Nørreport

LEGION

Pedestrian Simulation Technology

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

General Overview and Conclusions

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Contents

Legion Overview

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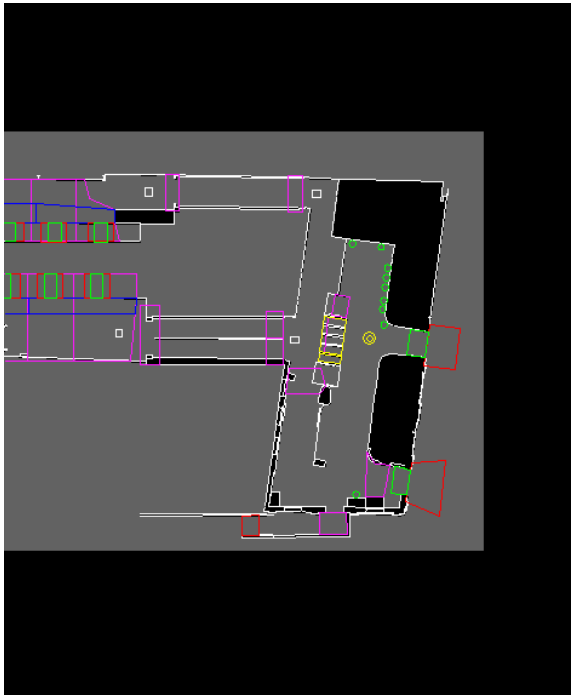
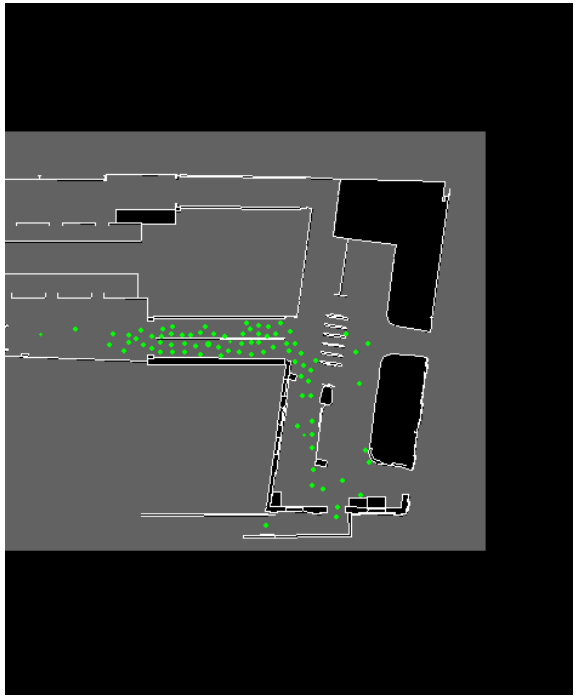
The Legion Suite comprises three applications

Model Builder



Simulator



Analyser

and Legion 3D

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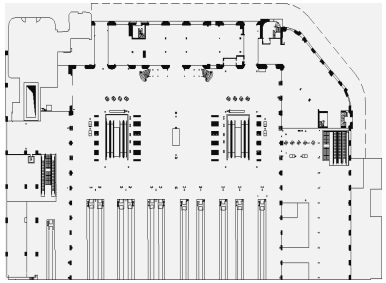
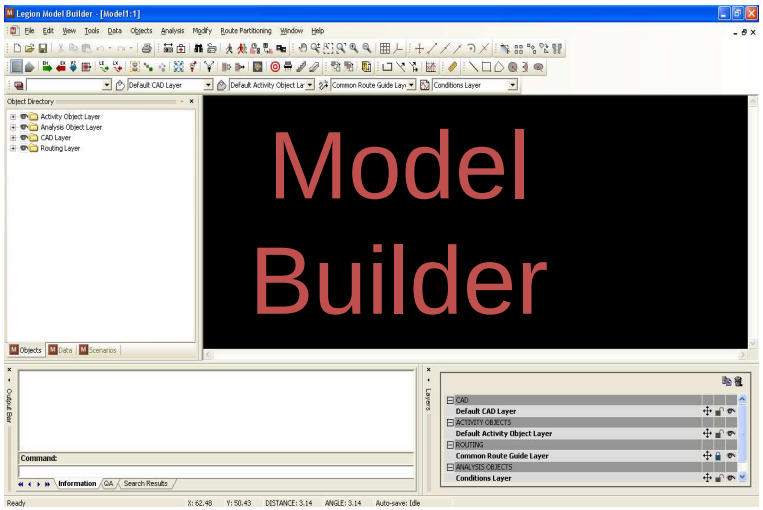
Simulation

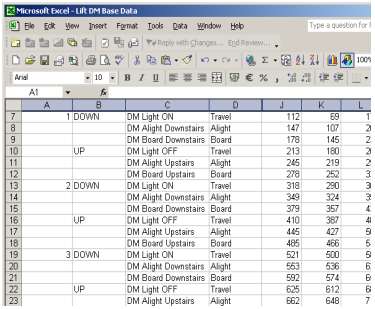
The Model Builder brings the inputs together



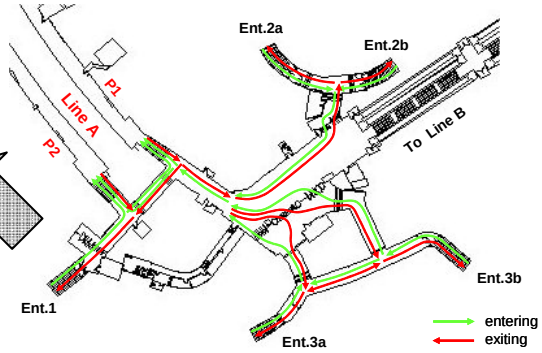
Venue Layout

Operational Information





Pedestrian Demand



Activities and Routes

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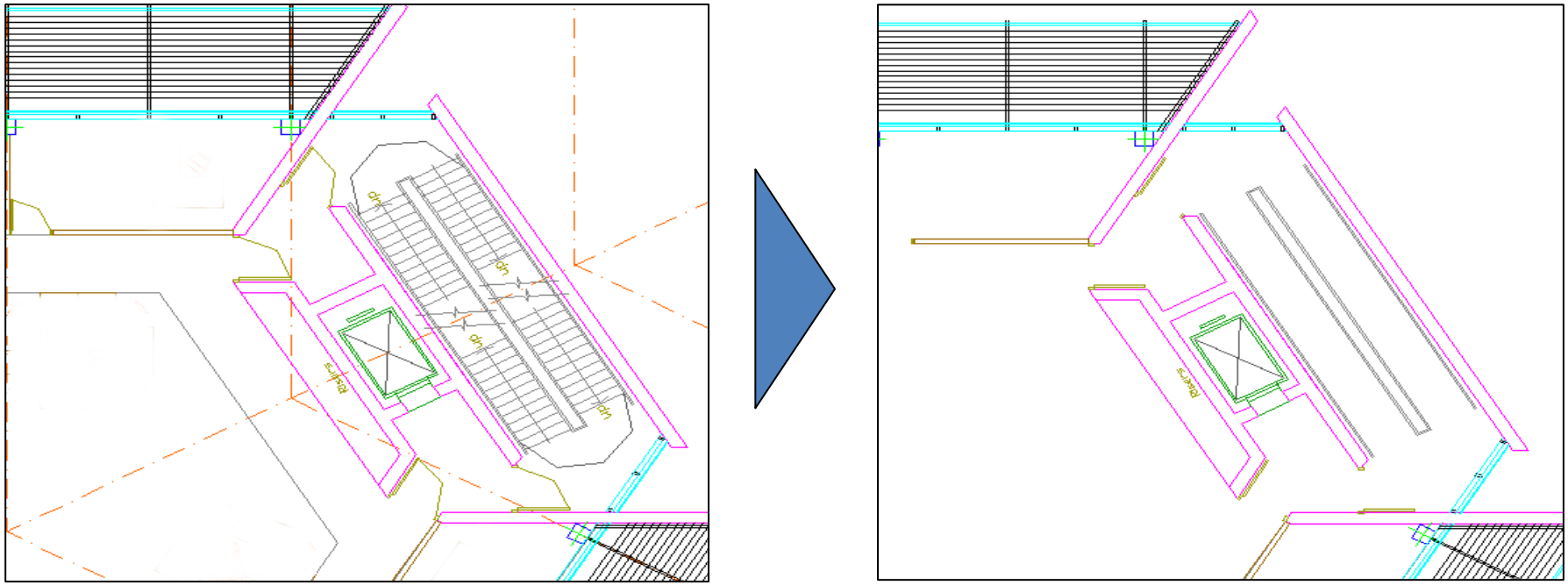
The architectural plans of the space, require adaptation to reflect a pedestrian's view



This is done by….

- removing non-obstacle lines
- introducing missing obstacles

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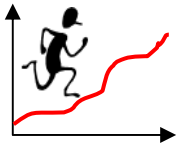
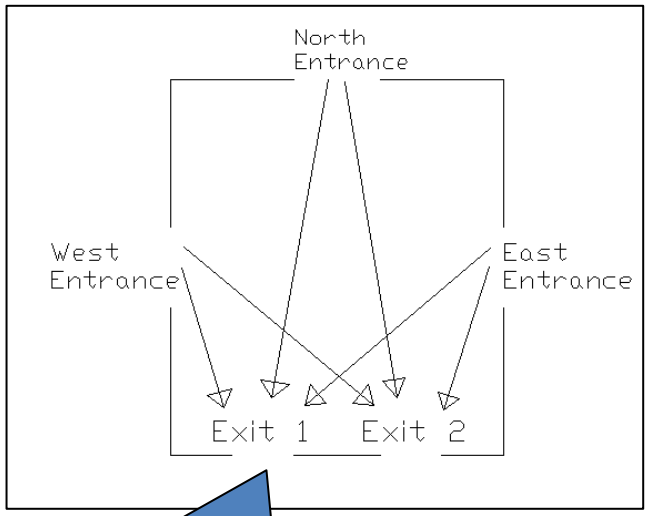


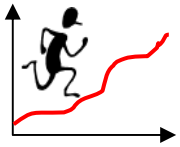
Demand data inputs have a quantitative component…

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



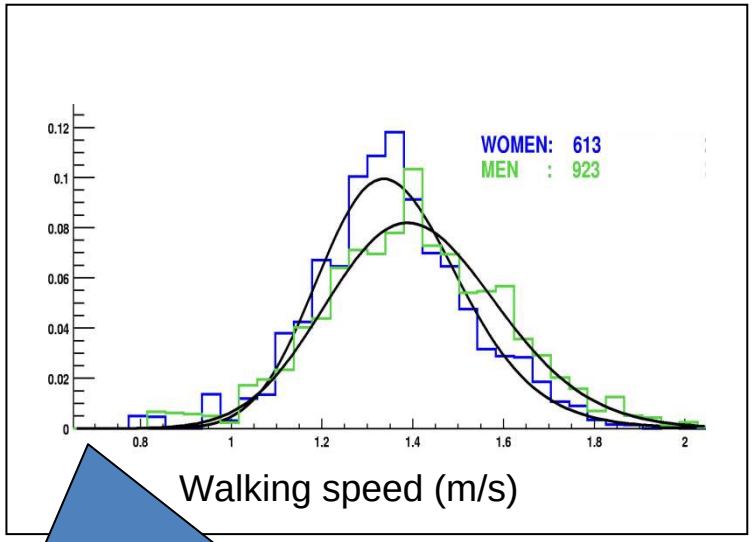
A demand "origin-destination" matrix should be prepared to cover all possible combinations



… 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

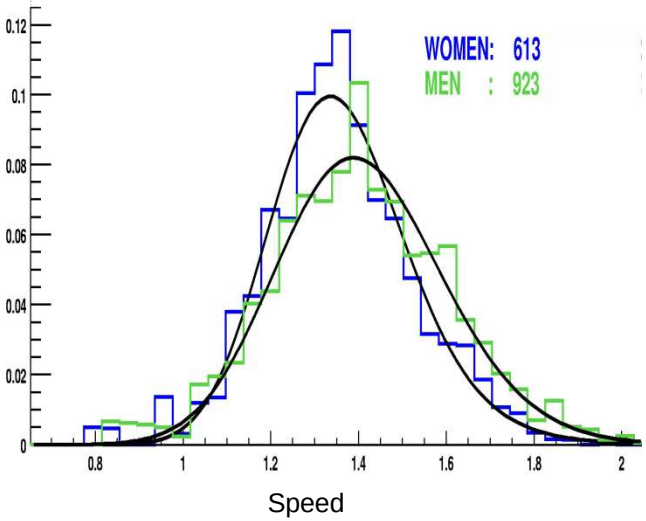
- Entities have varying preferences – for example
  - Walking speed
  - Personal space
  - Luggage allowance
  - etc…
- These distributions are taken from measurements of real people
- User-defined distributions can also be added

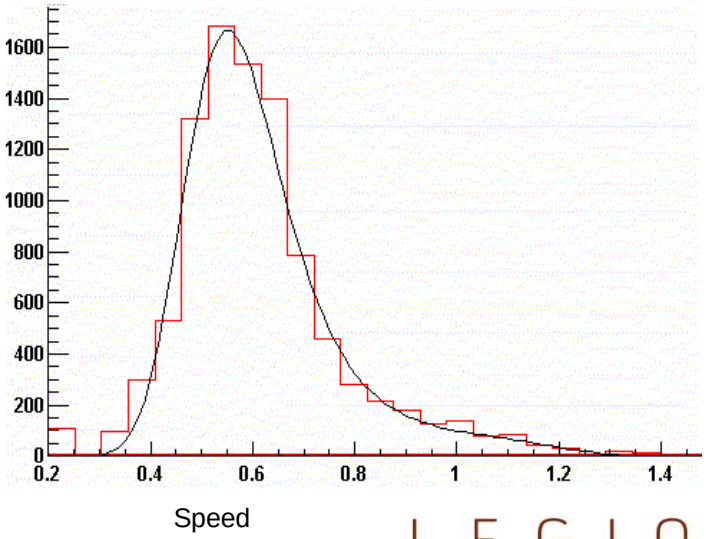


- Data available about the types using a space can affect the **distributions** used
- **Different colours** can also help highlight **different types** moving through a model

The ONLY product based on an real measurements

Graphs show unimpeded walking speeds on flat ground and up / down stairs





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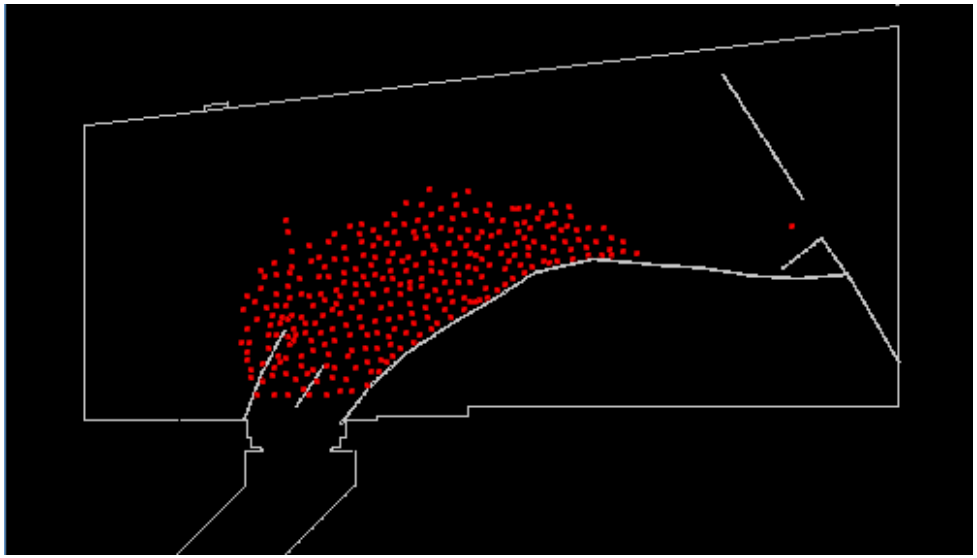
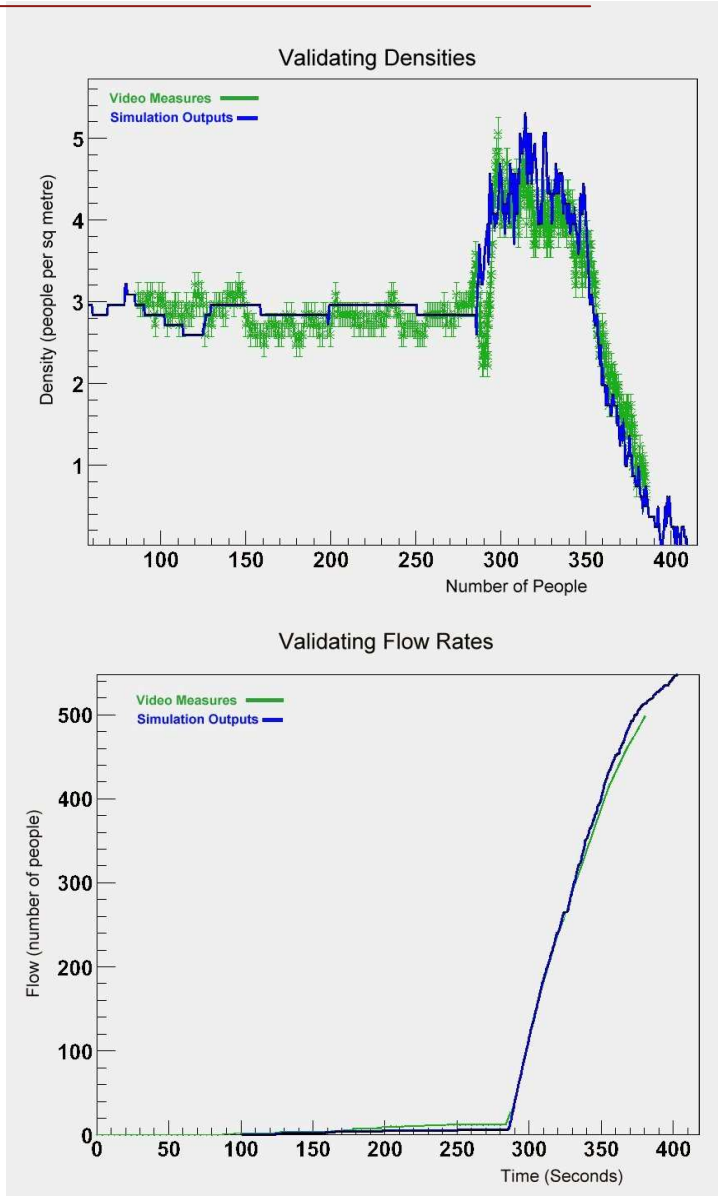
The ONLY software to pass independent validation tests





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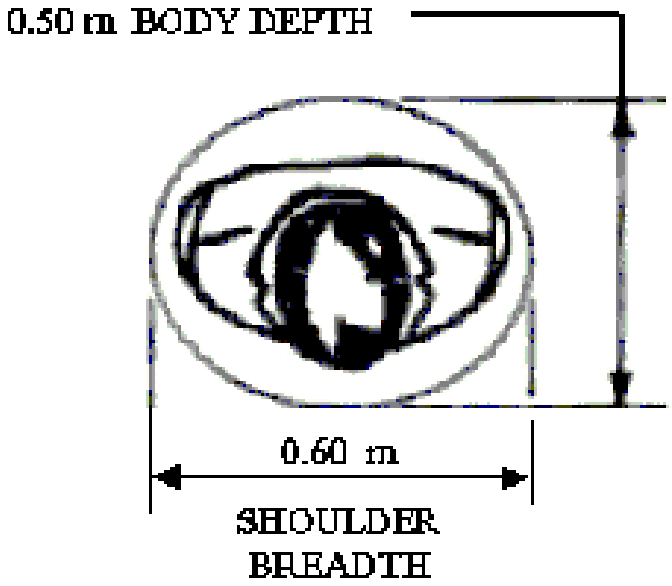
Pedestrian attributes: physical space

