The role of modelling in supporting transport policy

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Objectives of talk

- to show how modelling works in transport analysis
- in particular to show how choice modelling helps analysis to focus on relevant policy
- with reference to a (south) Welsh context

Overview of presentation

- context and review
- explanation of behaviour
  - utility maximisation
  - other paradigms
- model design
  - local issues
  - non-linearity and elasticity
- conclusion
  - achievements
  - challenges

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Welsh Transport Analysis takes place in a closely defined context

- WelTAG (2008) defines the procedures
  - previously used STAG (Scotland)
  - both obviously relate to WebTAG (UK, now England)
  - WebTAG now updated to 2014
- specific relationship to Welsh policy requirements
  - Wales Transport Strategy
  - specific road and public transport schemes
- appropriate level for size of scheme
- economic appraisal is key step and where modelling is needed
  - to test and screen options
  - for full appraisal of selected options

Economy, Environment, Society

- specifically Welsh specification of appraisal
  - but closely related to English '5 case' approach
  - *economy* involves Green Book CBA (UK Treasury)
- need to describe impacts of proposed schemes in terms of these 3 pillars
- each of the pillars needs demand forecasts
  - to measure the extent and nature of impact
- all modes of transport, freight & passenger
- distribution of impacts
  - by geography and socio-economic indicators
- so detailed models are needed

Modelling advice in WelTAG follows WebTAG

- reference case and variant scenarios
- variable demand modelling using nested logit models
- assignment and equilibration
- realism testing using elasticities

- 4 or 5 stage models
  - generation, distribution, mode split, assignment
  - maybe time period split
  - for major policy issues

- how can we ensure that the models deal with the key policy issues?
  - i.e. identify the most policy-relevant variants

Fundamental modelling insight: Travel demand results from choices

- goes back at least to Wardrop's first principle (1952)

  "The journey times in all routes actually used are equal and less than those which would be experienced by a single vehicle on any unused route."

- which implies that
  - the routes used are determined by choice
  - drivers are consciously minimising time

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- but we can find much earlier ideas that embody choice concepts e.g. Dupuit (1844)

Choice modelling contributes to several aspects of travel demand analysis

- understanding behaviour
  - why do people do what they do?
- forecasting
  - how will people respond to changes?
- valuation
  - how much are people willing to pay (or accept) for marginal changes?
- appraisal
  - what are changes worth to society?
- in each of these functions choice modelling offers advances in both plausibility and rigour
- choice modelling used to obtain key model parameters

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Quantitative travel demand Analysis goes back a long way

- early traffic analyses were based primarily on OD surveys without modelling
  - data processing costs impeded statistical analysis
- analytical conurbation study in Detroit from 1953
  - trip generation, distribution and assignment
  - physical analogies, not much behavioural content!
- Wardrop gave behavioural basis for assignment with congestion
- for a long period, **car was king:**
  - *predict and provide*

- i.e. modelling behaviour and choices was not very important
  (except for assignment)

Europe has public transport!

- *Traffic in Towns* (Buchanan 1963) recognised the damage done by unrestricted growth in car use
- modelling needed to look at a much more varied set of policy options
- systematic modelling of distribution and mode choice in UK from 1960s
  - books on entropy maximisation by Alan Wilson and collaborators
  - sophisticated and complete, e.g. very early use of logsum formula for composite cost (1969)
  - but still based on physical analogy
  - …and aggregate

Disaggregate approaches began to develop in the 60's (at least in the UK)

- Beesley (1965) estimated value of travel time
  - understood that revealed preferences could be used
  - but did not have techniques or computers to make a full analysis
- Quarmby (1967) studied commuter mode choice
  - realised that marginal time and cost impact ratio gave VOT
  - but only feasible technique was discriminant analysis, which does not model choice!
- MAU Note 179 (1970) began to integrate this work with Wilson's ideas
  - introduced the concept of generalised cost
  - gave a basis for economic appraisal

