Spatial network analysis

Spatial Data Analysis and Simulation modelling,
2020, Dr. Simon Scheider, Dr. Zhiyong Wang

Outline

- Basic concepts for spatial networks
  - Transport network data models in GIS
  - Transport network analysis
  - OD matrices
  - Networks as core concepts
  - Spatial network transformations
  - Computational diagram for spatial networks
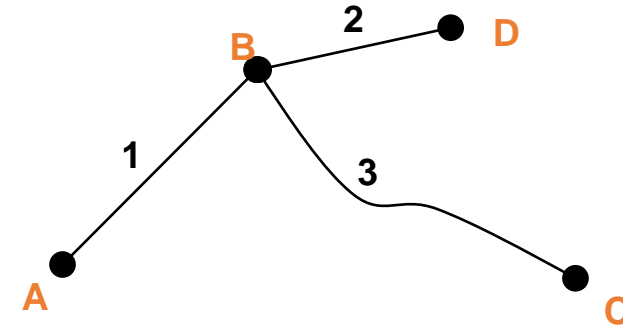- Accessibility analysis
- Flow analysis

Basic concepts
for spatial networks

Networks and GIS (1)

A geometric network contains the geometric points and lines of a network.

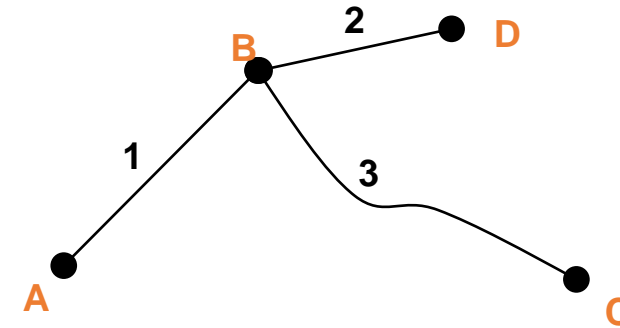Used for network «mapping»

Why is this not yet a GIS network?

Points

ID	Geometry
A	Point
B	Point
C	Point
D	Point

Lines

ID	Geometry
1	Polyline
2	Polyline
3	Polyline

Networks and GIS (2)

A logical network contains neighborhood information (junctions) between nodes and edges
- called "graph"
- can be used to compute paths

Node

Feature_ID	Element_ID
A	j1
B	j2
C	j3
D	j4

Edge

Feature_ID	Element_ID
1	e5
2	e6
3	e7

Connectivity Table

Junction	Adjacent elements
J1	J2,e5
J2	J1,e5
J2	J4,e6
j2	J3,e7
...	...

However: Is it really the case that spatial networks are just graphs with some embedding in space?

Transport network analysis

- Shortest or quickest path in a network

- Shortest: Based on distance

- Quickest: Based on time (using distance and speed)

- Using e.g. Dijkstra's algorithm
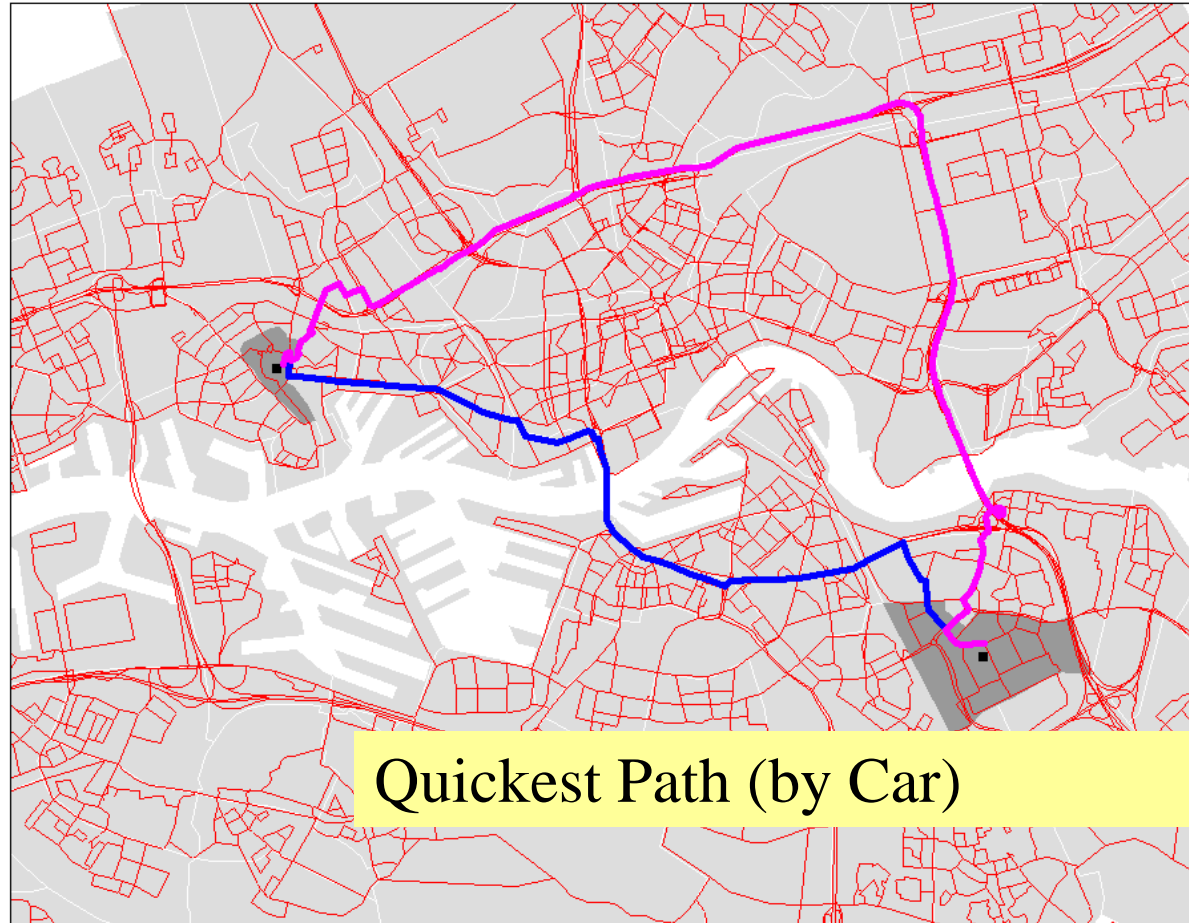
Quickest Path (by Car)

Transport network analysis

- Shortest or quickest path in a network
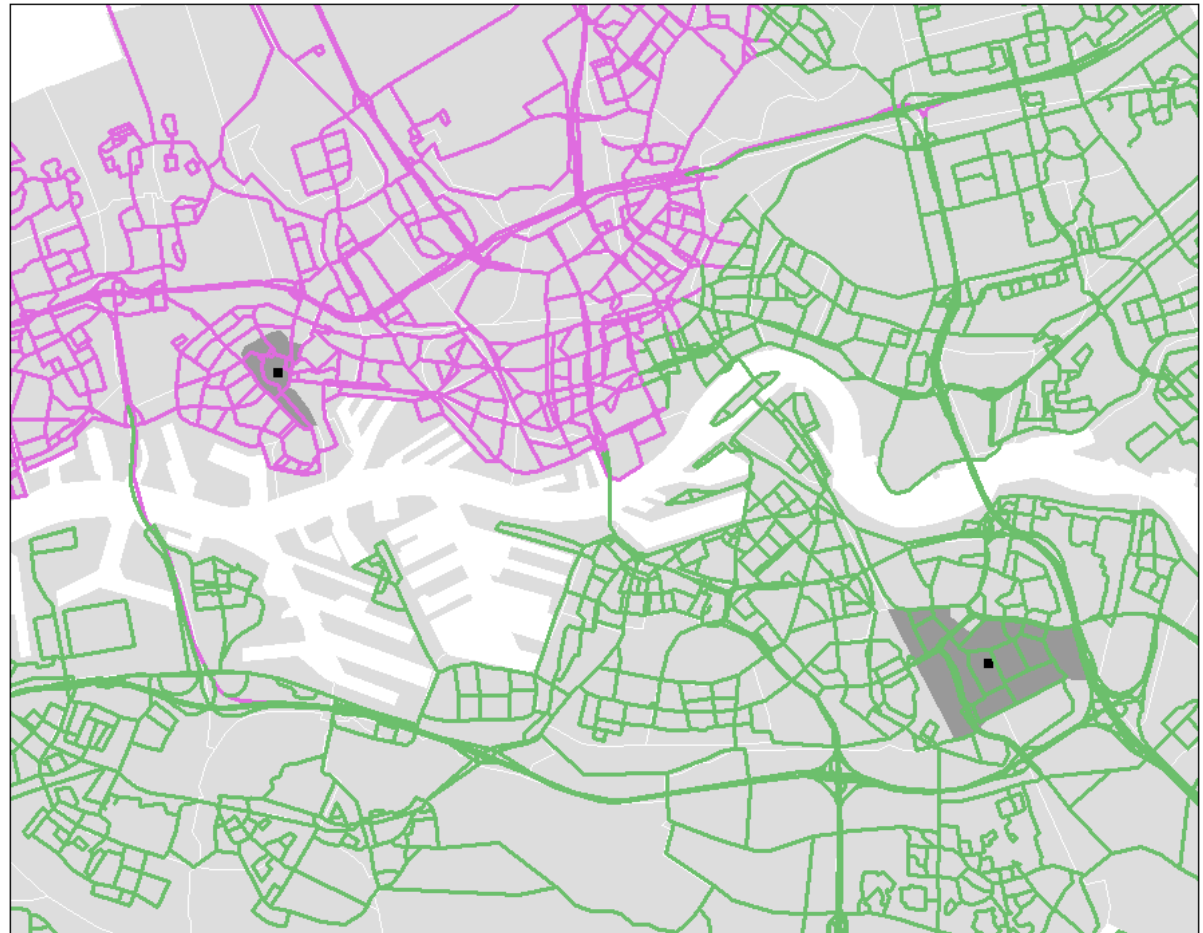
- Allows us to compute
  - zones

Zoning in minutes:

Yellow: 0-10

Olive: 10-20

Green 20-30

Transport network analysis

- Shortest or quickest path in a network

- Allows us to compute
  - zones
  - districts (catchment areas)

