



## CLC Street Network Modelling Project

SLA x NSCC Webinar

9th June 2021

- **Using spatial modelling as a bottom-up approach to analyse street accessibility**
- **How spatial analysis can inform and value-add planning processes and policies within govt agencies**





# SPACE SYNTAX LIMITED - LONDON HQ



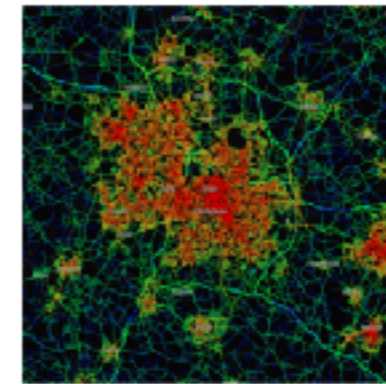
## CityZen Explorer

A tool to improve the quality of life of older people living in urban areas.



## OpenMapping GB

A pre-processed spatial network model of Great Britain, published as an open dataset.



## Urban Value modelling

A powerful modelling tool that measures the impact on land values of key urban design factors including spatial connectivity, land use attraction and transport infrastructure.



## Walkability Index

A tool to benchmark existing places and test new proposals in terms of whether they deliver walkability or car-dependence.





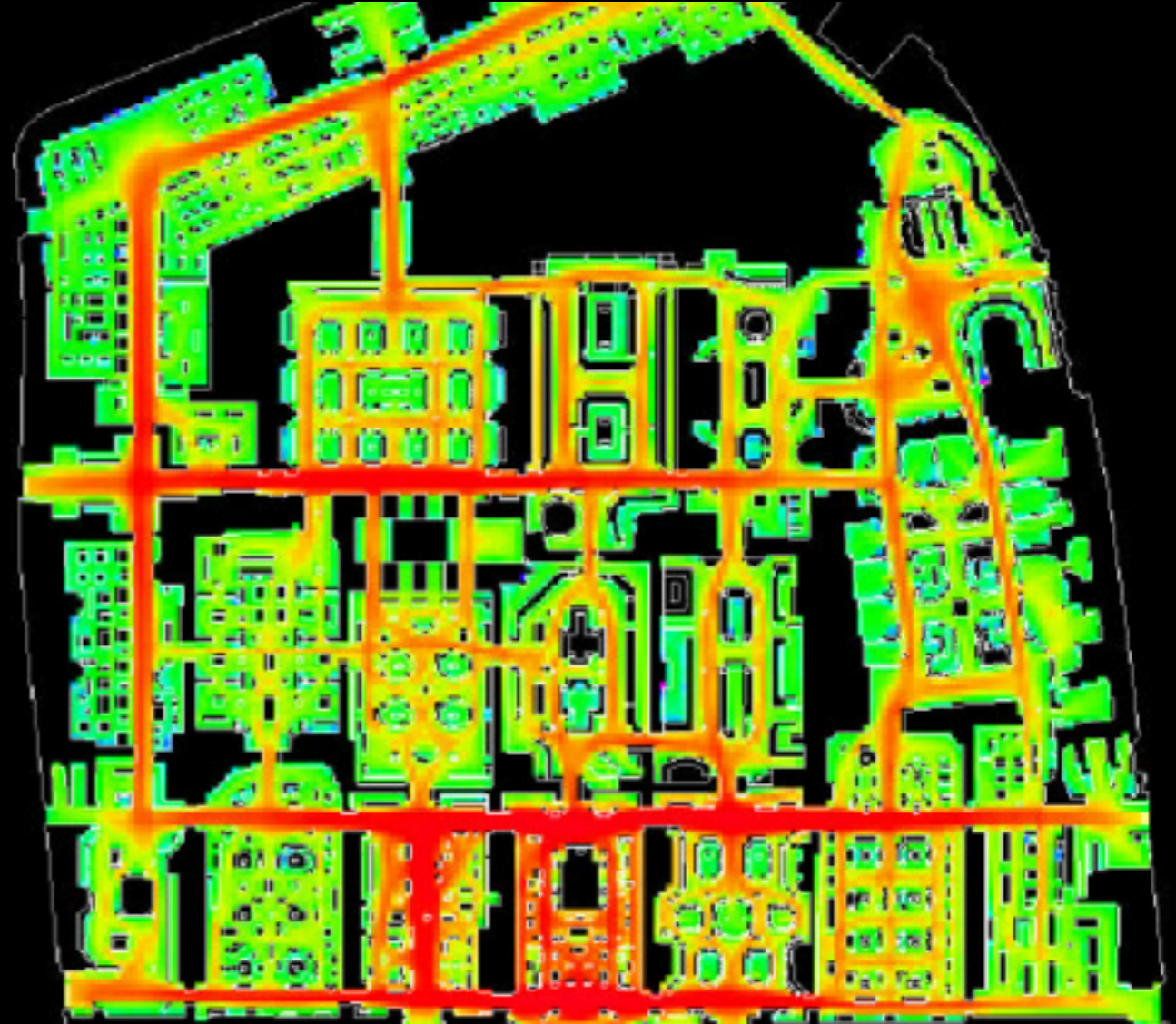
# SPACE SYNTAX LIMITED - LONDON HQ

TRAFALGAR SQUARE, LONDON



Analysing pedestrian flow and activity

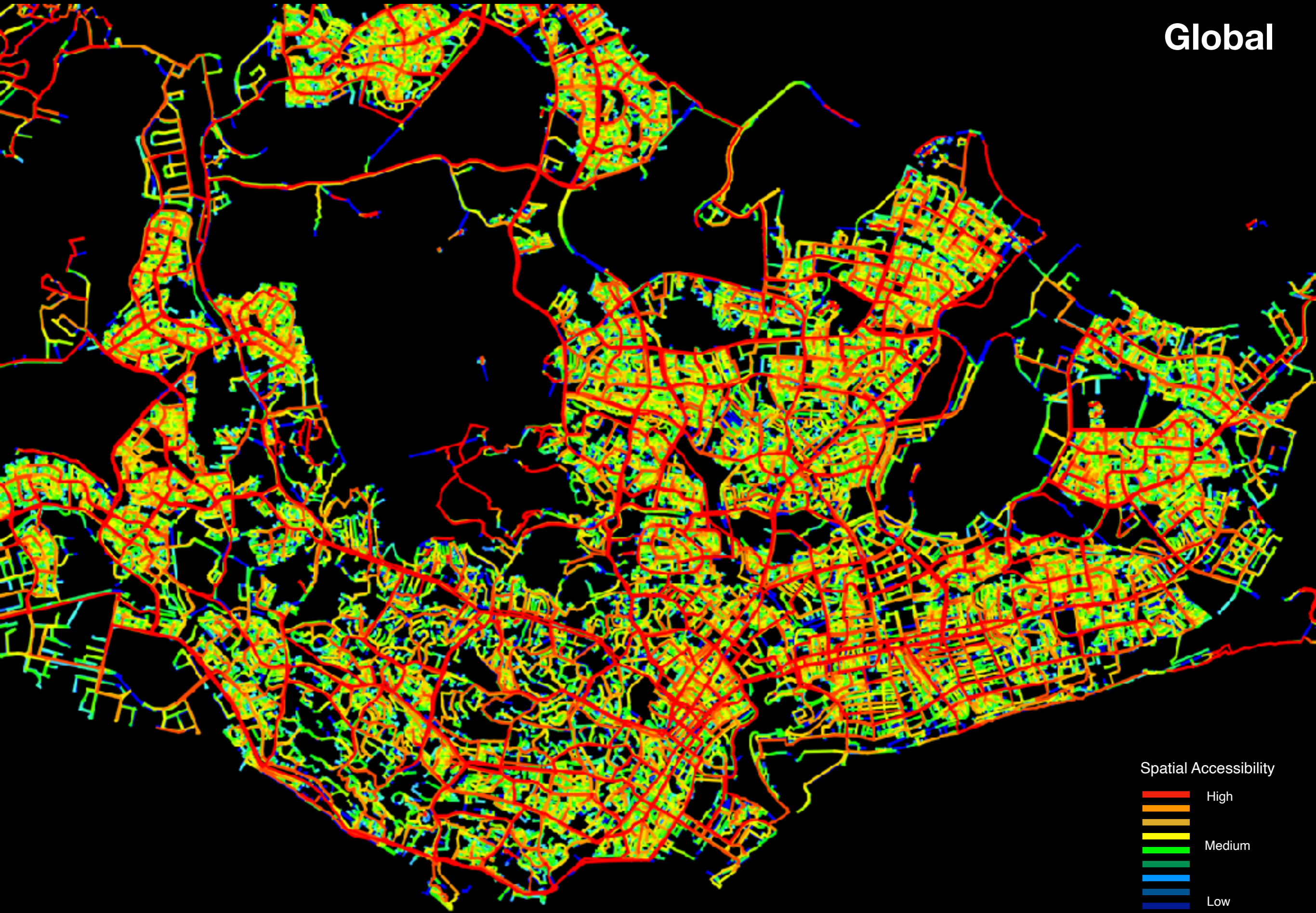
HARRODS, LONDON



Visibility Graph Analysis  
Agent-based Modelling



Global

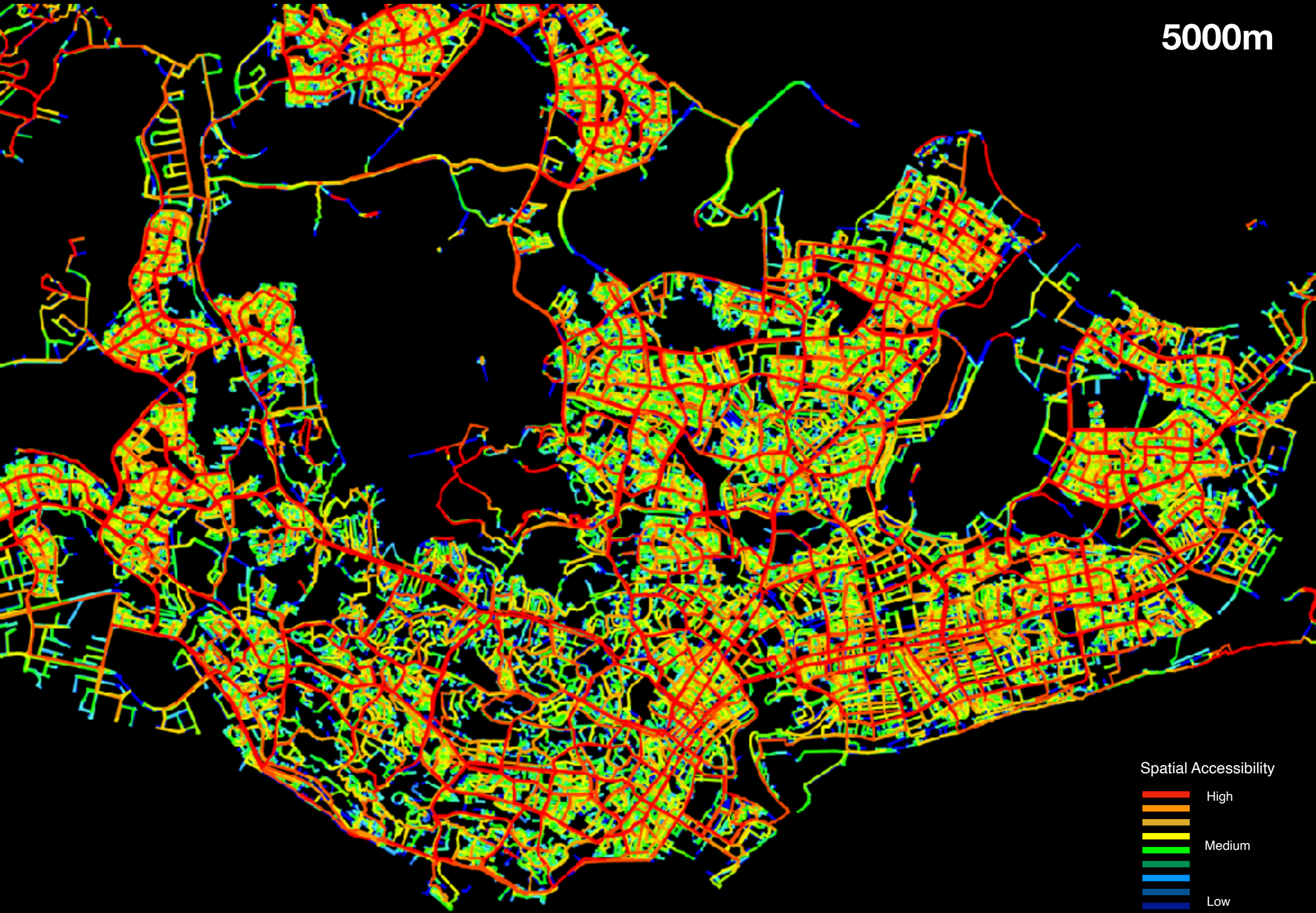


Spatial Accessibility

- High
- Medium
- Low



5000m

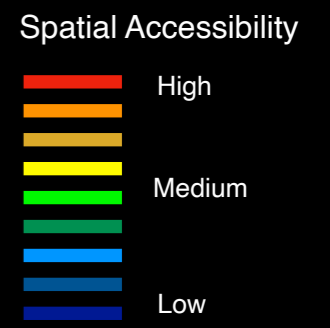
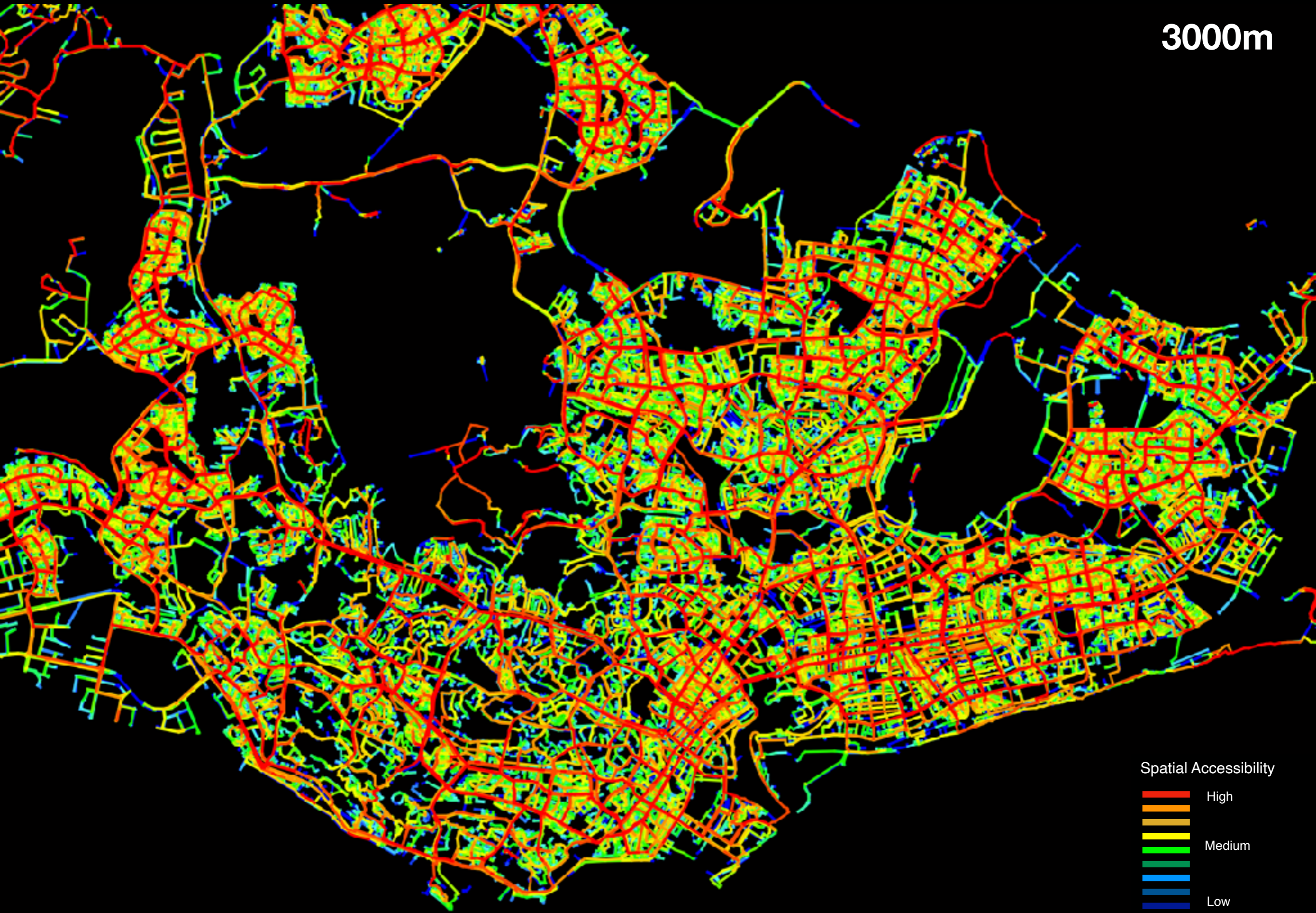


Spatial Accessibility

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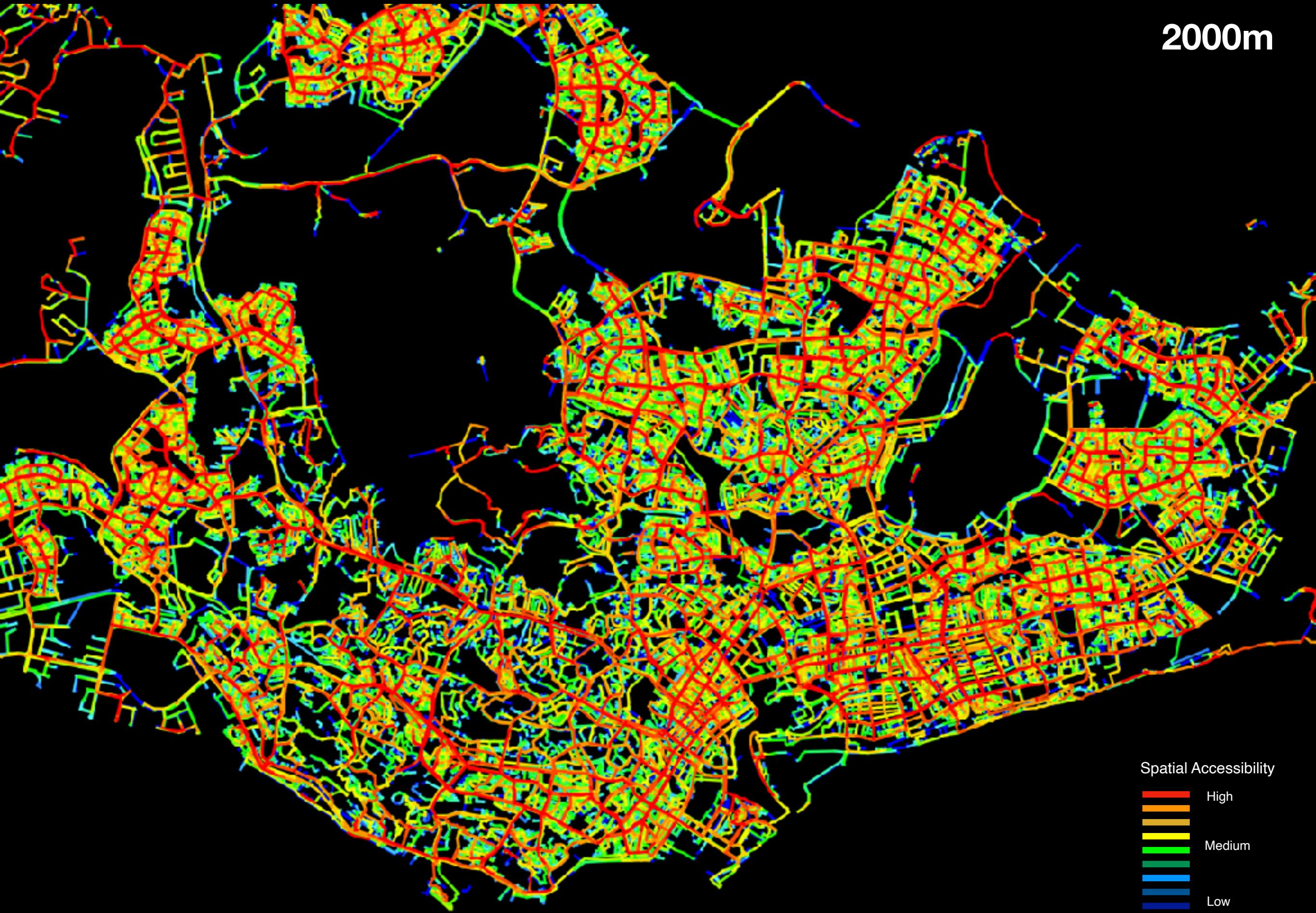


