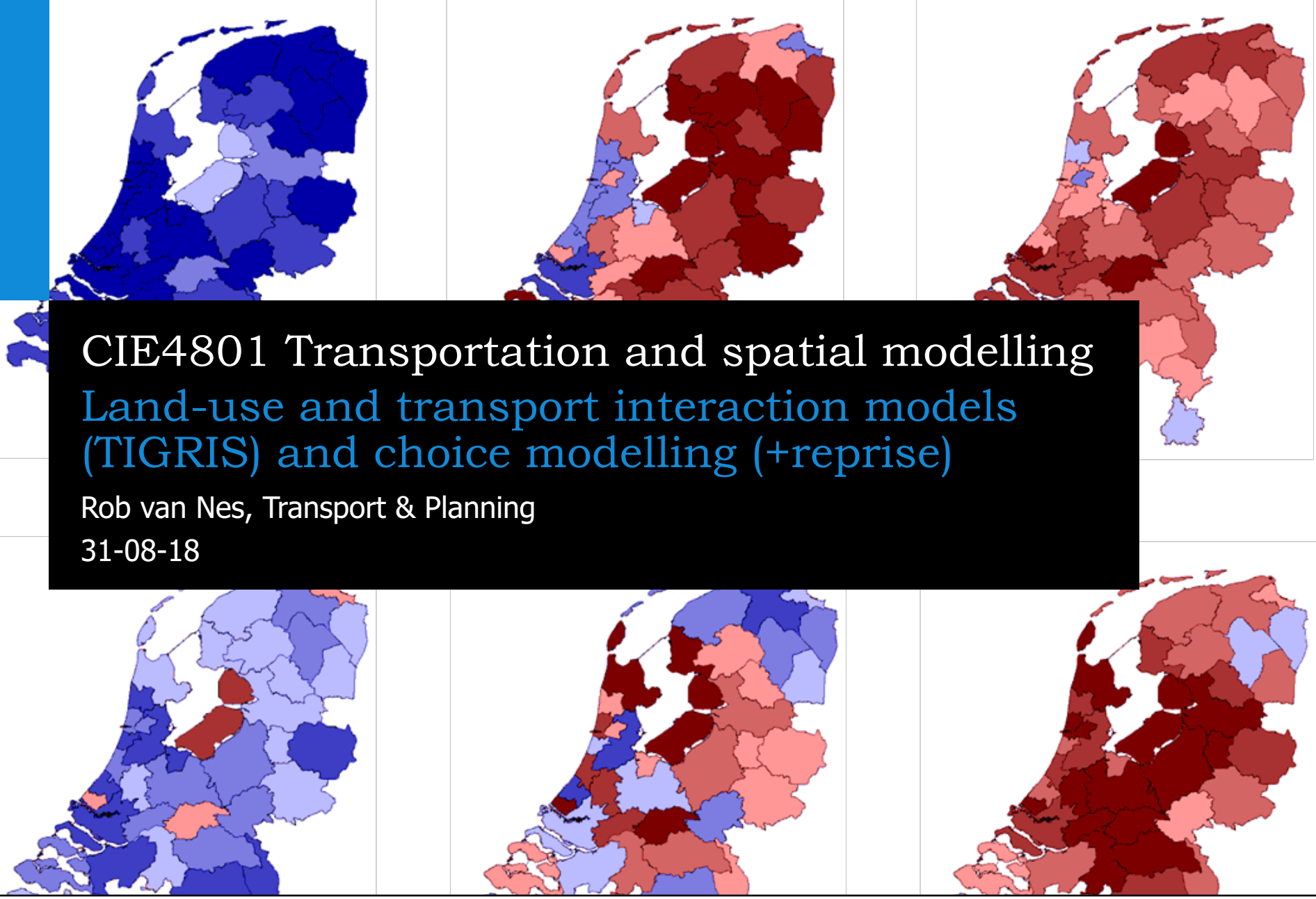


CIE4801 Transportation and spatial modelling

Land-use and transport interaction models (TIGRIS) and choice modelling (+reprise)

Rob van Nes, Transport & Planning

31-08-18

Content

- Land-use and transport interaction models (LUTI)
  - TIGRIS (Schoemakers & Van den Hoorn)
  - TIGRIS XL (Zondag & De Jong)
  - TIGRIS XL Applications
- Choice modelling for land-use
  - Firm location behaviour (De Bok)
  - Household location behaviour (Blijie & De Vries)
- Circle of Wegener revisited

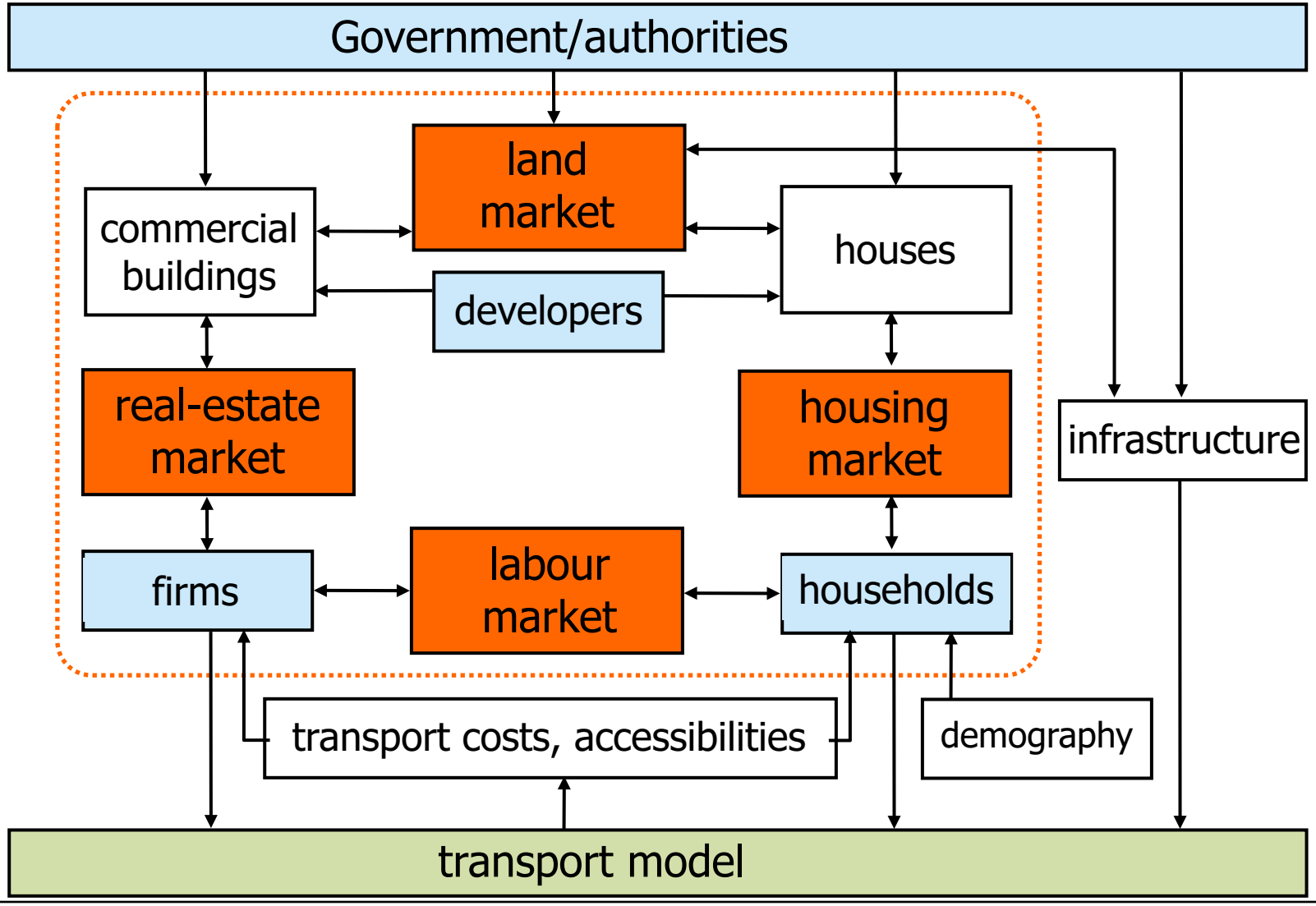
2.1

Land-use and transport interaction models

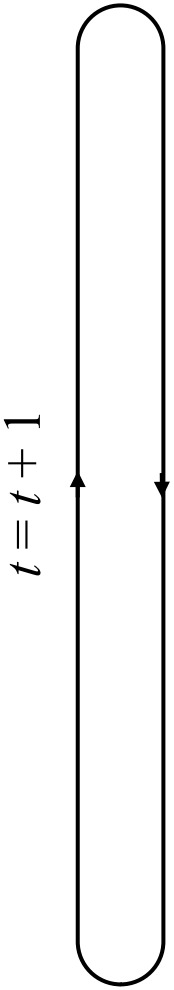
Integration of land-use models and transport models

- Circle of Wegener implies that transport models and spatial models should be integrated
- Simplest combination is a transport model combined with e.g. a Lowry model
- However, spatial modelling is not as straightforward as a Lowry-model…….

LUTI models: Framework



Land-use model structure (e.g. UrbanSim)



Accessibility model
determines the accessibility level, depending on transport model outcomes

Demographic & economic transition model
determines creation or loss of households and jobs

Household & employment mobility model
determines if households and jobs are moving within the region

Household & employment location model
determines the location choices of households and jobs from available vacant real-estate

Real-estate development model
determines the type, location, and quantity of new construction by developers

Where does the transport model fit in?

Land price model
determines the price of land at each location

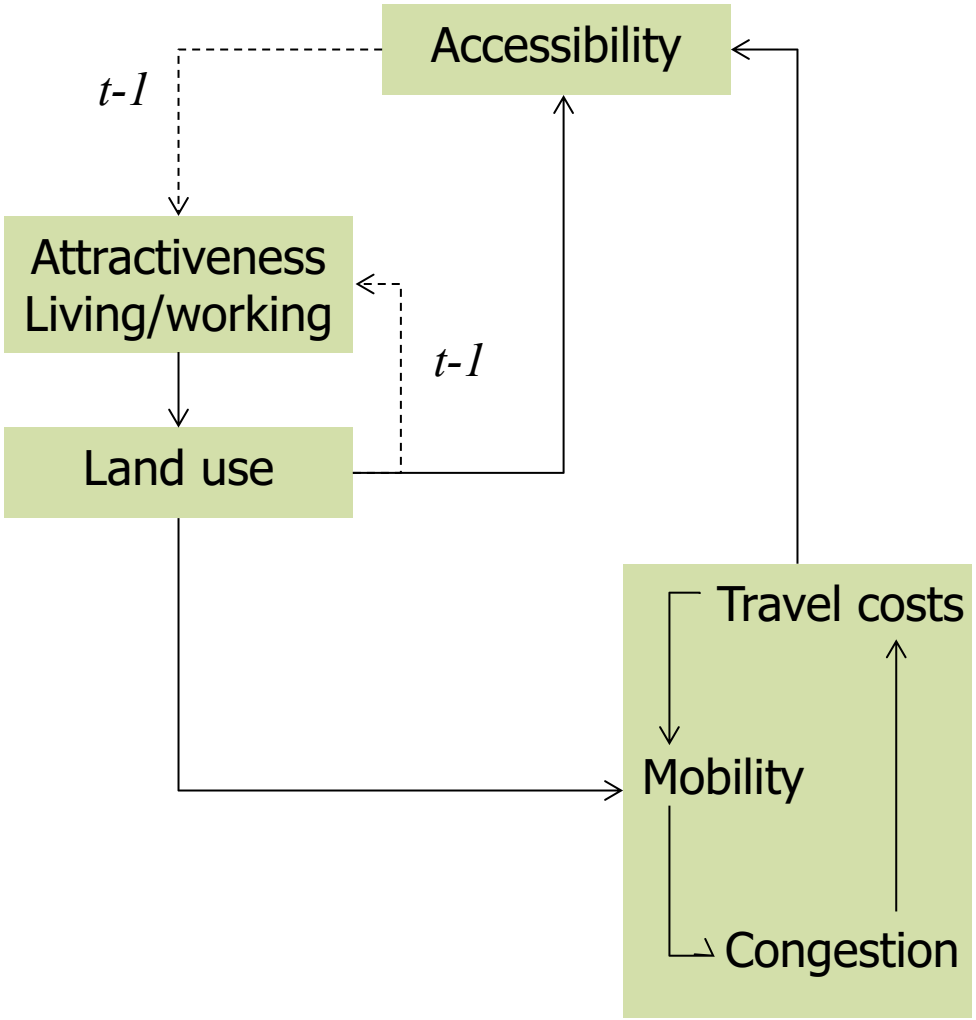
2.2

TIGRIS and TIGRIS XL

TIGRIS

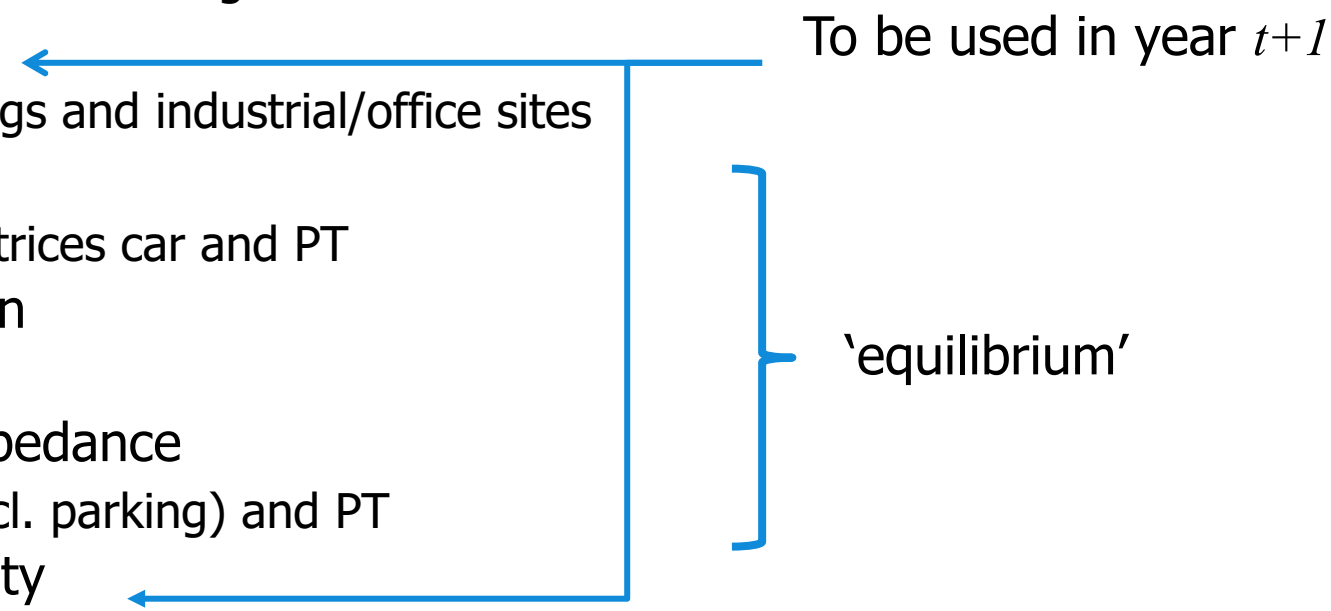
- Transport Infrastructure Land-use ('Grondgebruik') Interaction Simulation
- Developed in the 90's
- Primarily based on expert judgement
  - Model structure as well as parameters
- Meant to be a sketch-planning model
  - GIS-based, incremental development (year by year), dashboard

TIGRIS: Flow chart

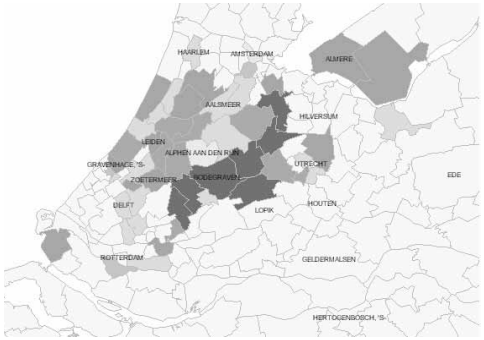


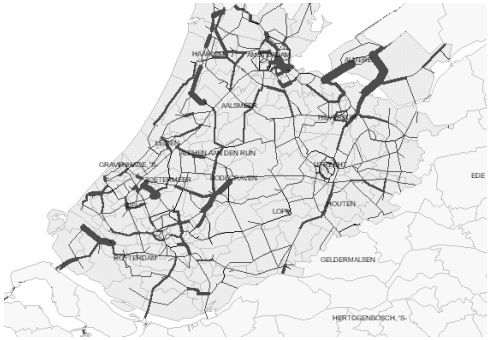
TIGRIS: Submodels

- Attractiveness of a zone
  - Living and working
- Land-use
  - Dwellings and industrial/office sites
- Mobility
  - OD matrices car and PT
- Congestion
  - Car
- Travel impedance
  - Car (incl. parking) and PT
- Accessibility
  - Amenities, population, jobs



