HUMAN MOBILITY SIMULATION:

Investigating the Impact of Urban Vitality Indicators on Human Movements

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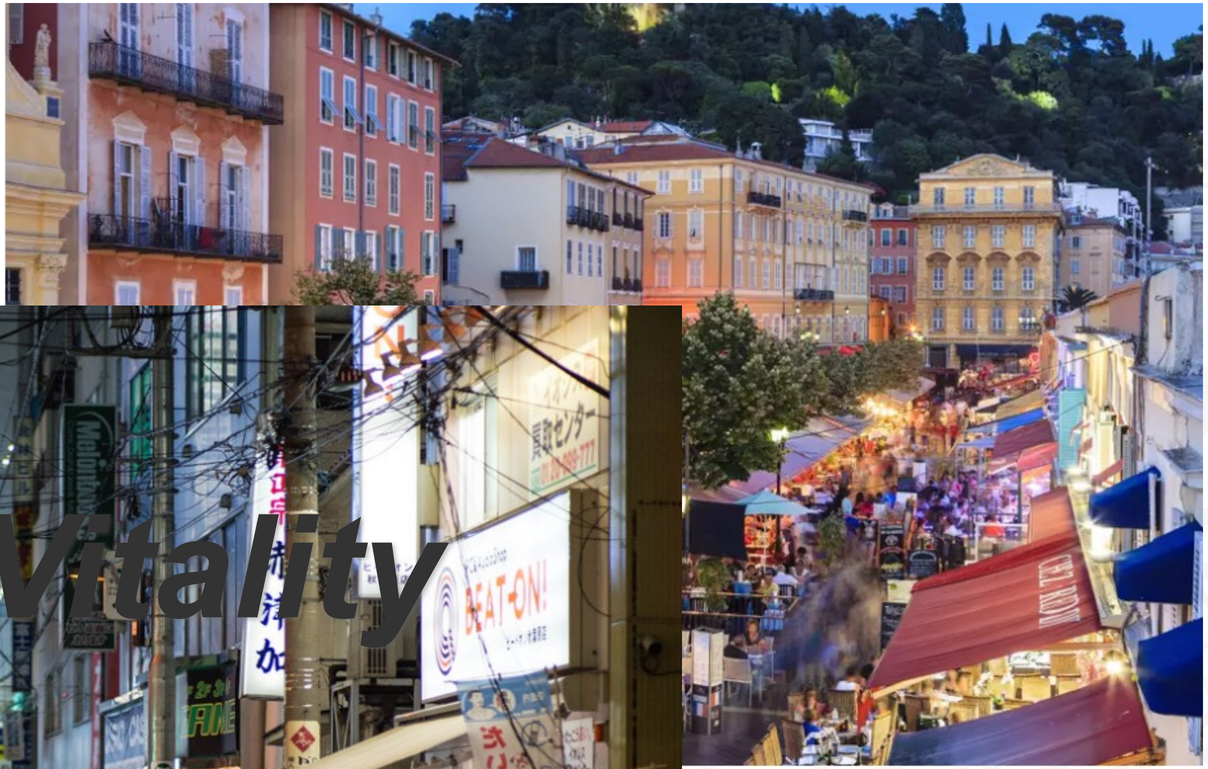
University at Buffalo The State University of New York

Presentation Outline

- Problem & Objective
- Data Preparation
- Model Development
- Conclusion & Reflection
- Q & A



Urban Vitality

The people and their activities in the space

Photography by ***Adrian Hu***

Urban Vitality

- *People Health*
- *Socio-economic Development*
- *Public Safety*
- *Space Quality*
- …

People

Interact with the ***Space*** or the ***Built Environment*** in their day-to-day life.

People in City Time lapse: *https://www.youtube.com/watch?v=2_bByG7IVzQ*

Problems

- There are various indicators has been used for evaluating urban vitality.
  - E.g., POIs, transport accessibility, safety, appearance, diversity, etc.
- The benchmark of factors used to quantify the urban vitality has not come with a consensus.

Research Questions

- How the indicators change human footprints?
- Which indicator is more influential?

Objective

Develop a model that provides the flexibility for exploring the impact of different urban vitality indicators on human footprints.

Study area: Kampong Glam in Singapore

- An ethnic enclave centered on busy Arab Street
- Home to mosques
- Abundant activities
    - Reasonably priced food
    - Café, bars, nightclubs
    - Accommodation
    - Souvenir shops
- 7 areas for comparison
- 4 urban vitality indicators:
    - Popularity
    - Comfort
    - Diversity of POIs
    - Safety