3000m





2000m

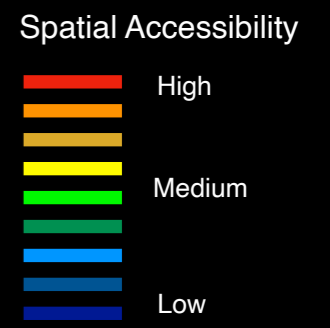
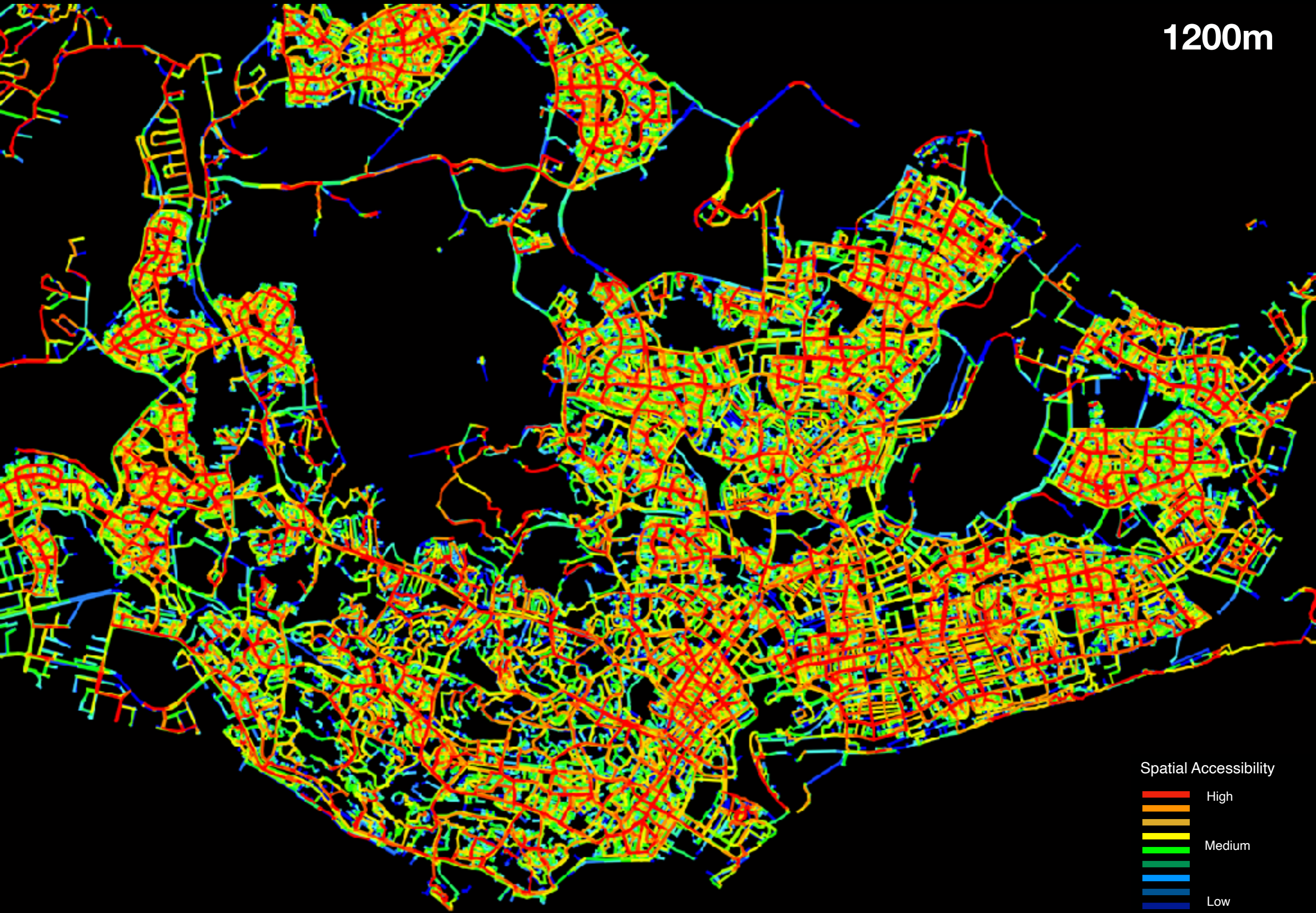


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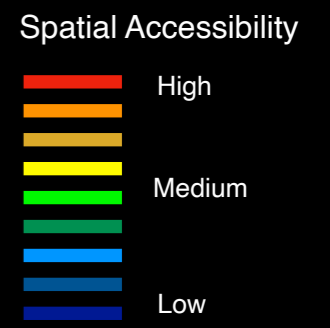
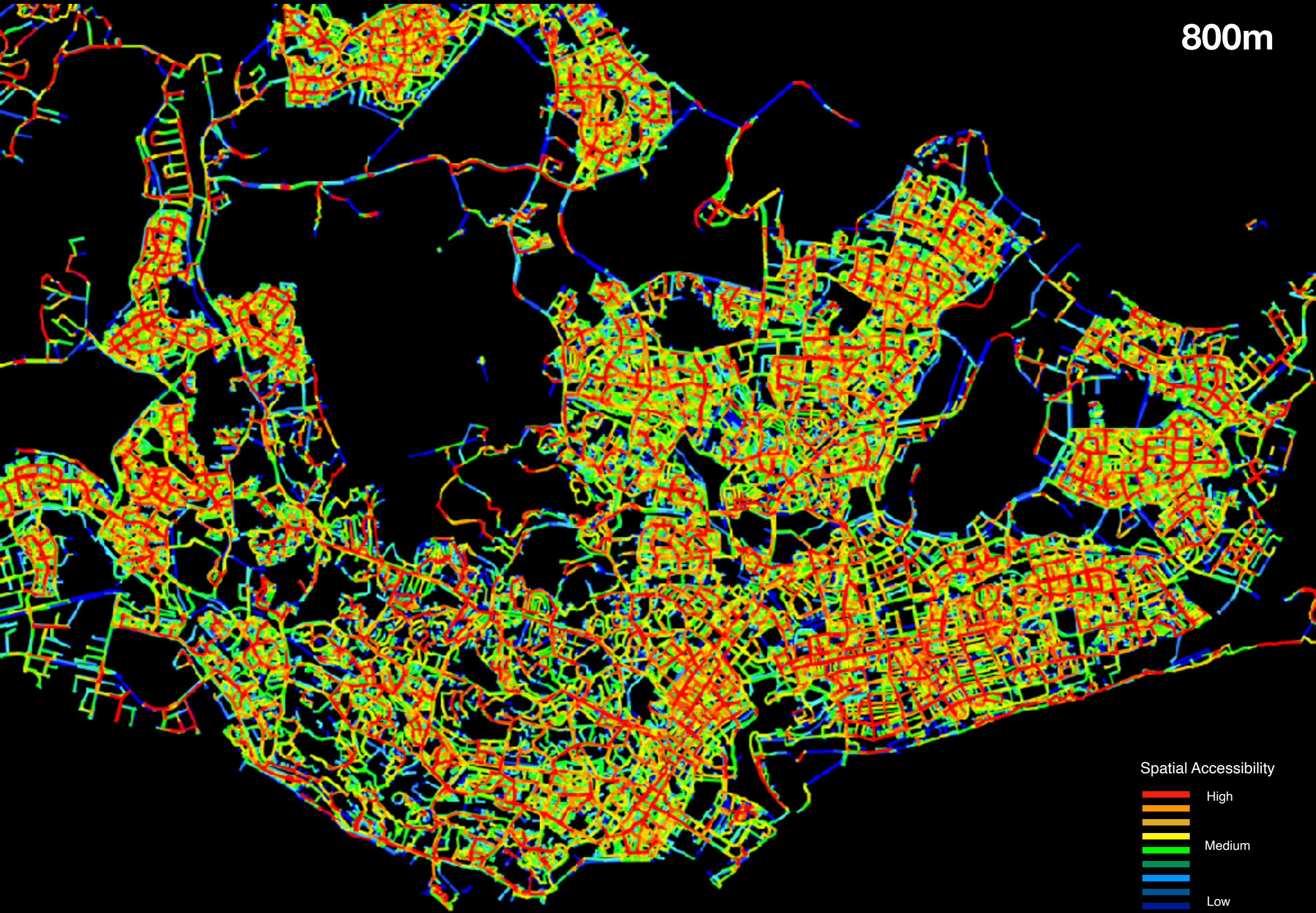


1200m





800m





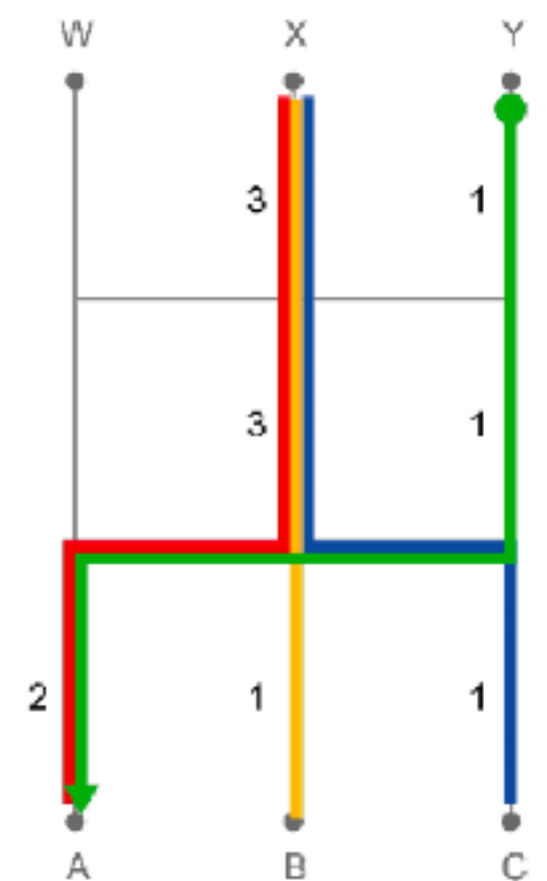
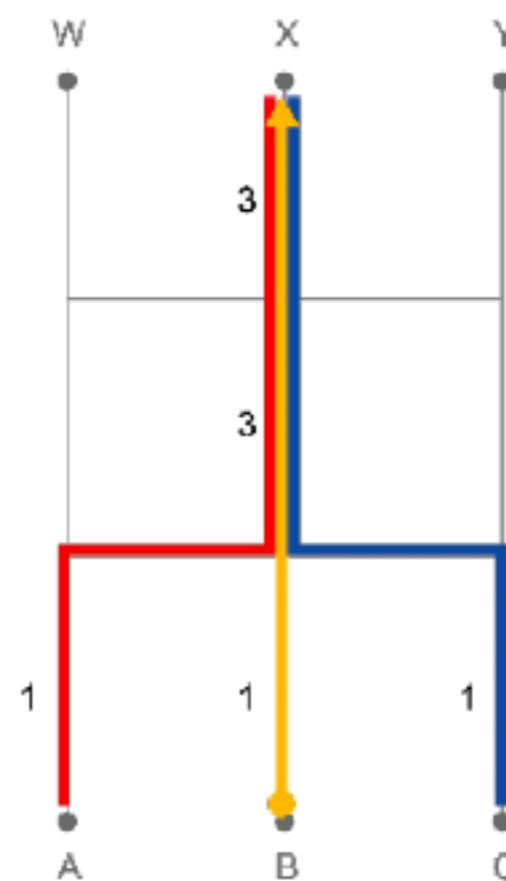
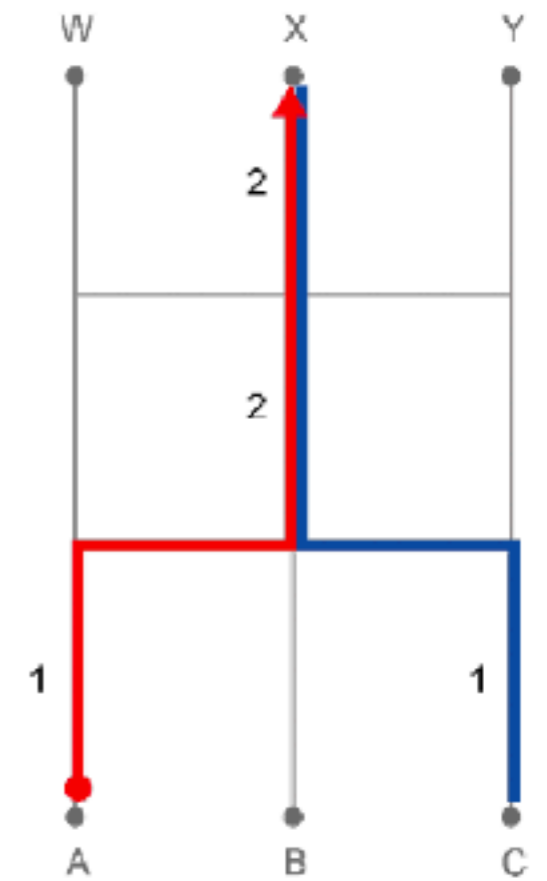
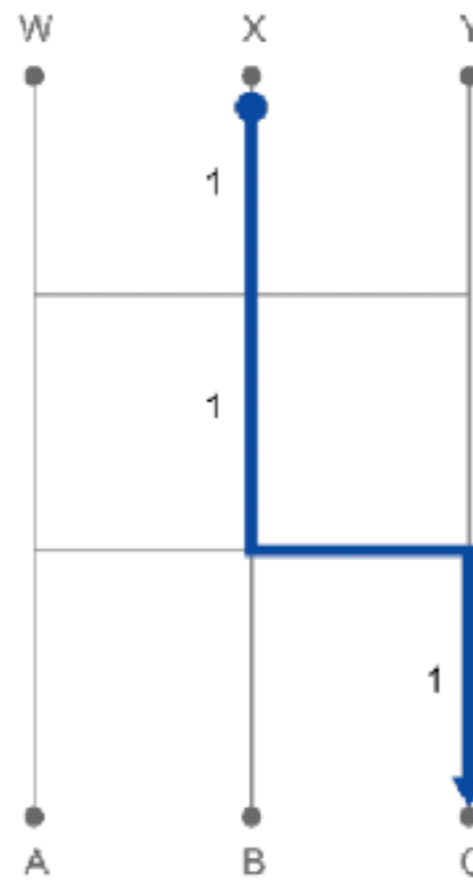
## Betweenness Centrality

### Choice / Through-Movement

In graph theory, betweenness centrality is a measure of centrality in a graph based on shortest paths.

For every pair of vertices in a connected graph, there exists at least one shortest path between the vertices such that 1) and 2) are **minimised**

- 1) the number of edges that the path passes through (unweighted)
- 2) the sum of the weights of the edges (weighted)





## Segment Angular Analysis

### Angular Change

Angular change is the primary weighting for this model.

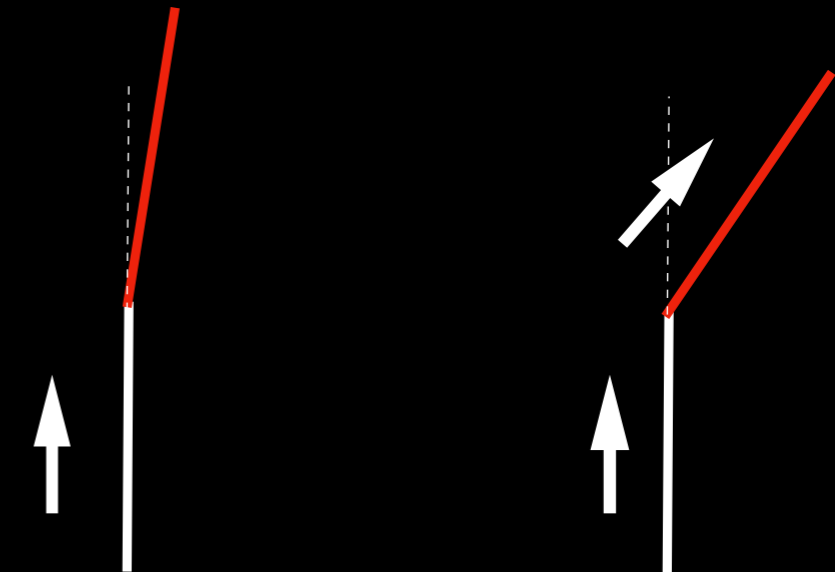
The higher the degree of angular change from line to line, the higher the weighting.

