Towards New Urban Mobility
preparing for the driverless future through multi-agent systems

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DEFINITION > INFORMATION SYSTEMS > FORMATION > EXPERIENCE
A 7000M2 PAVILION FOR THE WORLD EXPO 2025, ROTTERDAM

tackles global challenges

efficient tools to modernize transportation infrastructures

commonly abandoned or under use after the exhibition
WORLD’S POPULATION INCREASINGLY URBAN

1990 (43%)
today (54%)
2050 (66%)
Global challenge

FURTHER RISKS

polluted

gridlocked

green spaces

well connected

INSTEAD..

5/90
today’s cars are parked 96% of the time

smaller and lighter to reduce energy consumption

driverless, shared and electric

redesign the urban lay-out
Audi Urban Future Award 2014: Team Berlin’s “Flywheel”
Will there be a “No Drive Day” around the 2050 when driving tests and licenses are discontinued and replaced by access rules and obligations for passengers within a driverless system?
FUTURE URBAN MOBILITY, DRIVEN BY POLICY OR TECHNOLOGY?

addressing the difficult social, political and ethical issues

potential enabled by technological innovations

extensive public debate, exposure and familiarization
DESIGN GOALS

>> *informative experience*

about the innovations to encourage people’s involvement and participation

>> *valuable connection and program*

to promote walking + cycling and to support flexibility between transportation systems

>> *energy extracting solution*

to support the electric vehicles
ROTTERDAM’S FUTURE PLANS

location
OPPORTUNITIES

location
OPPORTUNITIES

location
WHO WILL USE THE PAVILION?

3 user groups

visitors
>> are invited to enjoy the informative experience

researchers and students
>> vehicle industry is invited to test and show their developments here

residents and commuters
>> will use the transportation systems and waterfront enjoyment
### 7000M2 FUNCTION OVERVIEW

3 function groups

<table>
<thead>
<tr>
<th>Transportation</th>
<th>Informative Experience</th>
<th>Innovation</th>
</tr>
</thead>
<tbody>
<tr>
<td>grab-a-(e)Bike</td>
<td>experience centre</td>
<td>think tank</td>
</tr>
<tr>
<td>bike storage</td>
<td>(mechanical 3D presentation + interactive roadway)</td>
<td>test track</td>
</tr>
<tr>
<td>boatstop</td>
<td>urban vehicle exhibit</td>
<td>maintenance / prototyping</td>
</tr>
<tr>
<td>bridge</td>
<td>workshop (test track)</td>
<td>vehicle storage</td>
</tr>
<tr>
<td></td>
<td>viewpoint</td>
<td></td>
</tr>
<tr>
<td></td>
<td>traffic space</td>
<td>400m2</td>
</tr>
<tr>
<td></td>
<td>information point</td>
<td>1200m2</td>
</tr>
<tr>
<td></td>
<td>cafe</td>
<td>400m2</td>
</tr>
<tr>
<td></td>
<td>retail</td>
<td>400m2</td>
</tr>
<tr>
<td></td>
<td>admin / sales</td>
<td>400m2</td>
</tr>
<tr>
<td></td>
<td>sanitary</td>
<td>400m2</td>
</tr>
<tr>
<td></td>
<td>1000m2</td>
<td>2400m2</td>
</tr>
</tbody>
</table>
DEFINITION > INFORMATION SYSTEMS > FORMATION > EXPERIENCE
SWARM INTELLIGENCE
bottum-up simulation

1. AGENT
   general + specific behavioural rules

2. MULTI-AGENT SYSTEMS
   different specific behavioural rules

   >> the ability of groups to exhibit greater intelligence than its individual members

   >> system composed of multiple interacting intelligent agents within an environment

3. OUTCOME
top-down
OVERVIEW

information systems (Processing)

1. FUNCTION ALLOCATION

Function to Agents -> Local Parameters -> Relationships -> Outcome -> Specifications -> Result

2. EXTERIOR PATH GENERATION

User to Agents -> Local Parameters -> Relationships -> Outcome -> Specifications -> Result
FUNCTION TO AGENTS

input

Function to Agents → Local Parameters → Relationships → Outcome → Specifications → Result

exhibit → 500m² → 7000m² → 14 agents → 200 agents
LOCAL PARAMETERS

input

attractor: **sun** following daily path  
>> **cohesion**

repeller: **boats** following routing + SS boat  
>> **separation**

curve attractor: **quays connection**  
>> **alignment**  
target mesh: **view area**  
>> **seek**

target mesh: **water and land proximity**  
>> **seek**
RELATIONSHIPS

---

input

Function to Agents → Local Parameters → Relationships → Outcome → Specifications → Result

Test track

Experience center

Exhibit

Boat stop

Bike storage

Grab-a-bike

Sanitary

Info

Cafe

Traffic space

Think tank

Workshop
simultaneously applied behaviours

random start positions <=> different strengths

infinite outputs

top-down evaluation

spatial layout

integration of local parameters
FUNCTION SPECIFICATIONS

**Function to Agents**
- Local Parameters
- Relationships
- Outcome
- Specifications
- Result

**Function Specification**
- **input:**
  - area
  - height
- centre of function agents is cylinder centre

**EXHIBIT**
- 12.6m
- 4m

**TEST TRACK**
- closed loop

**FUNCTION SPECIFICATIONS**
- centre of function agents is cylinder centre
- 12.6m
- 4m
- closed loop
OVERVIEW

information systems (Processing)

