CIE4801 Transportation and spatial modelling
Land-use and transport interaction models (TIGRIS) and choice modelling (+reprise)
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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

Government/Authorities

- Land market
  - Real-estate market
    - Commercial buildings
  - Labour market
    - Firms
  - Developers
  - Houses

- Housing market
  - Households

- Infrastructure

- Demography

Transport costs, accessibilities

Transport model
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

Land price model
determines the price of land at each location

Where does the transport model fit in?
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

Accessibility

Attractiveness
Living/working

Land use

Travel costs
Mobility
Congestion

$t-1$

$t-1$
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

To be used in year $t+1$
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

Regional Labor Market demand

Firms / jobs

Real estate market

Office space / Industrial zones

Labour market

Transport market

Land market

Regional workforce

Households / persons

Housing market

Houses

Demography

COROP regions
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 X

Stay

Move

Other COROP

Intra COROP

Zones (1308)
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

\[
\frac{E_{ge}(t)}{E_{ge}(t-1)} = \alpha_0 \cdot \prod_x LF_{xg}(t)^{\alpha_{xe}}
\]

Where:

- \( E \) = employment
- \( g \) = municipality
- \( e \) = sector
- \( NL \) = national
- \( LF \) = local factor, e.g. accessibility
- \( \alpha \) = 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
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)

Or see the book Land-use modelling in practice ([www.books.google.nl/books?isbn=9400718225](http://www.books.google.nl/books?isbn=9400718225))
Results trend scenario: Jobs

Industry

Logistics

Retail

Other consumer

Business services

Government services

% per jaar

0.72 of meer
0.48 tot 0.72
0.27 tot 0.48
0.00 tot 0.27
-0.31 tot 0.00
-0.58 tot -0.31
-0.98 tot -0.58
minder dan -0.98
Accessibility of jobs for households (by car) (defined as number of jobs that can be reached within 60 minutes)

morning peak

rest of the day
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

192 - 250000
250001 - 500000
500001 - 750000
750001 - 1000000
1000001 - 1250000
1250001 - 1500000
206 - 250000
250001 - 500000
500001 - 750000
750001 - 1000000
1000001 - 1250000
1250001 - 1500000
1500001 - 1917866
Accessibility of employees for firms (by public transport)
TIGRIS XL Concentration scenario

Appointed concentration areas
Results concentration scenario

Population

bevolkingsontwikkeling 2010-2040 bundeling (2010 = 1)

index40_10

<table>
<thead>
<tr>
<th>&lt;= 0.85</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.85 - 0.90</td>
</tr>
<tr>
<td>0.90 - 0.95</td>
</tr>
<tr>
<td>0.95 - 1.00</td>
</tr>
<tr>
<td>1.00 - 1.05</td>
</tr>
<tr>
<td>1.05 - 1.10</td>
</tr>
<tr>
<td>1.10 - 1.15</td>
</tr>
<tr>
<td>1.15 - 1.20</td>
</tr>
<tr>
<td>&gt; 1.20</td>
</tr>
</tbody>
</table>

CIE4801 Land-use and transport interaction models
Results concentration scenario
Population – concentration vs. trend

Bevolking 2040 bundeling vs trendvariant

bund_vs_TV2040

- >= 0.90
- 0.90 - 0.95
- 0.95 - 1.00
- 1.00 - 1.05
- 1.05 - 1.10
- 1.10 - 1.15
Results concentration scenario

Jobs – concentration vs. trend

Arbeidsplaatsen per jaar

- 508 of meer
- 200 tot 508
- 38 tot 200
- 0 tot 38
- -68 tot 0
- -164 tot -68
- -437 tot -164
- minder dan -437
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, validation 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

<table>
<thead>
<tr>
<th>Land-use model</th>
<th>Transport model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>no PT</td>
</tr>
<tr>
<td>none</td>
<td>PT, 24h</td>
</tr>
<tr>
<td>activity and judgement</td>
<td>PT, peak</td>
</tr>
<tr>
<td>no market-based land allocation</td>
<td>multimodal</td>
</tr>
<tr>
<td>logit allocation with price signals</td>
<td>activity-based</td>
</tr>
<tr>
<td>market-based land-use model</td>
<td></td>
</tr>
<tr>
<td>activity-based land-use model</td>
<td></td>
</tr>
</tbody>
</table>

