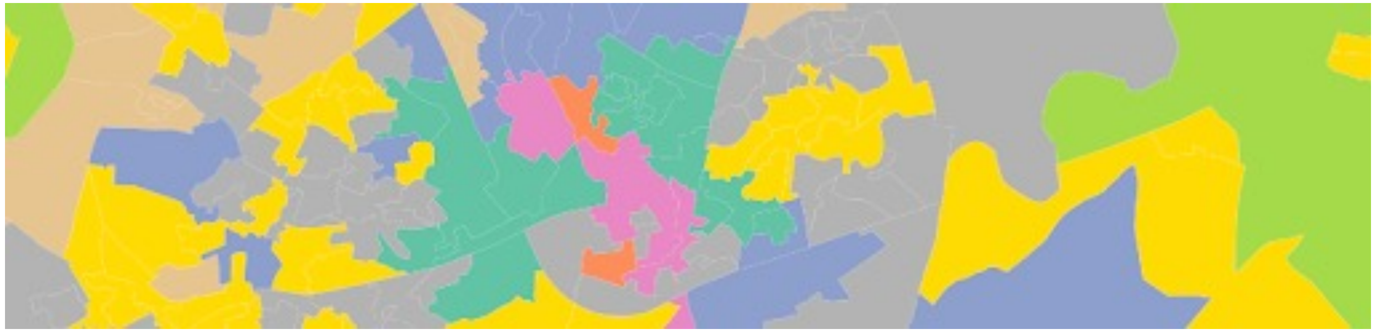
Principles of Spatial Analysis

WEEK 08: Transport Network Analysis



UCL

This week

- Transport network and accessibility analysis
- Spatial network structure
- Dijkstra’s shortest path algorithm
- An example of transport network and accessibility analysis

Spatial interaction

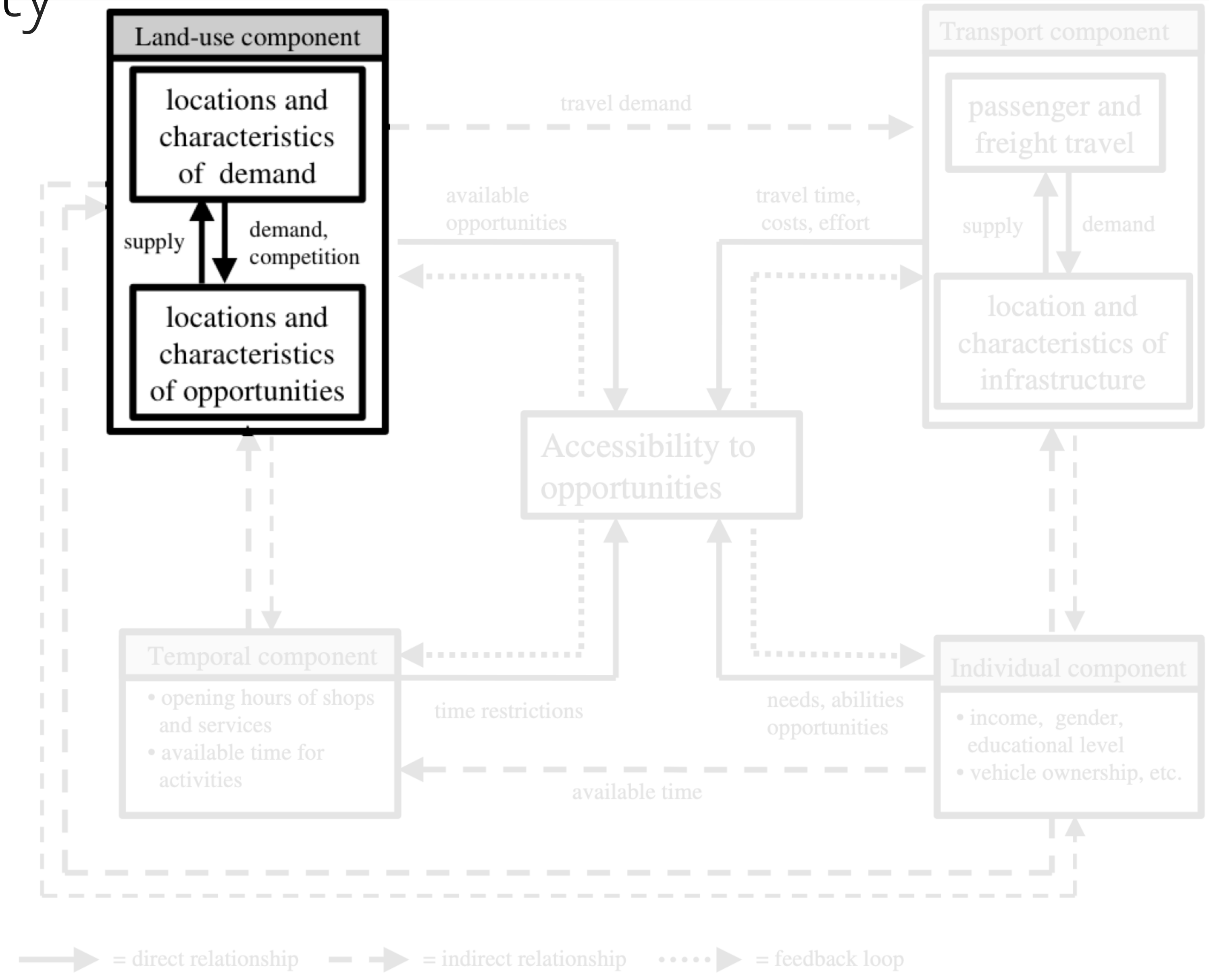
- We have mostly dealt with static events: events that happen at a particular point in time and space.
- Spatial interaction is concerned with the idea that there are relations between different locations (e.g. measured in people or goods travelling).