- The latter can be used to allocate services to a network (e.g. medical services etc.)
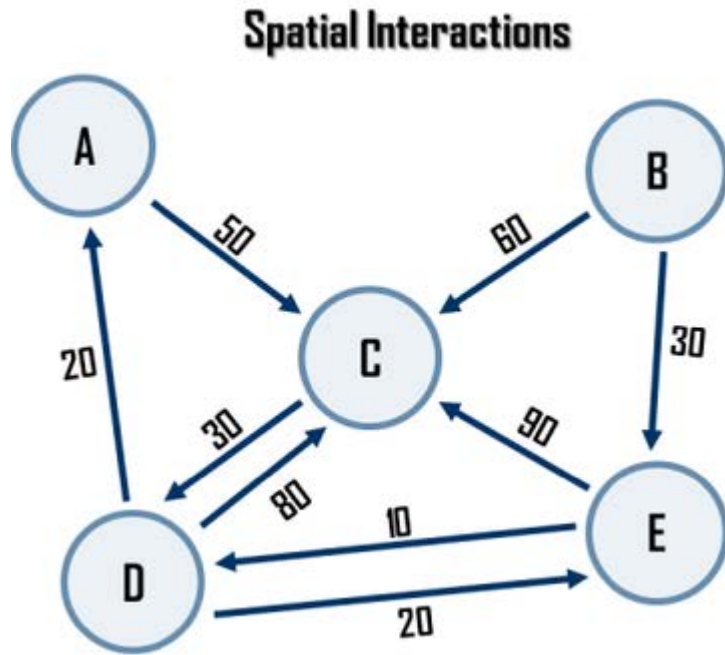
Spatial interaction data/ OD matrix
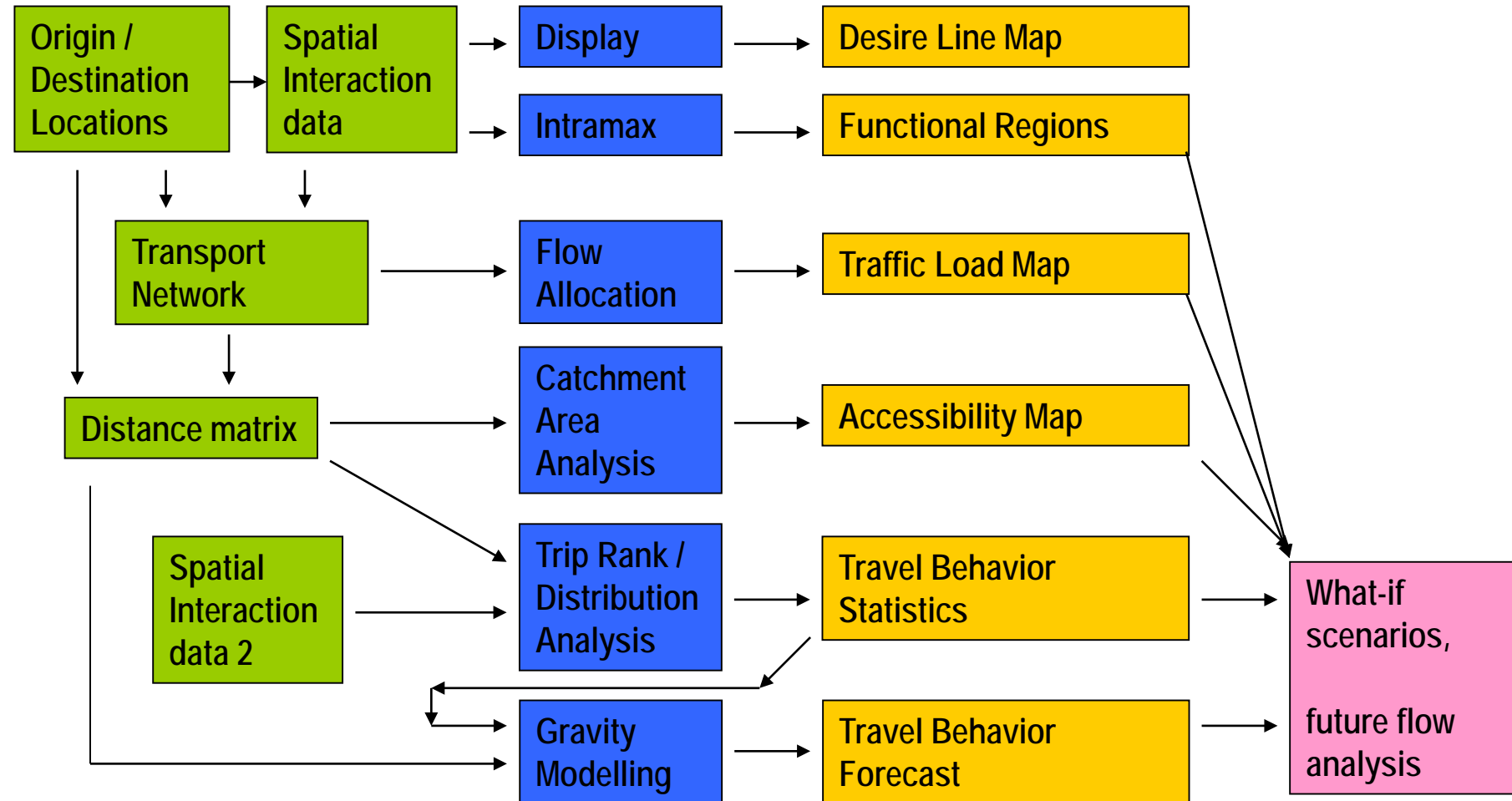
numbers as people moving between the points

- Allows us to do accessibility and flow analysis

Spatial Interactions

O/D Matrix

	A	B	C	D	E	Ti
A	0	0	50	0	0	50
B	0	0	60	0	30	90
C	0	0	0	30	0	30
D	20	0	80	0	20	120
E	0	0	90	10	0	100
Tj	20	0	280	40	50	390

Network analysis: some important methods

Networks as a core concept (CCD)

- Networks understood as quantified relations between objects
- Network quantifications can be either extensive (e.g. flow) or intensive (e.g. distance), or be on some other measurement level
- Object qualities can likewise be extensive (amount) or intensive (e.g. distance to nearest...) or be on some other measurement level
- *-> Spatial networks are more than embedded graphs!*
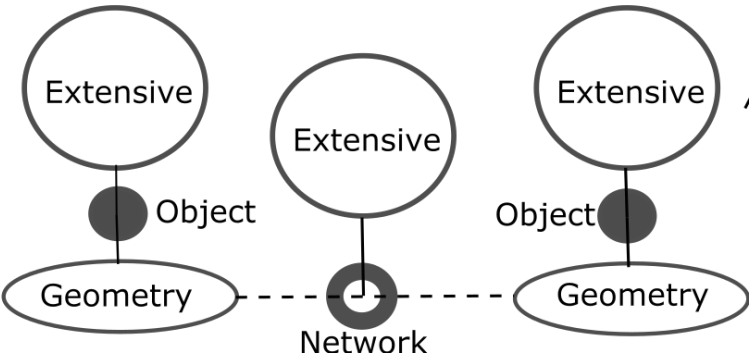
Measured quality	Unary concept	CCD type	Binary concept	CCD type
S (spatial region)	OS (object regions)	*ObjectQ RegionA/ LineA*	OSO (path network)	*NetworkQ LineA*
B (boolean quality)	OB (boolean object quality)	*ObjectQ BooleanA*	OBO (boolean network)	*NetworkQ BooleanA*
N (nominal quality)	ON (nominal object quality)	*ObjectQ NominalA*	ONO (nominal network)	*NetworkQ NominalA*
I (intensive quality)	OI (intensive object quality)	*ObjectQ IRA*	OIO (intensive network)	*NetworkQ IRA*
E (extensive quality)	OE (extensive object quality)	*ObjectQ ERA*	OEO (extensive network)	*NetworkQ ERA*

Spatial network transformations

- Methods transform between intensive/extensive object and network qualities

- For example, *catchment area methods* transform intensive network q. (*distance*) with extensive objects q. (*service potential, origins*) into intensive object qualities (*distance to the closest service*)

