Challenges, problems and solutions in transportation research

Prof. dr. Davy Janssens
Contents

- Understanding travel behaviour
  - Surveys and studies
  - Crowdsourcing

- From understanding travel behaviour ... towards solving real-world problems in transportation
  (Congestion, Emission and health, Electric vehicles)

- Activity-based transportation models as a solution?

- Research results
But first some psychological reflections...

- When asked for VOT of activities: travelling least important, leisure most important (D. Kahneman)

- However:
  - *ideal* travel time 16 minutes
  - everything < 16 minutes $\rightarrow$ positive experience/utility!
  - people become used to the environment, context they live in

- Aspen-effect (R. Frank):
  - city in Colorado
  - commuting distances become longer and longer because of *price of houses*
  $\rightarrow$ It comes down to a trade-off between a nice house and longer travel time & distance
- *Changes* in travel time are more troublesome than actual travel time → perceived level of control is lower in PT (D. Gilbert)

- Assume we would solve all congestion on main roads → less than 15% time gain! (Vanderbilt)

- Focus illusion existing in transport:
  - things become more important if you start thinking about it
  - research:
    - 1. How long does it take you to go to your work?
    - 2. How happy are you?

→ it is not as worse as it seems since people do not change their behaviour
- Modal split in Flanders
Mode choice and distance
Society reflected in travel behaviour

Understanding travel behaviour
Surveys and studies
## Travel time per kilometer

<table>
<thead>
<tr>
<th>Minutes per kilometer</th>
<th>Distance class</th>
<th>0.1 tot 1 km</th>
<th>1 tot 5 km</th>
<th>5.1 tot 25 km</th>
<th>meer dan 25 km</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Average (minutes)</td>
<td>N</td>
<td>Average (minutes)</td>
<td>N</td>
</tr>
<tr>
<td>By foot</td>
<td>4112</td>
<td>19.62</td>
<td>1505</td>
<td>14.99</td>
<td>261</td>
</tr>
<tr>
<td>Bicycle</td>
<td>2150</td>
<td>7.80</td>
<td>3127</td>
<td>4.73</td>
<td>954</td>
</tr>
<tr>
<td>Car driver/car passenger</td>
<td>2493</td>
<td>5.94</td>
<td>10893</td>
<td>2.70</td>
<td>12921</td>
</tr>
<tr>
<td>BTM (bus, tram, metro)</td>
<td>437</td>
<td>6.30</td>
<td>1024</td>
<td>3.53</td>
<td>150</td>
</tr>
<tr>
<td>By train</td>
<td>165</td>
<td>2.40</td>
<td>637</td>
<td>1.42</td>
<td></td>
</tr>
</tbody>
</table>
The importance of land use and regional differences
Growth also caused by other factors than individual travel behaviour

- Inhabitants (including migration: e.g. 6 mio in 2004, 6.3 mio in 2013)
- Sales of cars (average number of cars *per family*)
- Economy
“Moving Forward” as a crowdsourcing platform

Moving Forward is a GIS-based ICT application to produce digital accessibility maps. With the application you can visualize in a quick and easy way the accessibility of locations.
Application 1: Visualize safe school routes
Understanding travel behaviour through Crowdsourcing

Procedure

1. [Image of mobile devices with apps]

2. [Images of maps and data analysis]

3. [Image of computer interface]
Application 2: Participation and communication tool

- a) mobile version and a web based version
- b) Web application
- c) Overview map
How does it work?
It is simple to assign a reported issue to a third party
From understanding travel behaviour ... towards solving real-world problems in transportation
Topic 1: Congestion: context

- Caused by Demand (which follows from travel behaviour of individuals) >> Supply (also measured as I/C-rate)

- Major economic implications:
  - Normal traffic jam in Flanders: 140km (per day), 250000 euro (per day)

- Antwerp and Brussels number 1 and 2 in Europe (Inrix)

- Peak hour phenomenon; although only about 35% of traffic demand during peak hours is related to work activities

→ Example of wrong type of inductive reasoning
Congestion: identified research problems