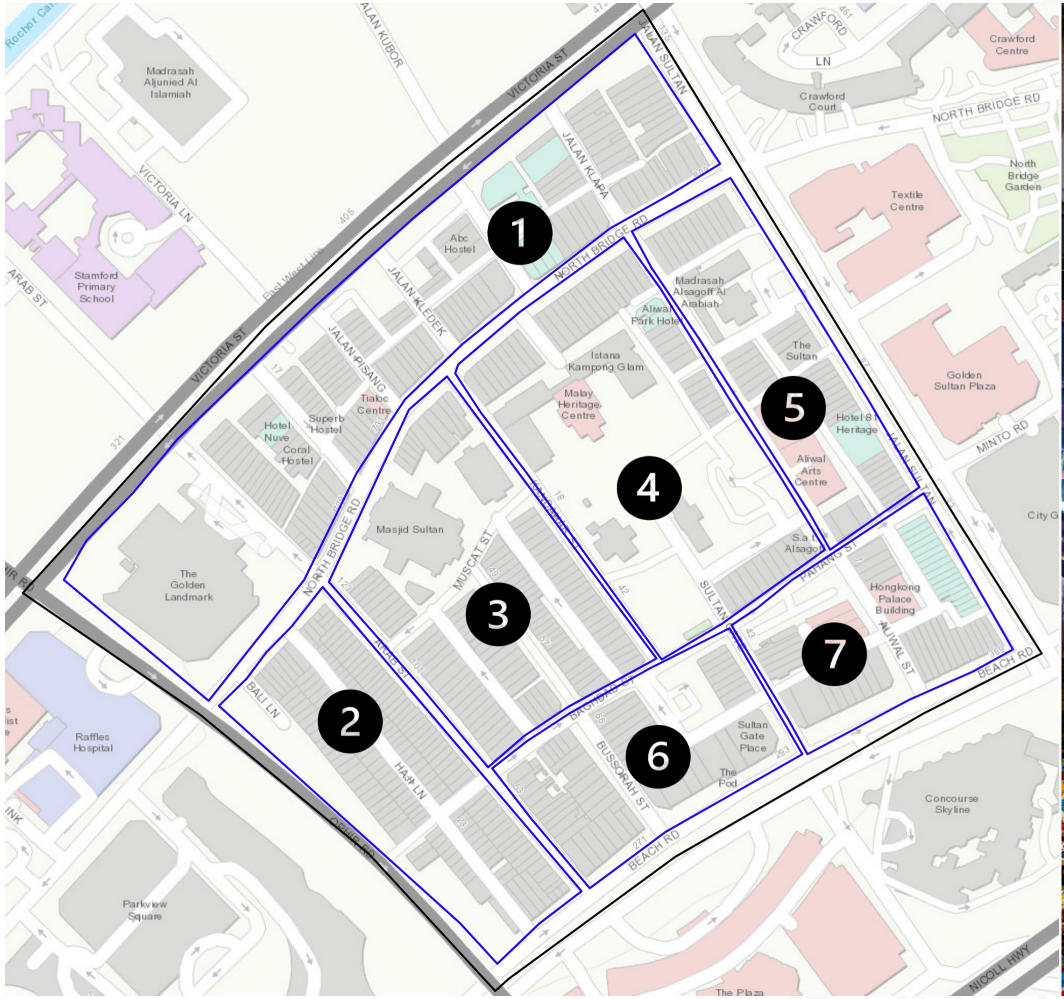
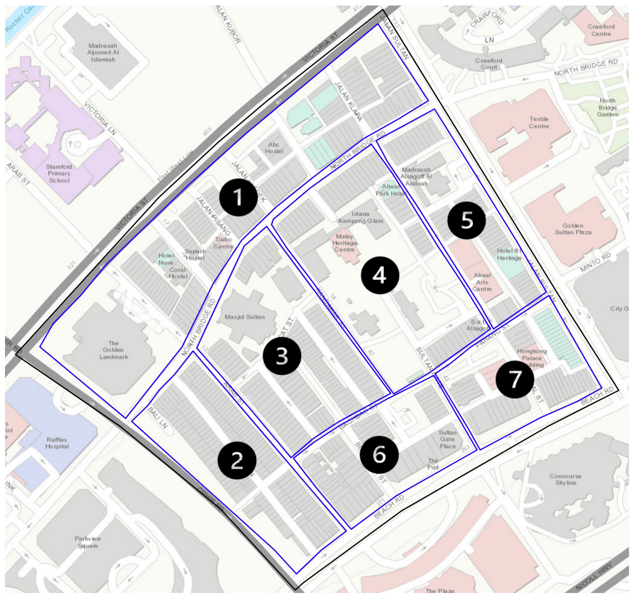


Figure 1. Map of Kampong Glam in Singapore. Labeled areas are seven distinct areas to be tested in the model

Indicator 1: Popularity



Twitter data sent from 2012 to 2016 in Singapore

- ~ 22.4 million tweets, 405.6k users

← *DOLLY project (Poorthuis and Zook 2017)*

<u>*Spatial intersection*</u> | Tweets sent only within Kampong Glam

73640 tweets, 27552 users

Assumption: $Popularity \propto Number\ of\ users$

Name	Number of users	Popularity
area1	14903	1.0000000
area2	14744	0.9893310
area3	10275	0.6894585
area4	4576	0.3070523
area5	2323	0.1558747
area6	4993	0.3350332
area7	3602	0.2416963

