Urban Vertical Agriculture
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Part 1 Interchange of Kleinpolder, Rotterdam
Location

The site is located on the northern part of Rotterdam city.
Nowadays, more than 70% of earth’s available land is already farmed, and agriculture production is dominated by monocultures. Economic Disadvantages of Monocultures:
- greater demand for chemical inputs;
- through disconnected energy and material cycle;
- inefficient use of space and time
- transportation cost

Traditional Agriculture is Threatening the Environment:
- deforestation
- 2/3 of the global fresh water are used for irrigation
- excessive use of fertilizers and pesticides
- improper soil management

The agriculture area in the Netherlands has decreased from 98.54% (1960) to 57% (2013)

The Dutch Market:
- 60% of the majority of fruits are imported
- 95% of domestic vegetable consumption from homegrown sources
- 2/3 of domestic fruits and vegetables are in exported
- the most popular fruits with best sales in the Netherlands are apple, orange, banana (apples and pears are the most commonly produced in the country)
- 1,500 tons of dried herbs imported per year
  Most of the herbs are for ethic food.

In Rotterdam, for example, the demand for more ethnic food is increasing due to the high percentage of non-Dutch origins. 47.7% of the population are from non-Dutch origins.

Multi-ethnic and multicultural diversity lead to the demands for diversity of food.

As we know, Rotterdam has quite large amount of foreigners and immigrants from non-industrialized countries, and these group of people together with the Dutch people make the city a multi-ethnic and multicultural place. Among these foreigners and immigrants, most of them are with low education level and low income. It is not easy for them to find jobs. On the other hand, because people are from different culture background, they would have different demands for various food with low prices.
History of The Site

The interchange (the site I choose) is the largest 3D interchange in Netherlands, and it was built in the 60’s. The interchange is surrounded by houses which were built in 30’s. Both of the interchange and the surrounding houses are the results of sophisticated urban planning. It emerges from the disagreement between the large highways logic and the traditional urban fabric.

For this Kleinpolder district, the interchange, on one hand separates Overschie from Rotterdam; on the other hand, it has already become a sculpture, an identity for the district.

source from http://www.engelfriet.net/
The Site

centralization of vehicles (>150,000 vehicles/day)

The interchange mainly joins highway A13 and A20. Both of the highways are two of the busiest ones in Netherlands. And this centralized traffic system brings air pollution to the surrounding areas.

<table>
<thead>
<tr>
<th>HIGHWAY</th>
<th>DIRECTION</th>
<th>AVERAGE SPEED (km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A20</td>
<td>NORTH</td>
<td>77-95</td>
</tr>
<tr>
<td></td>
<td>SOUTH</td>
<td>68-82</td>
</tr>
<tr>
<td>A13</td>
<td>EAST</td>
<td>70-93</td>
</tr>
<tr>
<td></td>
<td>WEST</td>
<td>72-89</td>
</tr>
</tbody>
</table>

Average speed v = 40 km/h

<table>
<thead>
<tr>
<th>POLLUTION FROM AUTOMOBILE</th>
<th>EMISSION FACTOR kg(1000 vehicles/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO</td>
<td>1.89</td>
</tr>
<tr>
<td>NO2</td>
<td>0.09</td>
</tr>
<tr>
<td>SO2</td>
<td>0.07</td>
</tr>
<tr>
<td>PM</td>
<td>0.01</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EMISSION OF CAR</th>
<th>NEUTRAL GEAR</th>
<th>LOW SPEED</th>
<th>HIGH SPEED</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOx</td>
<td>0-50PPm</td>
<td>1000PPm</td>
<td>4000PPm</td>
</tr>
<tr>
<td>CO2</td>
<td>6.5-8%</td>
<td>7-11%</td>
<td>12-13%</td>
</tr>
<tr>
<td>H2O</td>
<td>7-8%</td>
<td>9-11%</td>
<td>10-11%</td>
</tr>
<tr>
<td>O2</td>
<td>1-1.5%</td>
<td>0.5-2%</td>
<td>0.1-0.4%</td>
</tr>
<tr>
<td>CO</td>
<td>3-10%</td>
<td>3.8%</td>
<td>1-5%</td>
</tr>
</tbody>
</table>
The Site

Surrounding Infrastructure

The interchange is mainly surrounded by residential areas (on the north side) and the tourism area (on the south side). For the residential area, a care center for the aged people is just next to the interchange.

The tourism part includes the Rotterdam zoo and the park. The Rotterdam zoo is one of the most attractions in Netherlands, with daily visitors of 1,500.
The population density in Kleinpolder is much higher than the average level of Rotterdam, and the number of immigrant population takes up 27% of the total.

