; crossing movements severely restricted. Some probability of reaching critical density causing temporary stoppages.</td>
</tr>
<tr>
<td>E</td>
<td>Walking speed &amp; passing ability is restricted for all pedestrians. Forward movement is possible only by shuffling. Counter-flows &amp; crossing movements extremely difficult. Flow volumes approach limit of walking capacity.</td>
</tr>
<tr>
<td>F</td>
<td>Severely restricted walking speed; frequent unavoidable contact with others; reverse or cross movements are virtually impossible. Pedestrian flow is sporadic &amp; unstable.</td>
</tr>
</tbody>
</table>

Source: Pedestrian Planning and Design, John J. Fruin, 1987
Fruin level of service standards

<table>
<thead>
<tr>
<th>LOS</th>
<th>Description</th>
<th>Range</th>
<th>(Persons per square meter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOS A</td>
<td></td>
<td>$&lt; 0.31$</td>
<td></td>
</tr>
<tr>
<td>LOS B</td>
<td></td>
<td>$0.31 - 0.43$</td>
<td></td>
</tr>
<tr>
<td>LOS C</td>
<td></td>
<td>$0.43 - 0.72$</td>
<td></td>
</tr>
<tr>
<td>LOS D</td>
<td></td>
<td>$0.72 - 1.08$</td>
<td></td>
</tr>
<tr>
<td>LOS E</td>
<td></td>
<td>$1.08 - 2.17$</td>
<td></td>
</tr>
<tr>
<td>LOS F</td>
<td></td>
<td>$&gt; 2.17$</td>
<td></td>
</tr>
</tbody>
</table>

Walkways is the Definition for the Maps

Fruin, J.J., Pedestrian Planning and Design
AM Base Scenario

Time: 07:20 – 08:20
Cumulative Mean Density Map

Scenario: Base AM
Project: Nørreport Station

07:35 - 07:50
AM scenario: Passenger Experience on the Platforms

S-train platform: Density distribution
Distribution of entity density inside S-train platform

Re-train platform: Density distribution
Distribution of entity density inside Re-train platform
Cumulative Max Density Map

Scenario: Base AM
Project: Nørreport Station

07:20 - 08:20
AM and PM Scenarios
Peak 15 Cumulative Mean Density Maps – Platforms
Summary Slides
Cumulative Mean Density Map - Peak 15 Minutes Scenarios Comparison on Platforms

Project: Nørreport Station

LEGION
AM scenario: Passenger Experience on the Platforms

S-train platform: Density distribution
Distribution of entity density inside S-train platform

Re-train platform: Density distribution
Distribution of entity density inside Re-train platform
AM E1 scenario: Passenger Experience on the Platforms

S-train platform: Density distribution
Distribution of entity density inside S-train platform

Re-train platform: Density distribution
Distribution of entity density inside Re-train platform
AM E2 scenario: Passenger Experience on the Platforms

S-train platform: Density distribution
Distribution of entity density inside S-train platform

Re-train platform: Density distribution
Distribution of entity density inside Re-train platform
PM scenario: Passenger Experience on the Platforms

S-train platform: Density distribution
Distribution of entity density inside S-train platform

Re-train platform: Density distribution
Distribution of entity density inside Re-train platform
PM E1 scenario: Passenger Experience on the Platforms

S-train platform: Density distribution
Distribution of entity density inside S-train platform

Re-train platform: Density distribution
Distribution of entity density inside Re-train platform
Other Results Outputs – Journey Time

- The following sheets provide journey times for each scenario for Am and PM against the base or existing journey times through the station.

- Note other tabs show the entire data for each individual entity or person travelling through the station.
General conclusions

• The density levels on the Regional train platform and the S-train platform are generally not affected by closing half of the Regional train platform.
• Density levels on Re-train platform are low for all scenarios with density levels around Fruin Level of Service (LoS) B and C.
• Density levels on S-train platform are moderate for all scenarios with density levels around Fruin LoS C. For the AM scenario the area close to the main staircase experienced high densities up to Fruin LoS D.
Future possibilities

1. Model evacuation scenario i.e. All full trains and all have to exit the station

2. What if scenario:
   a) Missed headways e.g. 3 trains late or missing for Re-Train/S-trains/both
   b) Construction or repair to a staircase or elevator or one breaks down

3. Model at Street level for pedestrian and traffic flows

4. Major Event - concert/football match/other major event

5. Use of space utilisation maps for retail and the limited effects on pedestrian movement

6. Extend analysis into Metro and future demand in 30 to 40 years from now for the station

7. 3D models for review by the public, environmental aspects, signage and way finding issues.
LEGION – Market Sectors

- Rail and Metro
- Stadia, Sports and Special Events
- Air
- Public and Urban Realm, Commercial Buildings
- Retail
- Traffic
## Legion Representative Clients

<table>
<thead>
<tr>
<th>Rail/Metro</th>
<th>Sports</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consortio Regional de Trasportes de Madrid</td>
<td>Coventry Arena</td>
<td>Beijing University of Technology</td>
</tr>
<tr>
<td>Crossrail</td>
<td>Düsseldorf Arena</td>
<td>Hong Kong Jockey Club</td>
</tr>
<tr>
<td>Ferrocarrils de la Generalitat de Catalunya</td>
<td>Gillette Stadium</td>
<td>Lower Manhattan Development Corporation</td>
</tr>
<tr>
<td>Kowloon Canton Railway Corporation</td>
<td>Malaga Football Club</td>
<td>Malaga Fire Brigade</td>
</tr>
<tr>
<td>London Underground</td>
<td>Watford FC</td>
<td>London Fire Brigade</td>
</tr>
<tr>
<td>Metro de Madrid</td>
<td>Wembley Stadium</td>
<td>Norman Foster and Partners</td>
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<td>Metro de Santiago</td>
<td></td>
<td>Parkview International Limited</td>
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<td>Network Rail</td>
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<td>SAVE</td>
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<td>New Jersey Transit</td>
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<td></td>
<td>Sydney 2000</td>
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</table>
Metro Station meets surface level
Transit Oriented Development
Sports Events - Beijing Olympics 2008
High Quality 3D simulation outputs