Urban transport modal shift: an energy systems approach

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Passenger transport growth in the UK

- Growth in passenger km increased 4-fold in UK since 1950, driven by increased ownership and use of cars
- No question of positive benefits.......but also negative environmental impacts

Source: Transport Statistics Great Britain 2013
Going beyond technology: the need for behavioural representation

• A move to more sustainable transport systems will depend on consumer choices

• Schäfer (2012) highlights a deficit of behavioural representation in many E3-type models
  – Elastic transportation demand
  – Endogenous mode choice
  – Choice of no physical travel
  – Accounting for infrastructure capacity
  – Segmenting urban and intercity transport

• Daly et al. (2014) demonstrate an approach to incorporating modal shift in a TIMES model; this paper builds on that approach
How to represent urban modal shift?

• We want to consider the following –

1. **Demand**: focus on shorter trips in urban areas where application most relevant
2. **Mode speed**: consumers appear to have a travel time budget of ~1 hour per day; therefore mode speed matters
3. **Rate and level of shift**: there are constraints on timescale of shifts, and maximum levels
4. **Costs of shift**: different infrastructure costs need to be considered if we are exploring policy-optimal solutions

• So how can this be implemented in a bottom-up, optimisation model?
Standard model implementation

- Fuel inputs
- Motorised techs
- Mode-specific surface passenger travel demand (pkm) \( i,t \)
MS model implementation

Technologies control for:
- i. Time budget needed for different modes (based on average speed)
- ii. Current mode shares (calibration)
- iii. Investments for additional mode capacity
- iv. Rate and level of shift

Proxy infrastructure techs (pkm)

Travel time budget (TTB) \(i,t\)

Existing
- Bus
- Cars
- Rail
- Bikes
- Walking

New
- Modes x5 (as per above)

Fuel inputs

Urban surface passenger travel demand (pkm) \(i,t\)

Motorised techs

Non-motorised techs
How to represent urban modal shift?

- Four factors to consider -
  1. Demand
  2. Mode speed
  3. Rate and level of shift
  4. Costs of shift
1a. Demand: Disaggregating UK surface passenger demand

NTS annual mileage per capita (by area type)

- Rural: 8657
- Urban: 2107
- All: 6726

Average mileage / cap. / year, 2010

Modal shift in ESME, IEW2015
Steve Pye, 03.06.15
1b. **Demand**: Total urban and rural demand by mode, 2010

- Urban (<35 miles) accounts for 42% of surface transport passenger demand; disaggregated by region.

**Total ESME demands disaggregated by area type and mode, 2010**
2a. **Mode speed & the role of time budgets**

- Reason for introducing time budget in model is to ensure mix of modes
- The ‘need for speed’ means we can’t all switch to slower non-motorised modes

- Evidence base for time budgets
  - Aggregate constant time budget observed ~1 hr/day/cap; stability of time budgets as a concept (Zahavi and Ryan, 1980)
  - Large differences when disaggregated – age, car ownership, gender, income, spatial characteristics (Mokhtarian and Chen, 2004)
  - Different in other countries; rising in Netherlands (van Wee et al. 2006)
  - Sceptical positions; stability of concept is questioned (Goodwin 1981)
2b. **Mode speed & the role of time budgets**

- Problem of assuming constant budget for analysis
- Overall demand increasing at higher rate than population; holding time budget constant requires that average speeds have to increase (red dash line)
- However, mode shift potential may require a higher share of slower modes

![Graph showing urban population, urban demand, and average urban speed with and without adjusted time budget. The graph illustrates the increase in demand and speed from 2010 to 2050, with an adjusted time budget of +7.5% by 2050 (1.02 hrs compared to 0.95).]
3a. Rate & level of mode shift estimates

- Assess urban trip distance profile; replacement of car trips by other modes limited due to distance

Greater London: Average miles & trips /capita by MODE & TRIP DISTANCE
3b. Rate & level of mode shift estimates

- Determine maximum mode shift by 2050. Already limited by distance, additional information from other analysis / international experience
- Rates of mode shift over time based on linear interpolation, achieving maximum in 2050

Greater London; max. permitted change in per capita miles by mode

Trip mileage share by mode
4a. **Cost factors** in mode shift

- Within constraint of mode shift potential and rate, optimisation will play role
- Mode costs considered given inter-modal competition, and non-mechanised modes
- Inclusion of infrastructure costs; no repr. of other key factors (value of time, convenience etc.)

