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Toward an Activity-based System for Modelling Energy Consumption

Urban Energy Systems Project

31 January 2008

energy futures lab

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

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UES Vision

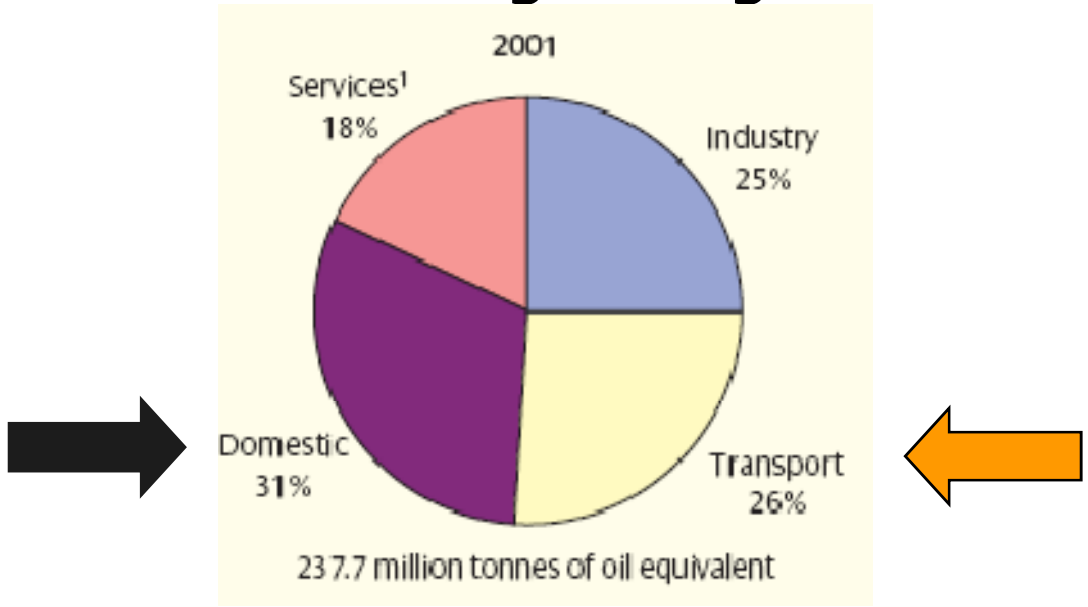
- To undertake an integrated analysis of urban energy systems through the development of an integrated model of the urban system and its various components

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 a aggregate and accounting-level
- Energy consumption by the transport sector is not isolated from business and residential energy consumption

Background & motivation

- 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...

