Toward an Activity-based System for Modelling Energy Consumption

Urban Energy Systems Project

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Overview

- Background and motivation
- Objectives
- Proposed approach
  - Fundamental transport modelling concepts
  - State-of-the-art travel demand models
- Challenges
- Data sources
- Initial conceptual framework
- Conclusions & further work
UES Vision

- To undertake an integrated analysis of urban energy systems through the development of an integrated model of the urban system and its various components
Background & motivation

- Depletion of resources, air quality and climate change are increasingly important issues that need to be addressed not only through government policy but also through lifestyle changes.

- Energy consumption and air quality assessment, however, continue to be on an aggregate and accounting-level.

- Energy consumption by the transport sector is not isolated from business and residential energy consumption.
A lot of energy is used directly by transport activities – fastest growing end use sector etc.

Total energy consumption, by sector, in primary energy equivalents, 2001
Source: UK Department of Trade and Industry (DTI, 2002)

But, in addition to this...
Background & motivation

Activities

- Eat
- Shopping
- Recreation
- Leisure

In-Home

Out-of-Home

Trade-offs & Substitutions

Energy Consumed

- Energy Consumed
- Socio-demographic Attributes
- Transport Policy
- Land-Use and Accessibility
- Behavioural Heterogeneity
- Use of technology

Travel Demand
Energy use and human activity

- Cities use energy as a result of human activity – economic, social, recreational etc.

- To understand and model energy use in cities we must model this human activity.

- Human activity is spatially and temporally distributed and transport facilitates, constrains and modulates all these activities.

- Moreover, model must able to capture heterogeneity in individual behavioural responses.
Example: unintended environmental impacts of early release from work policy

Activity Duration = 25 mins.  
“Warm Start”

Activity Duration = 70 mins.  
“Cold Start”
Energy use and human activity

- Several other consumption behaviours are related to energy use e.g.
  - Household technology holdings (gadgets, internet access etc.),
  - Use of ICT
  - Choice of heating/cooling energy (electricity, gas, renewable etc.),
  - Car ownership (number of cars, energy efficiency vs. speed & acceleration vs. comfort)
- Lifestyle factors – important to address
Objectives

- To understand lifestyle choices and motivations – at the level of the individual – include heterogeneities
  - Direct and indirect effects of technology holdings, ICT-use, energy choice, car ownership... on energy consumption

- To develop an integrated activity-based model of energy consumption that can
  - Accurately assess the behavioural responses to energy-sensitive policies
  - Help develop policies targeted at lifestyle modifications

- Provide inputs for more accurate modelling of emissions and air quality (e.g. disaggregate soak times)
Fundamental transport modelling concepts

- Activities – the things that people want to do with their time and money – e.g., work, shop, leisure
- Activity opportunities – the places and times where people can do these things
- Travel demand – the demand for travel that arises from the demand for participation in spatially and temporally distinct activities
- Transport network – the physical network linking places and people and generating travel costs
- Flows – the expression of travel demand over the network
Fundamental transport modelling concepts

Activity Opportunities

Transport Network

Activity Demand

Travel (Generalised) Costs

Travel Demand

Flows
What is the state-of-the-art in travel demand modelling?

- Activity-based models of travel behaviour
- Fully-integrated land-use and transport models
- Detailed inventory models of urban networks and activity opportunities
- Individual response/agent-based models (micro-simulation)
- Synthetic population generation for study area
Activity-based models – complete activity-travel pattern of a worker

3 a.m. on day d

Before-Work Tour

Home-Stay Duration

Home-Stay Commute

Home-Stay Duration

Work-Stay Duration

Work-Based Tour

Temporal fixity

Work-Home Commute

Work-Stay Duration

Home-Stay Duration

After Work Tour

Work-Stay Duration

Home-Stay Duration

3 a.m. on day d+1
Complete activity-travel pattern of a non-worker

3 a.m. on day d

Morning Home-Stay Duration

1st Tour

-S1

First Return-Home Episode

-S2

Departure for 2nd Tour

Home-Stay Duration before 2nd Tour

Departure for 3rd Stop (S3)

......

Home-Stay Duration before Mth Tour

-Mth Tour

-SK-1

Departure for (K-1)th Stop (SK-1)

Last Home-Stay Duration

3 a.m. on day d+1

(M-1)th Return-Home Episode

SK

Mth Return-Home Episode
Challenges

Data

- Very rarely available from a single data source (in-home and out-of-home activity and travel patterns, technology holdings, ICT-use, choice of household energy, residence type, vehicle holdings etc.)

Methodology

- Must pool data from different sources
- Deal with decisions with quite different timescales
- Energy choices are often nested in other consumption decisions

Interdisciplinary effort
Data sources

- National Travel Survey (NTS)
  - Travel diary data for 7 consecutive days
  - Detailed vehicle holdings data including emissions levels
  - Available transport options and employer benefits
  - Data explaining choice of transport mode
  - Some data on internet use at home
Data sources

- **UK Time Use Survey (TUS)**
  - 2 day activity diary – every 10 minutes
  - Over 250 categories of activities (including travel)
  - 16 household types
  - Technology holdings and ICT use

- **British Household Panel Survey (BHPS) (??)**
  - Panel data (15 waves, 1991-2007)
  - Heating/Fuel Type
  - Car Ownership
  - Computer ownership and usage (3 waves)
Initial conceptual framework

Regulatory System

Population: Lifestyle & Attitudes

Land-use Transport System

Activity-Travel Patterns

Energy Consumption
Initial conceptual framework

Activity Locations

Transport Demands

price signals

Society & Economy

flows

Transport Supply

Environment (externalities)
Elements of the framework

- Disaggregate and individual level
- Integrated treatment of production and consumption activities, inside and outside the home
- Micro-simulation approach with random utility maximisation based agent behaviour models (not just cost minimising technology choice)
- Population synthesis – to include residence type, technology holdings as well as activity pattern choice
- Links with transport and energy supply and performance models
Conclusions and further work

- There exists the need for an interdisciplinary effort toward building an integrated activity-based model of energy consumption.
- There are many challenges in undertaking such an effort – but not insurmountable.
- Started work on estimating models of in-home versus out-of-home activity participation in order to test the effects of energy-sensitive policies.
THANK YOU
What do travel demand models really model?

- how often people travel
- why
- where
- how
- when
- with whom

Frequency
Distribution
Mode choice
Time of day

Ultimately need the number of vehicles on the road networks, and the ridership on buses, trains, ferries, planes etc.
Disaggregate trip-based models

- Constrained optimization or random utility maximization models, applied to individual trips

2 HB Trips + 1 NHB Trip
Disaggregate tour-based models

- Random utility maximisation models applied to tours. Retains some linkages between trips but not truly behavioural.

1 HB Shopping tour
+
1 NHB Other trip