- Any transportation model can calculate effect of infrastructure adaptations (e.g. new/less roads)
- But most solutions are not sustainable because of problem of induced/latent demand (available capacity absorbed by new traffic)

<table>
<thead>
<tr>
<th></th>
<th>short run</th>
<th>long run (after 3y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SACTRA*</td>
<td></td>
<td>50-100%</td>
</tr>
<tr>
<td>Goodwin*</td>
<td>28%</td>
<td>57%</td>
</tr>
<tr>
<td>Johnson &amp; Ceerla*</td>
<td></td>
<td>60-90%</td>
</tr>
<tr>
<td>Hansen &amp; Hung*</td>
<td></td>
<td>90%</td>
</tr>
<tr>
<td>Fulton ea*</td>
<td>10-40%</td>
<td>50-80%</td>
</tr>
<tr>
<td>Marshall*</td>
<td></td>
<td>76-85%</td>
</tr>
<tr>
<td>Noland*</td>
<td>20-50%</td>
<td>70-100%</td>
</tr>
<tr>
<td>EC (2004)</td>
<td>25%</td>
<td>50%</td>
</tr>
<tr>
<td>Schiffer ea (2005)</td>
<td></td>
<td>0-40% 50-100%</td>
</tr>
</tbody>
</table>

19
Need for calculation of Transportation Demand Management (TDM) measures:

- Definition: Strategies and policies to reduce travel demand, or to redistribute demand in space or in time.

- E.g. Teleworking, parking pricing policies, congestion pricing, etc.

- Lack of understanding about travel behaviour put limitations to what can be done in traditional models.

- Also: travel demand is not about aggregate numbers (aggregation bias) but especially also about more detailed sub-groups and segmentations (e.g. day of week).
Topic 2: Emissions & health: context

- Pollutants: NO$_2$, Ozone, PM,...

- Different sources: industrial, household, traffic,...

- Consequences for human health (e.g. Meuse Valley fog in 1930, London smog of 1952,...)

- Guidelines and measures (EU Directive 2008/50/EC,...)
Topic 2: Exposure: research problems

- Classic method of calculation:
  - High resolution concentration data \(*multiplied by*\ Statistical population data

- Derived from measurements or air quality modelling
- Spatial / temporal
- Outdoor
- Averaged (cfr. AQ standards)

- Exposure = concentrations \(\times\) population

- Address based
- Static (annual)
- Poor resolution / Quality
**Topic 3: Electric vehicles: context**

- Electric vehicles: combines interesting (sustainability) aspects:
  - First/last mile problem in an interconnected city hub (congestion reduction in cities)
  - Environmental advantages, although shift towards factories where electricity is produced
  - Simply electricity users or an intelligent actor in an interconnected smart grid energy network?

- Lot of potential:
  - In theory: user, storage and perhaps producer
  - Several pitfalls
  - Technology is strongly pushed by governments/EU
European policy measures (Mobi, VUB)

United Kingdom
450 milj £
100,000 EVs asap
25,000 charging stations in 2015

The Netherlands
65 milj euro
10k EVs in 2015, 200k EVs in 2040
200 charging points by 2010

France
1500 milj euro
2 milj EVs by 2020
4 milj charging points by 2020

Portugal
180k EVs in 2020
25000 charging points by 2020

Spain
590 milj euro
20k EVs in 2011, 50k in 2012, 250k in 2014
25000 charging points by 2020

Sweden
2030 Electric vehicle city
2050 Fossil free city
2010: 100 charging stations
(65% households have engine heathers)

Germany
500 milj euro
1 milj. in 2020, 5 milj in 2030

Italy
10% EVs by 2020
**Topic 3: Electric vehicles: research problems**

- Several future projections exist. However:
  - Unable to quantify the microscopic point of view of the driver who needs to drive *and* charge: range anxiety

- Most transportation models are not coupled with energy models, although necessary for:
  - high demand of EV may have impact on electricity consumption
  - smart grid applications (peak shaving by using EVs as electricity storage)

- Unable to take into account behavioural adaptation of the user (e.g. charging when price is lowest)
In summary: research problems per topic

Calculation of TDMs

Exposure = concentrations (high detail) x population (low detail)