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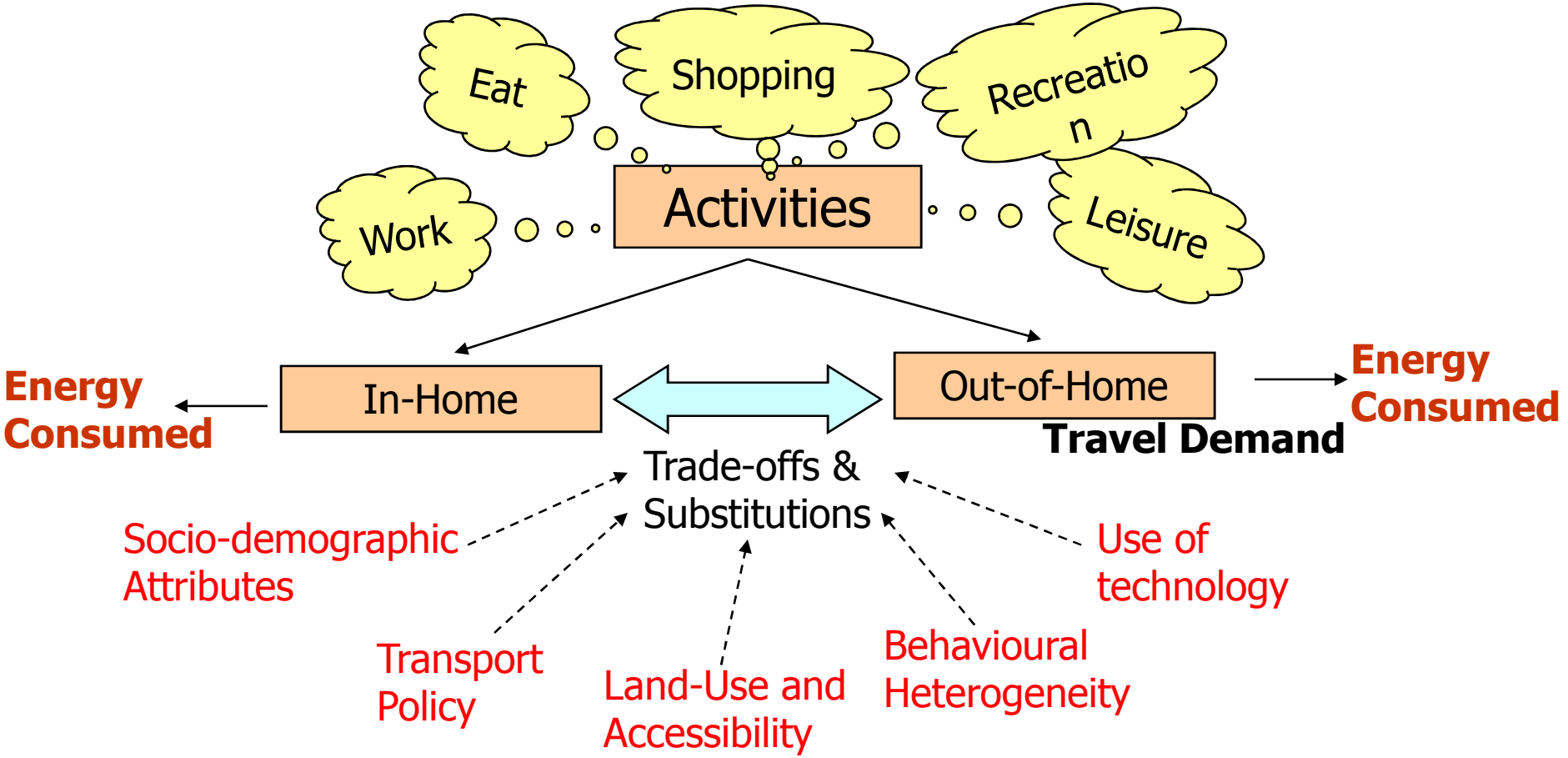
Background & motivation