1. FUNCTION ALLOCATION

Function to Agents ▶ Local Parameters ▶ Relationships ▶ Outcome ▶ Specifications ▶ Result

2. EXTERIOR PATH GENERATION

User to Agents ▶ Local Parameters ▶ Relationships ▶ Outcome ▶ Specifications ▶ Result
USER TO AGENTS

input

User to Agents → Local Parameters → Relationships → Outcome → Specifications → Result

pedestrian and cyclist

agents
direct pedestrian

agents
wander pedestrian

agents
direct cyclist

agents
wander cyclist
LOCAL PARAMETERS

Input

User to Agents → Local Parameters → Relationships → Outcome → Specifications → Result

LAND PROXIMITY

VIEW AREA

WATER PROXIMITY

BOAT AVOIDANCE

QUAYS CONNECTION

FINAL POINT

direct pedestrian

wander pedestrian

direct cyclist

wander cyclist
OUTCOME

simultaneously applied behaviours

User to Agents  Local Parameters  Relationships  Outcome  Specifications  Result

start points
>> from existing infrastructure

end points
>> to existing infrastructure
PATH SPECIFICATIONS

User to Agents → Local Parameters → Relationships → Outcome → Specifications → Result

Required widths:
- 1.5m
- 2m
- 2.5m

Average of swarm outcome

Main fast path (+vehicle)
DEFINITION > INFORMATION SYSTEMS > FORMATION > EXPERIENCE
ARCHITECTURAL GOAL

>> maximize accentuation of movement

>> maximize openness in relation to the environment
SPATIAL SUBDIVISION

function allocation result

shaped by the distribution flow from the path connections

functions connected to paths
SKIN

functions connected to paths

enclosed functions and paths
SKIN

continuous lines

solar radiation analysis
SPLIT AND MERGE STRATEGY

1. maximize openings on highest values

2. maximize openings for required functions (light and view) in curvature of skin

3. vertical support for bridge spans

4. visual connections from exterior to interior program
CONTINUOUS STRUCTURAL SKIN
BRANCHING STRUCTURE IN OPENINGS

1. select openings
2. create point grid in relation to thickness for substructure and curvature
3. main branching, start point and vector with moving direction of test track vehicles
4. sub branching (<12m²)
result: prefab concrete component for double curved glazing
EXPLODED VIEW PROGRAM
SOLAR RADIATION ANALYSIS

paths: energy extraction

balustrade: integrate furniture
EXTERIOR FURNITURE

- leaning >> sitting >> laying

- create space from path

- sitting

- transition in section

- wind cover (specific areas)
PLANS

bik storage

level +00

test vehicle storage

3D mechanical presentation

maintenance and prototyping

interactive roadway
PLANS

level +01

central space

grab-a-bike  retail & info

test track  think tank  workshop

test track  exhibit

wc
level +02
PLANS

viewpoint

top entrance  bike racks  seating areas

level +03
SECTION BB'

test track
vehicle exhibit
interactive roadway
3D mechanical representation
test track
workshop
ASSEMBLY METHOD

main structure obtained through branched interconnections between structural skin and interior structure

chunk
ASSEMBLY METHOD

1. robotically milled EPS molds for prefab components (keep for insulation)

2. connect main prefab concrete components including insulation

3. overall prefab concrete components mold

4. fill prefab concrete components with fibre reinforced concrete (in situ)

opening for in situ fiber reinforced concrete
5. connect substructure prefab concrete component with in situ reinforced concrete

6. filling up with EPS insulation with sprayed white polyurethane finish

7. connect double curved window frames and glass

result
1. fiber reinforced concrete 400mm (in situ)
2. prefab concrete component, integrated concrete housing for solar path and exterior LED light
3. LED light
4. rubber, compressed after tightening
5. EPS mold as insulation
6. local openings in EPS to connect prefab components
7. white polyurethane finish (sprayed)
8. solar path: transparent top layer, optical layer, solar cells
1. fiber reinforced concrete (230mm-400mm)
2. prefab concrete component
3. LED light
4. rubber, compressed after tightening
5. EPS mold as insulation
6. local openings in EPS to connect prefab components
7. white polyurethane finish (sprayed)
8. dark grey resin floor
9. opening to fill
1. 3D printed double curved aluminium window frame (further research)
2. hard rubber
3. blocking
4. sealant
5. backer rod
6. EPS mold as insulation
7. double curved glazing
1. fiber reinforced concrete 400mm
2. prefab concrete component
3. rubber, compressed after tightening
4. EPS mold as insulation
5. polyethylene vapor barrier
6. granular fill
7. opening to fill
CLIMATE CONTROL

EPS is double side milled to create space

mechanical ventilation system: in- and out shafts running through the building
DEFINITION > INFORMATION SYSTEMS > FORMATION > EXPERIENCE
TEST TRACK
EXTERIOR ROUTINGS

main fast routing
(+future urban vehicles)

cyclists

pedestrian
Thank you!