![Cost factors diagram]

<table>
<thead>
<tr>
<th>Mode</th>
<th>£/pkm, 2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bus</td>
<td>0.05</td>
</tr>
<tr>
<td>Car</td>
<td>0.10</td>
</tr>
<tr>
<td>Rail</td>
<td>0.25</td>
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<tr>
<td>Rail (exist)</td>
<td>0.20</td>
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<tr>
<td>Cycle</td>
<td>0.05</td>
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</table>
Model analysis

• Runs focus on exploring model behaviour and future application of approach
• All runs under LT climate policy scenario

<table>
<thead>
<tr>
<th>Run</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Ref (v3.3)</td>
<td>ESME v3.3 standard run for comparison</td>
</tr>
<tr>
<td>MS-Ref</td>
<td>Modal shift ref. case (as presented)</td>
</tr>
<tr>
<td>MS-High</td>
<td>Strong push on sustainable transport, increasing MS potential</td>
</tr>
<tr>
<td>MS-NoTTB</td>
<td>Innovation erodes assumptions of time budgets</td>
</tr>
<tr>
<td>MS-HighCC</td>
<td>External costs penalising car travel</td>
</tr>
<tr>
<td>MS-HighCC NoTTB</td>
<td>Combined sensitivity case</td>
</tr>
</tbody>
</table>
Levels of shift: key sensitivities

- Increasing levels of mode shift over time
- Levels of shift – 5-15% of demand by 2040/50

Cycle always maximises in model; however, issue w/ trade-off

Bus stronger role where time constr. relaxed / car costs hiked

Strong car reduction only if cost penalty introduced, and time constraint relaxed
Technology impacts: change in car capacity

- 2020-2040: Carbon constraint sees ICEs drop out of mix
- 2050: Reducing mitigation costs through MS headroom (reflected in marginal CO2 cost)

Change in car capacity, million vehicles

<table>
<thead>
<tr>
<th>Year</th>
<th>Car PHEV</th>
<th>Car ICE</th>
<th>Car hydrogen</th>
<th>Car hybrid</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020</td>
<td></td>
<td></td>
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<tr>
<td>2030</td>
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<td>2040</td>
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<tr>
<td>2050</td>
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</tbody>
</table>

Legend:
- Car PHEV
- Car ICE
- Car hydrogen
- Car hybrid
Reductions in passenger transport emissions

- Highest % reductions where non-motorised demand increases / motorised decreases
- Percentage reductions small in 2050 due to strongly decarbonised sector & reduction in ULEV vehicles
- Broadly speaking, shifts supply-side options down the technology cost curve

Change in TOTAL surface transport passenger emissions, MtCO₂

<table>
<thead>
<tr>
<th>Car</th>
<th>Rail</th>
<th>Bus</th>
</tr>
</thead>
<tbody>
<tr>
<td>MS-Ref</td>
<td>MS-High</td>
<td>MS-NoTTB</td>
</tr>
<tr>
<td>MS-High</td>
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</tr>
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<td>MS-HighCC</td>
<td>MS-NoTTB</td>
<td>MS-HighCC NoTTB</td>
</tr>
</tbody>
</table>

2020 | 2030 | 2040 | 2050
Findings

• Cost optimal solutions favour sustainable transport modes if included. Relative strength is contingent on disincentivising car travel, and affecting travel time considerations.

• Demonstrates application of approach to mode shift in energy systems models, and sub-optimality of supply-side focused approaches.