TIGRIS: Applications





- Four applications
  - Randstadrail
  - Leiden-Haarlem-Amsterdam
  - Arnhem-Nijmegen
  - Randstad: Urbanisation beyond 2030
- Primarily used as an explorative model
  - Unclear role in planning processes
- Evaluation
  - Not state of the art (no choice modelling)
  - Not tailored to the questions in practice (e.g. link with economic analyses)

TIGRIS XL: Modelling approach

- Dynamic spatial allocation model
  - Accessibility influences location choice
- Simulates annual changes
  - However, transport data is updated once every 5 years
- Uses aggregate zones, no detailed spatial data

- Determines effects of infrastructure concepts on land use
- Determines effects of spatial planning on transportation
- Used for policy development, not for evaluation

- See also PhD-Thesis B. Zondag (2007), Chapter 5:
  http://repository.tudelft.nl/view/ir/uuid%3A9378cee6-aeae-4e50-88de-a546681a42b3/

TIGRIS XL: inputs and output

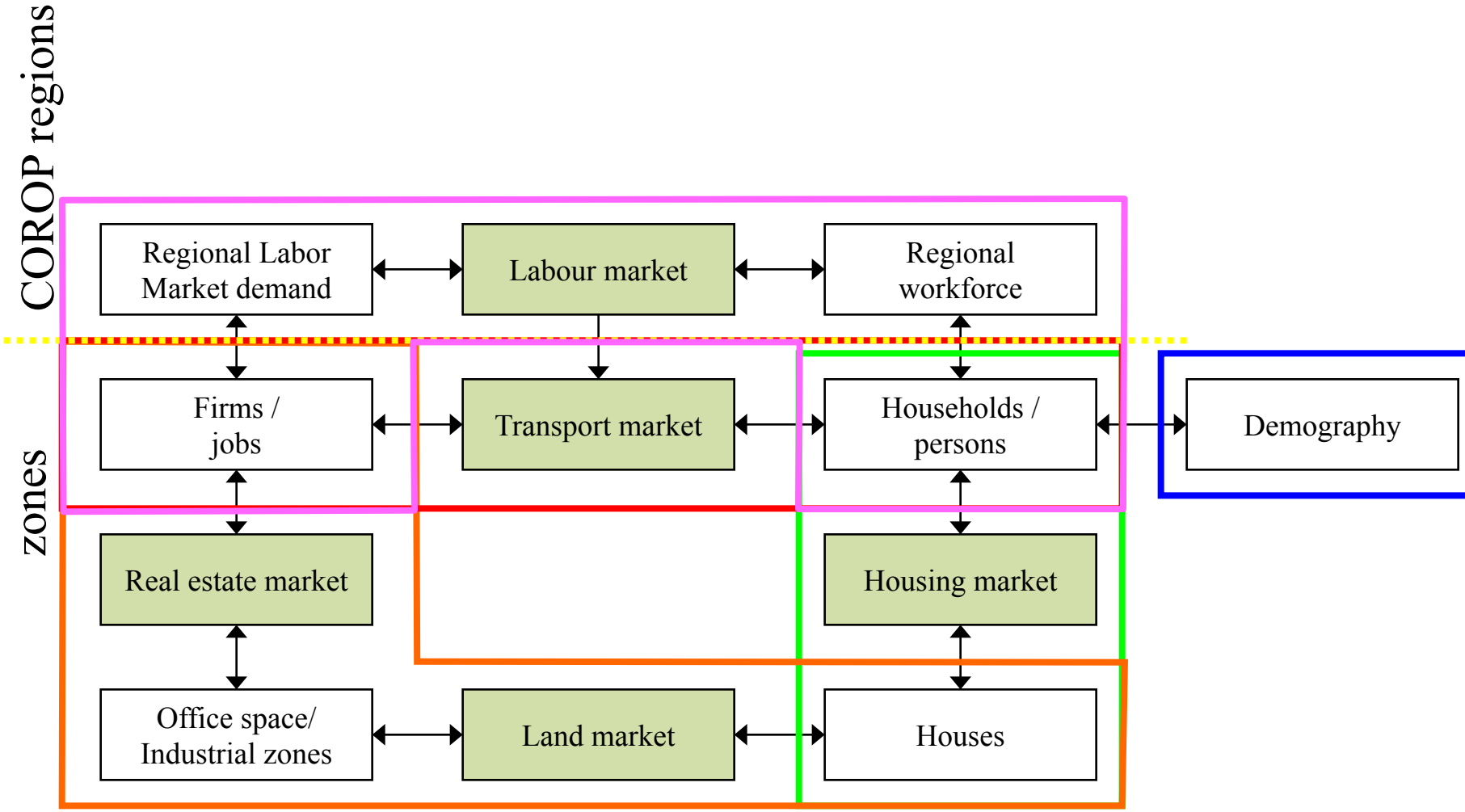
INPUT

- zones
- inhabitants
- car ownership
- employment levels
- services
- captives and non-captives
- population growth factors
- spatial development policies
- coarse infrastructure network

OUTPUT

- households by type
- employment by type
- real-estate development
- real-estate prices
- trips
- travel times
- safety & environment

Functional design of TIGRIS XL



Modules TIGRIS XL

- **Demography** - Module addressing basic demographic developments: aging, mortality, birth, income, migration
- **Land-use and real estate market** - Simplistic, excludes role of land-owners and project developers. Different policies are possible. Real estate market translates land use in number of new houses
- **Housing market** - Behavioral choice models estimated on housing market survey
- **Labour market** – Regression model, calibration on period 1986-2000
- **Transport module** - Integration of land-use modules with LMS (NMS)

Land and real estate market: role of government

TIGRIS XL can model different levels of government influence on the spatial development:

- **Regulated development ('directed allocation')**

  Spatial developments can only take place on planned locations

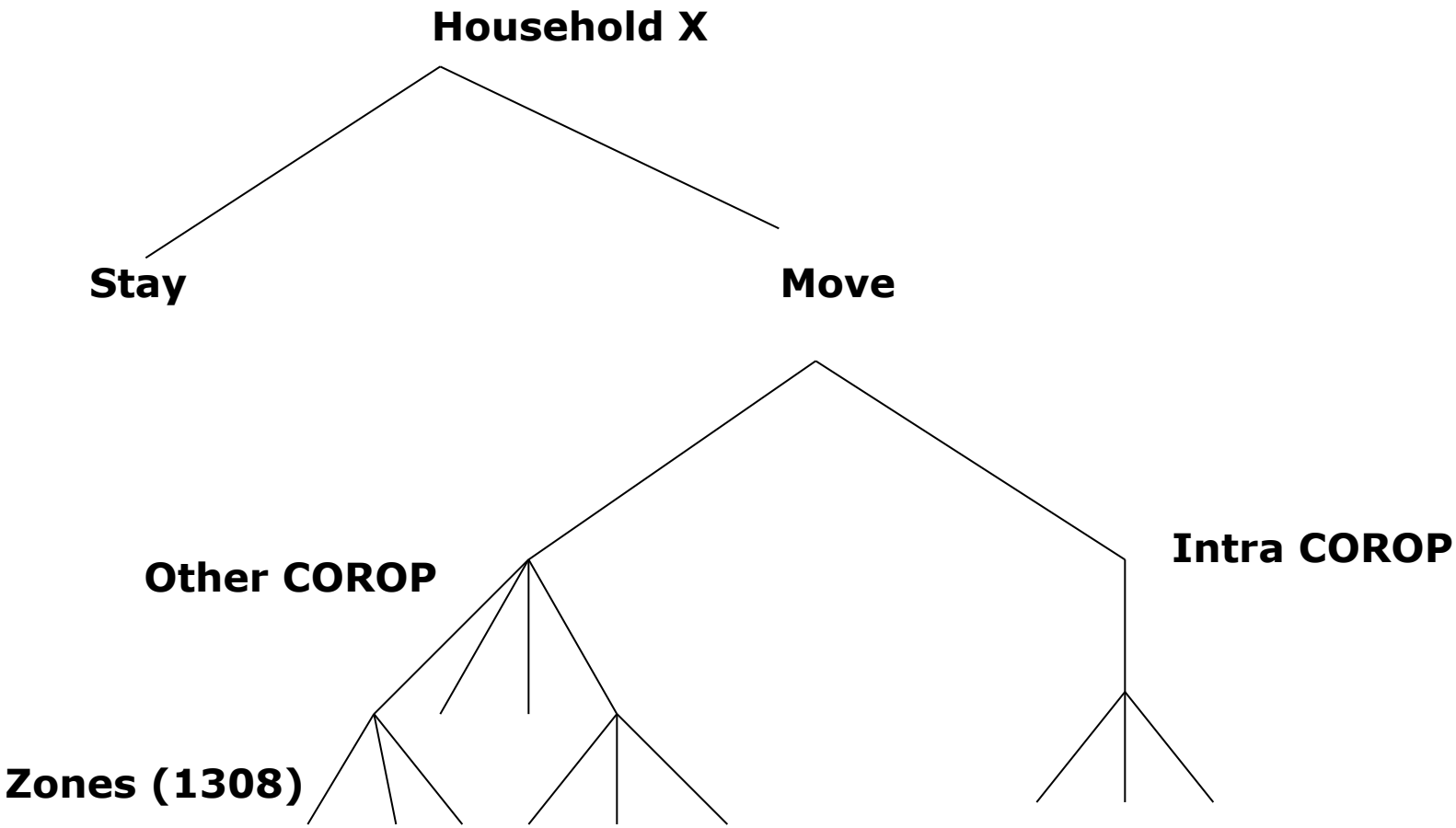
- **Free market development ('free allocation')**

  Spatial developments following preferences of households and firms. The developments are restricted by availability of land

- **Options in between**

  Flexible plans or Zoning policy

Household choices



Household move/stay choice

Explanatory variables

- Household size
- Employment
- Household income
- Age head of household
- Zone type classification (urban to rural)
- Vacant houses in region
- Accessibility current location

Household location choice

Explanatory variables

- Number of vacant houses in a zone
- Average price of houses in a zone
- Zone type classification (urban – rural, 5 categories)
- Travel time (travel time between old and new location)
- Accessibility location
- Zone characteristics
  (water, services, green, population density, etc.)

Labour market

Identification of **economic sectors** is important, because these sectors show different location preferences and responses to transport measures.

Sectors in TIGRIS XL are:

- Agriculture
- Industry
- Logistics
- Retail sector
- Other consumer services
- Business services
- Government

Labour market

Explanatory variables

- Accessibility employees
- Population in a region
- Accessibility business
- Accessibility freight
- Agglomeration
- Urbanisation
- Relative share of sector in a region

$$\frac{E_{ge}(t) \,/\, E_{ge}(t-1)}{E_{NLe}(t) \,/\, E_{NLe}(t-1)} = \alpha_0 \cdot \prod_x LF_{xg}(t)^{\alpha_{xe}}$$

E = employment
g = municipality
e = sector
NL = national
LF = local factor, e.g. accessibility
α = parameter

Note that taking the logarithm yields a linear equation for the employment at time step t

Accessibility variables

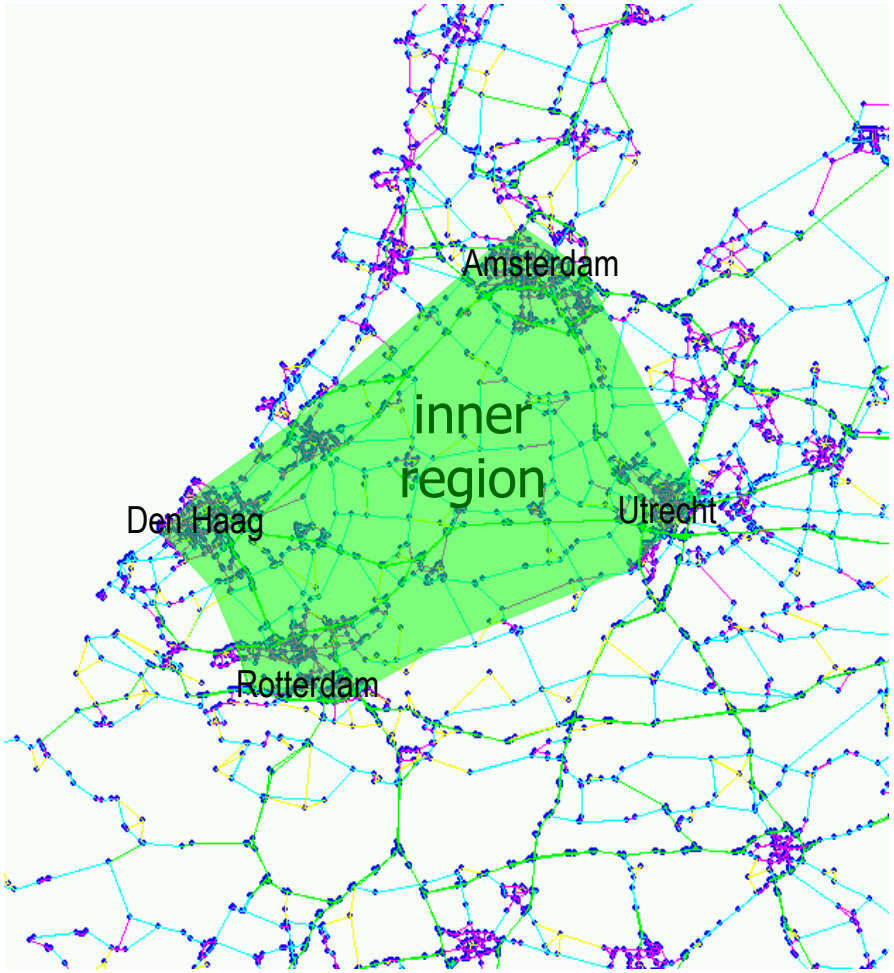
Utility based accessibility measures for (so-called logsum measures)

- Accessibility by household type
- Accessibility of firms for commuters
- Accessibility of firms for business

2.3

TIGRIS and TIGRIS XL: Applications

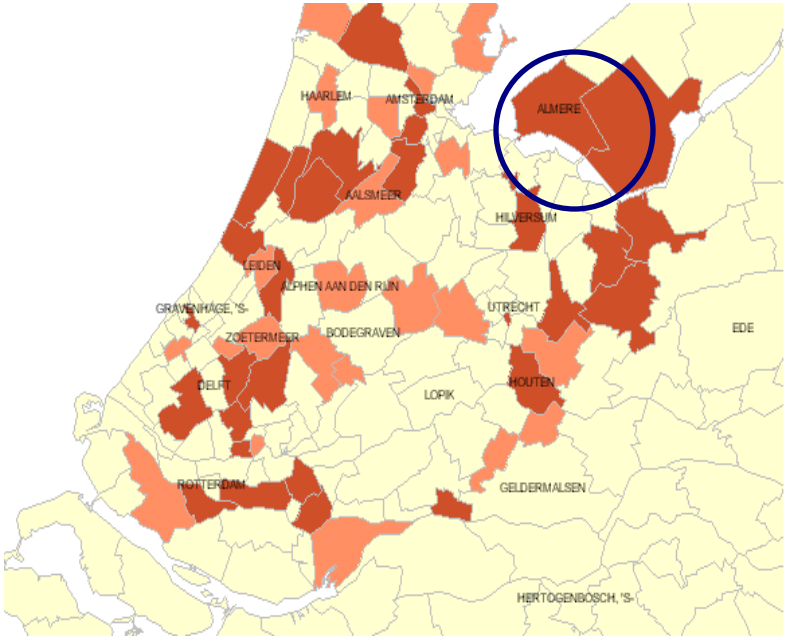
TIGRIS: Randstad



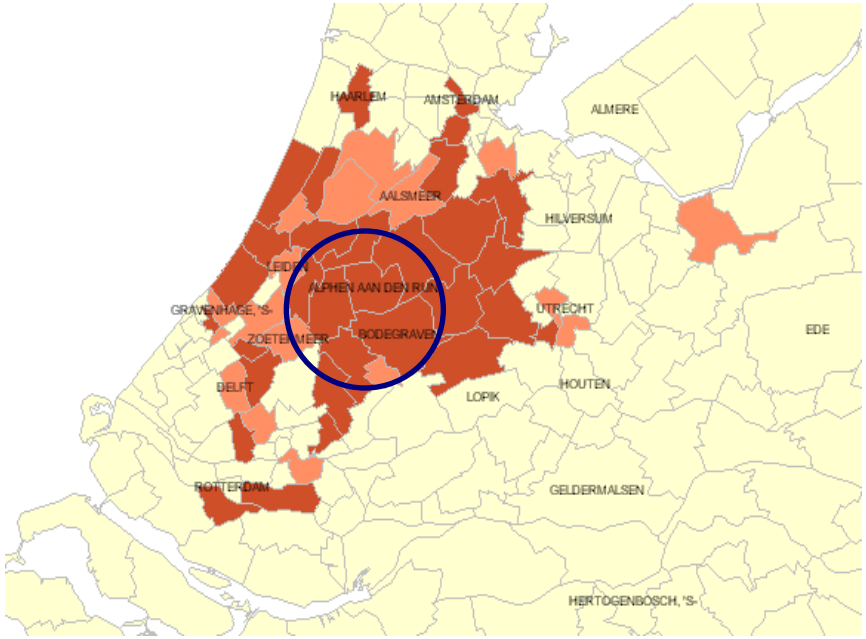
What are the consequences on land use and traffic when there is development
- in the outer region; or
- in the inner region

