Complexity methods applied to transport planning

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• Complexity in traffic/travel models
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  • Travel demand models
  • Land Use Transport Interaction (LUTI) models
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• Societal issues and complex transportation methods
• Conclusions
The transportation system

- Method = disaggregate/agent based model
- Nested, layered
- Established methods for modelling travel/traffic, also in applied policy support (less so for LUTI models)
- Aimed at quantitative forecasts

<table>
<thead>
<tr>
<th>Land use Transport Interaction Model</th>
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<tbody>
<tr>
<td>Travel Demand Forecasting Model</td>
</tr>
<tr>
<td>Traffic Simulation Model</td>
</tr>
<tr>
<td>- Lane choice</td>
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<tr>
<td>- Speed</td>
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<tr>
<td>- (Route choice)</td>
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<tr>
<td>- Trip frequency</td>
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<td>- Destination choice</td>
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<td>- Mode choice</td>
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<td>- Car ownership</td>
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<td>- Work status</td>
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<tr>
<td>- Residential/work location</td>
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<td>- Demographic events</td>
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<td>- Firmology (labour market)</td>
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<tr>
<td>- Land use change</td>
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<tr>
<td>- Housing market</td>
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</tbody>
</table>
Complexity

• Algorithmic complexity
  • E.g. enumeration, mathematical reproduction

• Deterministic complexity
  • Attractors, feedback, bifurcation, chaotic behaviour

• Aggregate complexity
  • Relations between agents/entities via structures
  • Agents have goals but limited knowledge/info
  • Memory and evolution of behavioural rules > resilience
  • Emergence and self organisation
  • Dissipation and path dependency
Traffic simulation models

- Cars as agents
  - Given origin/destination, departure time
  - Behavioural rules
    - Speed, following distance
    - Lane
    - Route
- Network (capacity)
- Signalling
- Dynamic, development through time, second by second
Traffic simulation models

- Complex effects
  - Aggregation: congestion, emissions
  - Interaction between cars
  - Road network = structure
  - Feedback mechanisms:
    - Speed, lane, route
  - Imperfect knowledge

![Traffic simulation model](image)
Travel demand forecasting models

• 4 steps
  • Generation, destination, mode, route

• Structure
  • Zones with households (push) and jobs, facilities (pull)
  • Network, travel times
Travel demand forecasting models

- Discrete choice models of generation, destination and mode choice (McFadden, Ben-Akiva):
  - choose alternative based on utility maximisation (time, cost, ....)
- Applied on aggregate (distribution) or disaggregate level (agent based)
Travel demand forecasting models

- Complex effects:
  - Aggregated effects
    - Traffic loads, congestion
    - Public transport patronage
  - Feedback effects
    - Frequency, destination, mode
- Tend to equilibrium
- Time frame: day, peak period
- For one day in the future
Travel demand forecasting models

- Activity based models
  - Scheduling and interdependencies
  - Trip chaining
  - Timing (peak spreading)
  - Household interactions
  - Operational models in US and Europe
Land Use Transport Interaction (LUTI) models

- Here: microsimulation approach
- Urbansim (Paul Waddell, Berkeley), ILUTE (Eric Miller, Toronto), ILUMASS (Michael Wegener)
- Also (up and above travel behaviour):
  - Households
    - Demographic events, Residential (re)location
    - Work status and job location, Car ownership
  - Firms
    - Job creation cancellation
    - Relocation
  - Developers
    - Land use change
    - Housing and real estate
  - Dynamic, year to year
Land Use Transport Interaction (LUTI) models

LONG TERM

activities, destinations

accessibility travel times

SHORT TERM
Land Use Transport Interaction (LUTI) models

- Agents: individuals, households, dwellings, firms, jobs, parcels/landowners
- Behaviour:
  - Probability distributions (demographic processes, work status, firm growth)
  - Discrete choice models (relocation, job location, land development)
  - Models of market behaviour (hedonic models, negotiation models)
- SPATIAL DIMENSION IS A COMPLICATING FACTOR
Land Use Transport Interaction (LUTI) models

- Interactions between agents:
  - Direct, one to one > markets
    - Housing market (households-dwellings)
    - Labour market (individuals-jobs)
    - Marriage (single men-single women)
  - Indirect, aggregate
    - Congestion < > travel decisions
    - Housing prices < > location preference and choice
    - N’hood composition < > location choice
    - TRAVEL TIMES, PRICES!
Land Use Transport Interaction (LUTI) models

- Examples (Erdogan et al., 2013)
  - Effect of fuel prices on travel behaviour, residential and job change

- Guerra (2014): effect of metro extension on travel and land use
Land Use Transport Interaction (LUTI) models

