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292_Real World Data-Driven Agent-Based Modeling for Health Policy Insights During Epidemics

Mario De Silva

IEEE Sri Lanka Section
IEEE COMPUTER SOCIETY Sri Lanka Chapter
Curtin University
BPC
DEAKIN UNIVERSITY
Creative Software
SLIIT Research and International
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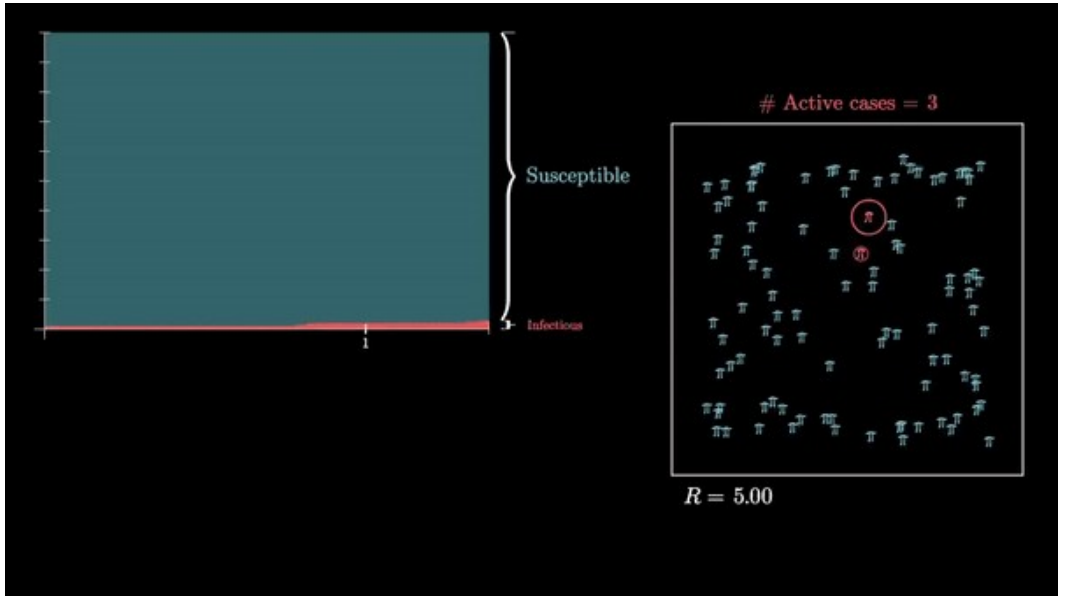
Objectives of the Study

- Develop an Agent Based Model (ABM) capable of utilizing real-world data to accurately model human behavior.
- Further enhance the model using a realistic environment and transportation modes.
- Use developed model to simulate the spread of an epidemic to validate the faithful representation of human interactions.