Individual behaviour: range anxiety and adaptations

Link with energy models

Understanding behaviour!
Activity based model theory

- Theory is based on theory that travel is a **derived demand**
- We model **daily activity patterns** (multidimensional AP)
  - Vertical lines represent activities
  - Diagonal lines are travel episodes
- Explicit representation of time of occurrence for all travel episodes, linked to associated activities
- ABM generates an activity pattern for modeled individuals
  - Know when and where they are traveling at all times
Dual worlds: simulator and big data

Modeling Reality
A behaviorally sensitive simulator

Observed Reality
Big Data

Validation and calibration

Storing and querying (with special operators) this info in a semantically enriched MOD

Semantic Datawarehouse
Big Data Warehouse
The FEATHERS framework

FEATHERS (Forecasting Evolutionary Activity-Travel of Households and their Environmental RepercussionS)

- Developed by IMOB, Hasselt University
- Model Framework incorporating different schedulers, currently one full scheduler operational for Flanders
- Sequential decision process consisting of 27 decision trees
- Configurable for multiple study areas
  - e.g. Flanders in Belgium, Netherlands, Slovenia and Seoul area in S. Korea
- Recuperation of research / implementation efforts
## Data inputs

- **(1) Zoning definition (different layers):** 41 km²; 12 km²; 5.5 km².

- **(2) Land use and transport network data:**
  - transport network: free floating car travel time, congested travel time, BTM travel time, etc.
  - Land use (per zone): urban density, total number of employees, total number of school children, number of employees, etc.

- **(3) Full population data:** (synthetic population data for all agents in study area: age, gender, household composition, income, etc.)

- **(4) Diary data (travel behaviour)**
<table>
<thead>
<tr>
<th>Current zoning definition</th>
<th>Submunicipalities</th>
<th>Subzones</th>
<th>Blocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Municipalities</td>
<td>&gt; Superzones (327) (41 km²)</td>
<td>&gt; Zones (1145) (12 km²)</td>
<td>&gt; Subzones (2386) (5.5 km²)</td>
</tr>
</tbody>
</table>
### Example

<table>
<thead>
<tr>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>03:00</td>
</tr>
<tr>
<td>05:00</td>
</tr>
<tr>
<td>07:00</td>
</tr>
<tr>
<td>09:00</td>
</tr>
<tr>
<td>11:00</td>
</tr>
<tr>
<td>13:00</td>
</tr>
<tr>
<td>15:00</td>
</tr>
<tr>
<td>17:00</td>
</tr>
<tr>
<td>19:00</td>
</tr>
<tr>
<td>21:00</td>
</tr>
<tr>
<td>23:00</td>
</tr>
<tr>
<td>01:00</td>
</tr>
</tbody>
</table>

**Description individual:**

- **Location:** 2215
- **Number of cars:** 1
- **HHtype:** double, two workers
- **Age:** 45-64
- **Socio-eco class:** > modal but < 2 x modal
- **Children class:** Children < 6 year
- **Gender:** Male
Example

- Morning sleep
- Work
- Evening sleep

1. Include work episode: Y
2. Total duration: 650 min
3. Number of episodes: 1
4. Start time: 7:58
5. Location: 2326
6. Travel mode: car
Example AB output once the simulation is completed

- For every person in population (6 mio agents)

- **Powerful analysis tool:**
  - infinite number of combinations: e.g. when shopping from when till when
  - sequential information
  - O/D matrices
  - detailed segmentation in time and space

- Beyond what you can do in a traditional transportation model
Output example

Analysis of tours and trips

- Frequencies
- Modal choice
- Distance and/or time distribution
- Detailed segmentation based on socio-demographics

E.g. Modal split for 65+

Relative amount of trips leaving each municipality in Flanders (Belgium)
Traffic assignment

- Vehicle flows
- Volume to network capacity

Trips for all activities in Flanders (Belgium)

Trips for work activity in Brussel
Evaluation of a telecommuting scenario as an example of a TDM measure
### General telecommuting model (Mokhtarian, 1998) in Flanders