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

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

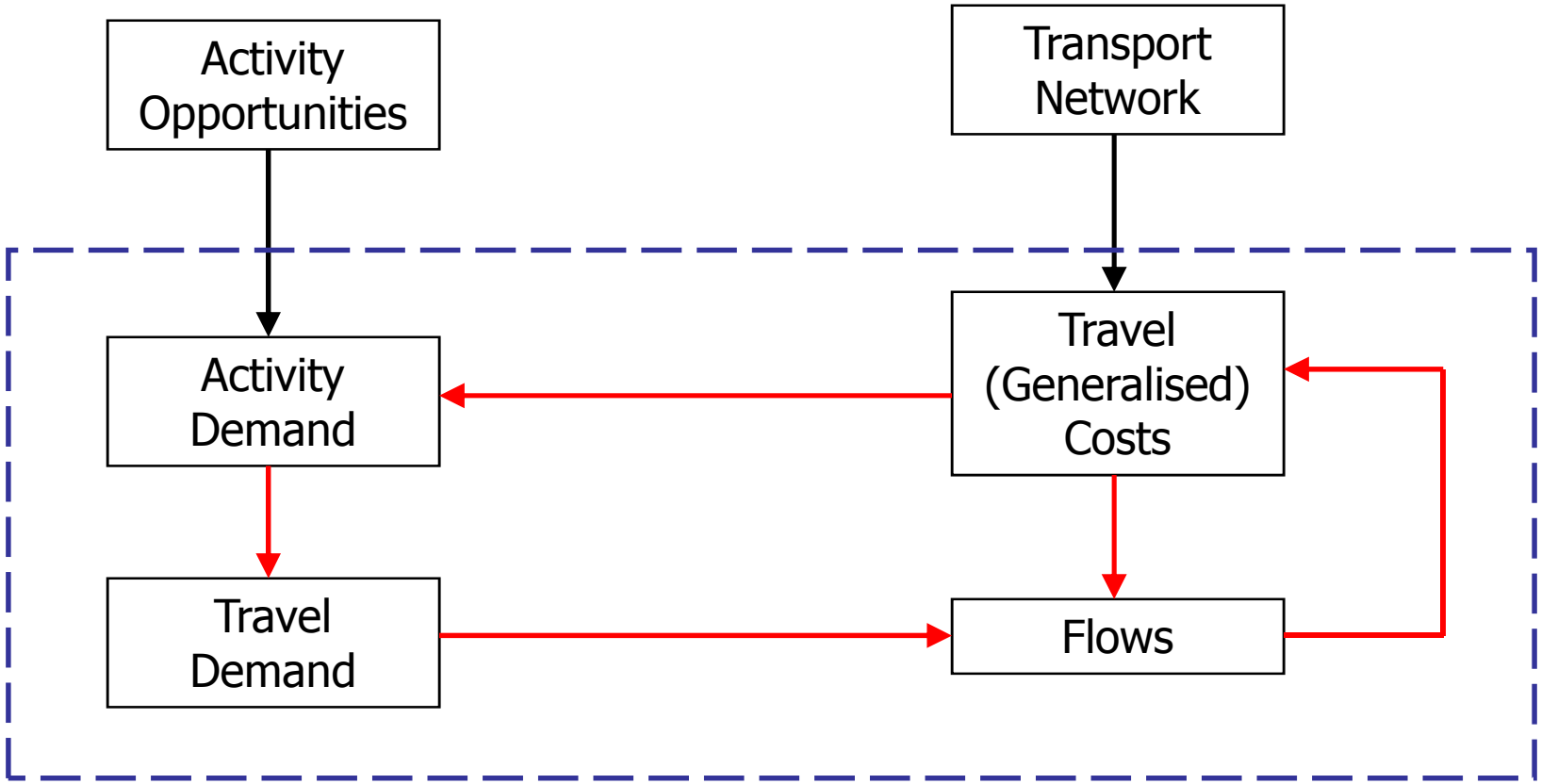
Objectives

- 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

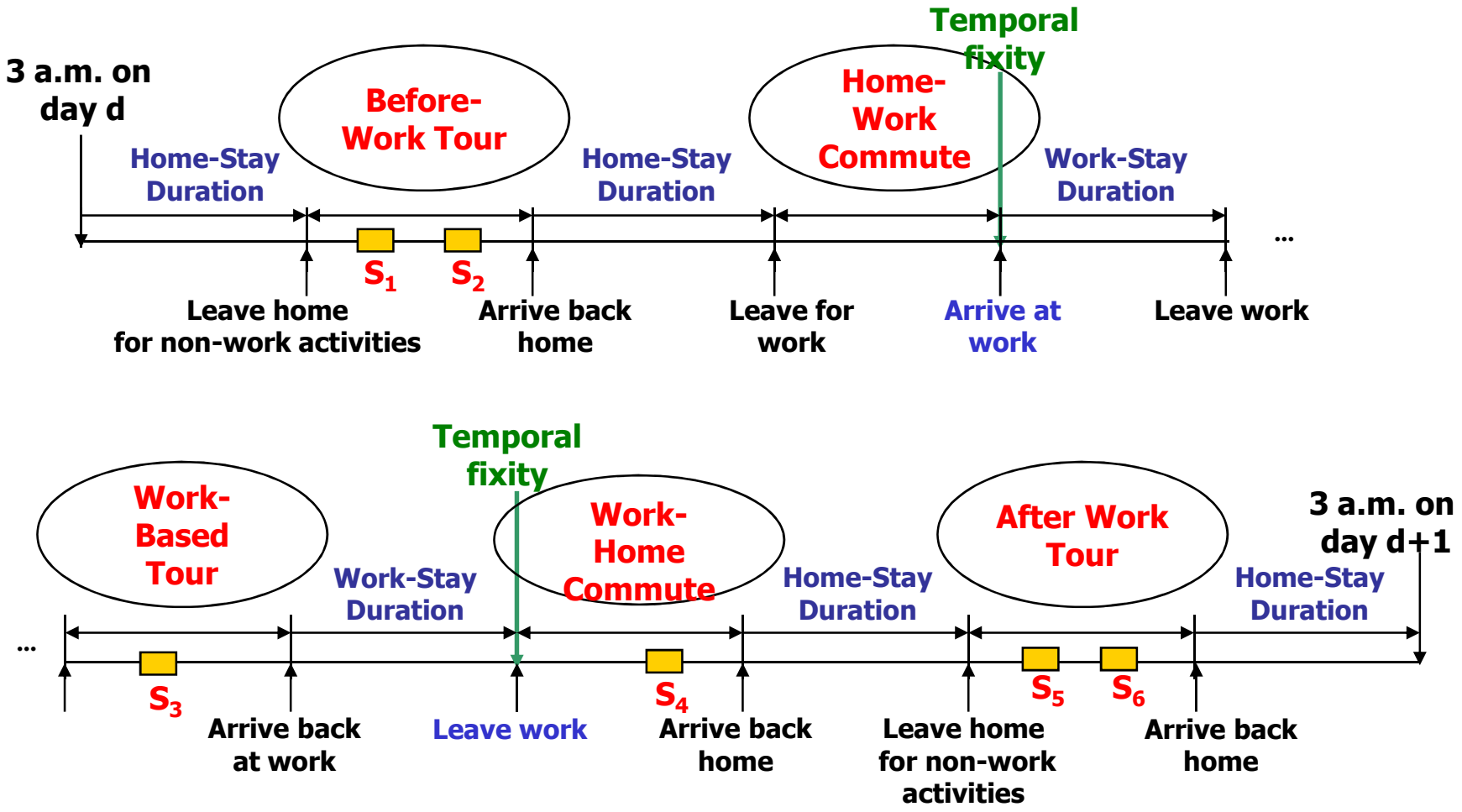
Fundamental transport modelling concepts