- And *gravity models* transform intensive network qualities (*distances*) between extensive object q. (*amount of residents*) into extensive network qualities (*flow*)
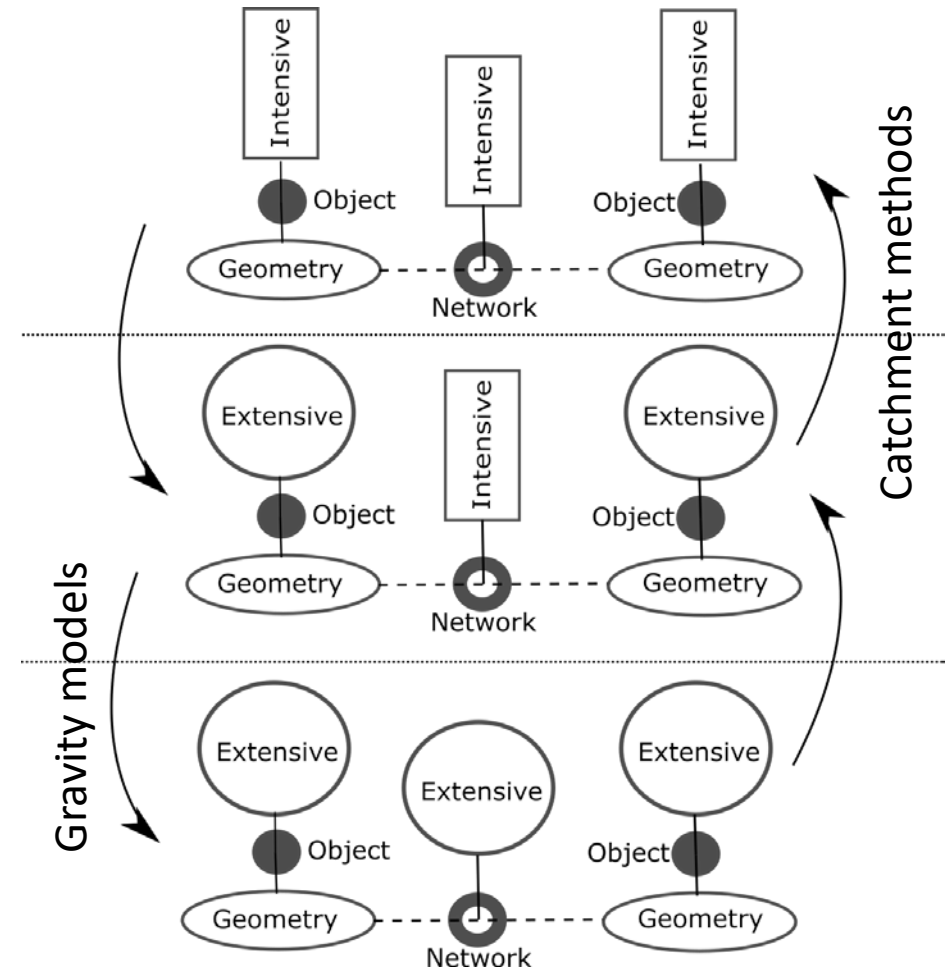
Computational diagram for spatial networks
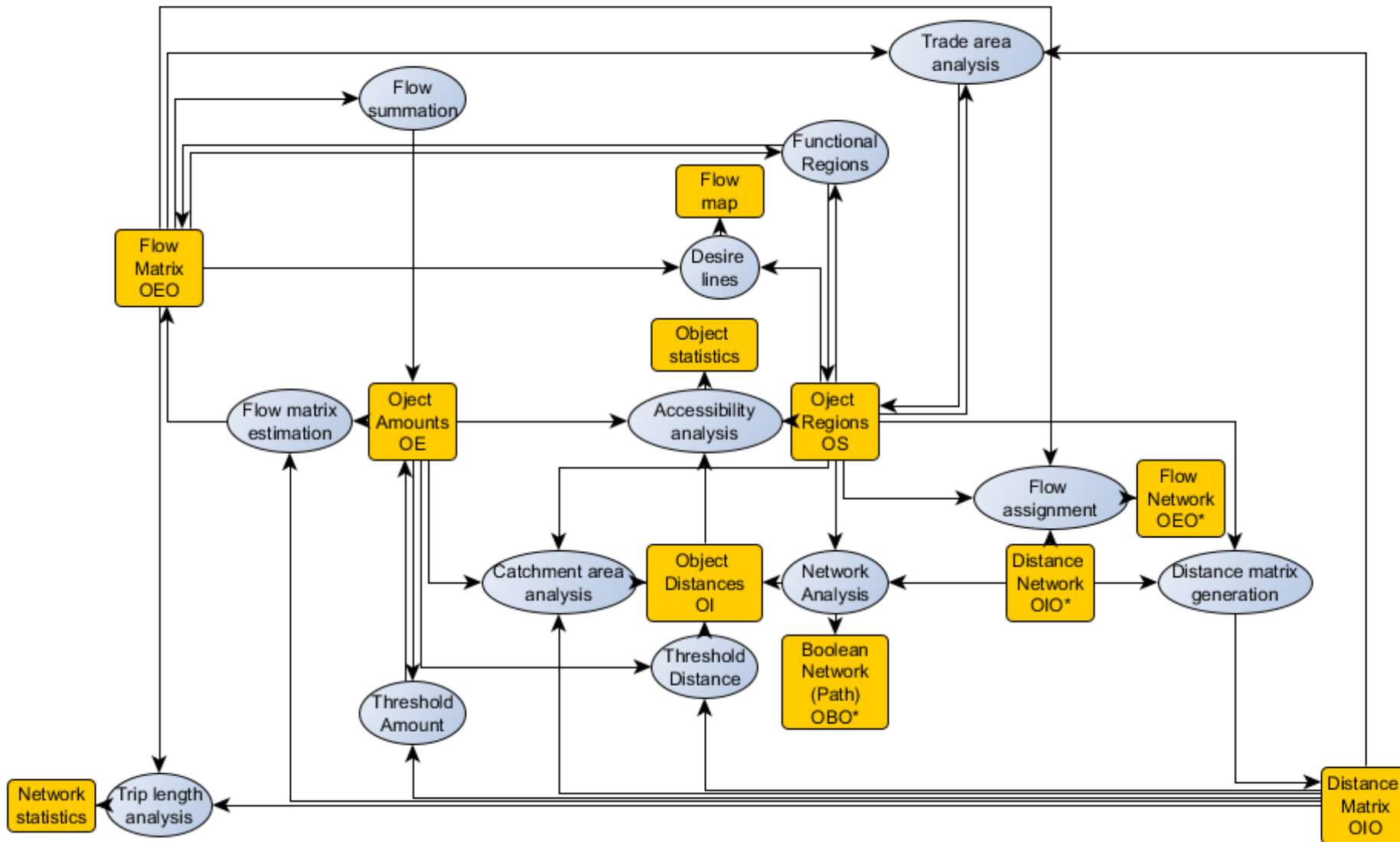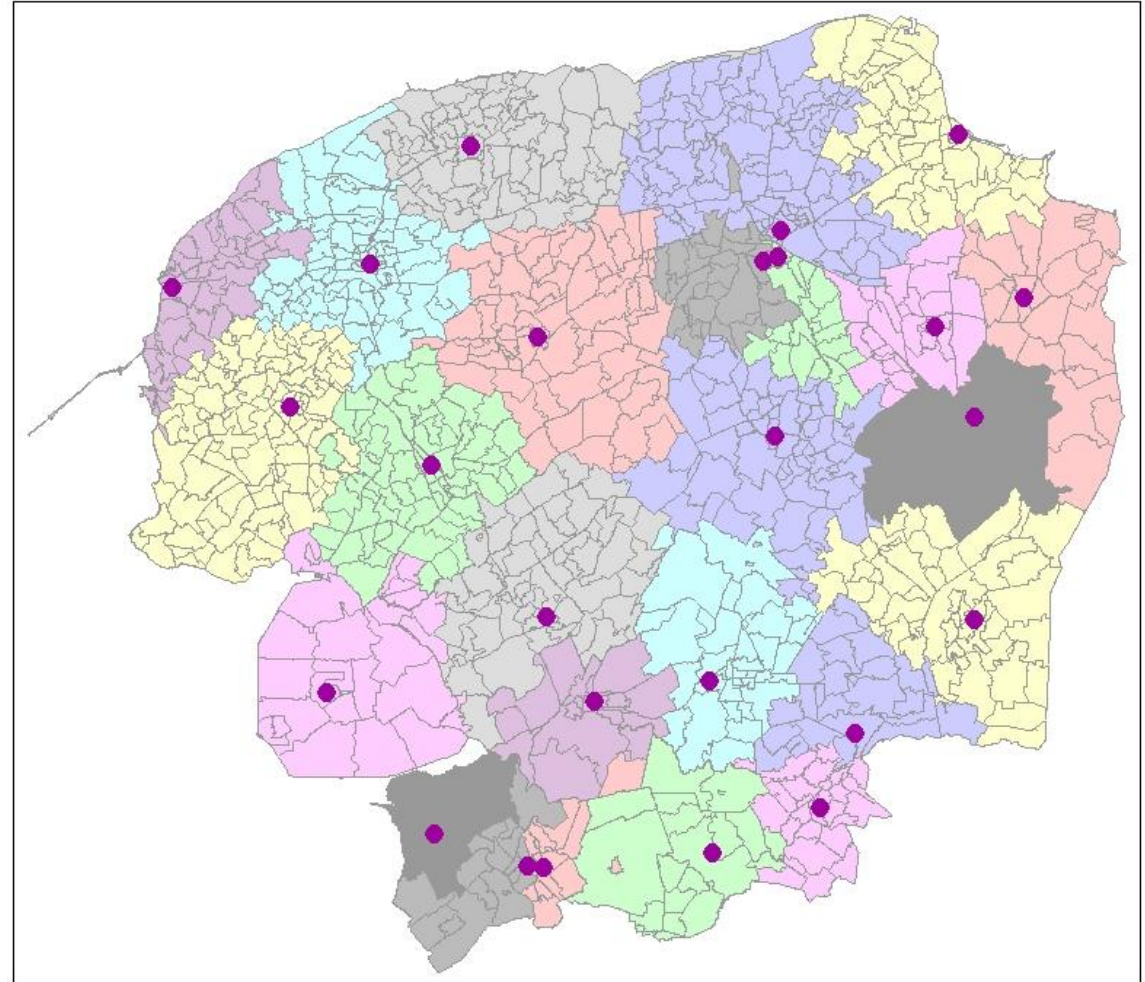
Accessibility analysis