← *Min-max normalization:*

$$\frac{N_{users} - \min(N_{users})}{\max(N_{users}) - \min(N_{user})}$$

Indicator 2: Diversity of POIs

Point of Interest (POI) data with a total number of 54 types

Filter ↓ POIs within Kampong Glam

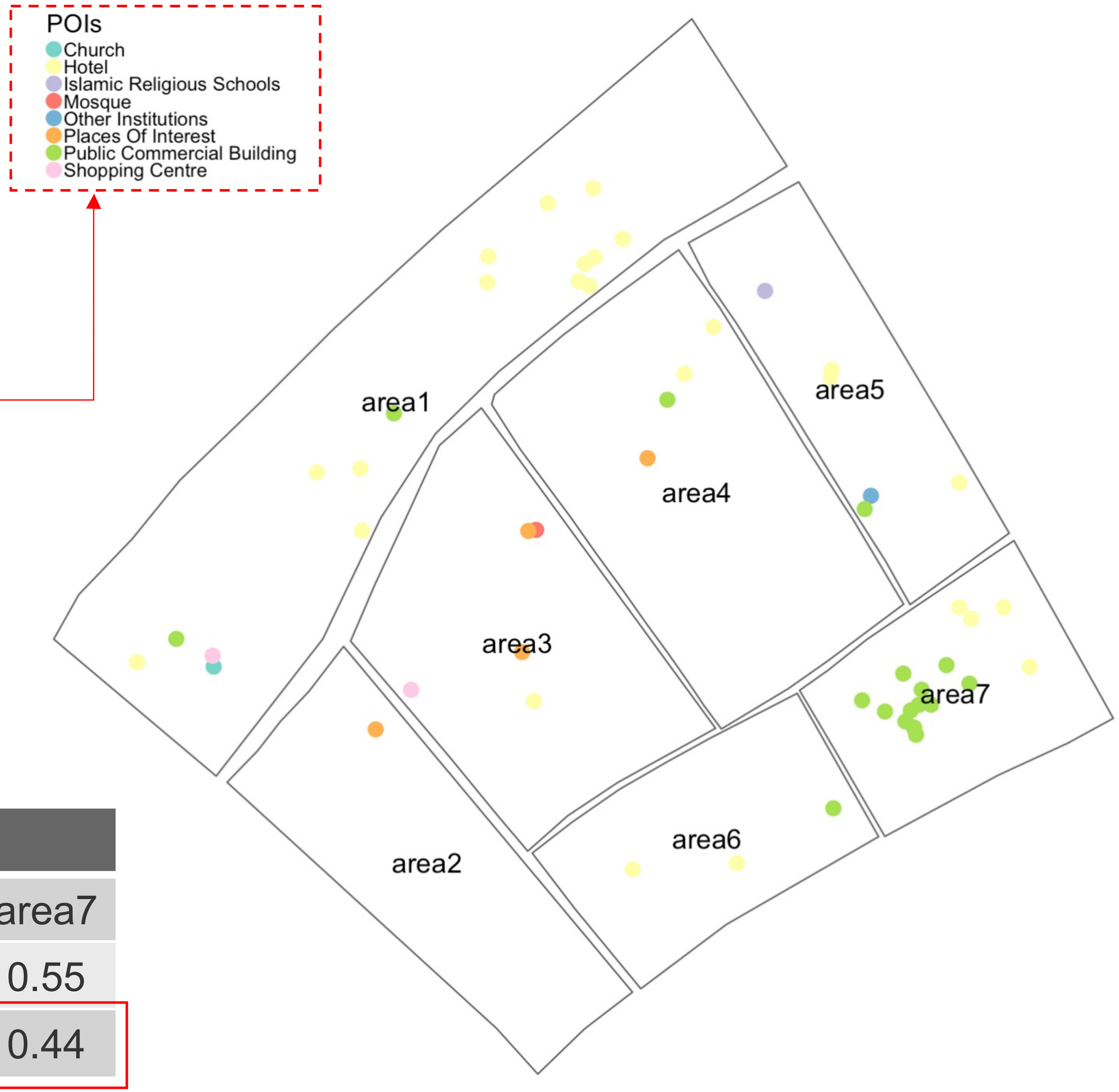
8 types of POIs

Shannon's diversity index ↓

$$H = -\sum_{i=1}^{s} p_i ln p_i$$

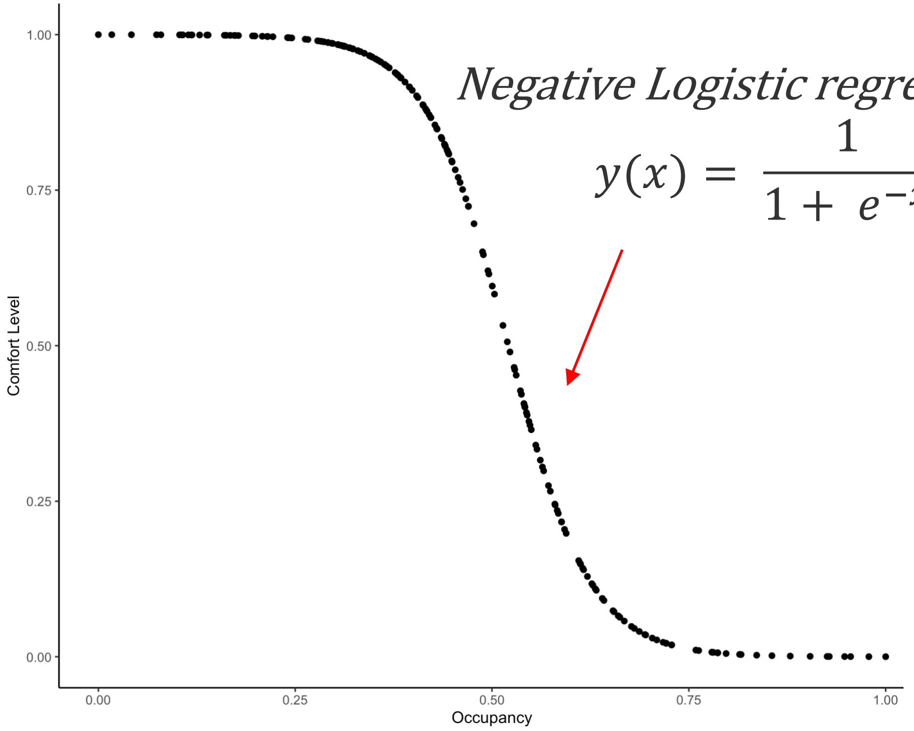
Diversity of POIs

Diversity of POIs in different area							
Area	area1	area2	area3	area4	area5	area6	area7
Diversity	0.79	0.00	1.24	1.04	1.24	0.64	0.55
Norm Diversity	0.64	0.00	1.00	0.84	1.00	0.51	0.44



Indicator 3: Comfort Level

Assumption: Comfort level is a function of occupancy, the more people in the space, the less comfortable people perceived.