- Example of applications (Ettema et al., 2008):
  - Almere-Amsterdam corridor
  - 41,639 households in Almere
  - Jobs in Amsterdam: 2% higher income
  - Job location, activity frequency/time, expenditure

<table>
<thead>
<tr>
<th>% working in Amsterdam</th>
<th>BASE</th>
<th>KM-price +50%</th>
<th>incomes Amsterdam 100%</th>
<th>quality sensitive (β=0.04)</th>
<th>Incomes +10%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>82%</td>
<td>70%</td>
<td>56%</td>
<td>87%</td>
<td>69%</td>
</tr>
</tbody>
</table>

**Time allocation**

- in home:
  - BASE: 4,241
  - KM-price +50%: 4,388
  - incomes Amsterdam 100%: 4,464
  - quality sensitive (β=0.04): 4,318
  - Incomes +10%: 4,285

- maintenance:
  - BASE: 904
  - KM-price +50%: 820
  - incomes Amsterdam 100%: 886
  - quality sensitive (β=0.04): 1,032
  - Incomes +10%: 910

- social:
  - BASE: 674
  - KM-price +50%: 614
  - incomes Amsterdam 100%: 669
  - quality sensitive (β=0.04): 789
  - Incomes +10%: 660

- travel:
  - BASE: 613
  - KM-price +50%: 558
  - incomes Amsterdam 100%: 568
  - quality sensitive (β=0.04): 722
  - Incomes +10%: 637

**Frequencies**

- work:
  - BASE: 9.17
  - KM-price +50%: 8.75
  - incomes Amsterdam 100%: 8.44
  - quality sensitive (β=0.04): 8.11
  - Incomes +10%: 8.74

- maintenance:
  - BASE: 8.28
  - KM-price +50%: 8.20
  - incomes Amsterdam 100%: 8.86
  - quality sensitive (β=0.04): 10.20
  - Incomes +10%: 9.10

- social:
  - BASE: 6.08
  - KM-price +50%: 6.14
  - incomes Amsterdam 100%: 6.69
  - quality sensitive (β=0.04): 7.74
  - Incomes +10%: 6.60

**Travel distance (km)**

- BASE: 438
- KM-price +50%: 399
- incomes Amsterdam 100%: 406
- quality sensitive (β=0.04): 516
- Incomes +10%: 455

**Expenditures**

- In home:
  - BASE: 1,063
  - KM-price +50%: 1,037
  - incomes Amsterdam 100%: 1,077
  - quality sensitive (β=0.04): 1,032
  - Incomes +10%: 1,202
- maintenance:
  - BASE: 149
  - KM-price +50%: 104
  - incomes Amsterdam 100%: 149
  - quality sensitive (β=0.04): 191
  - Incomes +10%: 174
- social:
  - BASE: 95
  - KM-price +50%: 59
  - incomes Amsterdam 100%: 104
  - quality sensitive (β=0.04): 126
  - Incomes +10%: 136
- travel:
  - BASE: 245
  - KM-price +50%: 458
  - incomes Amsterdam 100%: 227
  - quality sensitive (β=0.04): 289
  - Incomes +10%: 255
- goods:
  - BASE: 280
  - KM-price +50%: 217
  - incomes Amsterdam 100%: 171
  - quality sensitive (β=0.04): 231
  - Incomes +10%: 163
Land Use Transport Interaction (LUTI) models

- Example of applications (Jackson et al., 2008):
  - Gentrification in Boston
  - Agents: professionals, non-professionals, students, elderly
  - Rents depend on % (high income) professionals
  - Relocation based on affordability
  - Accessibility of jobs, amenities counts
Land Use Transport Interaction (LUTI) models

- Example of application (Ettema, 2011):
  - (non spatial) model of housing market negotiation
  - Buyers decide whether to relocate, if a dwelling is acceptable, whether to accept price > based on beliefs about prices and probabilities