Compared with the average income level of the city, the income level of this district is lower.

People aged from 46 to 65 (and over 65) accounts for almost half of the total population in this district.
Global Problem

- We are having less and less agricultural-capability land to supply the fast growing population and agricultural product’s diversity.

- Traditional 2D agriculture causes serious pollution problems.

Existing Problems on Site

Problem 3: centralized traffic system leads to large amount of vehicle emission and noise

Problem 2: lack of consideration of pedestrian traffic

Problem 1: waste of urban resources (land, money, rainwater)

Advantages of the site

- There is no high-rise building around it.

- It provides abundant water resource.
Design Strategy

-a harmonious design that fits into the site, which can transform the interchange in a vertical green farm without losing the interchange’s characters

-provide more job opportunities for the low-education residents

-reconnect the separate parts for pedestrians, and recover the ecological footprint lost by the growth in transportation construction in big city

-solving contradiction situation between decreasing farm land and growing food demand
Part 2 Agriculture Research
- considering load the floor can bear, clusters of crops should be with short roots no longer than 40cm
- the food’s popularity among people from different cultural backgrounds
- crops do not occupy too much space

What could be planted in the building?

<table>
<thead>
<tr>
<th>Crop Types</th>
<th>Daylight Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perennial Crop 1 (prefered chilled hours &lt;100h or 450 hours per year)</td>
<td></td>
</tr>
<tr>
<td>Rosemary</td>
<td>high</td>
</tr>
<tr>
<td>Asparagus</td>
<td>medium to low</td>
</tr>
<tr>
<td>Grape</td>
<td>high</td>
</tr>
<tr>
<td>Borage</td>
<td>high</td>
</tr>
<tr>
<td>Thyme</td>
<td>medium</td>
</tr>
<tr>
<td>Strawberry</td>
<td>high</td>
</tr>
<tr>
<td>Marigold</td>
<td>high</td>
</tr>
<tr>
<td>Comfrey</td>
<td>medium</td>
</tr>
<tr>
<td>Hyssop</td>
<td>medium</td>
</tr>
<tr>
<td>Perennial Crop 2 (prefered chilled hours 900h)</td>
<td></td>
</tr>
<tr>
<td>Sorrel</td>
<td>medium</td>
</tr>
<tr>
<td>Currant</td>
<td>medium</td>
</tr>
<tr>
<td>Annual Crop (chilled annually)</td>
<td></td>
</tr>
<tr>
<td>Nasturtium</td>
<td>high</td>
</tr>
<tr>
<td>Zucchini</td>
<td>high</td>
</tr>
<tr>
<td>Bean</td>
<td>high</td>
</tr>
<tr>
<td>Carrot</td>
<td>high</td>
</tr>
<tr>
<td>Cucumber</td>
<td>high</td>
</tr>
<tr>
<td>Dill</td>
<td>high</td>
</tr>
<tr>
<td>Garlic</td>
<td>medium</td>
</tr>
<tr>
<td>Onion</td>
<td>high</td>
</tr>
<tr>
<td>Peas</td>
<td>high</td>
</tr>
<tr>
<td>Peppers</td>
<td>medium</td>
</tr>
<tr>
<td>Tomato</td>
<td>medium</td>
</tr>
</tbody>
</table>

From the end of October daylength is shorter than 10 hours, winter time

<table>
<thead>
<tr>
<th>Month</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>October</td>
<td>During these periods, due to the low temperature, crops such as beans, carrots cucumbers potatoes zucchini, garlic prefer warm temperature need heating system to keep the enviroment in a stable warm condition.</td>
</tr>
<tr>
<td>November</td>
<td>Crops like broccoli, lettuce which prefer low temperature could be cultivated in the normal winter condition.</td>
</tr>
</tbody>
</table>

From the mid of February daylength is longer than 10 hours, spring time

<table>
<thead>
<tr>
<th>Month</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>February</td>
<td>During these periods, beans, carrots cucumbers potatoes zuc- chini, garlic could be sow straight into the ground.</td>
</tr>
<tr>
<td>March</td>
<td>Broccoli, lettuce, tomatoes, onion, peppers need to be grown seedlings, and be kept in a stable cool temperature.</td>
</tr>
<tr>
<td>April</td>
<td></td>
</tr>
<tr>
<td>May</td>
<td></td>
</tr>
<tr>
<td>June</td>
<td></td>
</tr>
<tr>
<td>July</td>
<td></td>
</tr>
<tr>
<td>August</td>
<td></td>
</tr>
<tr>
<td>September</td>
<td></td>
</tr>
</tbody>
</table>
the solutions for in and out door cultivation

6 basic types of hydroponic systems:

- aeroponic system is the most high tech one
- EBB & FLOW system
- N. F. T. (nutrient film technique) system
- drip system
- water culture
- wick system

Through the comparison in these 6 types of hydroponics systems, the final choice systems are aeroponic system and drip system.
the solution for in and out door cultivation

LED indoor farming

The weather in Netherlands is usually rainy. When the amount of natural daylight cannot reach the demanded level, the building need to use artificial lights.