Spatial interaction

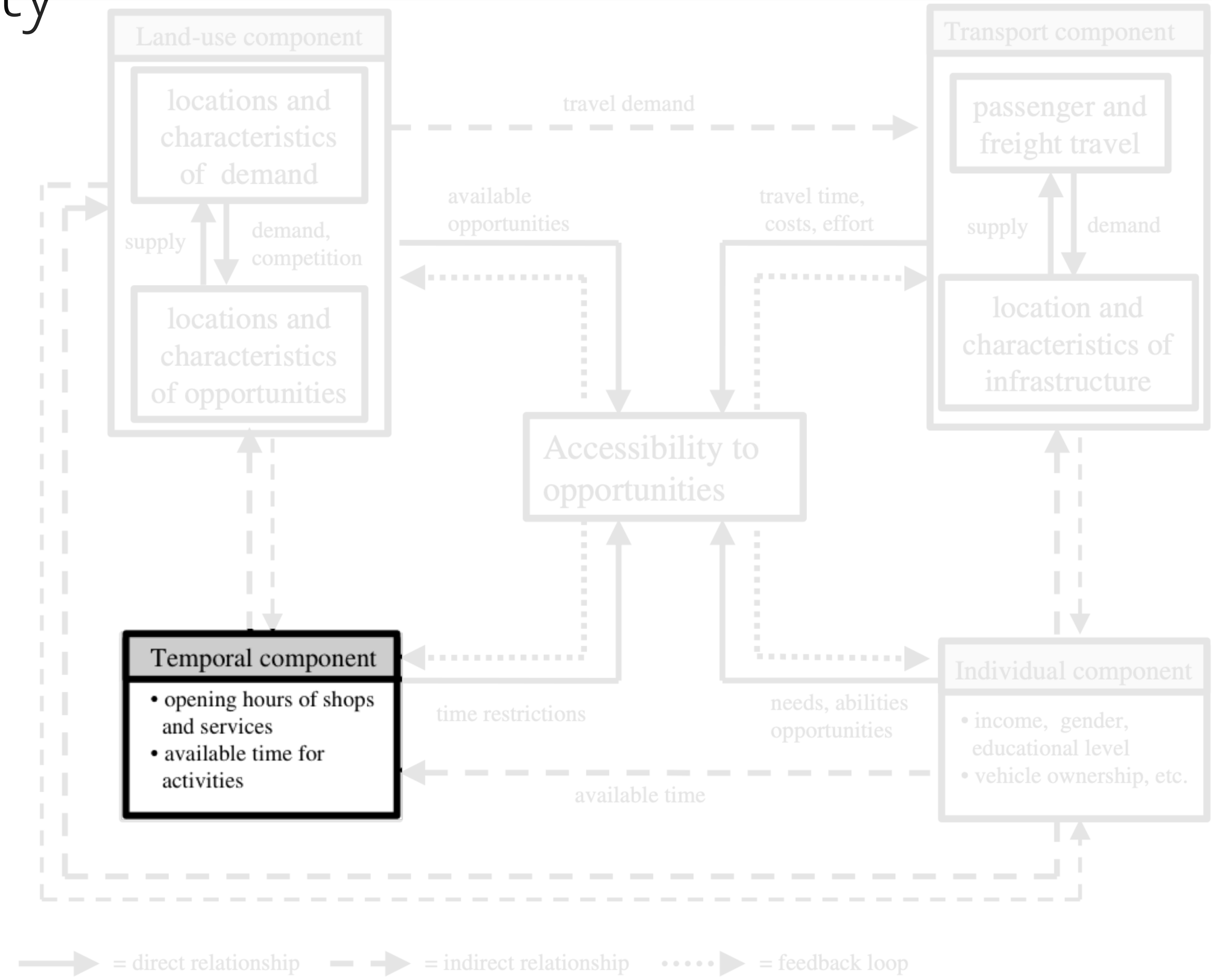
$A \longrightarrow B$

Actor Transport Activities

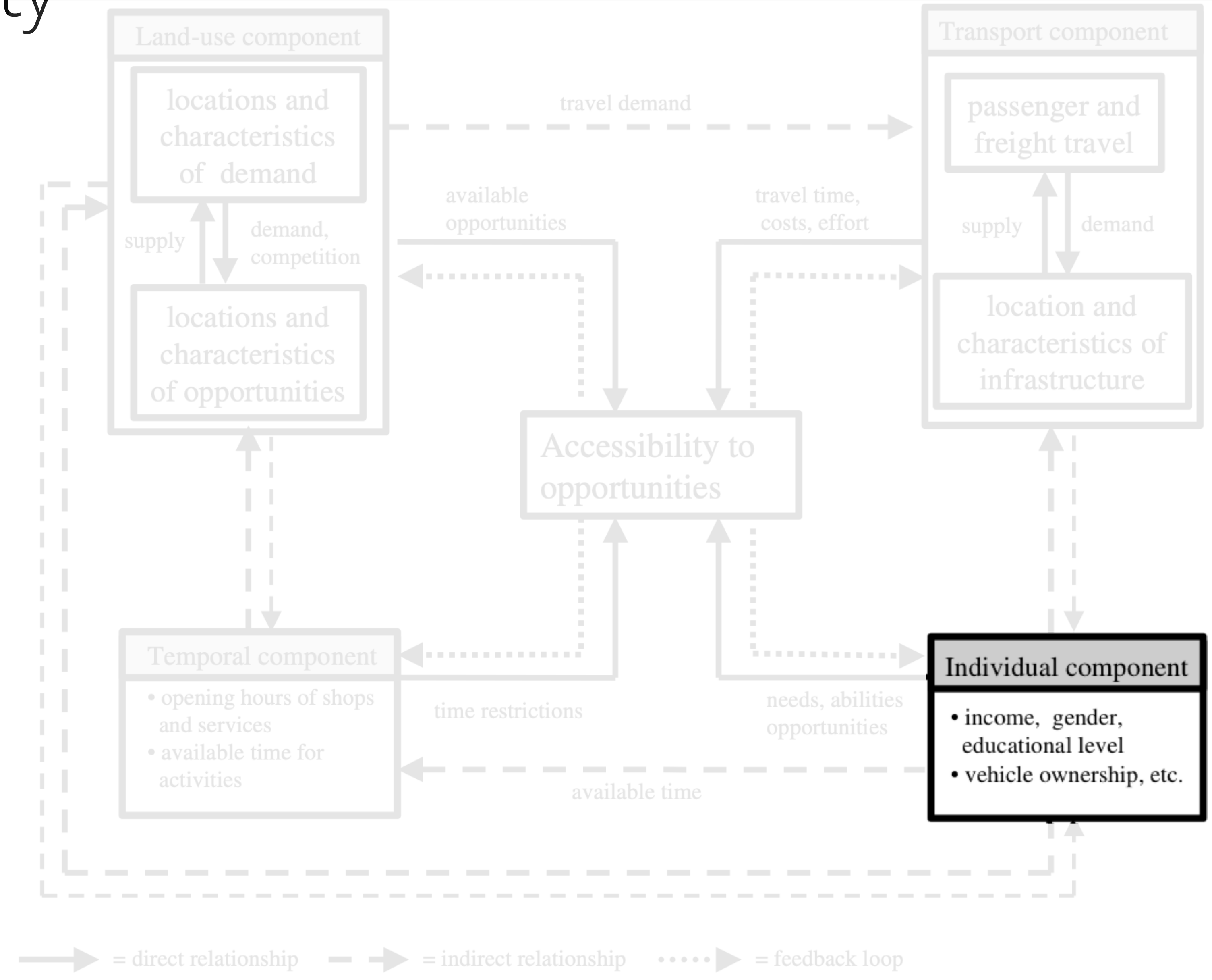
Accessibility



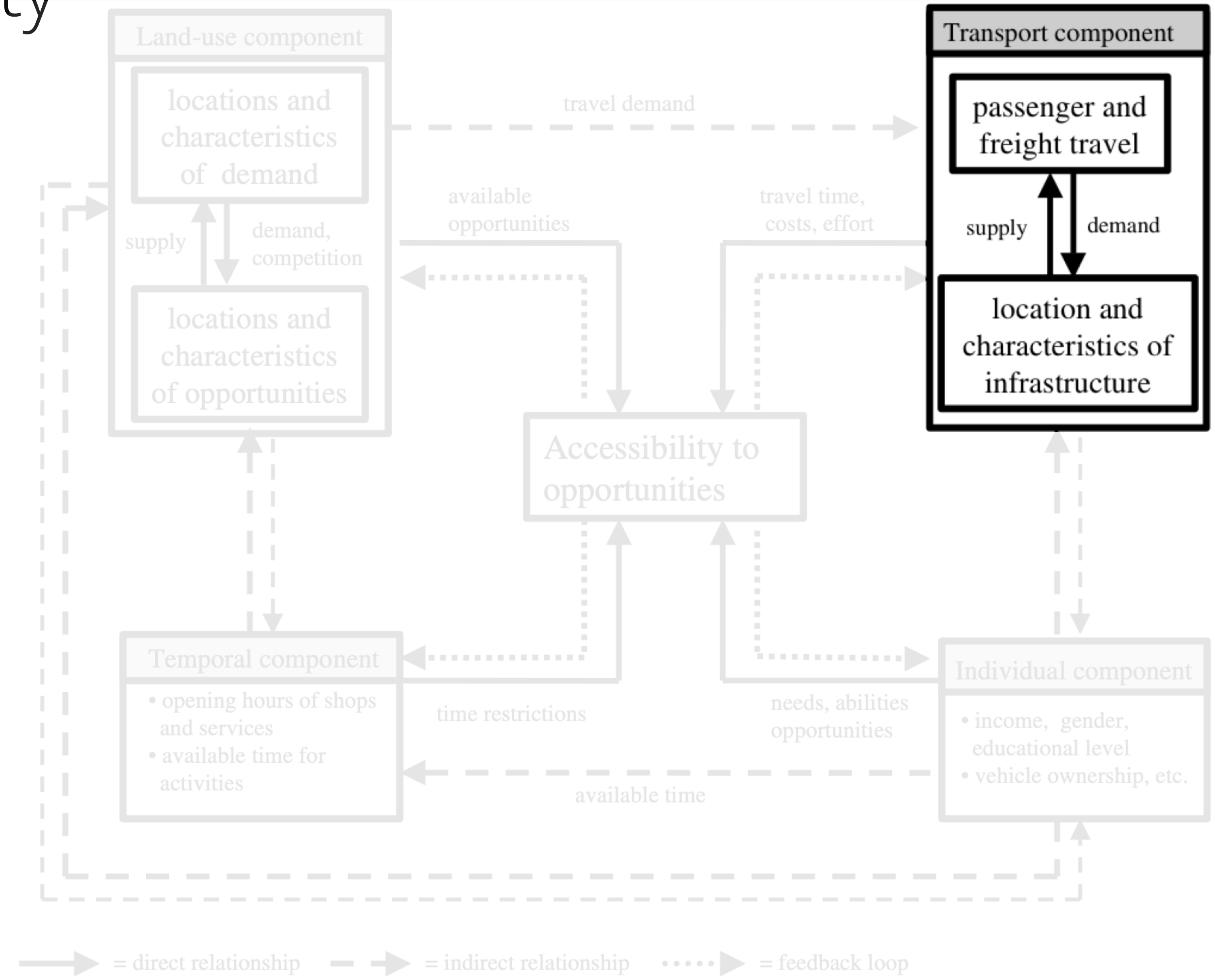
Accessibility



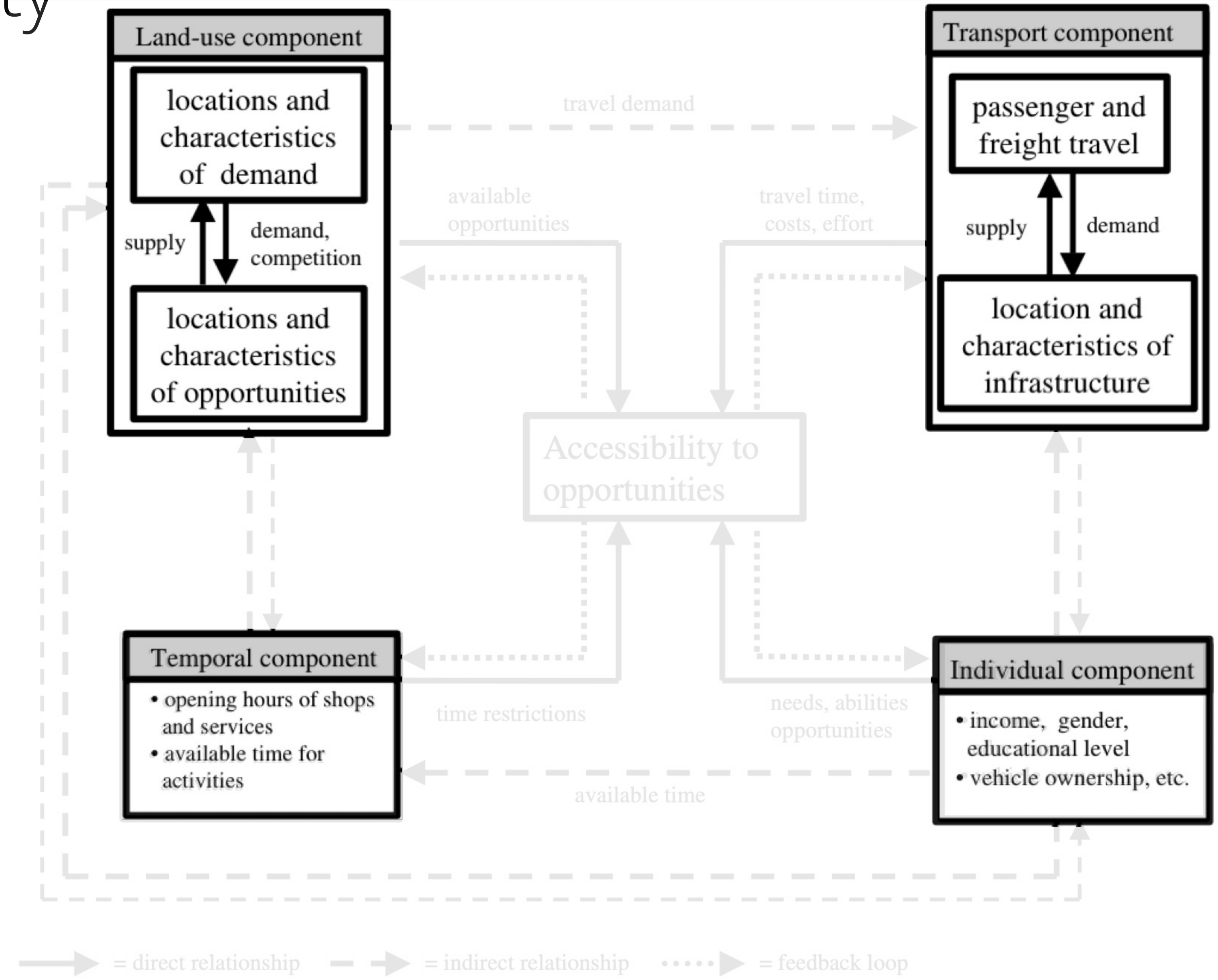
Accessibility



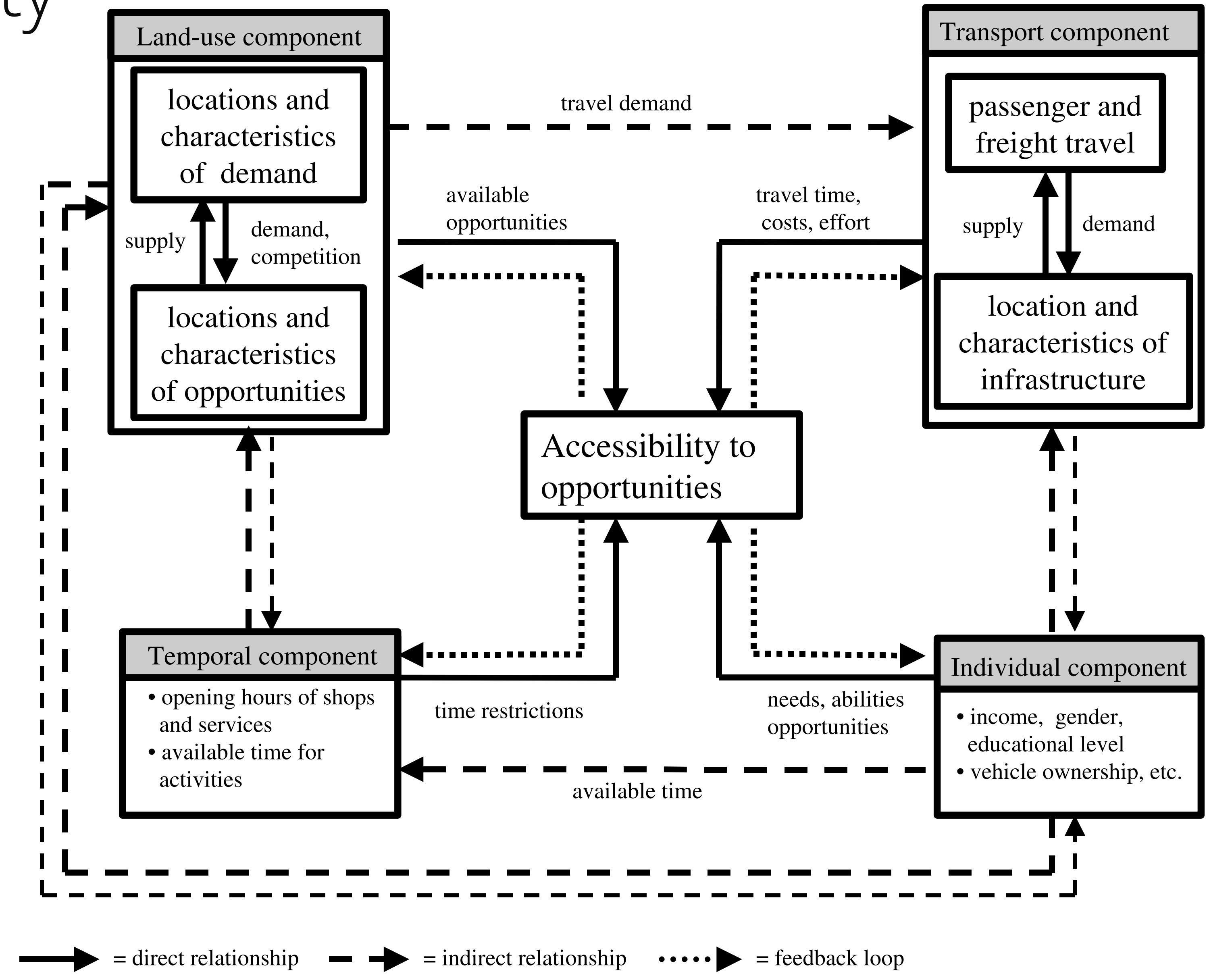
Accessibility



Accessibility



Accessibility

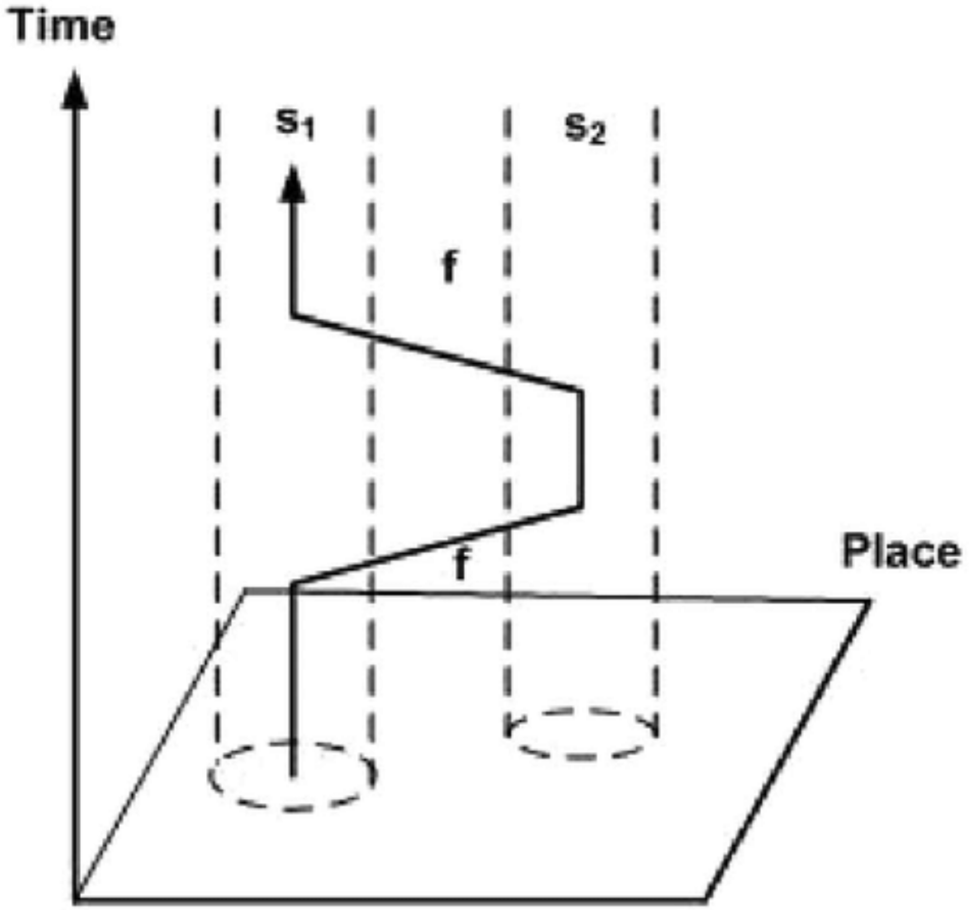


Geurs and Van Wee 2004

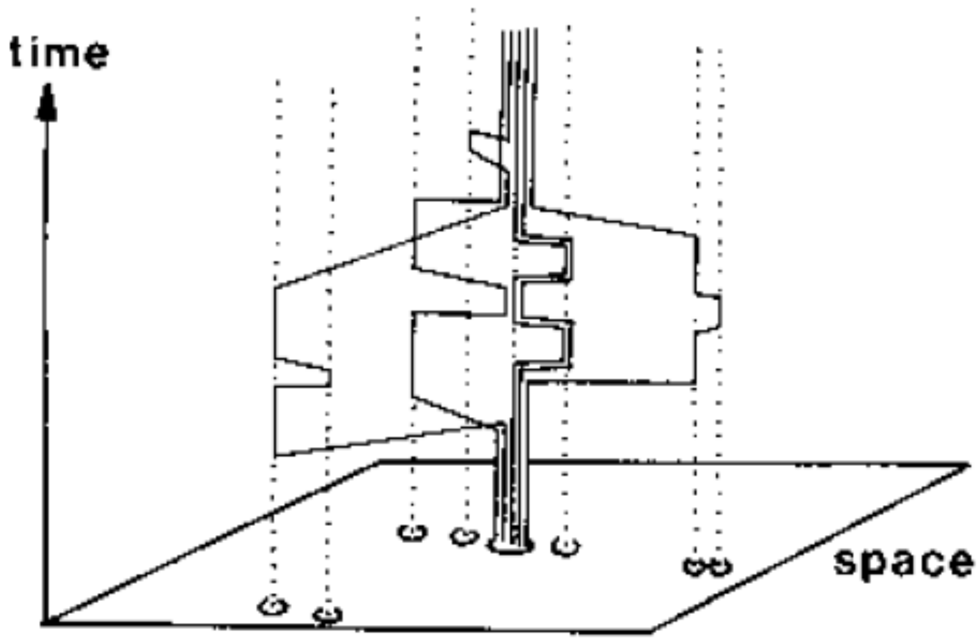
Time geography

- Proposed by Torsten Hägerstrand in the 1970s.
- Time geography describes the life of an individual as a continuous path through time and space, constituted by movements through space and activities localised in space.
- All activities are governed by three constraints: physiological constraints, capability constraints, and coupling constraints.
- These constraints can mitigate but also reinforce one another's impacts on activity participation and travel behaviour.
- When people meet their individual space-time paths form a bundle.