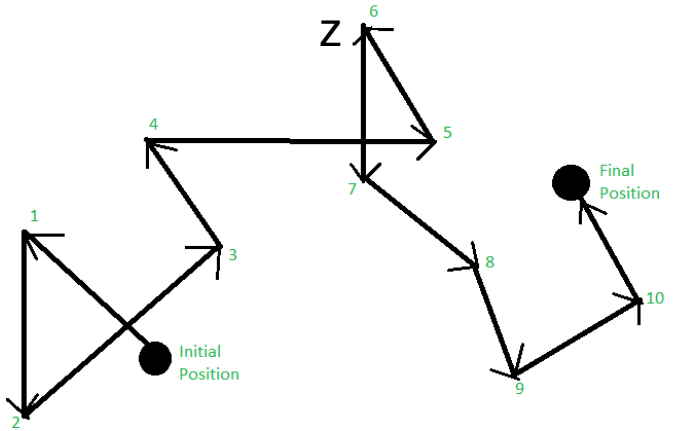


3Blue1Brown: Simulating an epidemic

Background

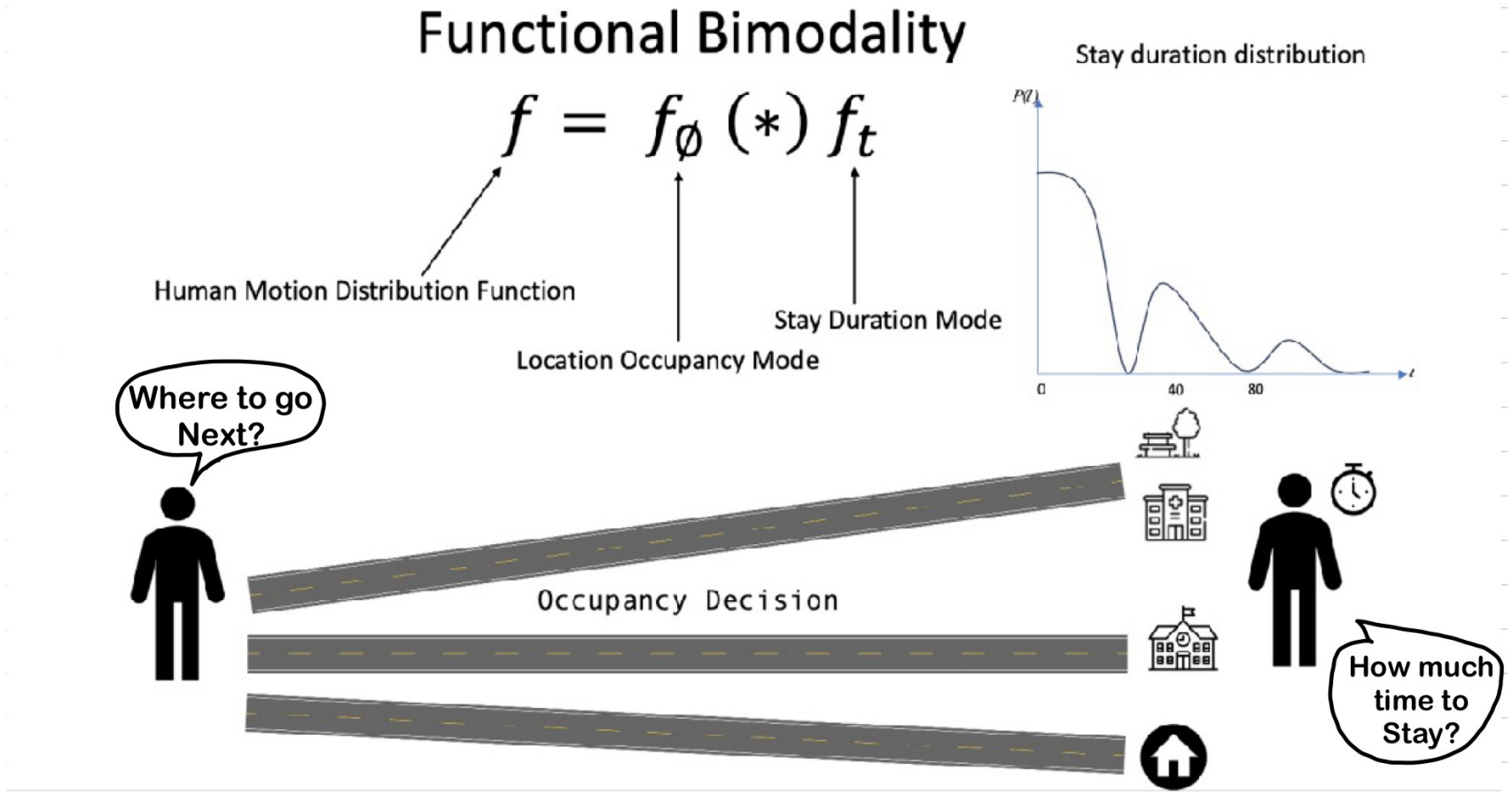
Current research on ABMs uses random walk algorithms and purely mathematical based approaches to generate the walking patterns.

- Even the ones that are based on data have environments that are oversimplified and/or do not have realistic transportation methods.
- Hence, we need a better practical approach to model ABM when we are trying to model cities/populations.



A Random Walk Route

Bi-Modality


Functional Bimodality
$f = f_{\emptyset}(*) f_t$
Human Motion Distribution Function
Location Occupancy Mode
Stay Duration Mode
Stay duration distribution
P(t)
0
40
80
t
Where to go Next?
Occupancy Decision
How much time to Stay?

Utilized Dataset

- A publicly available dataset about motion patterns of professionals in Kandy city was used for this study.
- The data is in the form of location strings, where the location of an individual is given as a label at 5-minute intervals.

	A	B	C	D	E	F
447	7:25:00	School	School	School	Home	Home
448	7:26:00	School	School	School	Home	Home
449	7:27:00	School	School	School	Home	BusStation
450	7:28:00	School	School	School	Home	BusStation
451	7:29:00	School	School	School	Home	BusStation
452	7:30:00	School	School	School	Home	BusStation
453	7:31:00	School	School	School	Home	BusStation
454	7:32:00	School	School	School	Home	School
455	7:33:00	School	School	School	Home	School
456	7:34:00	School	School	School	Home	School
457	7:35:00	School	School	School	Home	School
458	7:36:00	School	School	School	Home	School
459	7:37:00	School	School	School	BusStation	School
460	7:38:00	School	School	School	BusStation	School
461	7:39:00	School	School	School	BusStation	School
462	7:40:00	School	School	School	BusStation	School
463	7:41:00	School	School	School	BusStation	School