Negative Logistic regression:

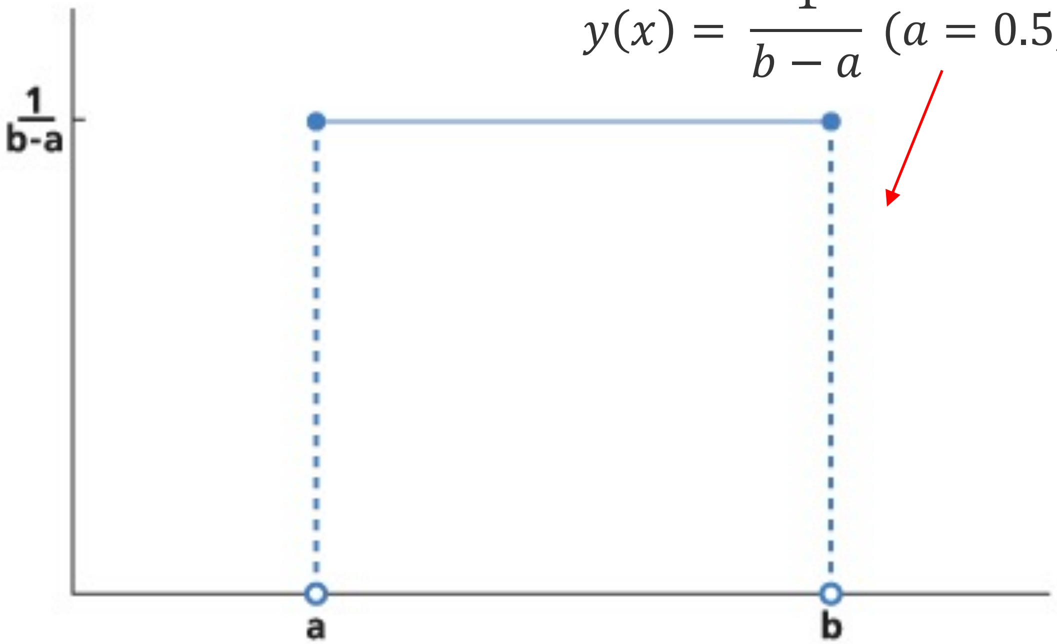
$$y(x) = \frac{1}{1 + e^{-x}}$$

Indicator 4: Safety

Assumption: No significant difference within the neighborhood.

Uniform distribution:

$$y(x) = \frac{1}{b - a} \quad (a = 0.5, b = 0.7)$$



Model Structure

- Accumulation and feedback → describe system behavior
- Individual properties of people → describe individual behavior