Human body cross section approximately an ellipse

Figure: S. Pheasant, *Bodyspace Anthropometry* (1988)



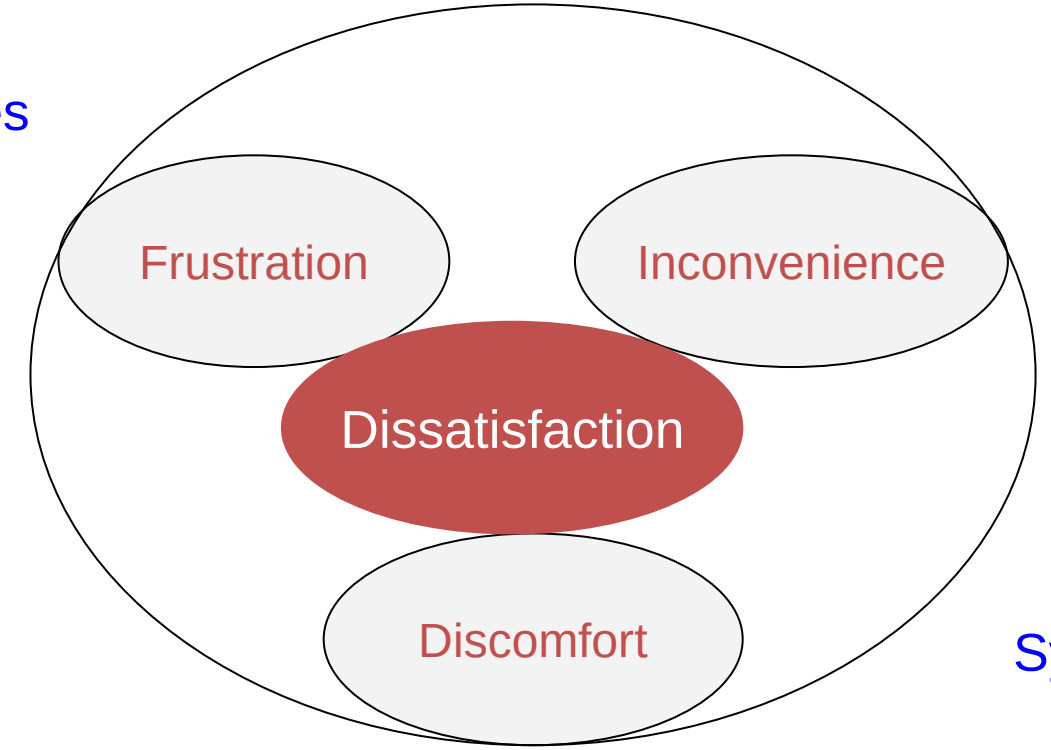
Incompressible area:

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

Negotiation with others

Awareness of circumstance (waiting, stairs)

Physical constraints

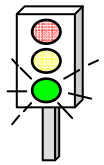
Objectives

Synchronisation

Awareness of time

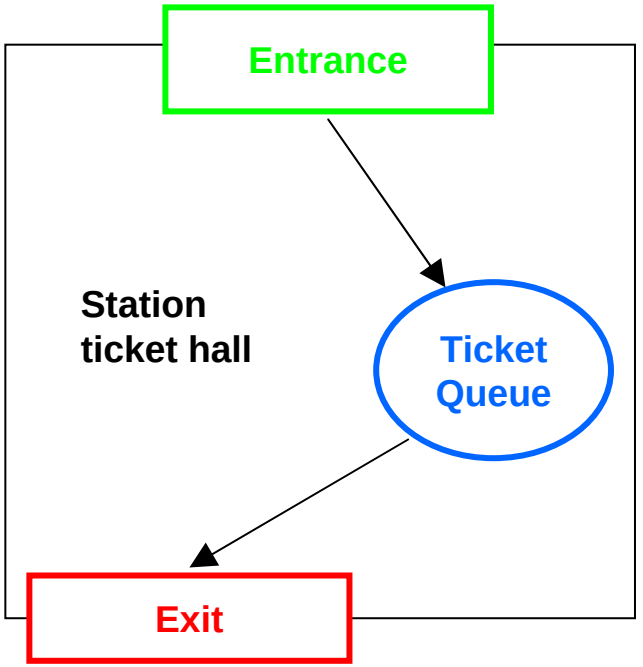
Memory

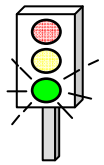
Perception of others behaviour



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*



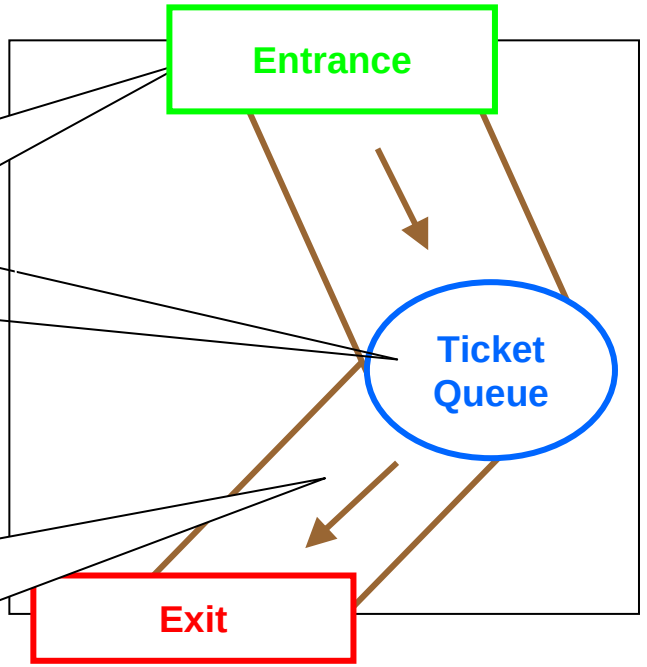


Activity objects define the nature & location of activities, *Route Map objects* define routes

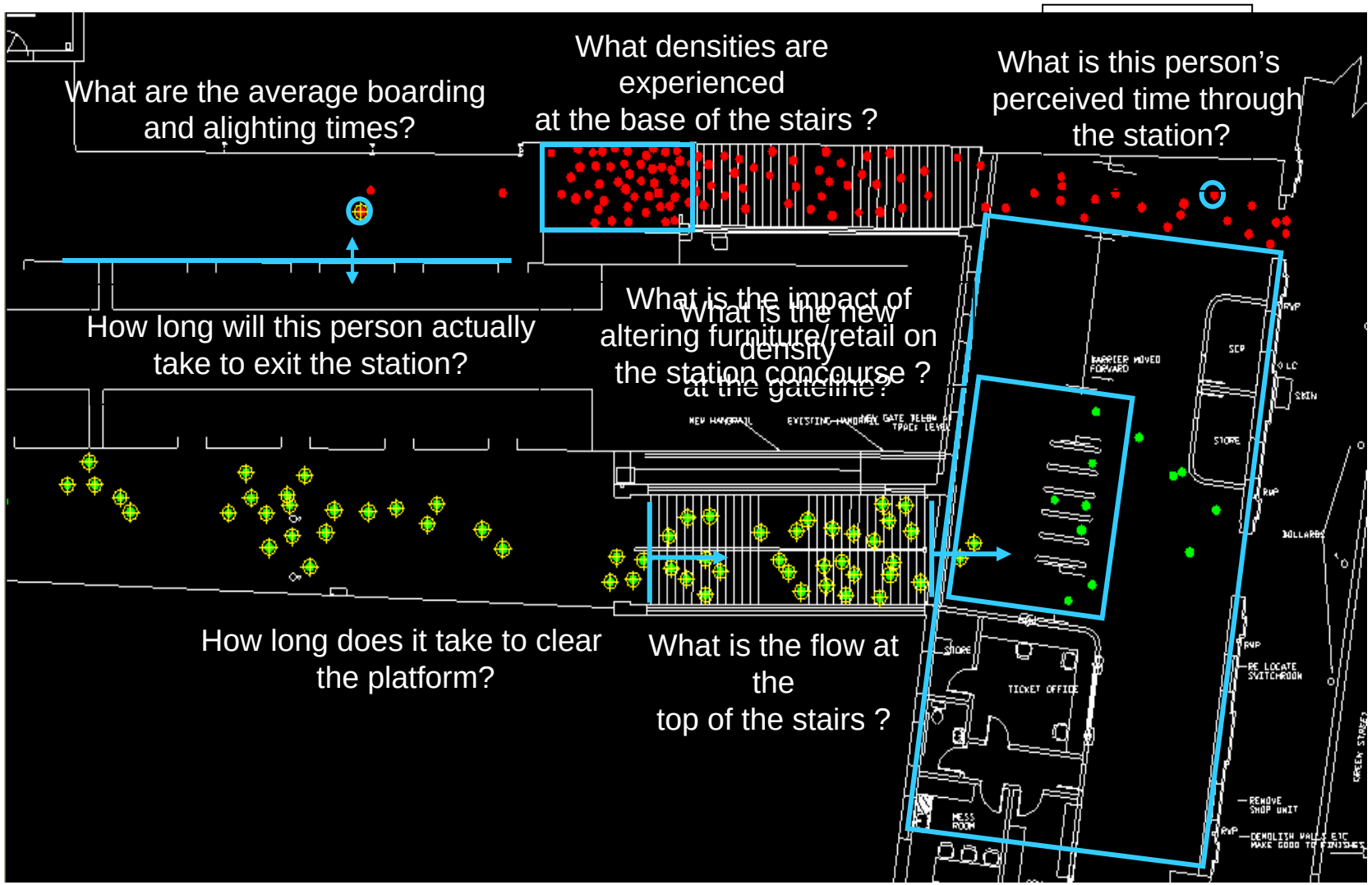
Spatial objects can be:

- ***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



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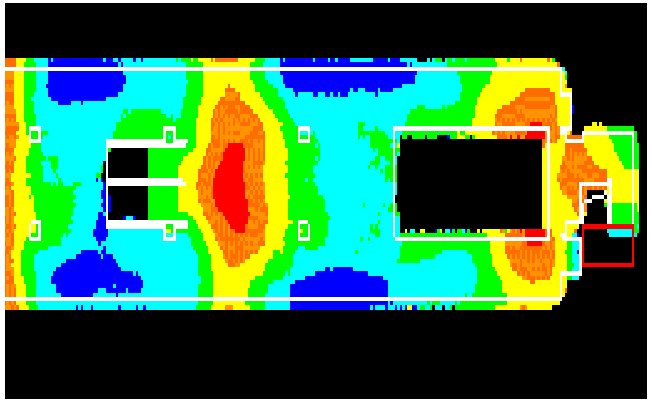
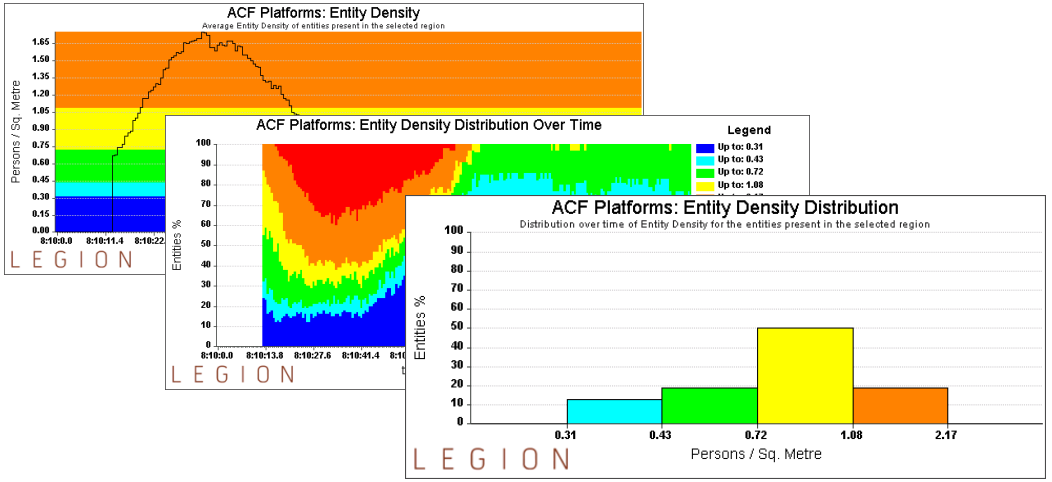
Outputs can be Maps, Graphs, Tables or Raw Data





	Ramp exit	Corner exit to street	Main exit to street
WB C1 D4	4	3	4
WB C6 D3		1	
WB C6 D2	1		
WB C5 D4	1	1	
WB C2 D2	3	4	2
WB C1 D3	3	2	4
WB C6 D1	1		
WB C5 D3	2		
WB C2 D1	3	4	2
WB C4 D2	2		
WB C3 D4	1	4	2
WB C1 D2	3	4	4
WB C6 D4	1		
WB C3 D1	2	4	1
WB C2 D3	1	5	2

subTitle: Number of entities crossing the selected flow line

time (h:m:s	Escalator fl # Entities	Escalator fl # Entities	Escalator flow: Flow Rate Averaged # Entities / minute
23:27.0	0	149	15
23:27.6	1	150	20
23:28.2	0	150	20
23:28.8	0	150	20
23:29.4	0	150	20
23:30.0	0	150	20
23:30.6	0	150	20
23:31.2	1	151	25
23:31.8	0	151	25
23:32.4	0	151	25
23:33.0	1	152	30
23:33.6	0	152	30
23:34.2	0	152	30
23:34.8	1	153	30
23:35.4	0	153	30
23:36.0	1	154	30
23:36.6	1	155	35
23:37.2	1	156	40
23:37.8	0	156	35

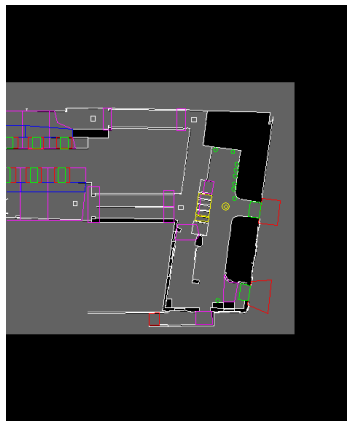
In summary

CAD data
.dxf, .dwg, .dgn

Demand Data
.csv

Operational Data

Model Builder



Model File

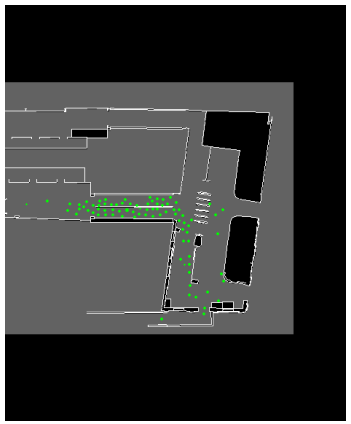
- Import demand data and obstacles
- Introduce activity and route map objects

.LGM

Model Export

.ORA

Simulator



- Run simulations and record results

Simulation Results

.RES

Analyser

Analysis Repository

- Play and analyse recorded simulations
- Produce maps, graphs and tables
- Output images, data and video for presentation materials

.ANA

FINAL Output

- **The results from the Modelling, Simulation and Analysis can be saved for viewing with A Legion Viewer**

.LGV

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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

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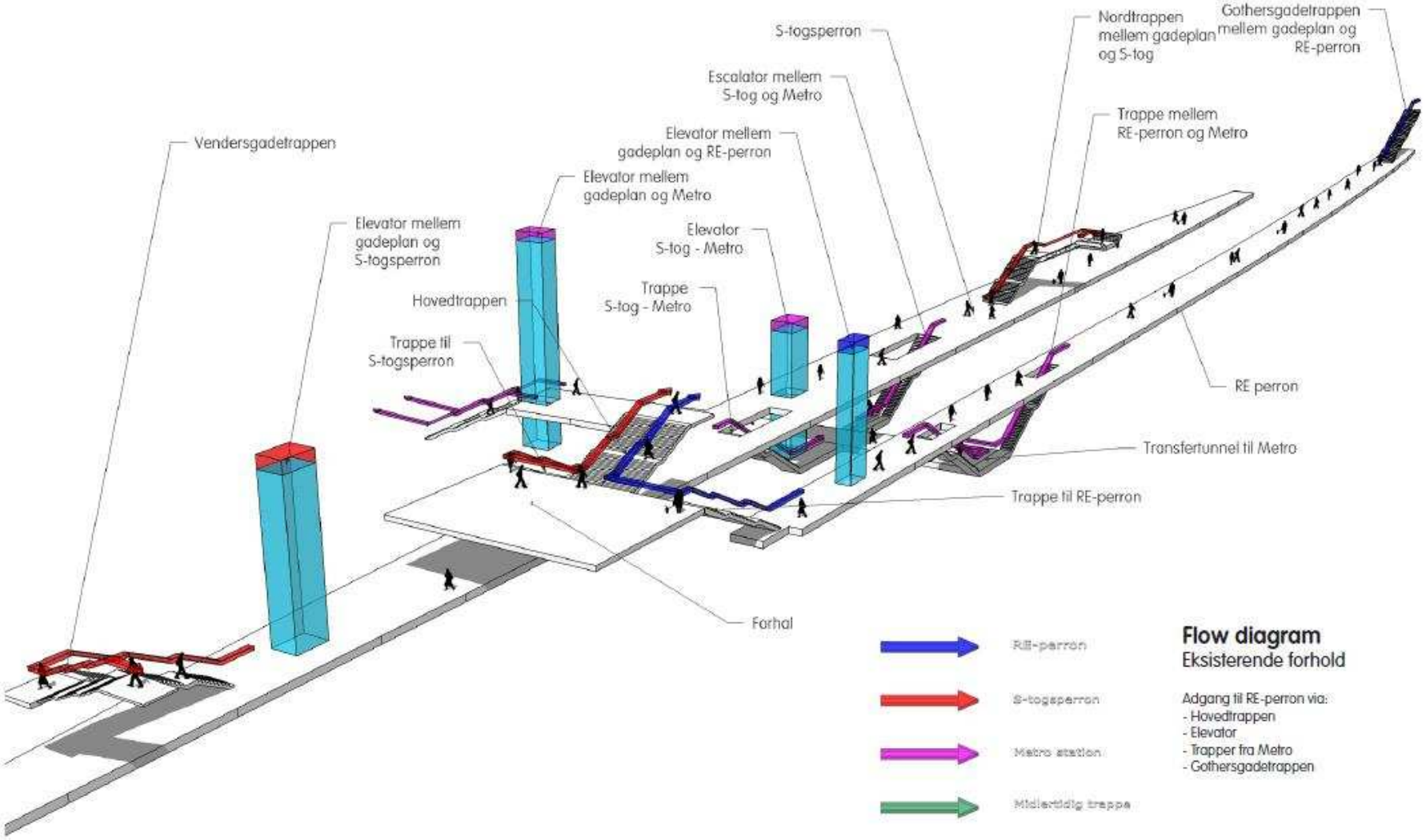
Eksisterende forhold