Randstad: results land-use

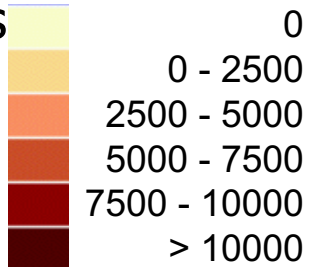
Developing in outer region



Developing in inner region

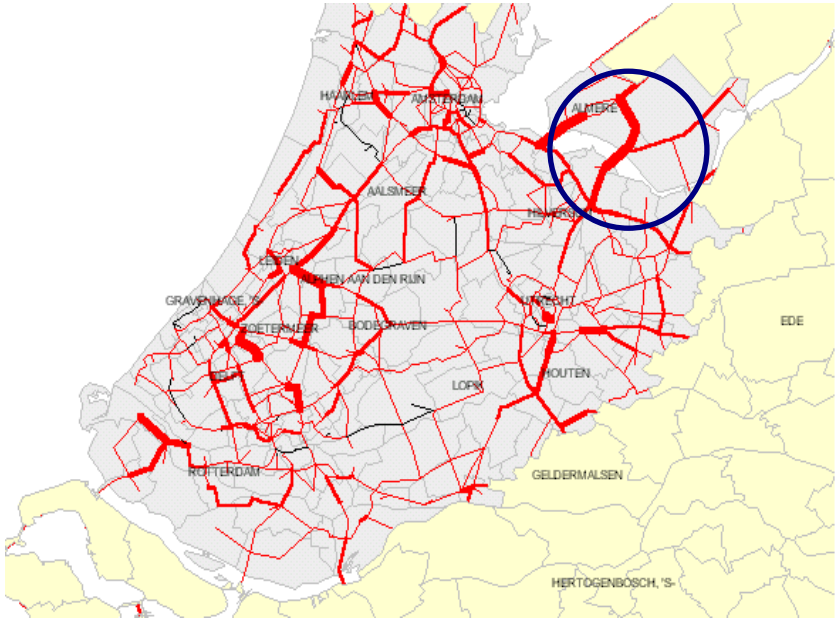


increase in houses
2010 - 2030

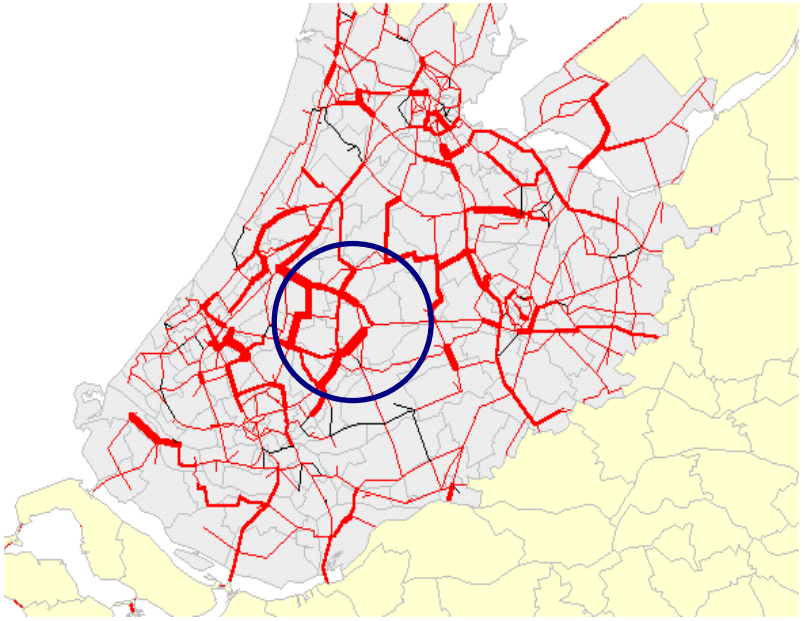


Randstad results transportation

Developing in outer region



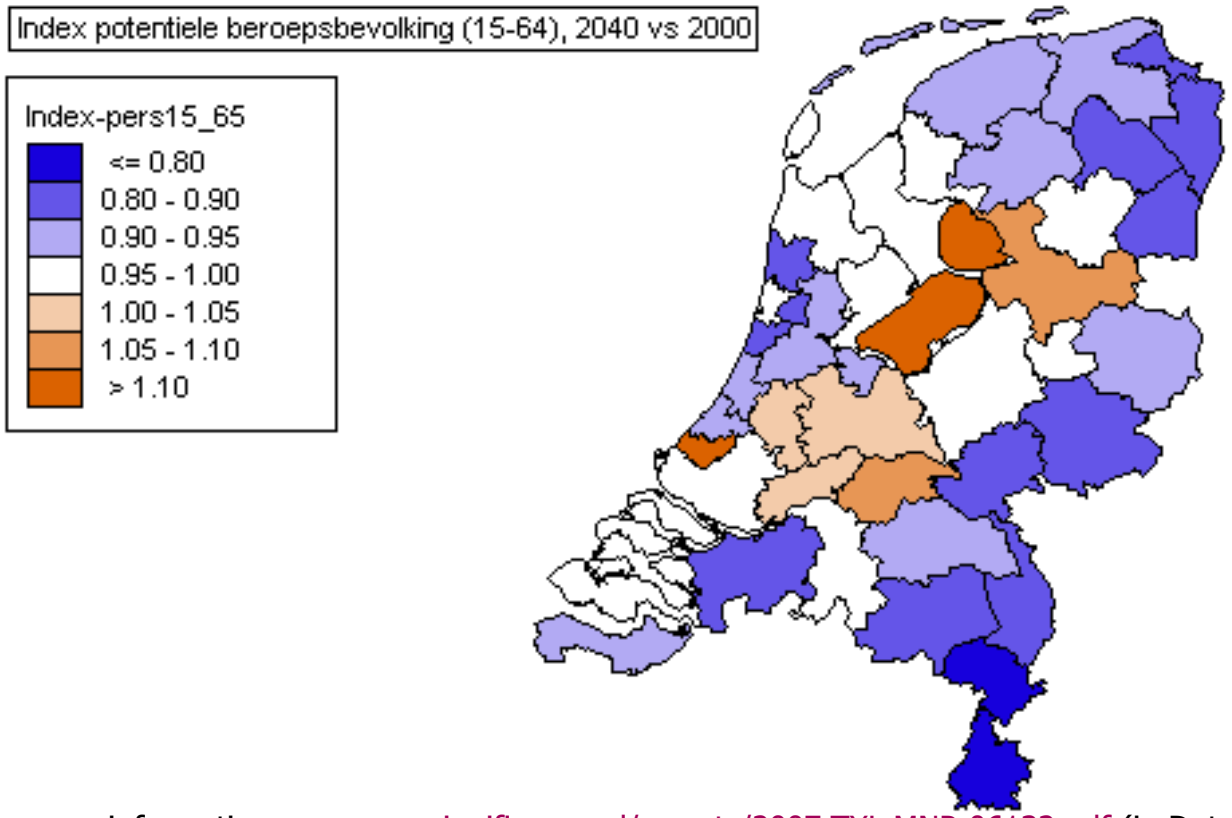
Developing in inner region



Congestion

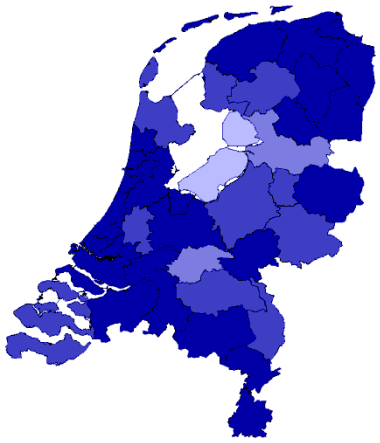
TIGRIS XL Trend scenario

Working population (15-64)

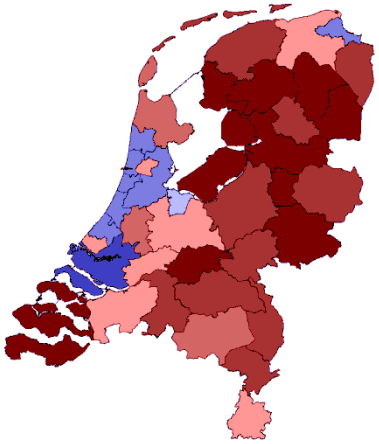


For more information: see www.significance.nl/reports/2007-TXL-MNP-06132.pdf (in Dutch)
Or see the book Land-use modelling in practice (www.books.google.**nl**/books?isbn=9400718225)

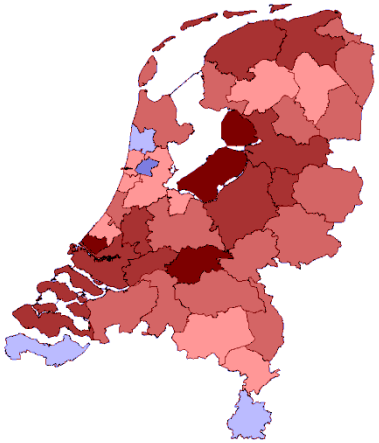
Results trend scenario: Jobs



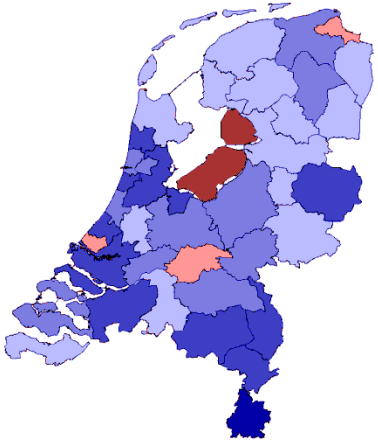
Industry



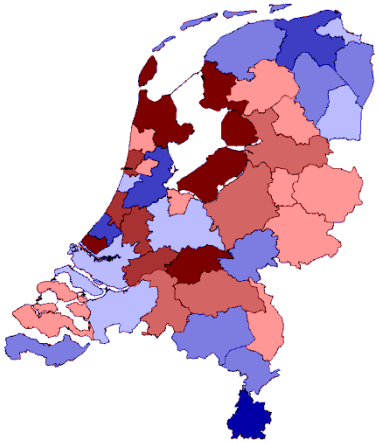
Logistics



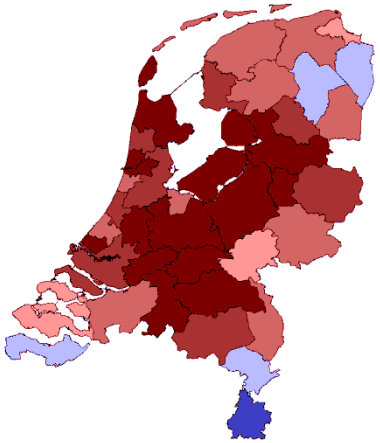
Retail



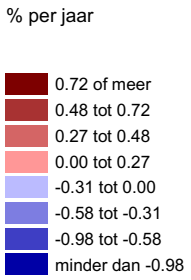
Other consumer



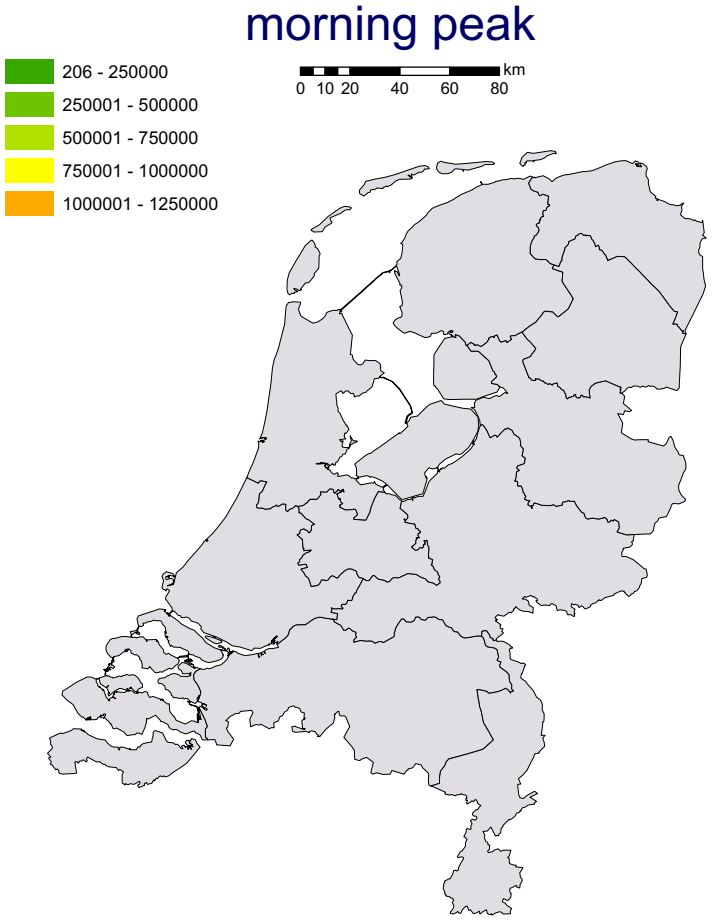
Business services

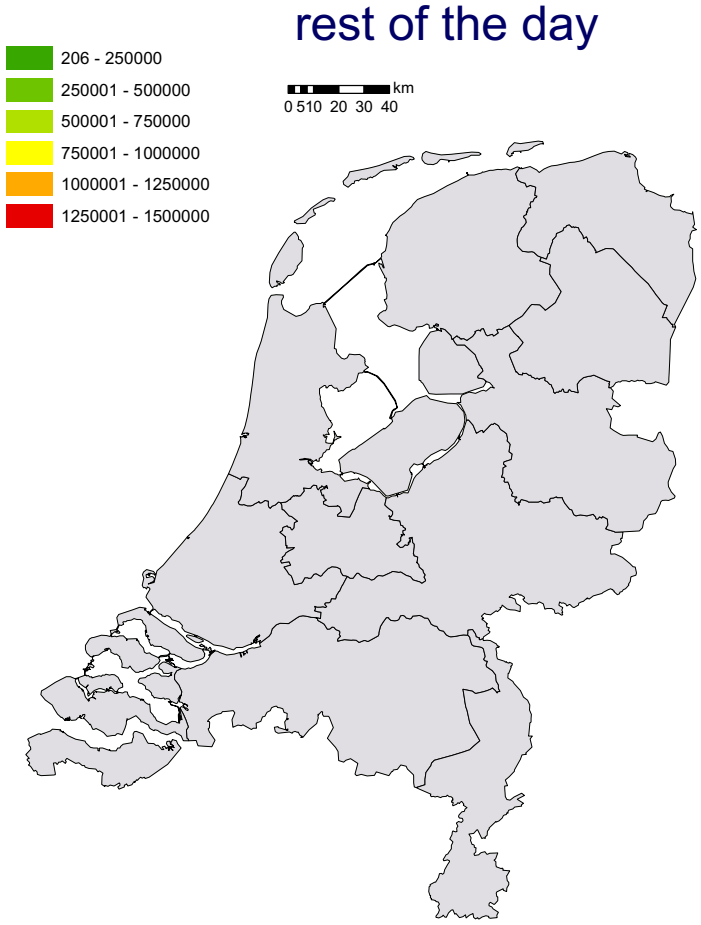


Government services

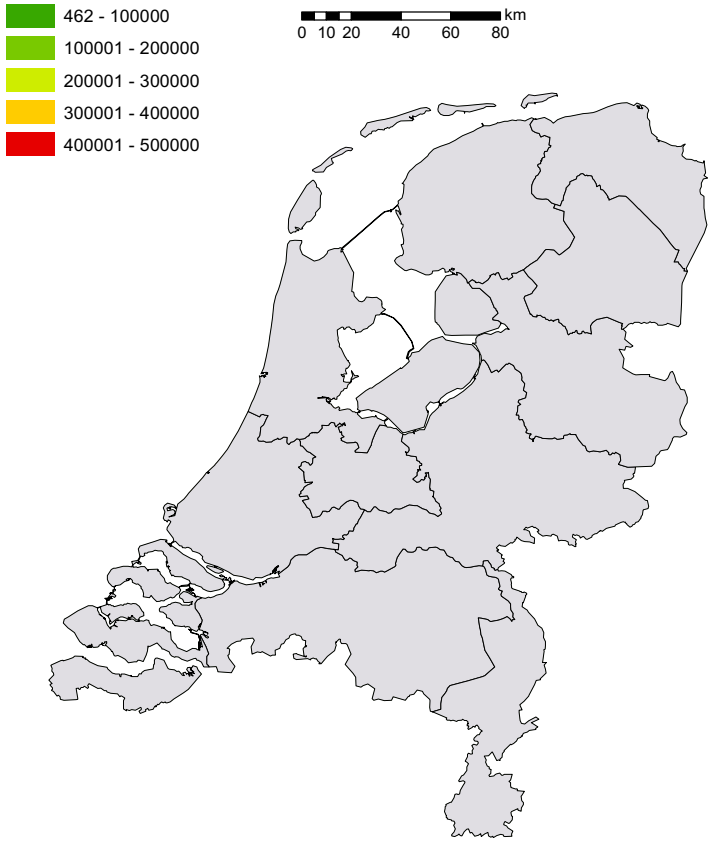


Accessibility of jobs for households (by car) (defined as number of jobs that can be reached within 60 minutes)