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>The number of employees on an average work day</td>
<td>2,504,000</td>
</tr>
<tr>
<td>C</td>
<td>Proportion of employees that are able and willing to telecommute (Kordey, 2002)</td>
<td>0.106</td>
</tr>
<tr>
<td>F</td>
<td>Average telecommuting frequency (Walrave and De Bie, 2005)</td>
<td>0.36</td>
</tr>
<tr>
<td>O</td>
<td>The expected number of telecommuters during an average work day</td>
<td>95,553</td>
</tr>
<tr>
<td>D</td>
<td>Average back and forth home-work distance during a non-telecommuting work day (Zwerts and Nuyts, 2002; Dooms and Illegems, 2006)</td>
<td>57 km</td>
</tr>
<tr>
<td>α</td>
<td>Proportion of the number of telecommuting opportunities that eliminates a home-work trip (Zwerts and Nuyts, 2002; Anon., 2002)</td>
<td>0.501</td>
</tr>
<tr>
<td>V</td>
<td>The total eliminated home-work distance during an average work day</td>
<td>2,728,707 km</td>
</tr>
<tr>
<td>P</td>
<td>The net change in total vehicle travel as a proportion of the total vehicle travel during an average day</td>
<td>-1.6%</td>
</tr>
</tbody>
</table>
Input data:

• Study area data
  - Attractiveness of locations
    - # shops, # inhabitants, employment, …
  - Transportation networks
    - LOS PT, distances, FF travel times, …
    - Flemish road network

• Synthetic population
  - 6M persons for Flanders

• Activity-Travel schedules for model calibration
Scenario implemented in the model

Telecommuting scenario:

```
<table>
<thead>
<tr>
<th>Hour</th>
<th>Activity</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>03:00</td>
<td>Sleep</td>
<td>H</td>
</tr>
<tr>
<td>05:00</td>
<td>Sleep</td>
<td>H</td>
</tr>
<tr>
<td>07:00</td>
<td>Sleep</td>
<td>H</td>
</tr>
<tr>
<td>09:00</td>
<td>Work</td>
<td>A</td>
</tr>
<tr>
<td>11:00</td>
<td>Work</td>
<td>A</td>
</tr>
<tr>
<td>13:00</td>
<td>Work</td>
<td>A</td>
</tr>
<tr>
<td>15:00</td>
<td>Social visit</td>
<td>B</td>
</tr>
<tr>
<td>17:00</td>
<td>Leisure</td>
<td>C</td>
</tr>
<tr>
<td>19:00</td>
<td>Leisure</td>
<td>C</td>
</tr>
<tr>
<td>21:00</td>
<td>Leisure</td>
<td>C</td>
</tr>
<tr>
<td>23:00</td>
<td>Sleep</td>
<td>H</td>
</tr>
<tr>
<td>01:00</td>
<td>Sleep</td>
<td>H</td>
</tr>
</tbody>
</table>
```

```
<table>
<thead>
<tr>
<th>Hour</th>
<th>Activity</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>03:00</td>
<td>Sleep</td>
<td>H</td>
</tr>
<tr>
<td>05:00</td>
<td>Sleep</td>
<td>H</td>
</tr>
<tr>
<td>07:00</td>
<td>Sleep</td>
<td>H</td>
</tr>
<tr>
<td>09:00</td>
<td>Work</td>
<td>A</td>
</tr>
<tr>
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</tr>
<tr>
<td>23:00</td>
<td>Sleep</td>
<td>H</td>
</tr>
<tr>
<td>01:00</td>
<td>Sleep</td>
<td>H</td>
</tr>
</tbody>
</table>
```
Processing steps:

First, run Feathers and aggregate travel demand in OD matrices

- Create activity-travel diary data sets
  - for a null scenario and a telecommuting scenario
  - for 7 days of the week
- OD matrices focused on car mode
  - 168 OD matrices per scenario (7x24)

Subsequently, assign OD matrices to the Flemish road network

- use an equilibrium traffic assignment model
  → use an iterative process to achieve a convergent solution in which no travelers can improve their travel times by shifting routes
Results

Tour activity sequence distribution: Work vs. Telework

- Work
- B/G
- Flex. Act.
- Other Act.