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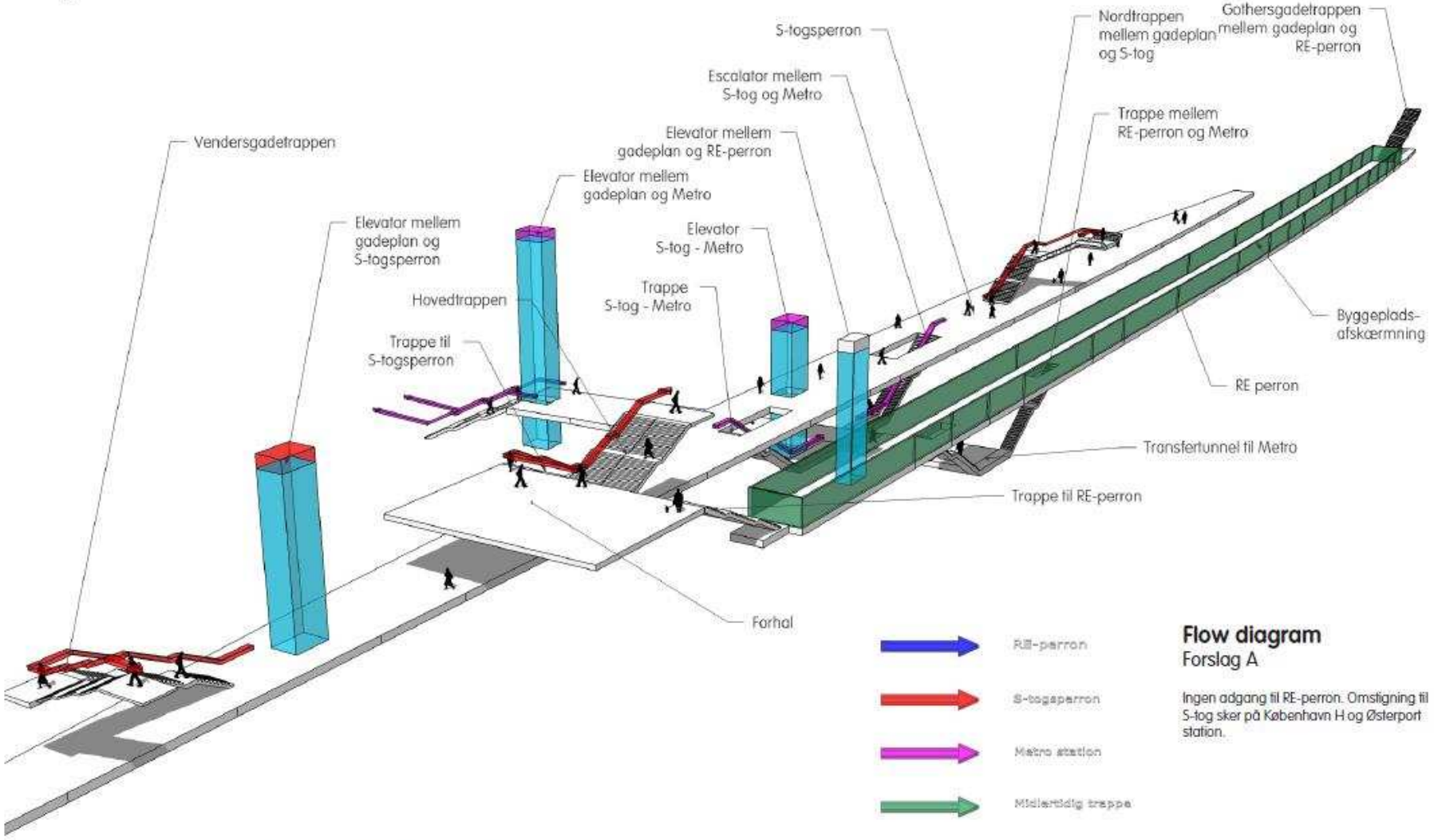
Forslag A



Flow diagram
Forslag A

Ingen adgang til RE-perron. Omstigning til S-tog sker på København H og Østerport station.

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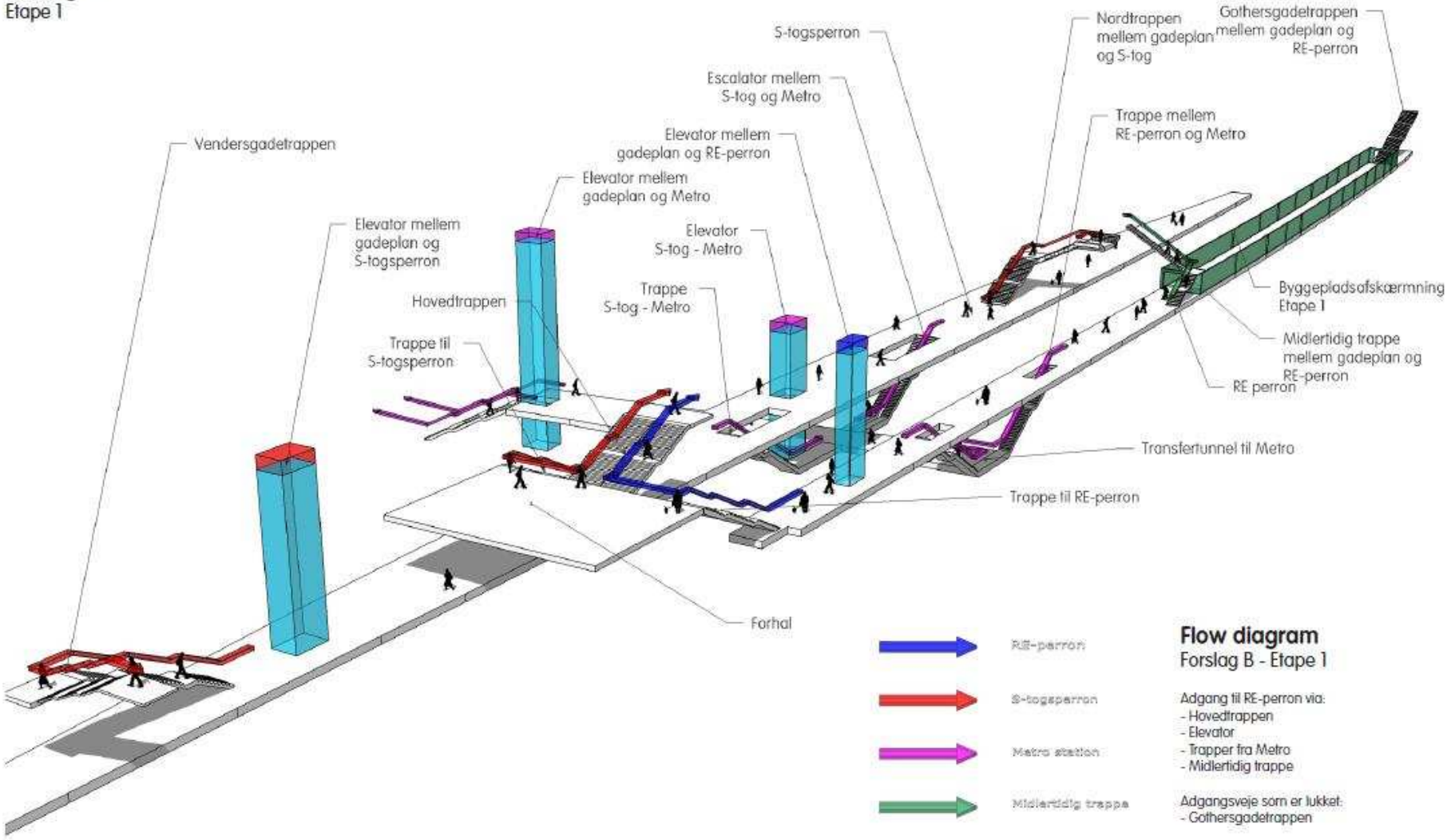
Forslag B

Etape 1



Flow diagram

Forslag B - Etape 1

Adgang til RE-perron via:
- Hovedtrappen
- Elevator
- Trapper fra Metro
- Midlertidig trappe

Adgangsveje som er lukket:
- Gothersgadetrappen

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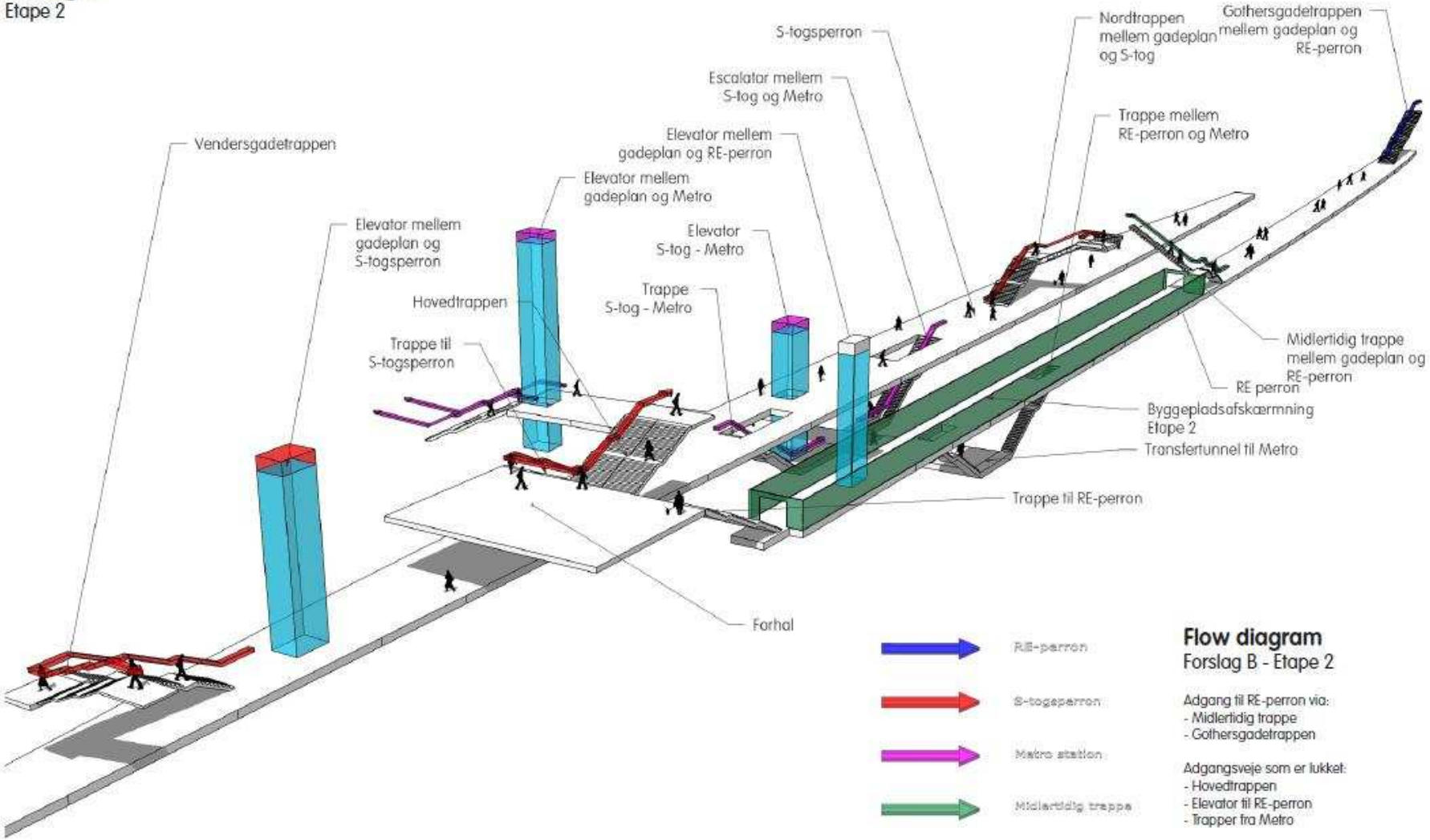
Forslag B

Etape 2



Flow diagram

Forslag B - Etape 2

Adgang til RE-perron via:
- Midlertidig trappe
- Gothersgadetrappen

Adgangsveje som er lukket:
- Hovedtrappen
- Elevator til RE-perron
- Trapper fra Metro

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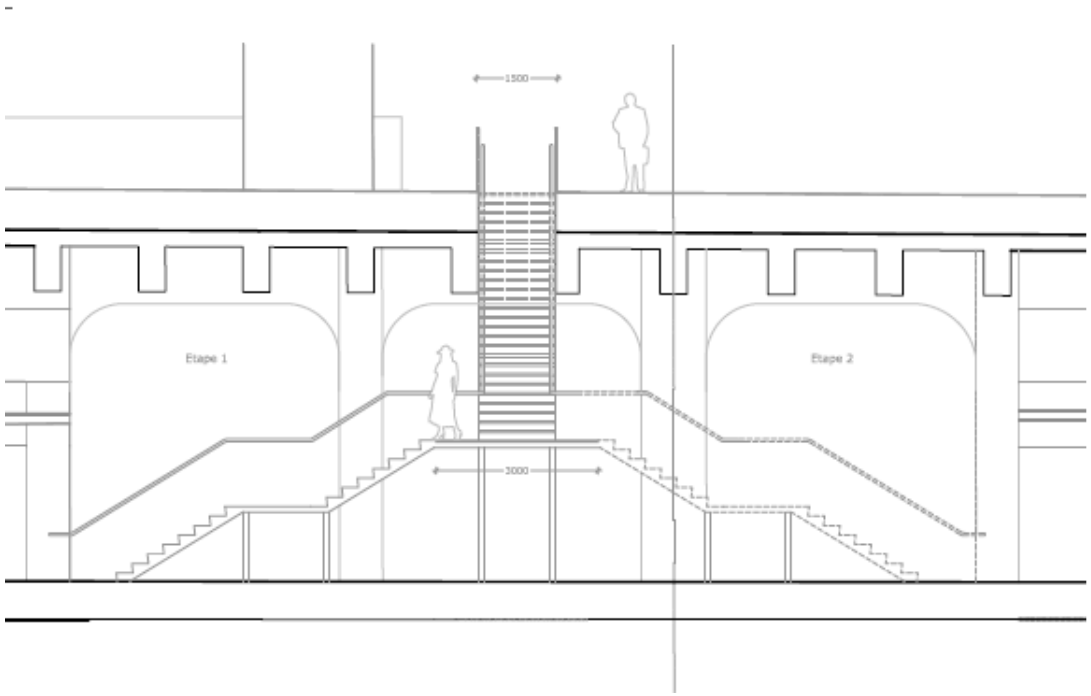

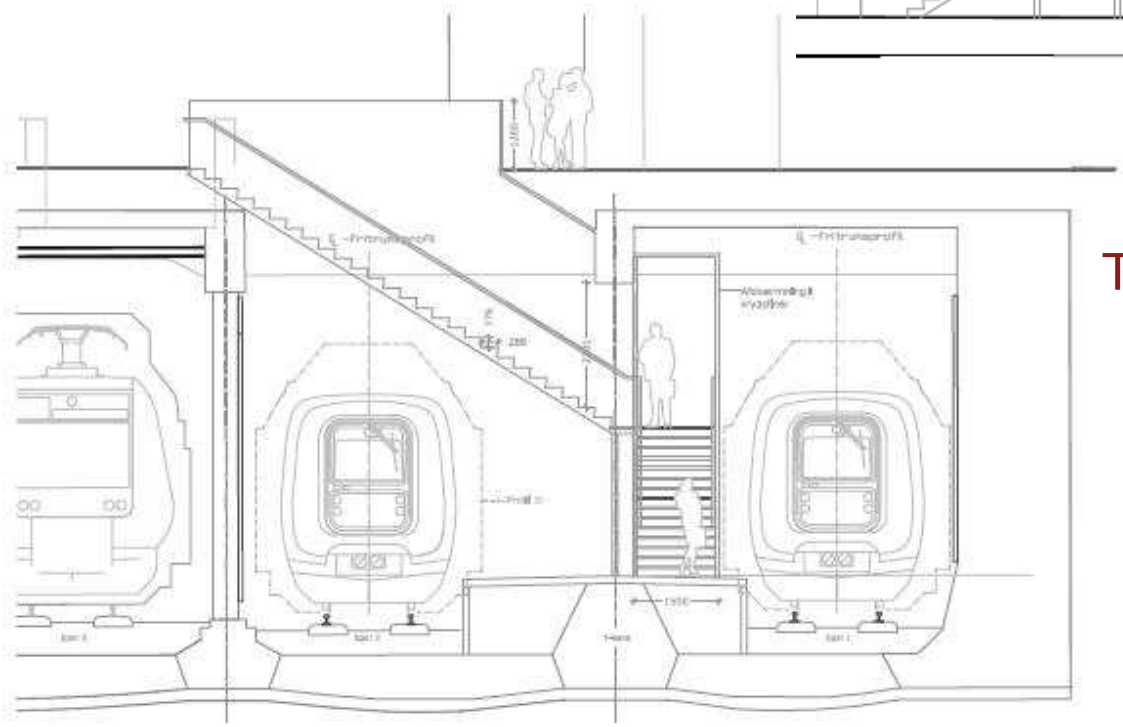

Temporary staircase provided in the centre of the platform for passengers on regional trains to get to the S-train and the Metro

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Input - AM demand

OD matrix

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

Arrival distribution

20 min Warm up	(NOTE: - the warm up is allow the station to fill up with people)			
07:00 - 07:20	07:20 - 07:35	**07:35 - 07:50**	07:50 - 08:05	08:05 - 08:20
20%	23%	**30%**	23%	23%

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Input - PM demand

OD matrix

O/D	S-train	Re-train	Metro	Street	Sum
S-train		72	2,660	2,491	5,223
Re-train	77		296	669	1,042
Metro	3,420	356		1,068	4,844
Street	2,764	694	921		4,380
Sum	6,262	1,123	3,877	4,228	15,489

Arrival distribution

20 min Warm up			
15:40 - 16:00	16:00 - 16:20	16:20 - 16:40	16:40 - 17:00
20%	32%	37%	32%

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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

Microsoft Office
el 97-2003 Worksh

This provides a true definition of how the whole station works

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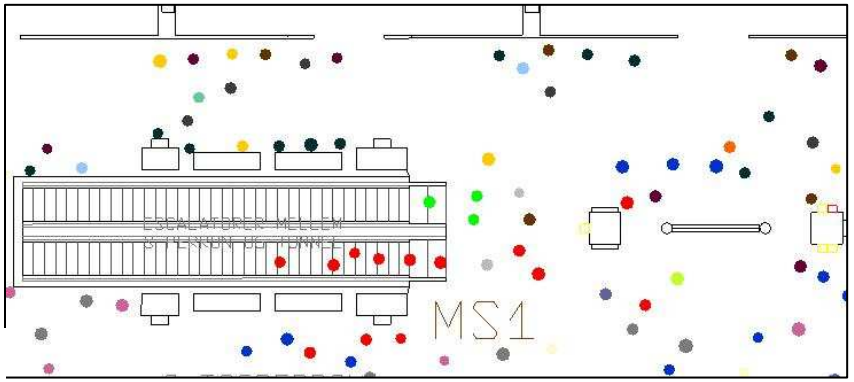
Norreport Simulations

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 <u>change</u> 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 <u>change</u> as they get onto the platform as they decide on their final destination



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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

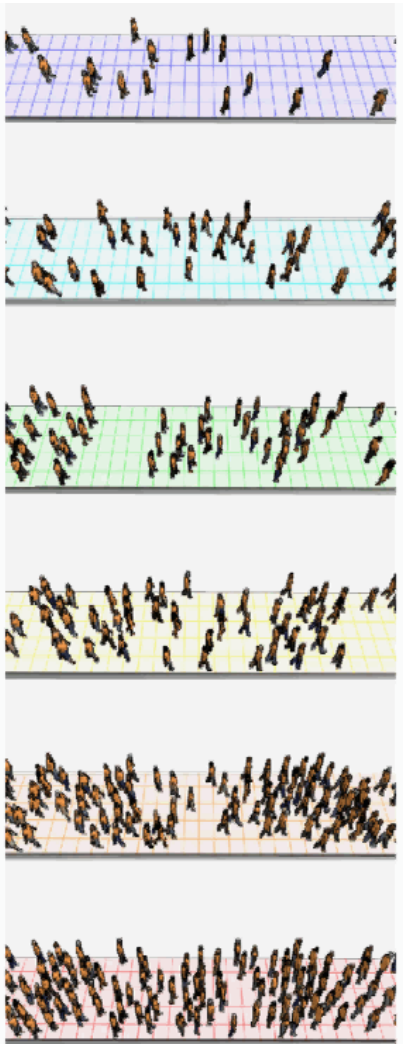
FRUIN Level of Service area occupancy standards						
	Persons per square meter					
	A	B	C	D	E	F
Walkways	< 0.31	0.31 to 0.43	0.43 to 0.72	0.72 to 1.08	1.08 to 2.17	> 2.17
Queuing	< 0.83	0.83 to 1.08	1.08 to 1.54	1.54 to 3.59	3.59 to 5.38	> 5.38
Staircases	< 0.54	0.54 to 0.72	0.72 to 1.08	1.08 to 1.54	1.54 to 2.69	> 2.69

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

A	Normal walking speed can be freely selected & slower pedestrians can be easily overtaken. Crossing conflicts can be easily avoided.
B	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.
C	Restricted ability to select normal walking speed & freely pass others. High probability of conflict where crossing movements & counter-flows exist. Conflict avoidance requires frequent adjustment of walking speed & direction. Flow is reasonably fluid, however considerable friction & interaction between pedestrians is likely to occur.
D	Restricted walking speed; overtaking slower pedestrians is difficult. Counter-flows & crossing movements severely restricted. Some probability of reaching critical density causing temporary stoppages.
E	Walking speed & passing ability is restricted for all pedestrians. Forward movement is possible only by shuffling. Counter-flows & crossing movements extremely difficult. Flow volumes approach limit of walking capacity.
F	Severely restricted walking speed; frequent unavoidable contact with others; reverse or cross movements are virtually impossible. Pedestrian flow is sporadic & unstable.