Actually, the dominant type of chlorophyll in plants only needs purple light for working. When growing the crops, red and blue LEDs could create this special light and reduce the energy used in indoor cultivation.

image from http://www.ledinside.com/news/2014/7/japanese_farmer_partners_with_ge_to_develop_world_largest_led_indoor_farm
Part 3 Computational Simulation
## System for Generating Configuration

<table>
<thead>
<tr>
<th>Function</th>
<th>Area demand (sqm)</th>
<th>light demand</th>
<th>cooling hours/hr</th>
<th>height</th>
<th>main users</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultivation Area</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>annual cultivation mode</td>
<td>1000</td>
<td>high</td>
<td>annual</td>
<td>4m</td>
<td>workers</td>
<td></td>
</tr>
<tr>
<td>perennial cultivation mode 1</td>
<td>400</td>
<td>high</td>
<td>&lt;100</td>
<td>6m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>perennial cultivation mode 2</td>
<td>1500</td>
<td>medium to high</td>
<td>450</td>
<td>5m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>hydroponics cultivation mode</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mushroom</td>
<td>700</td>
<td>low</td>
<td></td>
<td>3m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>fish</td>
<td>200</td>
<td>low</td>
<td></td>
<td>3m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crop and Food Research Lab</td>
<td>200</td>
<td>medium</td>
<td></td>
<td>4m</td>
<td>researchers</td>
<td>researching</td>
</tr>
<tr>
<td>Crop Processing</td>
<td>100</td>
<td>low</td>
<td></td>
<td>3m</td>
<td>workers</td>
<td>crops from cultivation area are delivered to here and processed</td>
</tr>
<tr>
<td>Crop Storage</td>
<td>250</td>
<td>low</td>
<td></td>
<td>3m</td>
<td>workers</td>
<td>crop storing</td>
</tr>
<tr>
<td>Crop Packing and Distributing</td>
<td>100</td>
<td>low</td>
<td></td>
<td>3m</td>
<td>workers</td>
<td>packing and distributing</td>
</tr>
<tr>
<td>Workshop</td>
<td>600</td>
<td>medium</td>
<td></td>
<td>5-6m</td>
<td>visitors</td>
<td>learning how to plant crops</td>
</tr>
<tr>
<td>Reception Hall</td>
<td>400</td>
<td>low to medium</td>
<td></td>
<td>6m</td>
<td>visitors</td>
<td>visitors enter the building</td>
</tr>
<tr>
<td>Restaurant and Cafe</td>
<td>650</td>
<td>low to medium</td>
<td></td>
<td>6m</td>
<td>visitors</td>
<td>recreation</td>
</tr>
<tr>
<td>Administration</td>
<td>400</td>
<td>medium</td>
<td></td>
<td>4m</td>
<td>staff</td>
<td>working</td>
</tr>
<tr>
<td>Building System</td>
<td>800</td>
<td>low</td>
<td></td>
<td>4m</td>
<td>workers</td>
<td>generating energy</td>
</tr>
</tbody>
</table>
System for Generating Configuration

Rules for generating the configuration:

- all functions should be at least 4 meters away from the flyovers;
- cultivation areas (perennial 1&2, annual cultivation) should be located in the place where they can have the best daylight environment;
- building system should be on the levels with poor daylight, as well should be near the parking place;
- compared with other community areas, workshops need to be located in the place with more daylight (it means that there should be less shading in front of it);
- labs and food processing, storage and packing parts should be near cultivation areas;
- functions like food processing, storage, mushroom, which is not much affected by the highways and the light environment, could be set next to the flyovers, and they can be decorated by green facade.
System for Generating Configuration
System for Generating Configuration

During a sunny day in winter, the system should ensure that the cultivation areas, which have daylight demand, can gain direct sunlight at least from 11:00 to 15:00.