Snapshot of Location Strings for a Teacher

Agents

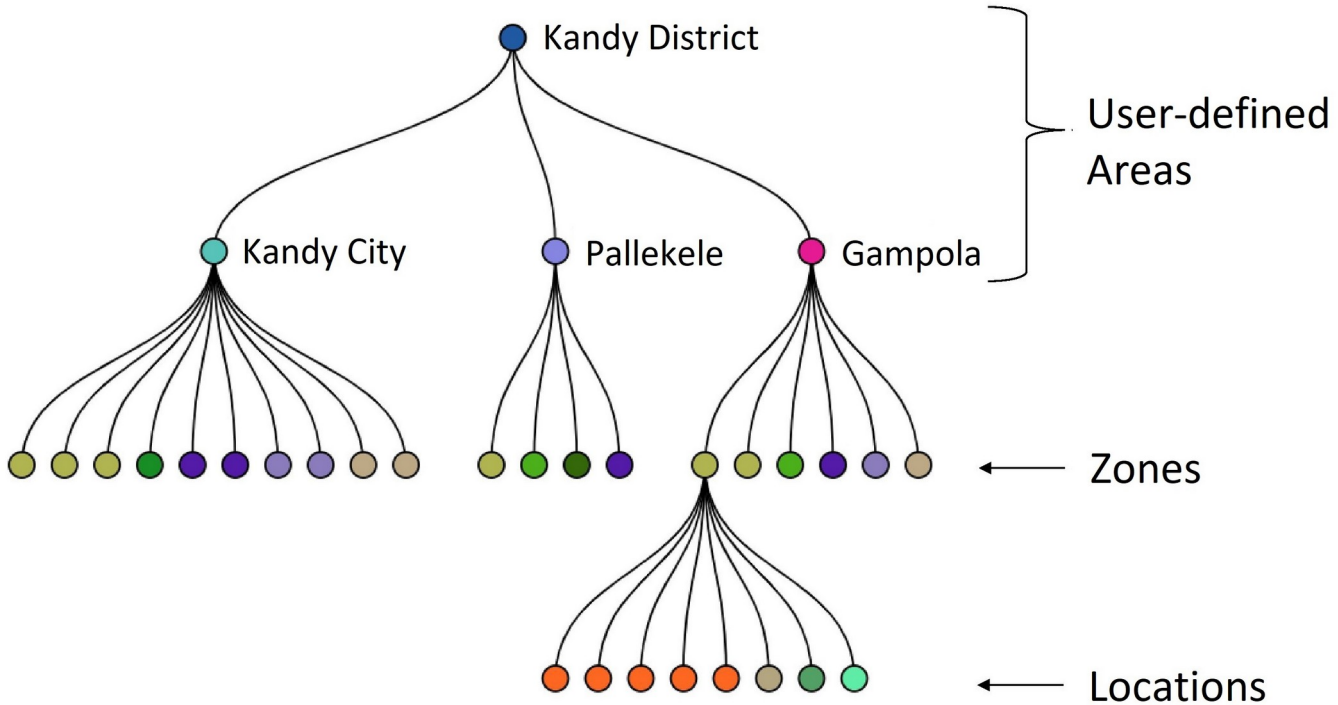
- Simulates real-world humans with daily routines and capable of interacting with each other.
- Categorized into professional classes based on professions represented in the dataset used.

```
Total Agents in simulation : 183
<class 'dict'>
Student_1 : Student
Student_2 : Student
Student_3 : Student
Student_4 : Student
Student_5 : Student
Student_6 : Student
Student_7 : Student
Student_8 : Student
Student_9 : Student
Student_10 : Student
Student_11 : Student
Student_12 : Student
Student_13 : Student
Student_14 : Student
Student_15 : Student
Student_16 : Student
Student_17 : Student
Student_18 : Student
```

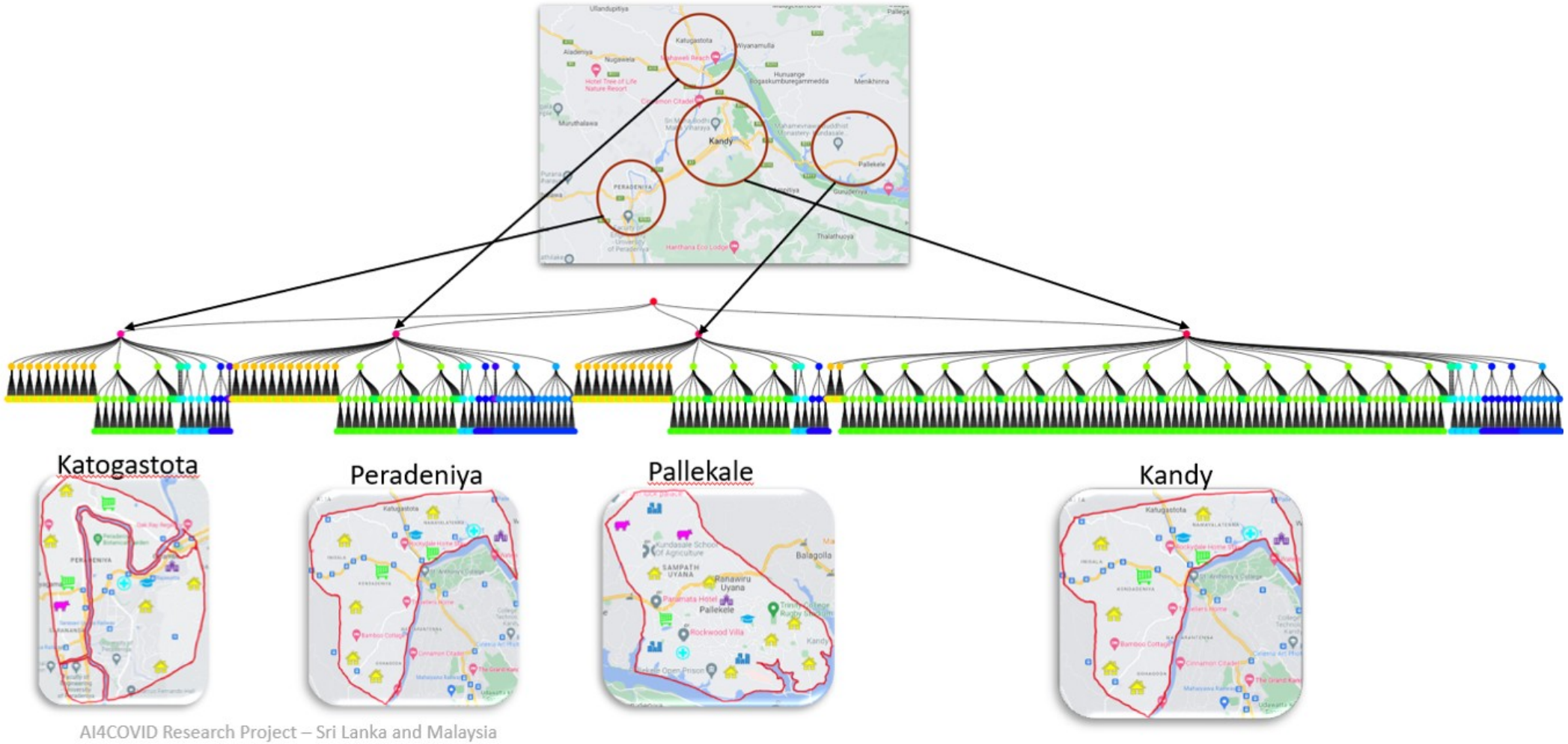
Snapshot of Location Strings for a Teacher