Catchment areas of hospitals in Friesland

focus on distances again
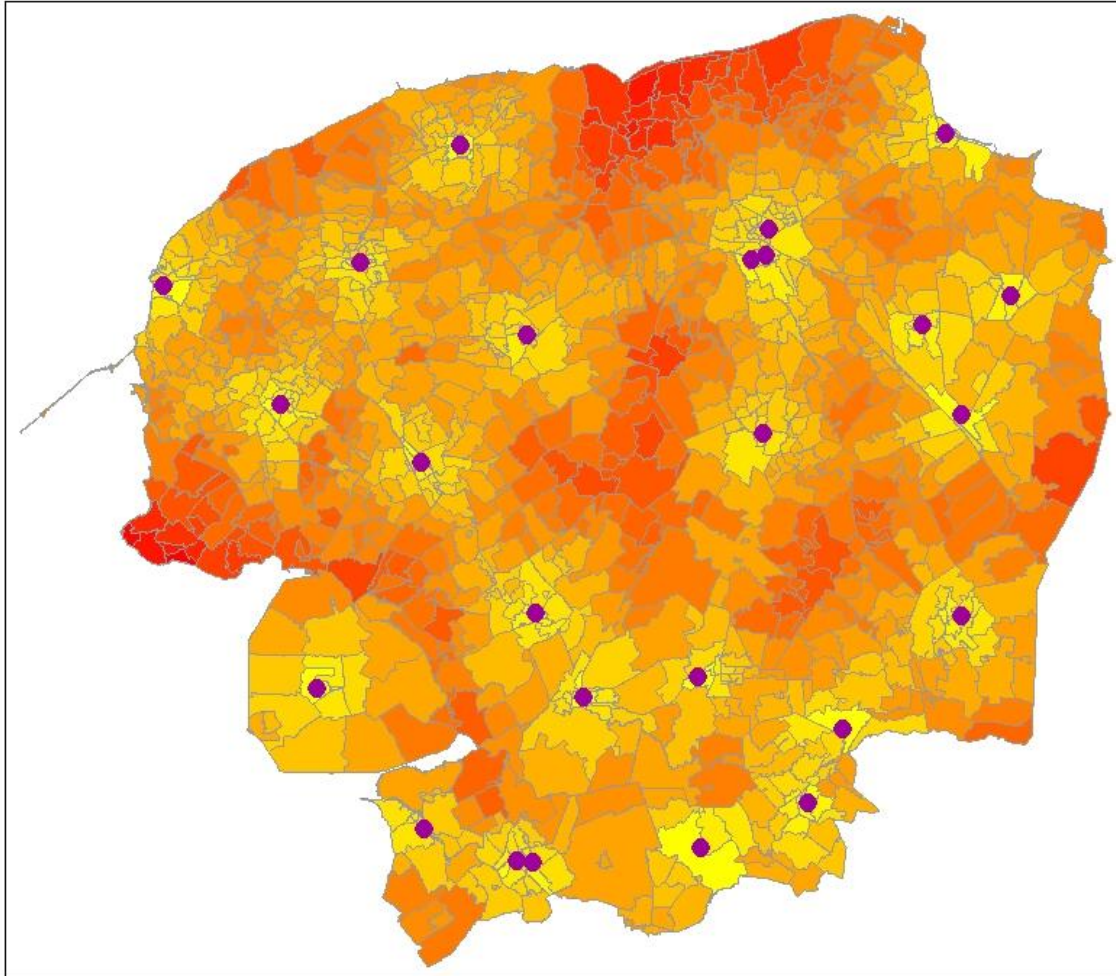
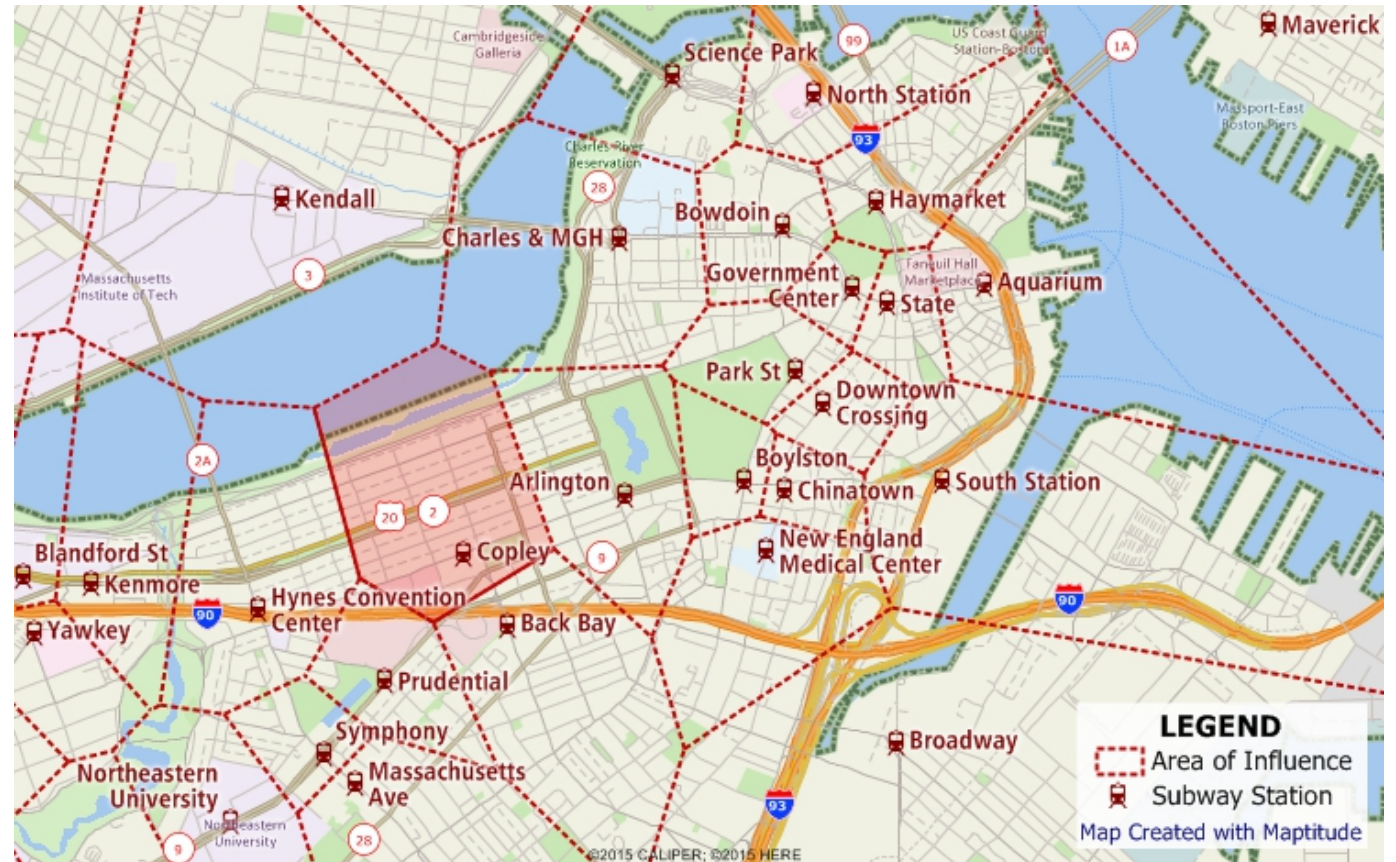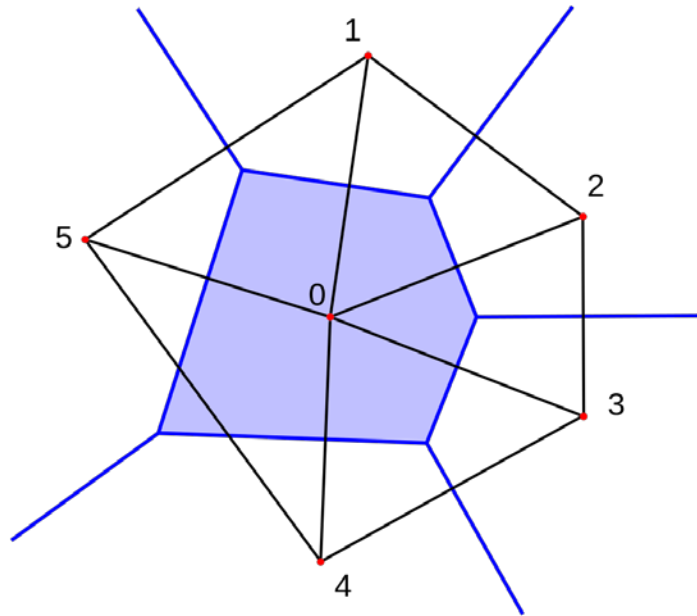municipality and where they're assigned to

red= difficult to reach

Thiessen polygons vs. Catchment areas

euclidean instead of network distances

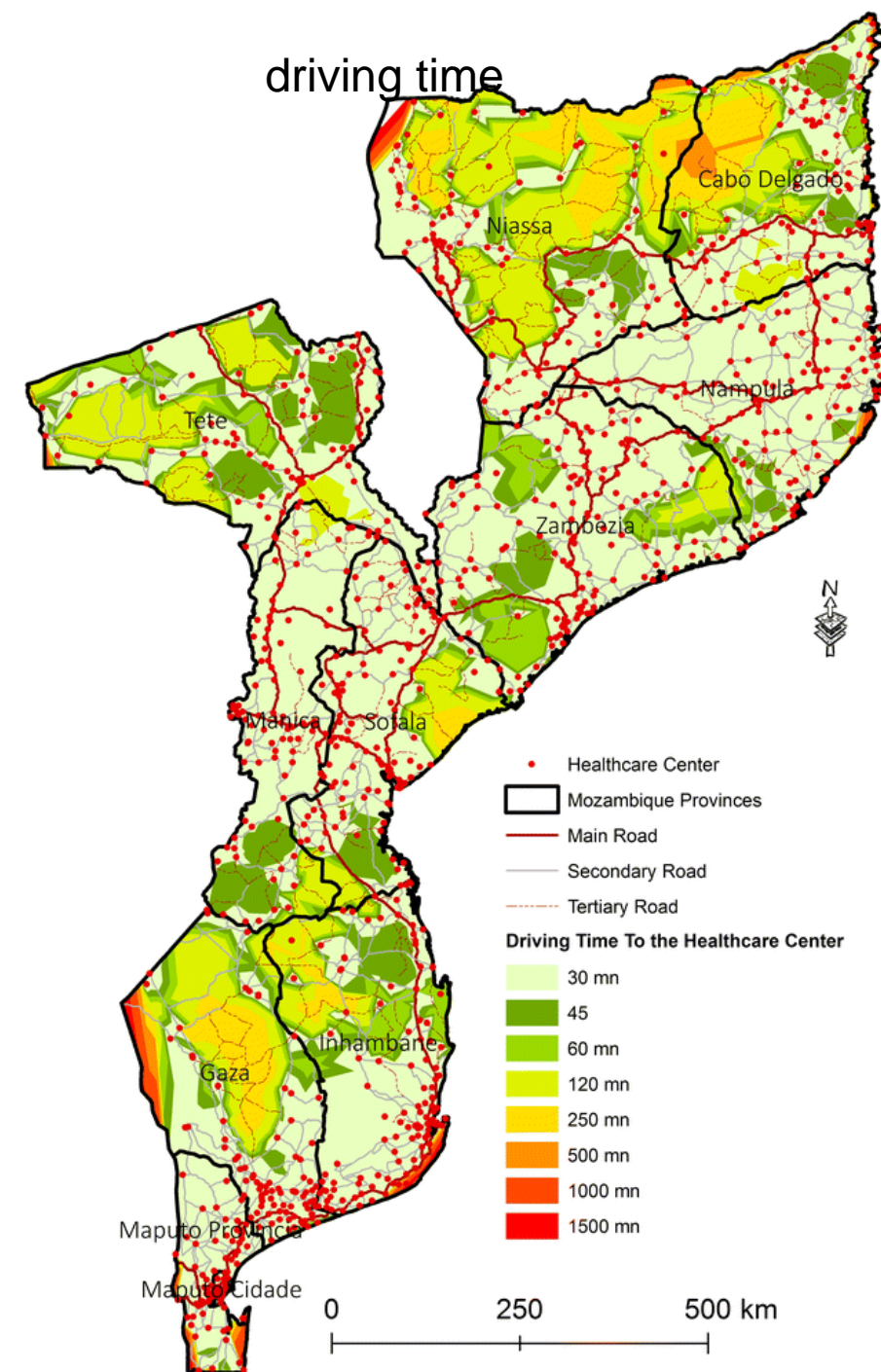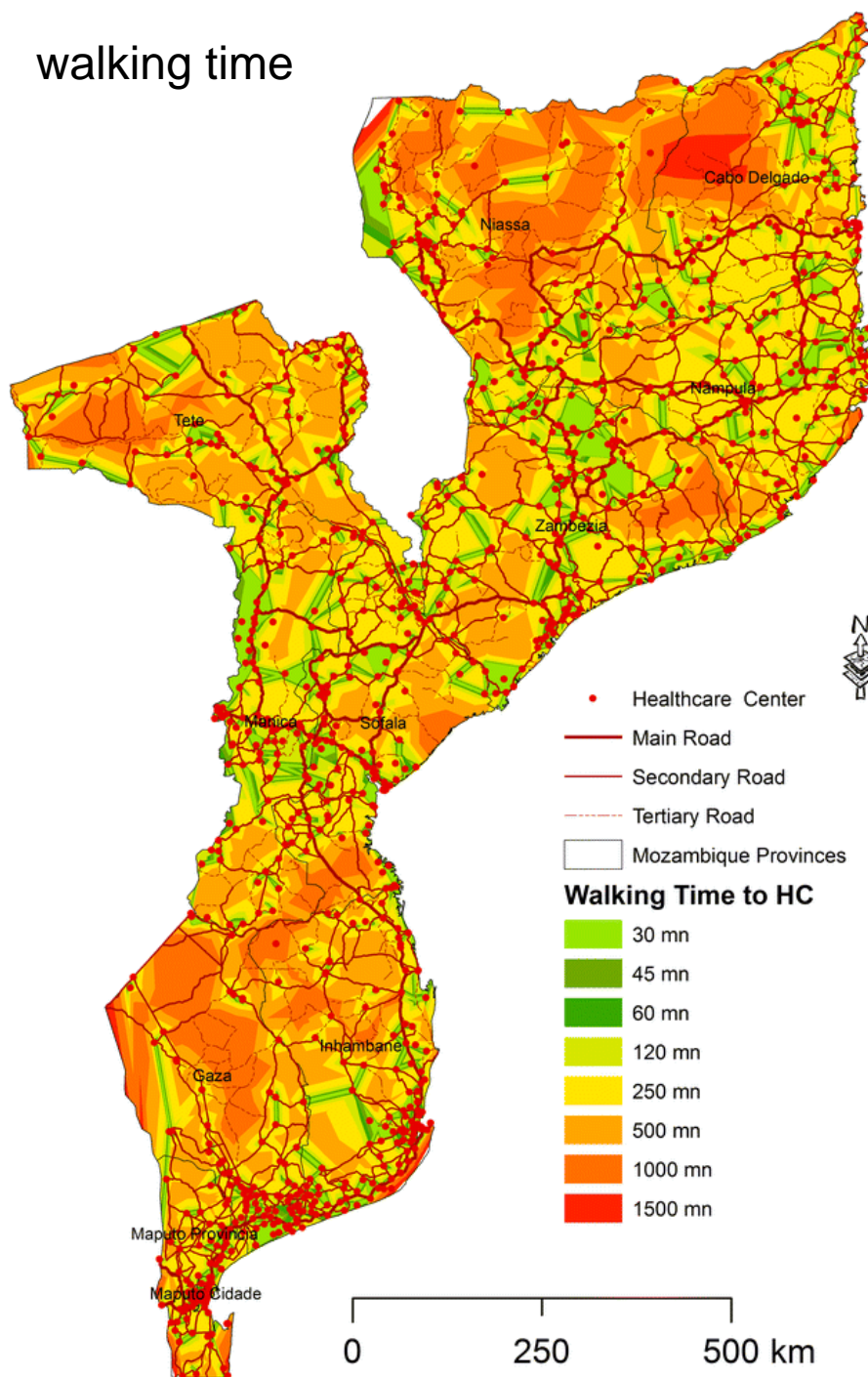problem as e.g. river cannot be crossed