System Dynamics Model

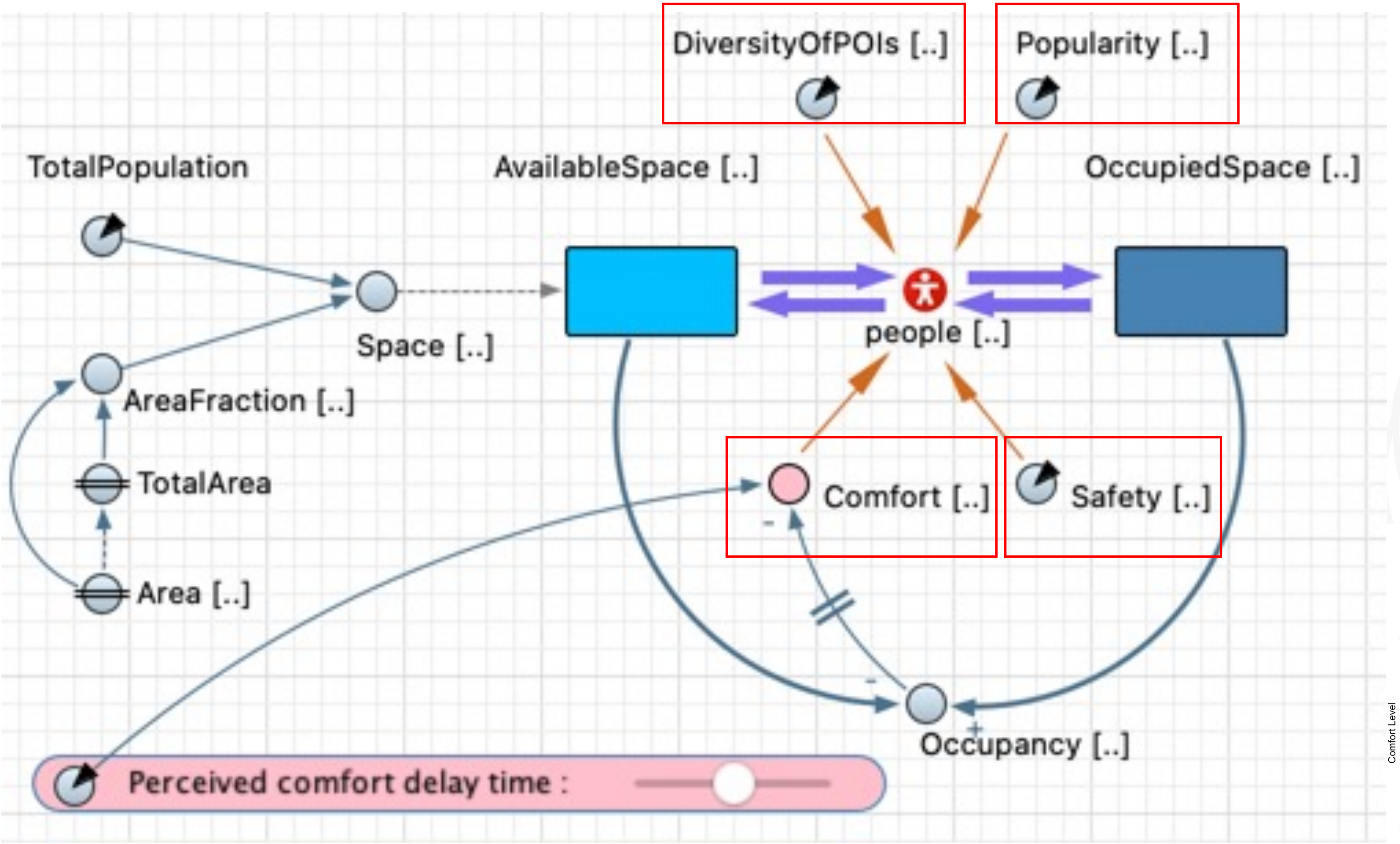
+

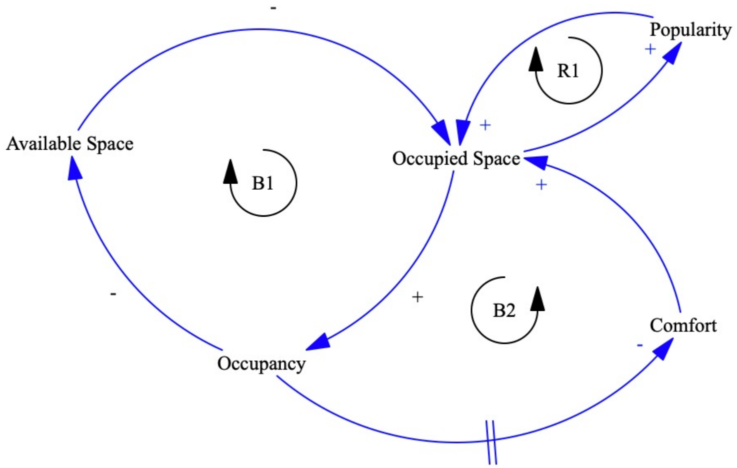
Agent-Based Model

anylogic

A multimethod simulation modelling tool developed by The AnyLogic Company.

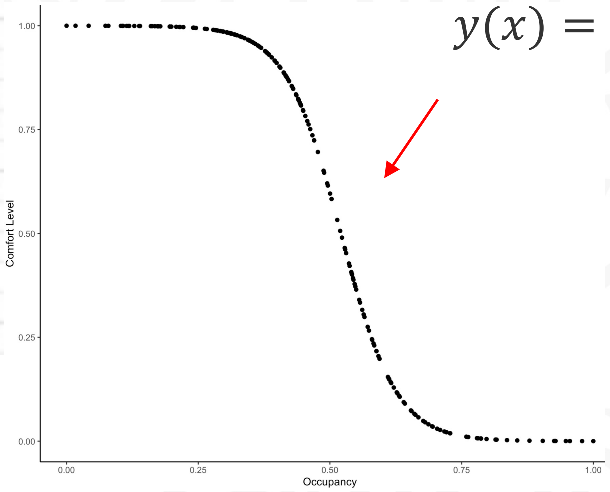
System Dynamics



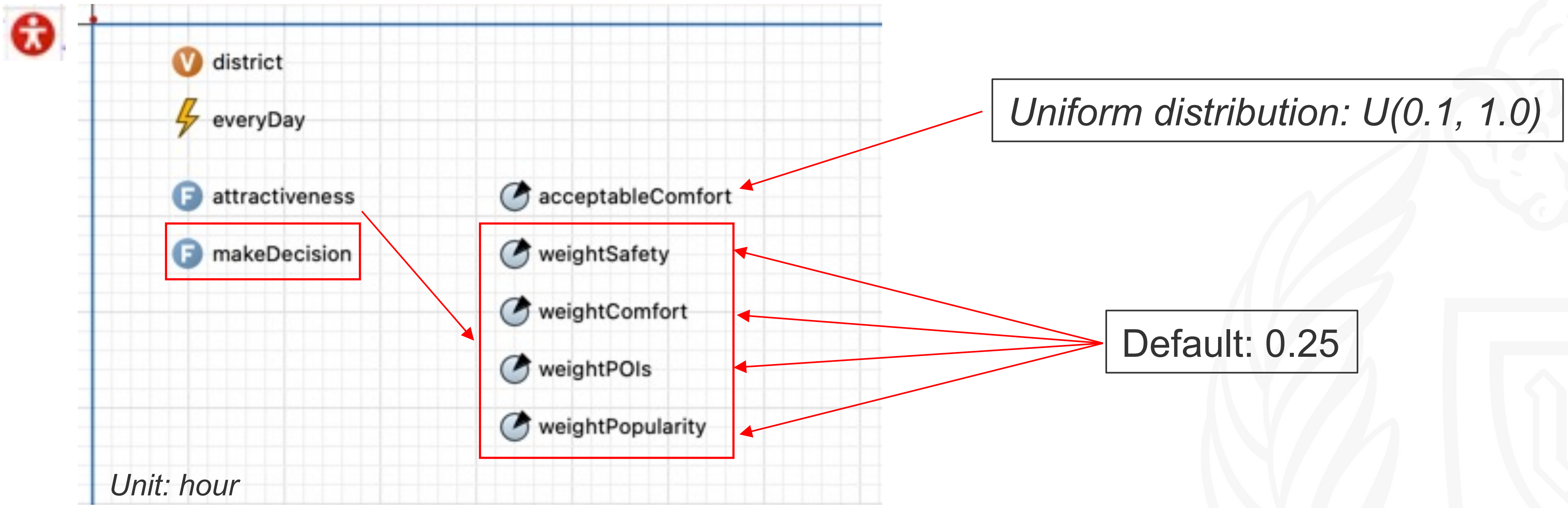


Negative Logistic regression:

$$y(x) = \frac{1}{1 + e^{-x}}$$



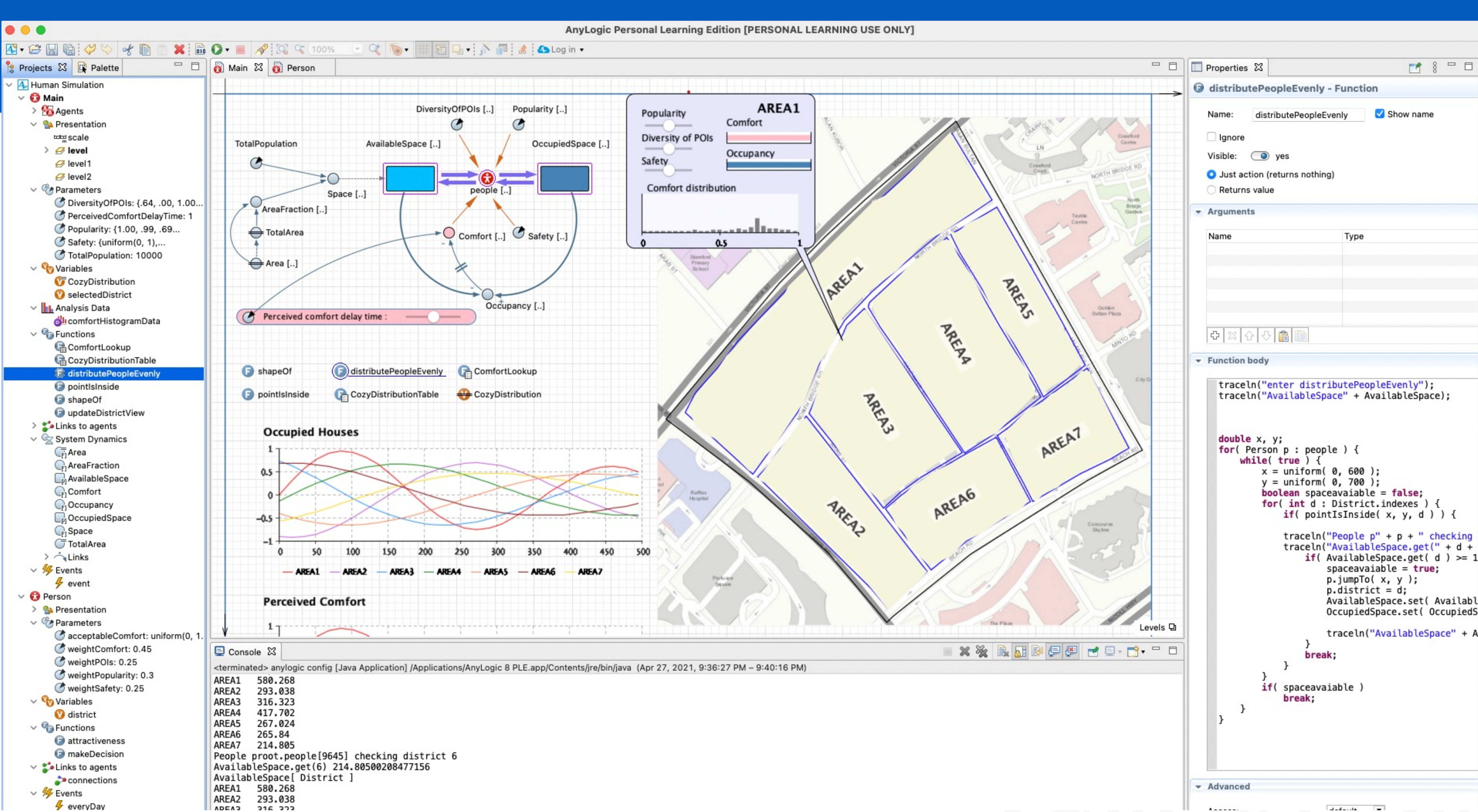
Agent-Based Model



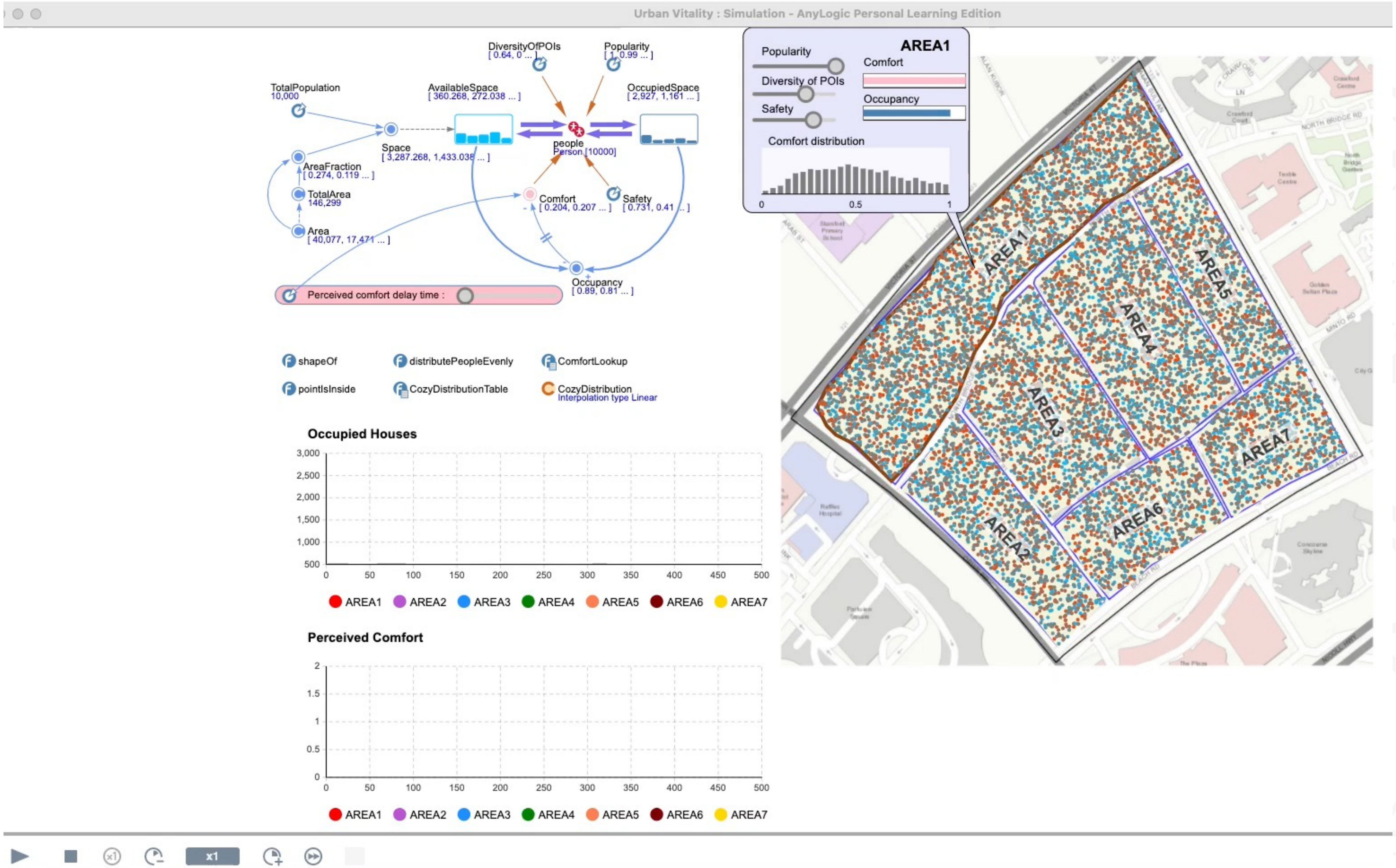
$$Attractiveness = \frac{Comfort * weightComfort + Diversity\ of\ POIs * weightPOIs + Popularity * weightPopularity + Safety * weightSafety}{4}$$

Make Decision:

- Perceived comfort < Acceptable comfort → Must move
- Find area with higher attractiveness than that of the current area (target area)
- If available space of target area > 0 → move to target area
- Else search another place until find the suitable one to move.


AnyLogic Personal Learning Edition [PERSONAL LEARNING USE ONLY]
Projects
Palette
Main
Person
Properties
Human Simulation
Main
Agents
Presentation
scale
level
level1
level2
Parameters
DiversityOfPOIs: {.64, .00, 1.00...
PerceivedComfortDelayTime: 1
Popularity: {1.00, .99, .69...
Safety: {uniform(0, 1),...
TotalPopulation: 10000
Variables
CozyDistribution
selectedDistrict
Analysis Data
comfortHistogramData
Functions
ComfortLookup
CozyDistributionTable
distributePeopleEvenly
pointIsInside
shapeOf
updateDistrictView
Links to agents
System Dynamics
Area
AreaFraction
AvailableSpace
Comfort
Occupancy
OccupiedSpace
Space
TotalArea
Links
Events
event
Person
Presentation
Parameters
acceptableComfort: uniform(0, 1...
weightComfort: 0.45
weightPOIs: 0.25
weightPopularity: 0.3
weightSafety: 0.25
Variables
district
Functions
attractiveness
makeDecision
Links to agents
connections
Events
everyDay
DiversityOfPOIs [..]
Popularity [..]
TotalPopulation
AvailableSpace [..]
OccupiedSpace [..]
Space [..]