Source: Pedestrian Planning and Design, John J. Fruin, 1987

Fruin level of service standards

Walkways is the Definition for the Maps

LOS A < 0.31
(Persons per square meter)

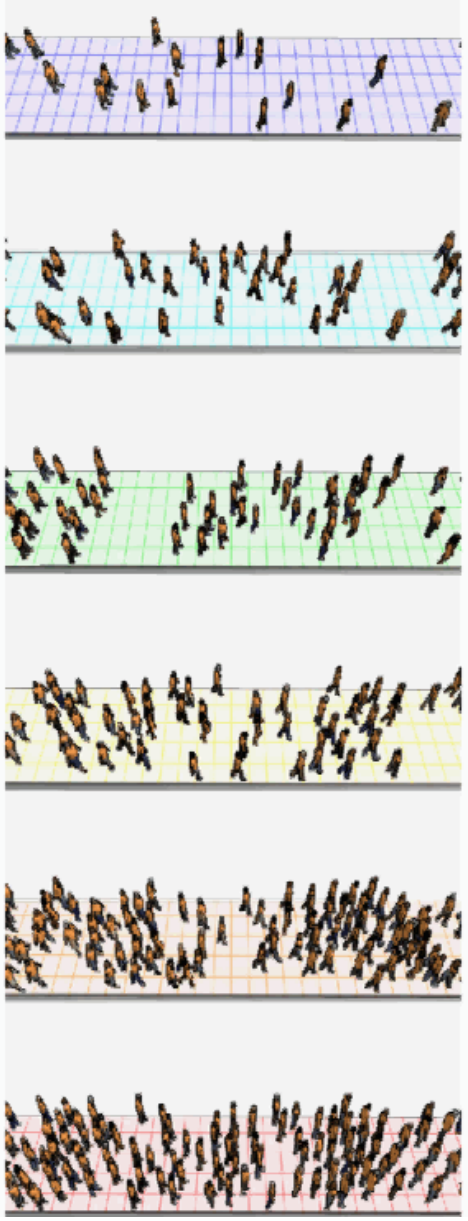
LOS B 0.31 - 0.43
(Persons per square meter)

LOS C 0.43 - 0.72
(Persons per square meter)

LOS D 0.72 - 1.08
(Persons per square meter)

LOS E 1.08 - 2.17
(Persons per square meter)

LOS F > 2.17
(Persons per square meter)



Fruin, J.J., Pedestrian Planning and Design

LEGION

AM Base Scenario

Time: 07:20 – 08:20

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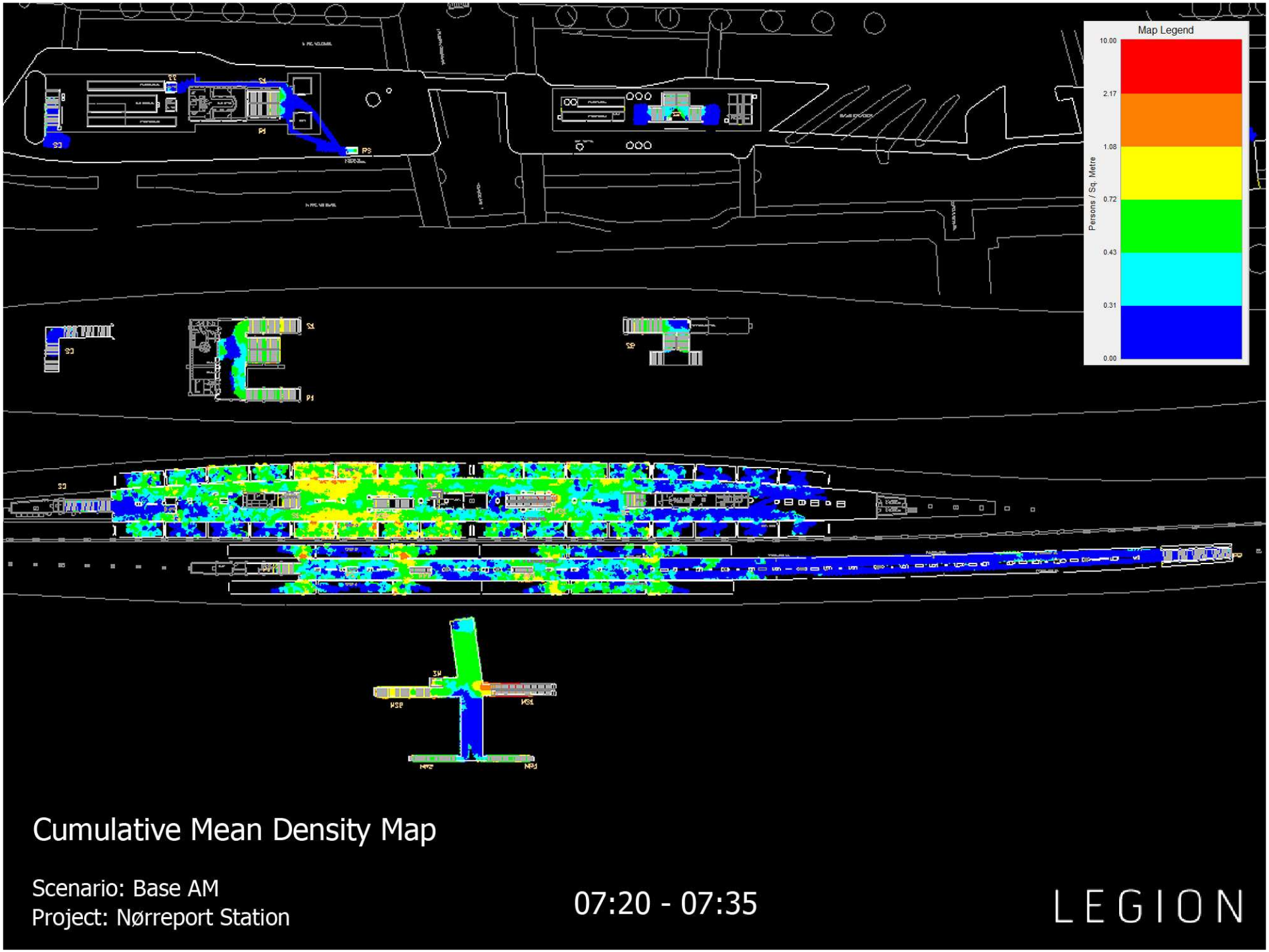
LEGION

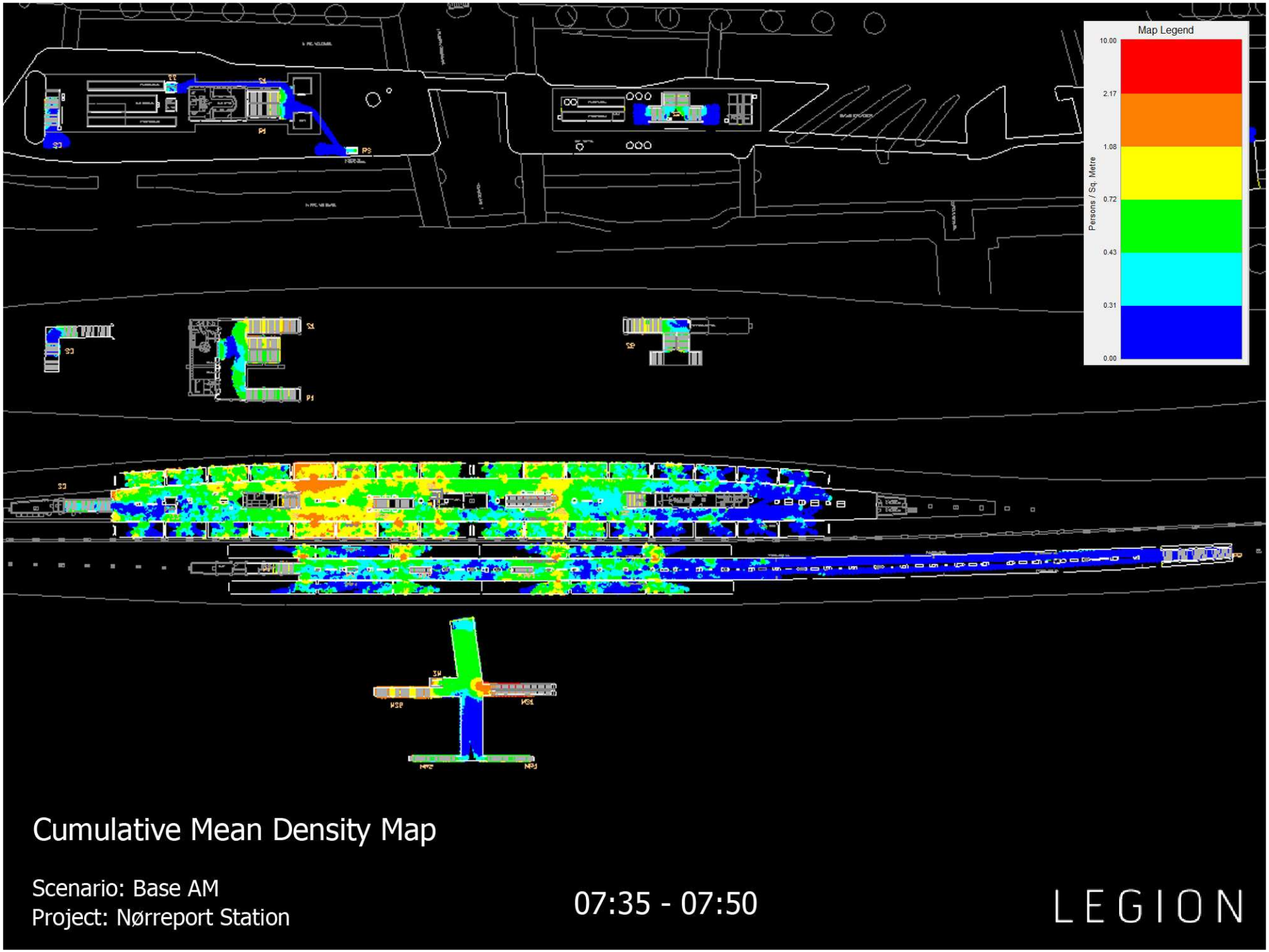


Cumulative Mean Density Map

Scenario: Base AM
Project: Nørreport Station

07:20 - 07:35

LEGION



Cumulative Mean Density Map

Scenario: Base AM
Project: Nørreport Station

07:35 - 07:50

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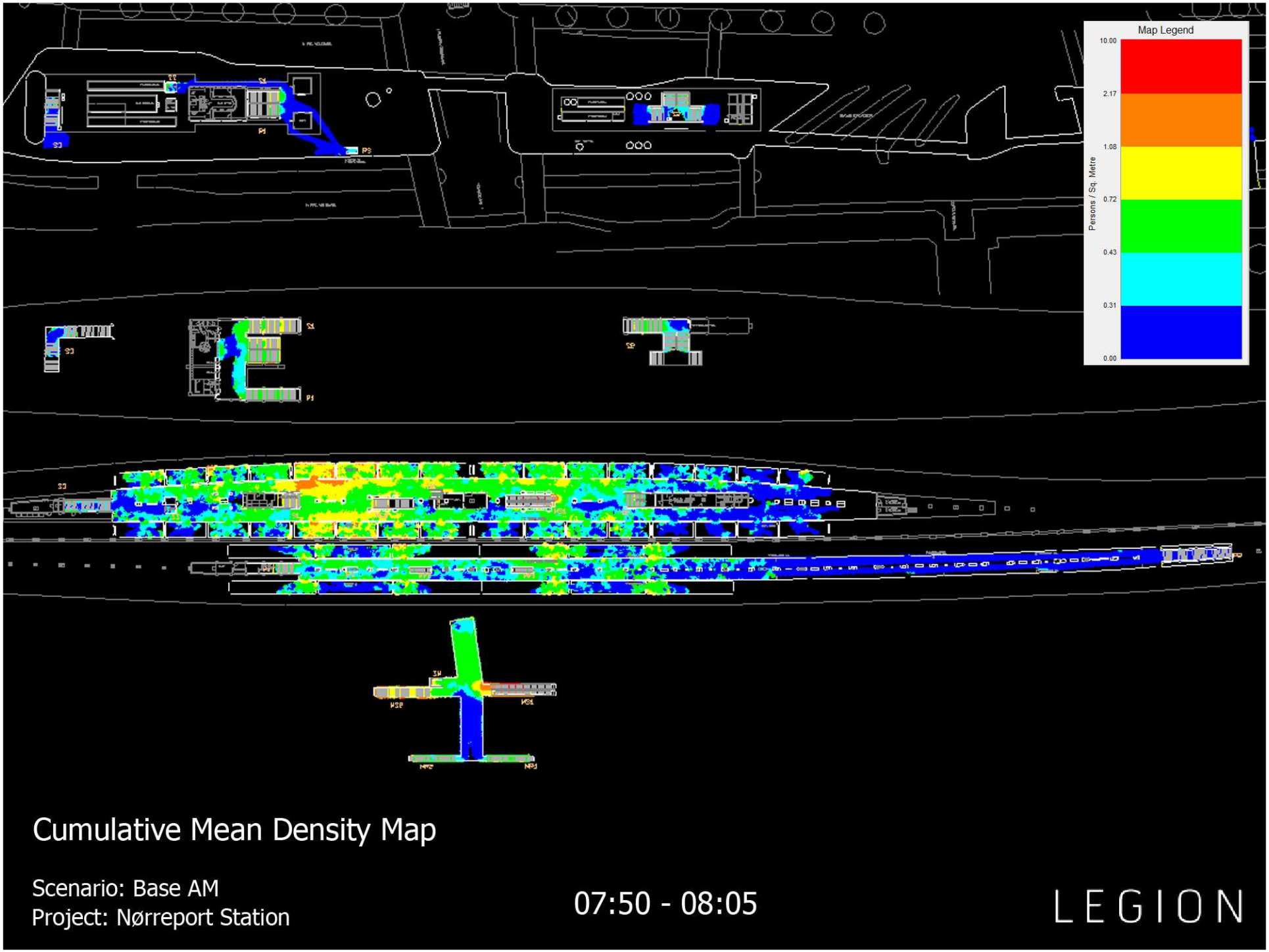

Cumulative Mean Density Map

Scenario: Base AM
Project: Nørreport Station

07:50 - 08:05

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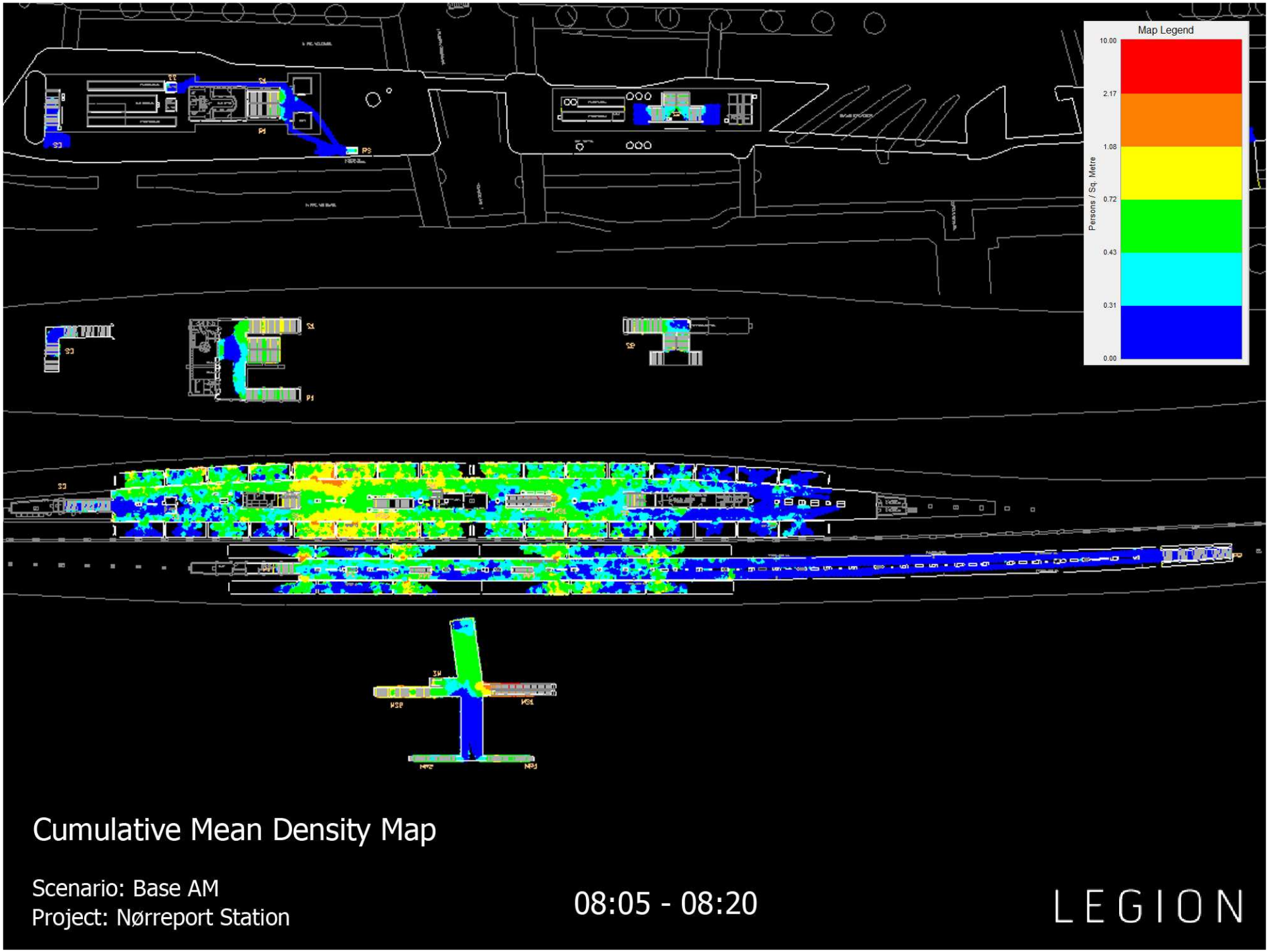