(A) A turn of less than 22.5 degrees has **0** weighting

(B) A turn of 45 degrees is weighted by **0.5**

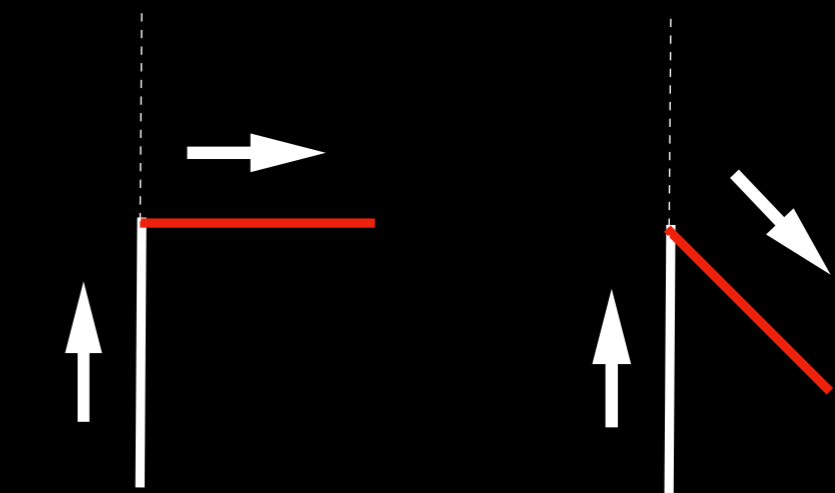
(C) A turn of 90 degrees is weighted by **1**

(D) The maximum is 180 degrees with a weighting by **2**



(A)

(B)



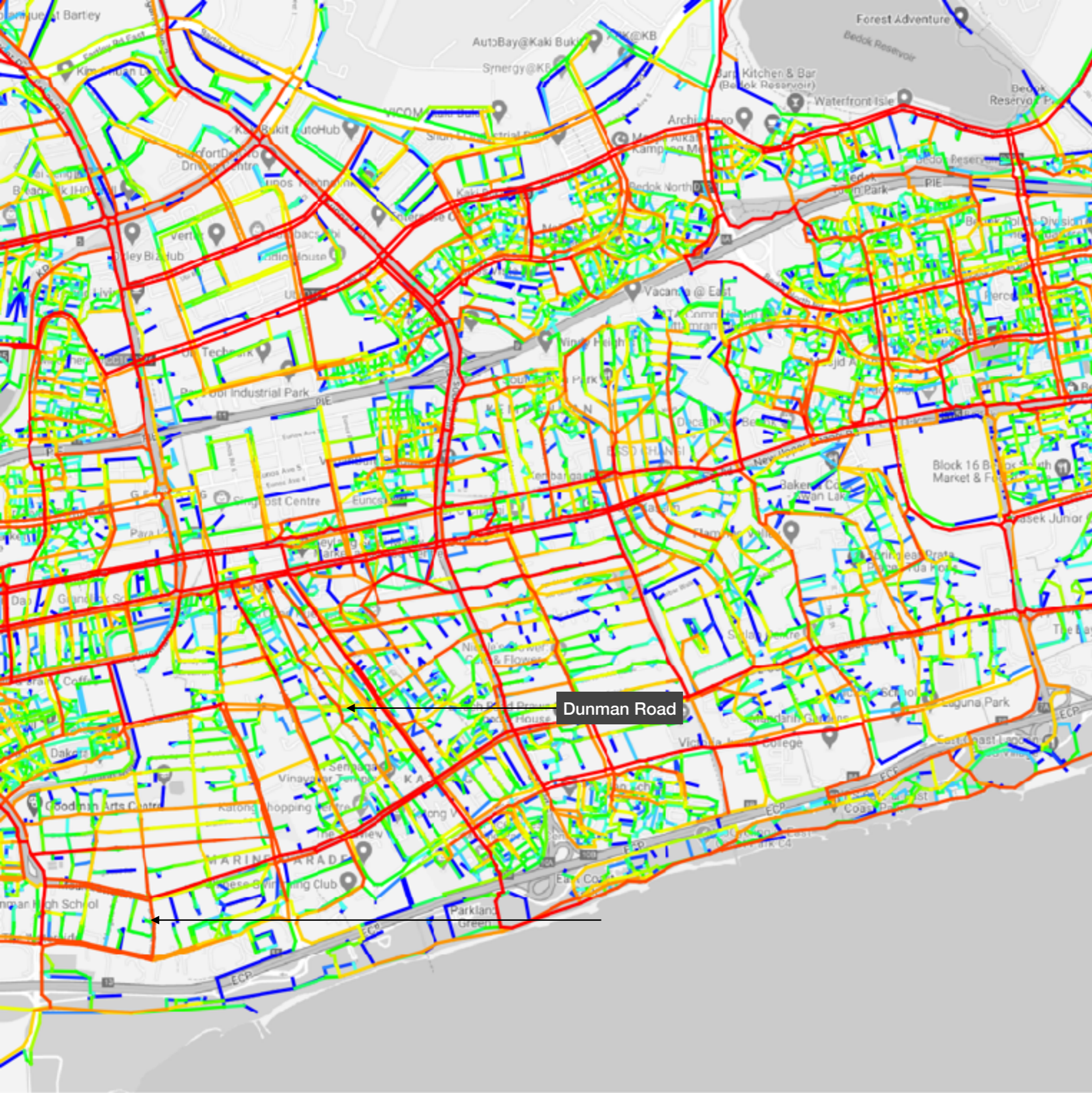
(C)

(D)



# Choice Accessibility

Global



- Choice Accessibility**
- Betweenness Centrality
  - Potential for Human Movement
  - Multi-scale

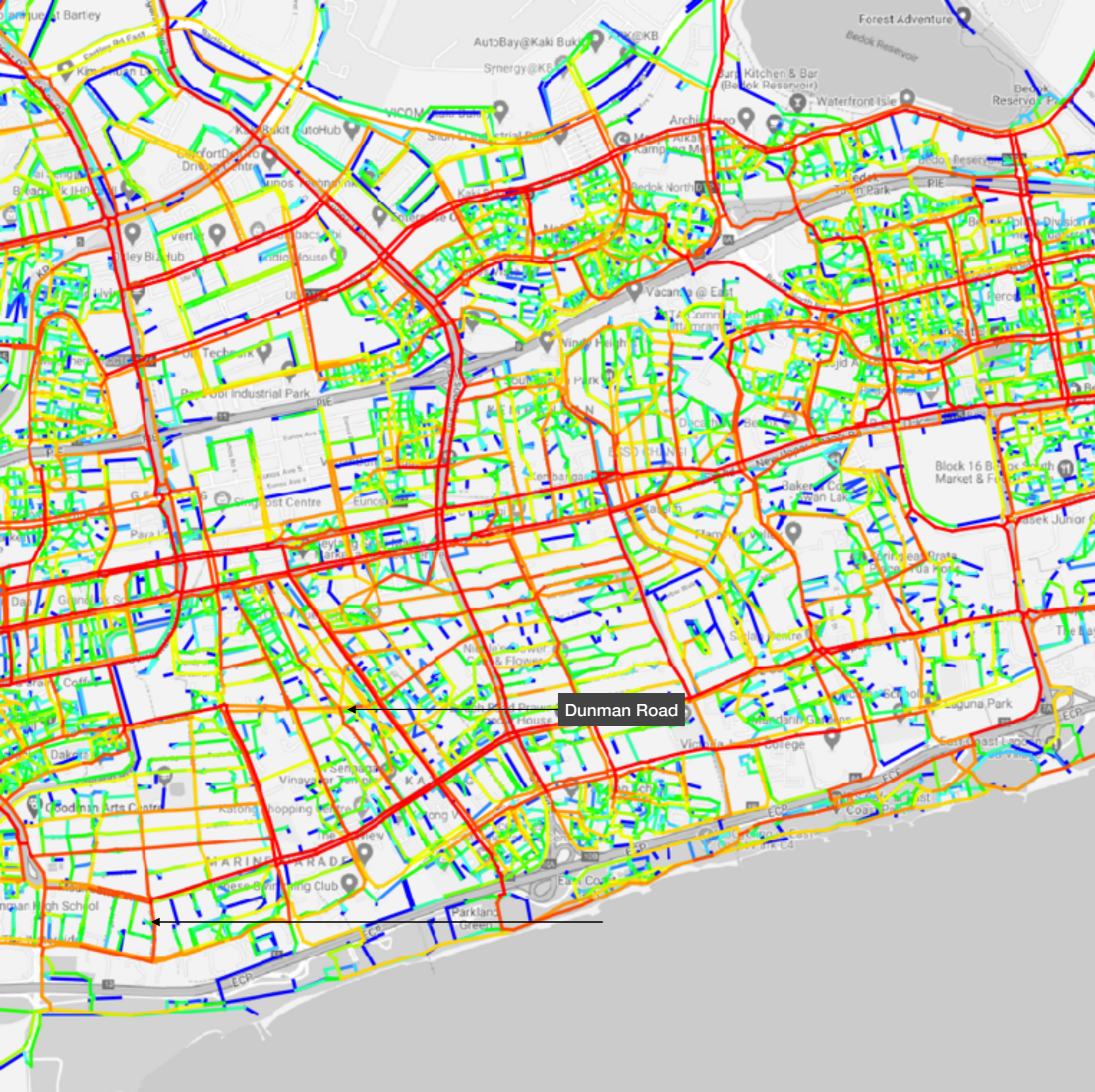
## Spatial Accessibility





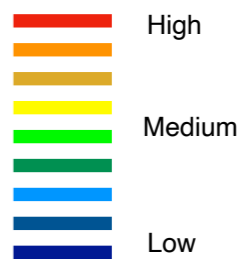
# Choice Accessibility

Radius 5000m



- Choice Accessibility**
- Betweenness Centrality
  - Potential for Human Movement
  - Multi-scale

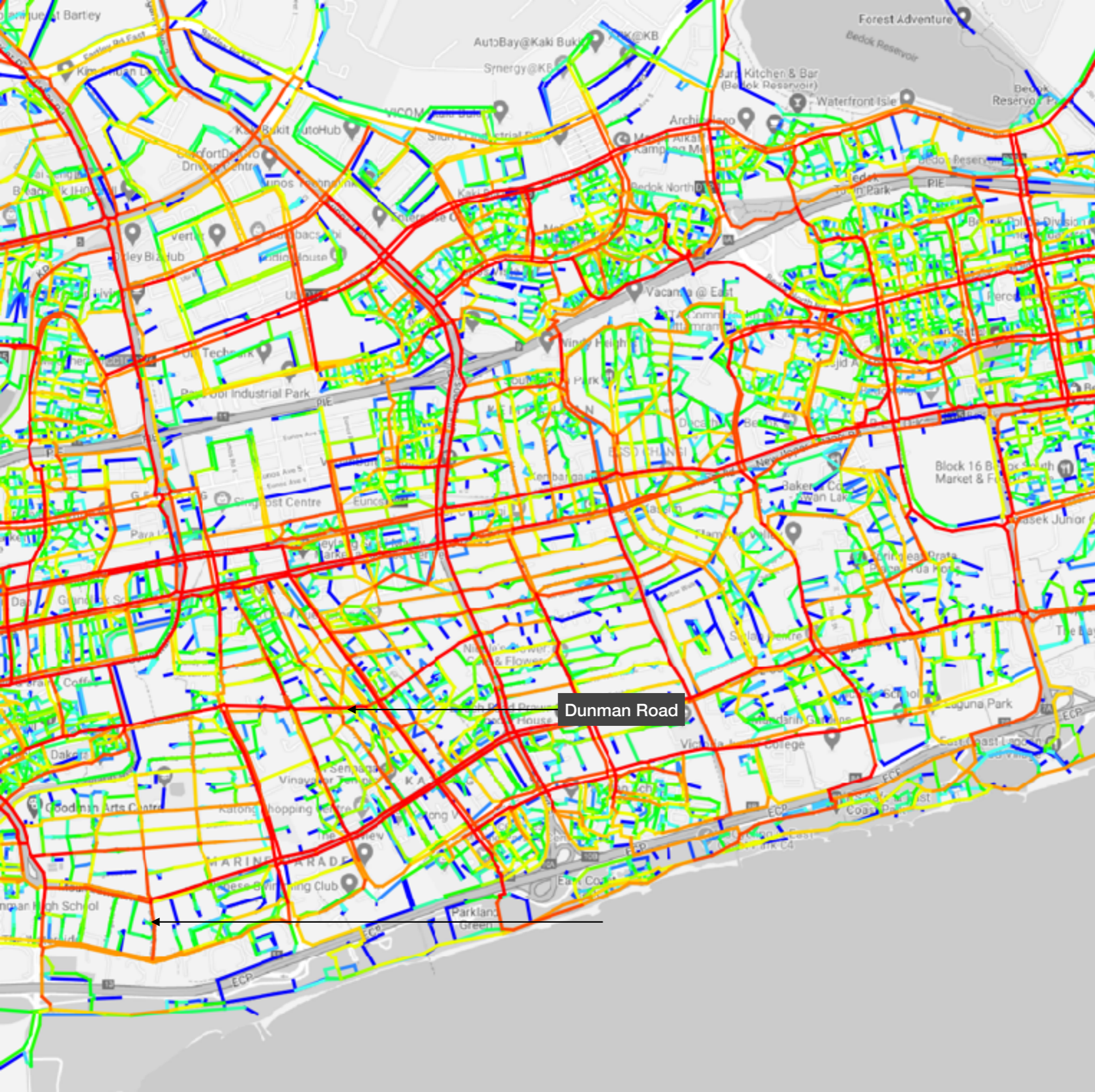
## Spatial Accessibility





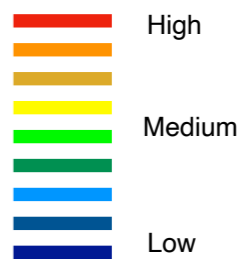
# Choice Accessibility

Radius 3000m



- Choice Accessibility**
- Betweenness Centrality
  - Potential for Human Movement
  - Multi-scale

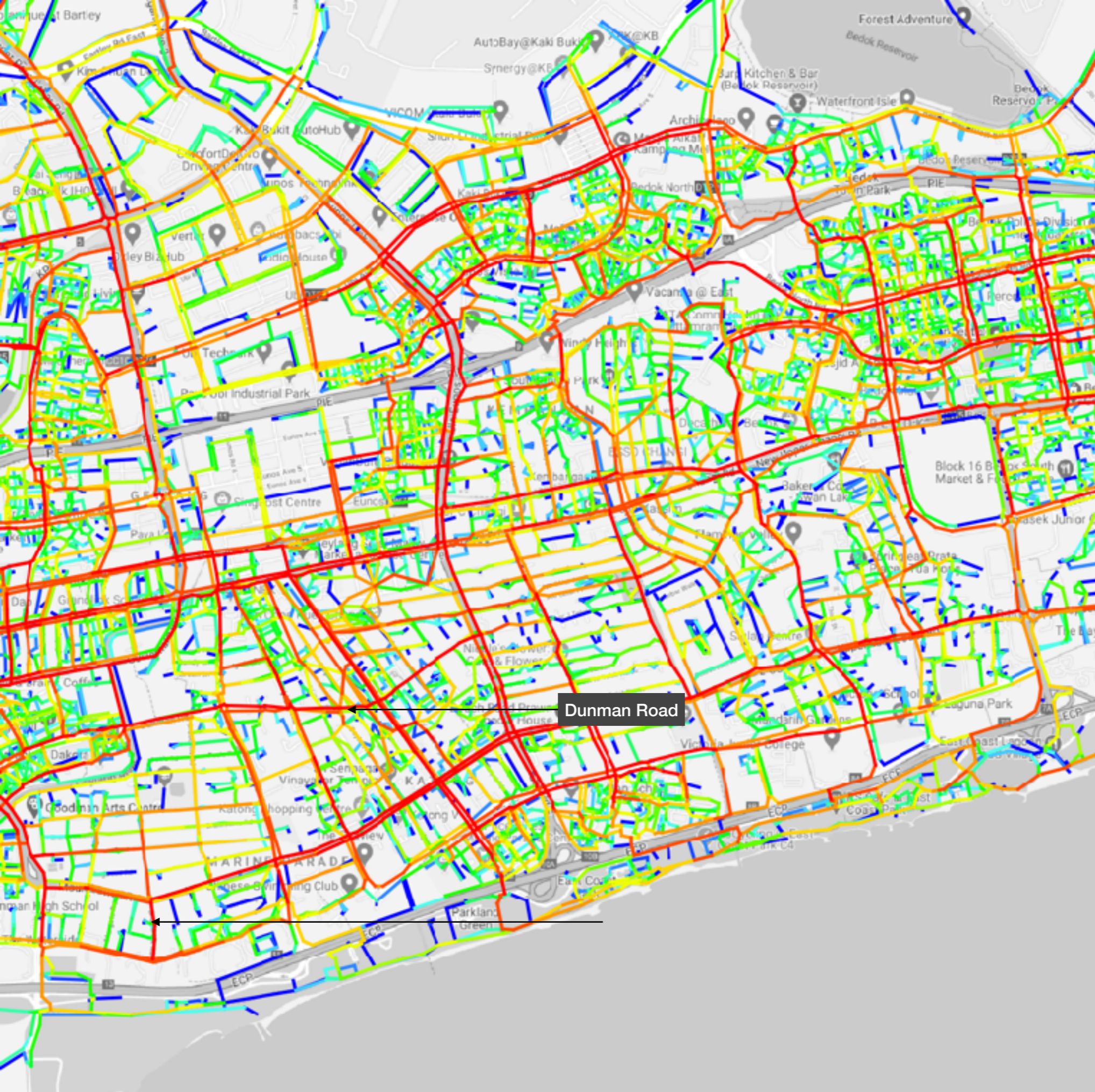
## Spatial Accessibility





# Choice Accessibility

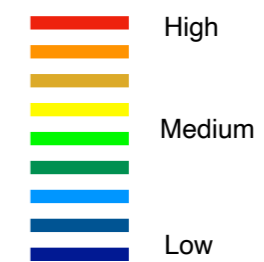
Radius 2000m



## Choice Accessibility

- Betweenness Centrality
- Potential for Human Movement
- Multi-scale

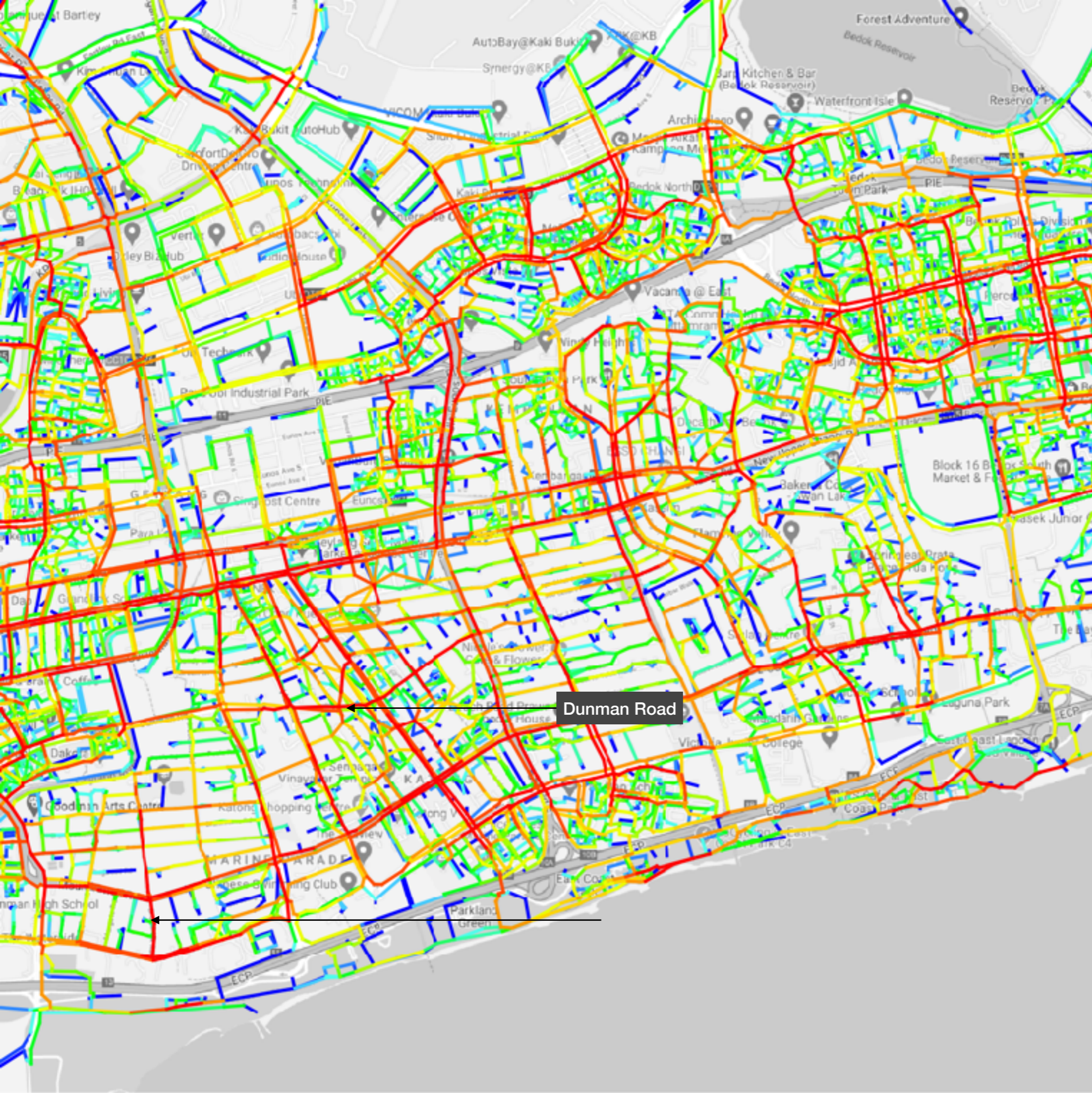
## Spatial Accessibility





# Choice Accessibility

Radius 1200m



- Choice Accessibility**
- Betweenness Centrality
  - Potential for Human Movement
  - Multi-scale