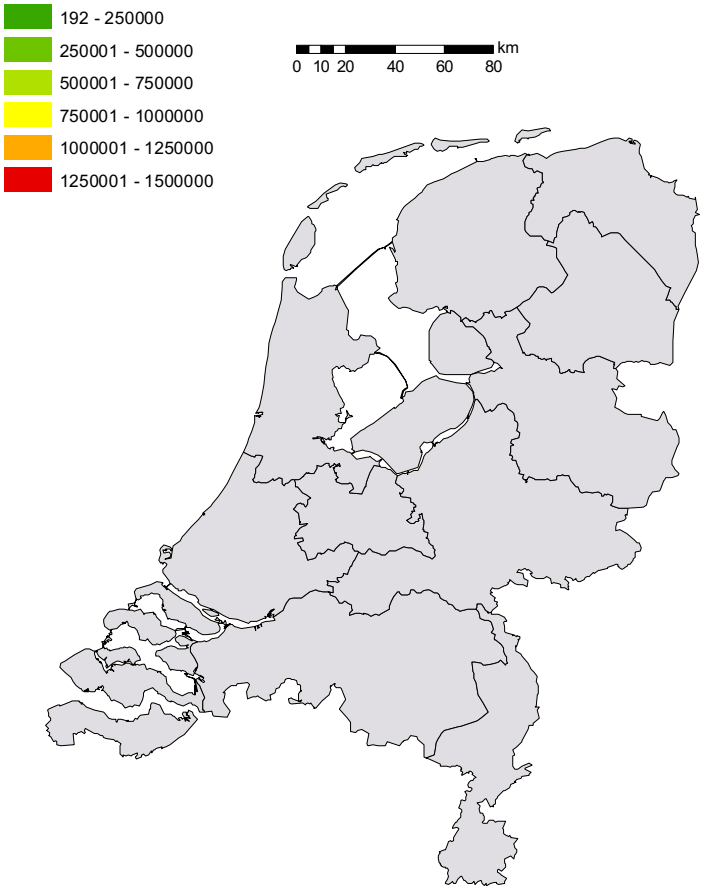


Accessibility of jobs for households (by public transport) (defined as number of jobs that can be reached within 90 minutes)

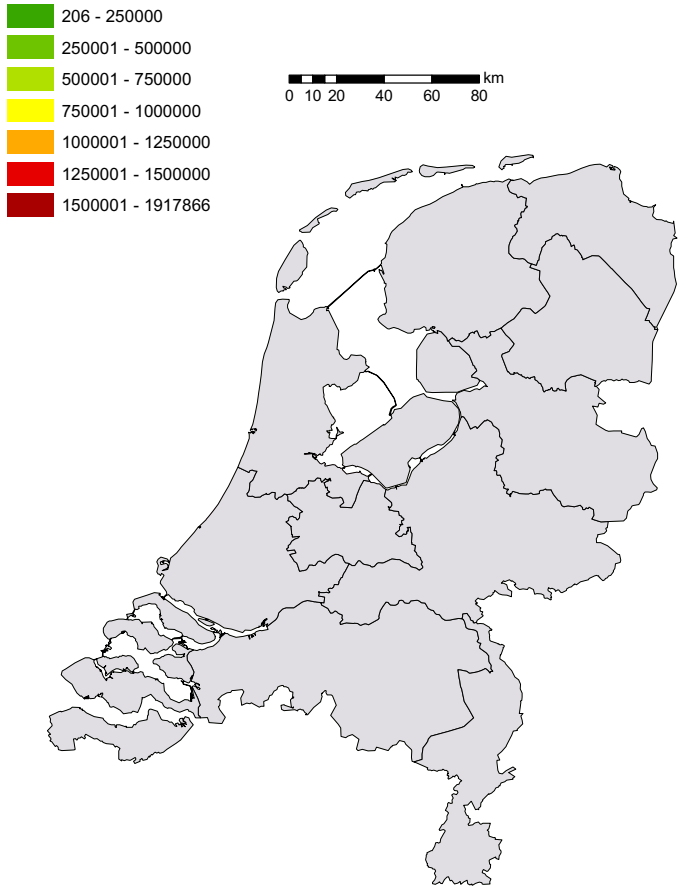


Accessibility of employees for firms (by car)

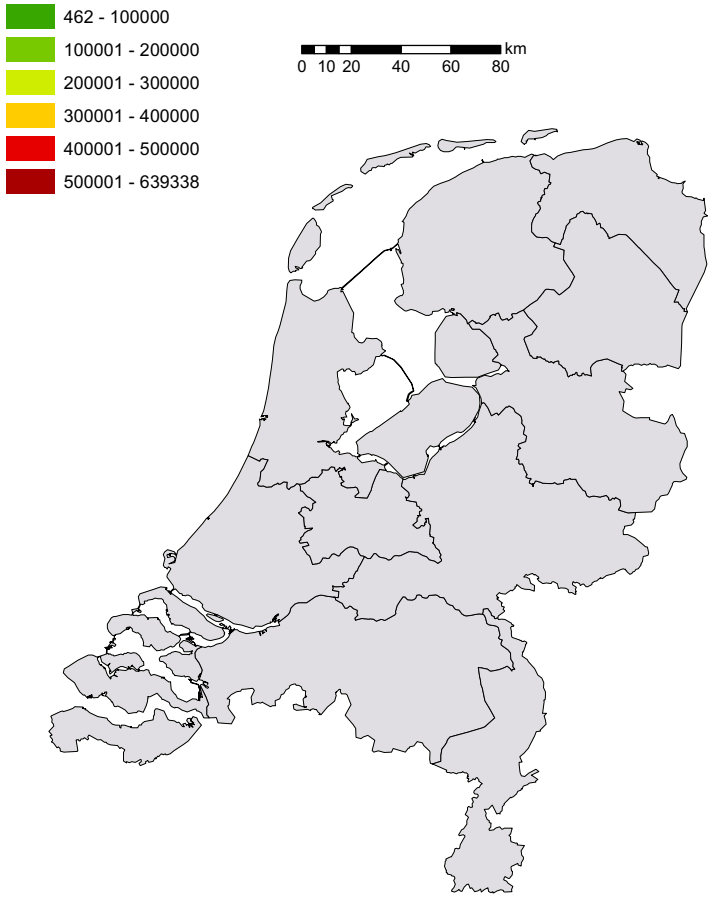
morning peak



rest of the day



Accessibility of employees for firms (by public transport)