(Thiessen polygons are the Euclidean version of catchment areas)

Accessibility of Health care centers in Mozambique

Luis, Cabral 2016:
Geographic accessibility to primary healthcare centers in Mozambique

walking time

driving time

Healthcare Center
Main Road
Secondary Road
Tertiary Road
Mozambique Provinces

Walking Time to HC
- 30 mn
- 45 mn
- 60 mn
- 120 mn
- 250 mn
- 500 mn
- 1000 mn
- 1500 mn

Healthcare Center
Mozambique Provinces
Main Road
Secondary Road
Tertiary Road

Driving Time To the Healthcare Center
- 30 mn
- 45
- 60 mn
- 120 mn
- 250 mn
- 500 mn
- 1000 mn
- 1500 mn

0   250   500 km

0   250   500 km

Ambulance Service Location Planning (Rijnmond)

Maximize Competition

Spatial Efficiency

Average Time: **5.7** min
Worst Case: 32 min
Customers: **67820**-174120

close to highly populated
areas

Minimize Worst Case
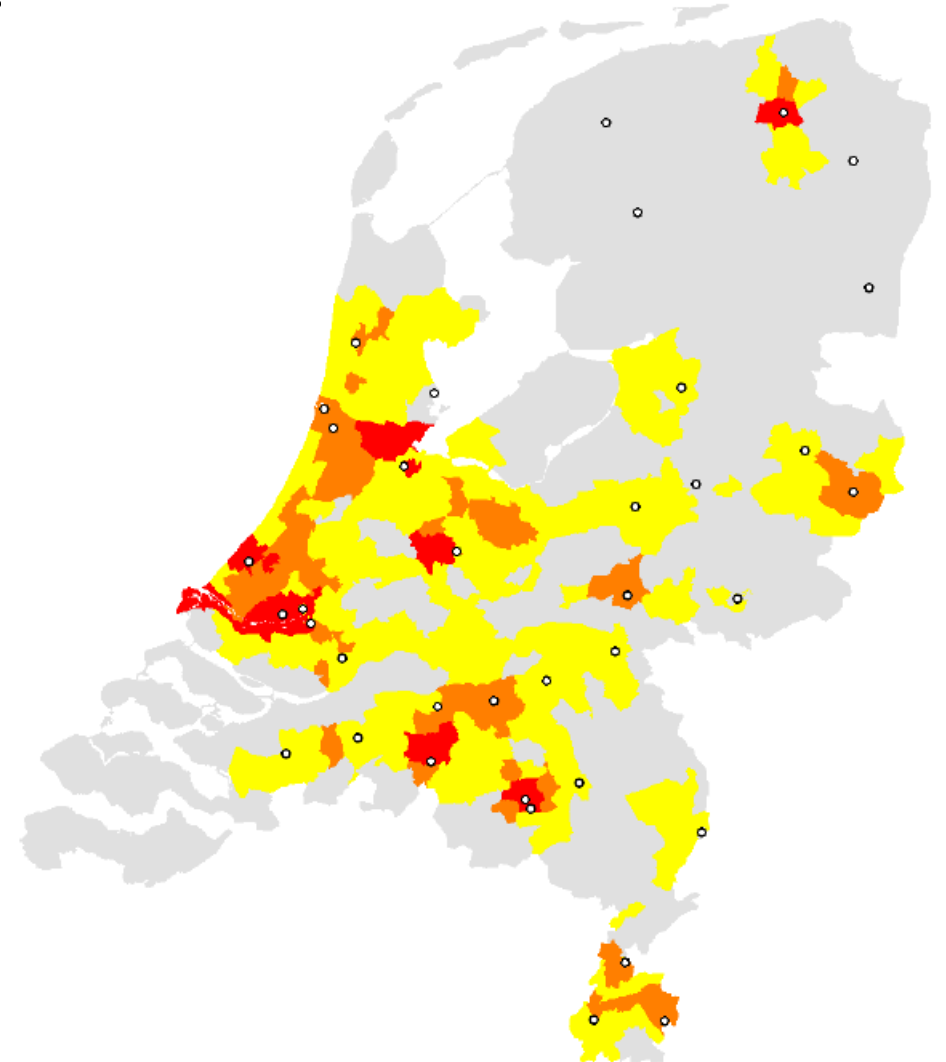
Spatial Equity

Average Time: 7.2 min
Worst Case: **12** min