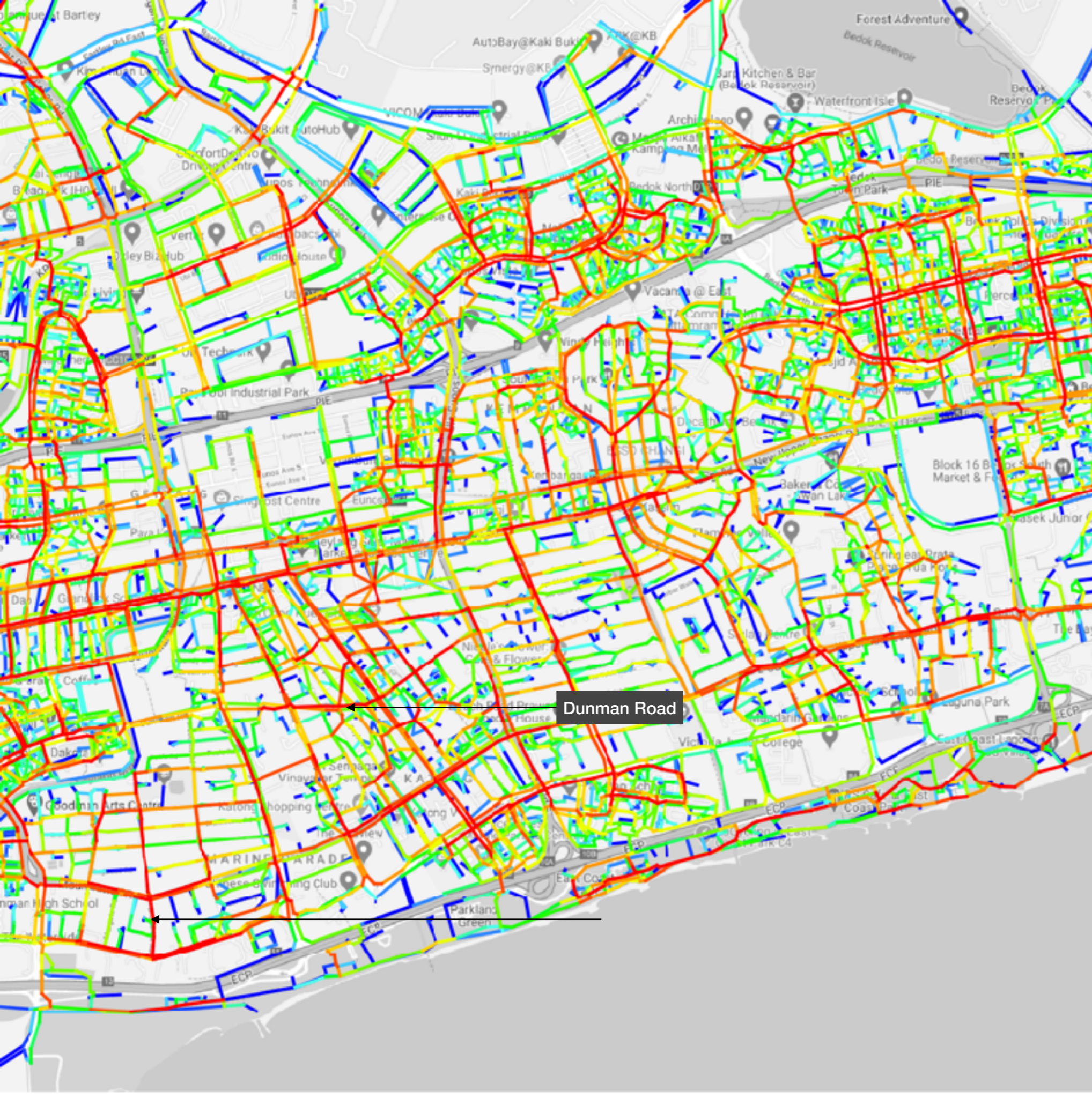
## Spatial Accessibility





# Choice Accessibility

Radius 800m



- Choice Accessibility**
- Betweenness Centrality
  - Potential for Human Movement
  - Multi-scale

## Spatial Accessibility





# SLA 3D SANDBOX

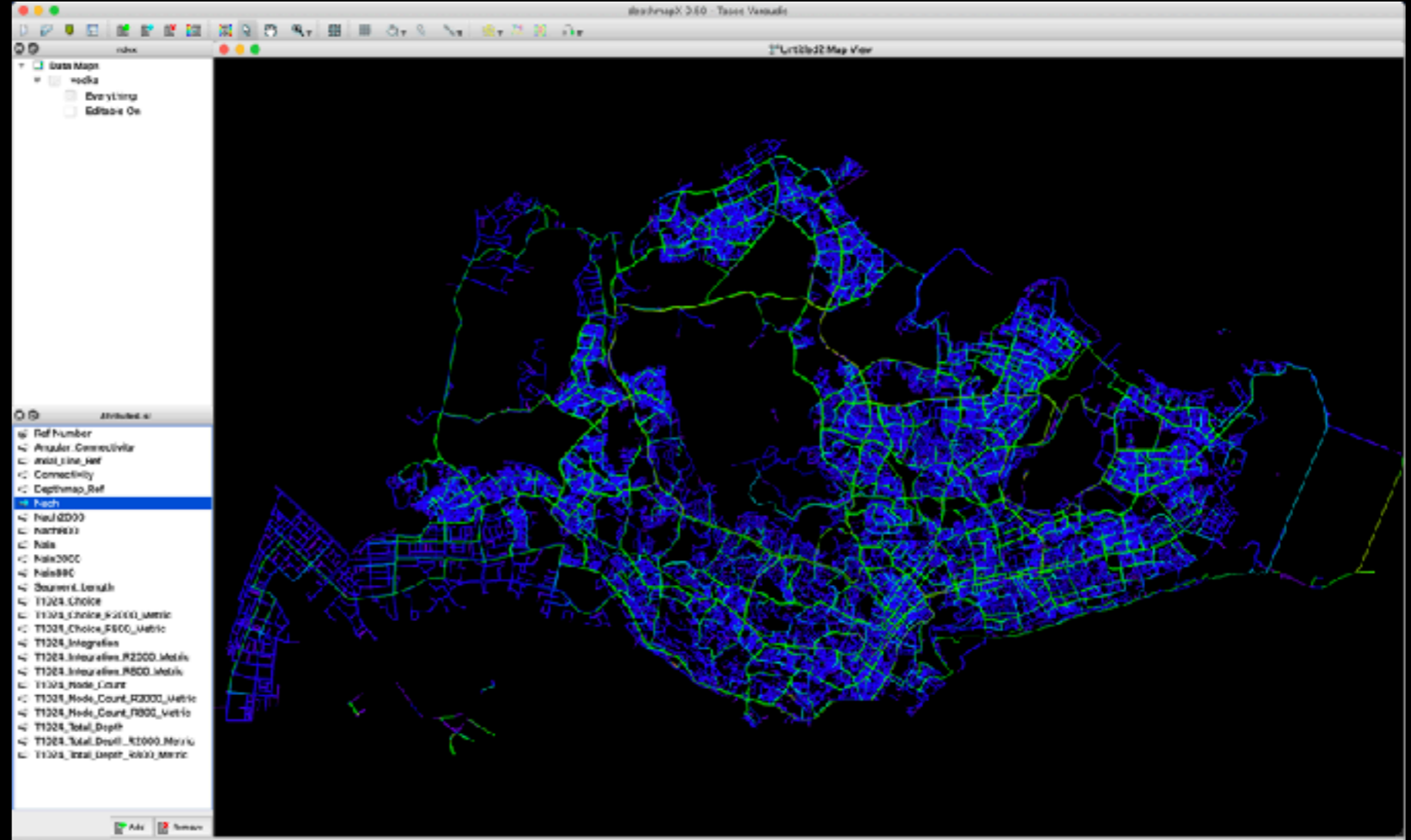
VISUALIZING THE MODEL WITH 3D





depthmapX software

Running analysis using depthmapX software (open source)  
Processing time: 24-48 hours

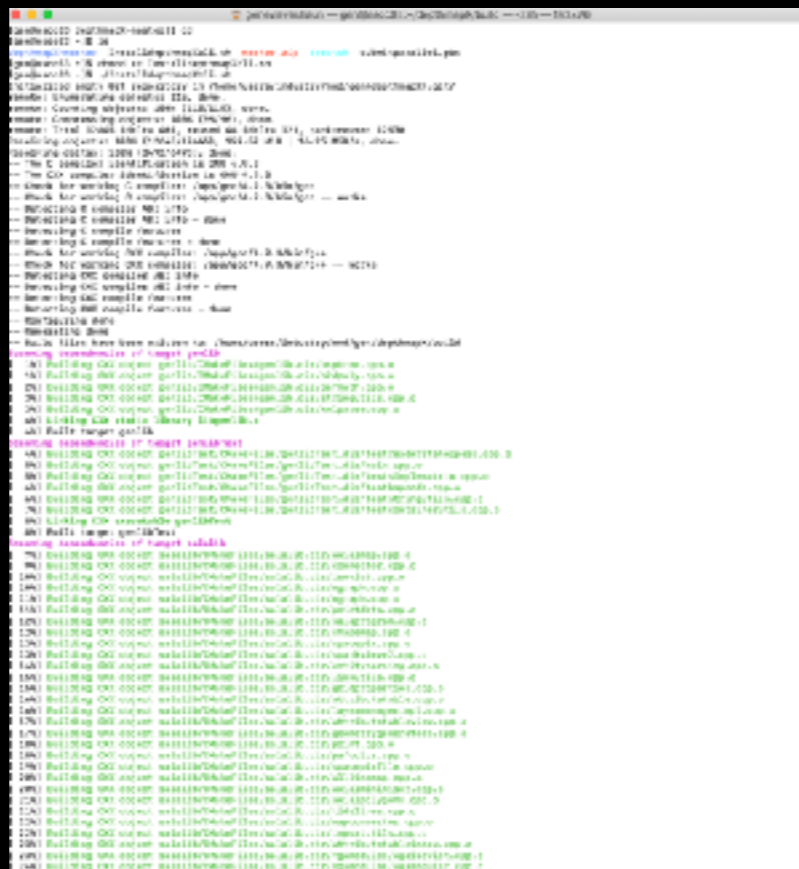




depthmapX software

1. Building depthmapX onto NSCC's server

2. Running DepthmapX on NSCC's server Using DepthmapX CLI (Command Line Interface)



3. Split the different radius analysis as different tasks to make use of HPC parallel computing



# Typical workflow - With HPC

NSCC

HIGH PERFORMANCE COMPUTING

```
[ 65%] Building CXX object depthmapXcli/CMakeFiles/depthmapXcli.dir/depthmapXcli.cpp.o
[ 70%] Building CXX object depthmapXcli/CMakeFiles/depthmapXcli.dir/depthmapXcli.cpp.o
[ 75%] Building CXX object depthmapXcli/CMakeFiles/depthmapXcli.dir/depthmapXcli.cpp.o
[ 80%] Building CXX object depthmapXcli/CMakeFiles/depthmapXcli.dir/depthmapXcli.cpp.o
[ 85%] Building CXX object depthmapXcli/CMakeFiles/depthmapXcli.dir/depthmapXcli.cpp.o
[ 90%] Building CXX object depthmapXcli/CMakeFiles/depthmapXcli.dir/depthmapXcli.cpp.o
[ 95%] Building CXX object depthmapXcli/CMakeFiles/depthmapXcli.dir/depthmapXcli.cpp.o
[100%] Linking CXX executable depthmapXcli
[100%] Built target depthmapXcli
Scanning dependencies of target segmentpathscore
[ 78%] Building CXX object cliTest/modules/segmentpathscore.cpp.o
[ 80%] Built target segmentpathscorecliTest
Scanning dependencies of target cliTest
[ 80%] Building CXX object cliTest/CMakeFiles/cliTest.dir/depthmapXcli.cpp.o
[ 82%] Building CXX object cliTest/CMakeFiles/cliTest.dir/depthmapXcli.cpp.o
[ 84%] Building CXX object cliTest/CMakeFiles/cliTest.dir/depthmapXcli.cpp.o
[ 86%] Building CXX object cliTest/CMakeFiles/cliTest.dir/depthmapXcli.cpp.o
[ 88%] Building CXX object cliTest/CMakeFiles/cliTest.dir/depthmapXcli.cpp.o
[ 90%] Building CXX object cliTest/CMakeFiles/cliTest.dir/depthmapXcli.cpp.o
[ 92%] Building CXX object cliTest/CMakeFiles/cliTest.dir/depthmapXcli.cpp.o
[ 94%] Building CXX object cliTest/CMakeFiles/cliTest.dir/depthmapXcli.cpp.o
[ 96%] Building CXX object cliTest/CMakeFiles/cliTest.dir/depthmapXcli.cpp.o
[ 98%] Building CXX object cliTest/CMakeFiles/cliTest.dir/depthmapXcli.cpp.o
[100%] Linking CXX executable cliTest
[100%] Built target cliTest
Scanning dependencies of target moduleTest
[ 44%] Building CXX object moduleTest/moduleTest.cpp.o
[ 46%] Built target moduleTestcliTest
Scanning dependencies of target moduleTest
[100%] Linking CXX executable moduleTest
[100%] Built target moduleTest
Installation completed! You can now type depthmapXcli
[gen@nsccc03 build]$ depthmapXcli
No command-line parameters provided - don't know what to do
Type 'depthmapXcli -h' for help
[gen@nsccc03 build]$ client_loop: send disconnect: Broken pipe
(base) genevieve@genevieve-MacBook-Pro-2:~$ ssh -i /Users/genevieve/.ssh/id_rsa -p 2222 gen@nsccc03
Last login: Sat Feb 13 19:16:21 on ttys004
[gen@nsccc03 ~]$ cat submitparallel.phs
#!/bin/bash
#PBS -N Project1
#PBS -q normal
#PBS -o depth.out
#PBS -e depth.error
#PBS -l select=1:ncpus=24:mem=96G:mpiprocs=1:ompithreads=1
#PBS -l walltime=24:00:00
#PBS -P ENTERYOURPROJECTNUMBER
#PBS -m abe
#PBS -M ENTERYOUREMAIL.sg
#PBS -V

# Comment: Change ncpus=23:mem=92G for much shorter queue time but you will not have a dedicated node to yourself, which might or might not work.
# Comment: Can change the walltime to 120 hours. Please do so only when necessary as the queue time is very long.
module load cmake/3.14.4
cd $PBS_D_WORKDIR
# Convert Axial Map. You can run two or more graphs in parallel.
depthmapXcli -m MAPCONVERT -f S_Big_Test.graph -o S_Big_Test_1.graph -p -1 S_Big_Test_1.csv -co axial -con axialmap &

# Remove the # below to run second axial map conversion in parallel. Note to change the input and output files.
# depthmapXcli -m MAPCONVERT -f S_Big_Test.graph -o S_Big_Test_1.graph -p -1 S_Big_Test_1.csv -co axial -con axialmap &

wait

# Axial Analysis
depthmapXcli -m AXIAL -f S_Big_Test_1.graph -o S_Big_Test_2.graph -p -1 S_Big_Test_2.csv -xo n,800,2000 &

wait

# Convert Segment Map
depthmapXcli -m MAPCONVERT -f S_Big_Test_2.graph -o S_Big_Test_3.graph -p -1 S_Big_Test_3.csv -co segment -con segmap -con -crsl 40 &

wait

# Segment Analysis(n, 800, 2000 run separately)
depthmapXcli -m SEGMENT -f S_Big_Test_3.graph -o S_Big_Test_4_n.graph -p -1 S_Big_Test_4_n.csv -st tulip -sr n -srt metric -sic -stb 100 &

depthmapXcli -m SEGMENT -f S_Big_Test_3.graph -o S_Big_Test_4_800.graph -p -1 S_Big_Test_4_800.csv -st tulip -sr 800 -srt metric -sic -stb 100 &

depthmapXcli -m SEGMENT -f S_Big_Test_3.graph -o S_Big_Test_4_2000.graph -p -1 S_Big_Test_4_2000.csv -st tulip -sr 2000 -srt metric -sic -stb 100 &

# Remove the # below to run n, 800, 2000 sequentially. it is found that the time taken for 800 and 2000 is too short compared to n so the
# depthmapXcli -m SEGMENT -f Small_Test_3.graph -o Small_Test_4.graph -p -1 Small_Test_4.csv -st tulip -sr 800,n -srt metric -sic -stb 100 &

wait
echo [jobs done]

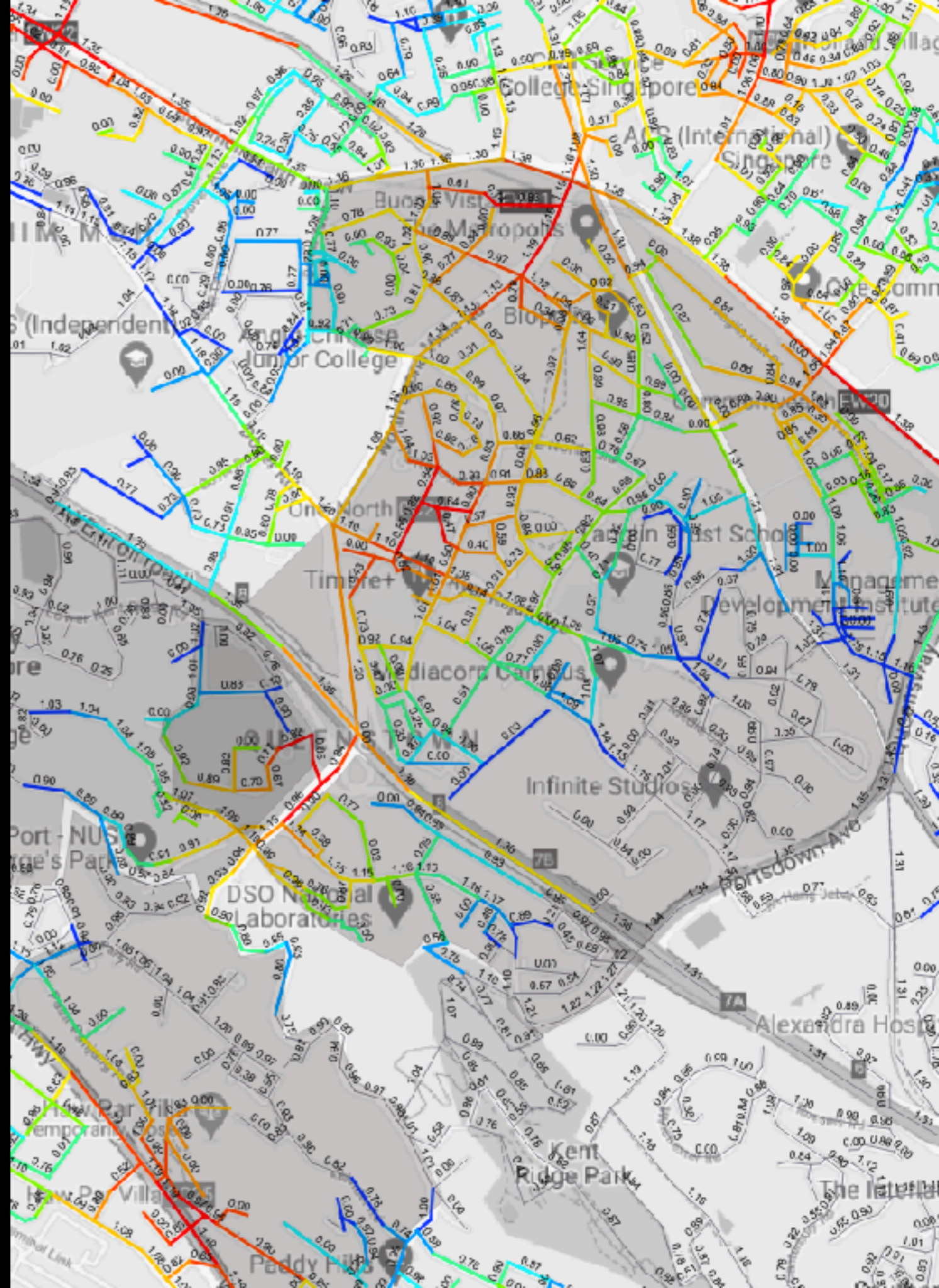
[gen@nsccc03 ~]$ vi submitparallel.phs
[gen@nsccc03 ~]$ ls
depthmapXcli depthmapX-master installdepthmapXcli.sh master.zip S_Big_Test.graph scratch submitparallel.phs
[gen@nsccc03 ~]$ qsub
^C
[gen@nsccc03 ~]$ qsub submitparallel.phs
3365636.wl#01
[gen@nsccc03 ~]$ qstat
[gen@nsccc03 ~]$ qstat
Job id Name User Time Use S Queue
-----
3365636.wl#01 Project1 gen 0 0 01
[gen@nsccc03 ~]$ client_loop: send disconnect: Broken pipe
(base) genevieve@genevieve-MacBook-Pro-2:~$
```