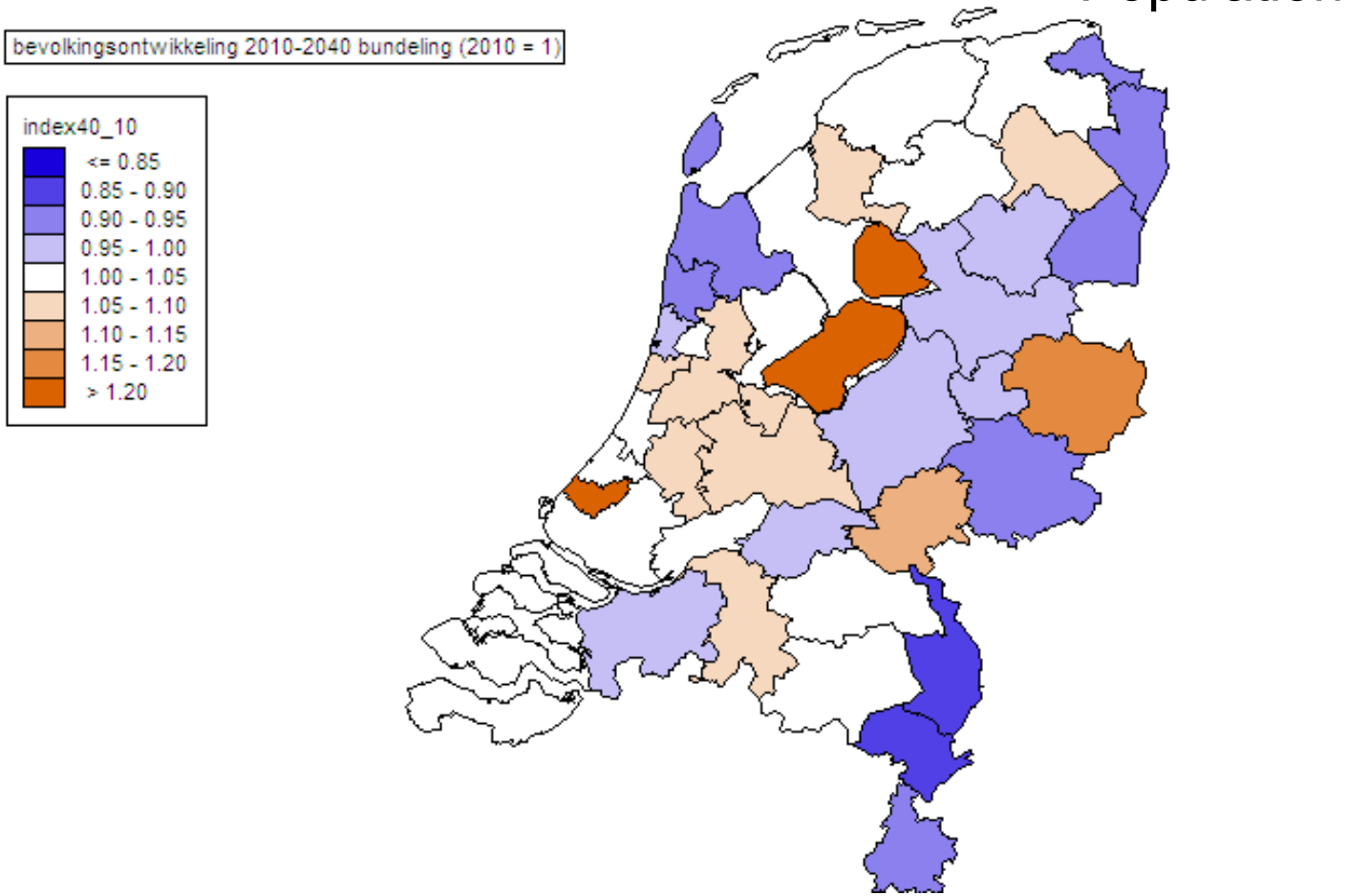


TIGRIS XL Concentration scenario

Appointed concentration areas

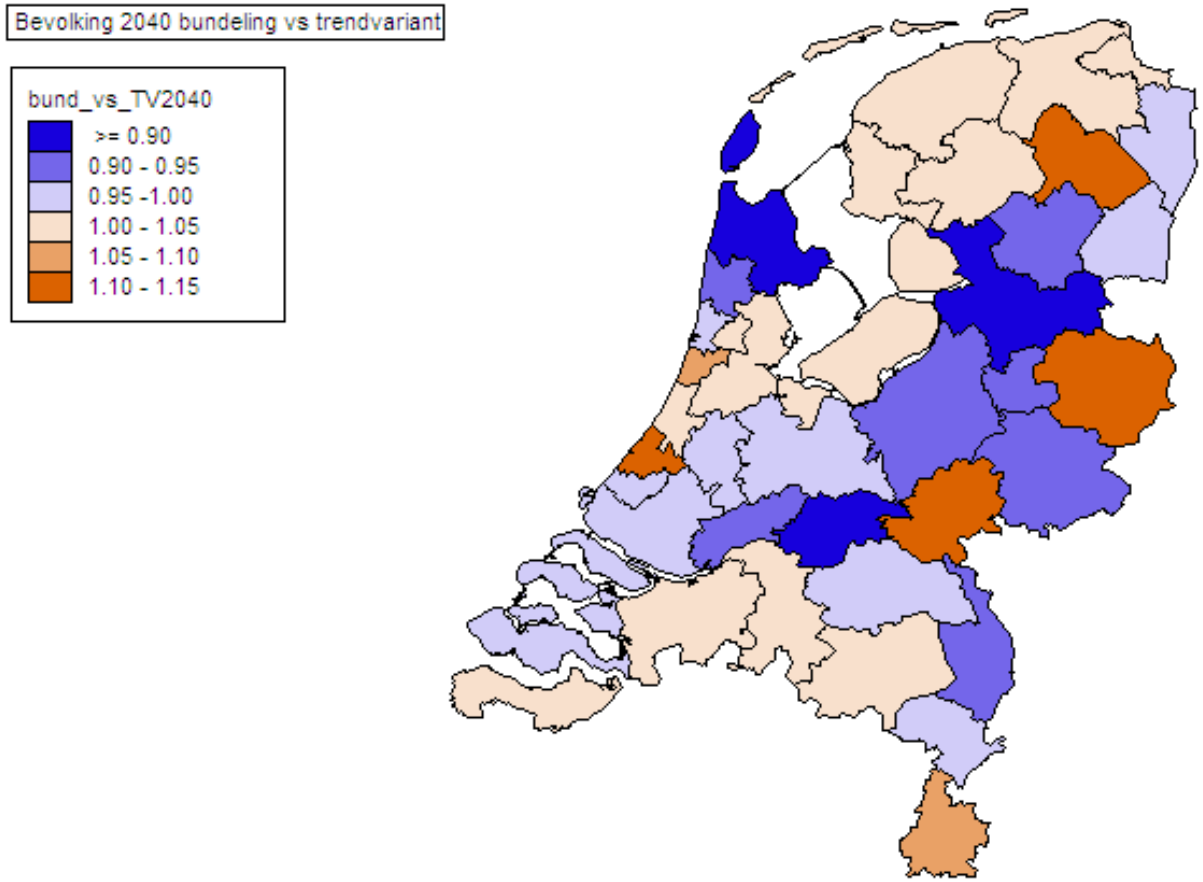
Results concentration scenario

Population



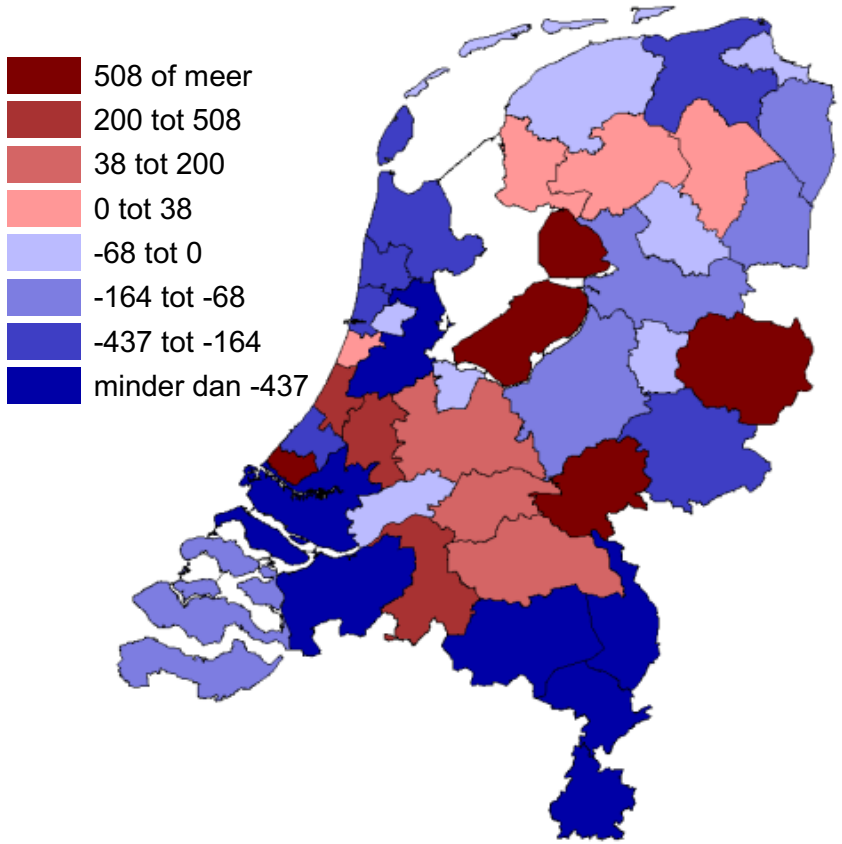
Results concentration scenario

Population – concentration vs. trend



Results concentration scenario

Jobs – concentration vs. trend



2.4

Criteria for land-use models and development in land-use models

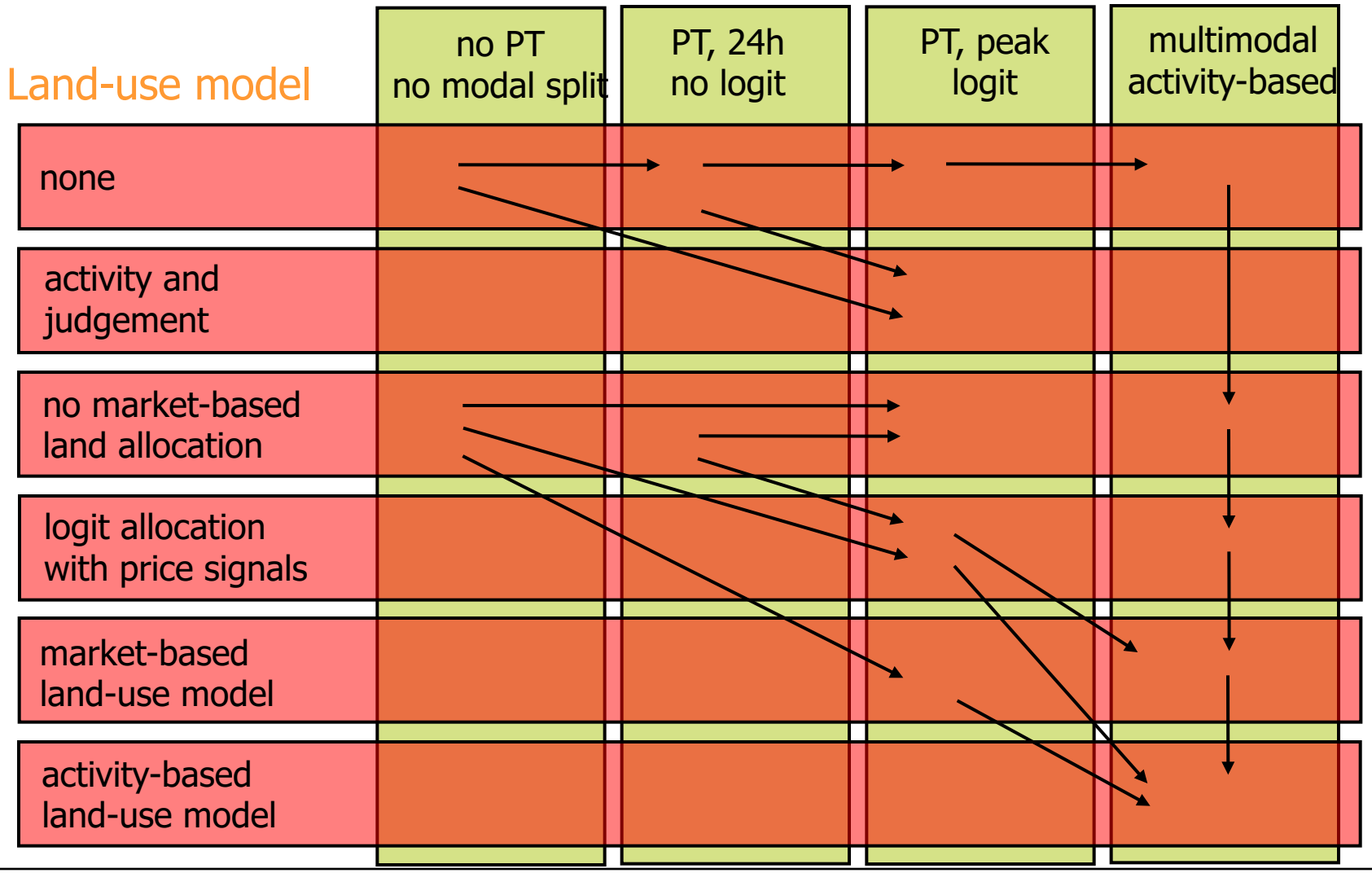
Criteria for model comparison (1/2)

- Comprehensiveness
  - Choice of subsystems that are included
- Model structure
  - Unified or composite
- Theory
  - Random utility, bid-rent, entropy, equilibrium
- Modelling techniques
  - Discrete periods, integrated (singly constrained), accessibility indicators, assignment, aggregate/disaggregate
- Dynamics
  - Recursive simulation or quasi dynamic, time lags

Criteria for model comparison (2/2)

- Data requirements
  - Substantial
- Calibration and validation
  - Calibration for cross sections, validition over a longer period of time
- Operationality
  - Only a few are suited for a wider market
- Applicability
  - Limited scope compared to actual issues

Evolution of LUT models



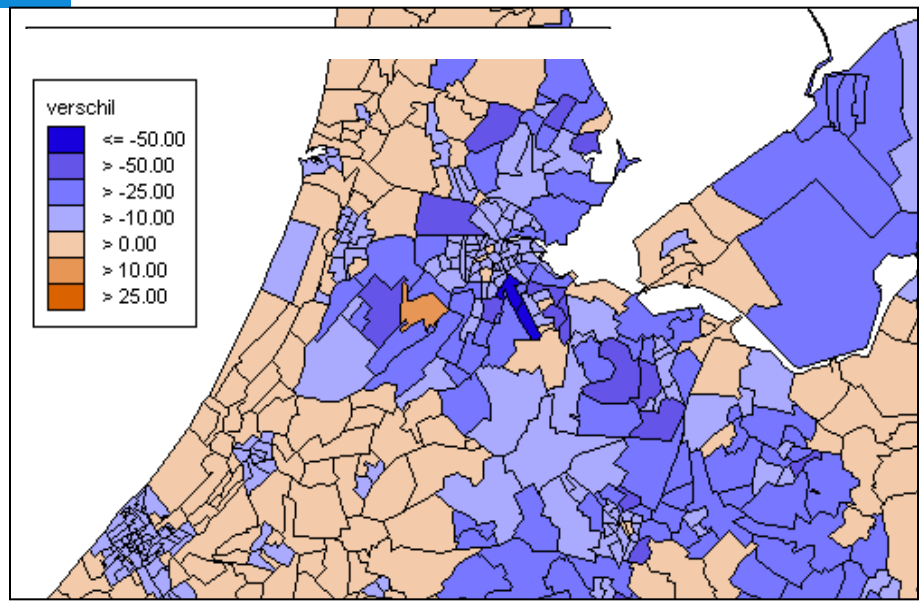
3.1

Choice modelling:
Firm location behaviour

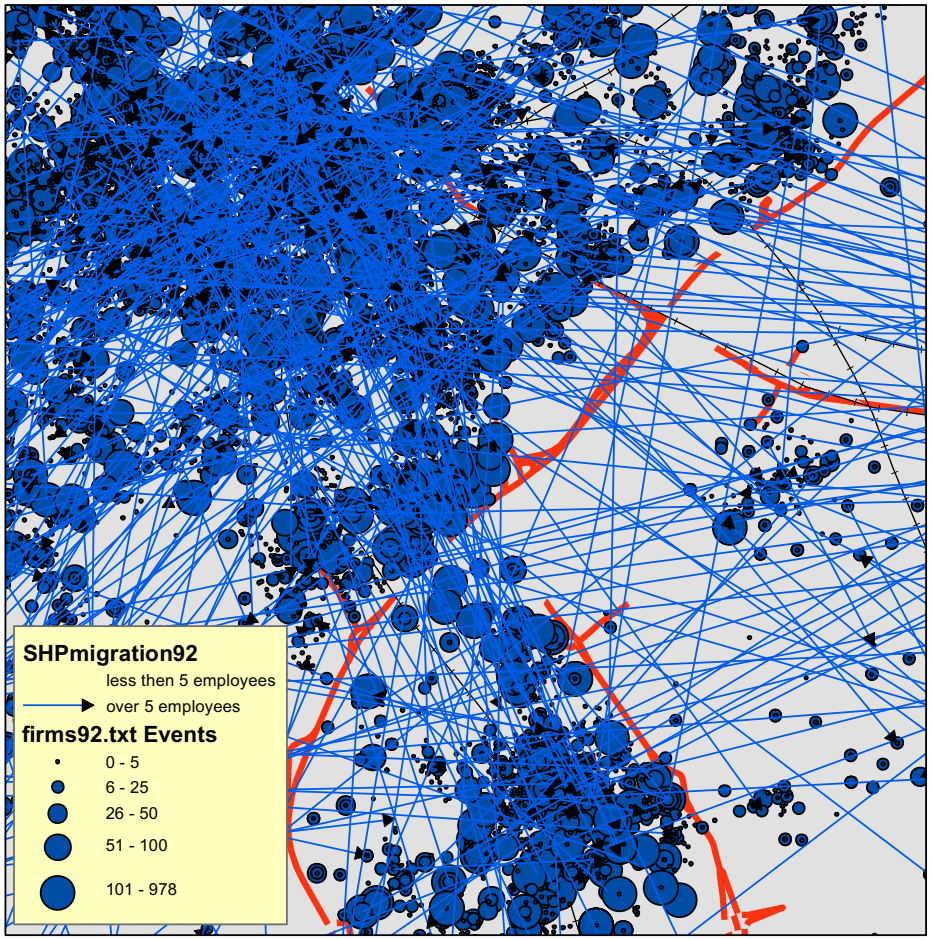
Factors influencing location choice of firms

- Characteristics of the firm
  - Size
  - Growth
  - Age
  - Sector
- Characteristics of the location
  - Vicinity of infrastructure
  - Accessibility of the market and of employees
  - Neighborhood of other firms
    - Specialisation or diversity

Aggregated approach: All firms in a zone



Disaggregated approach: Individual firms



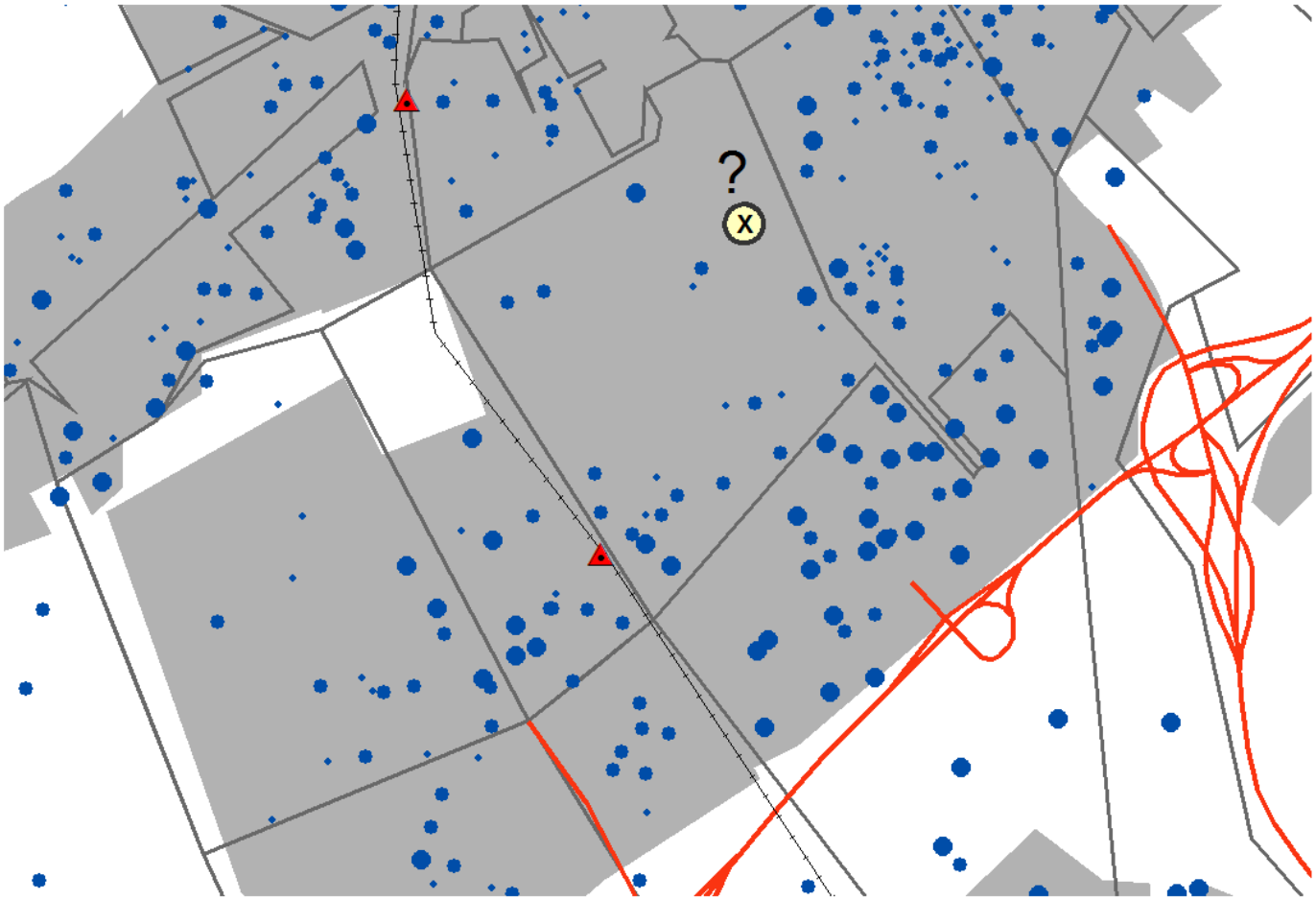
Data available in the Netherlands

- LISA
  National information system of employment, contains information on the whole firm population

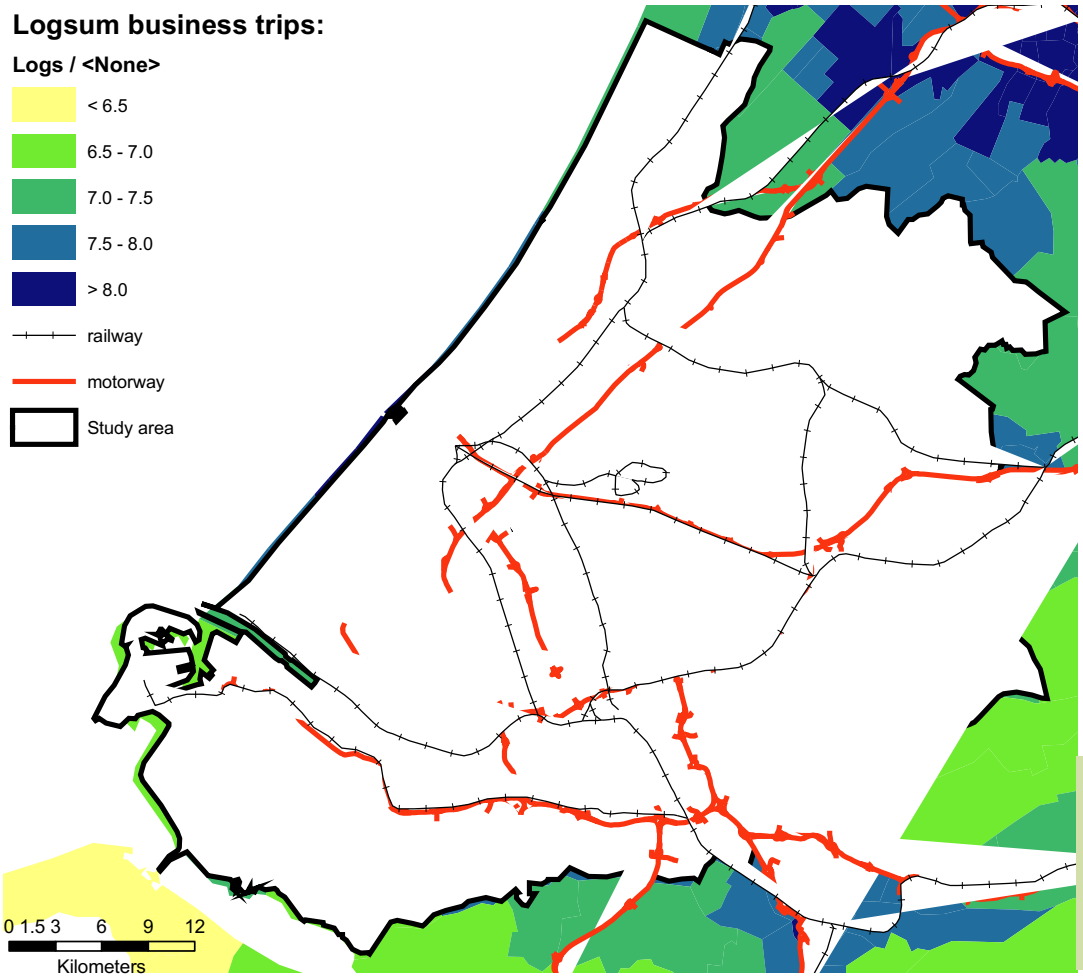
- LMS
  National model system, contains information on accessibilities

- GIS
  Geographic information system, contains information on location of railways, freeways, etc.