Percentage

Tour activity sequence

- Work
- Telework
## Total vehicle travel

<table>
<thead>
<tr>
<th>Day</th>
<th>Null scenario vkm (10^9)</th>
<th>Telecommuting vkm (10^9)</th>
<th>Difference (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mon</td>
<td>0.137</td>
<td>0.134</td>
<td>-1.96</td>
</tr>
<tr>
<td>Tue</td>
<td>0.141</td>
<td>0.138</td>
<td>-1.89</td>
</tr>
<tr>
<td>Wed</td>
<td>0.135</td>
<td>0.132</td>
<td>-2.16</td>
</tr>
<tr>
<td>Thu</td>
<td>0.138</td>
<td>0.135</td>
<td>-2.11</td>
</tr>
<tr>
<td>Fri</td>
<td>0.136</td>
<td>0.134</td>
<td>-1.96</td>
</tr>
<tr>
<td>Sat</td>
<td>0.119</td>
<td>0.118</td>
<td>-0.95</td>
</tr>
<tr>
<td>Sun</td>
<td>0.102</td>
<td>0.102</td>
<td>-0.31</td>
</tr>
<tr>
<td>Total sum</td>
<td>0.909</td>
<td>0.894</td>
<td>-1.68</td>
</tr>
</tbody>
</table>
Topic 2: Emissions and Health (Beckx et al., 2010; Dhondt et al., 2013; Dons et al., 2014)
Application: Activity-based models for air quality purposes

» Information on travel demand (Shiftan, 2000)
  » ‘driving forces’ of environmental problem (why, who, when, …)
  » Secondary effects

» Enriched O/D-matrix ⇒ detailed traffic streams
  » Vehicle emissions (incl. cold start) and pollutant concentrations
    per time of day (↔ peak hour values)
  » Distribution of people during the day (↔ ‘static’)

⇒ Exposure assessment
Beckx et al.: methodology combining different models

**ACTIVITY-BASED MODEL** (ALBATROSS)
- Time-activity patterns

**EMISSION MODEL** (MIMOSA)
- Vehicle emissions

**DISPERSION MODEL** (AURORA)
- Pollutant concentrations

- "A Learning-Based Transport Oriented Simulation System" Developed by Arentze and Timmermans (2000) in The Netherlands
- 10,000 personday activity diaries
- Hourly emissions, per km², in The Netherlands
- Hourly concentrations on 3 x 3 km grid cells
- "Air quality modelling in Urban Regions using an Optimal Resolution Approach"

- "Air quality maps for regional down to urban scale" (Arendt, 2000)

- "Population maps and dynamic concentration maps"
Beckx et al.: Exposure calculation in The Netherlands

- Dynamic NO₂ exposure relative to static exposure estimates
  - Differences during the day (up to 30%)
  - Overall difference: 4% underreported by static approach
Beckx et al.: Disaggregated exposure analysis: population

‘Subpopulation exposure’ relative to ‘mean population exposure’
Dhondt et al.: Activity Based Air quality assessment

![NO₂](image1)

![Ozone](image2)
Exposure (Human health) (e.g. NO$_2$)
- Higher dynamic exposure for residents of 'rural' areas
- Lower dynamic exposure for residents of urban areas
→ Effect of travel (more kms travelled on highways in rural areas)
Topic 3: Electric vehicles (Knapen et al. 2012)
Electric vehicles/energy demand

Scenario 1

Scenario 2
- 78% of all trips is feasible to execute by Battery only EV
- Electric Vehicle Scenarios
  - Power requirement: All EV are PHEV
    - “Uniform Low Cost” (max. use of low tariff)
    - “Last Home”
    - “Always at Home” (each home arrival)

Distribution of the maximal power demand (9% of EV market share)
EVC-WIDRS: Electric vehicle Within Day Rescheduling

- WIDRS: Rescheduling because of delayed travel times (e.g. incidents)
- EVC-WIDRS: Rescheduling activities because of charging price is time-dependent

Constraints:
- Be able to carry out your schedule
- Minimum battery state
- Charging cheap
Questions/remarks?

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