## SPACE SYNTAX

### Benefits of a street network model as a baseline analysis

- Conducting preliminary studies before making a case to stakeholders
- Simple analysis can help in engaging stakeholders and develop deeper ideas
- Avoid guesswork between various stakeholders and govt agencies
- These ideas can be tested through the model, to examine its effectiveness

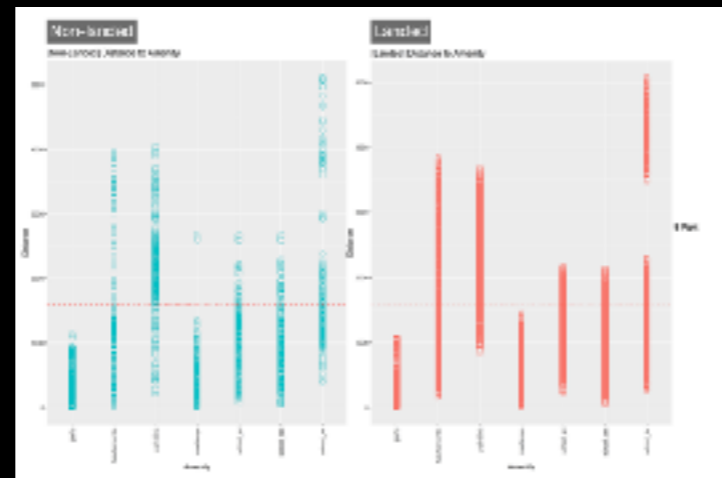




case 01  
impact assessment (one-north)



case 02  
20-min city (east coast grc)



case 03  
east coast park accessibility





case 01

impact assessment

**street connectivity btw plots of land by various stakeholders**

- mapping out new masterplan proposals
- calculating percentage increase / decrease in accessibility



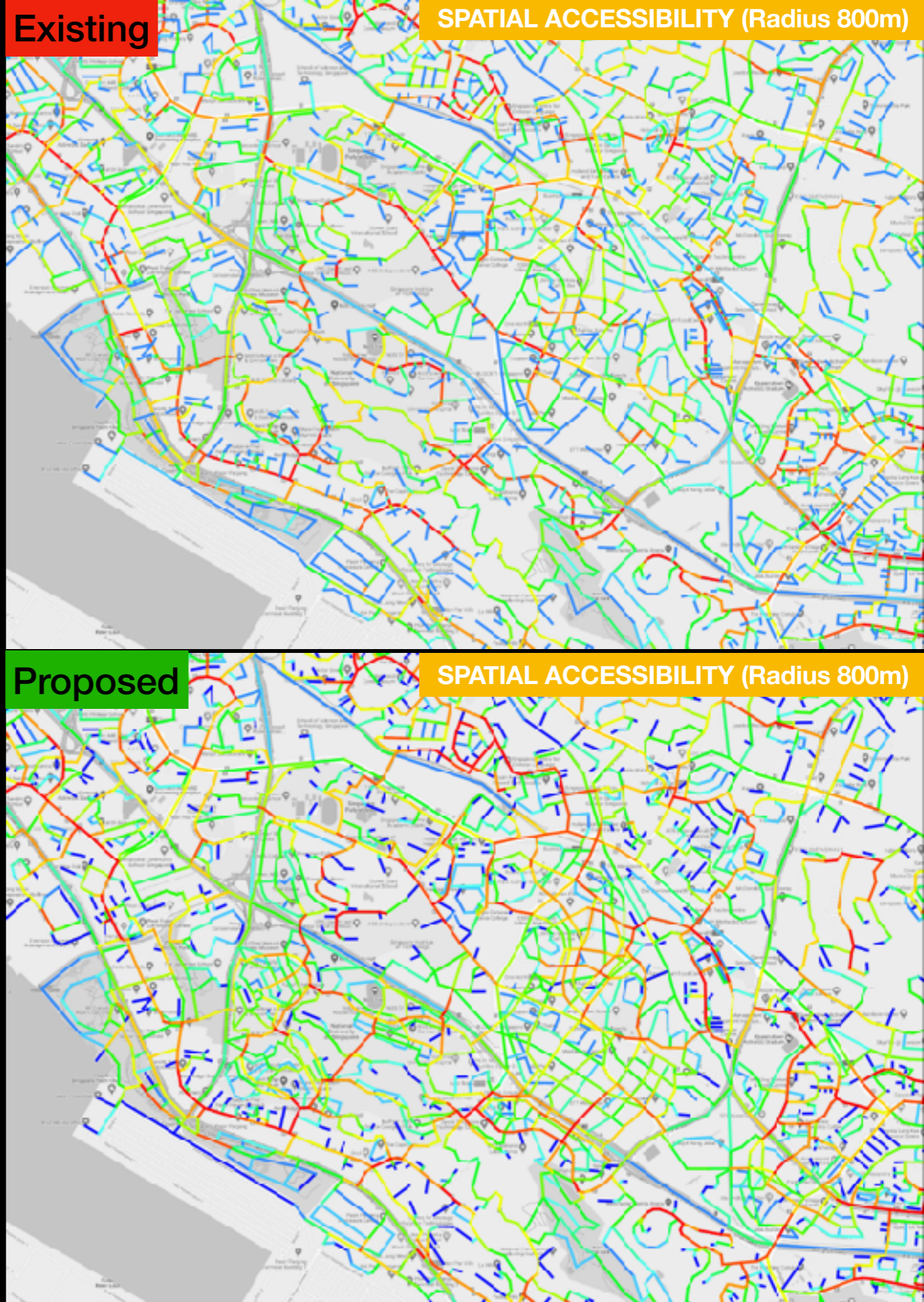
# Measures accessibility of existing and proposed masterplans

What it can do for SID:

- A. Analysing connections *between* the various plots of land
- B. Analysing connections *within* the various plots of land

Methodology:

1. Process and evaluate existing street network model, calculate global, local & multi-scale accessibility
2. Geo-reference masterplans. Digitise proposed network to stitch it into the street network model.
3. Run analysis on the proposed network. Evaluate the differences in accessibility between existing and proposed.
4. Identify missed opportunities in connections, or better placement of connects. Run tests.





# Measures accessibility of existing and proposed masterplans

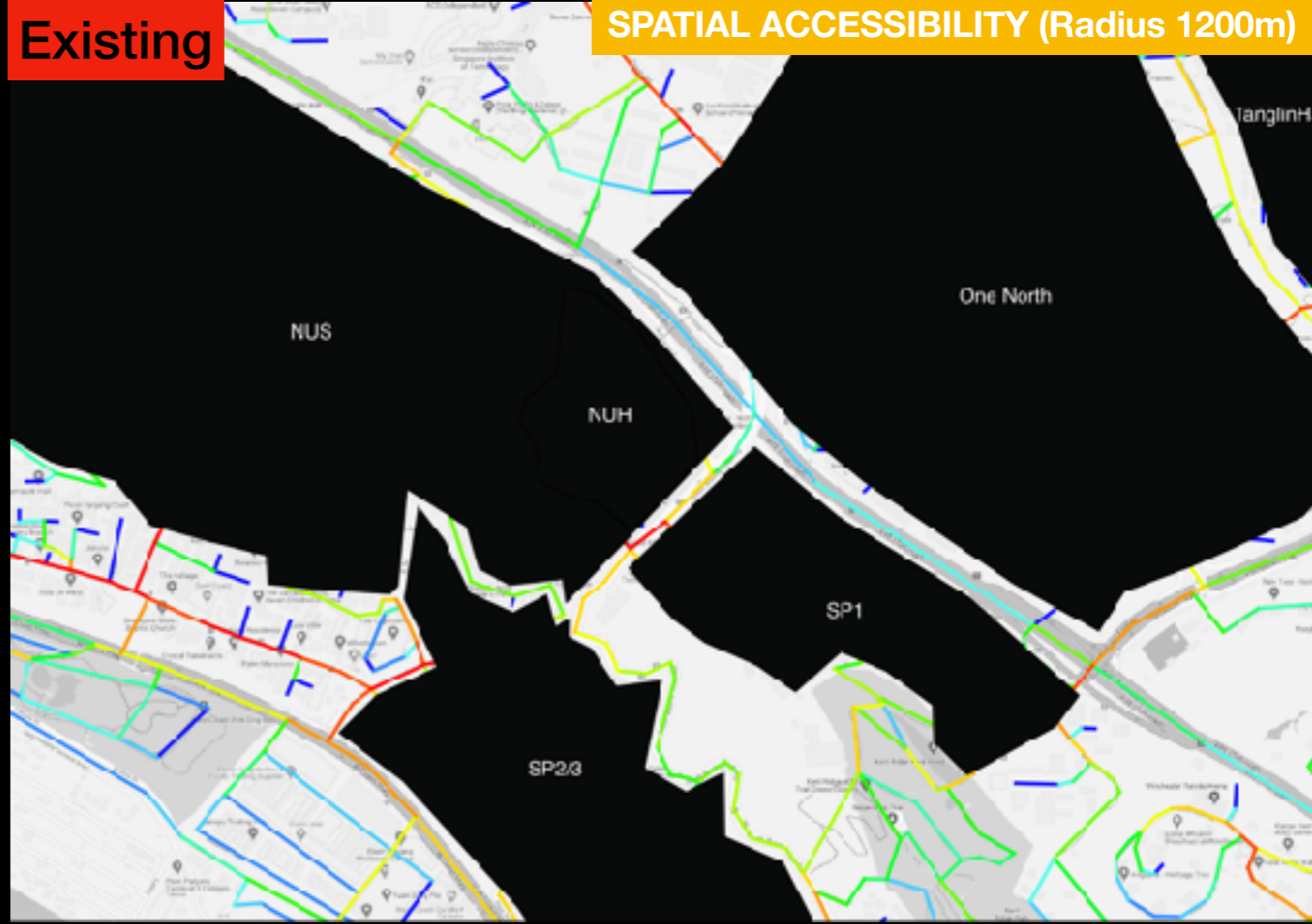
What it can do for SID:

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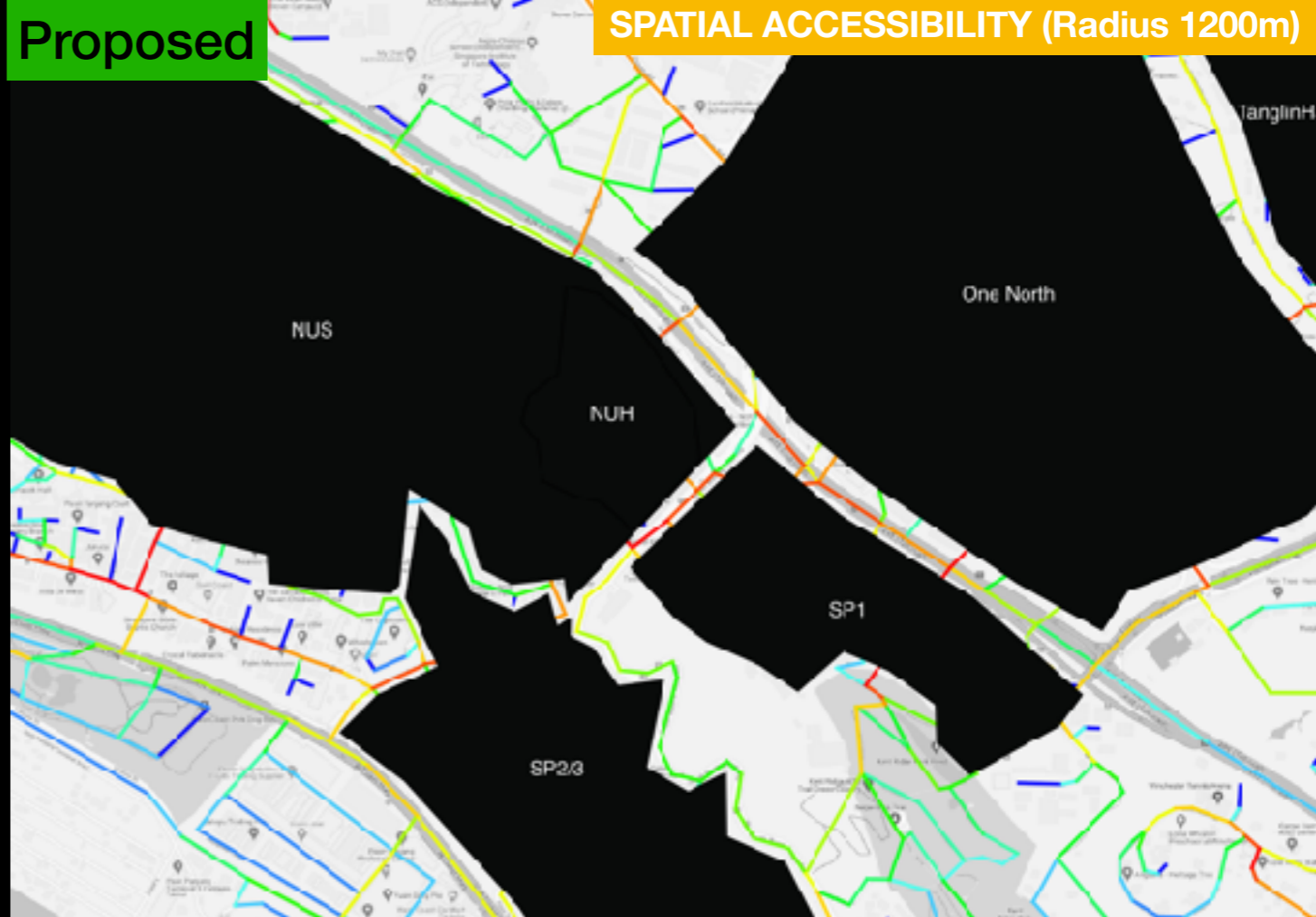
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## case 02

accessibility studies

homes to various amenities

20 minute city - East Coast GRC

baseline data sources for POI:

schools (primary, secondary, tertiary) - OSM & cleaned

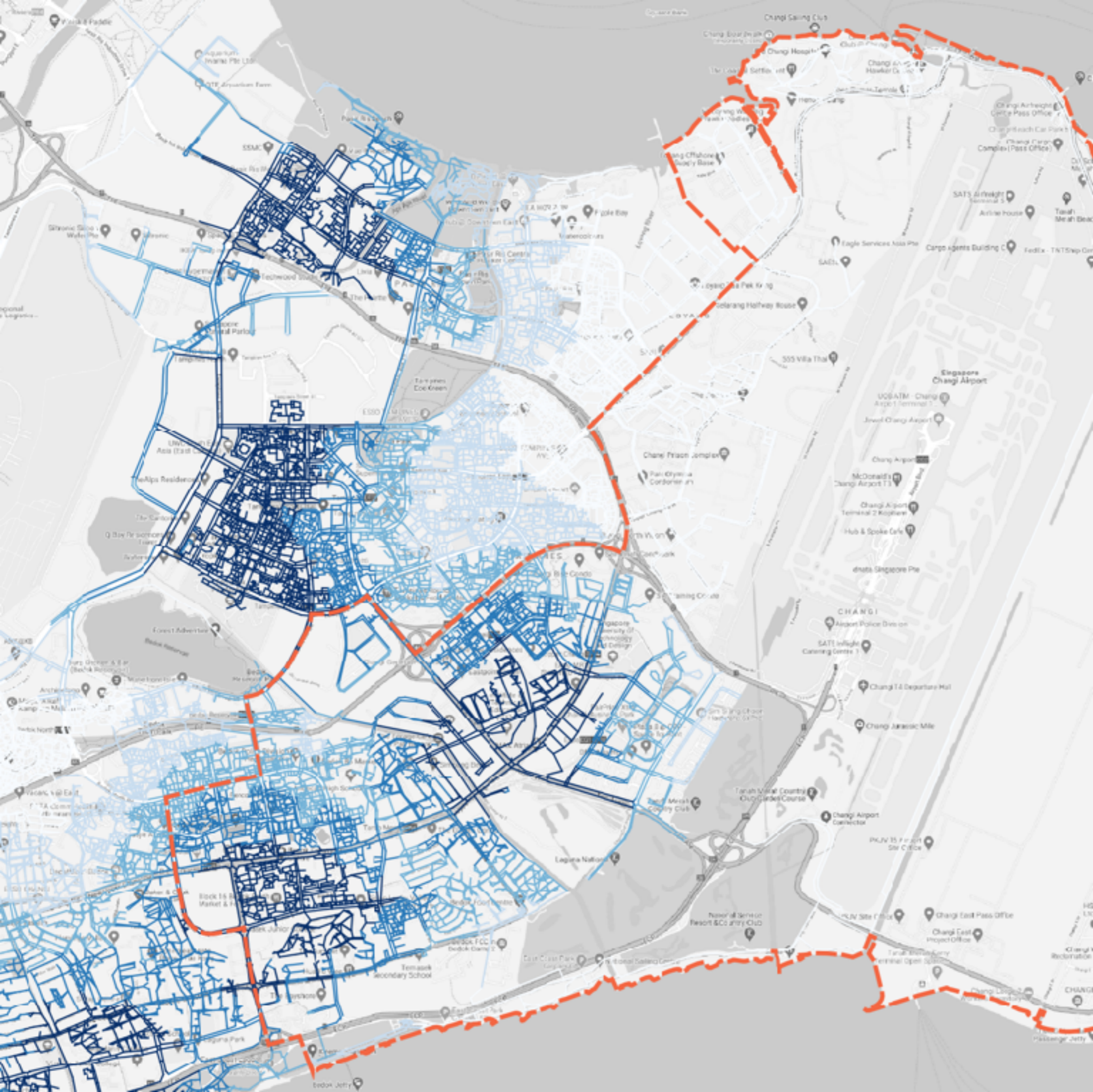
polyclinics - OSM & cleaned

hawker centres - [data.gov.sg](http://data.gov.sg)

parks - URA landuse masterplan

retail shops - OSM & cleaned





# schools tertiary

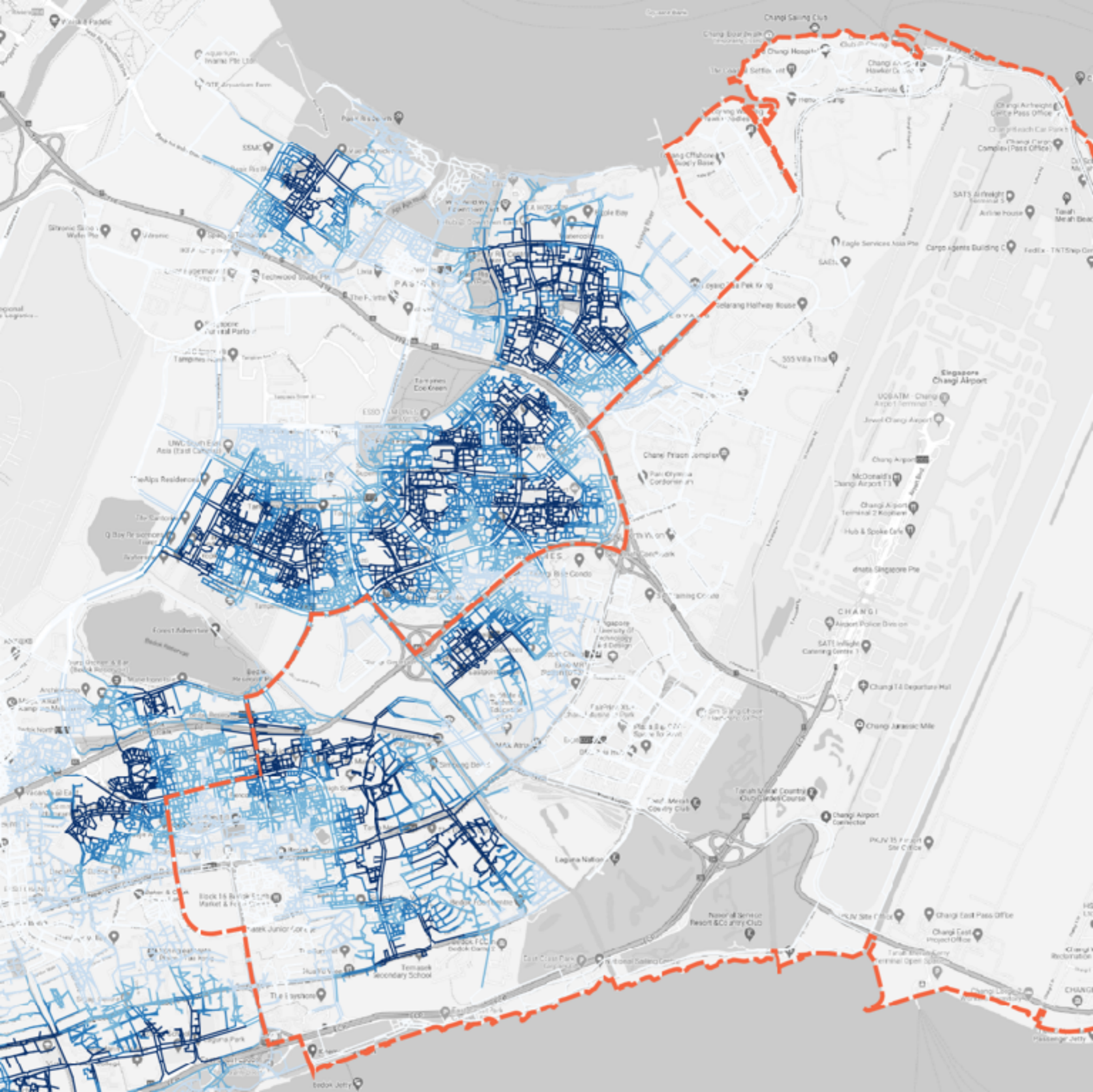
0-1600m (20 min walk)

baseline data sources for POI:  
schools (primary, secondary, tertiary) - OSM & cleaned  
polyclinics - OSM & cleaned  
hawker centres - [data.gov.sg](http://data.gov.sg)  
parks - URA landuse masterplan  
retail shops - OSM & cleaned







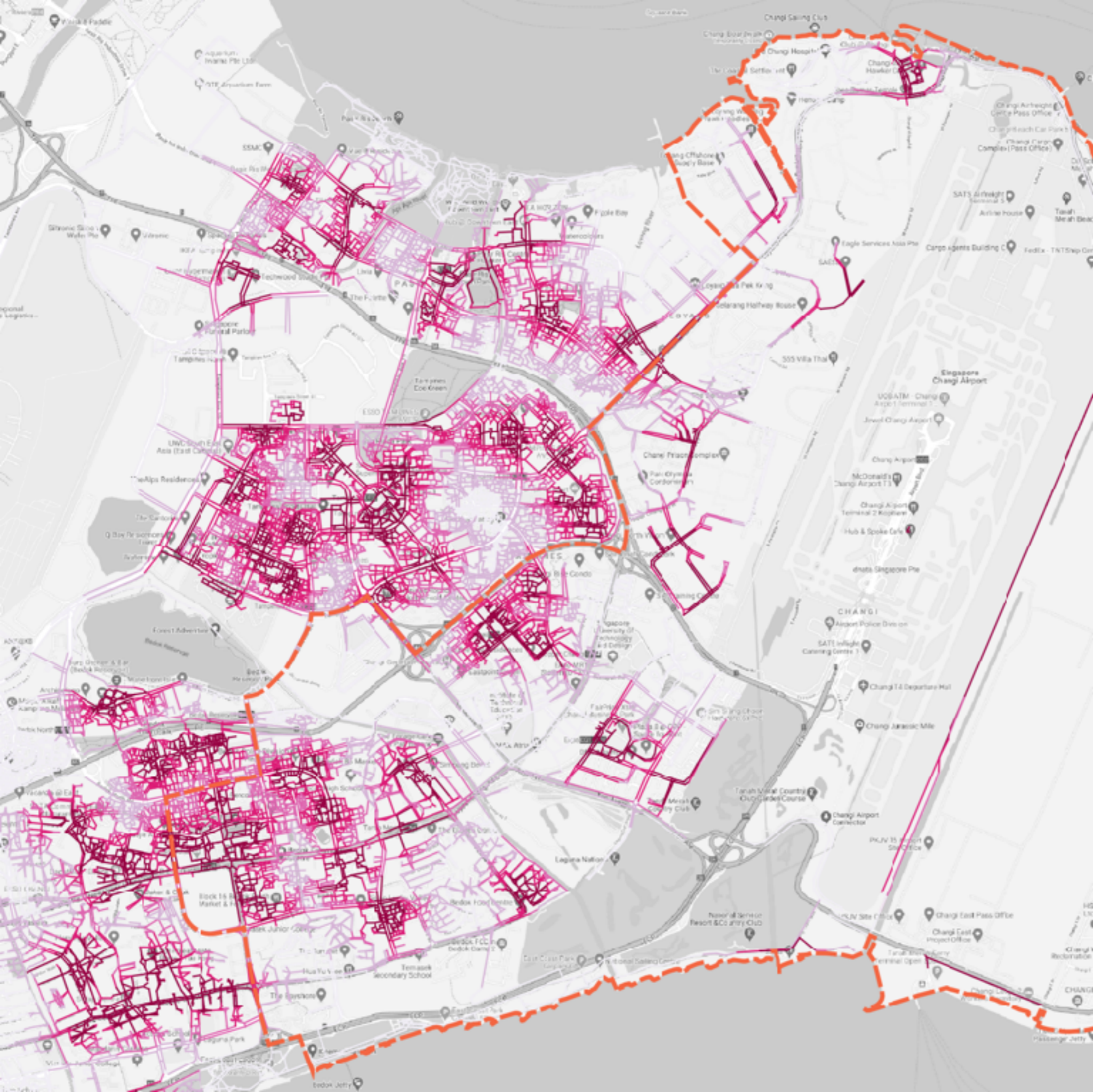


# schools secondary

0-1600m (20 min walk)

baseline data sources for POI:  
schools (primary, secondary, tertiary) - OSM & cleaned  
polyclinics - OSM & cleaned  
hawker centres - data.gov.sg  
parks - URA landuse masterplan  
retail shops - OSM & cleaned



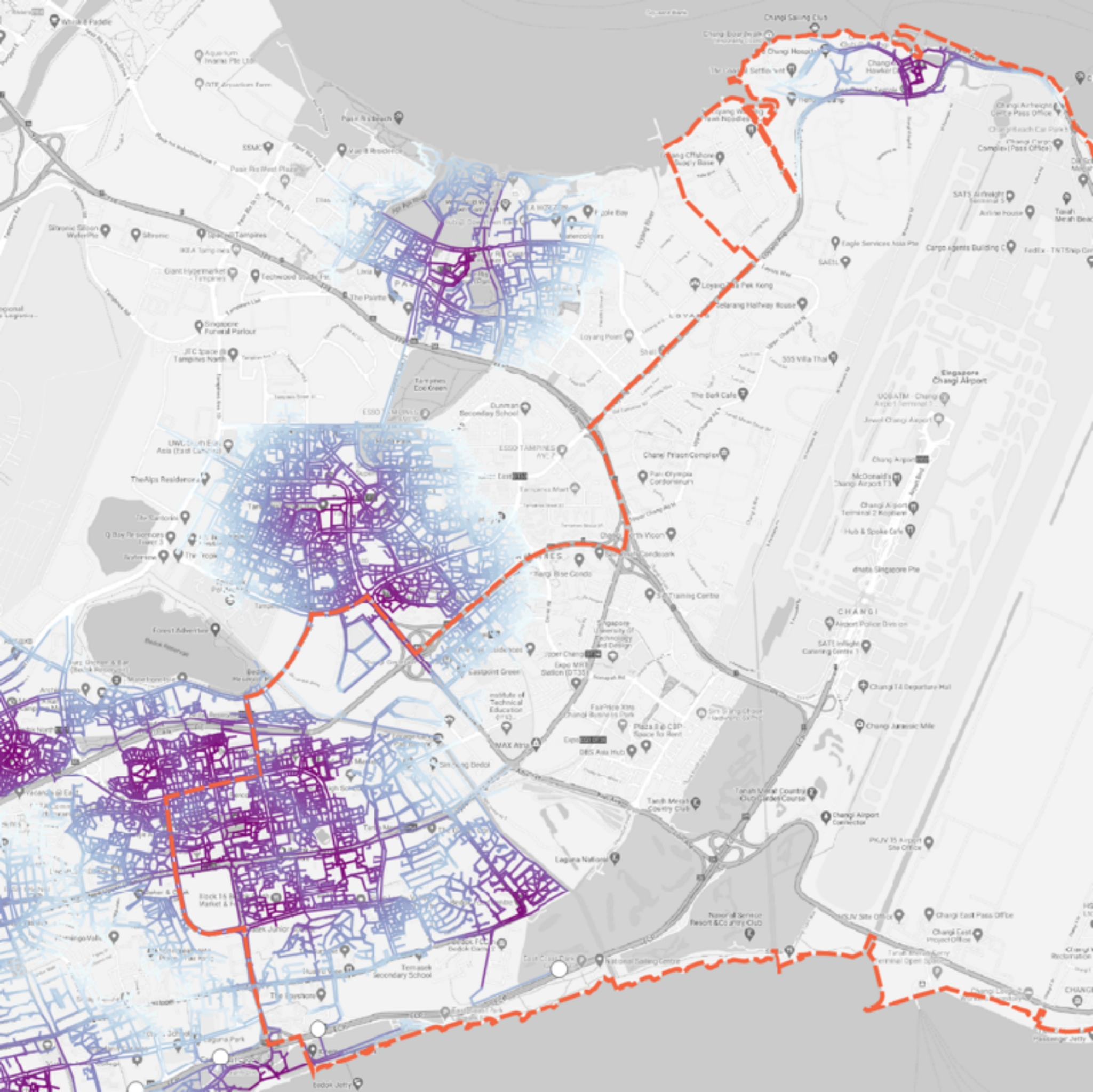


# retail shops

0-1600m (20 min walk)

baseline data sources for POI:  
schools (primary, secondary, tertiary) - OSM & cleaned  
polyclinics - OSM & cleaned  
hawker centres - [data.gov.sg](http://data.gov.sg)  
parks - URA landuse masterplan  
retail shops - OSM & cleaned





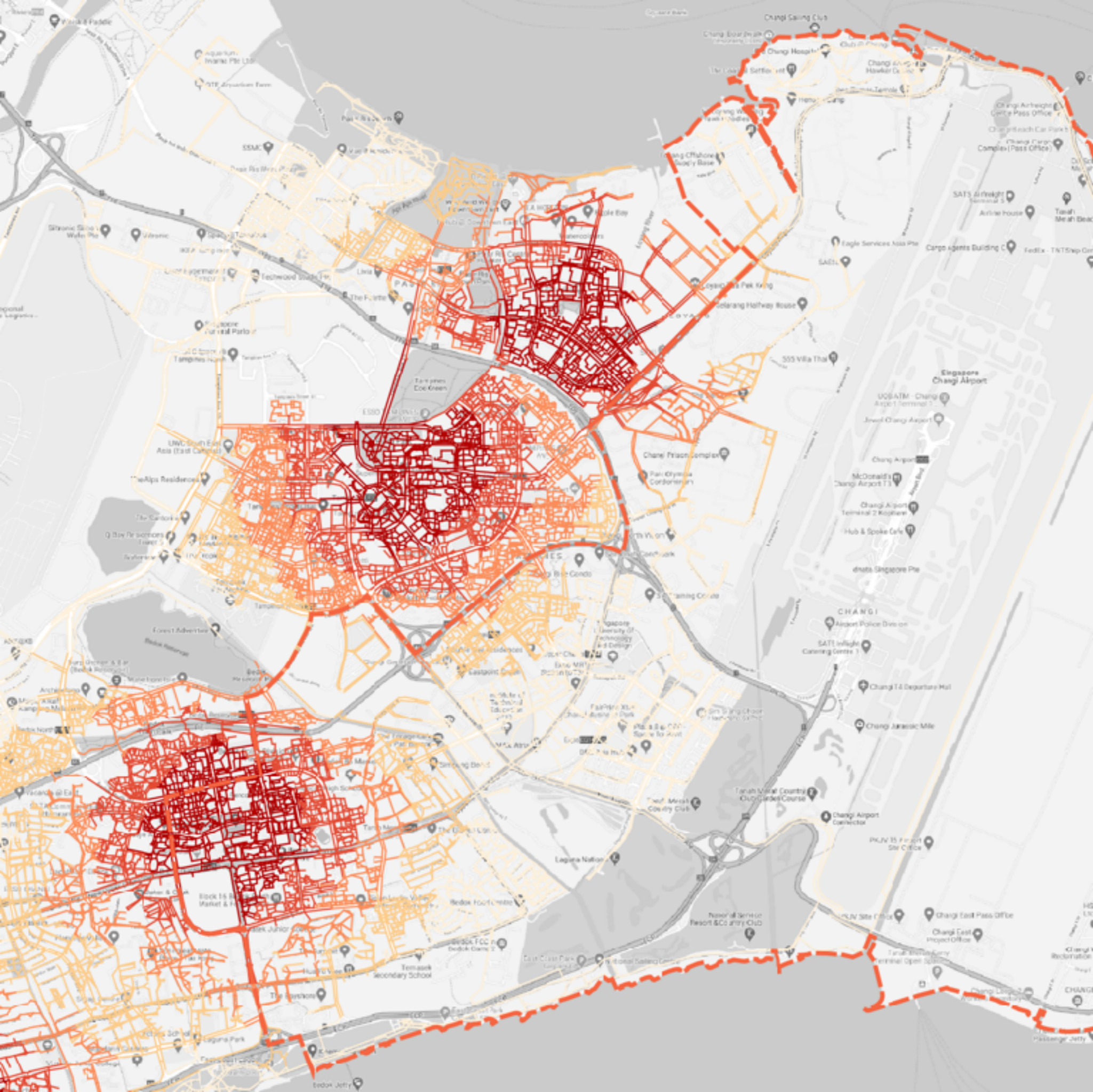
# hawker centres

0-1600m (20 min walk)

baseline data sources for POI:

- schools (primary, secondary, tertiary) - OSM & cleaned
- polyclinics - OSM & cleaned
- hawker centres - [data.gov.sg](http://data.gov.sg)
- parks - URA landuse masterplan
- retail shops - OSM & cleaned