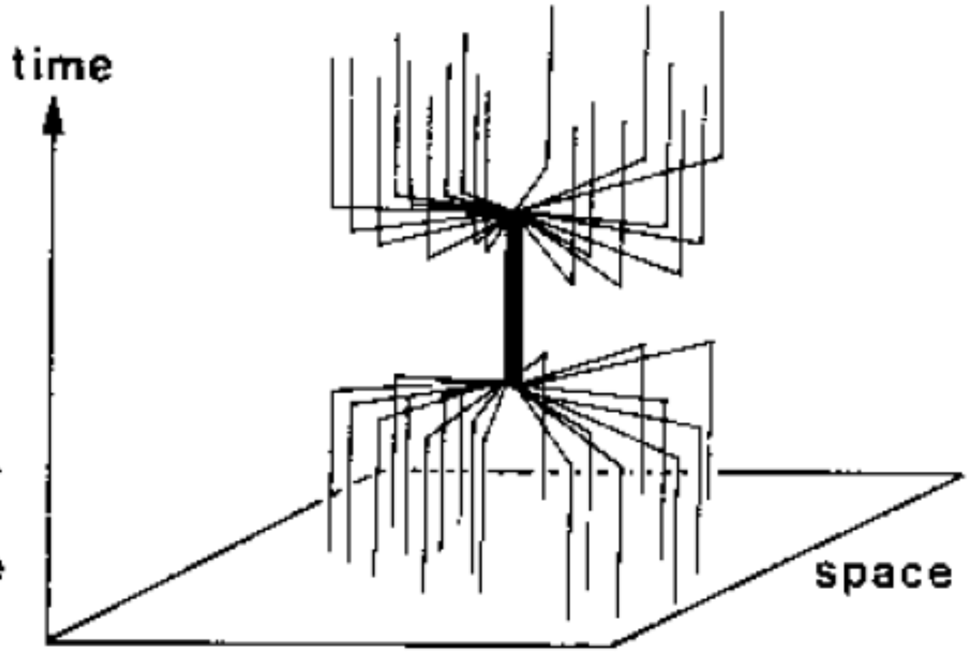
Time geography



Time geography



Household
"bundle"



School
"bundle"

Accessibility

Typical questions where accessibility analysis comes in:

- How many jobs / shops / people can I reach within 15 / 30 / 45 / 60 minutes of travel?
- How long do I need to travel to reach N jobs / shops / people?
- How does accessibility differ spatially?
- How does accessibility differ temporally?

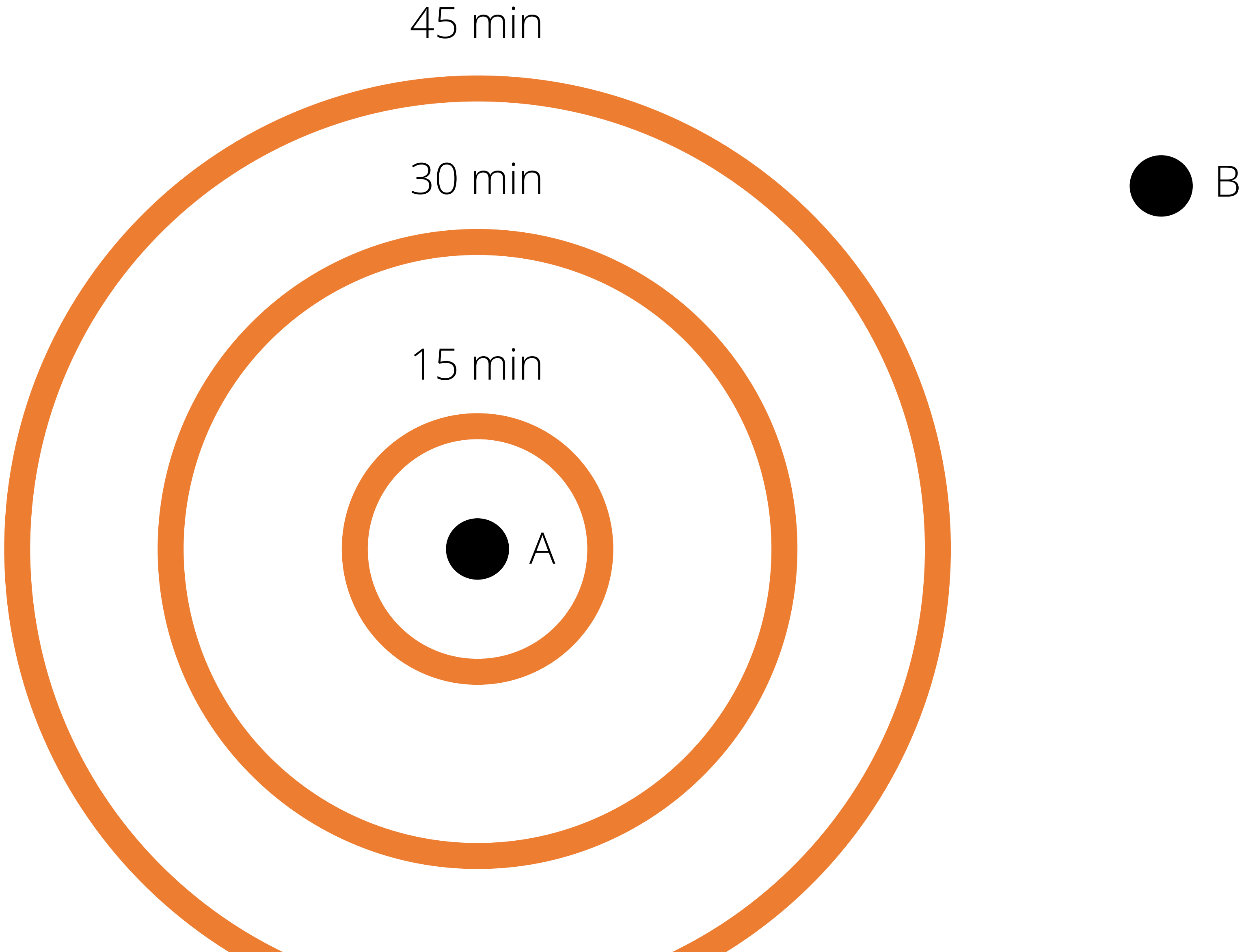
Accessibility

To quantitatively measure accessibility in a GIS we need at least:

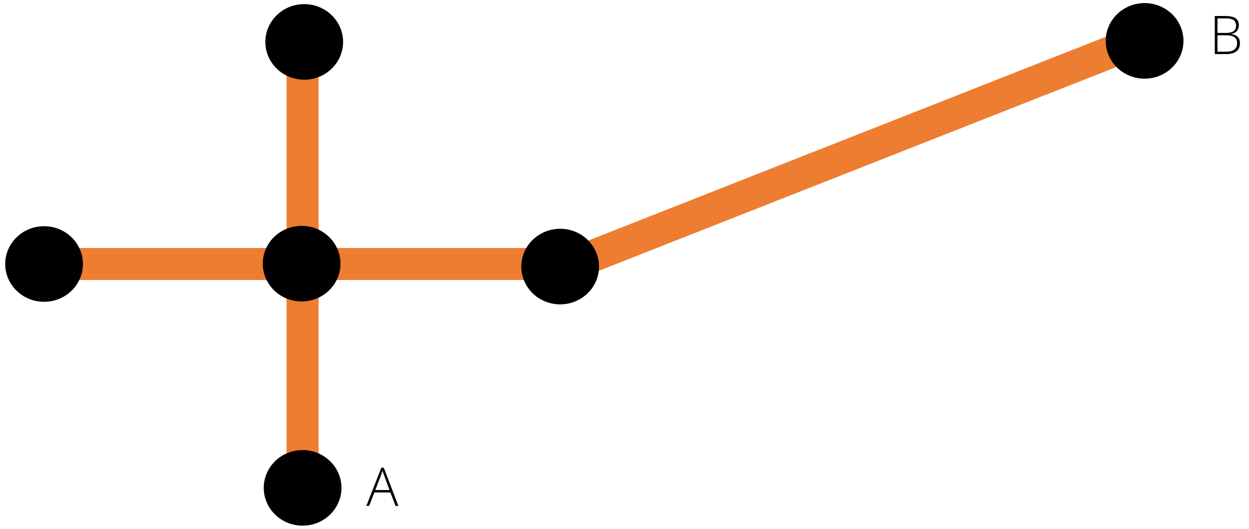
- A set of origins (e.g. set of fastfood outlets) [point vectors]
- A set of destinations (e.g. set of schools in an area) [point vector]
- Some form of a digital spatial network to connect origins and destinations [polyline vector]

Accessibility

Accessibility



Connectivity



Spatial network

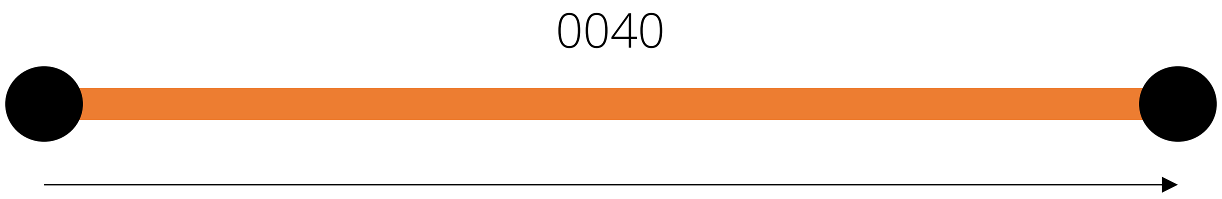
- A spatial network is an organised system or collection of nodes and edges embedded in geographic space.
- Nodes can be a representation of physical objects in geographical space, and edges show what connections are formed between the objects.
- Examples of networks: street configuration, transportation and shipping routes, river basins, telecommunication lines, etc.

Spatial network structure

Characteristics of a polyline vector in a GIS data model:

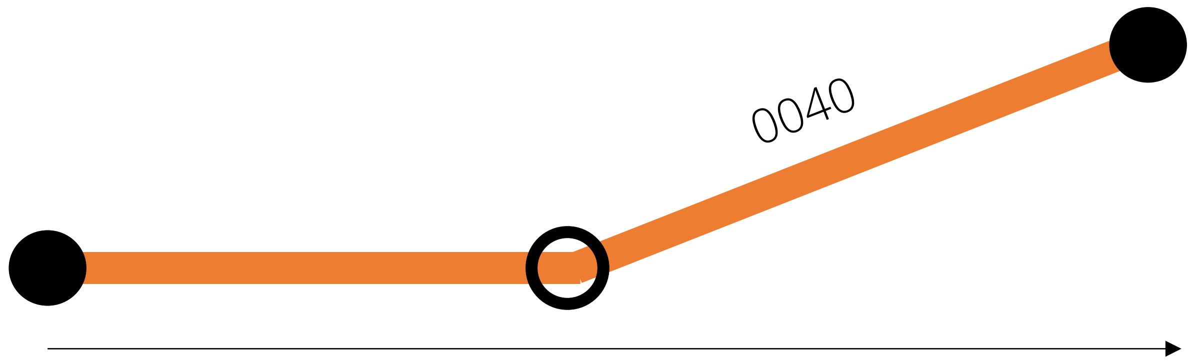
- Series of XY locations (coordinates) that form a line
- Has no area
- Has a length
- Has a direction (importance when it comes to roads, rivers, etc.)
- Can be connected to other polyline vectors to form a network
- Geometry consists of 2 nodes (start node and end node) and can have one or more vertices
- Used for: features without an area but with a length

Spatial network structure



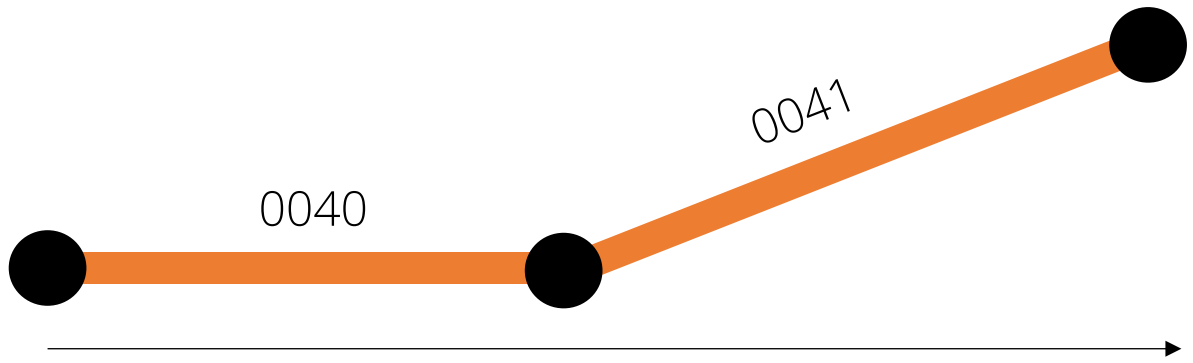
FeatureID	Type	Length
0040	Bicycle lane	1,500