**Transport model**
- no PT
- PT, 24h
- PT, peak
- multimodal activity-based
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

SHPmigration92
less than 5 employees
over 5 employees
firms92.txt Events
- 0 - 5
- 6 - 25
- 26 - 50
- 51 - 100
- 101 - 978
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 business trips:
Logs / <None>
- < 6.5
- 6.5 - 7.0
- 7.0 - 7.5
- 7.5 - 8.0
- > 8.0

railway
motorway
Study area

Logsum is based on destination and mode choice
Neighborhood of other firms

Specialization / Diversity
Specialization

PS Business Services Rb < 7.5 minutes

- < 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- > 1.5

\[ PS_{jsb} = \frac{E_{sR_{jb}}}{\sum_j E_{sj}} \cdot \frac{\sum_s E_{sR_{jb}}}{\sum_j \sum_s E_{sj}} \]

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

- Railway
- Highway

Diversity Index Range Band <7.5 minutes

<table>
<thead>
<tr>
<th>Range Band</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.750001 - 1.060000</td>
<td>1.00</td>
</tr>
<tr>
<td>0.500001 - 0.750000</td>
<td>0.75</td>
</tr>
<tr>
<td>0.440001 - 0.500000</td>
<td>0.50</td>
</tr>
<tr>
<td>0.030000 - 0.440000</td>
<td>0.03</td>
</tr>
</tbody>
</table>

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

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

Note that in this case the sectors are sorted on size.
Firm location choice model

Firm

Stay

Move

move probability

Location 1

 ...... 

location probability

Location N
Move probability

\[ V_{fi}^{\text{stay}} = 0 \]

\[ V_{fi}^{\text{move}} = \theta_0 + \theta_1 Gr_f + \theta_2 (1/ Age_f) + \theta_3 Sec_f + \theta_4 Acc_i + \ldots \]

\[ P_{fi}^{\text{move}} = \exp(V_{fi}^{\text{move}}) \]

firm characteristics

location characteristics

\[ f \text{ – firm index} \]

\[ i \text{ – location index} \]

\[ Gr = \text{firm growth} \]

\[ Age = \text{firm age} \]

\[ Sec = \text{firm sector} \]

\[ Acc = \text{location accessibility} \]
Move probability

Parameter estimates

<table>
<thead>
<tr>
<th>CONSTANT</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIRM CHARACTERISTICS</td>
</tr>
<tr>
<td>Log of size</td>
</tr>
<tr>
<td>Growth rate</td>
</tr>
<tr>
<td>1 / age</td>
</tr>
<tr>
<td>INDUSTRY SECTOR</td>
</tr>
<tr>
<td>Finance</td>
</tr>
<tr>
<td>Business services</td>
</tr>
<tr>
<td>Government</td>
</tr>
<tr>
<td>Education</td>
</tr>
<tr>
<td>Health service</td>
</tr>
<tr>
<td>General Services (ref.)</td>
</tr>
<tr>
<td>ACCESSIBILITY</td>
</tr>
<tr>
<td>α-location; near trainstation</td>
</tr>
<tr>
<td>β-location; near trainstation &amp; highway onramp</td>
</tr>
<tr>
<td>γ-location; near highway onramp</td>
</tr>
<tr>
<td>ρ-location; neither</td>
</tr>
<tr>
<td>URBANISATION ECONOMIES</td>
</tr>
<tr>
<td>Logsum business and commuting trips</td>
</tr>
<tr>
<td>LOCALISATION ECONOMIES</td>
</tr>
<tr>
<td>Diversity within &lt; 7,5 min.</td>
</tr>
<tr>
<td>Specialisation within &lt; 7,5 min.</td>
</tr>
</tbody>
</table>

| Parameter estimates |

-6.000 -5.000 -4.000 -3.000 -2.000 -1.000 0.000 1.000 2.000

[Legend: Significant □ Non significant]
Location probability

\[ V_{sij}^{\text{location}} = \theta_{s1} \text{Dist}_{ij} + \theta_{s2} \text{Acc}_j + \ldots \]

\[ \text{Dist} = \text{relocation distance} \]
\[ \text{Acc} = \text{location accessibility} \]

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

- \( s \) – firm sector index
- \( i \) – current location index
- \( j \) – new location index
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)

-2.5 -2.0 -1.5 -1.0 -0.5 0.0 0.5 1.0

MIGRATION ATTRIBUTE
Distance to original loc. [km^1/2]

ACCESSIBILITY ATTRIBUTE
near station
near station & onramp
near onramp
neither

URBANISATION ECONOMIES
Logsum business and commuting trips

LOCALISATION ECONOMIES
Diversity firms within 7,5 min.
Specialisation firms within 7,5 min.