• Strengths of approach
  – Demonstrates approach in full systems model, and considers non-motorised modes
  – Begins to capture infrastructure requirements explicitly
  – Allows for endogenous shift, capturing technology trade-offs

• Limitations
  – Lack of ‘choice’ considerations (engineering perspective only)
  – Data needs and model re-configuration not insignificant
Further research

• Extend scope of approach to capture longer distance trips; this is where most emissions are derived

• Key questions across constraints
  – Level of time budget?
  – Maximum shift achievable, and rate of change?

• Development of consumer level choice parameters

• Develop infrastructure capacity constraints, impacting on mode speed (depending on investment)

• Consideration of externalities, particularly relevant for urban transport (pollution, noise, congestion etc.)
Thanks for listening. Any questions?

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References

References


Additional slides
Per capita transport demand by area type and mode

Mileage
- Average mileage dominated by car travel
  - 87% (Rural + Urban, >35)
  - 78% (Urban, <35)
- Greater London profile distinctive; more bus and rail travel, and lower overall demand

Trips
- Urban <35 travel dominates trip profile (97%)
- Distinctive trip profile for Greater London
Mode shift: factors

![Graph showing reasons for not choosing the public transport system.]

**Reasons for not choosing the public transport system**

- **Lack of connections**: 49% Very important, 23% Rather important, 9% Rather unimportant, 13% Not important at all, 6% DK/NA
- **Not as convenient as a car**: 48% Very important, 23% Rather important, 13% Rather unimportant, 10% Not important at all, 6% DK/NA
- **Low frequency of service**: 40% Very important, 24% Rather important, 14% Rather unimportant, 15% Not important at all, 8% DK/NA
- **Lack of reliability**: 32% Very important, 22% Rather important, 15% Rather unimportant, 25% Not important at all, 7% DK/NA
- **Too expensive**: 26% Very important, 24% Rather important, 18% Rather unimportant, 22% Not important at all, 10% DK/NA
- **Lack of information on schedules**: 26% Very important, 23% Rather important, 20% Rather unimportant, 25% Not important at all, 7% DK/NA
- **Security concerns**: 22% Very important, 18% Rather important, 22% Rather unimportant, 31% Not important at all, 7% DK/NA

Q3. If your main mode of transportation is not public transport, please tell me how important the following reasons are for not choosing the public transport system?

Base: those who use car as a main mode of transport, % EU27

Source: Flash Eurobarometer “Future of transport” (EC 2011)
Mode shift factors

Literature suggests many factors at play -

– Lifestyle stability. Change of home, workplace often key factor, known as ‘churn’ (Goodwin 2007).
  • ‘9 year period, 50% of commuters changed main mode at least once’
– Habit of mode choice (Schwanen et al. 2012).
– Public acceptability and demonstration (Bannister 2008).
– Travel as valued activity, not just derived demand e.g. use of ICT on public transport (Bannister 2008).
– The role of affective (emotional) considerations. Car travel provides autonomy, personal space and ownership / identity (Mann and Abraham 2006).
– Land use patterns. Future planning of communities has strong bearing on transport choices (Bannister 2008).
Mode shift rates and potential

- Projected urban passenger demands from ESME projections (blue continuous line)
- Max shift multiplier applied to 2050 demands (excl. cars), and linear extrapolation back to 2010
- Shift above projected demand (purple shaded area)
- Any additional growth (total shaded area) subject to infrastructure costs
## Mode shift costs: infrastructure considerations

- Infrastructure costs considered for different modes, to ensure greater cost comparability

<table>
<thead>
<tr>
<th>Mode</th>
<th>Cost Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cycling</td>
<td>Under Get Britain Cycling report, consensus around £10-20 / capita year-on-year spend being able to deliver trip mode shares of 20-40% (Goodwin 2013); London Strategy funded at £18 / head to deliver 400% increase by 2026 (GLA 2013). Cost of bikes not included.</td>
</tr>
<tr>
<td>Bus</td>
<td>As for cars but lower costs in model due to occupancy factor, as McKinsey estimates in vkm.</td>
</tr>
</tbody>
</table>