Vicinity of infrastructure

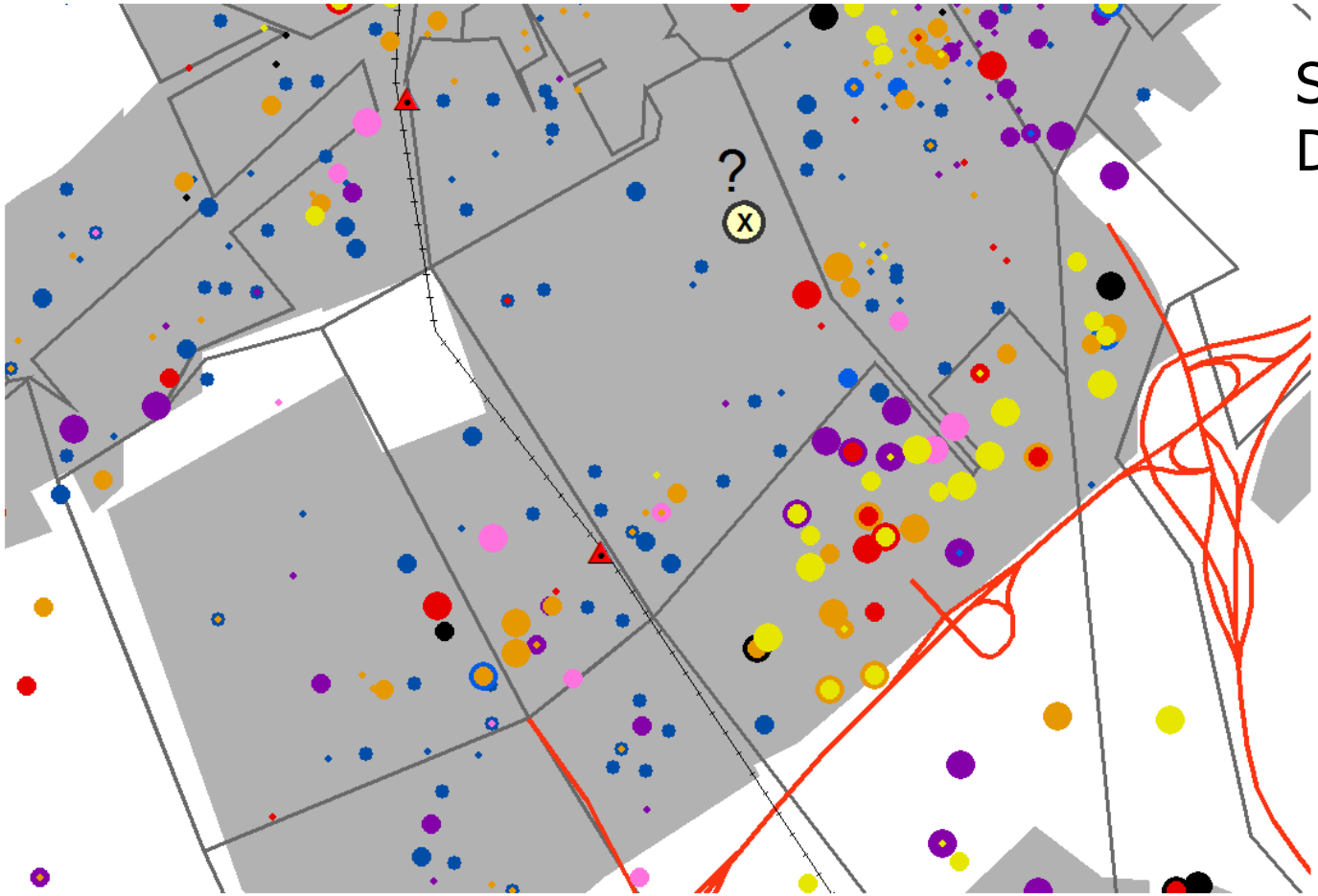


Accessibility



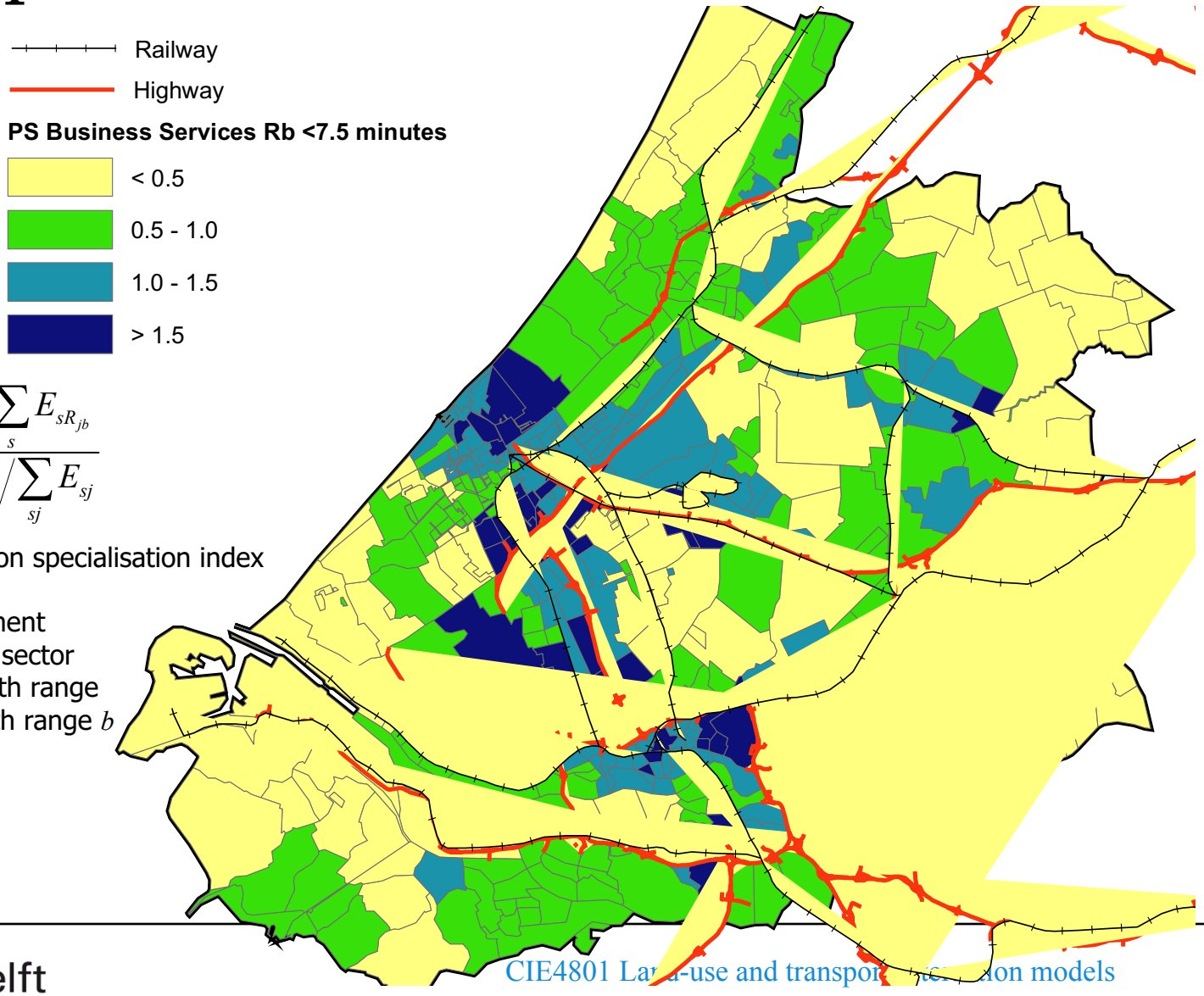
Logsum is based on destination and mode choice

Neighborhood of other firms



Specialization / Diversity

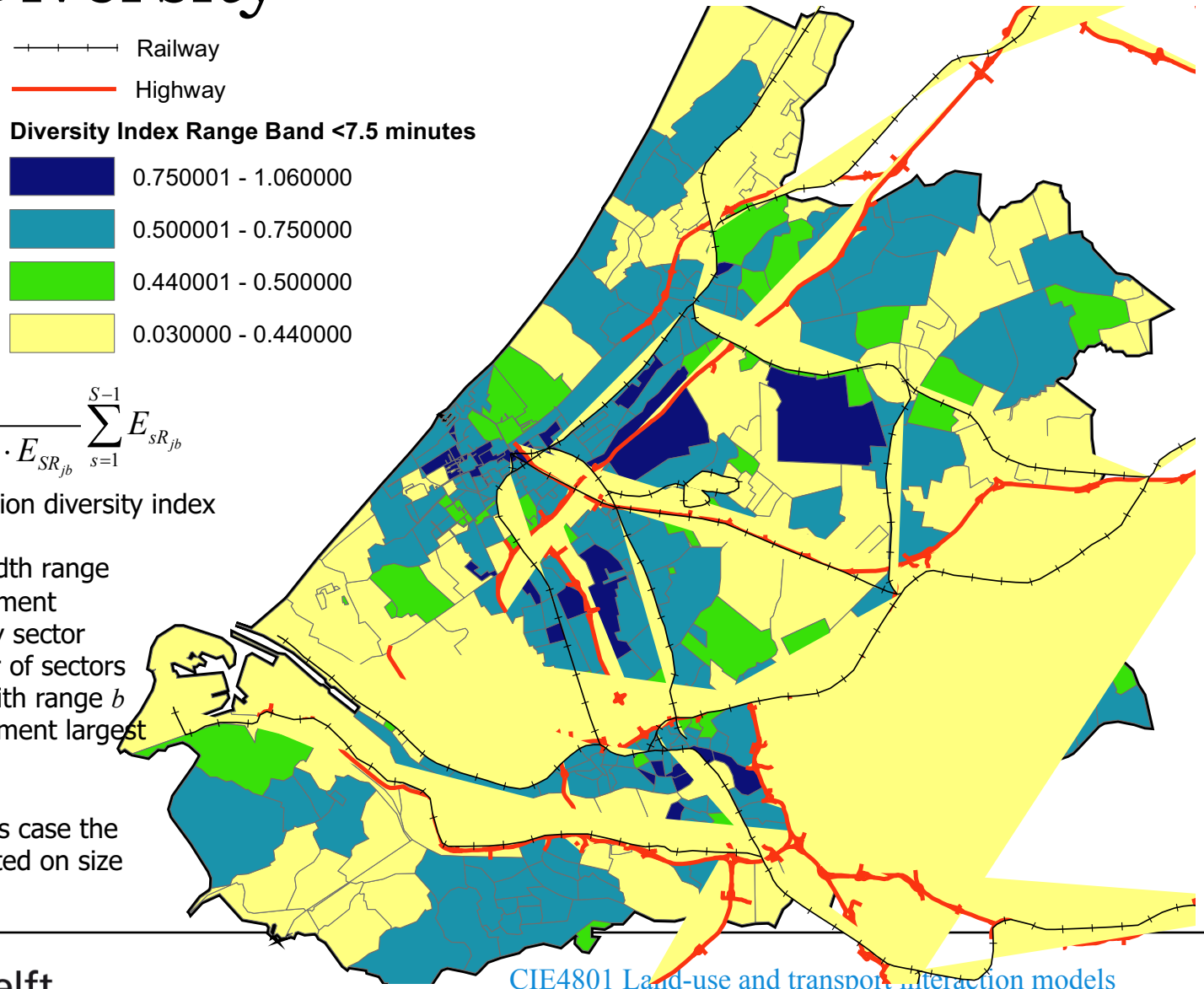
Specialization



$$PS_{jsb} = \frac{E_{sR_{jb}} \Big/ \sum_{s} E_{sR_{jb}}}{\sum_{j} E_{sj} \Big/ \sum_{sj} E_{sj}}$$

PS = Production specialisation index
j = location
E = employment
s = industry sector
b = bandwidth range
R_{jb} = band with range b

Diversity

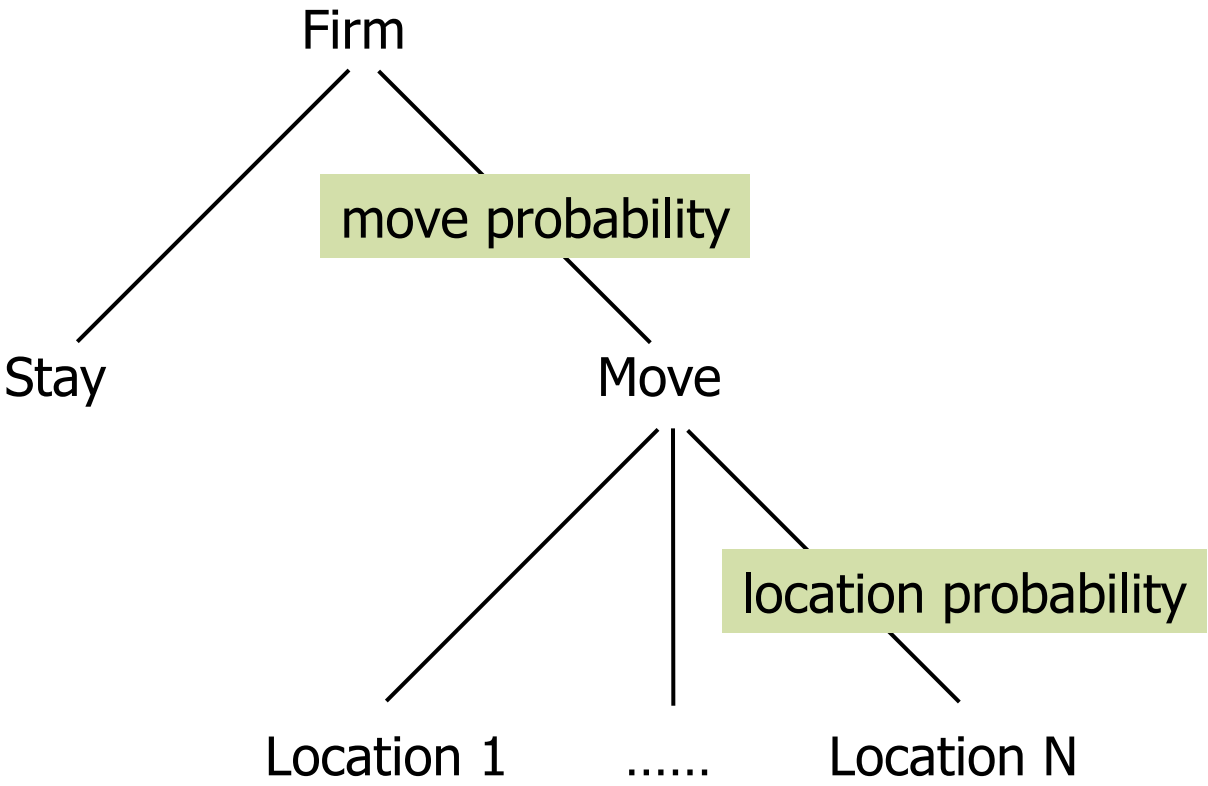


$$PD_{jb} = \frac{1}{(S-1)\cdot E_{SR_{jb}}} \sum_{s=1}^{S-1} E_{sR_{jb}}$$

PD = production diversity index
j = location
b = bandwidth range
E = employment
s = industry sector
S = number of sectors
R_{jb} = band with range b
E_{SRjb} = employment largest industry

Note that in this case the sectors are sorted on size

Firm location choice model



Move probability

$$V_{fi}^{\text{stay}} = 0$$

$$V_{fi}^{\text{move}} = \theta_0 + \underbrace{\theta_1 Gr_f + \theta_2 (1/Age_f) + \theta_3 Sec_f}_{\text{firm characteristics}} + \underbrace{\theta_4 Acc_i + \ldots}_{\text{location characteristics}}$$