Spatial network structure



FeatureID	Type	Length
0040	Bicycle lane	1,650

Spatial network structure

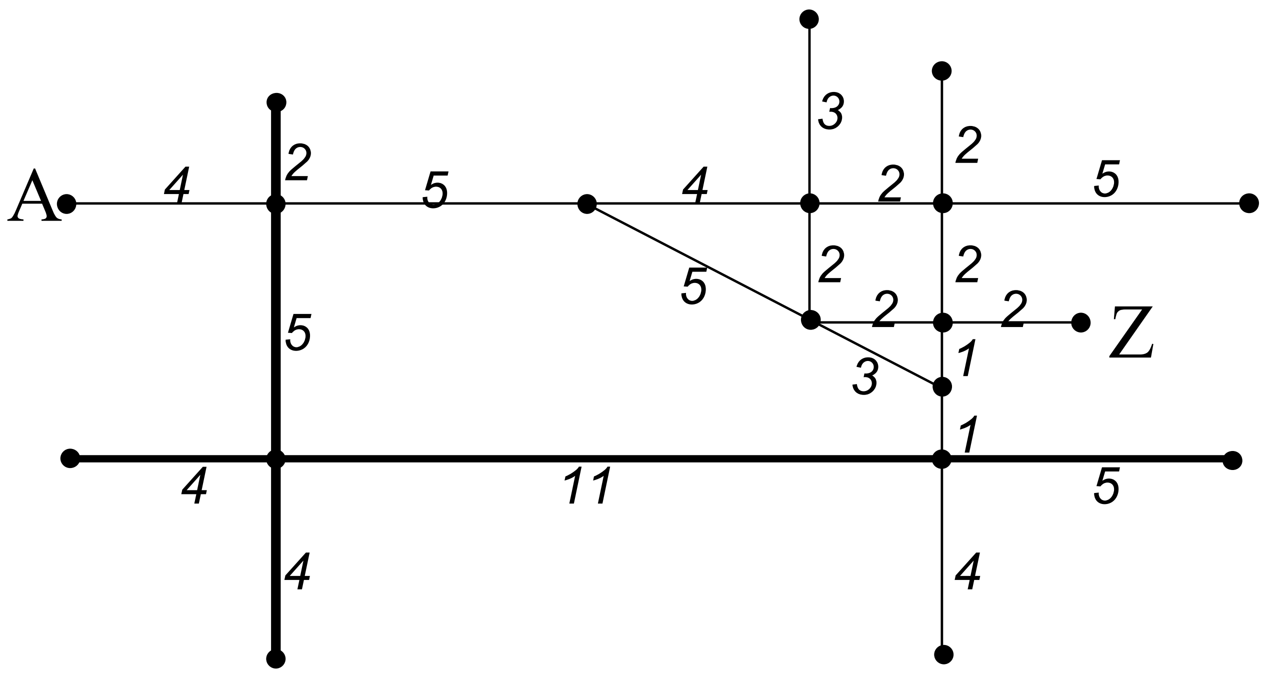


FeatureID	Type	Length
0040	Bicycle lane	600
0041	Bicycle lane	1,050

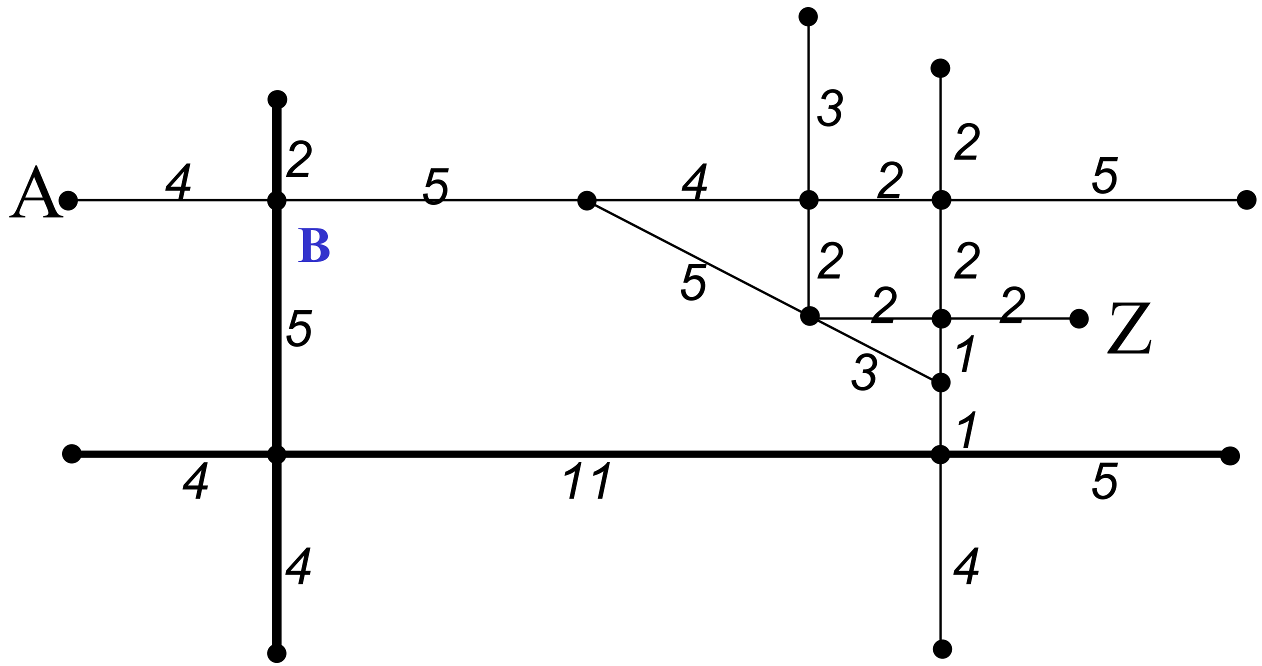
Dijkstra’s shortest path algorithm

- Shortest path
- Quickest path
- Cheapest path

Dijkstra’s shortest path algorithm

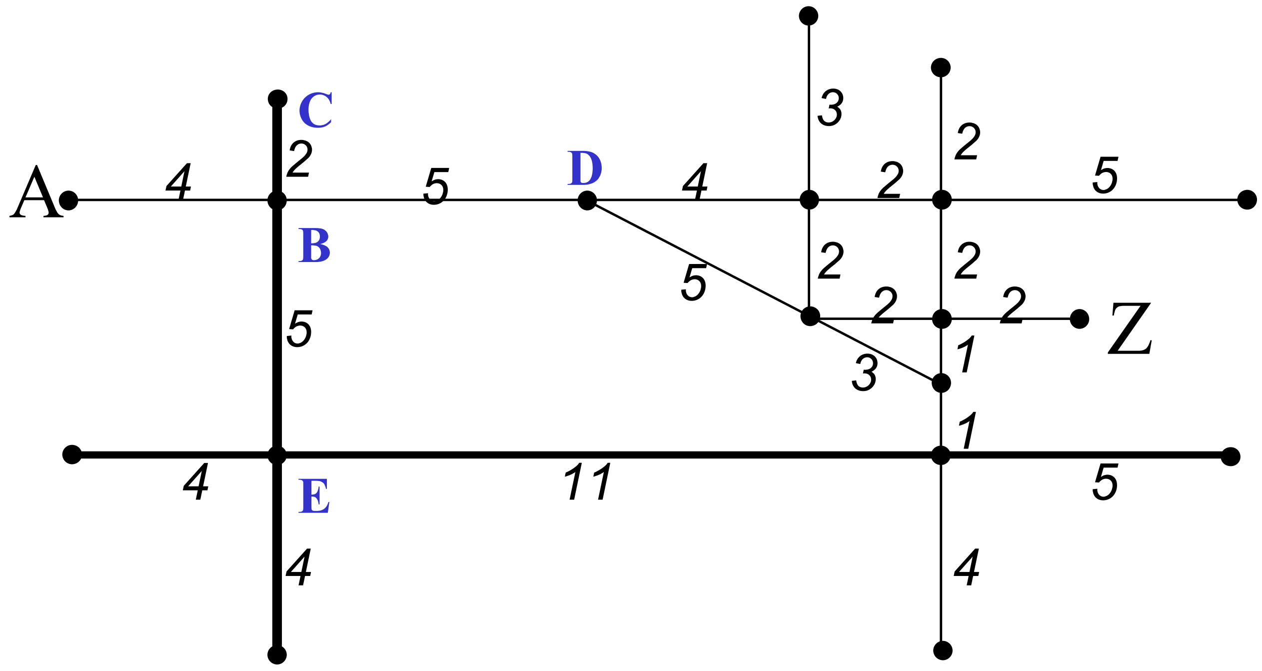


Dijkstra's shortest path algorithm

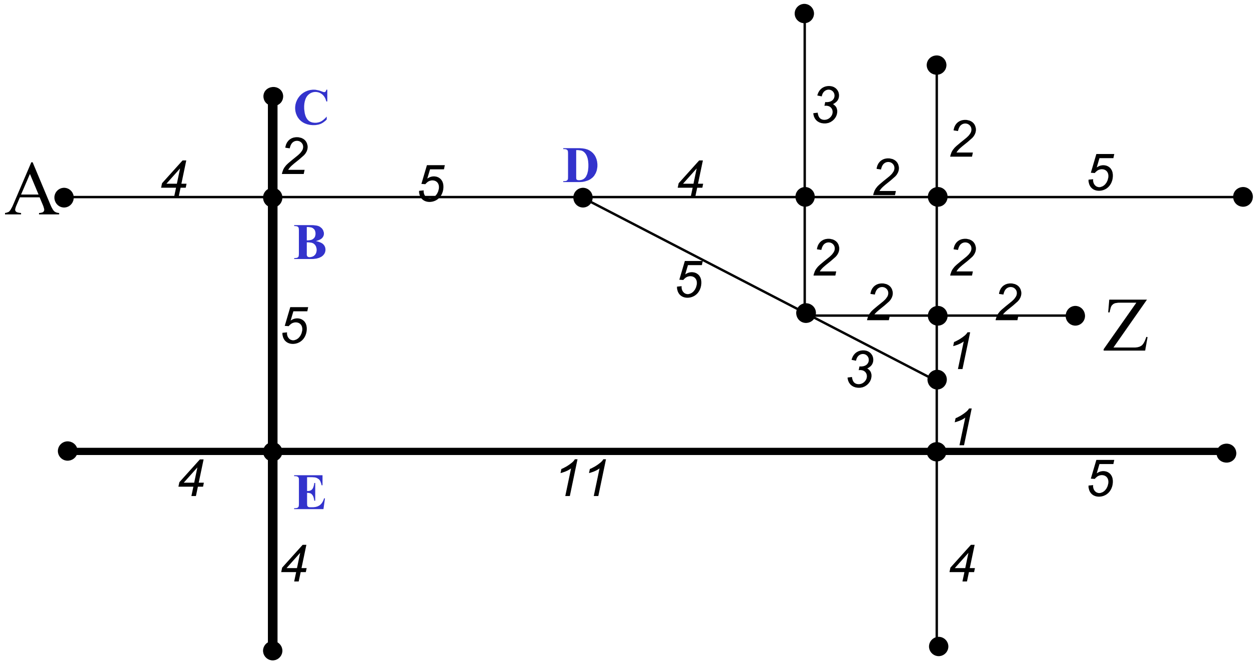


Dijkstra’s shortest path algorithm

…	
ABC	6
ABD	9
ABE	9
B – AB	4



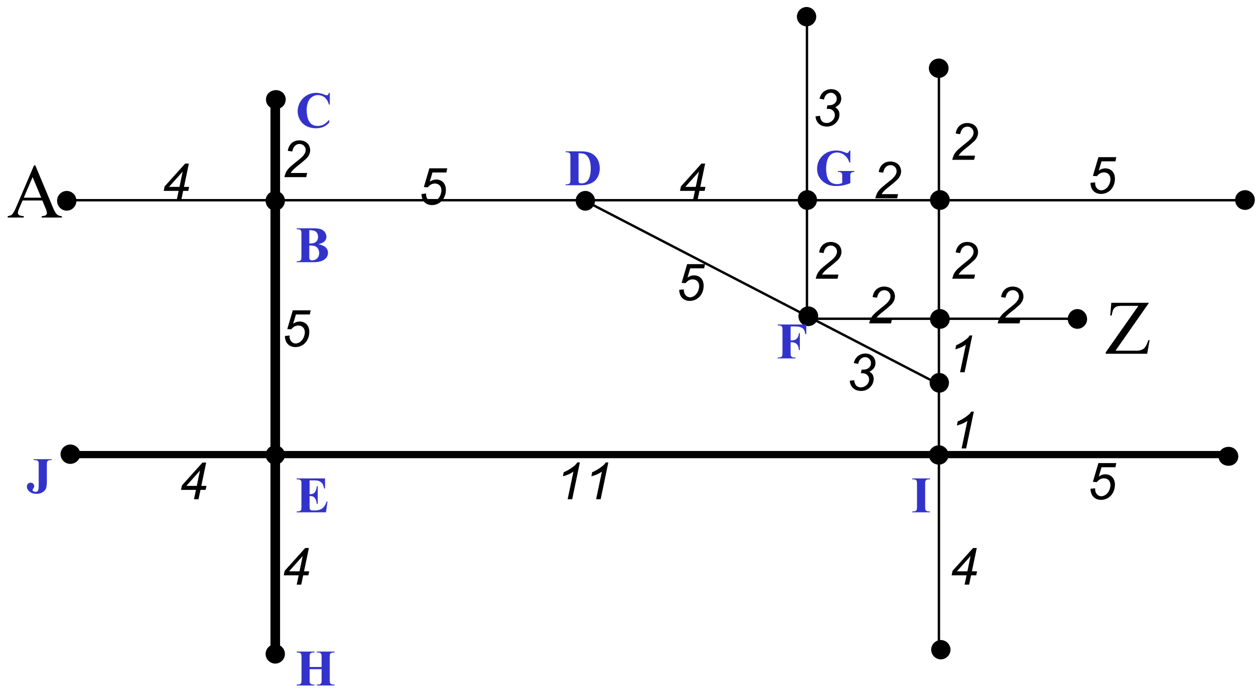
Dijkstra’s shortest path algorithm



…

ABD	9
ABE	9
B – AB	4
C – ABC	6

Dijkstra's shortest path algorithm

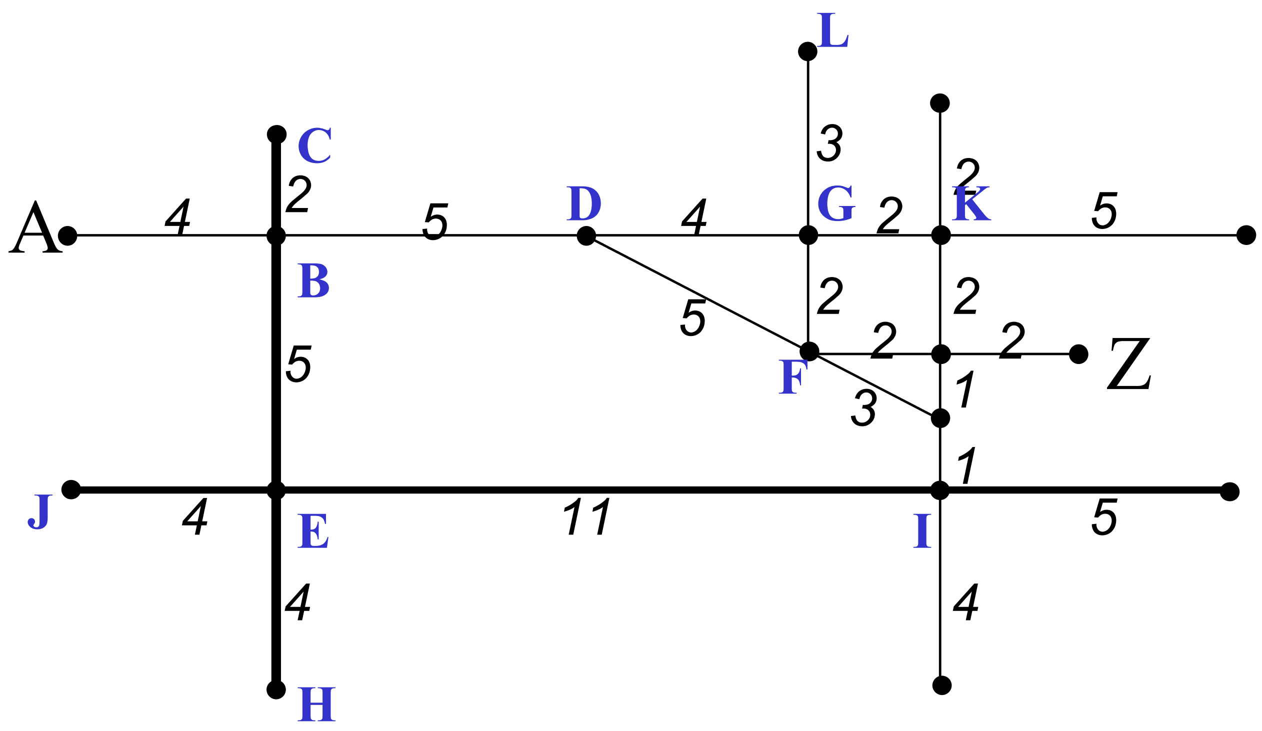


…

ABDG	13
ABEJ	13
ABEH	13
ABDF	14
ABEI	20

B – AB	4
C – ABC	6
D – ABD	9
E – ABE	9

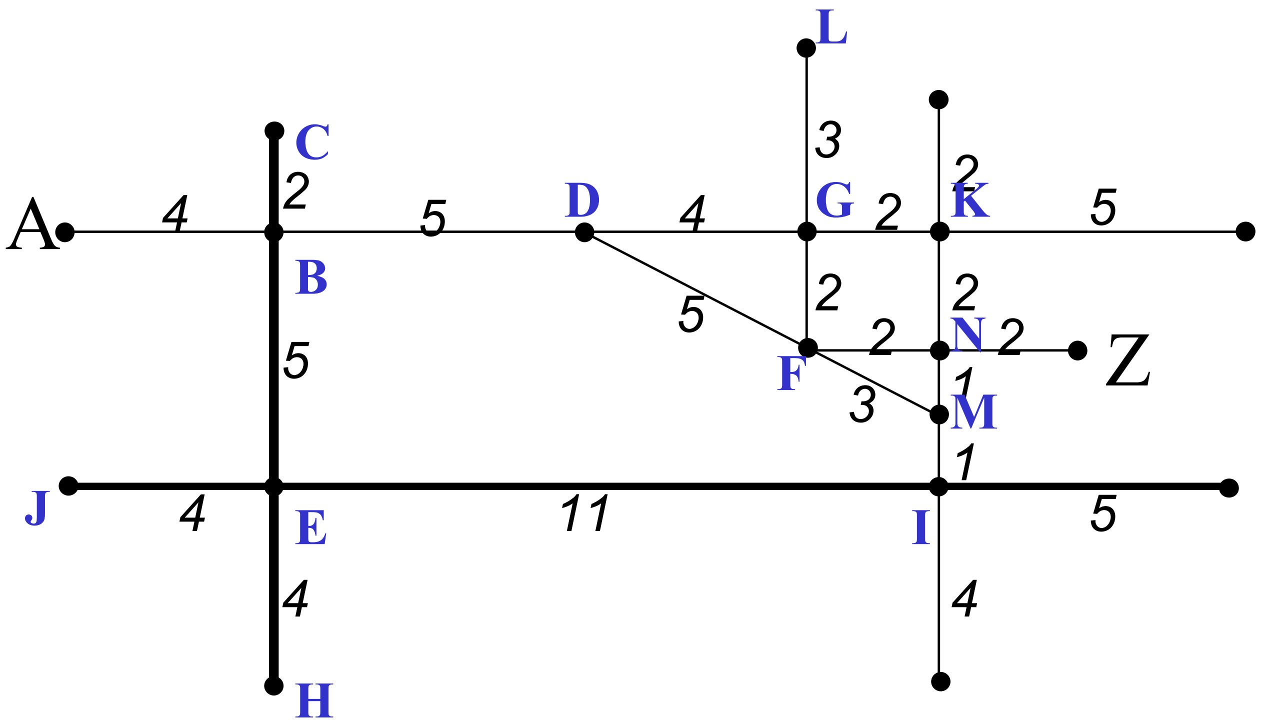
Dijkstra's shortest path algorithm