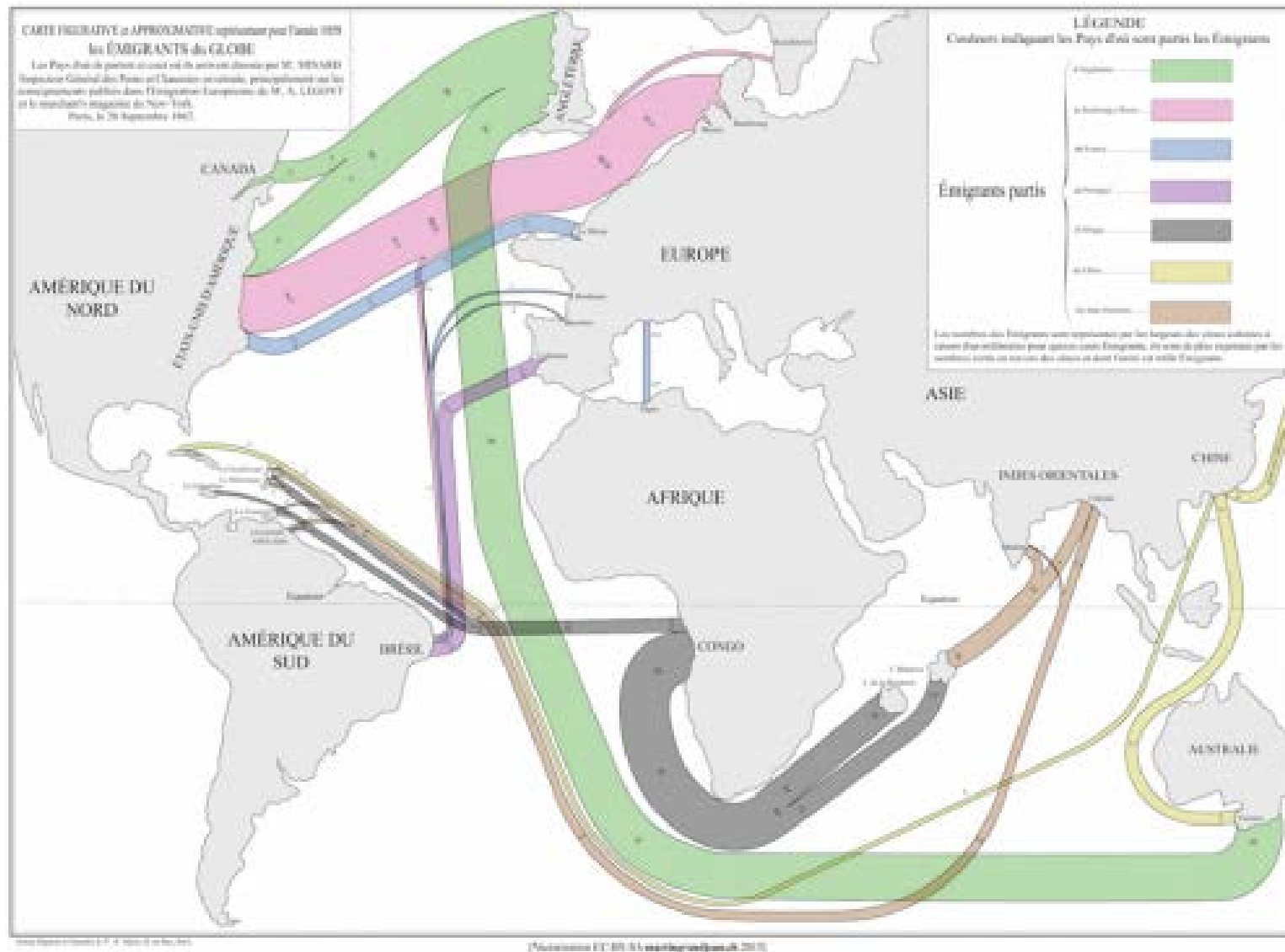Customers: 9320-376280
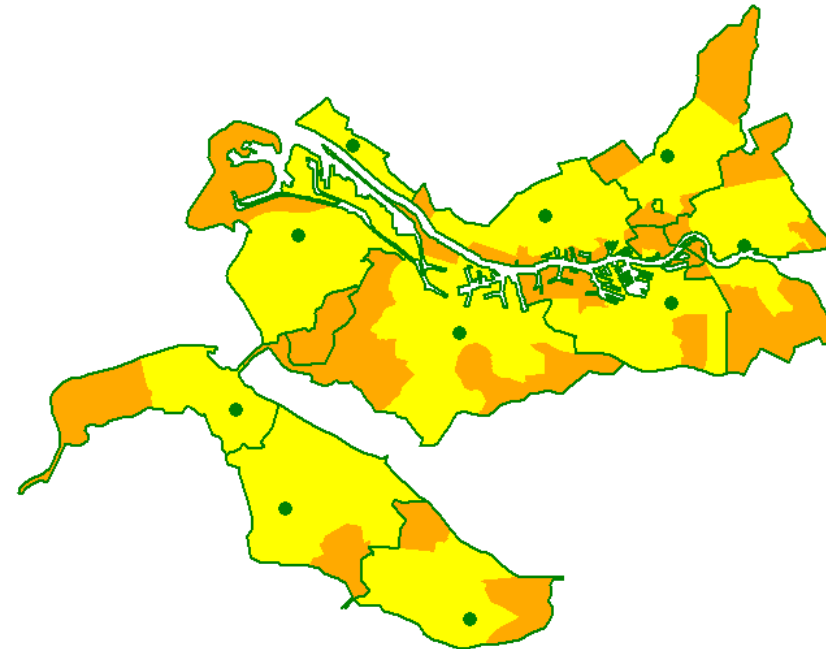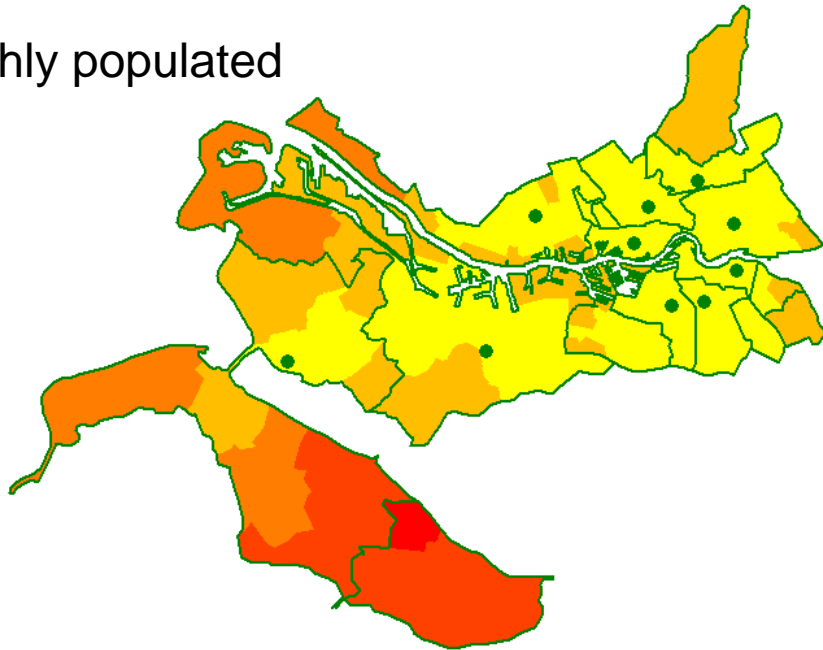
Threshold amount/distance

- Amount reachable at some maximal distance

- Distance needed to reach some minimal amount

Threshold potential map for Dutch soccer clubs.
Red: 5100 tickets within 5 minutes
Orange:.. within 10 minutes
Yellow: ... within 15 minutes

Flow analysis

Minard's 1858 map of world migration

Desire line maps =
Lines representing movement of people or goods between regions

migration patterns

The refugee project (http://www.therefugeeproject.org)

Gravity models

estimate number of people traveling a one place to another place and te distance and the number of people living at the place

- Estimate flows from object amounts and distance networks
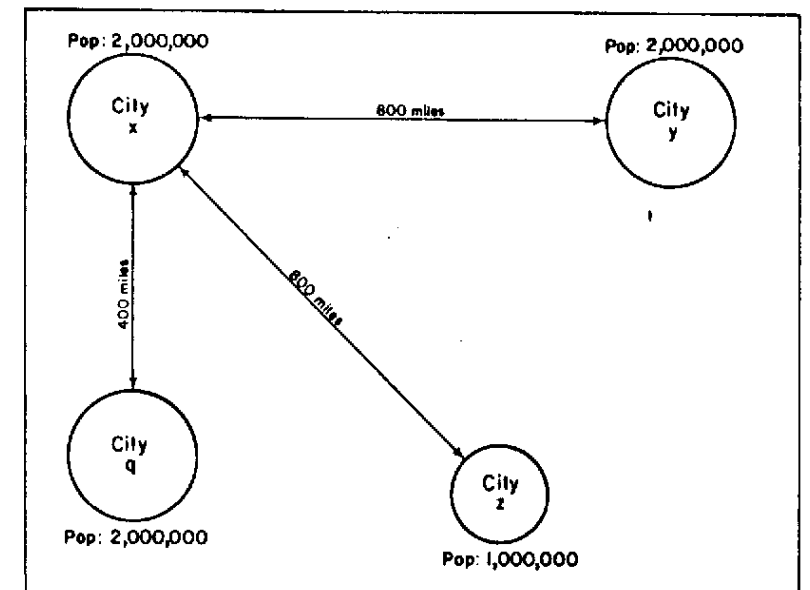 (=flow matrix estimation)
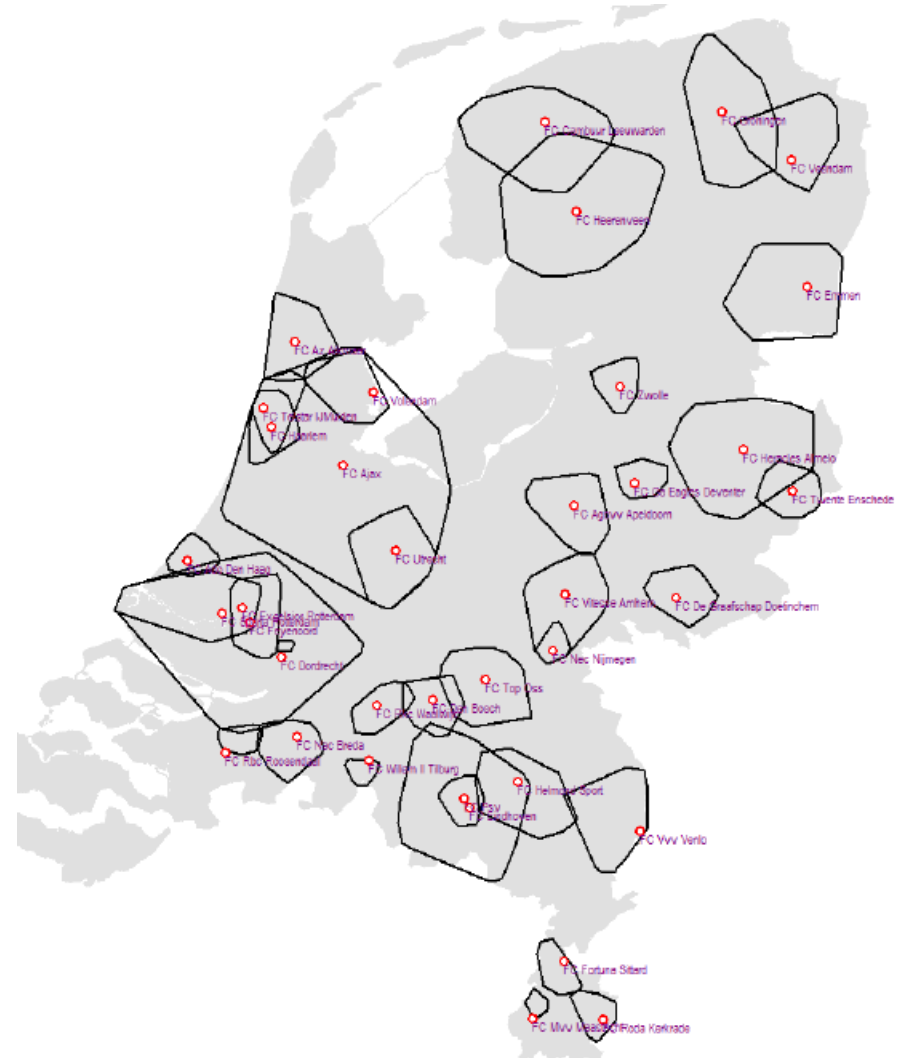
Actual Interaction