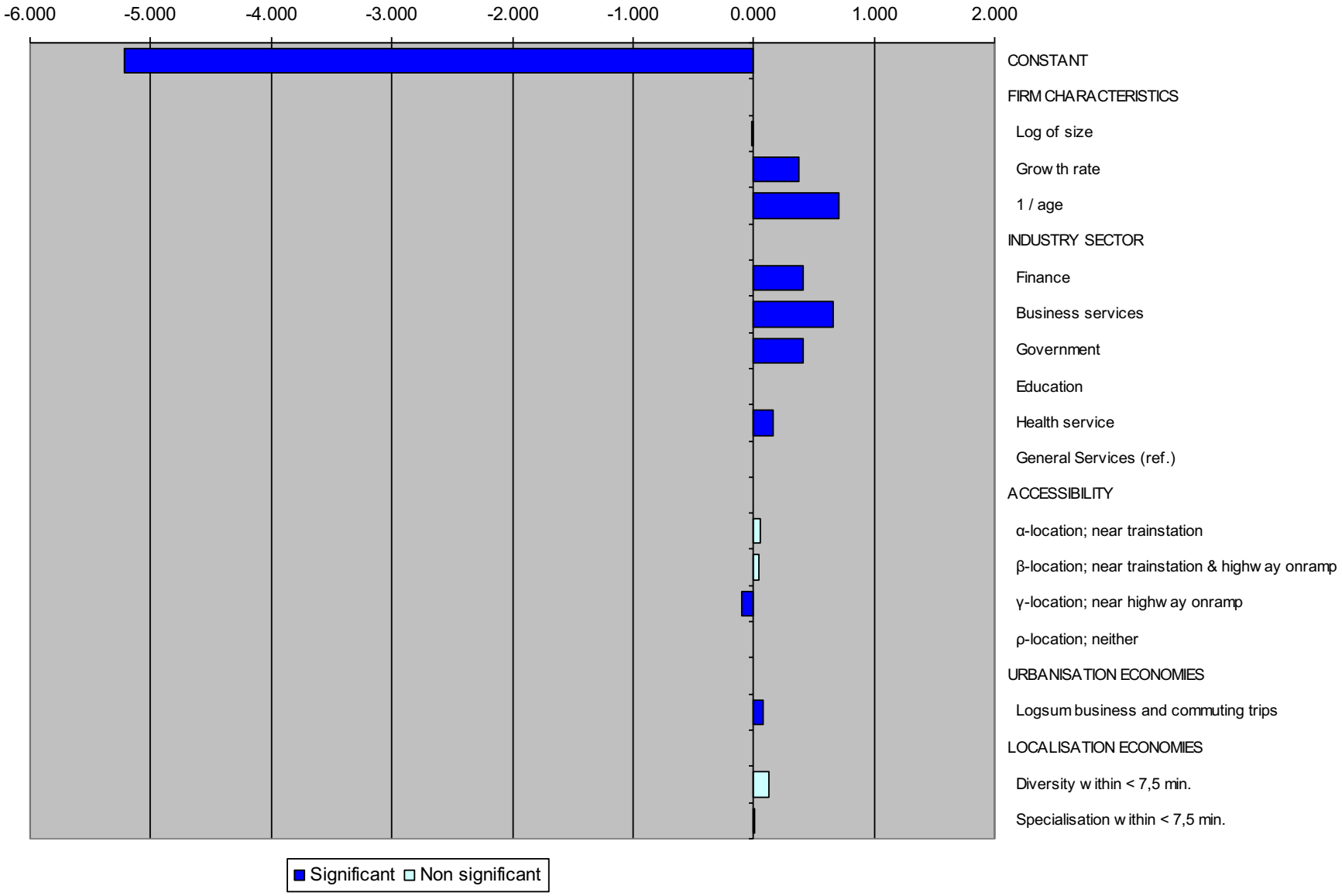
Gr = firm growth
Age = firm age
Sec = firm sector
Acc = location accessibility

f – firm index
i – location index

$$P_{fi}^{\text{move}} = \frac{\exp(V_{fi}^{\text{move}})}{\exp(V_{fi}^{\text{move}}) + \exp(V_{fi}^{\text{stay}})} = \frac{1}{1 + \exp(-V_{fi}^{\text{move}})}$$

Move probability

Parameter estimates



Location probability

$$V_{sij}^{\text{location}} = \theta_{s1} Dist_{ij} + \theta_{s2} Acc_j + \ldots$$

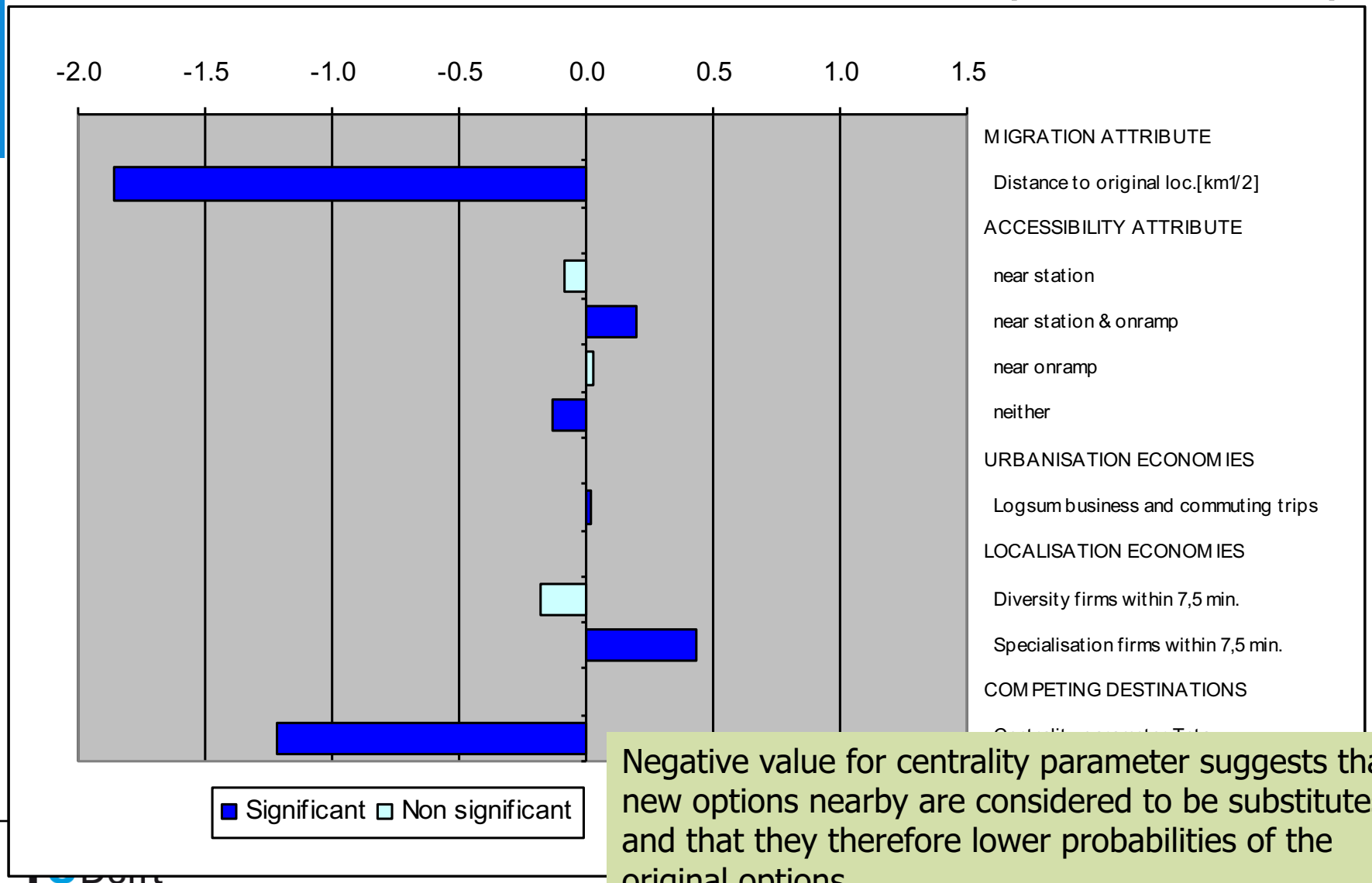
$Dist$ = relocation distance
Acc = location accessibility

s – firm sector index
i – current location index
j – new location index

$$P_{sij}^{\text{location}} = \frac{\exp(V_{sij}^{\text{location}})}{\sum_k \exp(V_{sik}^{\text{location}})}$$

Location probability

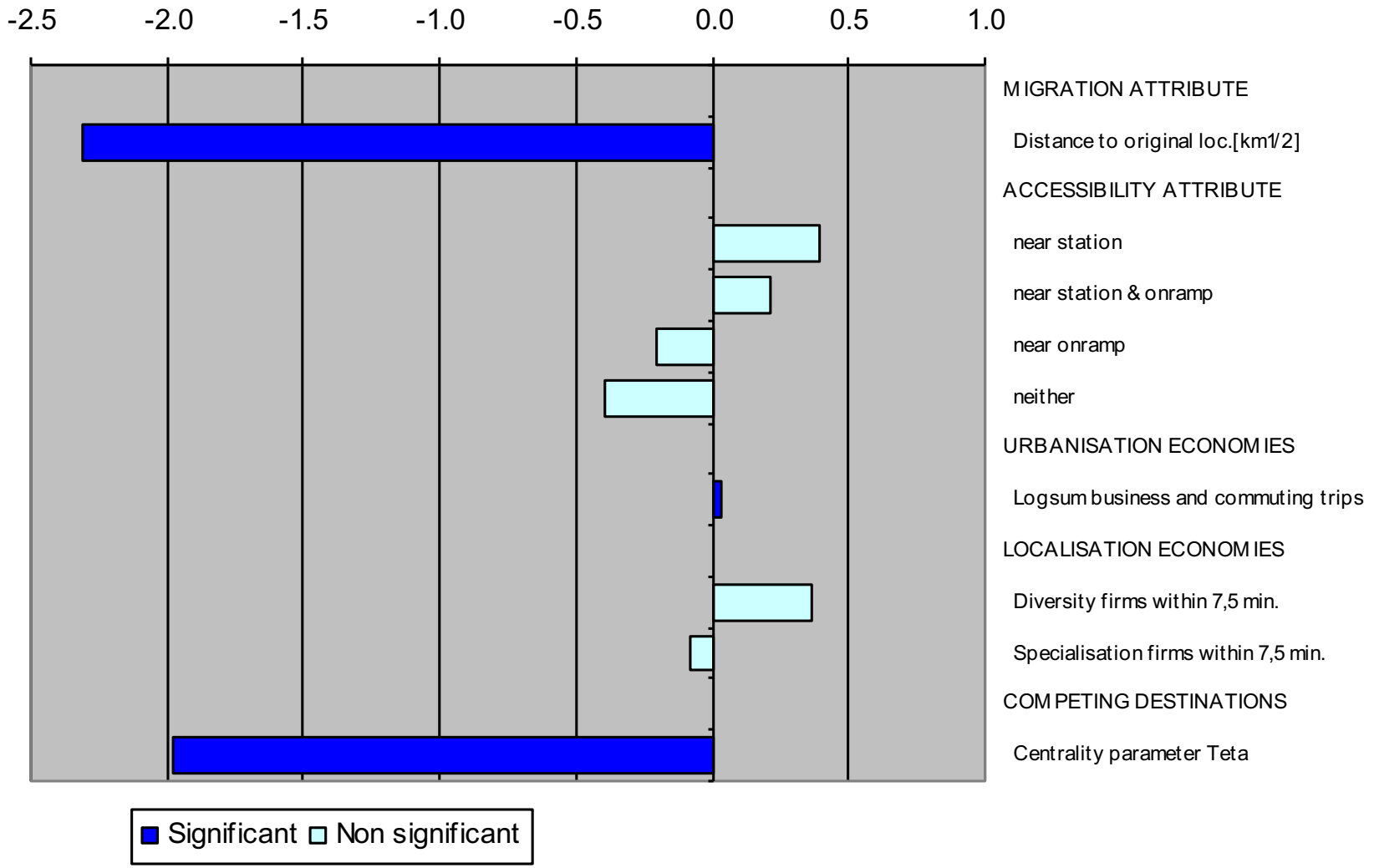
Parameter estimates (sector Business)



Negative value for centrality parameter suggests that new options nearby are considered to be substitutes, and that they therefore lower probabilities of the original options

Location probability

Parameter estimates (sector Finance)



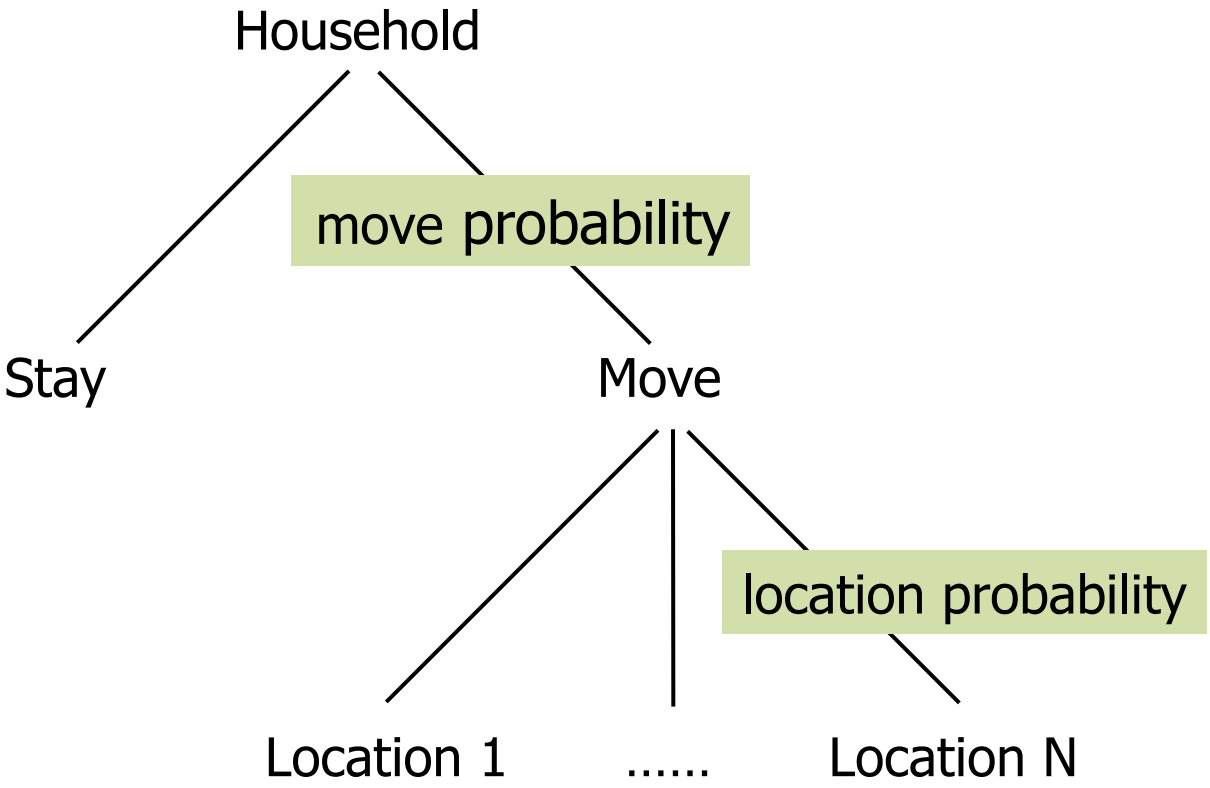
Location choice companies

- For the choice to consider another location characteristics of companies themselves are dominant
- For the location choice accessibility attributes play a role.
- Main accessibility attributes:
  - Distance to original location
  - Distance to freeway on-/off-ramp
  - Distance to railway station
    - financing, education, catering
  - Accessibility by car
    - business, financing, manufacturing, logistics, trading and retail

3.2

Choice modelling:
Household location behaviour

Household location choice model



Location probability: MNL approach

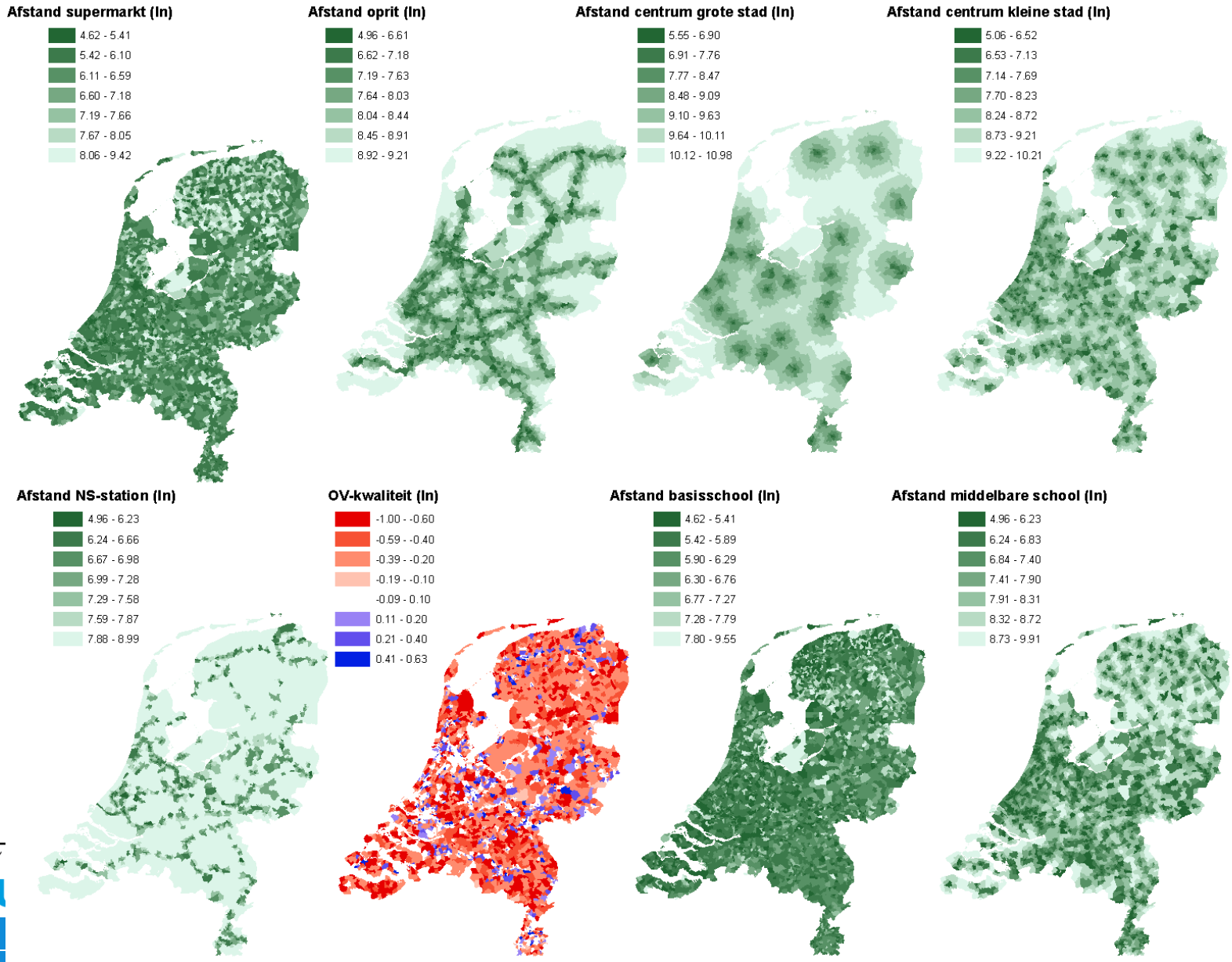
$$V_{hij}^{\text{location}} = \theta_{h1} Dist_{ij} + \theta_{h2} Acc_j + \theta_{h3} Eth_j + \ldots$$