…	
ABDF	14
ABDGK	15
ABDGF	15
ABDGL	16
ABEI	20

B – AB	4
C – ABC	6
D – ABD	9
E – ABE	9
G – ABDG	13
H – ABEH	13
J – ABEJ	13

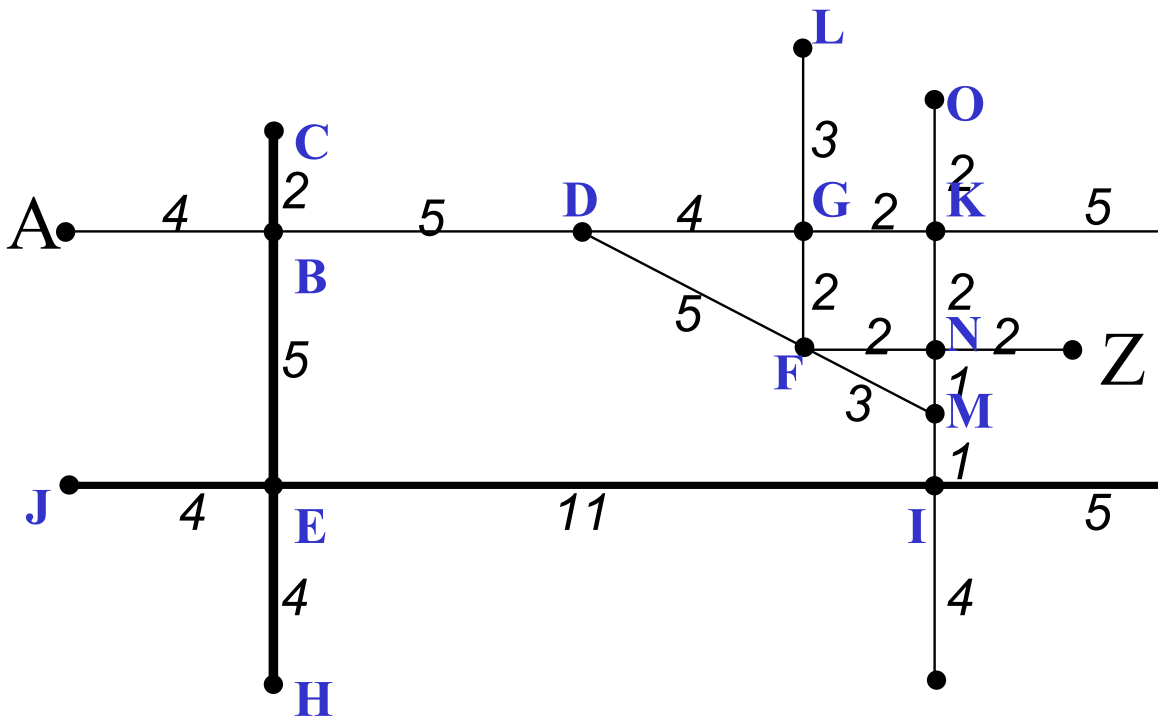
Dijkstra's shortest path algorithm



...	
ABDGK	15
ABDGL	16
ABDFN	16
ABDFM	17
ABEI	20

B – AB	4
C – ABC	6
D – ABD	9
E – ABE	9
G – ABDG	13
H – ABEH	13
J – ABEJ	13
F – ABDF	14

Dijkstra’s shortest path algorithm

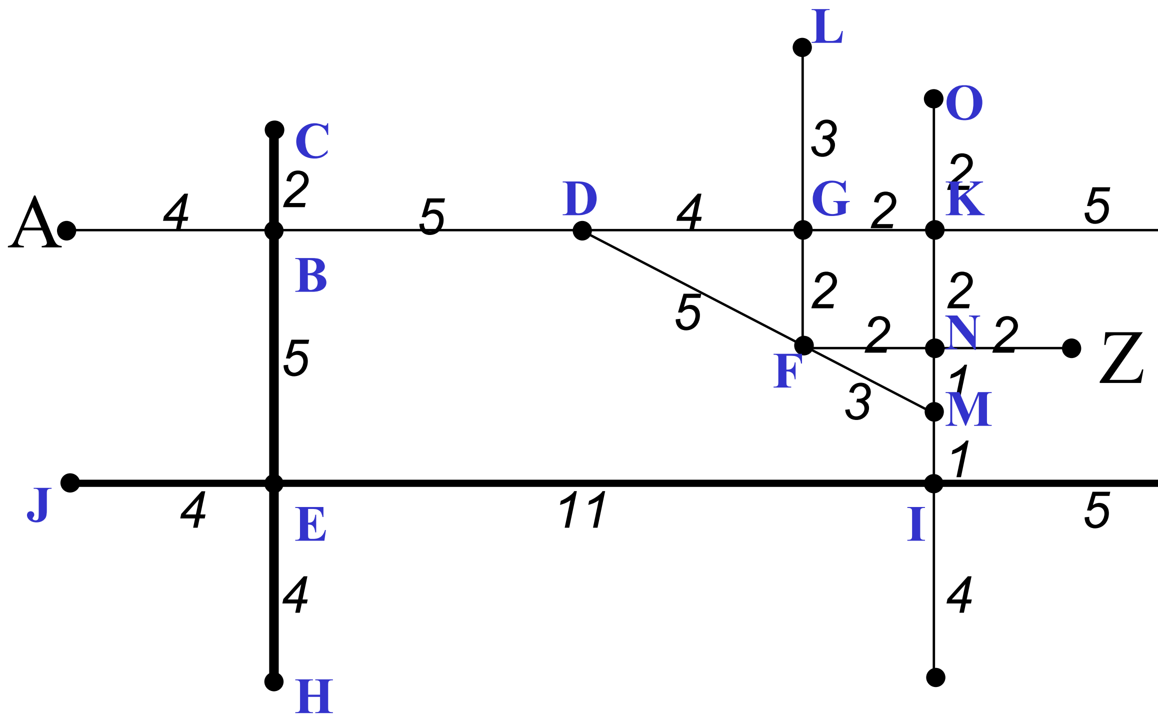


...

ABDGL	16
ABDFN	16
ABDFM	17
ABDGKO	17
ABDGKN	17
ABDGKP	20
ABEI	20

B – AB	4
C – ABC	6
D – ABD	9
E – ABE	9
G – ABDG	13
H – ABEH	13
J – ABEJ	13
F – ABDF	14
K – ABDGK	15

Dijkstra's shortest path algorithm

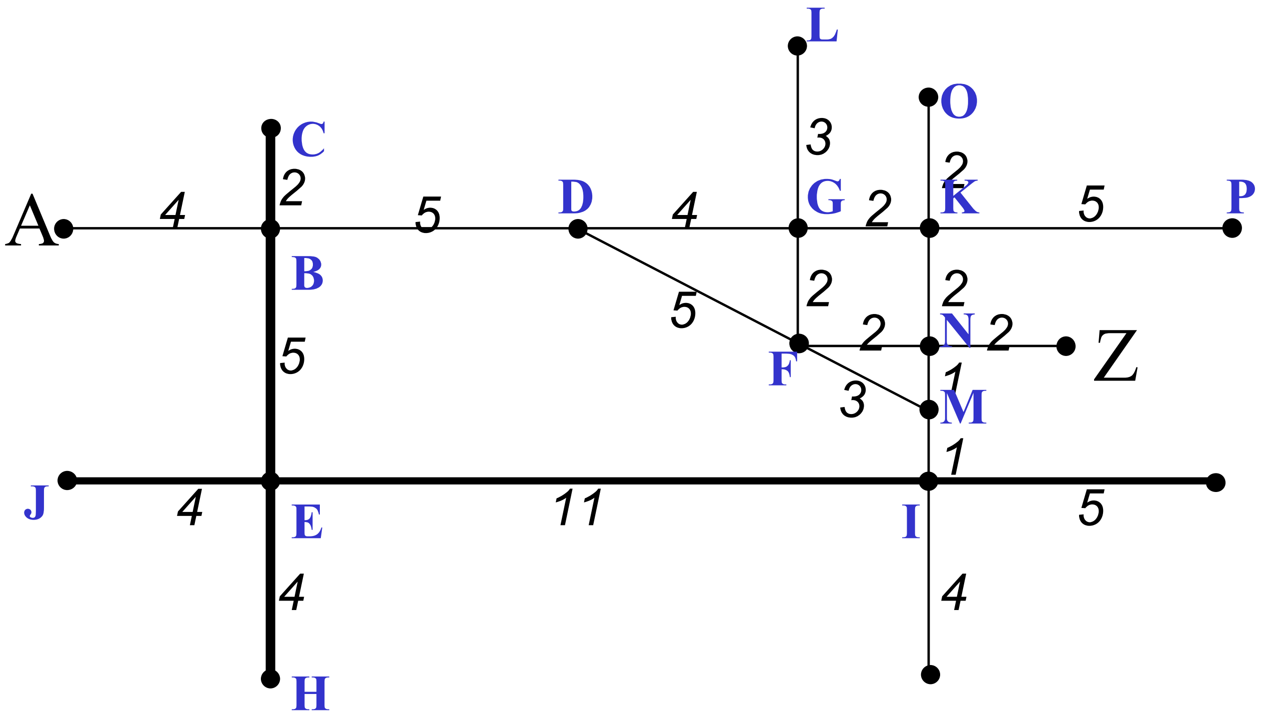


...

ABDFNM	17
ABDGKO	17
ABDFNZ	18
ABDGKP	20
ABEI	20

B – AB	4
C – ABC	6
D – ABD	9
E – ABE	9
G – ABDG	13
H – ABEH	13
J – ABEJ	13
F – ABDF	14
K – ABDGK	15
L – ABDGL	16
N – ABDFN	16

Dijkstra's shortest path algorithm



...