Modelled Interaction

Gravity model used to assess flows of soccer fans to Dutch soccer clubs
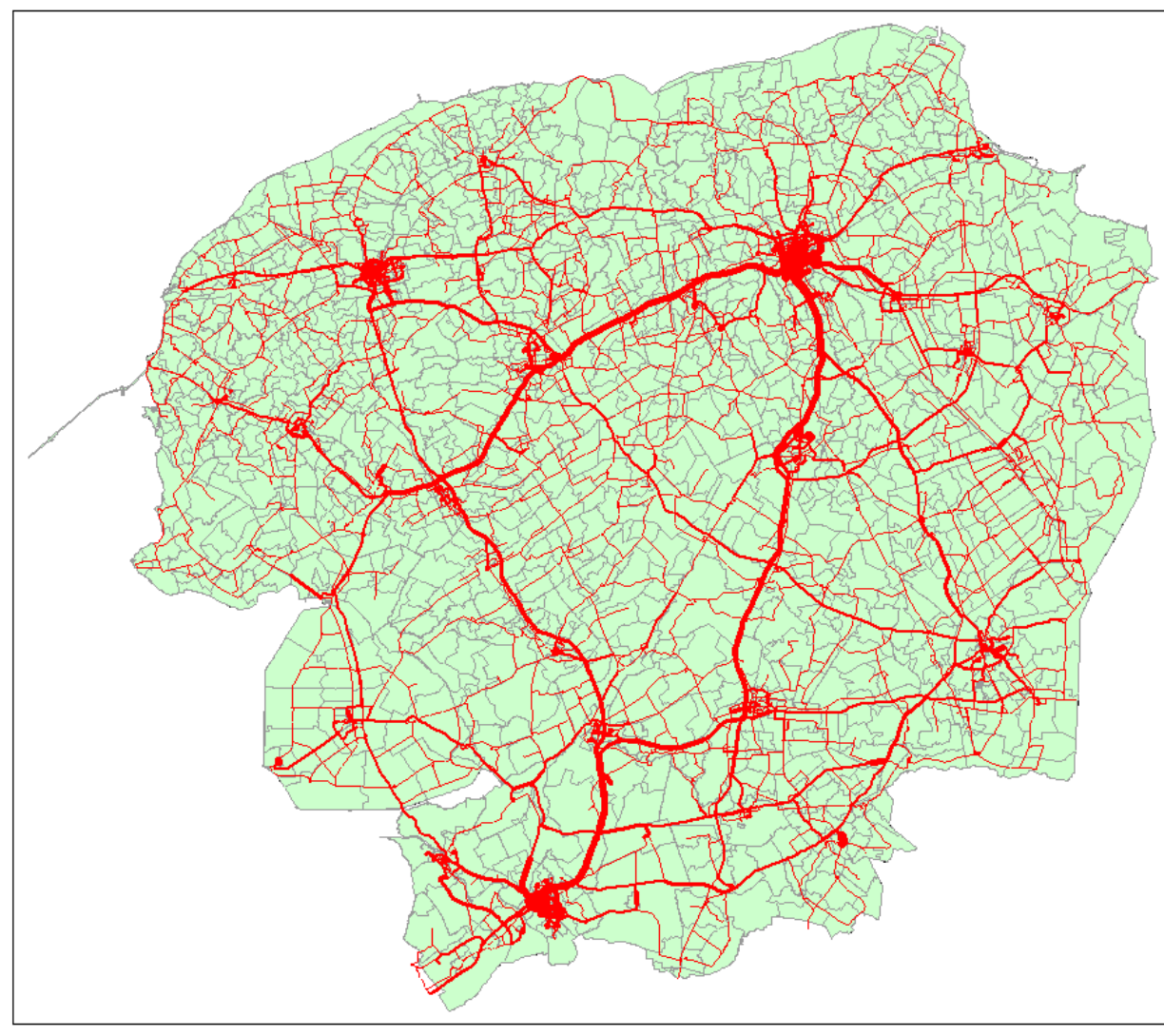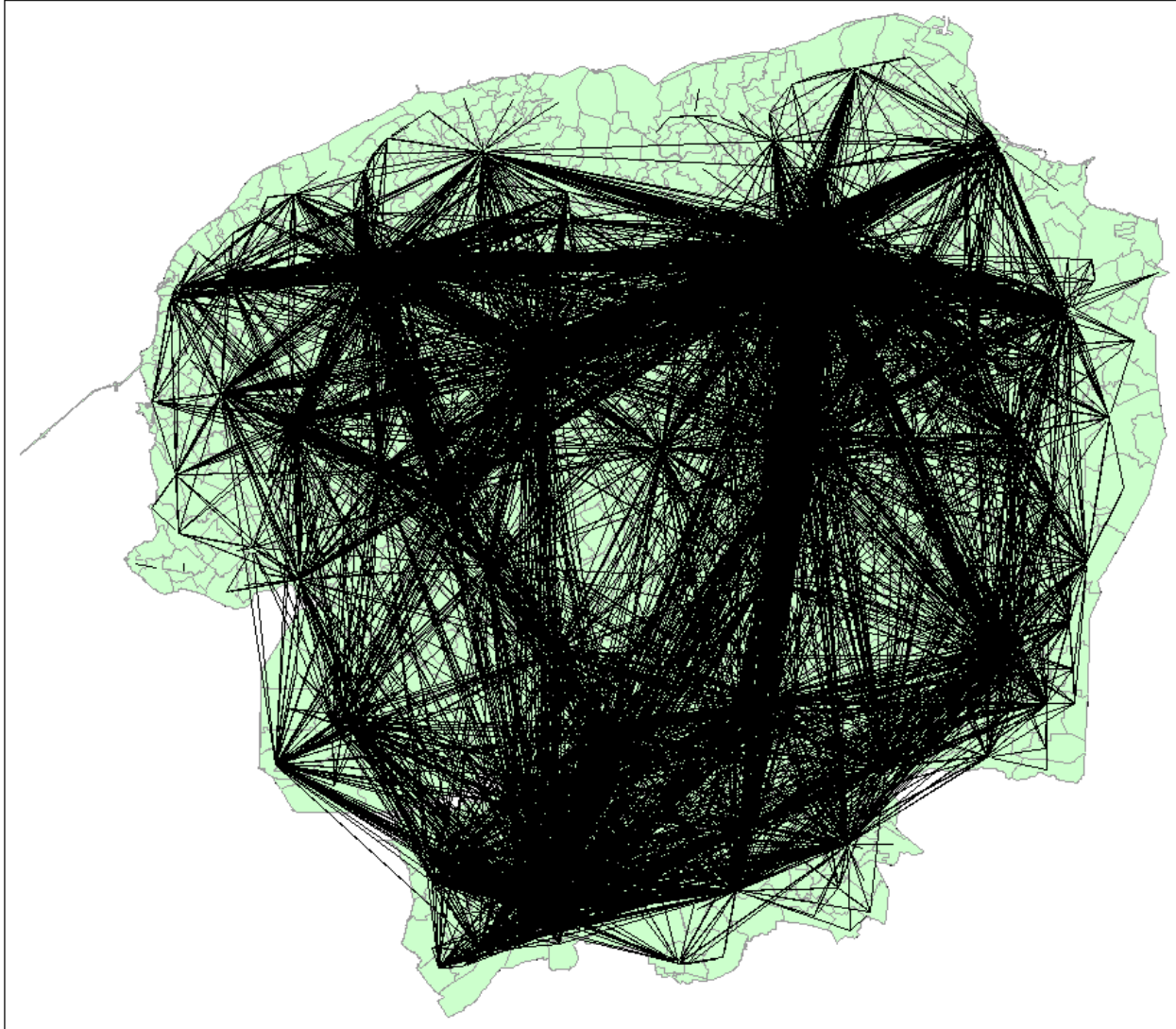
Trade area analysis

- Trade areas are regions encompassing some percentage of the overall flow towards a service center.

- For example, the areas with the nearest 60% of all trips
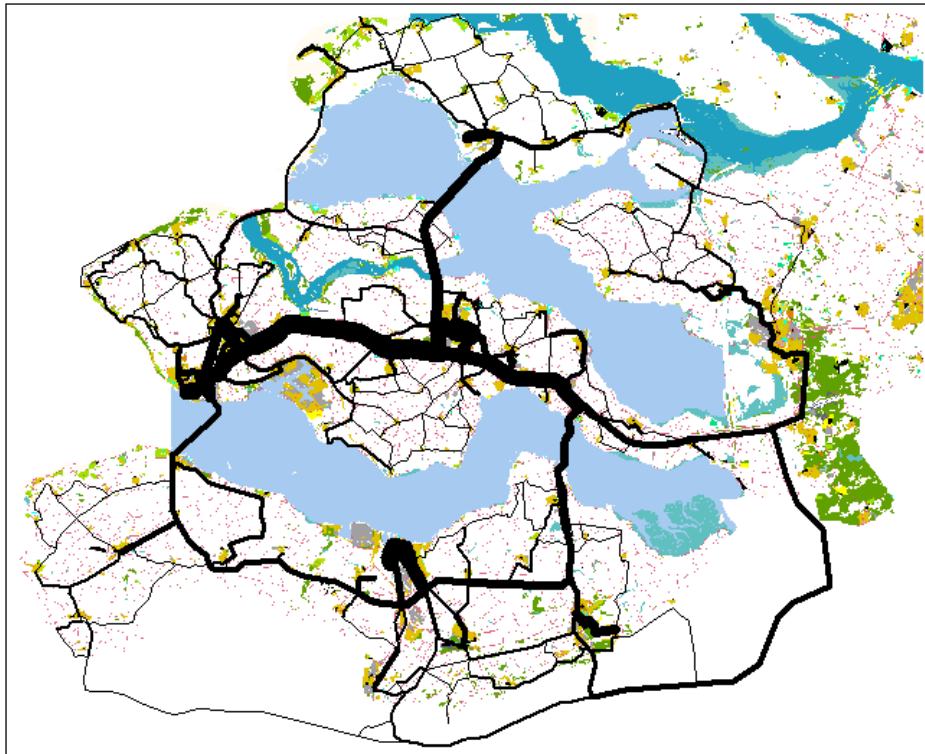
Flow assignment in Friesland