Environment

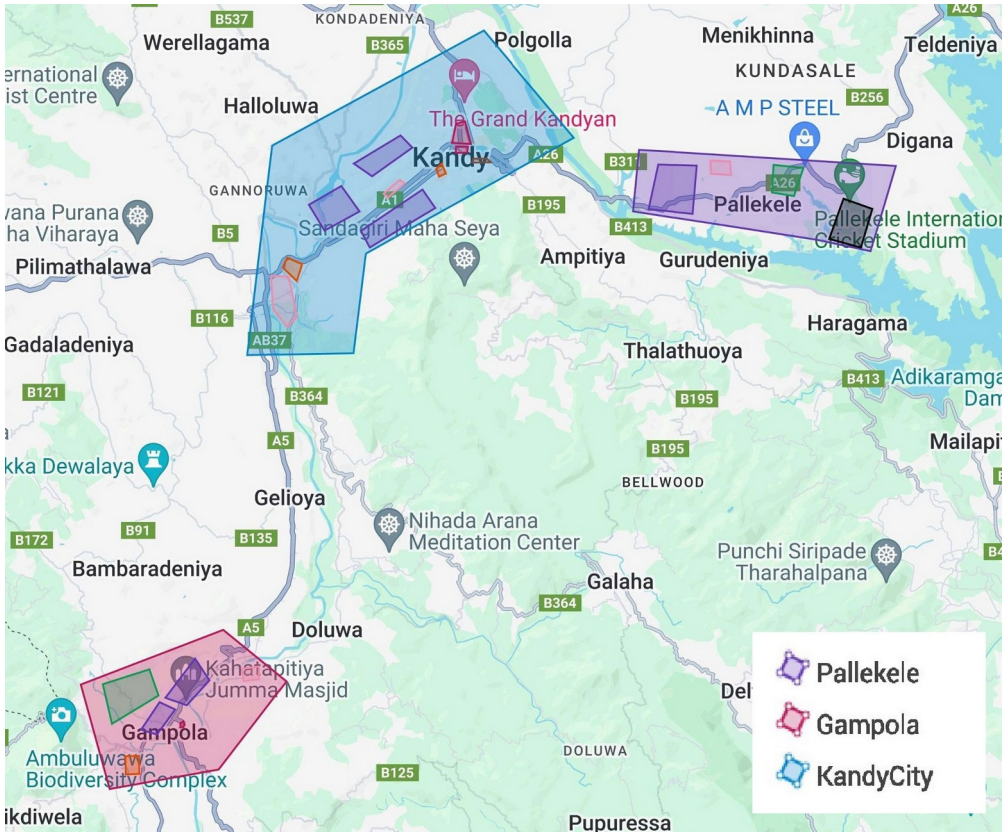
- The environment is the space within which agents operate and interact with each other.
- A **graph network** was used to represent the environment within the emulator.
- A **tree structure** was used based on the geometric locations of the places to indicate the hierarchy of locations



Environment



Simulated Environment



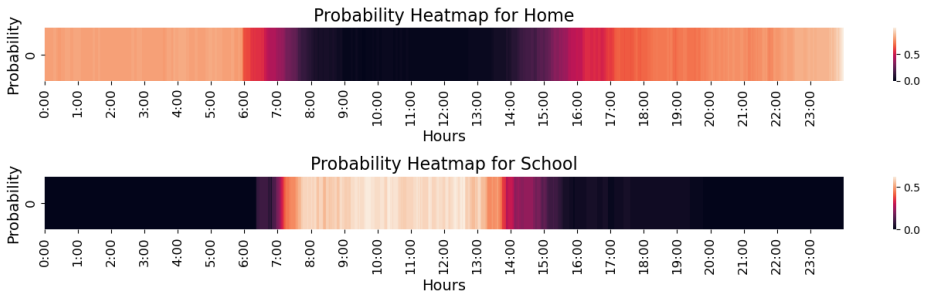
Simulated Environment
Based on
Kandy District

Agent Behavior

- Two probability distributions are used to model human behavior.