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



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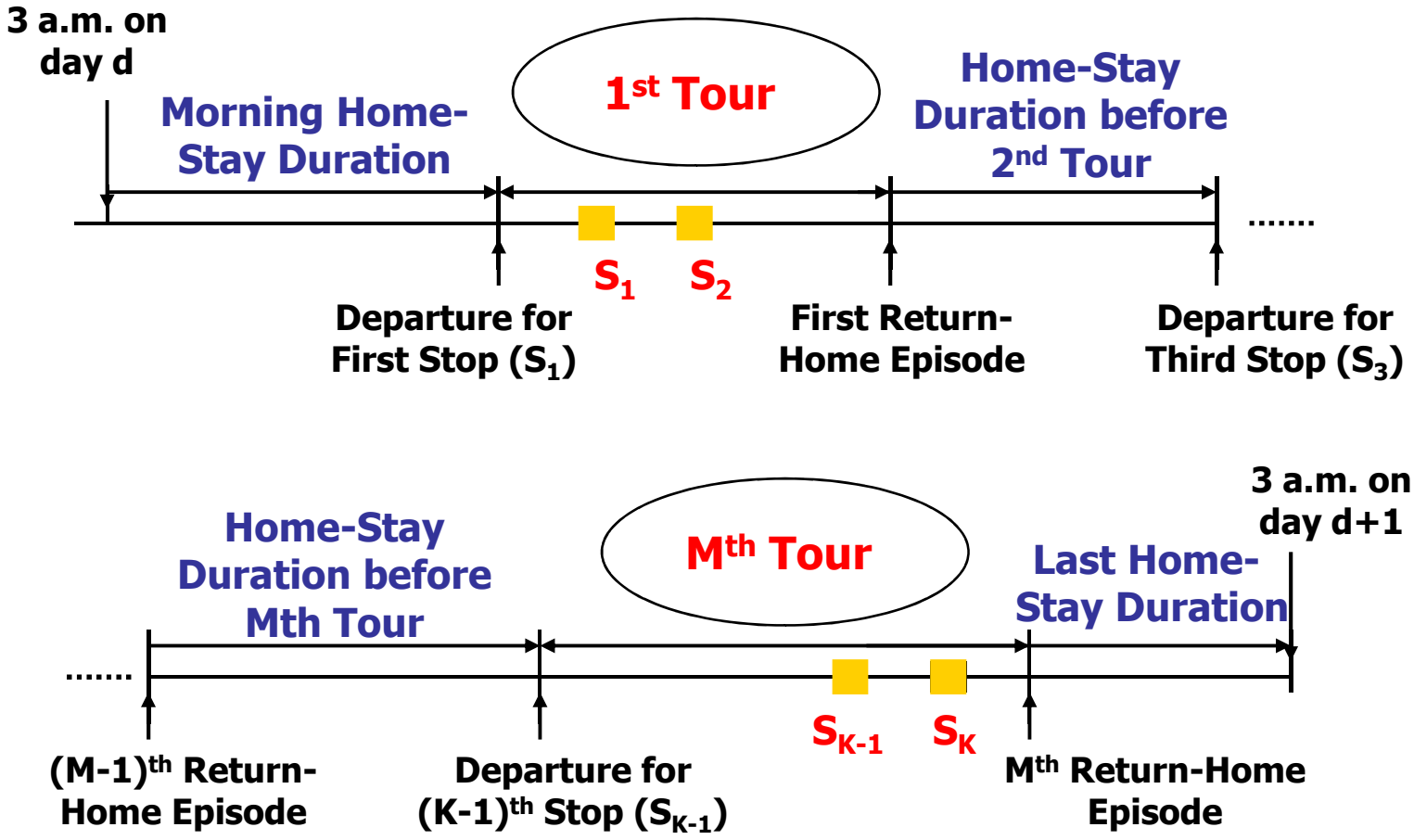
Complete activity-travel pattern of a non-worker