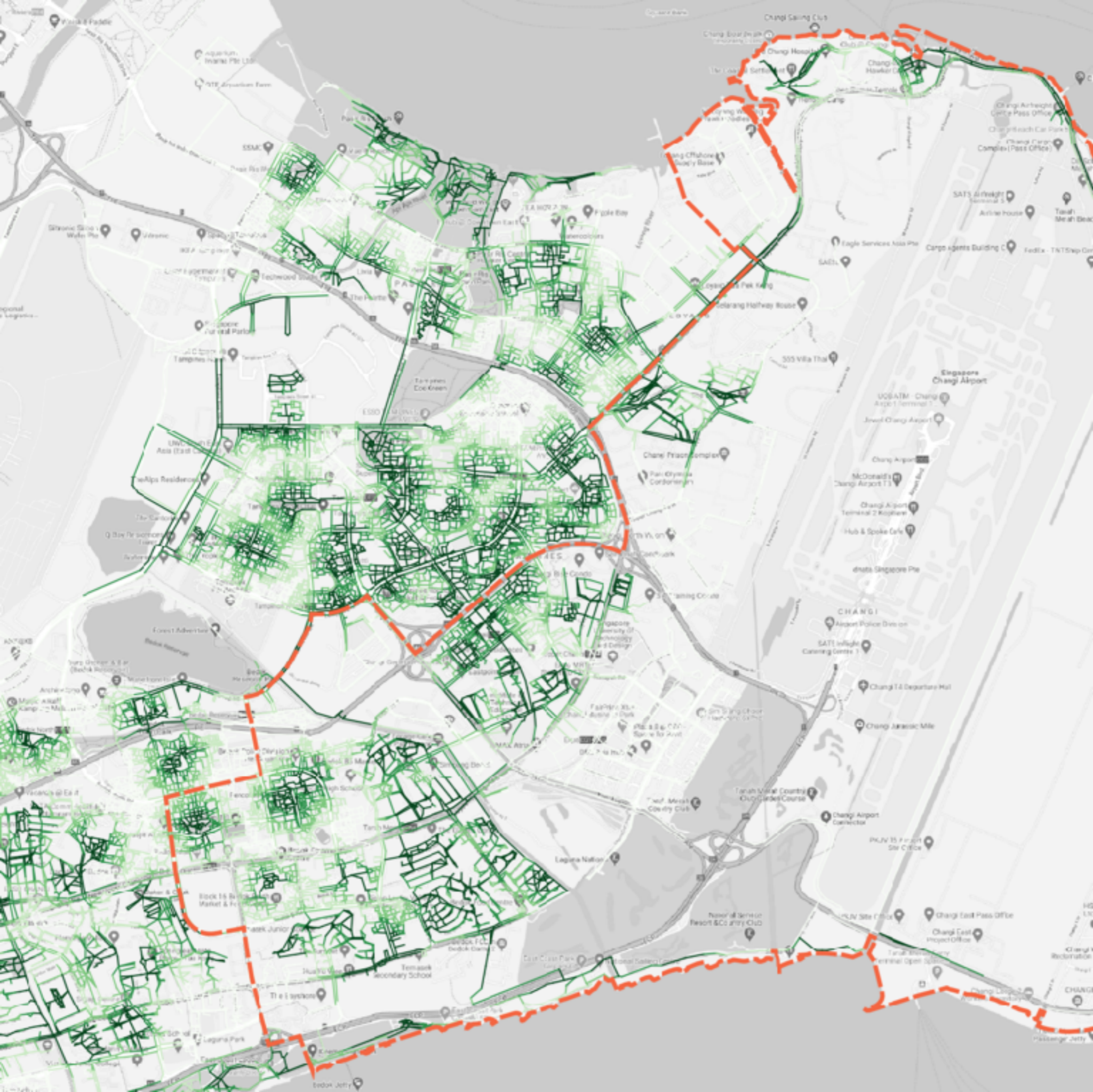


# polyclinics

0-1600m (20 min walk)

baseline data sources for POI:  
schools (primary, secondary, tertiary) - OSM & cleaned  
polyclinics - OSM & cleaned  
hawker centres - [data.gov.sg](http://data.gov.sg)  
parks - URA landuse masterplan  
retail shops - OSM & cleaned





# parks

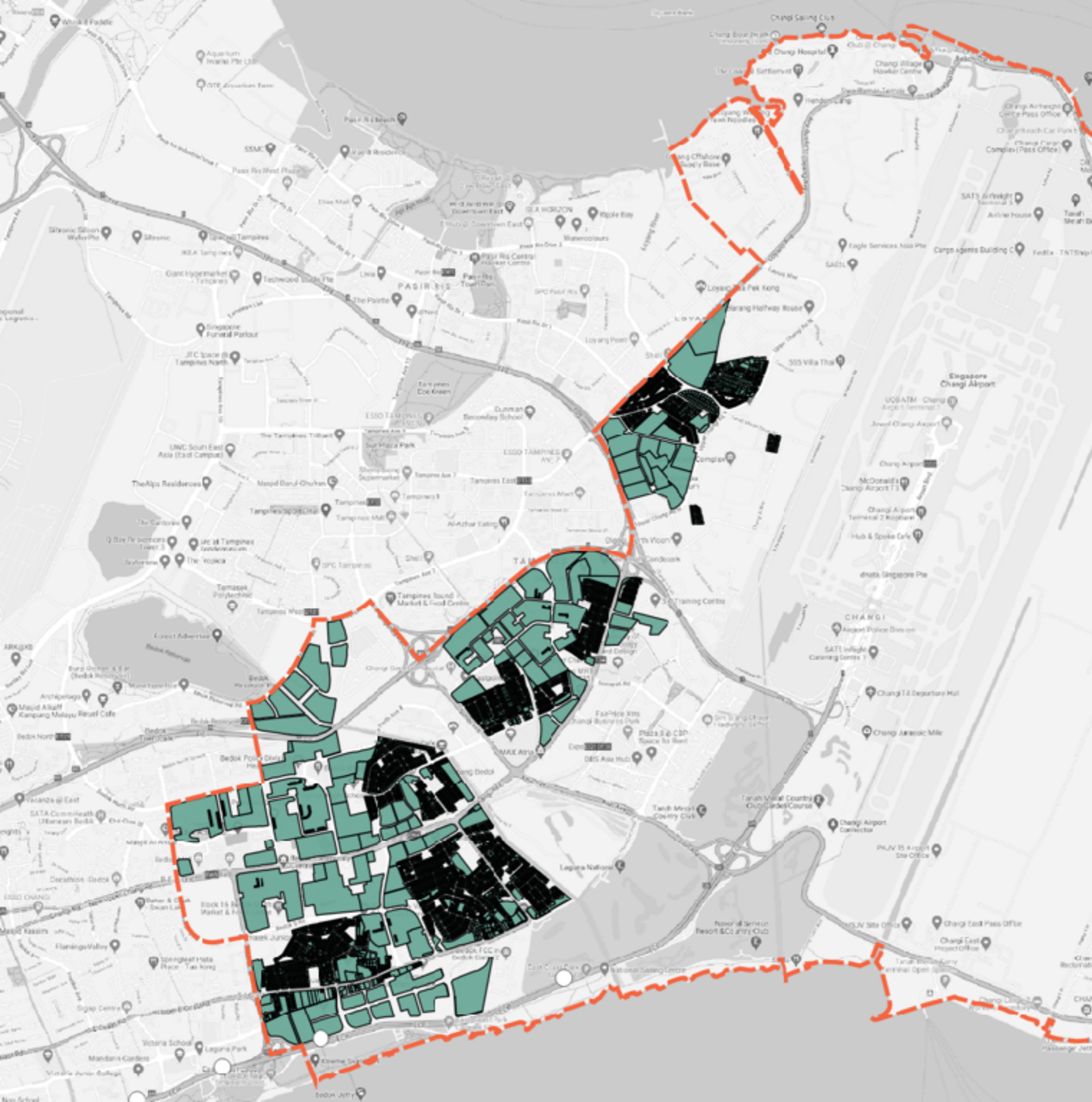
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polyclinics - OSM & cleaned  
hawker centres - [data.gov.sg](http://data.gov.sg)  
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# residential plots

east coast grc

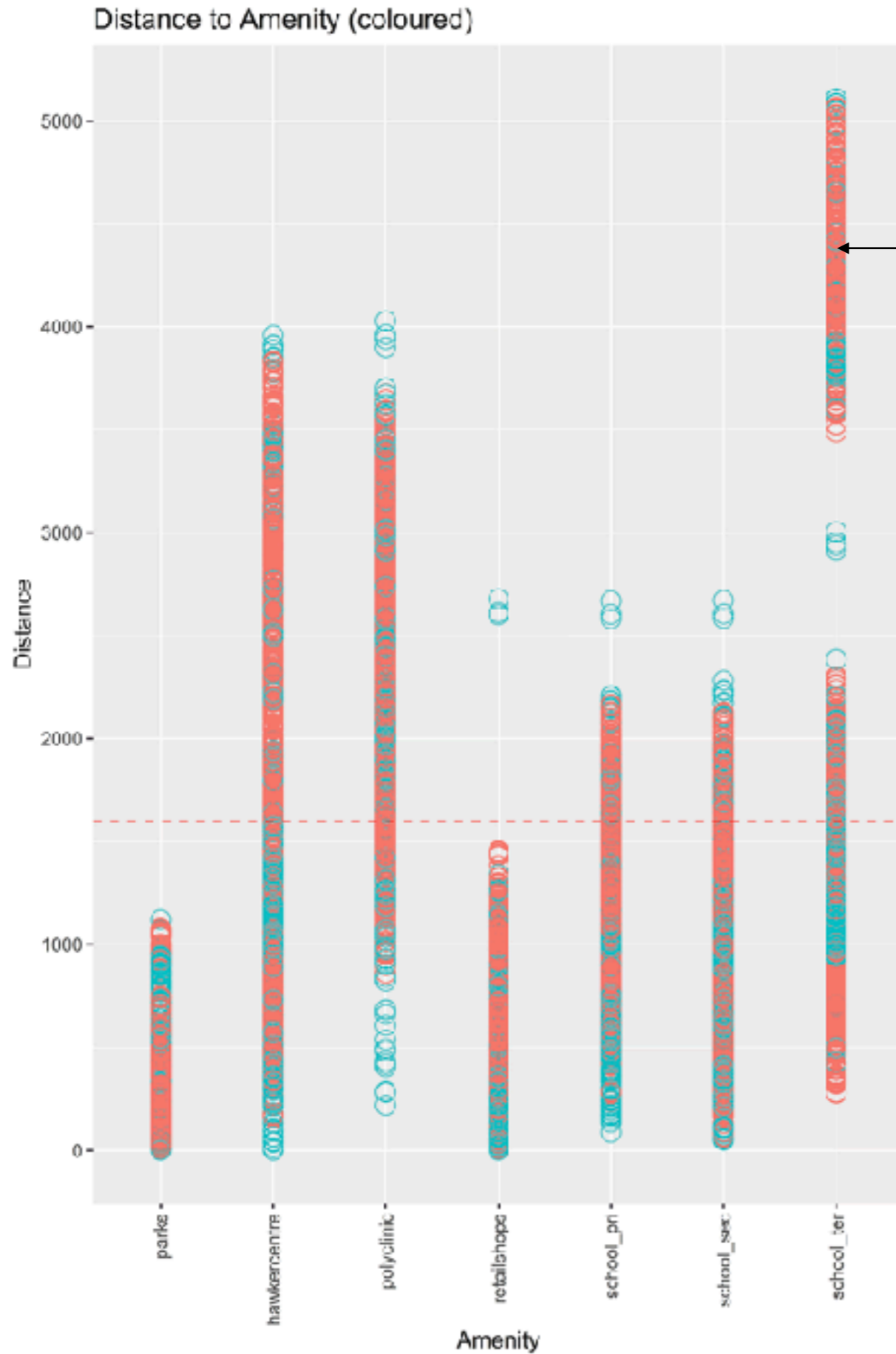


Street network **catchment** from all residential plots to the ***nearest*** amenity (by type)

baseline data sources for POI:  
schools (primary, secondary, tertiary) - OSM & cleaned  
polyclinics - OSM & cleaned  
hawker centres - [data.gov.sg](http://data.gov.sg)  
parks - URA landuse masterplan  
retail shops - OSM & cleaned



# minimum distance from home to amenity



Each point represents a residential plot. Minimum distance away to the closest amenity.

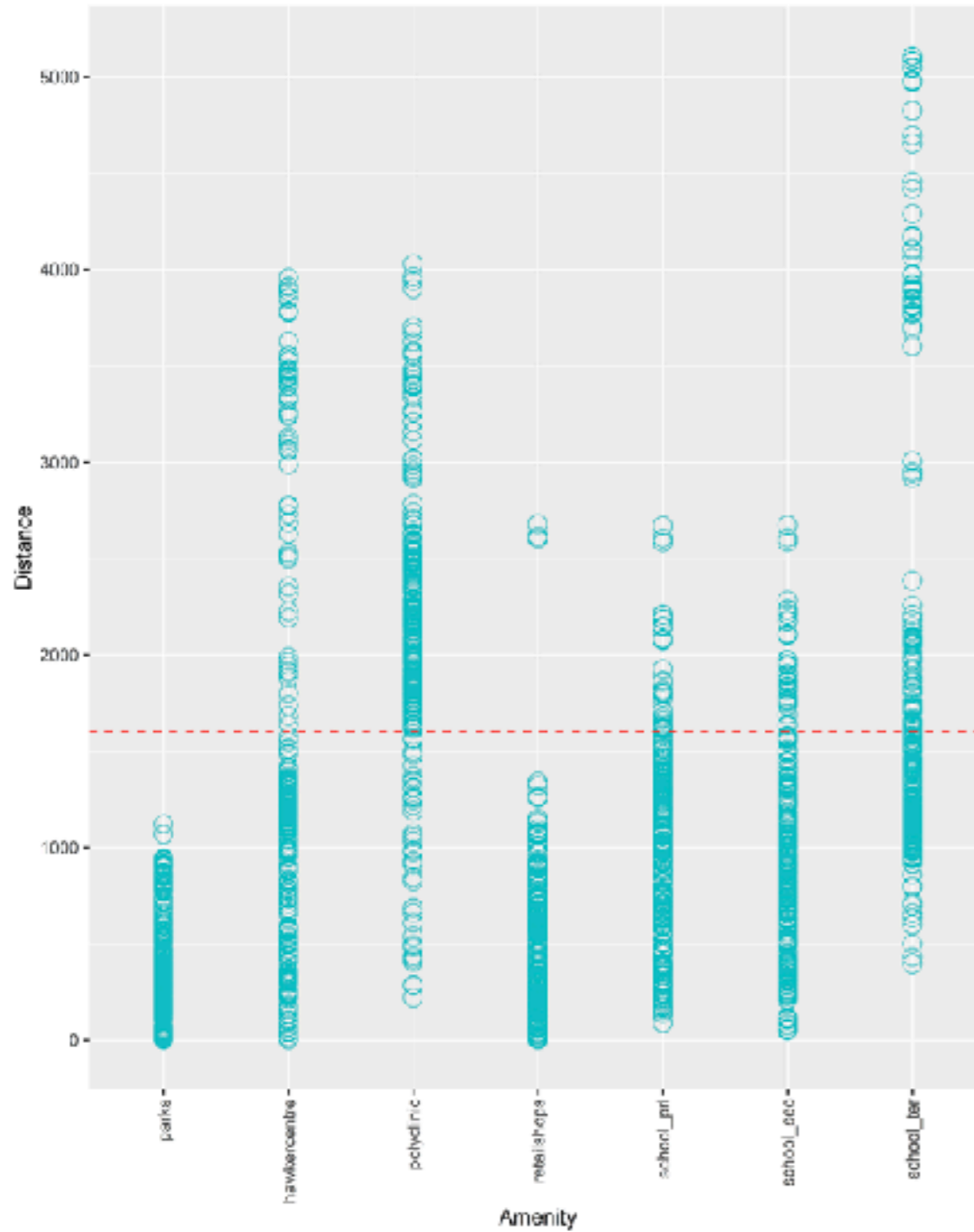
1600m (20 min walk)