I. Location Visit Probability Matrix
   - Determines the location to be visited at a given time of day

II. Stay Duration Matrix
   - Determines the time spent at the location



Probability Distributions

		Timestamp					
		00:00:01	00:00:02	00:00:03	00:00:04	00:00:05	.....
Location	_home	0.6429	0.6429	.....			
	_w_home	0.2143	0.2143	.....			
	_work	0.0000	0.0000	.....			
	AdministrativeZone	0.0000	0.0000	.....			
	AdminOffice	0.0000	0.0000	.....			
	AdminWorkArea	0.0000	0.0000	.....			
	AgriculturalZone	.....	.....	.....			
	AvgProvince	.....	.....	.....			
	Bank						
	BusStation						

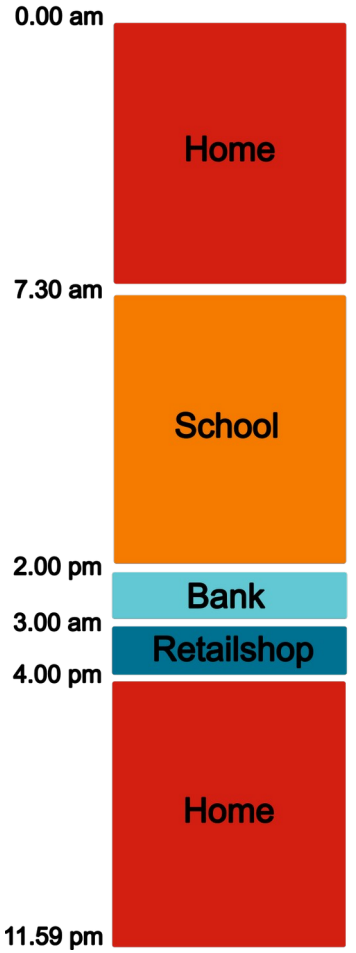
Location Visit Probability Matrix

		Stay Duration (min)					
		001	002	003	004	005	.....
Location	_home	0.6429	0.6429	.....			
	_w_home	0.2143	0.2143	.....			
	_work	0.0000	0.0000	.....			
	AdministrativeZone	0.0000	0.0000	.....			
	AdminOffice	0.0000	0.0000	.....			
	AdminWorkArea	0.0000	0.0000	.....			
	AgriculturalZone	.....	.....	.....			
	AvgProvince	.....	.....	.....			

Stay Duration Matrix

Time Table Generation

- The probability matrices are used to generate a daily schedule for each agent in the simulation.
- The agent will follow this routine, utilizing the transport modes available to access locations.
- The illustration shows a time table generated for a student