<table>
<thead>
<tr>
<th></th>
<th>Vacancy rate 20%</th>
<th>Vacancy rate 10%</th>
<th>Vacancy rate 5%</th>
<th>Vacancy rate 2.5%</th>
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<tbody>
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<td>mean -2.73</td>
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<td>mean -19.72</td>
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<td>mean -28.19</td>
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<td>UOPT</td>
<td>mean 55.87</td>
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<td>mean 0.30</td>
<td>s.d. 5.29</td>
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<td>mean -12.99</td>
<td>s.d. 1.25</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>mean -19.18</td>
<td>s.d. 1.94</td>
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<tr>
<td>Price</td>
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<td>mean 1.66</td>
<td>s.d. 0.17</td>
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<td></td>
<td></td>
<td></td>
<td>mean 2.21</td>
<td>s.d. 0.06</td>
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<td></td>
<td></td>
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<td>mean 2.46</td>
<td>s.d. 0.11</td>
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<tr>
<td>%wait</td>
<td>mean 0.99</td>
<td>s.d. 0.01</td>
<td>mean 0.61</td>
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<td></td>
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<td>mean 0.52</td>
<td>s.d. 0.23</td>
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<tr>
<td>P'3</td>
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<td>mean 0.45</td>
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<td>mean 0.36</td>
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<td>mean 0.33</td>
<td>s.d. 0.03</td>
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<td>P'80</td>
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<td>mean 0.30</td>
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<td></td>
<td></td>
<td></td>
<td>mean 0.28</td>
<td>s.d. 0.05</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>mean 0.32</td>
<td>s.d. 0.05</td>
</tr>
<tr>
<td>%sold</td>
<td>mean 0.01</td>
<td>s.d. 0.01</td>
<td>mean 0.42</td>
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<td>mean 0.32</td>
<td>s.d. 0.15</td>
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<td>mean 0.29</td>
<td>s.d. 0.18</td>
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<tr>
<td>#search</td>
<td>mean 470.21</td>
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<td>mean 299.78</td>
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<td>mean 400.85</td>
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<td>mean 461.75</td>
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<td>#sold</td>
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<td>mean 9.74</td>
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<td>mean 4.28</td>
<td>s.d. 2.70</td>
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Impacts for city and society

- Transportation models: aggregate outcomes of transport system (for given spatial configuration):
  - Congestion, travel time, pollution, noise
  - Accessibility and travel times > QoL
  - QoL indicators: time use, activity participation

- LUTI models: wider spatial and societal developments.....
Relevant societal developments

• Rising incomes and car ownership
  • income > car ownership, housing aspiration > job accessibility > relocation > suburban res. development > firm relocations > car dependency > social exclusion of marginal groups, excess commuting, congestion, pollution
Relevant societal developments

• Expanding cities (London)
  • Influx of habitants > urban residential extension > lack of jobs/services > excess travel times > commercial development

• Shrinking regions
  • Relocation and demographic processes > firm and institution relocation > reduced accessibility and QoL
Relevant societal developments

• ICTs
  • Teleworking, working on the move > accepting longer commute times > living in suburban locations
  • Teleshopping > fewer B&M shops > reduced accessibility for some > more delivery traffic
Relevant societal developments

- Electric vehicles
  - Introduction of charging outlets > accessibility by EV, impact on daily schedules > EV acquisition > market for charging outlets, price reduction, social influence > EV adoption > emissions > health effects

**Tesla Motors, China Unicom to build car charging outlets across China**

Fri, Aug 29 2014

By Samuel Shen and Norihiko Shirouzu

SHANGHAI (Reuters) - U.S. electric carmaker Tesla Motors (TSLA.O: Quote, Profile, Research, Stock Buzz) said on Friday that it would partner with China's No.2 mobile carrier China Unicom (0762.HK: Quote, Profile, Research, Stock Buzz) to build charging outlets across the country to push sales in the world's biggest auto market.

The companies have signed a deal to build charging posts at 400 China Unicom stores in 120 cities, and will also set up super-charging outlets in 20 Chinese cities, Tesla's China spokeswoman Peggy Yang said.

Tesla's billionaire co-founder Elon Musk has said he expects to invest hundreds of millions of dollars building charging outlets in China as the company seeks to compete more effectively with foreign rivals such as BMW (BMWG.DE: Quote, Profile, Research, Stock Buzz) and Daimler AG (DAIGn.DE: Quote, Profile, Research, Stock Buzz) and address Chinese customers' complaints about belated product delivery.
Conclusions/discussion (1)

- Land use/transportation system is a complex system
- Agent based traffic, travel and land use models can be used to represent/study complex effects
- Agent based models offer flexible structure to implement new components

- Agent based models may deliver valuable insights
  - Feed back effects, secondary effects becoming game changers
  - Insight in process and path dependency
  - Order of magnitude, tipping points, policy options
  - Illustration and visualisation
Conclusions/discussion (2)

• But...modelling complexity is complex
  • ‘Downward spiral of ever increasing complexity’ (Eric Miller)
  • ‘Building a 1 to 1 Spitfire model’ (Michael Wegener)
  • .... especially if it is spatial
  • Calibration of agents’ behaviour, interaction, total system
  • Error propagation
  • Tractability/theory
  • Data availability
Conclusions/discussion (3)

• Issues
  • Where to draw system boundary?
  • Full fledged agent based model or dedicated model using existing travel demand model?
  • What output do you expect: Exact forecasts? Argumentation? Insight in process? Sensitivity analysis?
  • Challenges: markets, social interactions, changes in behavioural rules/preferences/attitudes
Thank you

Questions?

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