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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

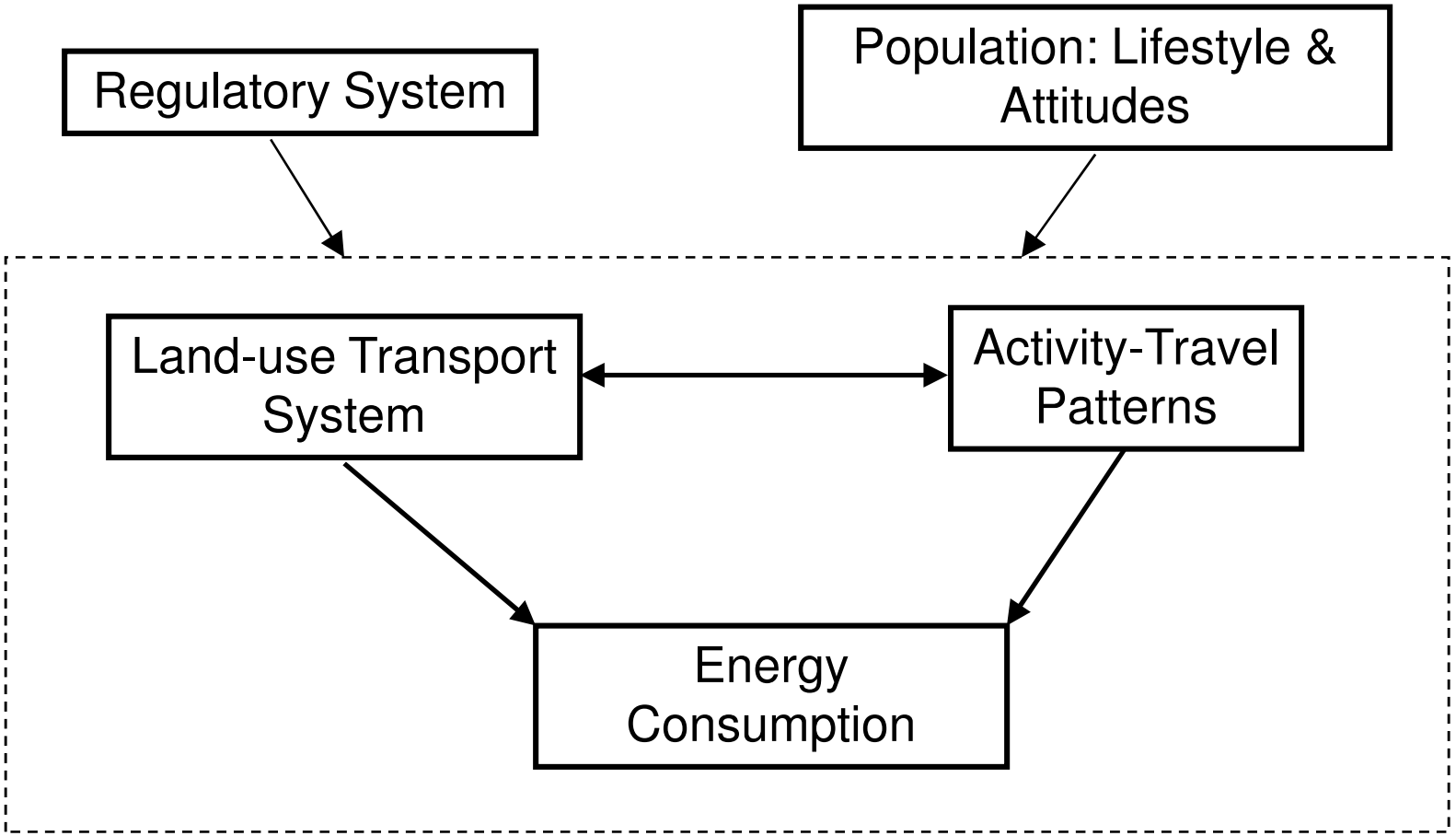
- National Travel Survey (NTS)
  - Travel diary data for 7 consecutive days
  - Detailed vehicle holdings data including emissions levels
  - Available transport options and employer benefits
  - Data explaining choice of transport mode
  - Some data on internet use at home