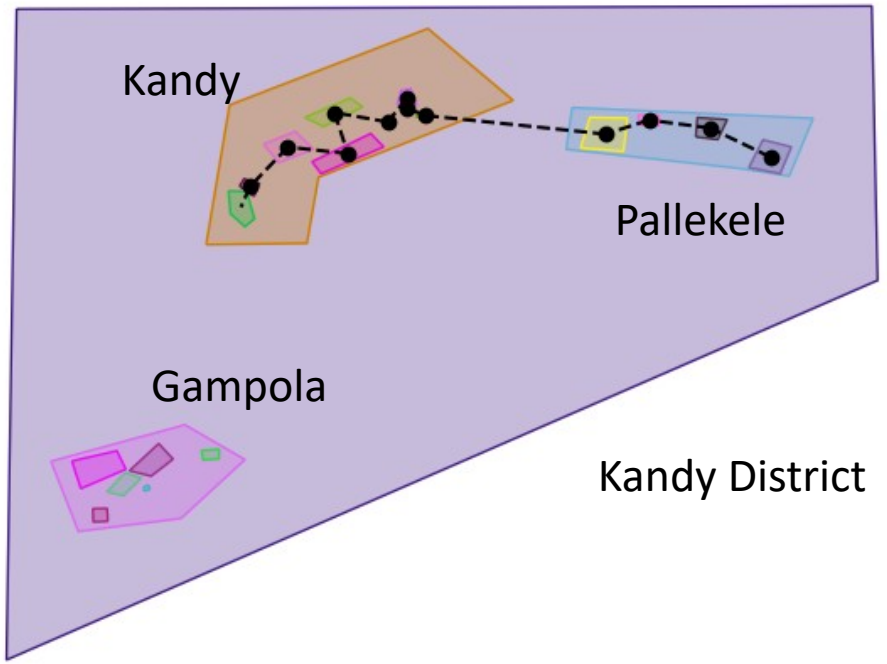
Transport

- Three main transport modes are modeled in the ABM

I. Public Transport (Buses)

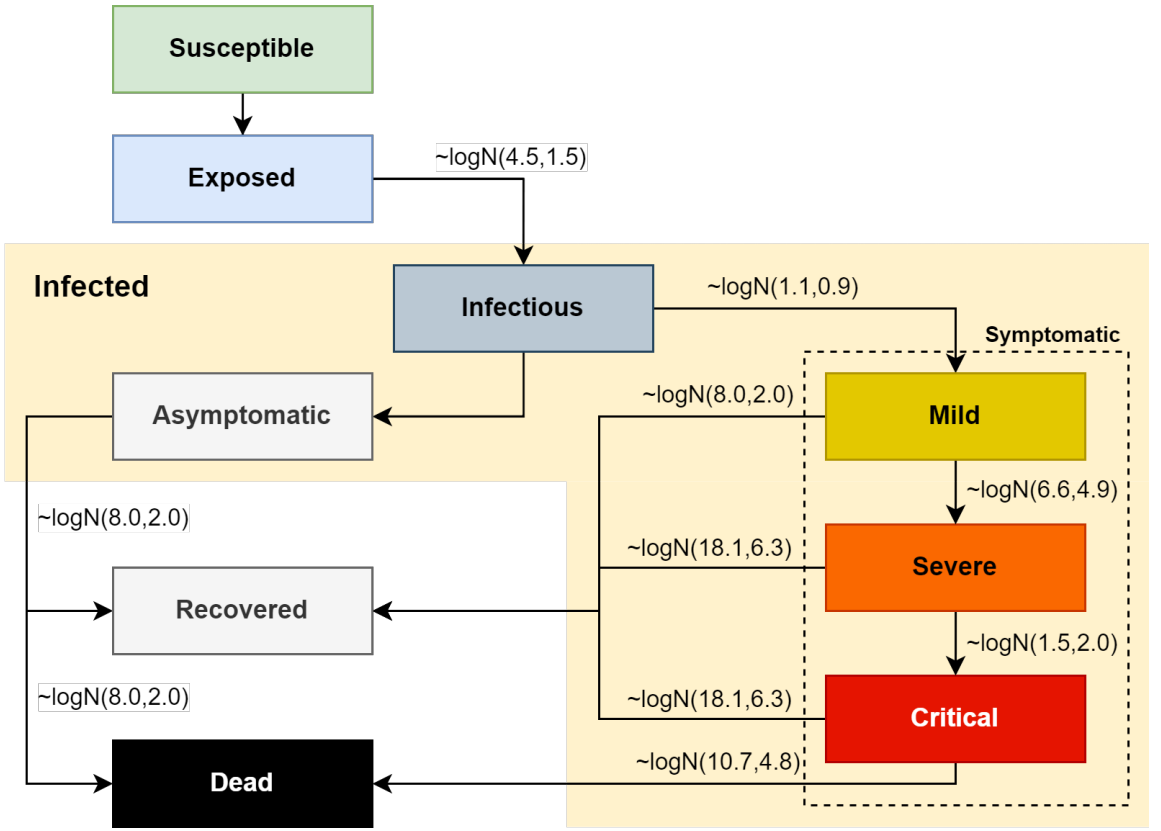
II. Three Wheelers

- The agents will utilize these modes to fulfill their daily routines.