people [..]
AreaFraction [..]
TotalArea
Comfort [..]
Safety [..]
Area [..]
Occupancy [..]
Perceived comfort delay time :
AREA1
Popularity
Comfort
Diversity of POIs
Safety
Occupancy
Comfort distribution
0
0.5
1
AREA1
AREA2
AREA3
AREA4
AREA5
AREA6
AREA7
shapeOf
distributePeopleEvenly
ComfortLookup
pointIsInside
CozyDistributionTable
CozyDistribution
Occupied Houses
AREA1 AREA2 AREA3 AREA4 AREA5 AREA6 AREA7
Perceived Comfort
Levels
distributePeopleEvenly - Function
Name: distributePeopleEvenly
Show name
Ignore
Visible: yes
Just action (returns nothing)
Returns value
Arguments
Name
Type
Function body
traceln("enter distributePeopleEvenly");
traceln("AvailableSpace" + AvailableSpace);
double x, y;
for(Person p : people) {
while(true) {
x = uniform(0, 600);
y = uniform(0, 700);
boolean spaceavaiable = false;
for(int d : District.indexes) {
if(pointIsInside(x, y, d)) {
traceln("People p" + p + " checking
traceln("AvailableSpace.get(" + d +
if(AvailableSpace.get(d) >= 1
spaceavaiable = true;
p.jumpTo(x, y);
p.district = d;
AvailableSpace.set(Availabl
OccupiedSpace.set(OccupiedS
traceln("AvailableSpace" + A
}
break;
}
}
if(spaceavaiable)
break;
}
}
Advanced
Console
<terminated> anylogic config [Java Application] /Applications/AnyLogic 8 PLE.app/Contents/jre/bin/java (Apr 27, 2021, 9:36:27 PM – 9:40:16 PM)
AREA1 580.268
AREA2 293.038
AREA3 316.323
AREA4 417.702
AREA5 267.024
AREA6 265.84
AREA7 214.805
People proot.people[9645] checking district 6
AvailableSpace.get(6) 214.80500208477156
AvailableSpace[District]
AREA1 580.268
AREA2 293.038