Data sources

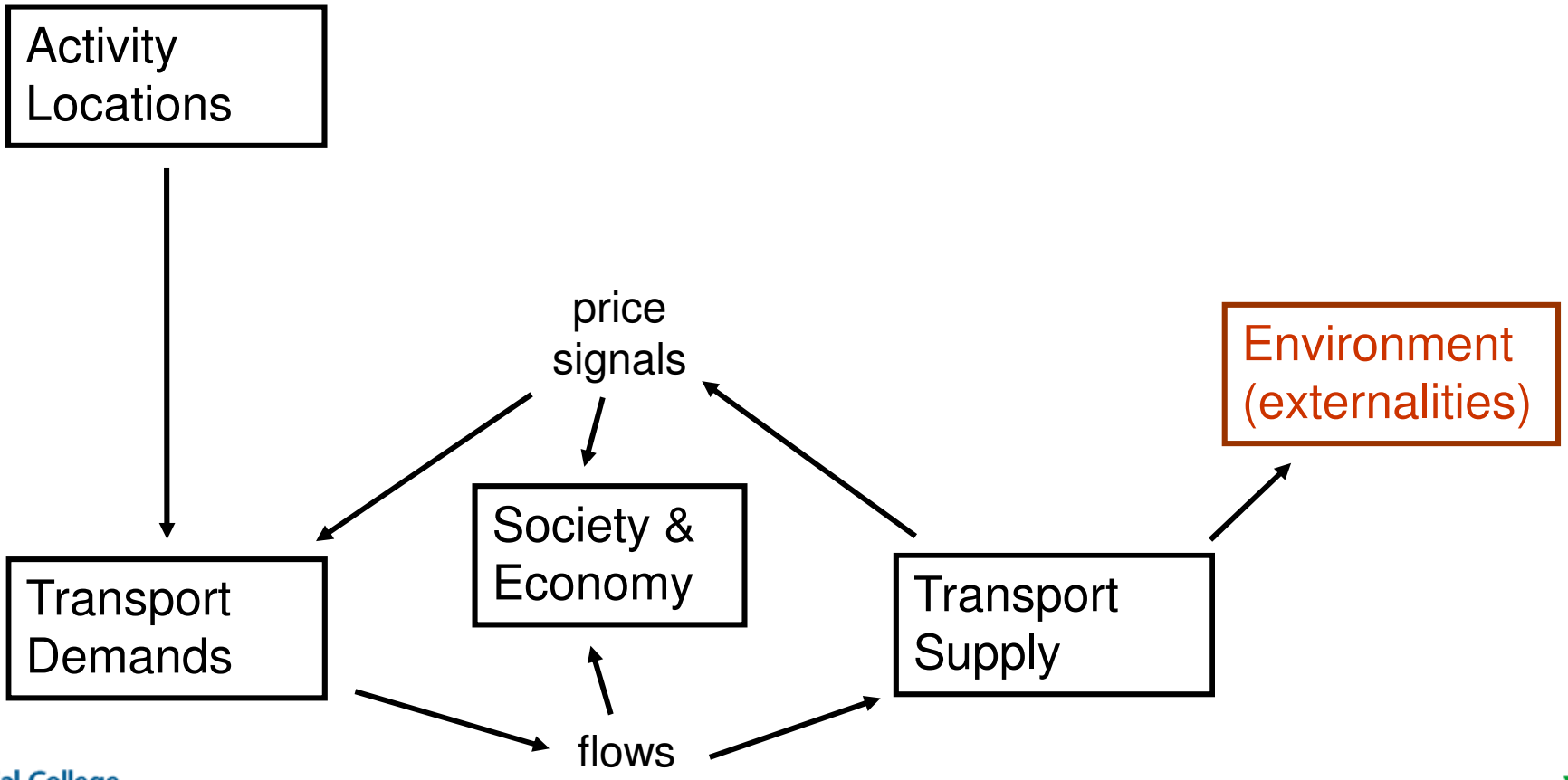
- UK Time Use Survey (TUS)
  - 2 day activity diary – every 10 minutes
  - Over 250 categories of activities (including travel)
  - 16 household types
  - Technology holdings and ICT use