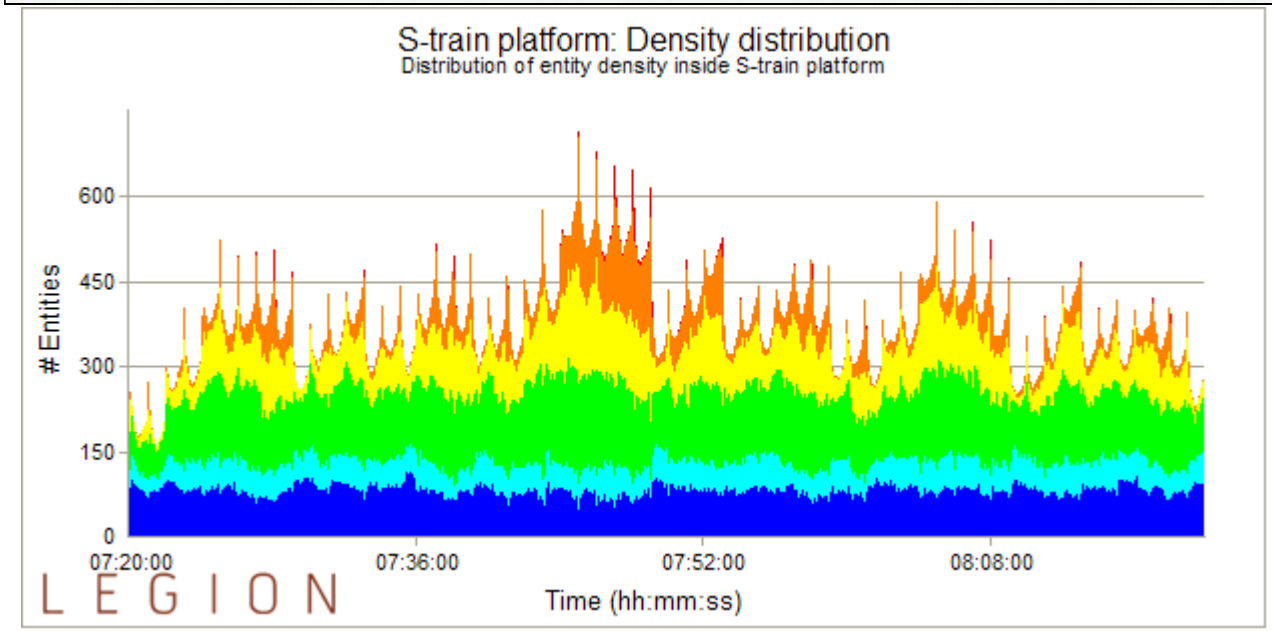
Cumulative Mean Density Map

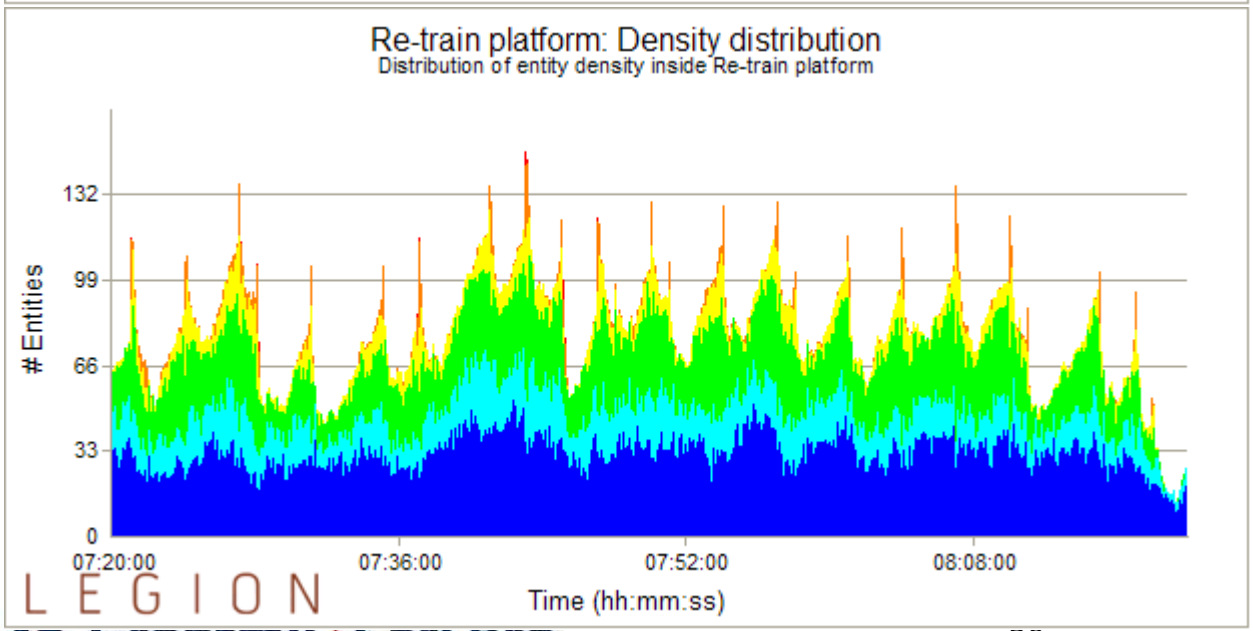
Scenario: Base AM
Project: Nørreport Station

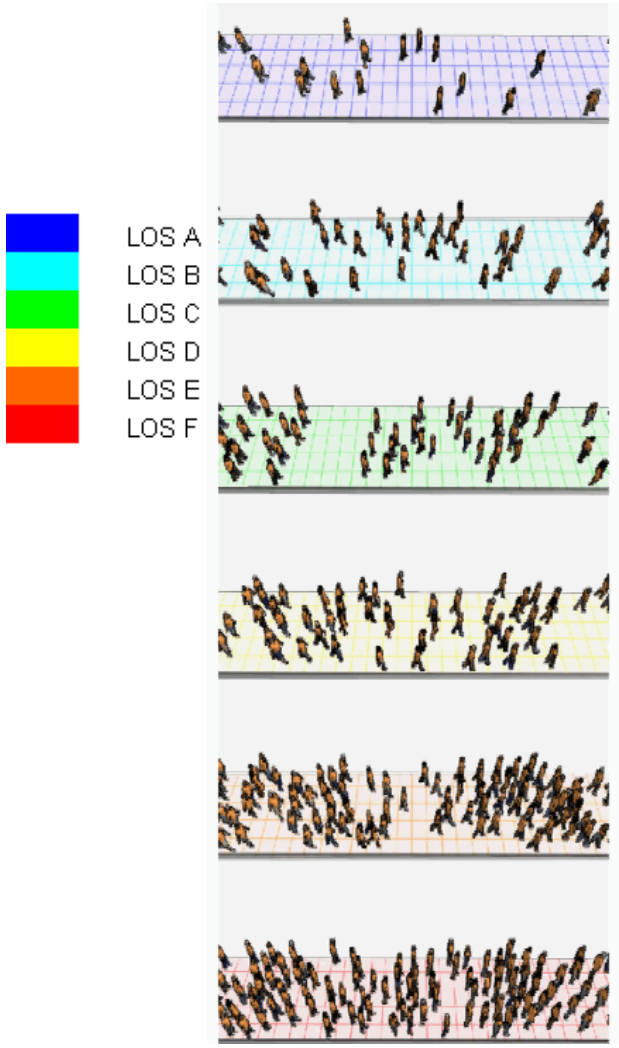
08:05 - 08:20

LEGION

AM scenario: Passenger Experience on the Platforms







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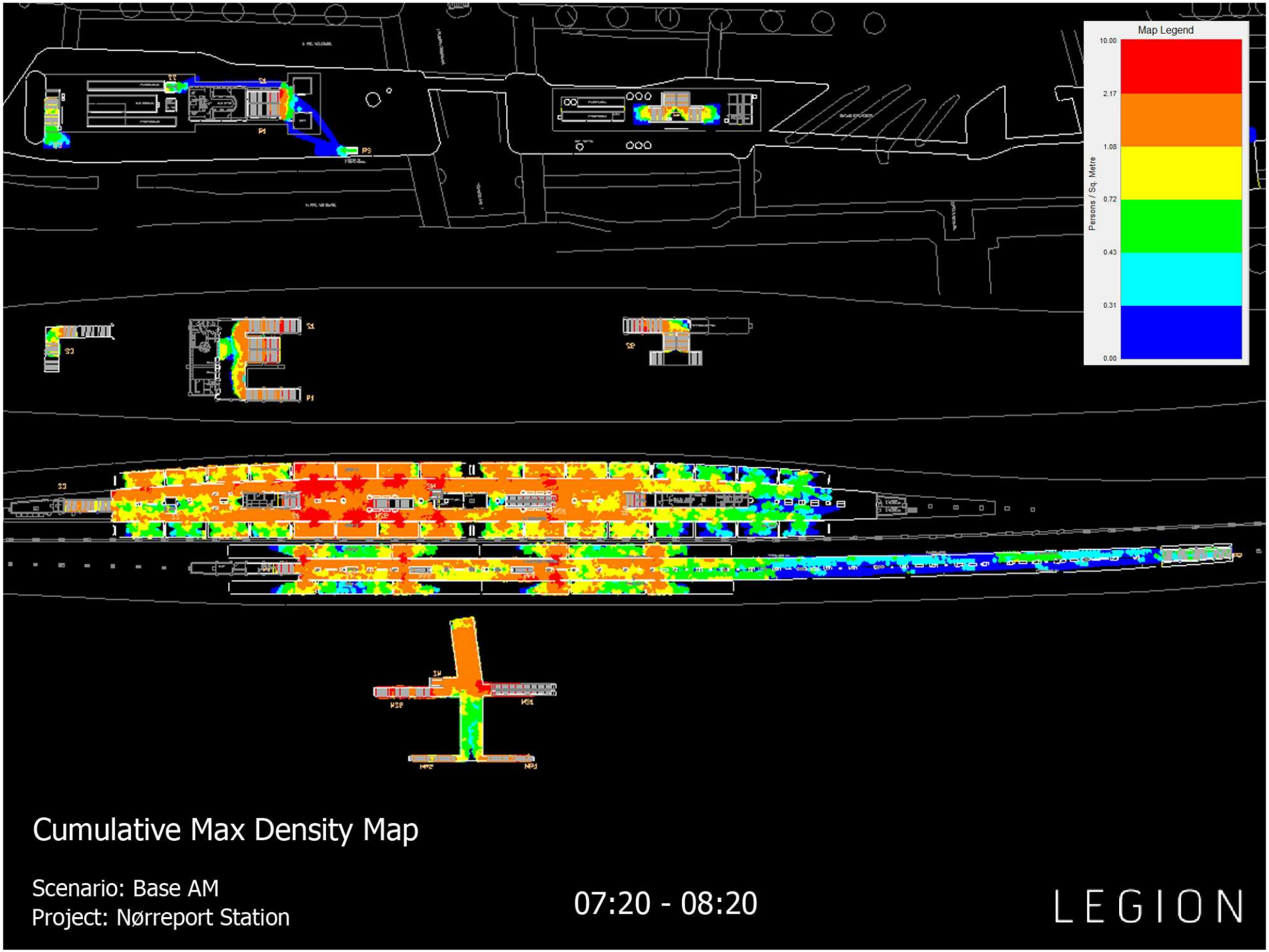
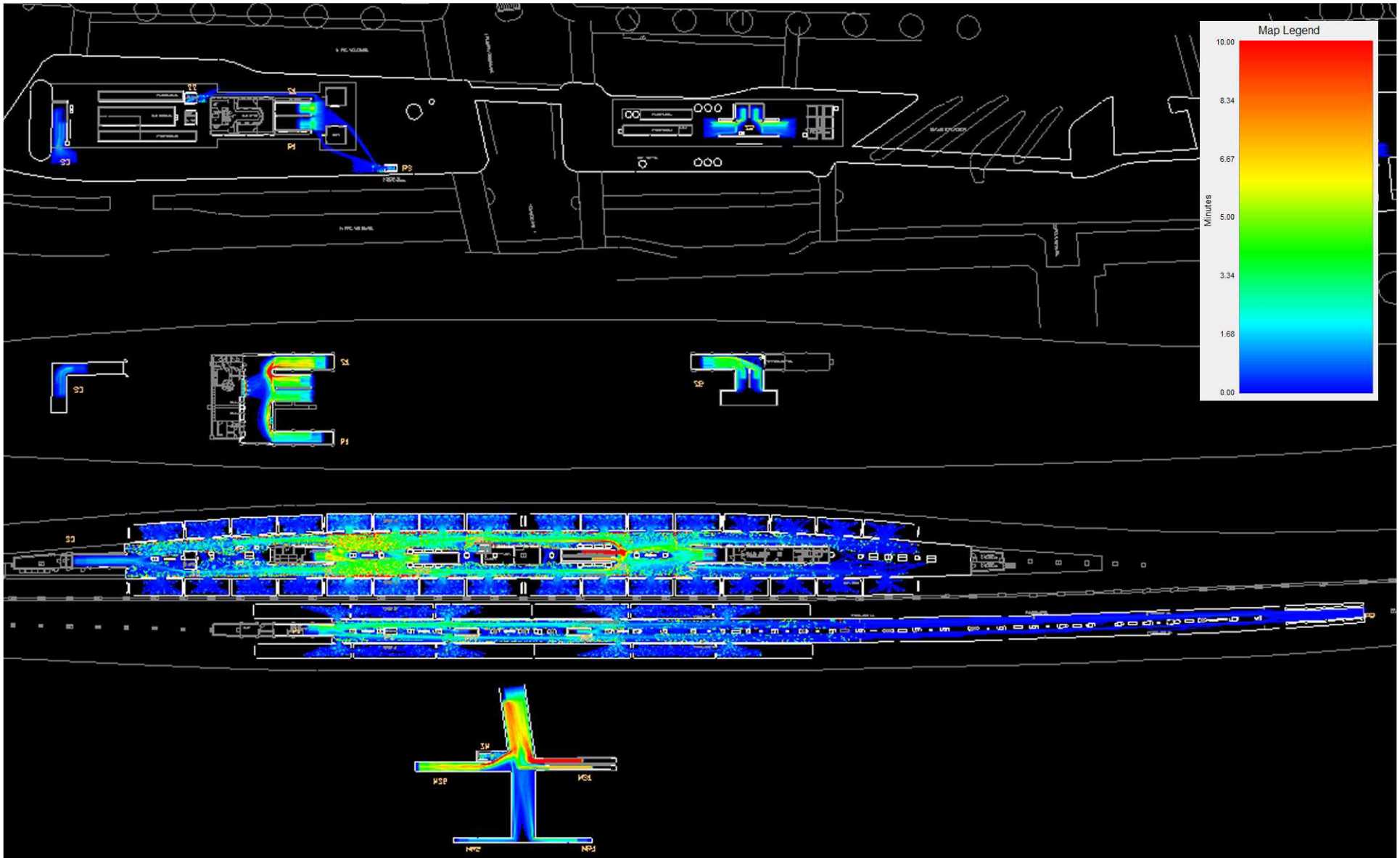