ABDFNZ	18
ABDFMN	18
ABDFMI	18

B – AB	4
C – ABC	6
D – ABD	9
E – ABE	9
G – ABDG	13
H – ABEH	13
J – ABEJ	13
F – ABDF	14
K – ABDGK	15
L – ABDGL	16
N – ABDFN	16
M – ABDFM	17
O – ABDGKO	17

To measure accessibility

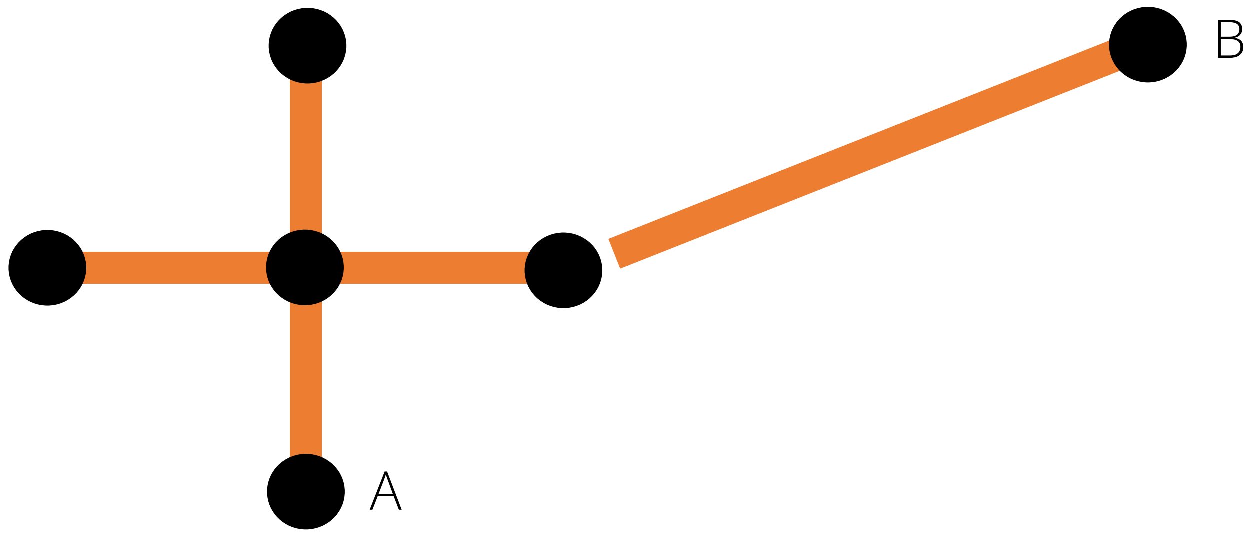
... with Dijkstra’s algorithm we need

- A set of origins (e.g. set of fastfood outlets) [point vectors]
- A set of destinations (e.g. set of schools in an area) [point vector]
- Some form of a digital spatial network to connect origins and destinations [polyline vector]
- Impedance values per mode of transport / costs for each network segment
- If available: access indicators to construct a weighted graph

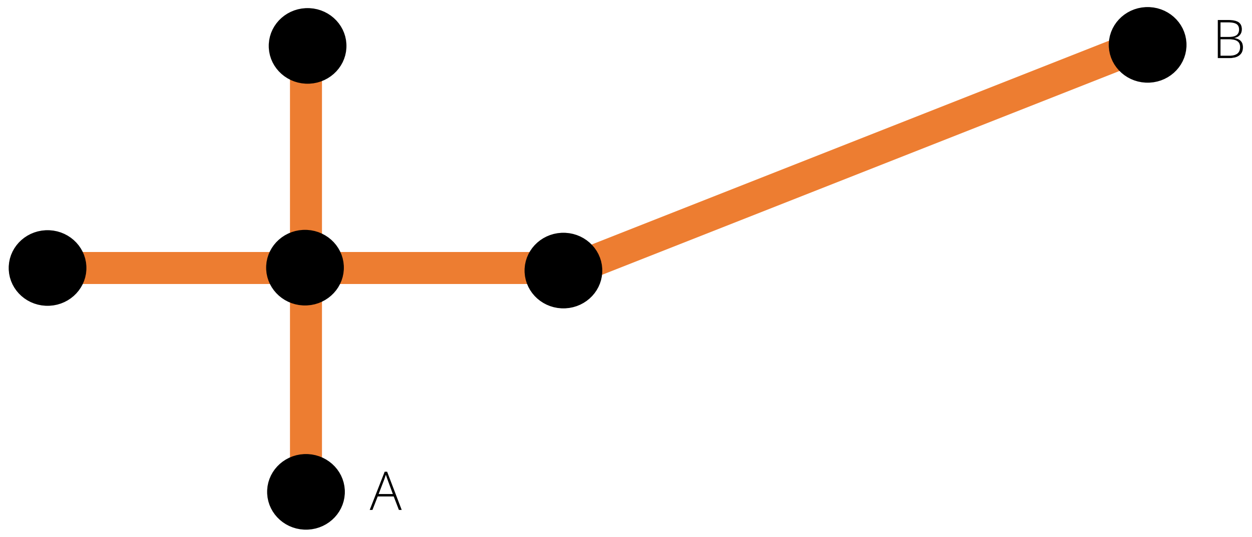
To consider

- Completeness – are all areas covered?
- Attributes – are they correct?
- Connectivity – are all network segments that should be connected, connected?
- Topology – are all network segments connected the way they should be?
- Coverage – is the full network covered?