- 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



Initial conceptual framework



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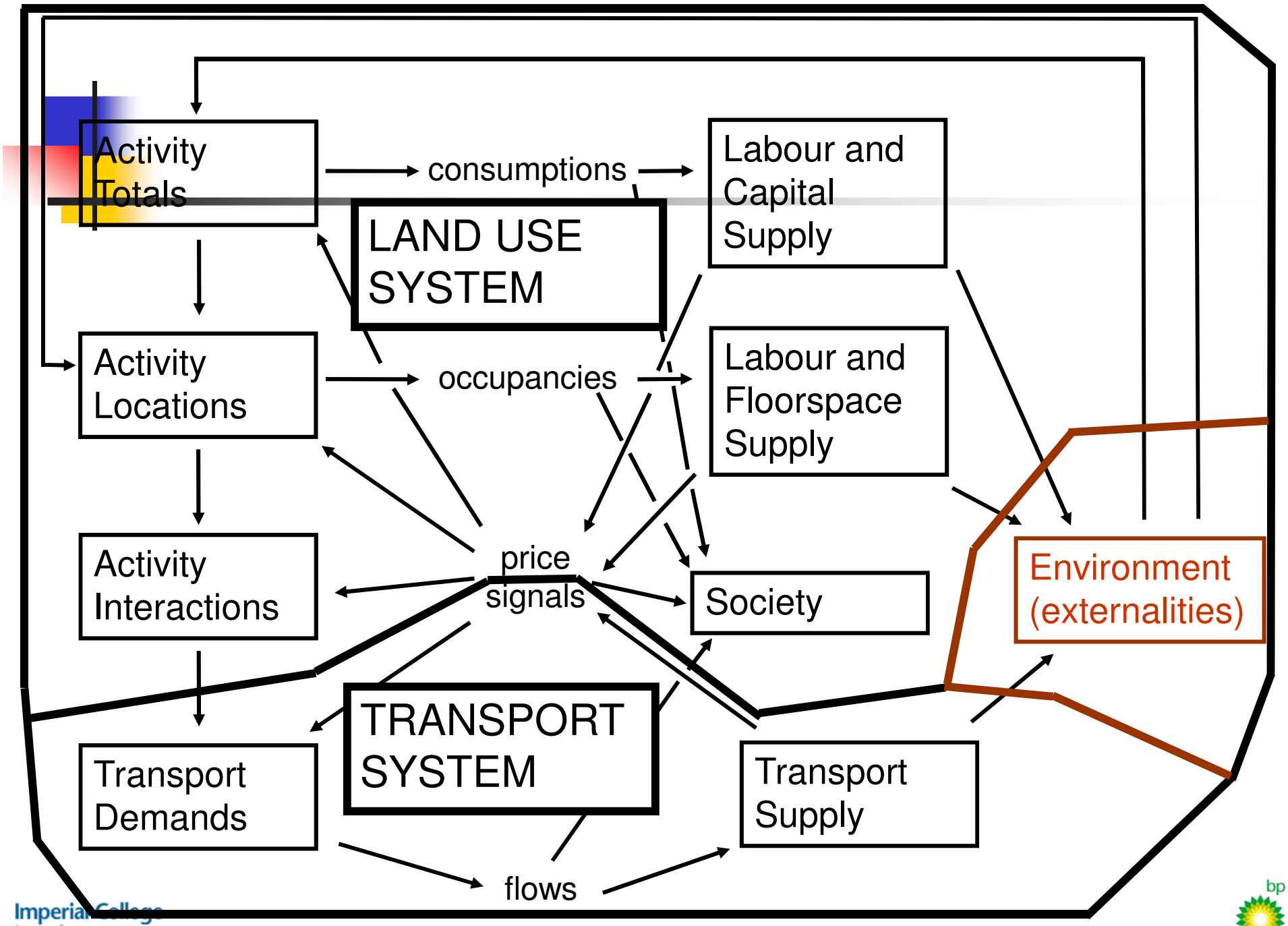