Cumulative Max Density Map

Scenario: Base AM
Project: Nørreport Station

07:20 - 08:20

LEGION



Space Utilisation Map

Scenario: Base AM
Project: Nørreport Station

07:20 - 08:20

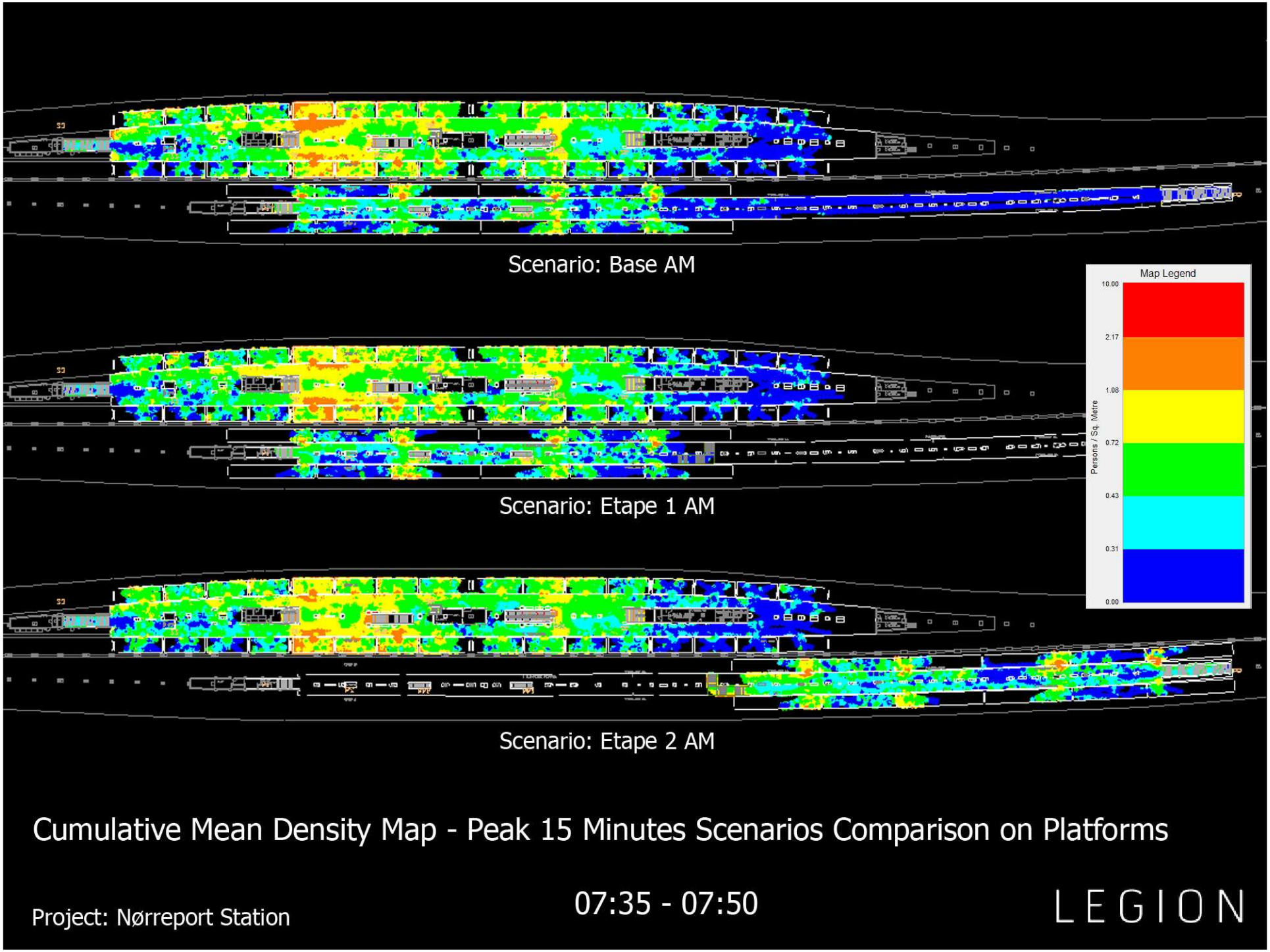
LEGION

AM and PM Scenarios

Peak 15 Cumulative Mean Density Maps – Platforms

Summary Slides

LEGION

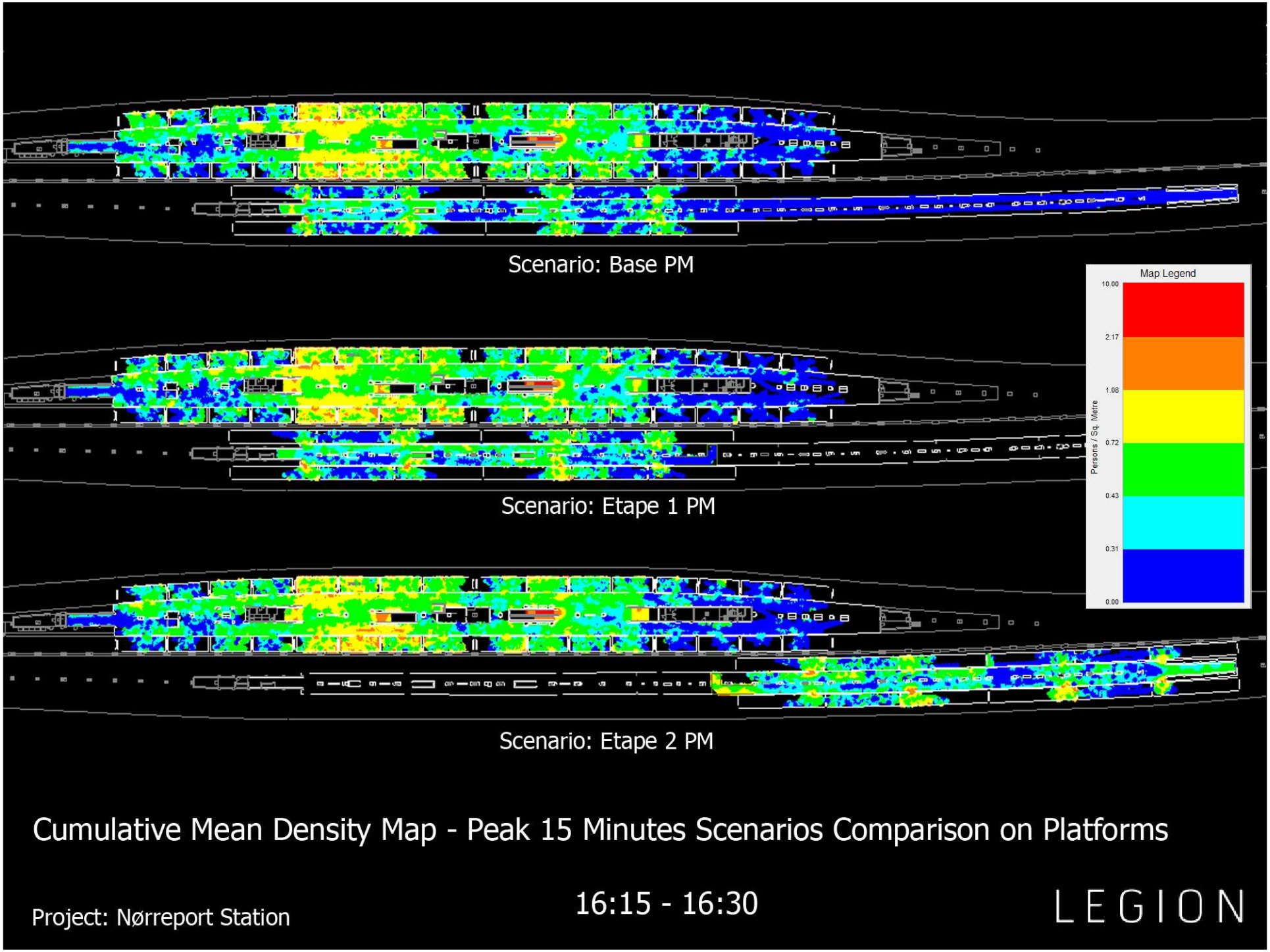


Cumulative Mean Density Map - Peak 15 Minutes Scenarios Comparison on Platforms

Project: Nørreport Station

07:35 - 07:50

LEGION



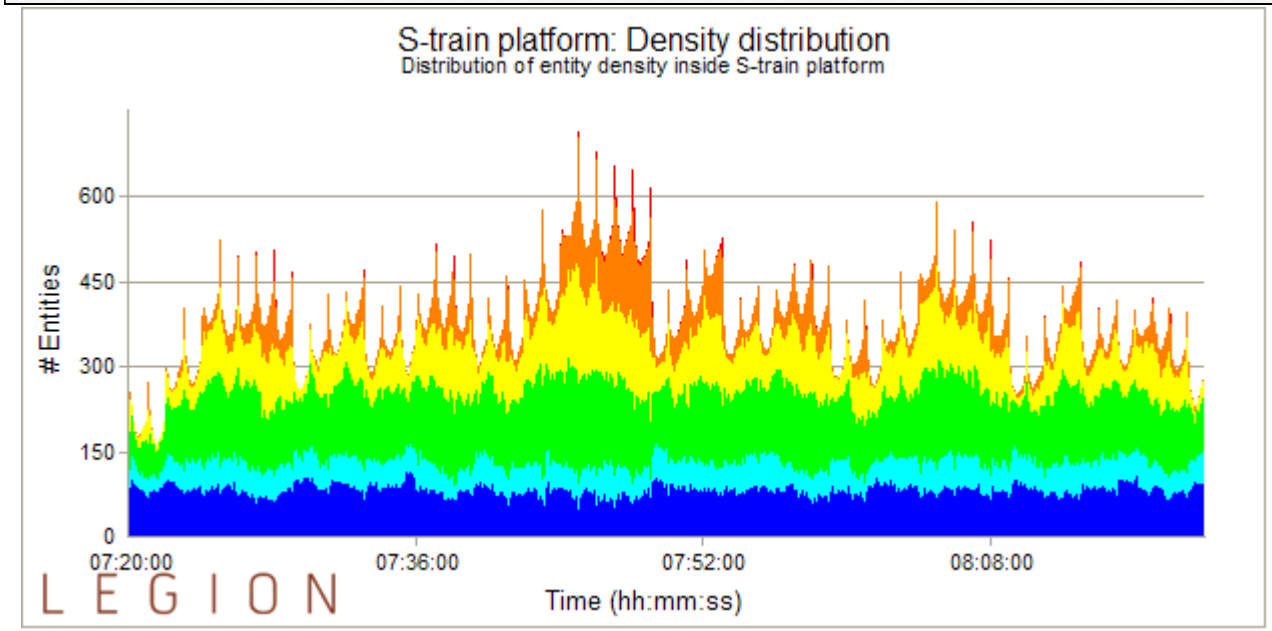
Cumulative Mean Density Map - Peak 15 Minutes Scenarios Comparison on Platforms

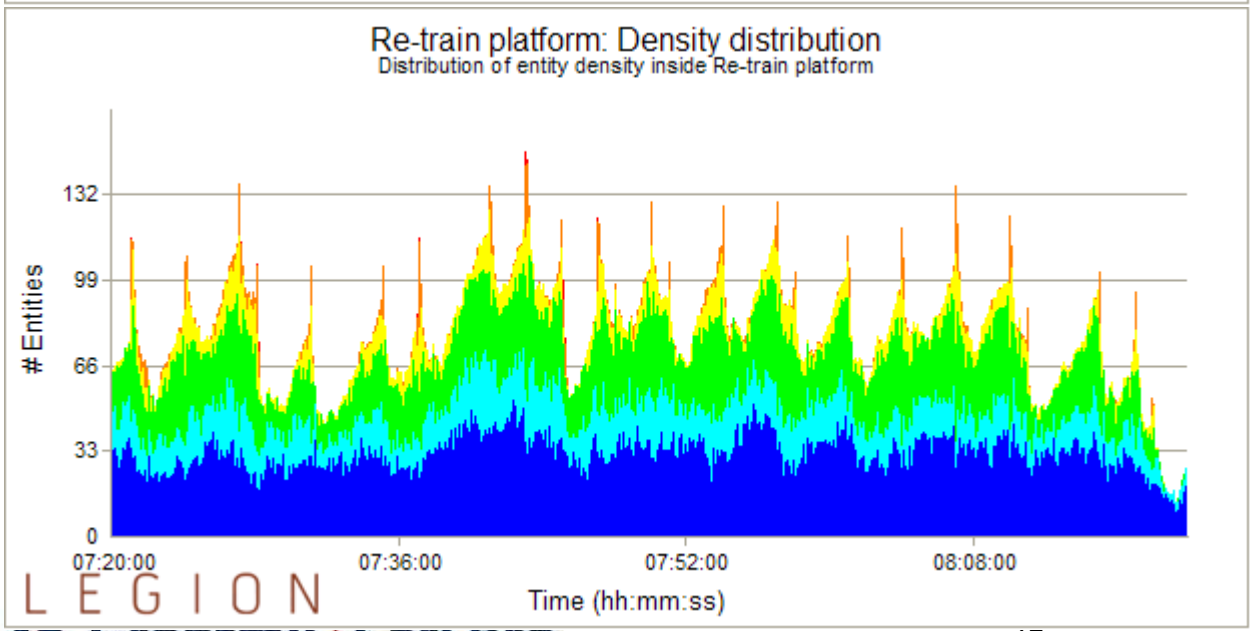
Project: Nørreport Station

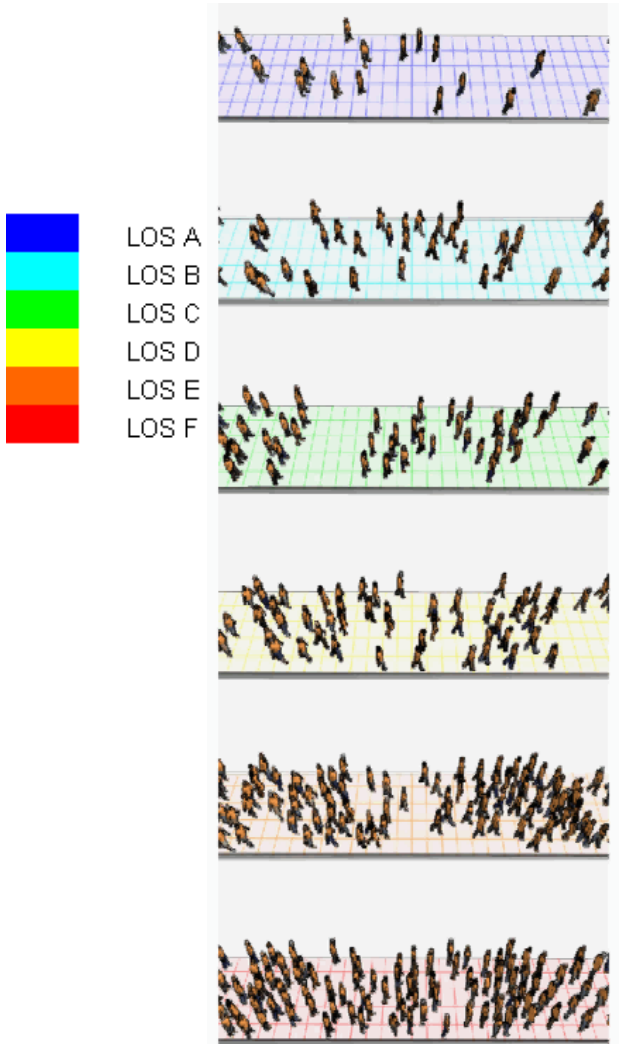
16:15 - 16:30

LEGION

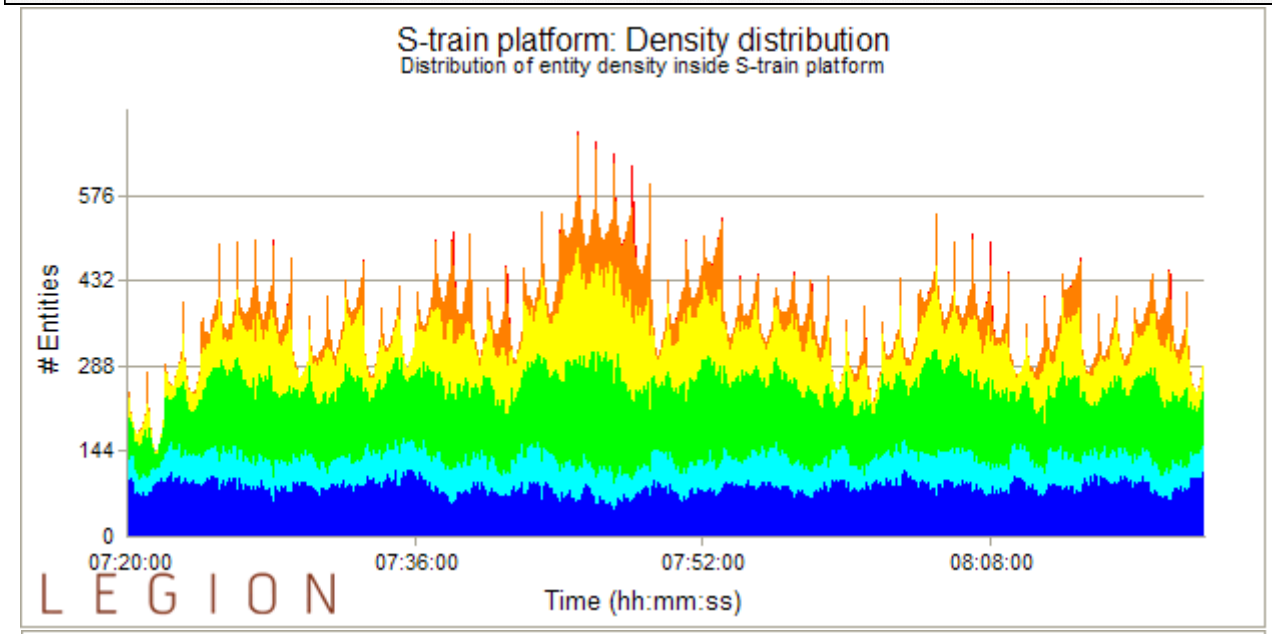
AM scenario: Passenger Experience on the Platforms