$Dist$ = relocation distance
Acc = location accessibility
Eth = similarity ethnical background

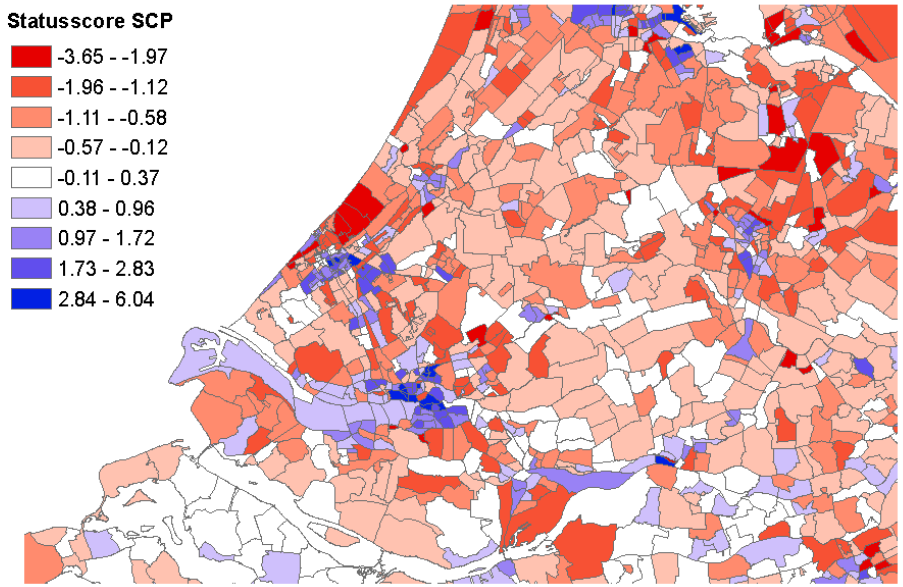
h – household type index
i – current location index
j – new location index

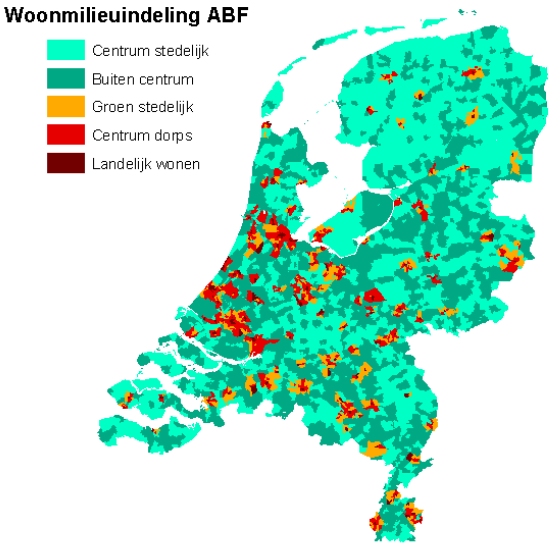
$$P_{hij}^{\text{location}} = \frac{\exp(V_{hij}^{\text{location}})}{\sum_k \exp(V_{hik}^{\text{location}})}$$

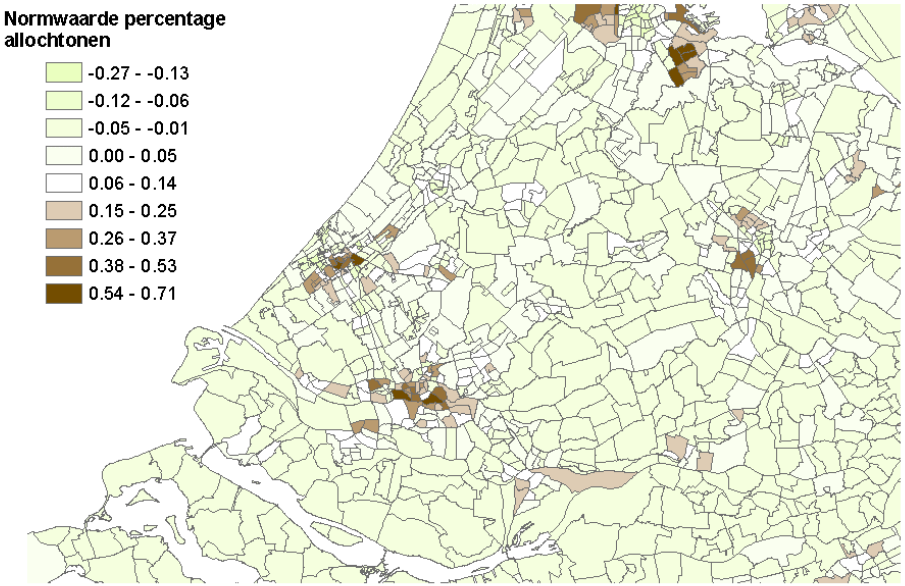
Location accessibility

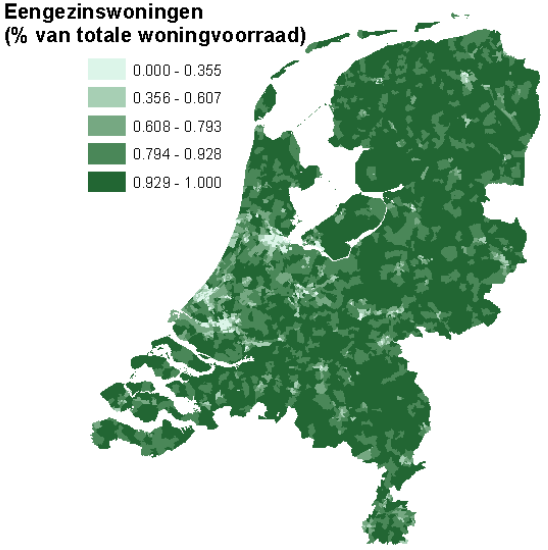


Other factors









Location choice households

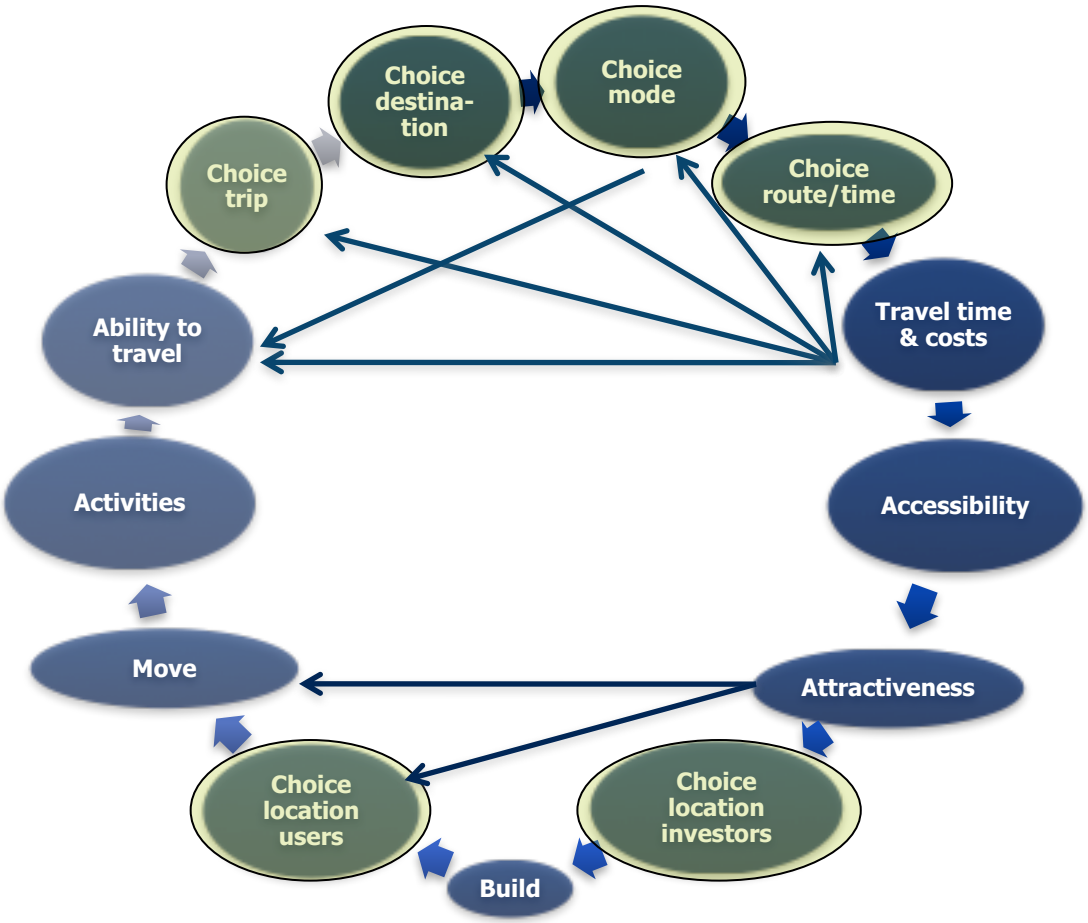
- Characteristics of house and neighbourhood are dominant
- Accessibility plays a limited role; key variables are:
  - Distance to previous house
  - Distance to work by car
- Nested models provide more insight
  - E.g. distance to station (households without car)

NB. Check sign of the parameters!

4.

Circle of Wegener revisited

Choice processes



Empirical evidence?

- Databases of observed behaviour
- Observed or generated choice alternatives
- Formulating choice models (logit models)
- Estimating perception factors or weights
- Resulting models of attributes having significant weights

Location choice investors

- Different decision makers thus different objectives
  - Project developers
  - Authorities
- I've got no empirical evidence for this type of choice, however…
- Given the bi-level nature of the decision problem they should consider the choice behaviour of (future) users of the location

Location choice companies

- For the choice to consider another location characteristics of companies themselves are dominant
- For the location choice accessibility attributes play a role.
- Main accessibility attributes:
  - Distance to original location
  - Distance to freeway on-/off-ramp
  - Distance to railway station
    - financing, education, catering
  - Accessibility by car
    - business, financing, manufacturing, logistics, trading and retail

Location choice households

- For decision to move accessibility plays a role
- Characteristics of house and neighbourhood are dominant
- Accessibility plays a limited role:
  - Distance to previous house
  - Distance to work by car
- More advanced modelling provides more insight
  - E.g. distance to station (for household without a car)

Overall conclusions location choice

- Shift towards disaggregated approaches (individual firms and households)
  - Proposition: disaggregate approach show a larger role of non-transport factors
- Relocation distance is preferably small
- Accessibility plays a role in the location choice behavior
  - Accessibility is relevant for the location choice of firms, not in the decision to move
  - Best accessible locations may not be preferred by households

Trip choice

- To travel or not to travel…..
- No real impact of accessibility
  - Recall constant number of trips per day
- Although: for some trip purposes an effect has been found, still having a minimal impact

Destination choice

- Distance/time has a substantial impact:
  the larger the distance (or the longer the time), the lower the probability of choosing the destination (assuming similar attractiveness of the destinations)
- Car accessibility is usually dominant, except for households without a car
- Alternative modes improve accessibility, however, net impact on total attractiveness is limited

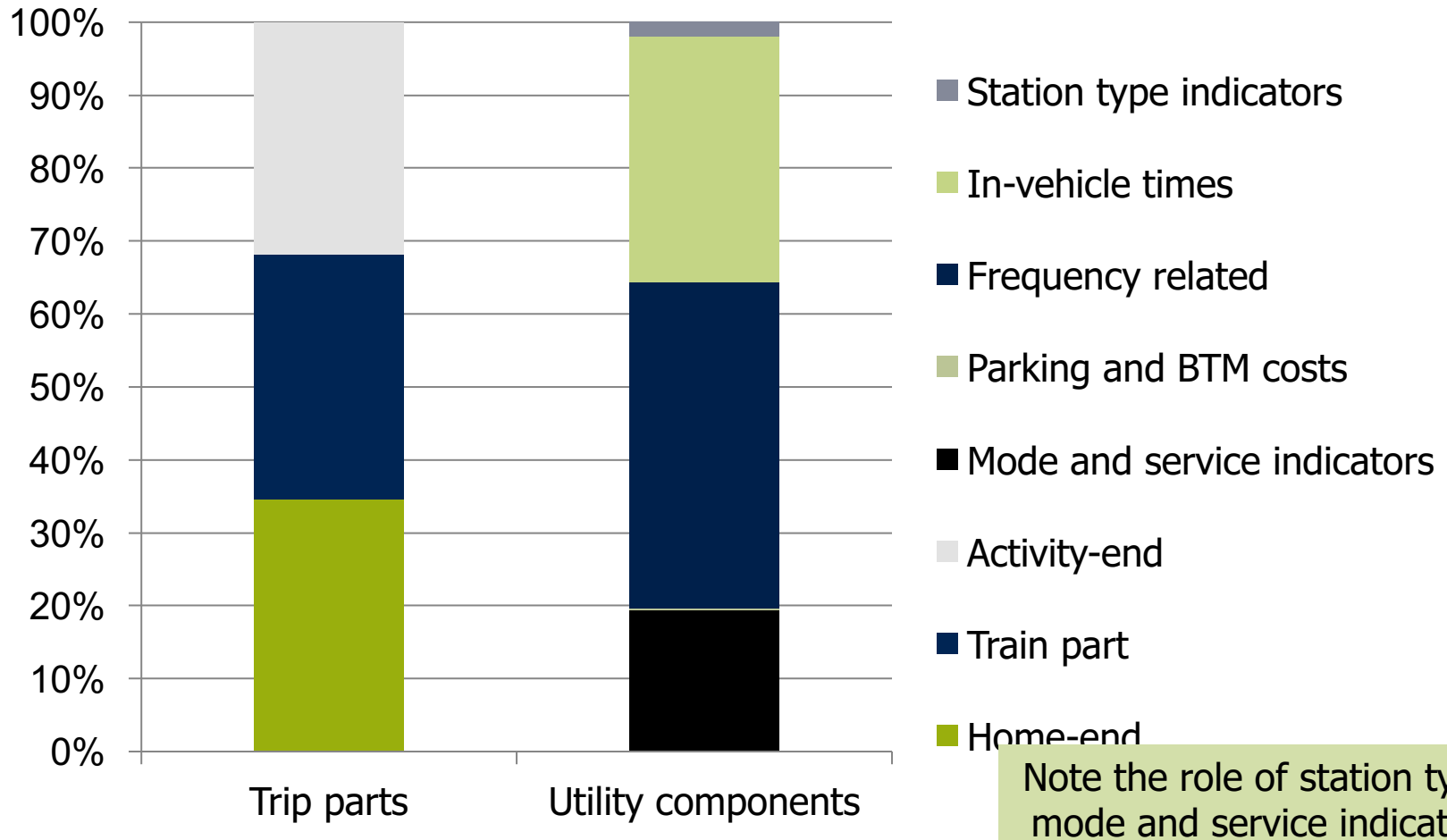
Mode choice

- Clear role of mode availability
  - Recall impact of 'captiveness'
- Clear role for quality (travel times) of each mode
- However, preferences for specific modes play a major role too!
  - Recall impact of 'captiveness'

Route choice

- Clear role of travel time
- In public transport different weights for trip time elements
  - $2.2*T_a+1.5*T_w+T_i+2.3*T_{wt}+5.9*N_t+1.1*T_e$
- Train trips are in fact multi-modal (80% of train travellers uses another mode to travel to or from the station)
- Consequence of multimodality…….

Main components utility function multi-modal route choice



Note the role of station type, mode and service indicators

Conclusion

- There is empirical evidence for the mechanism in Wegener's circle
- However, in nearly every choice situation many other factors play a role, and often quite dominantly
- Often simple and more specific accessibility indicators are significant in location choice:
  - distance to former location, distance to freeway
- Mechanism is stronger for car accessibility, however:
  - Increasing car usage leads to congestion, thus making other locations more attractive