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Elements of the framework

- 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

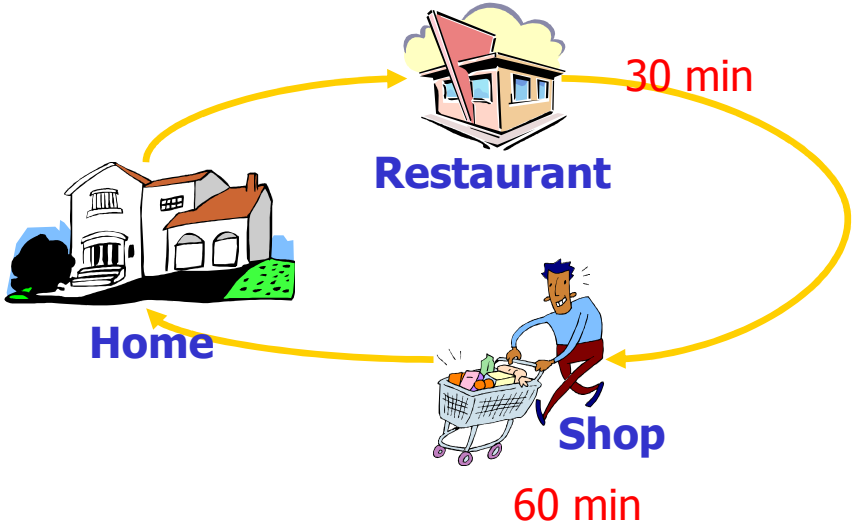
Mode choice

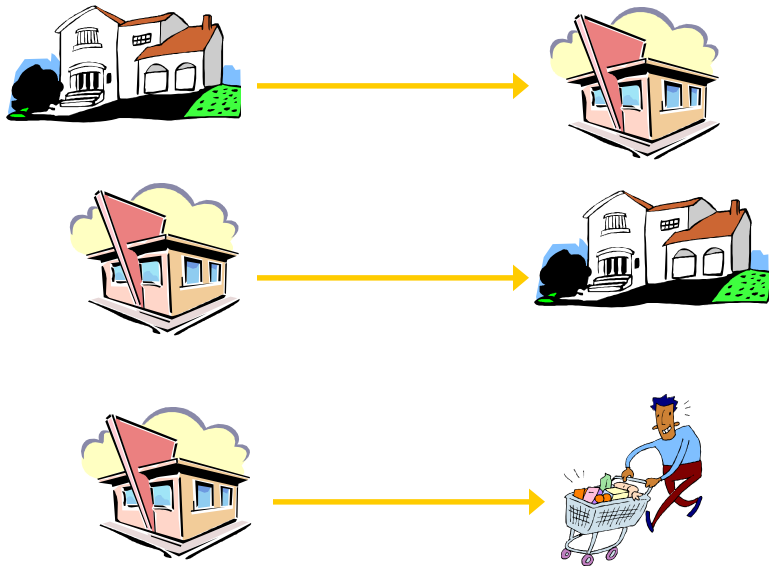
Time of day

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

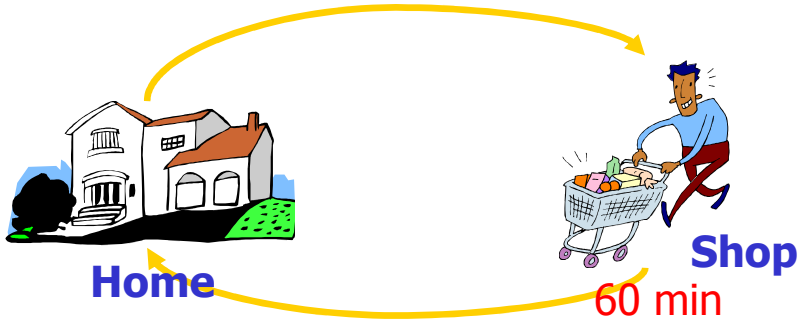


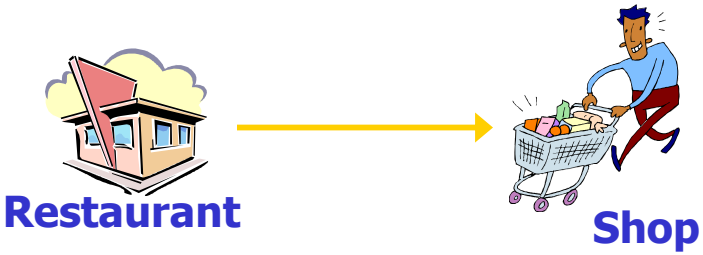


2 HB Trips + 1 NHB Trip

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