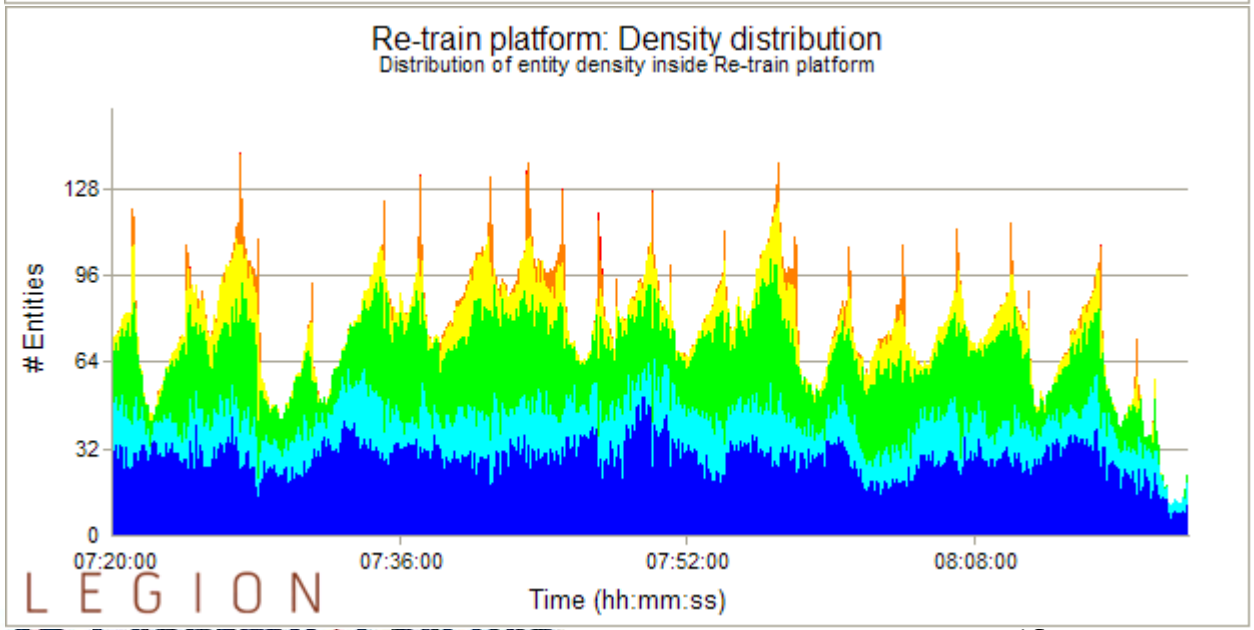


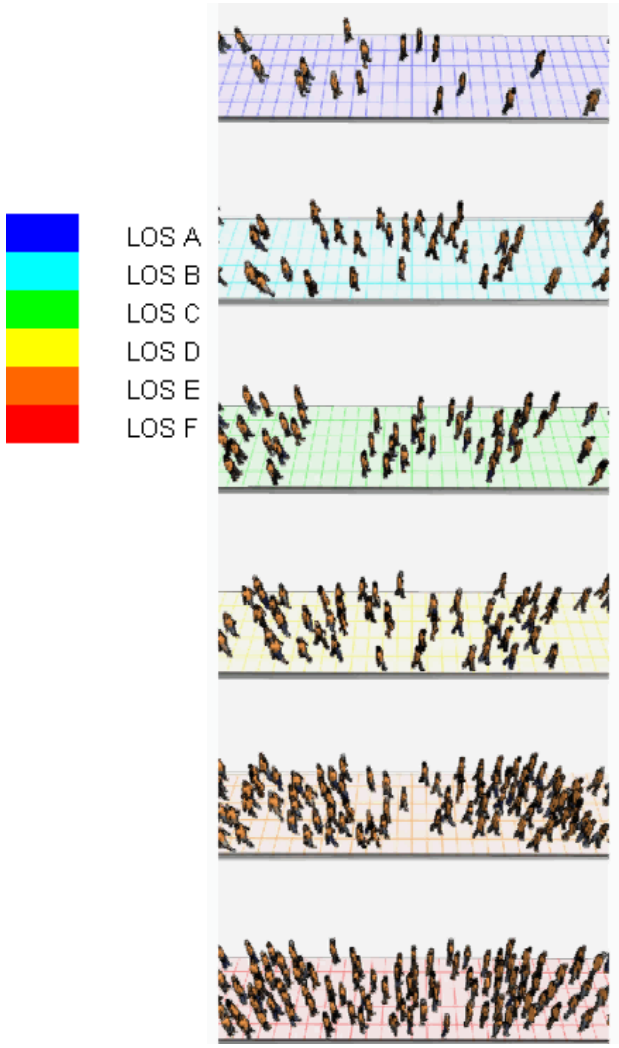




AM E1 scenario: Passenger Experience on the Platforms

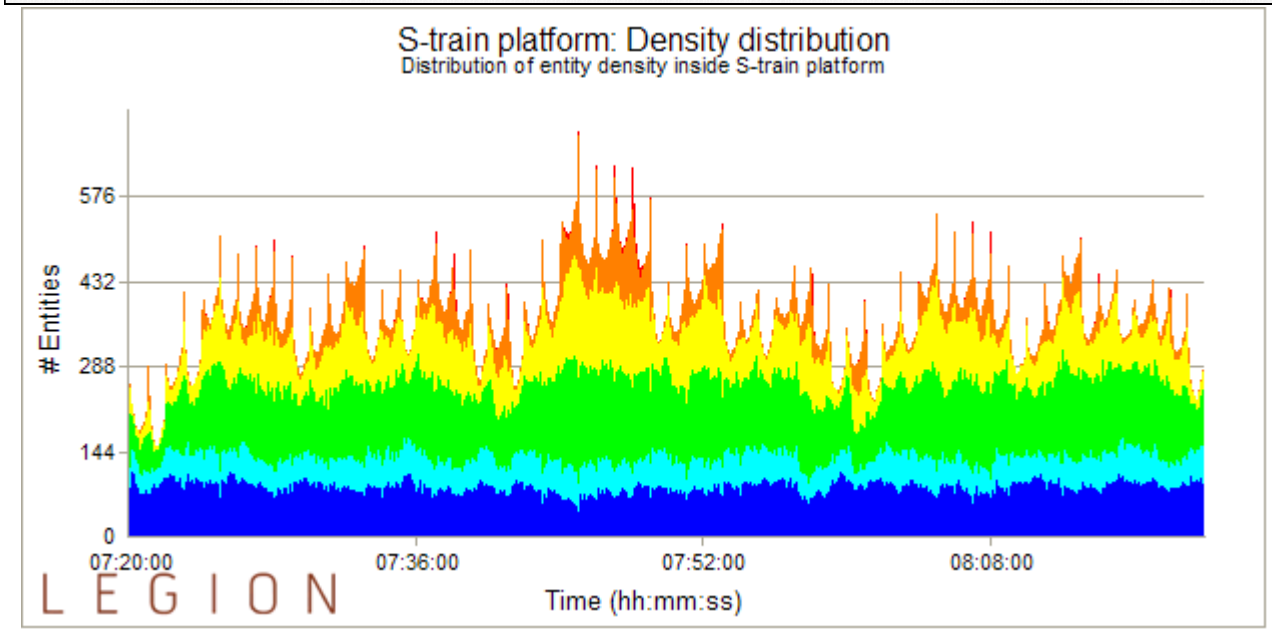


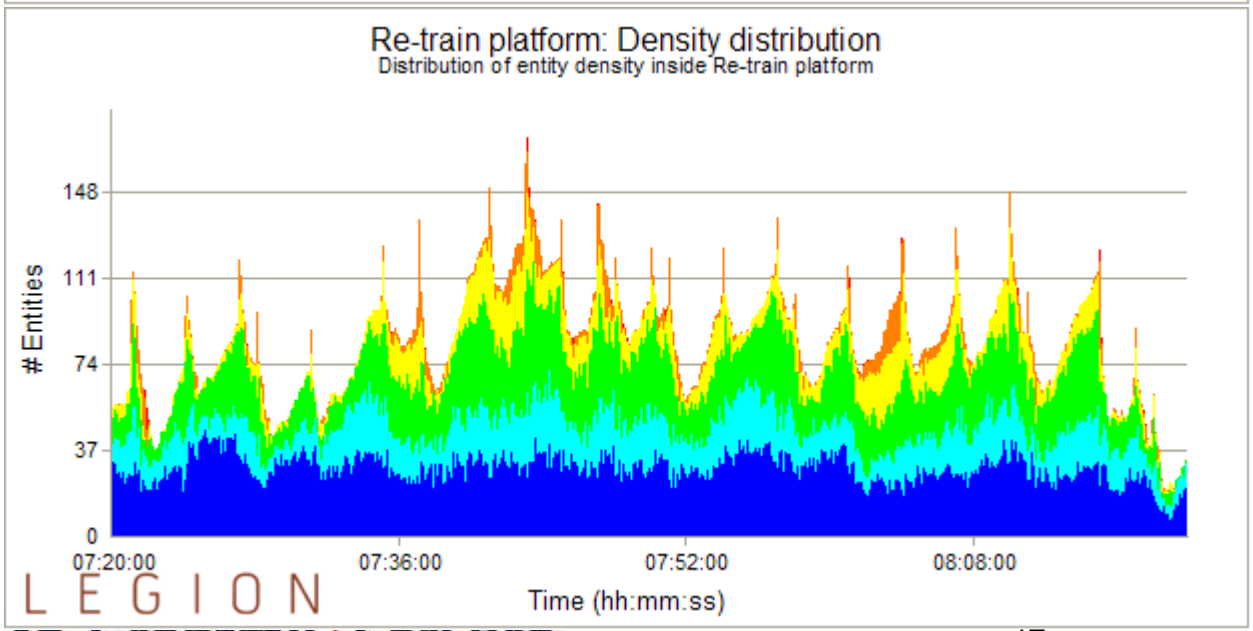


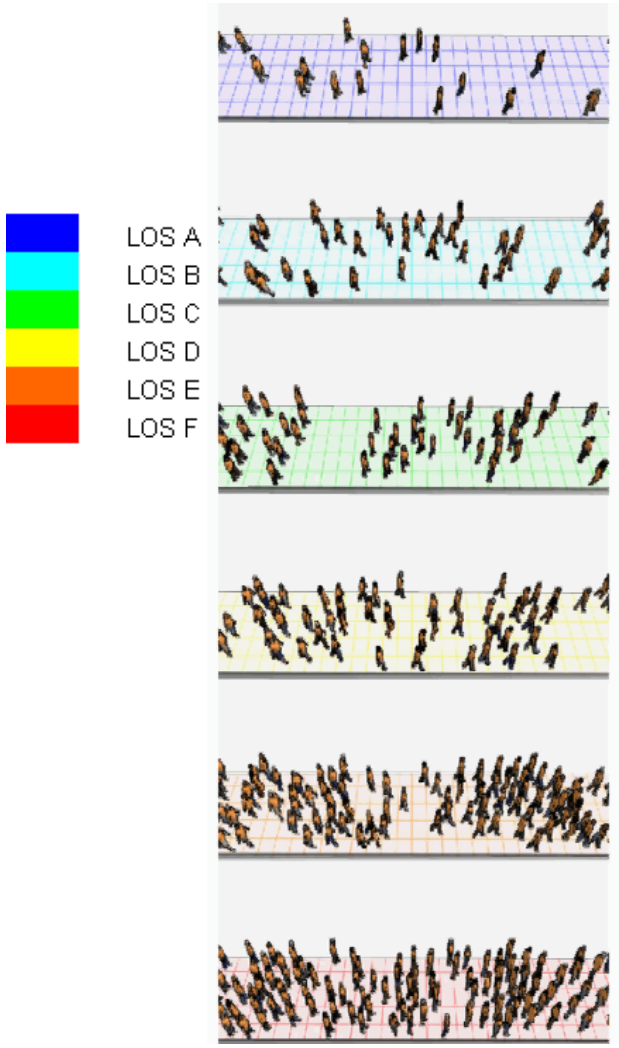


LEGION

AM E2 scenario: Passenger Experience on the Platforms







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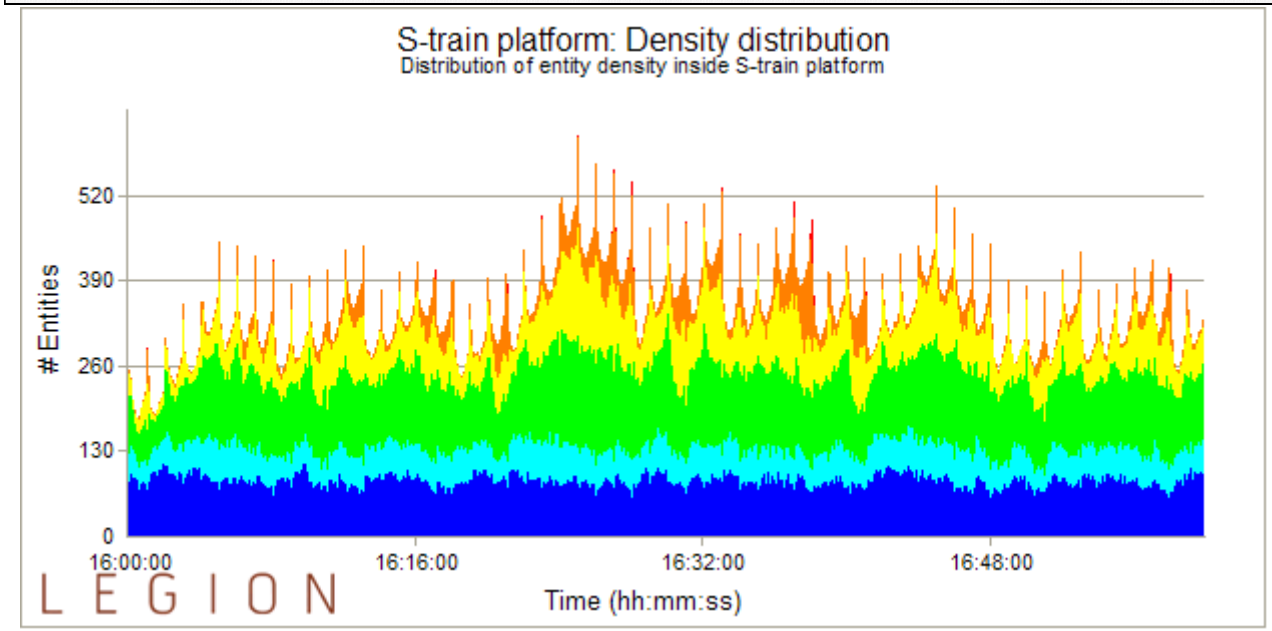
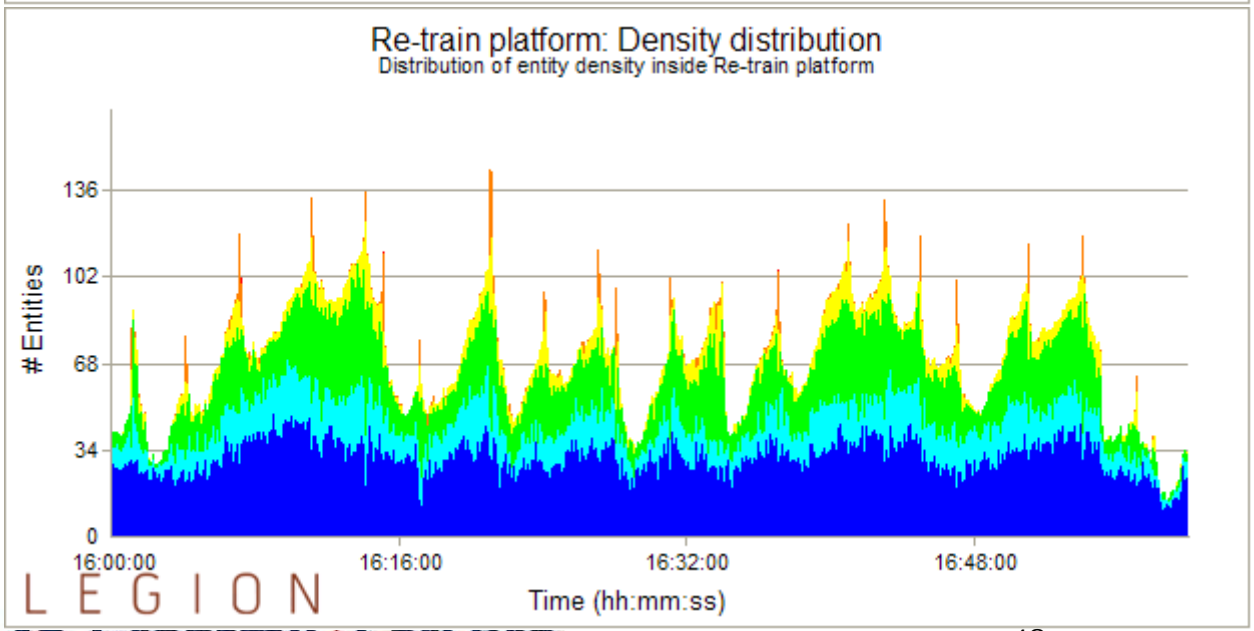
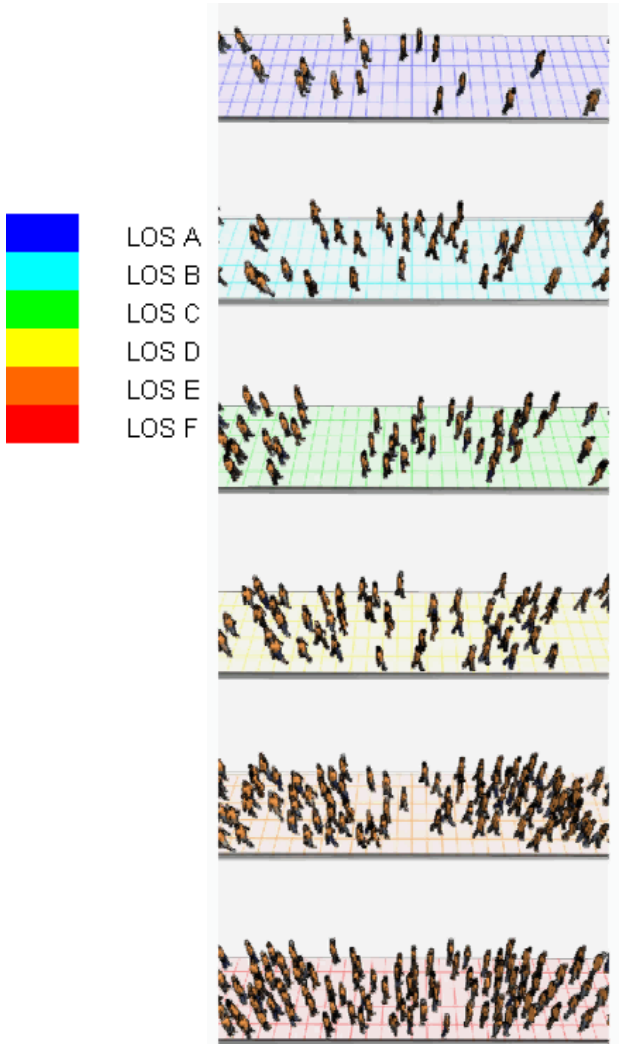
PM scenario: Passenger Experience on the Platforms