COMPETING DESTINATIONS
Centrality parameter Teta

Significant
Non significant
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

Household
  \[\text{move probability}\]
  \[\text{Stay}\]
  \[\text{Move}\]
    \[\text{location probability}\]
    Location 1       ......       Location N
Location probability: MNL approach

\[ V_{hij}^{\text{location}} = \theta_1 \text{Dist}_{ij} + \theta_2 \text{Acc}_j + \theta_3 \text{Eth}_j + \ldots \]

- \( Dist \) = relocation distance
- \( Acc \) = location accessibility
- \( Eth \) = similarity ethnical background

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

- \( h \) – household type index
- \( i \) – current location index
- \( j \) – new location index
Location accessibility

Afstand supermarkt (in)
- 4.62 - 5.41
- 6.42 - 6.10
- 6.11 - 6.59
- 6.69 - 7.18
- 7.19 - 7.66
- 7.67 - 8.05
- 8.06 - 8.42

Afstand oprit (in)
- 4.96 - 6.61
- 6.62 - 7.19
- 7.19 - 7.63
- 7.64 - 8.03
- 8.04 - 8.44
- 8.46 - 8.91
- 8.92 - 9.21

Afstand centrum grote stad (in)
- 5.55 - 6.90
- 6.91 - 7.76
- 7.77 - 8.47
- 8.48 - 9.09
- 9.10 - 9.63
- 9.64 - 10.11
- 10.12 - 10.99

Afstand centrum kleine stad (in)
- 5.06 - 6.52
- 6.53 - 7.13
- 7.14 - 7.69
- 7.70 - 8.23
- 8.24 - 8.72
- 8.73 - 9.21
- 9.22 - 10.21

Afstand NS-station (in)
- 4.96 - 6.23
- 6.24 - 6.68
- 6.67 - 6.99
- 6.99 - 7.28
- 7.29 - 7.68
- 7.69 - 7.87
- 7.88 - 8.94

OV-kwaliteit (in)
- -0.00 - -0.68
- -0.69 - -0.48
- -0.59 - -0.30
- -0.39 - -0.20
- -0.19 - -0.10
- -0.09 - 0.10
- 0.11 - 0.20
- 0.21 - 0.40
- 0.41 - 0.63

Afstand basisschool (in)
- 4.62 - 5.41
- 5.42 - 5.89
- 5.90 - 6.29
- 6.30 - 6.76
- 6.77 - 7.27
- 7.28 - 7.79
- 7.80 - 8.55

Afstand middellare school (in)
- 4.96 - 6.23
- 6.24 - 6.83
- 6.84 - 7.40
- 7.41 - 7.98
- 7.91 - 8.31
- 8.32 - 8.72
- 8.73 - 9.11
Other factors

Statusscore SCP
-3.65 - -1.97
-1.96 - -1.12
-1.11 - -0.58
-0.57 - -0.12
-0.11 - 0.37
0.38 - 0.96
0.97 - 1.72
1.73 - 2.93
2.84 - 6.04

Woonmilieuindeling ABF
- Centrum stedelijk
- Buiten centrum
- Groen stedelijk
- Centrum dorp/s
- Landelijk wonen

Normwaarde percentage allochtonen
-0.27 - -0.13
-0.12 - -0.06
-0.06 - -0.01
0.00 - 0.05
0.06 - 0.14
0.15 - 0.25
0.26 - 0.37
0.38 - 0.53
0.54 - 0.71

Eengezinswoningen (% van totale woningvoorraad)
- 0.008 - 0.355
- 0.355 - 0.682
- 0.682 - 0.793
- 0.793 - 0.928
- 0.928 - 1.000
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

![Diagram showing utility function components]

- Trip parts
  - Station type indicators
  - In-vehicle times
  - Frequency related
  - Parking and BTM costs
  - Mode and service indicators
- Utility components
  - Activity-end
  - Train part
  - Home-end

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