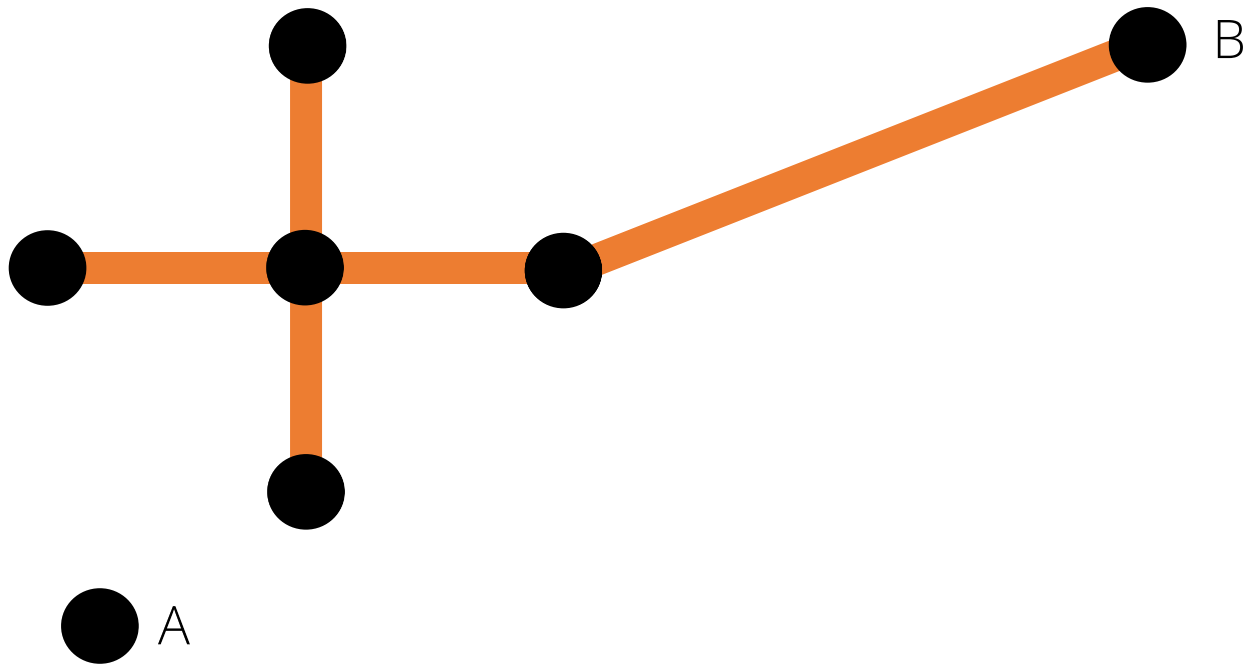
Connectivity



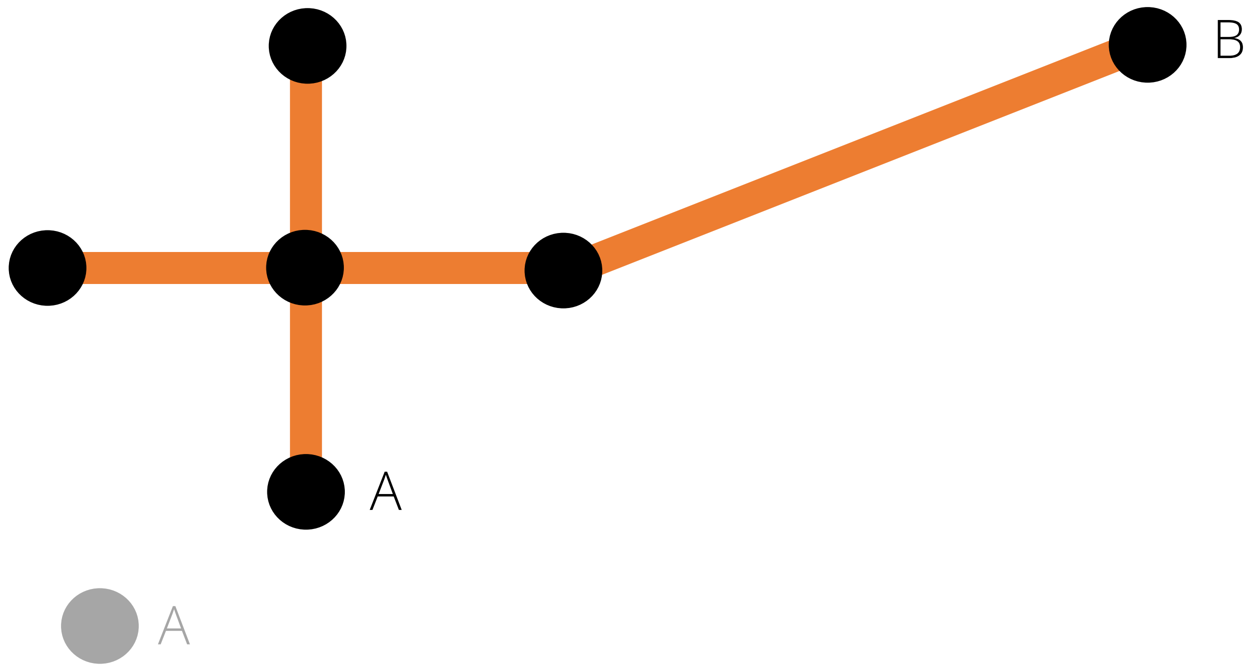
Connectivity



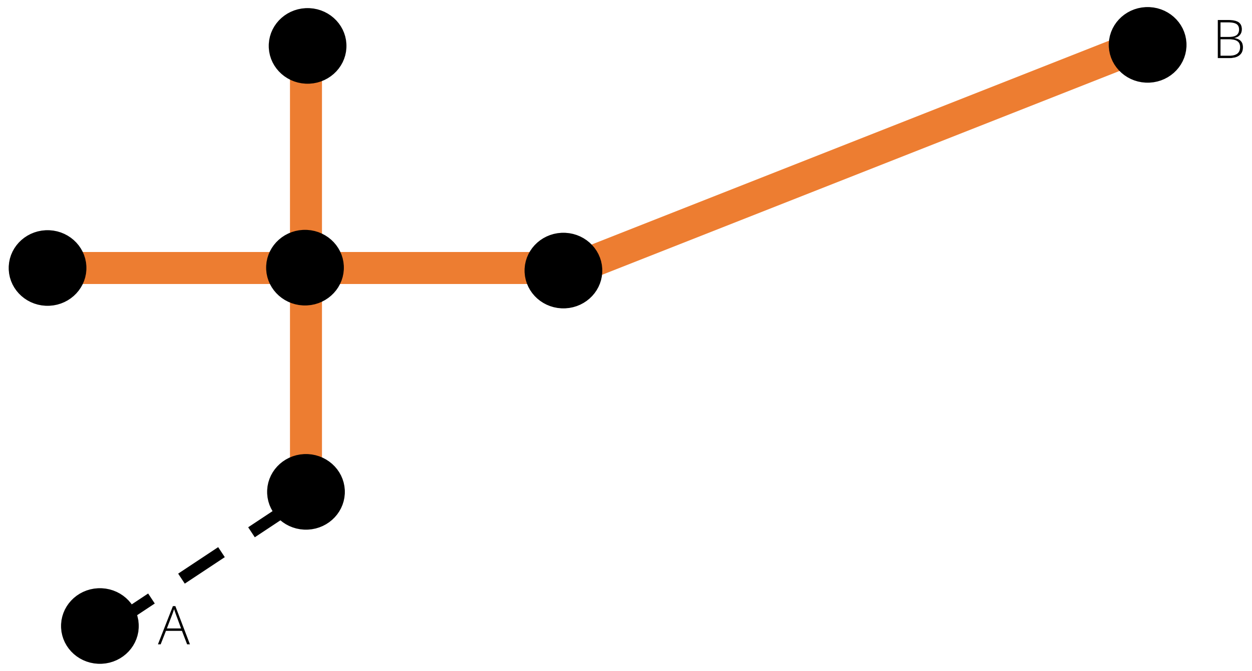
Connectivity



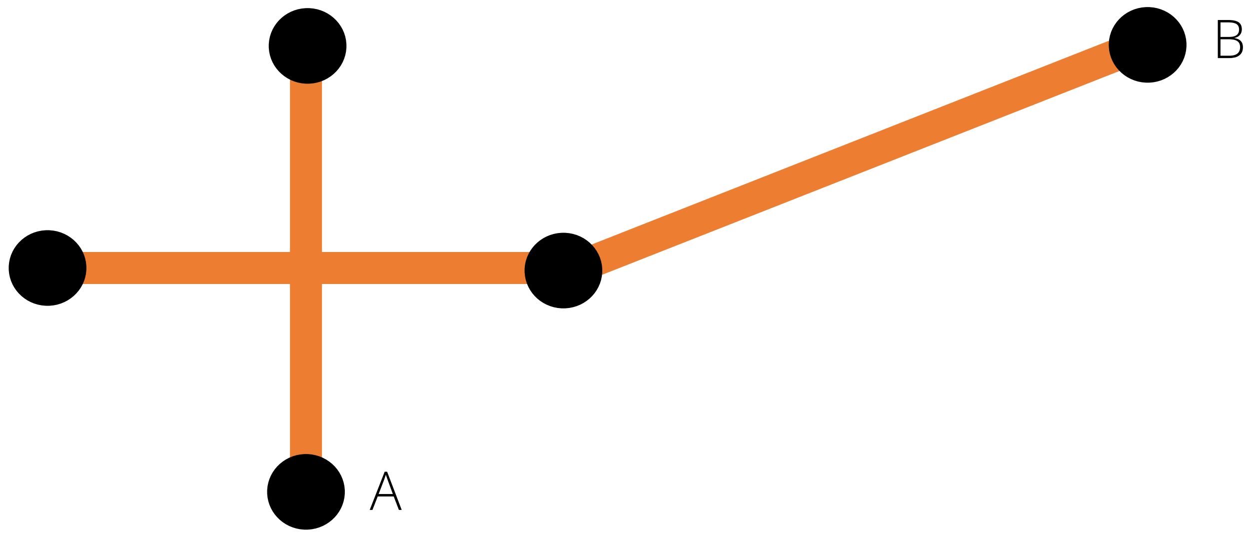
Connectivity



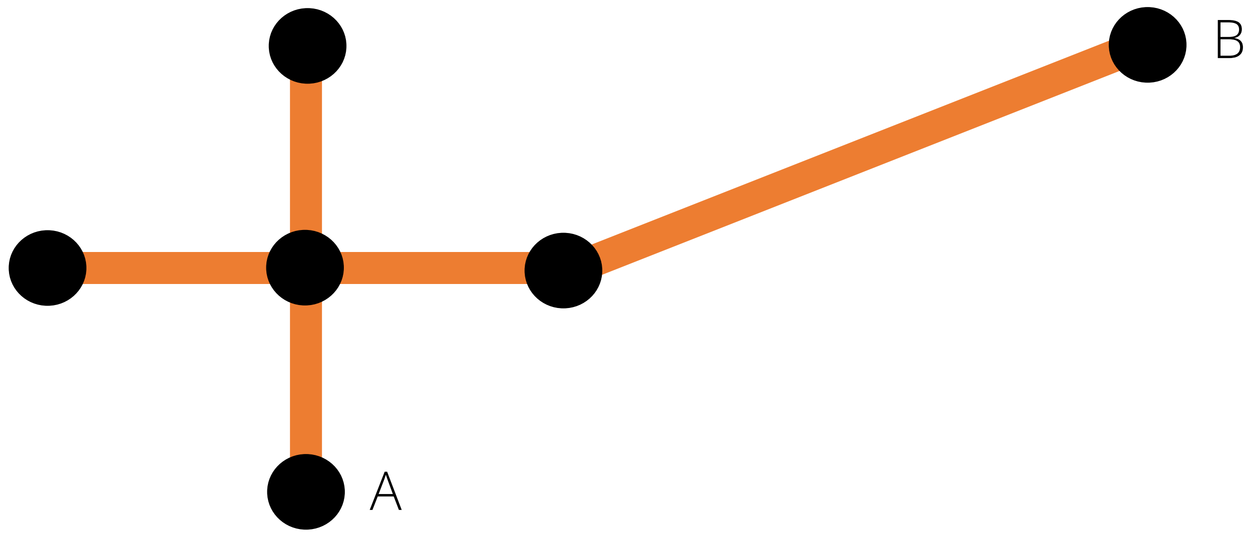
Connectivity



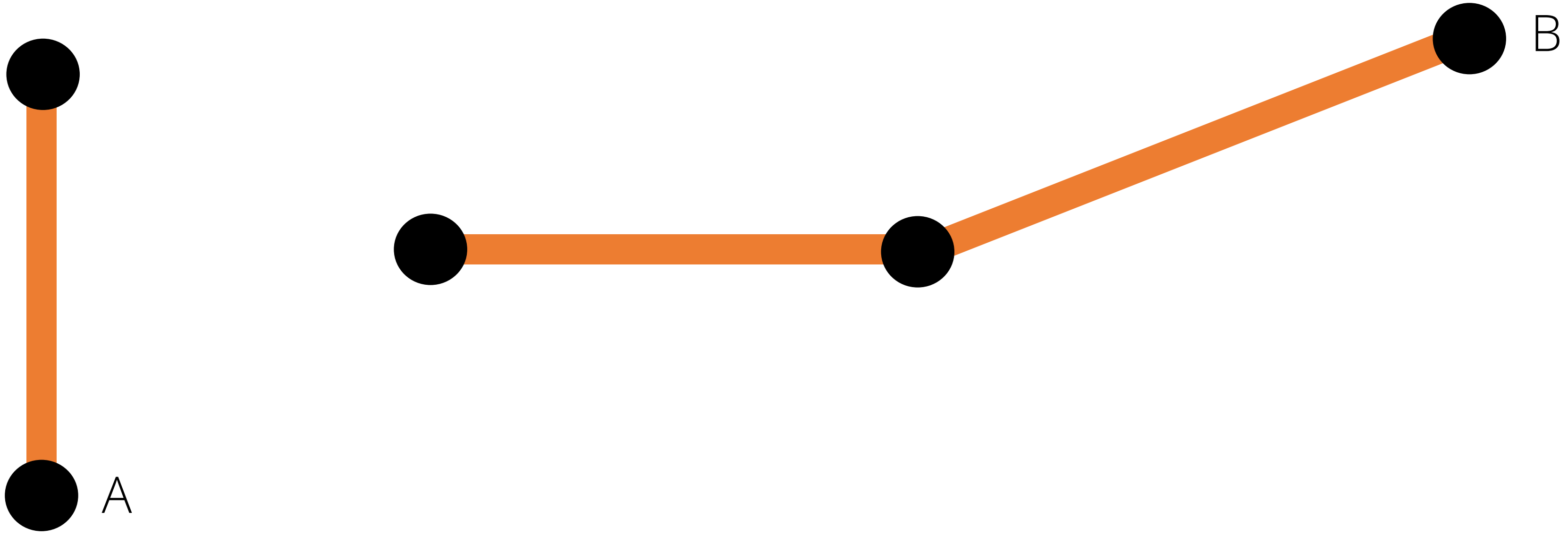
Topology



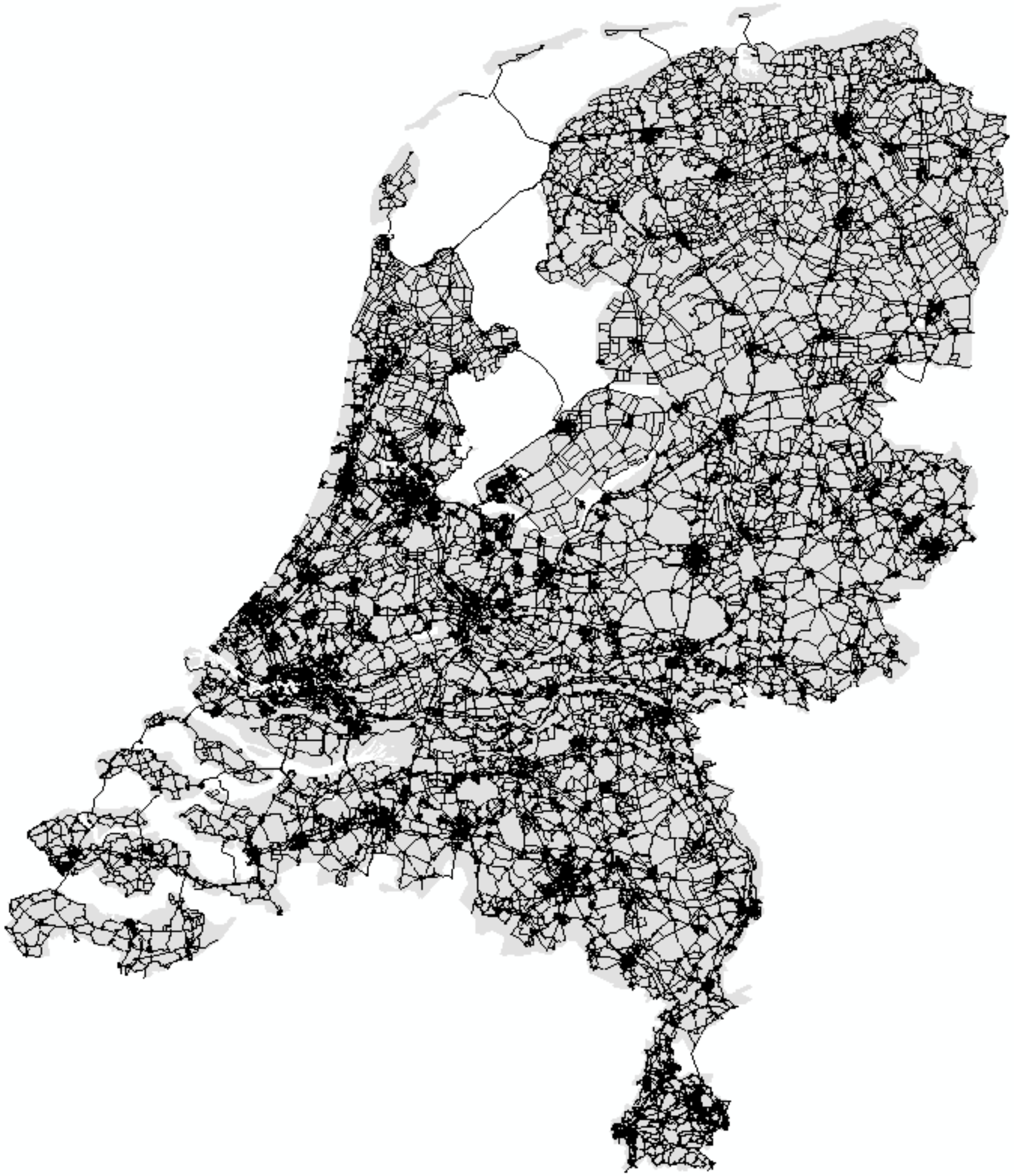
Topology



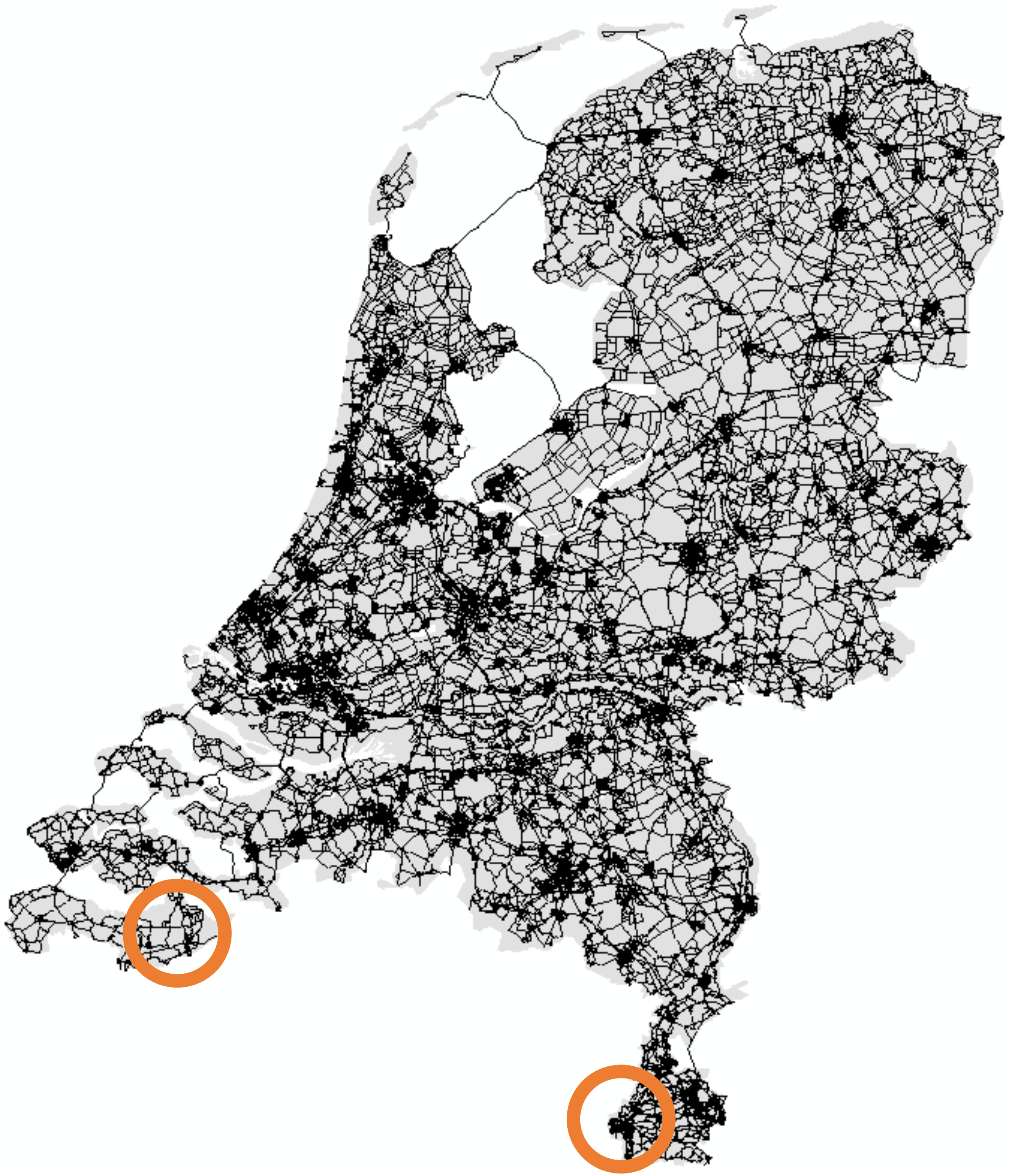
Topology



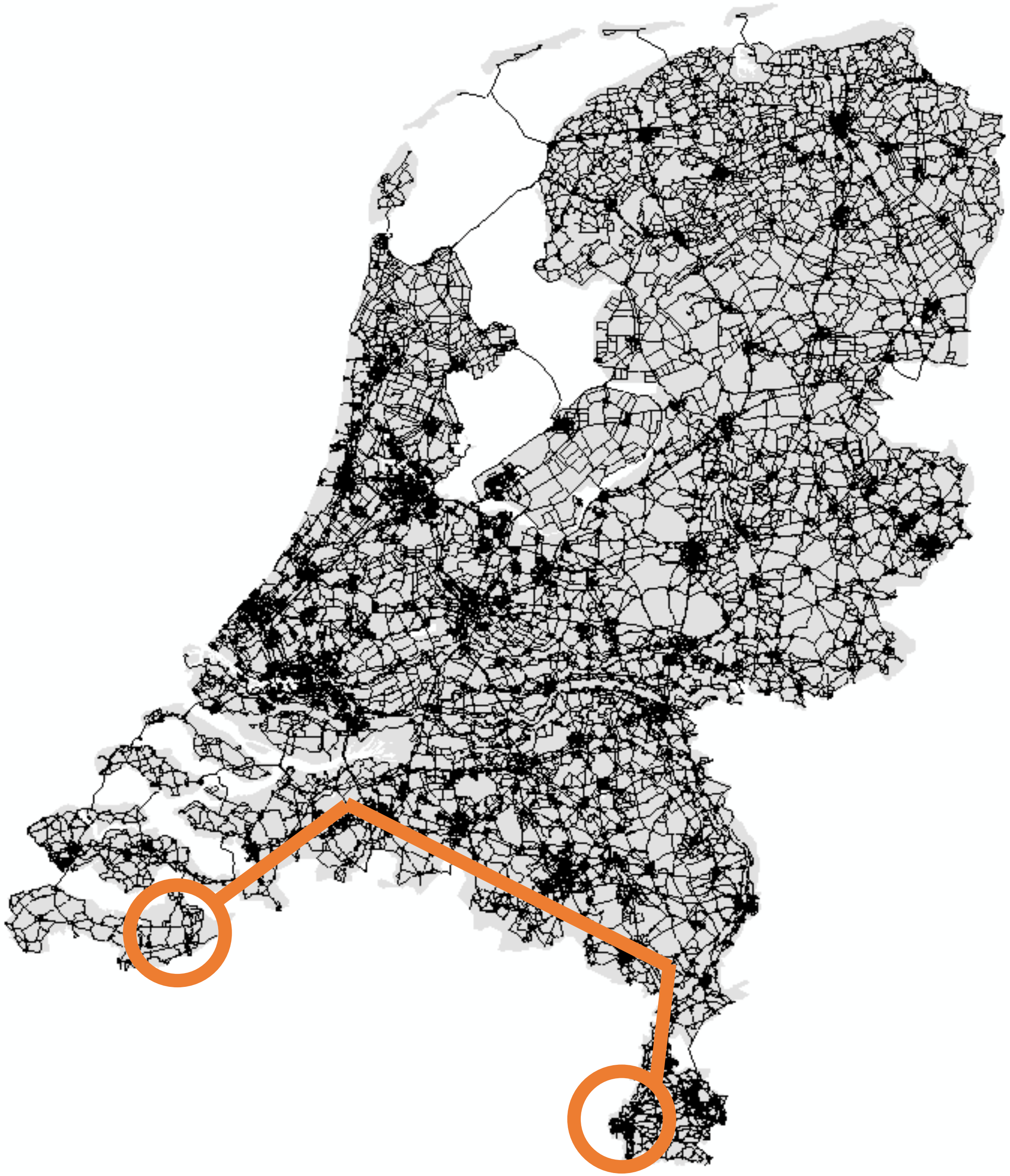
Coverage



Coverage



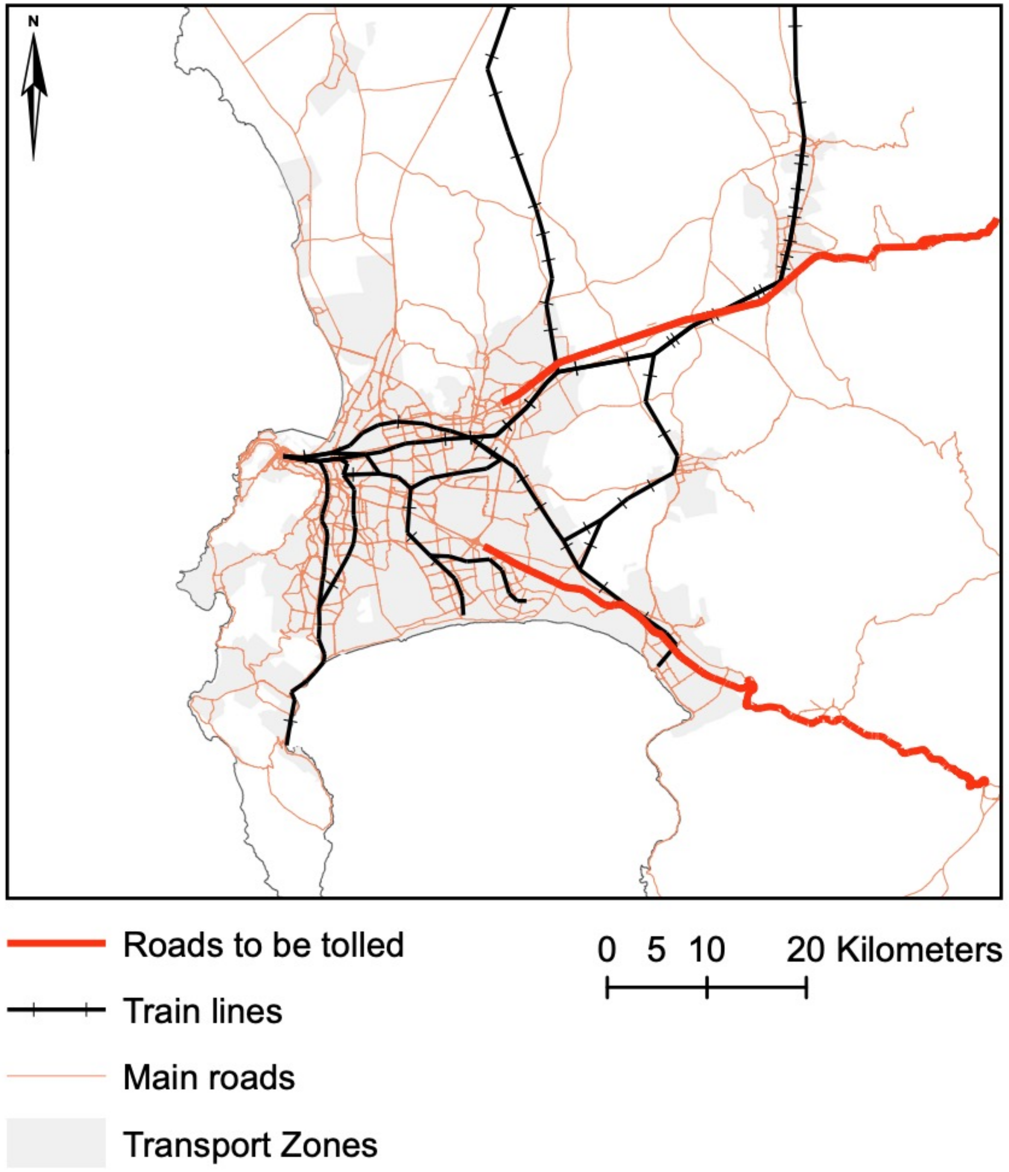
Coverage

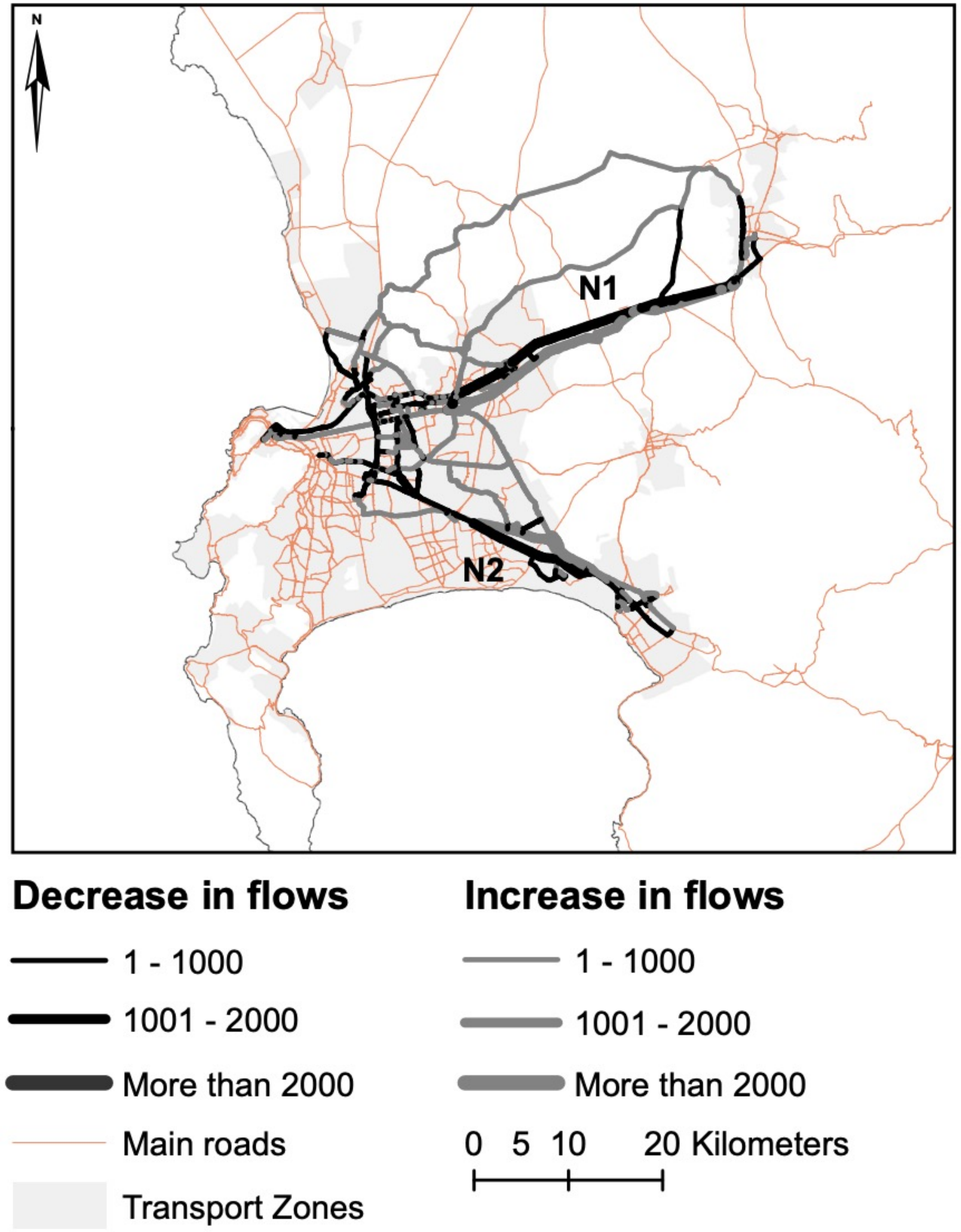


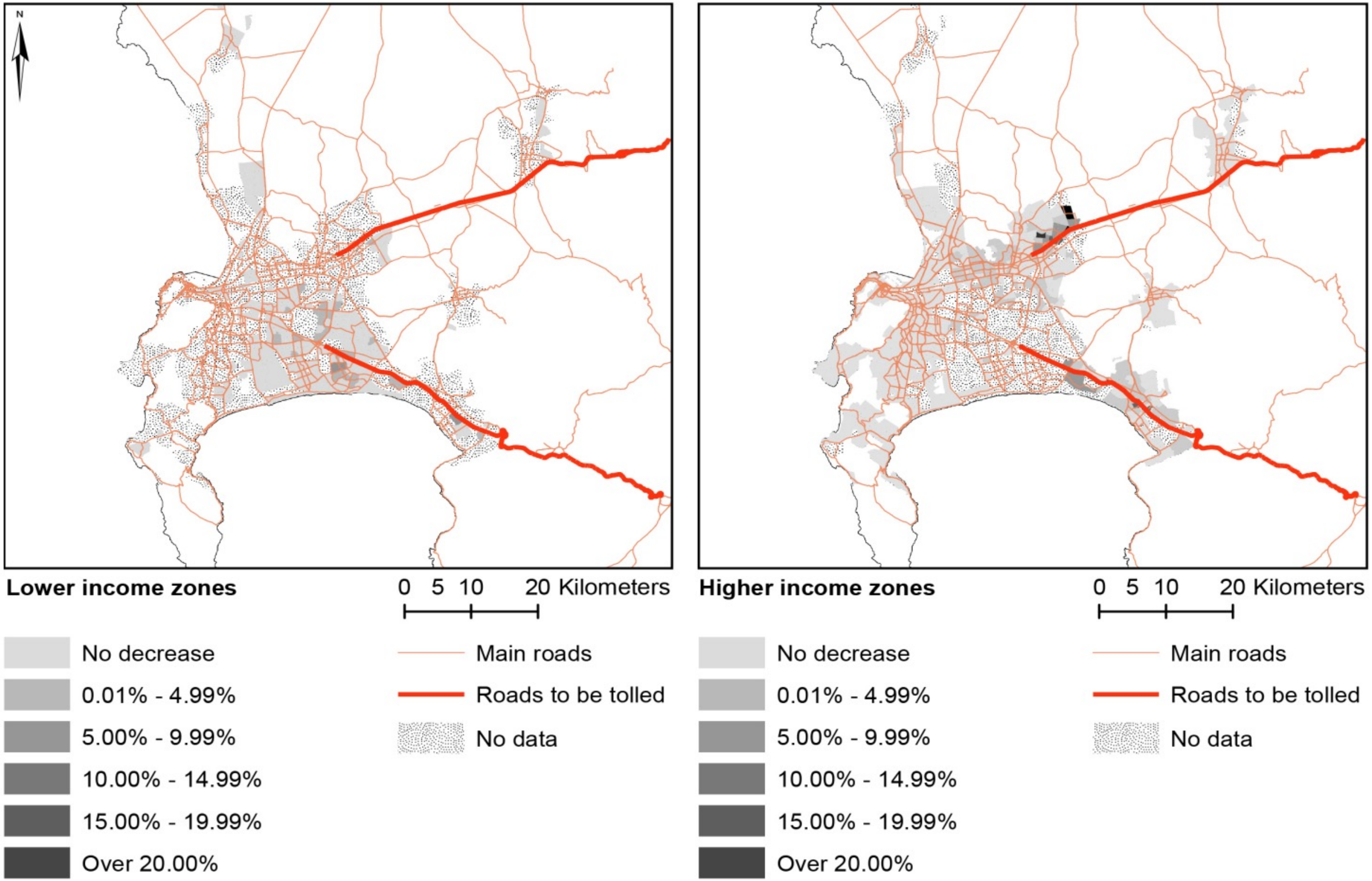
Coverage

Accessibility in Cape Town

- Equity effects of a proposed toll charge on the traffic diversions and geographical accessibility of work locations in Cape Town, South Africa.
- High dependency on road transport, largely inherited from the racial and spatial segregation of the apartheid regime.
- Hypothesis: a toll in this region will take a proportionally greater amount from those on lower incomes.


N
Roads to be tolled
Train lines
Main roads
Transport Zones
0 5 10 20 Kilometers


N
N1
N2
Decrease in flows
1 - 1000
1001 - 2000
More than 2000
Main roads
Transport Zones
Increase in flows
1 - 1000
1001 - 2000
More than 2000
0 5 10 20 Kilometers


N
Lower income zones
0 5 10 20 Kilometers
No decrease
0.01% - 4.99%
5.00% - 9.99%
10.00% - 14.99%
15.00% - 19.99%
Over 20.00%
Main roads
Roads to be tolled
No data
Higher income zones
0 5 10 20 Kilometers
No decrease
0.01% - 4.99%
5.00% - 9.99%
10.00% - 14.99%
15.00% - 19.99%
Over 20.00%
Main roads
Roads to be tolled
No data

Conclusion

- Pretty much talked about modelling accessibility scenarios using transport network analysis. Accessibility needs to be operationalised – accessibility in terms of what?
- Need at least some origins, some destinations, some form of network.
- Shortest path between origins and destinations is typically calculated using Dijkstra's Algorithm.
- Network properties are important – especially connectivity, but coverage can make a big difference.
- There is much more: including all types of network centrality measures.
- Lots of open source tools available: dodgr, R^5 (r5r, r5py)

Questions

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