Flow Assignment in Zeeland
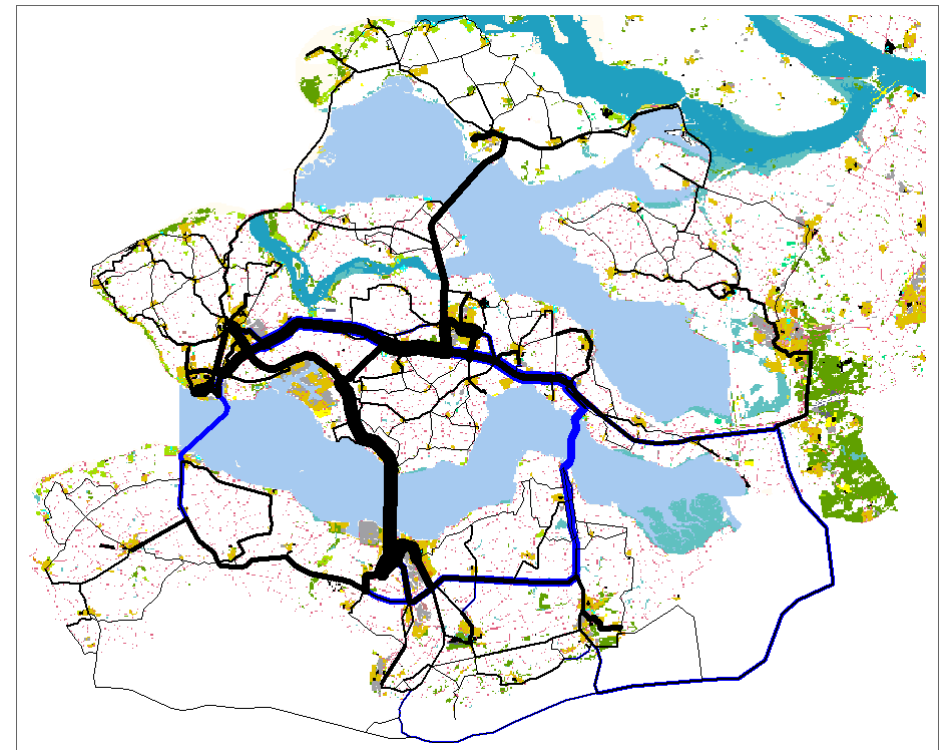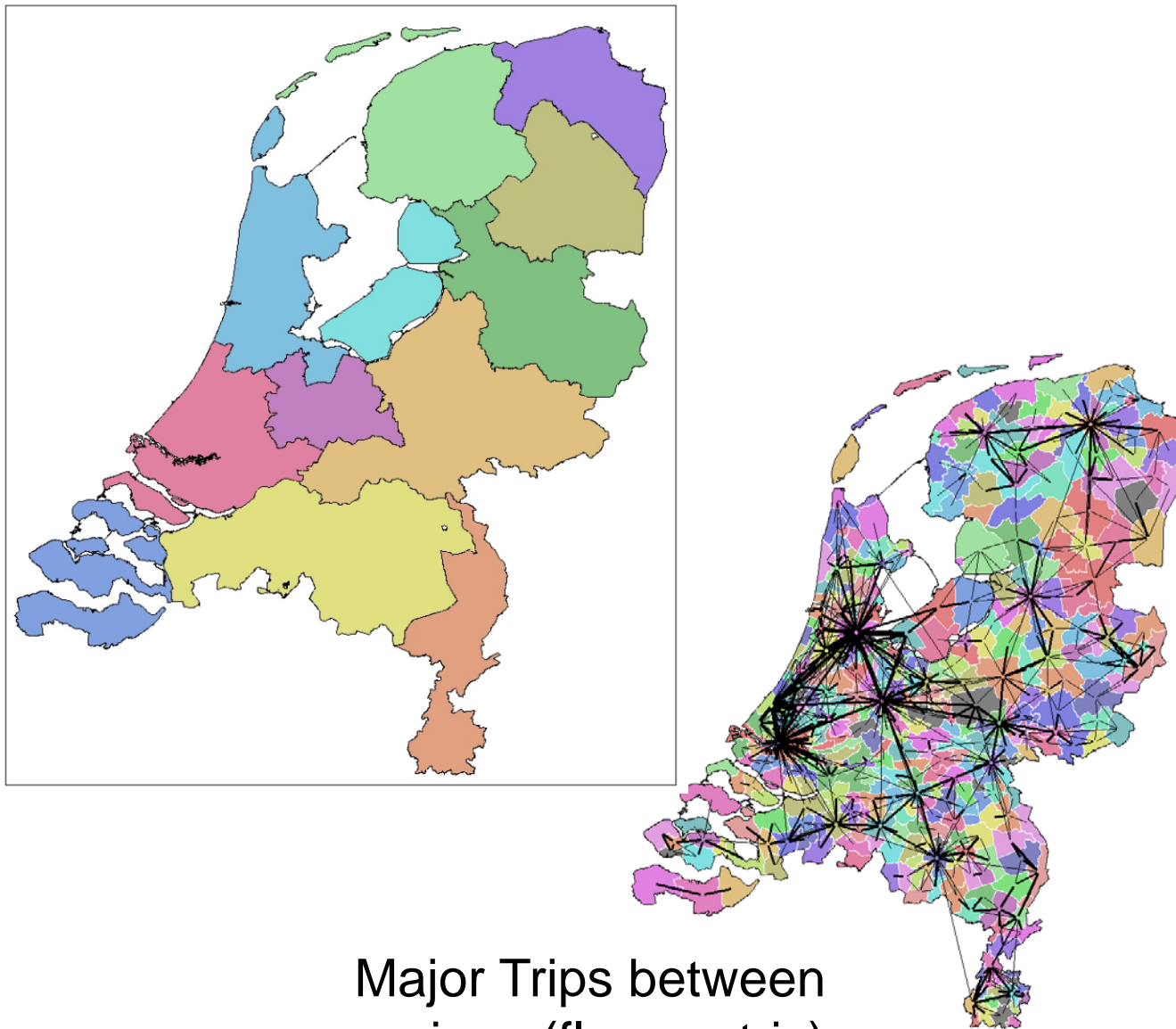## Effect of Westerschelde Tunnel on Commuter flows

Before   Tunnel   After
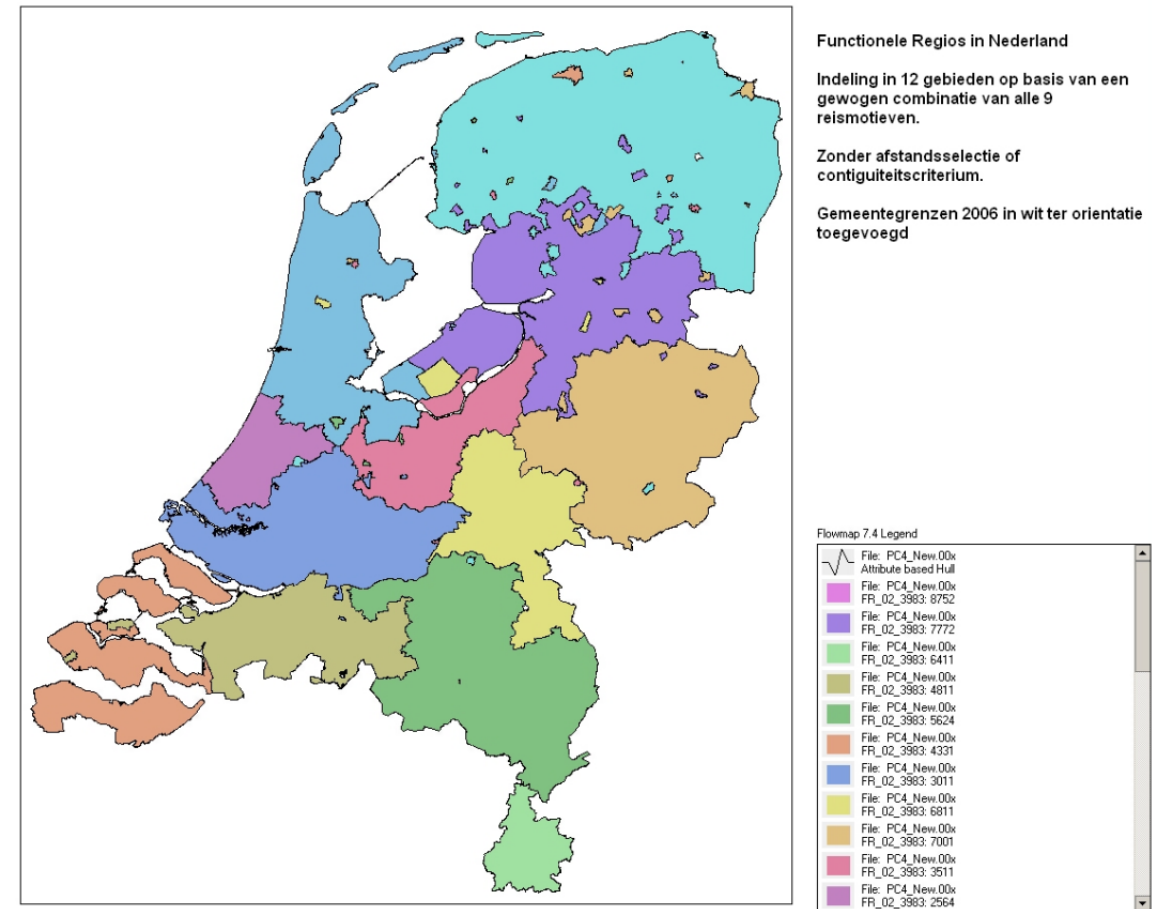

once the tunnel is constructed

Functional regions of the Netherlands (based on flow matrix)

Functionele Regios in Nederland

Indeling in 12 gebieden op basis van een gewogen combinatie van alle 9 reismotieven.

Zonder afstandsselectie of contiguiteitscriterium.

Gemeentegrenzen 2006 in wit ter orientatie toegevoegd

Major Trips between regions (flow matrix)

[Geertman et al 2003]

Questions?
(online Q&A session)

http://flowmap.geo.uu.nl/
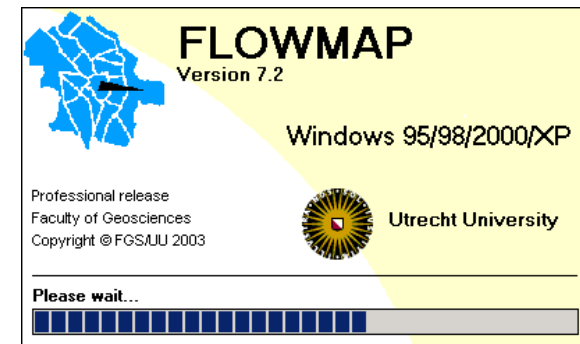
References

- Geertman, Stan, Tom de Jong, and Coen Wessels (2003). "Flowmap: A support tool for strategic network analysis." *Planning support systems in practice*. Springer Berlin Heidelberg. 155-175

- Burrough, P. A., & McDonnell, R. A. (1998). Principles of Geographical Information Systems. Oxford University Press. Chapter 6.5 Network Analysis, http://www.gdmc.nl/oosterom/PoGISHyperlinked.pdf

- Ingram, D.R., (1971). The concept of accessibility: a search for an operational form. Re-gional studies, 5 (2), 101–107.

- Moseley, M.J., (1979). Accessibility: the rural challenge. Technical report.