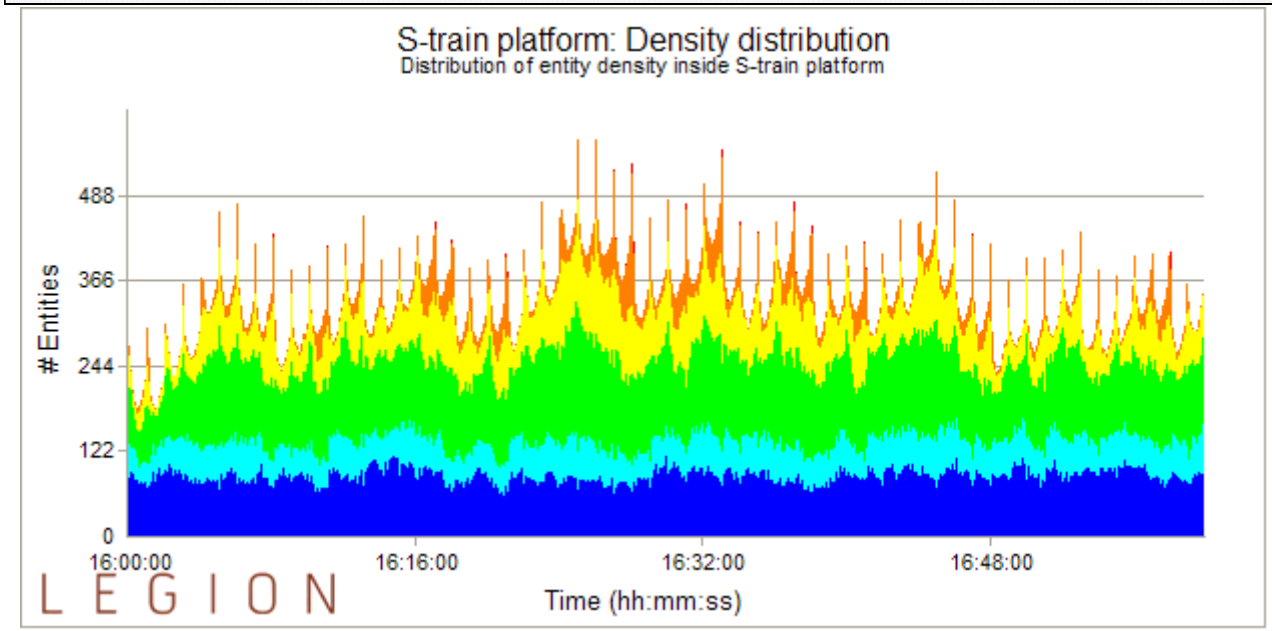


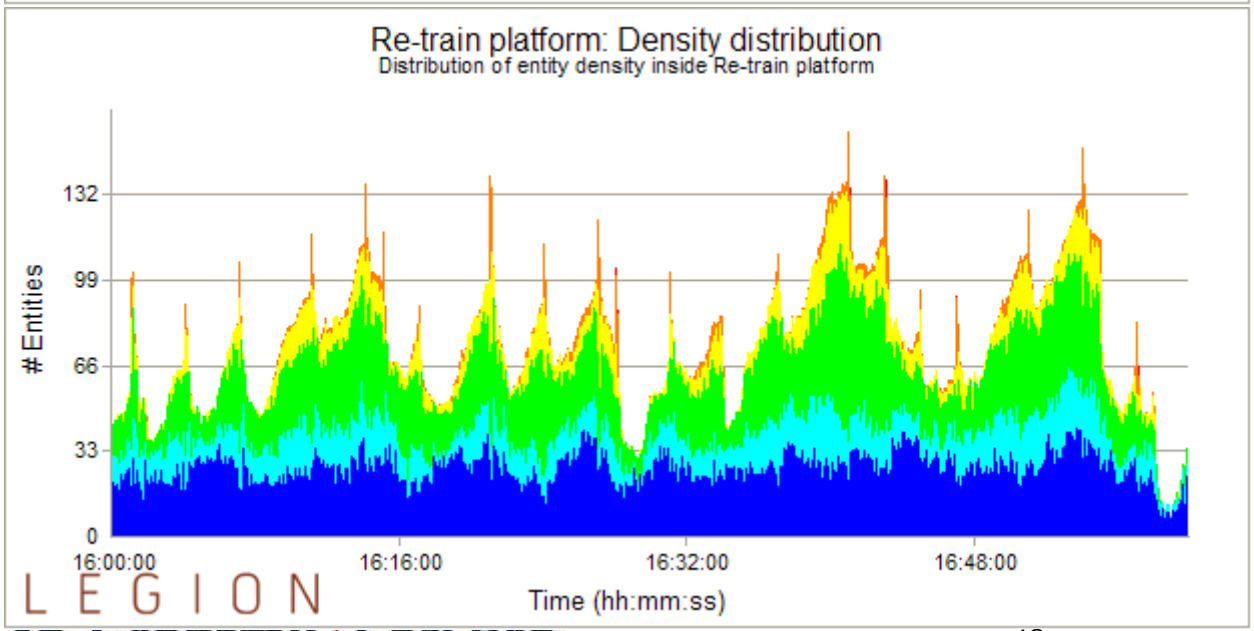


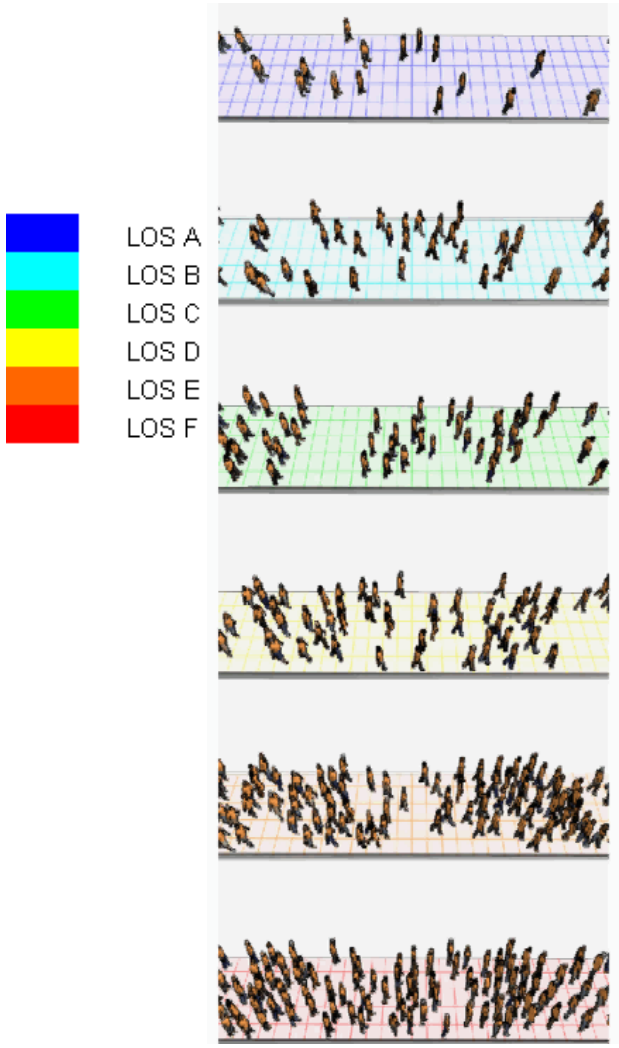


LEGION

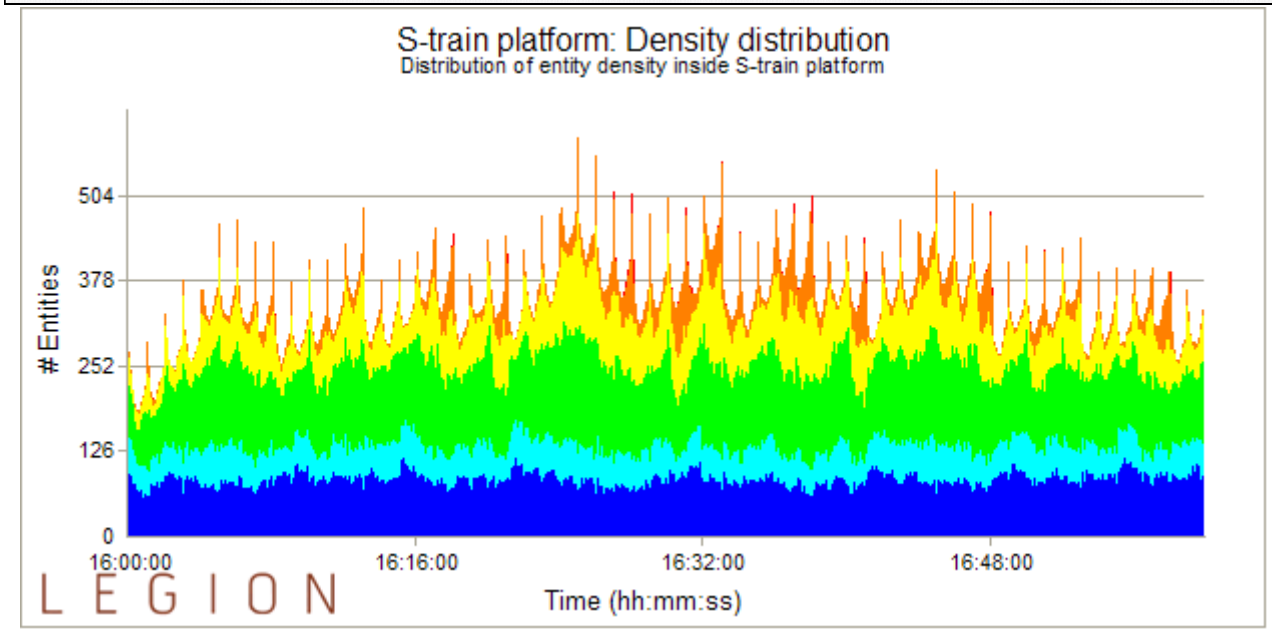
PM E1 scenario: Passenger Experience on the Platforms

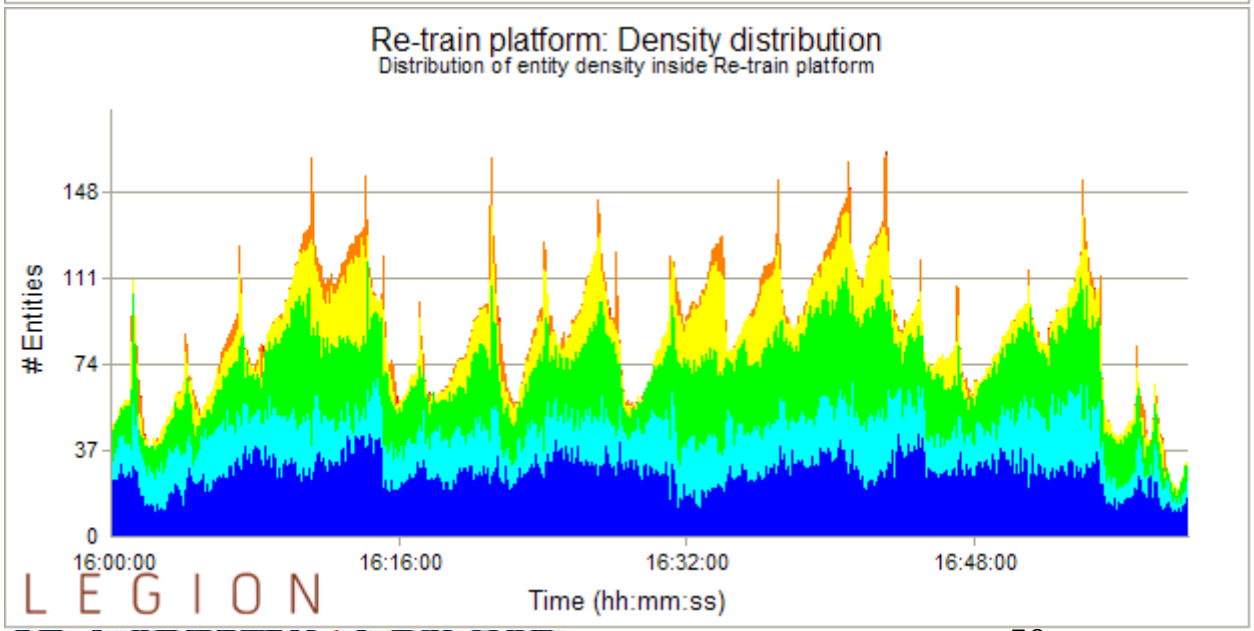


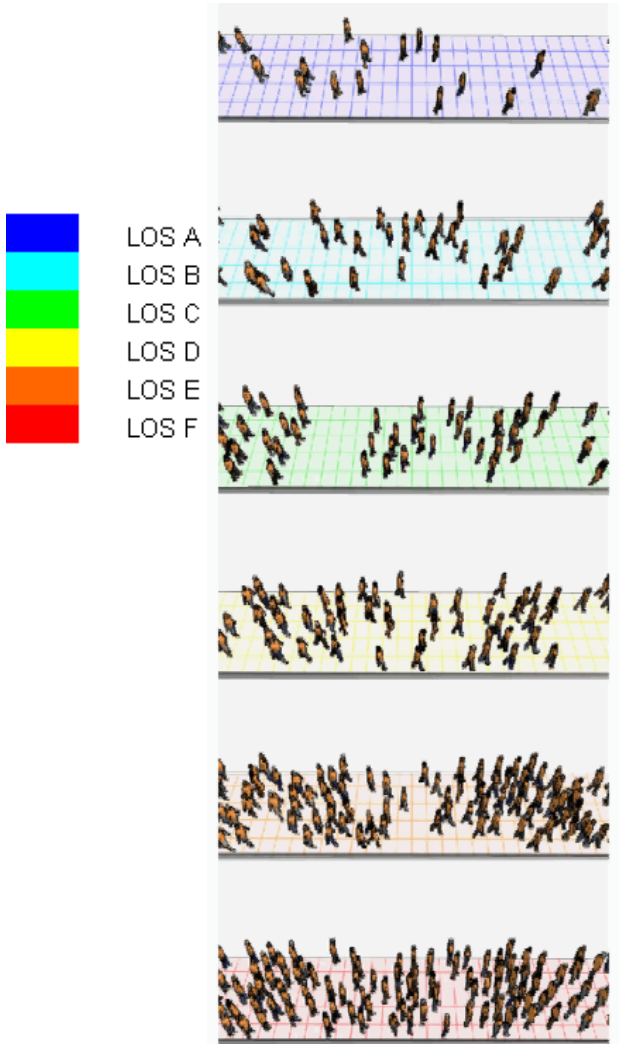




PM E2 scenario: Passenger Experience on the Platforms







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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

Microsoft Office
el 97-2003 Worksh

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

Microsoft Office
el 97-2003 Worksh

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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.

Photo:

Public Arkitekter / COBE

Grontmij | Carl Bro

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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.

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LEGION – Market Sectors

Rail and Metro

Stadia, Sports and Special Events

Air

Public and Urban Realm, Commercial Buildings

Retail

Traffic

Legion Representative Clients

Rail/Metro

- Consorcio Regional de Trasportes de Madrid
- Crossrail
- Ferrocarrils de la Generalitat de Catalunya
- Kowloon Canton Railway Corporation
- London Underground
- Metro de Madrid
- Metro de Santiago
- Network Rail
- New York City Transit
- New Jersey Transit
- Mass Rapid Transit Authority of Thailand
- RailCorp Sydney
- Transport of London

Sports

- Coventry Arena
- Düsseldorf Arena
- Gillette Stadium
- Malaga Football Club
- Watford FC
- Wembley Stadium
- West Ham United FC

Super Events

- London 2012
- Beijing 2008
- Athens 2004
- Sydney 2000

Other

- Beijing University of Technology
- Hong Kong Jockey Club
- Lower Manhattan Development Corporation
- Malaga Fire Brigade
- London Fire Brigade
- Norman Foster and Partners
- Parkview International Limited
- SAVE

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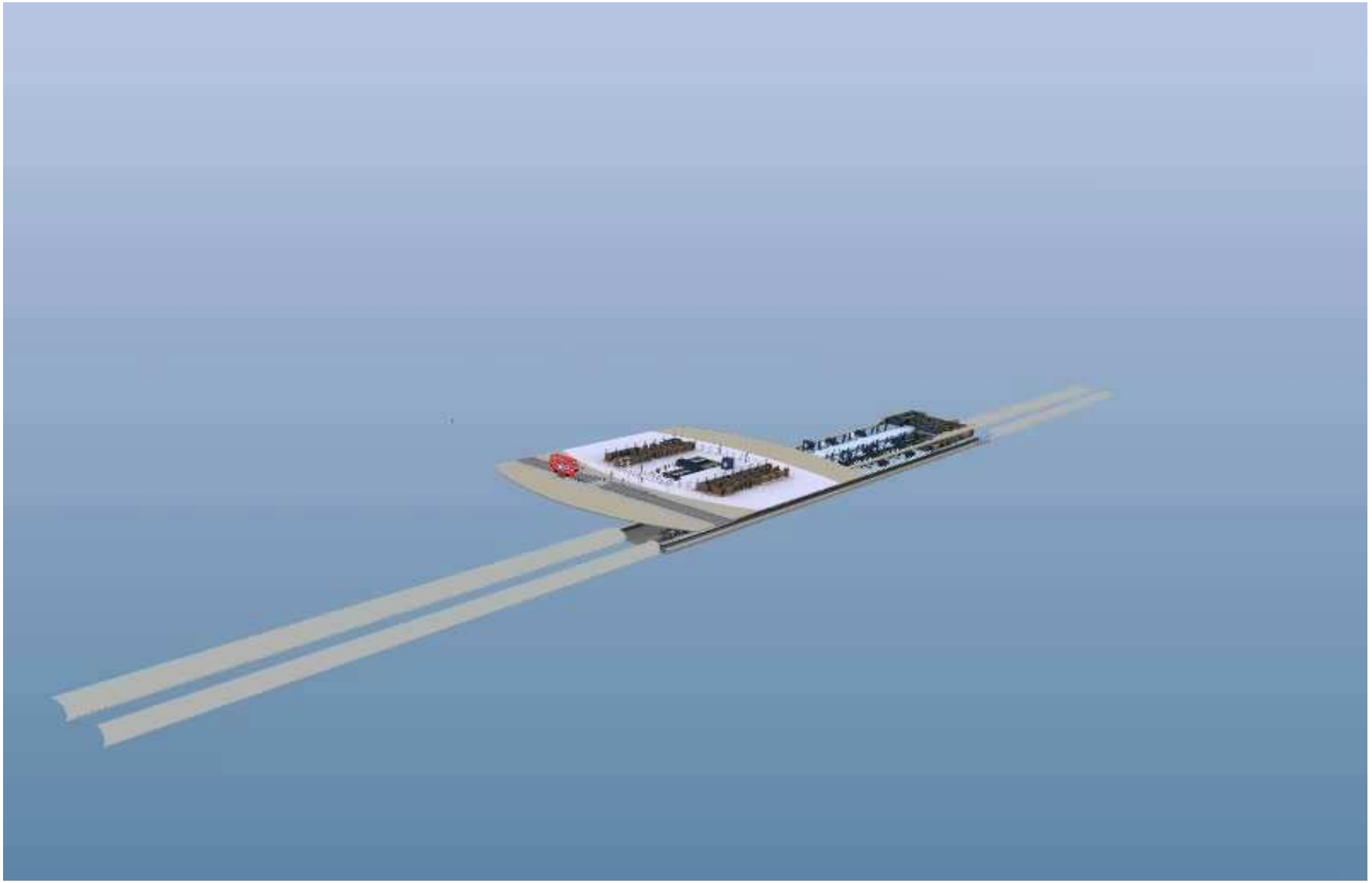
Metro Station meets surface level



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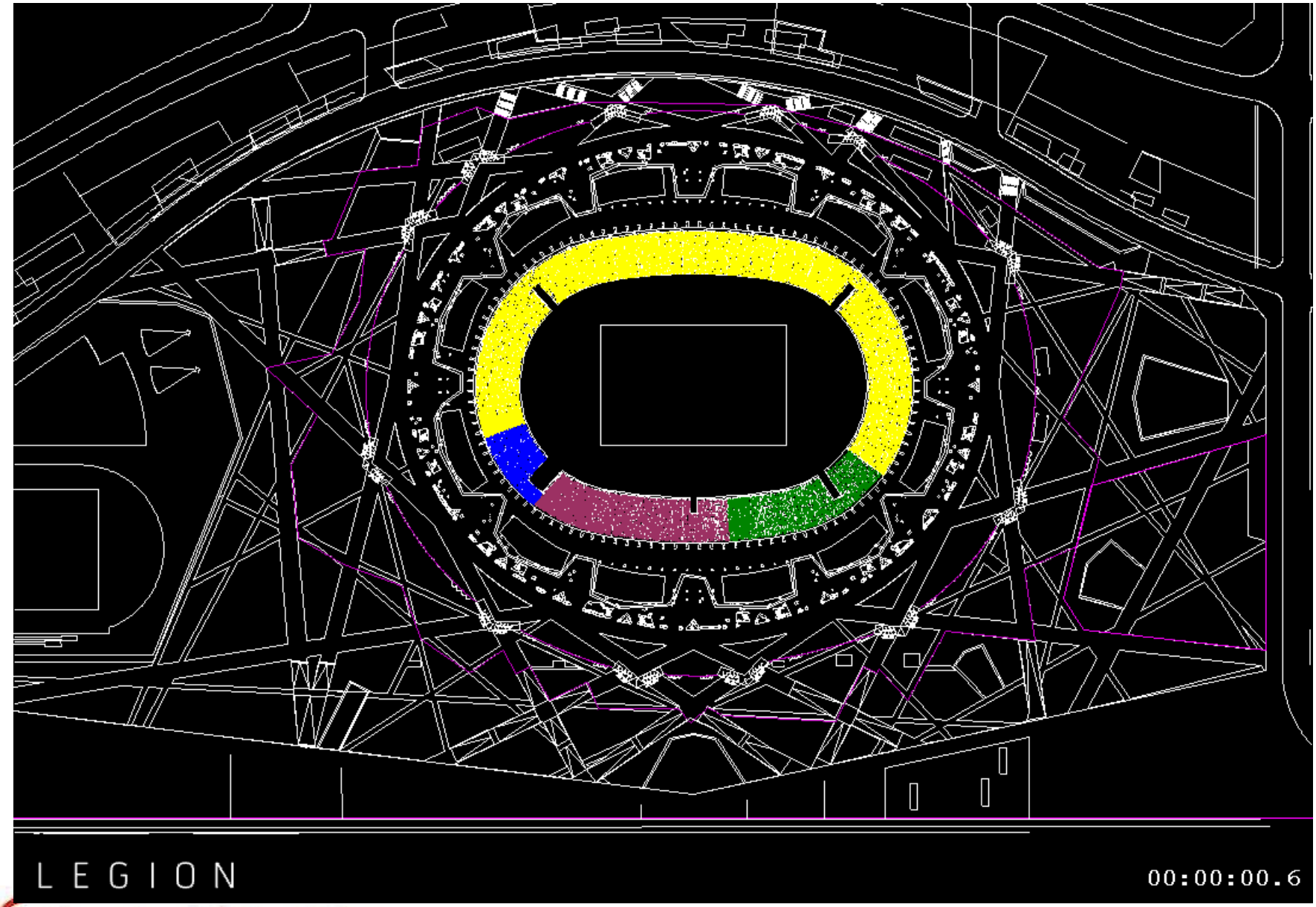
Transit Oriented Development

Sports Events - Beijing Olympics 2008



High Quality 3D simulation outputs