# minimum distance from home to amenity

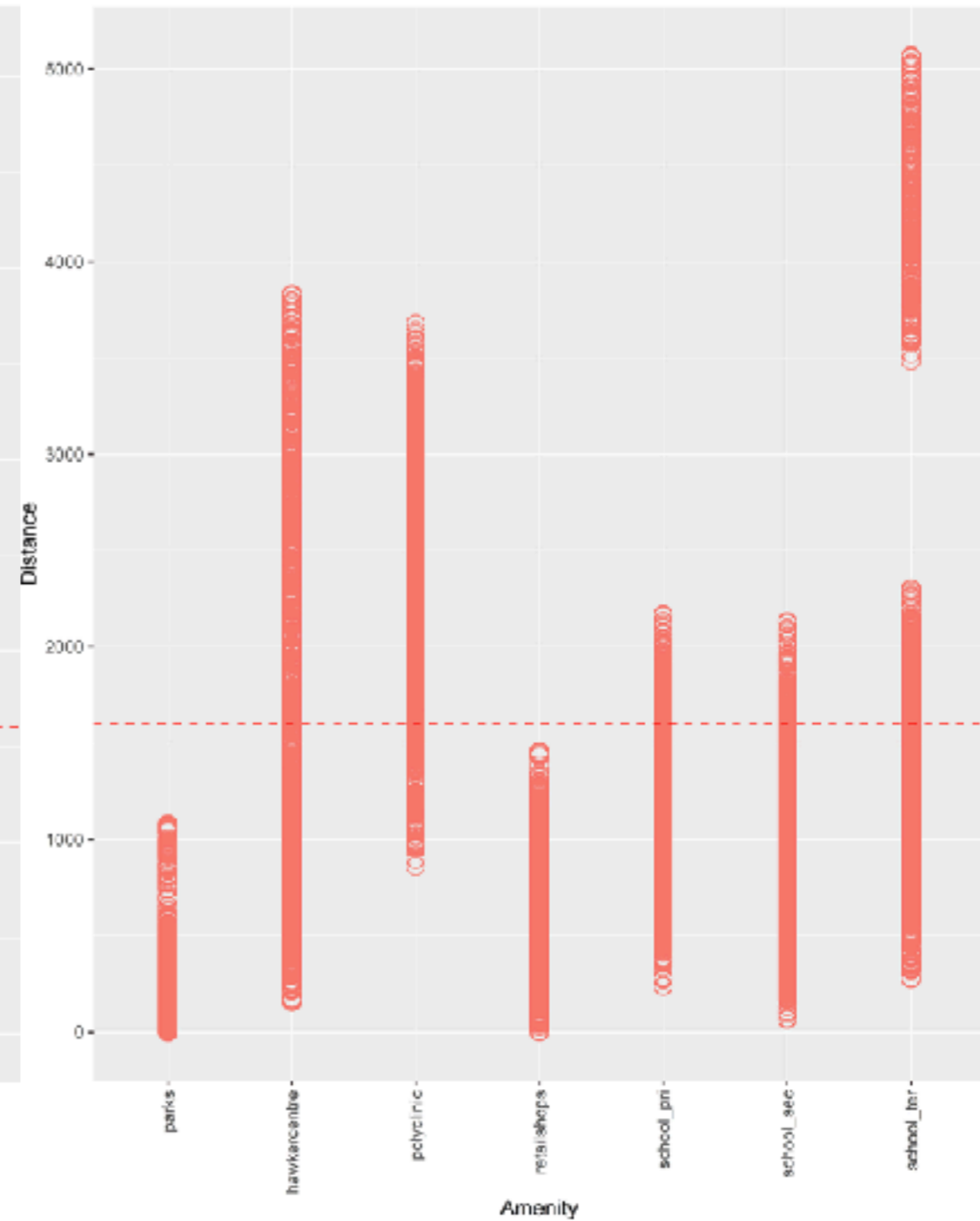
## Non-landed

[Non-Landed] Distance to Amenity



## Landed

[Landed] Distance to Amenity

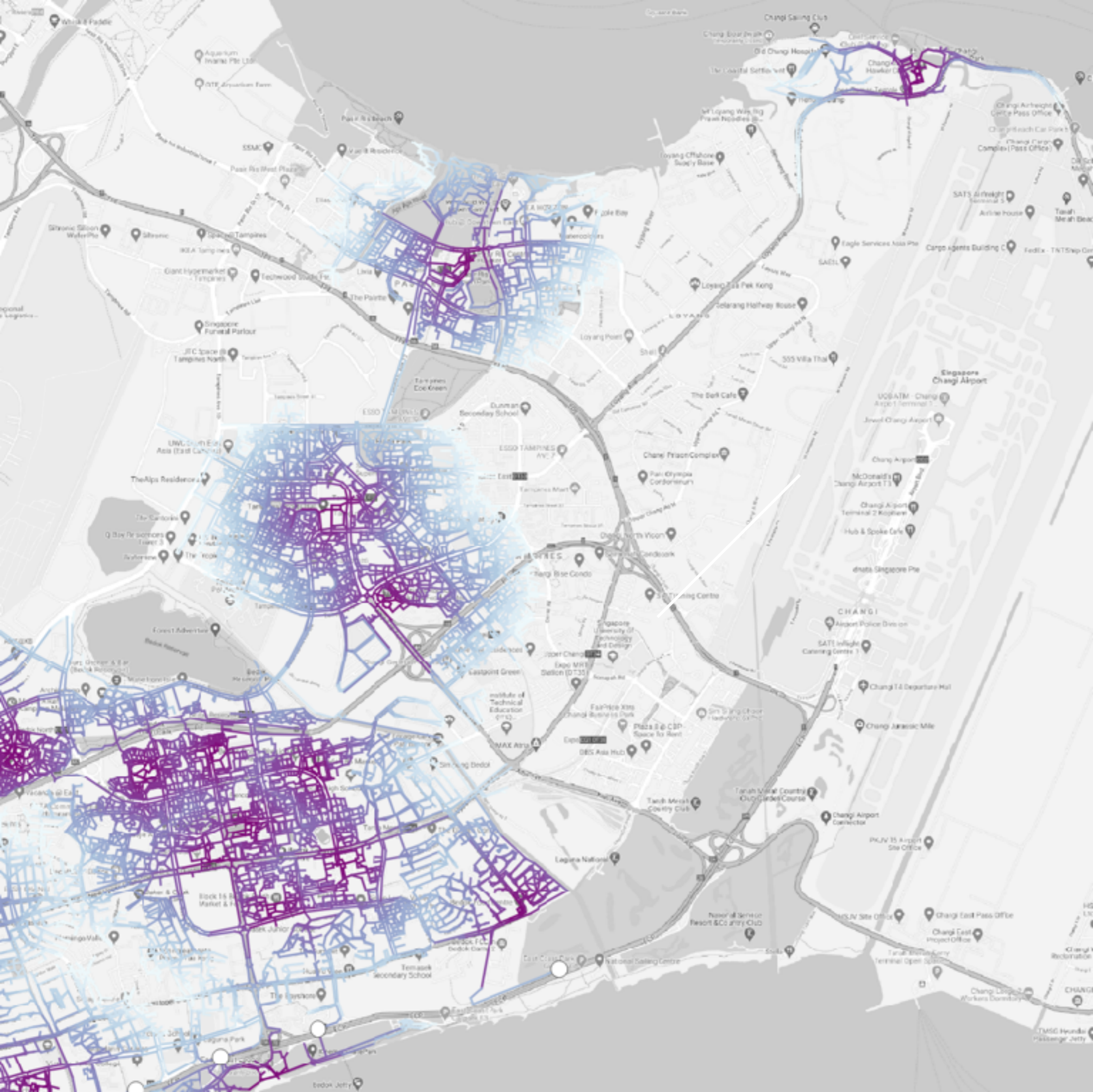


[note] landed v non-landed could be an indicator for socio-economic background, as well as reliance on car as a main form of commute



# hawker centres

0-1600m (20 min walk)



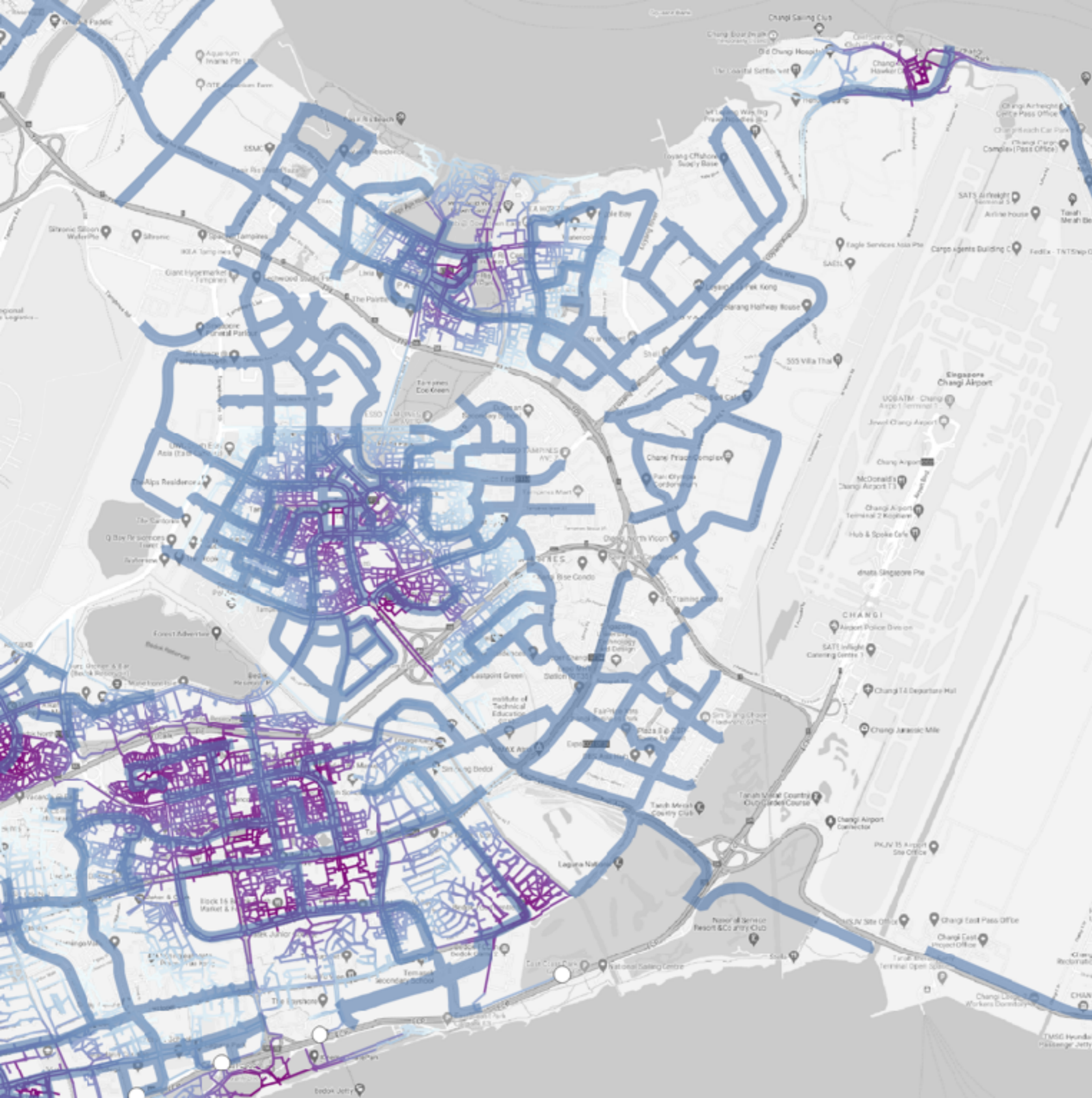
hawker centre street catchment


baseline data sources for POI:  
schools (primary, secondary, tertiary) - OSM & cleaned  
polyclinics - OSM & cleaned  
hawker centres - [data.gov.sg](http://data.gov.sg)  
parks - URA landuse masterplan  
retail shops - OSM & cleaned



# hawker centres

0-1600m (20 min walk)



 hawker centre street catchment

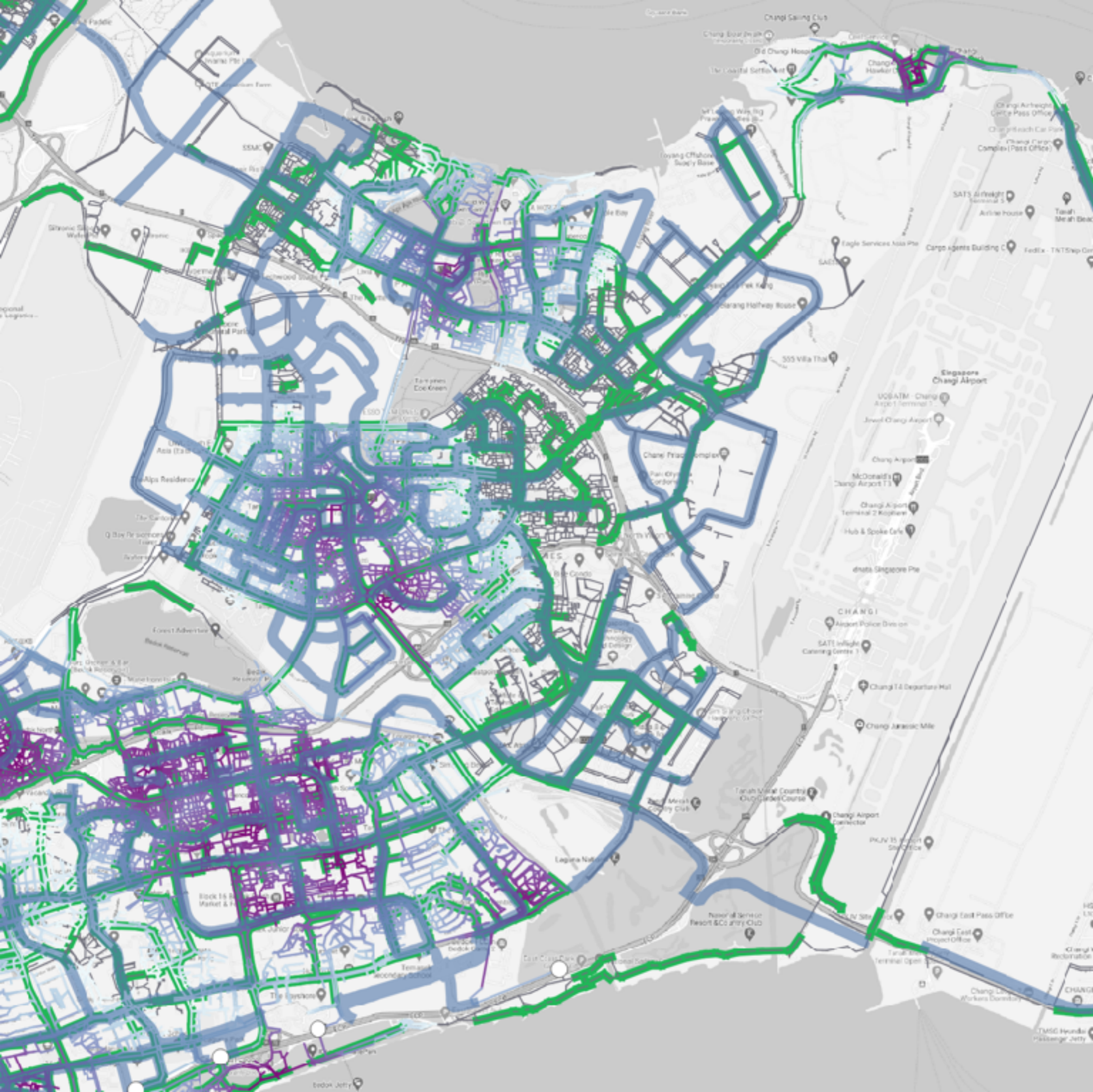
 URA SDCP Cycling Path 2019


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# hawker centres

0-1600m (20 min walk)



 hawker centre street catchment

 URA SDCP Cycling Path 2019

 space syntax recommended cycling routes  
(High Choice Accessibility values for 1200, 2000, 3000m radius)


baseline data sources for POI:  
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polyclinics - OSM & cleaned  
hawker centres - [data.gov.sg](http://data.gov.sg)  
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retail shops - OSM & cleaned



# hawker centres


0-1600m (20 min walk)



 hawker centre street catchment

 URA SDCP Cycling Path 2019

 space syntax recommended cycling routes

 residential plots within East Coast GRC

baseline data sources for POI:  
schools (primary, secondary, tertiary) - OSM & cleaned  
polyclinics - OSM & cleaned  
hawker centres - [data.gov.sg](http://data.gov.sg)  
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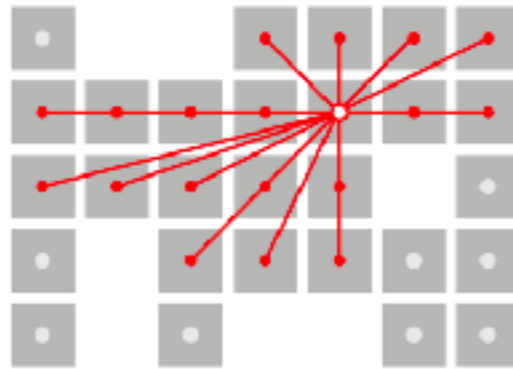


# providing analytical training to URA urban designers & architects (Analytical Immersion Program) analysing public spaces in Singapore

## Connectivity & Visibility

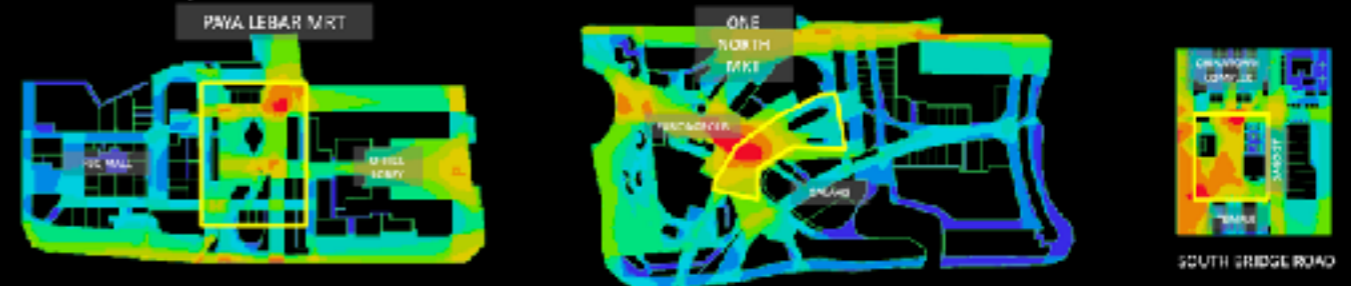
Visibility Graph Analysis investigates the properties of a visibility graph derived from a spatial environment.

1. Knee level (connectivity) – how people can move
2. Eye level (visibility) - where people can see



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## VGA: Connectivity



Paya Lebar Quarter (PLQ)	
Site area studied	19,700 sqm
Public space area (nominal)	3,500 sqm
Public space %	17.8%
High Connectivity	7%
Med Connectivity	55%
Low Connectivity	38%

Fusionopolis	
Site area studied	28,200 sqm
Public space area (nominal)	1,400 sqm
Public space %	5%
High Connectivity	18%
Med Connectivity	50%
Low Connectivity	32%

Kreta Ayer Square	
Site area studied	9,200 sqm
Public space area (nominal)	1,730 sqm
Public space %	18.8%
High Connectivity	23%
Med Connectivity	63%
Low Connectivity	14%

### Observations:

1. Structure - PLQ and Fusionopolis public spaces have more focused points of entry, compared to the more porous Kreta Ayer Square.
2. Connectivity proportions - Kreta Ayer Square has the best proportion of connectivity, with few physical barriers in the way. Fusionopolis functions as a connecting space, while PLQ plaza is both a connector and destination in itself.



## Research Question & Framework

### RESEARCHING QUESTIONS

To what extent is a public space successful in engaging human activity?

- What are the key qualities that enable the success of a public space?
- What are the features that will strengthen or diminish these qualities?

### MACRO

To what extent is a public space accessible within the neighbourhood?

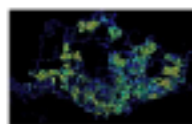
#### QUANTITY

Catchment Analysis  
ArcGIS/Pro



#### QUALITY

Network Analysis  
SpaceSyntax

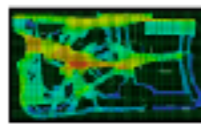


### MICRO

To what extent are the amenities within a public space well/intuitively located?

#### VISIBILITY

Visibility Graph Analysis  
SpaceSyntax



#### ACCESSIBILITY

Amenities & Furniture  
Empirical Studies



#### INTERNAL COMFORT

Shade Analysis  
Shadow Study  
+ Thermal Analysis

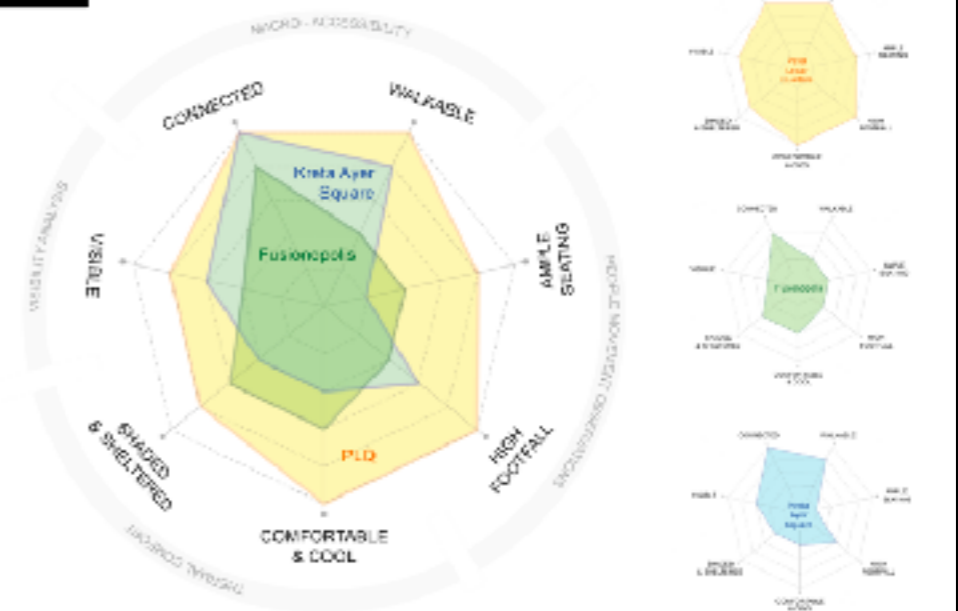


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## Conclusions & Insights

To what extent is a public space successful in engaging human activity?

Our studies help to pinpoint which particular criteria affects both the connectivity and comfort of a public space



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