Also, due to the minimal and maximum sun altitude angles, each cluster should move within a certain area defined by these angles.
System for Generating Configuration
System for Generating Configuration

- perennial cultivation 1
- perennial cultivation 2
- annual cultivation
- labs
- hydroponics, mushroom
- packing and distributing
- community spaces
- admin
- building system
geco daylight analysis

67% of the area >=10000lux
lowest level is 7882lux

74.5% of the area >=10000lux
lowest level is 7635lux

86% of the area >=10000lux
lowest level is 7949lux

90% of the area >=10000lux
lowest level is 9293lux

95% of the area >=10000lux
lowest level is 8636lux

92% of the area >=10000lux
lowest level is 9595lux

45% of the area >=10000lux
lowest level is 7218lux

73% of the area >=10000lux
lowest level is 7839lux
Part 4 Architectural Design
formation of the geometry of building
Architectural Design

formation of the geometry of building

- perennial cultivation1
- perennial cultivation2 with high daylight demand
- perennial cultivation2 with midle to low demand
- outdoor green space (outdoor cultivation/grass land)
- annual cultivation
- hyroponics (including mushroom and fish)
- food processing, storage, packing and distributing
- workshop
- community spaces (reception, cafe, restaurant, bar, shop)
- outdoor market
- building system
Architectural Design

formation of the geometry of building

perennial cultivation1
perennial cultivation2 with high daylight demand
perennial cultivation2 with midle to low demand
outdoor green space (outdoor cultivation/grass land)
annual cultivation
hyroponics (including mushroom and fish)
food processing, storage, packing and distributing
workshop
community spaces (reception, cafe, restaurant, bar, shop)
outdoor market
building system
Creating various identities for guiding visitors

The representations of various directions to different functions are achieved through applying materials to guide visitors, as well as through placing signs at some strategic points of different functions.

The identities of each function is reflected through equipments, floors, ceilings, walls, lights, and furniture.
Kleinpolder plan 1: 500
food market zone/path

education zone/path
Architectural Design

- food market zone/path
- education zone/path
- tourism zone/path
- cultivation zone/path
Architectural Design

- Food market zone/path
- Education zone/path
- Tourism zone/path
- Cultivation zone/path
LEVEL 3 PLAN

1 Food Shop
2 Cafe
3 Food packing and distributing
4 Market
5 Botanic Workshop

CIRCULATION ROUTE

- pedestrian flow from residential area
- direction to the market
- direction botanic workshop
interior view
LEVEL 4 PLAN

1 Reception
2 Botanic Workshop
3 Bar
4 Storage
LEVEL 4 PLAN

1 Reception
2 Botanic Workshop
3 Bar
4 Storage

CIRCULATION ROUTE

- pedestrian flow from residential area
- direction to upper foyer
- direction to reception
- direction to the workshop
- direction to down workshop or the direct connection to the other side residential area
- direction to the bar and upper entrance to visit the hydroponics area
Architectural view of the entrance
LEVEL 5 PLAN

1 Foyer
2 Botanic Workshop
3 Food Processing
4 Visitor entrance to the hydroponics area
Architectural Design view of the entrance
a. fragment section
b. fragment plan
c. aerial view

1 Hydroponics
2 Perenniel
3 Outdoor Cultivation
4 Annual Cultivation
Architectural Design

view of transition space
1. annual cultivation
2. perennial cultivation 1 (high demand for daylighting and with shorter roots)
3. perennial cultivation 2 (medium to low demand for daylighting)
4. perennial cultivation (high or high for daylighting and with longer roots)
5. hydroponics
6. aquaponics
7. labs
8. processing, storage, packing and distributing
9. office
10. building system, energy generation and collection
11. botanic workshop
12. public cultivation space and green space
13. public community space (shops, markets, bar, cafe, etc.)
14. public space for having bird’s eye-view of Rotterdam city
15. crop gathering
1. Ceiling cooling and heating system
2. Ceiling mechanical ventilation system
3. Sprinkler system
4. LED (light-emitting diode) system
5. Reflective surface

detail section / cultivation area
Part 5 Structure and Fabrication
Structure and Fabrication

This is the fragment of the structure (hybrid concrete columns and slabs).

The building is mainly supported by these straight column beams vertically and laterally.

Use CNC machine to produce the model for the shape, and then pour the concrete to cover the column beams with the model in place (cast-in-situ-concrete).
1. coating, waterproof layer, reinforced concrete,
2. 43mm double curving glazing glass fin
3. ceiling ventilation system, ceiling heating and cooling system
4. 285mm bubble deck floor, 80mm concreteslab, 5mm polyurethane
5. 200mm insulation, shoe for fixing the glass fin
1:10 Detail Section