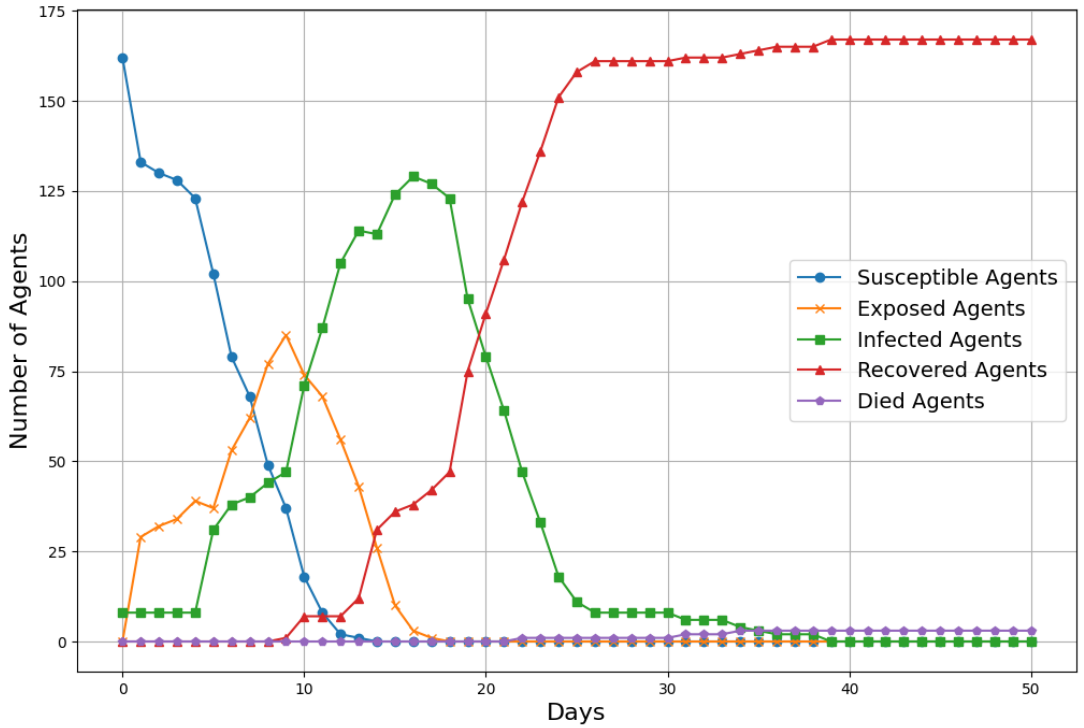


Disease Modeling

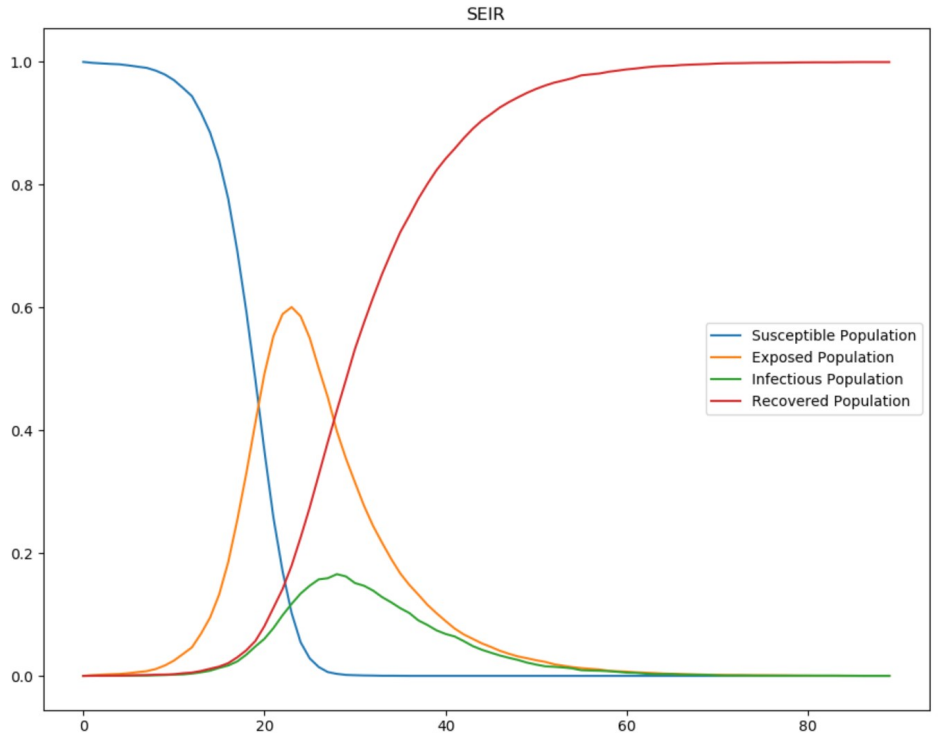
A Markov chain with lognormal distributions is used to model disease states and transitions.