Model Demo


Urban Vitality : Simulation - AnyLogic Personal Learning Edition
DiversityOfPOIs
[0.64, 0 ...]
Popularity
[1, 0.99 ...]
TotalPopulation
10,000
AvailableSpace
[360.268, 272.038 ...]
OccupiedSpace
[2,927, 1,161 ...]
Space
[3,287.268, 1,433.038 ...]
people
Person [10000]
AreaFraction
[0.274, 0.119 ...]
TotalArea
146,299
Comfort
[0.204, 0.207 ...]
Safety
[0.731, 0.41 ...]
Area
[40,077, 17,471 ...]
Occupancy
[0.89, 0.81 ...]
Perceived comfort delay time :
shapeOf
distributePeopleEvenly
ComfortLookup
pointIsInside
CozyDistributionTable
CozyDistribution
Interpolation type Linear
Occupied Houses
Perceived Comfort
AREA1
AREA2
AREA3
AREA4
AREA5
AREA6
AREA7
Popularity
Diversity of POIs
Safety
Comfort
Occupancy
Comfort distribution
x1

Conclusion

Strengths

- Integrate system dynamic model with agent-based model
- The model have the capability to investigate the impact of urban vitality indicators on human movement
- The model is flexible to add other indicators based on specific research focus (e.g., economic status, demographic characteristic, etc.)

Limitations

- Each indicator is assigned equal weight, it could be better to add the flexibility for weight tuning (e.g., slider) to reflect different importance of indicators
- Simple linear regression is used to evaluate the attractiveness, more complex model be employed in future work

Reflection

Challenges:

- How to get dynamic feedback look (e.g., Comfort as a function of Occupancy)
- How to examine the areas separately (e.g., use array feature to transfer values independently)
- How to constrain agents' movements within the map (e.g., space makeup + design function find agent position)
- How to trace model errors (e.g., add '*traceln*' to java source code and monitor output message in console)
- …

Learning Gains:

- Understand the modeling procedure (e.g., problem definition, dynamic hypothesis, model development, etc.)
- Gain basic knowledge of Anylogic software (e.g., create agents, write functions, add properties, integrate multiple types of models, setup database, debugging, etc.)

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About

workflowr ✔

Urban vitality has been a long-standing interest in Geography and plays an important role in evaluating urban development (Liu et al. 2019). Generally, urban vitality refers to the people and their activities in the space (Gehl and Gemzøe 2001, Jacobs 2016). Individuals, particularly city dwellers who like the core of a city, interact with the space or the built environment in their day-to-day life. Thus, uncovering and understanding the correlation between human mobility patterns and built environment is essential in evaluating space vitality within a city.

With the proliferation of new emerged big data technologies in recent years (Batty et al. 2012, Bettencourt 2014), the study related to analyzing urban vitality is able to go deeper at a much granular scale. Different factors have been used for evaluating urban vitality. For example, Lu et al. (2019) use regulatory planning management units, land use, road network, and building as built environment factors and examine their impacts on urban vitality through regression analyses. Their results show the neighborhood vibrancy is highly related to the points of interest (POI) diversity and public transport accessibility indicators. Liu et al. (2019) propose an approach to identify different vitality patterns from both spatial and temporal perspectives by using a POI-based land use matrix, where they also found POI has a strong impact on urban vitality. Parker et al. (2017) discuss a series of factors that related to urban vitality and viability and classify the top 25 priorities (e.g., appearance, diversity, accessibility, attractiveness, safety/crime, etc.) for action in order to improve local decision making for developing a sustainable high street. The benchmark of factors used to quantify the urban vitality has not come with a consensus in the current state-of-the-art. What kinds of indicators impact the vitality of urban space? How the indicators change human movement in the urban space? Which indicator is more influential?

These questions may perhaps have been exemplified in the recent uptake of '15-minute city planning ideas sought after by cities around the world (Weng et al. 2019, Pozoukidou and Chatziyiannaki 2021). This notion has been sharply discussed lately during the Covid-19 pandemic, as the pandemic has significantly restricted human movement, forcing people to stay at home and only go out for basic needs (Dinah Lewis Boucher, 2020). As such, ushering in a new era of integrated urban fabric which combines most of residents' life essentials to each local community while maintaining the vitality of the community is promoted. It is at this junction, I develop a model that combined agent-based model with system dynamic model to simulate population movement within the city under different indicator constrains that related to urban vitality. The model is put to the test in application to a neighborhood named "Kampong Glam" (an ethnic enclave) in Singapore, and examine how do four indicators – Diversity of POIs, Popularity, Comfort level and Safety – change human movements within the study area.