Disease Spread Patterns

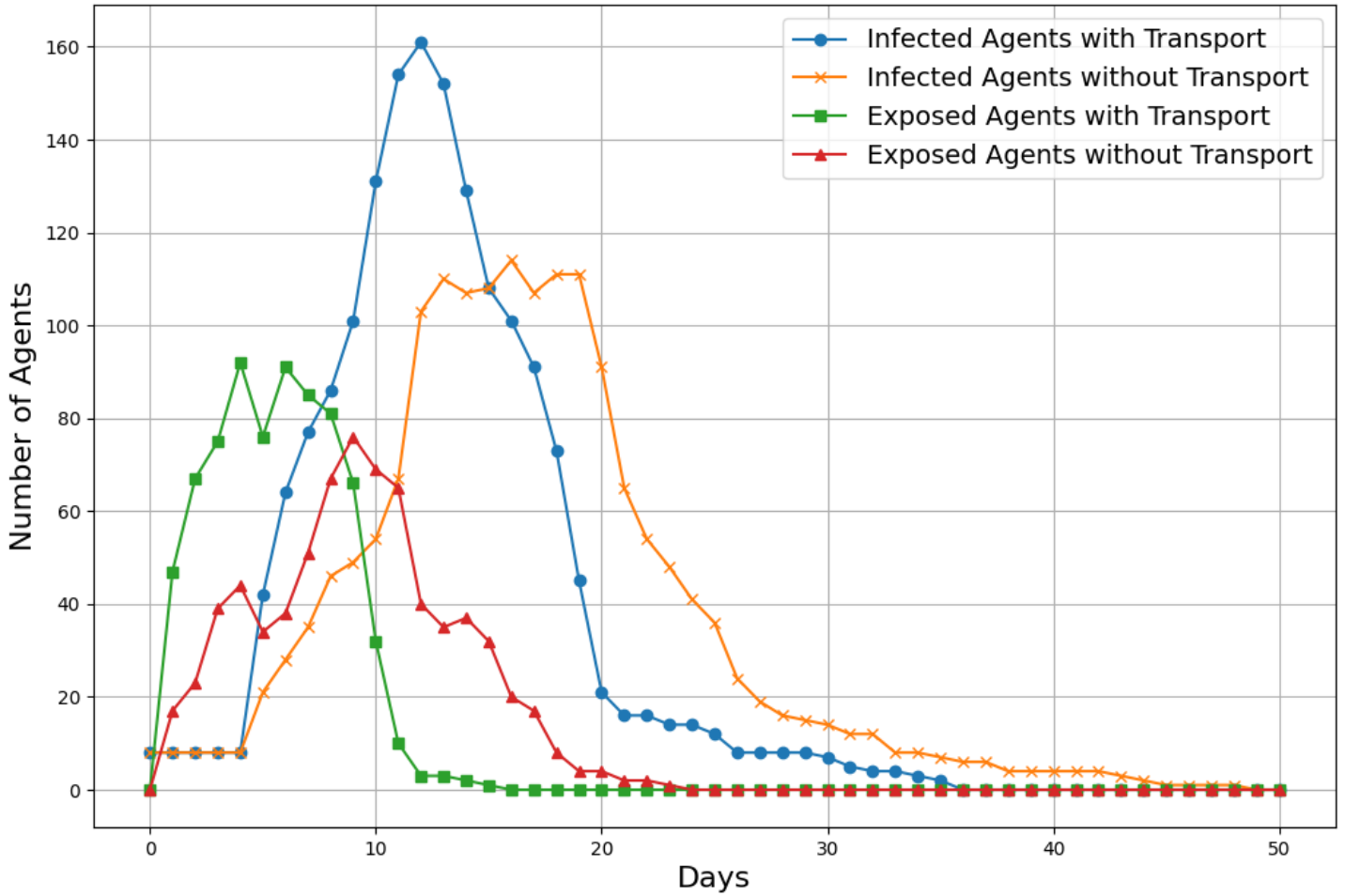


Progression of Each State over 50 Days
(Output of the ABM)



Theoretical SEIR Output Curve
(Based on Differential Equations)

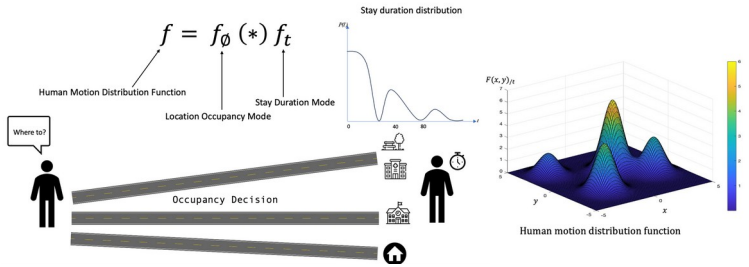
Effect of Transport on Air-Borne Diseases



Variation of Exposed/Infected Agents with the Presence/Absence of Transportation

Conclusion

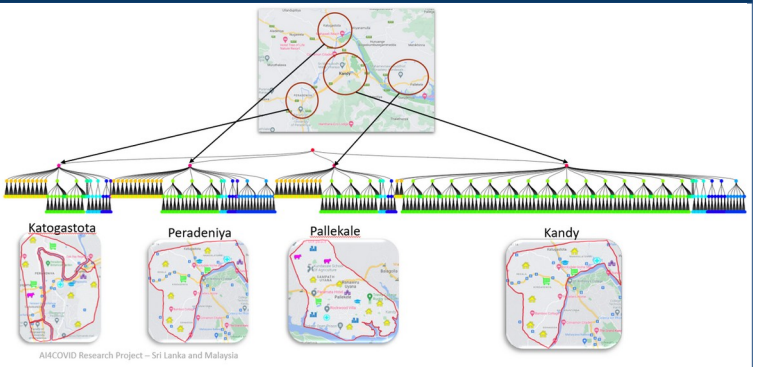
Motion Distribution Model

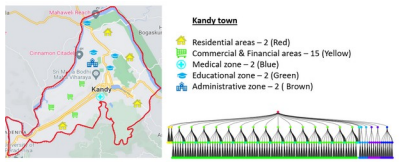


When at a specific location state: based on '**Stay Duration Mode**', time spent on random walk state are estimated.

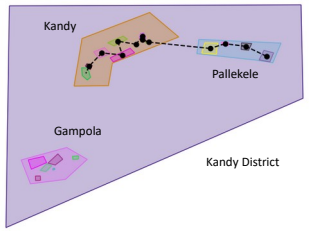
When stay duration expires: based on '**Location Visit Mode**', the decision on next Location state is generated.

Environment Builder





Location States of the Motion Distribution Models are linked to Location States identified in the real world environment

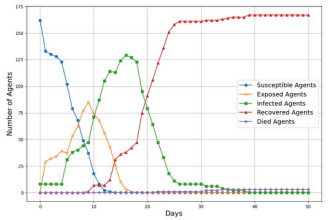


Simulate transportations routes to detect disease propagation

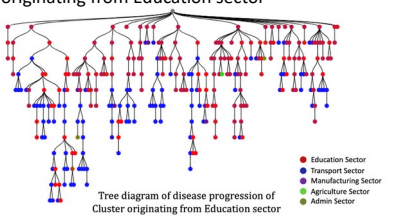
Macro Level Insights

Insights of **disease propagation dynamics** in terms of occupation class interactions at the micro level

Disease propagation of COVID-19 in the environment over time.



Covid19 disease propagation clustering originating from Education sector



THANK YOU