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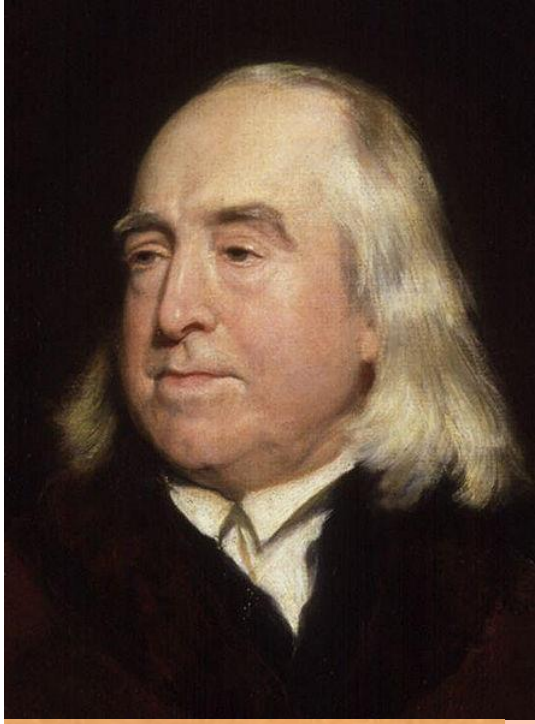
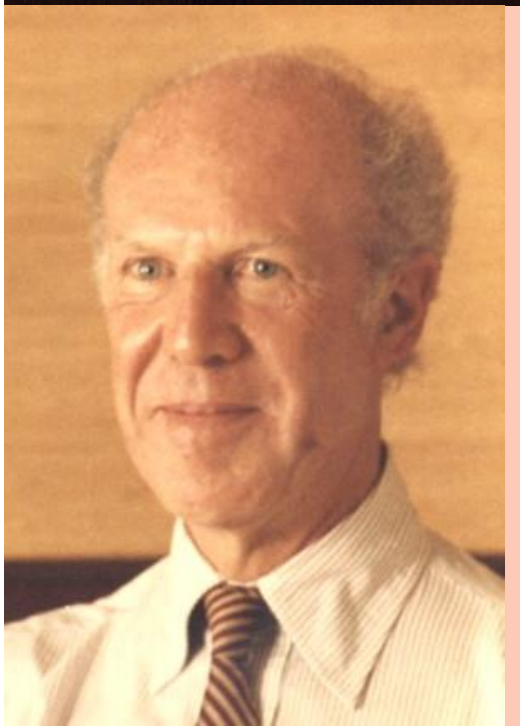
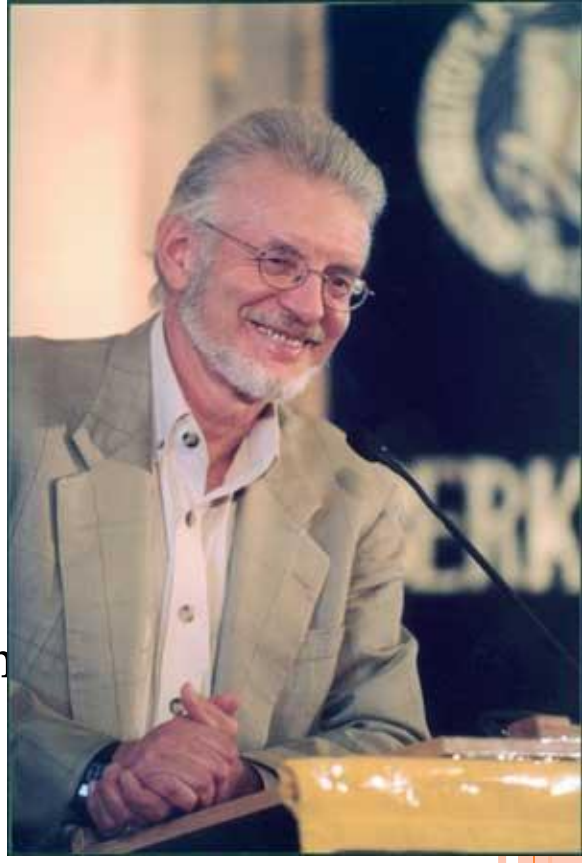
Utility maximisation offers a clear explanation

- value or benefit can be expressed as a single measure, which we try to increase
  - i.e. all relevant aspects of alternatives can be traded for other aspects
  - characteristics of unchosen alternatives are not relevant to utility enjoyed
- in transport context exactly the negative of generalised cost
- utility maximisation describes behaviour if and only if preference is transitive
  - and complete and continuous
- often described as 'rational'





Formal choice modelling introduced in 1970s



- random utility, in US, then UK
  - initially to explain behaviour
    - of a bureaucracy, or
    - of travellers to estimate values of time
  - allows rigorous estimation using maximum likelihood criterion
- use in travel forecasting from mid 70s
  - destination/mode choice (Williams 1976-7)
  - mode/bus route choice (Daly & Zachary 1976-8)
  - key US study was McFadden's BART work
- wider application from late 70s
  - MTC work in California
  - work leading to Netherlands National Model
- links to Wilson's entropy-based work

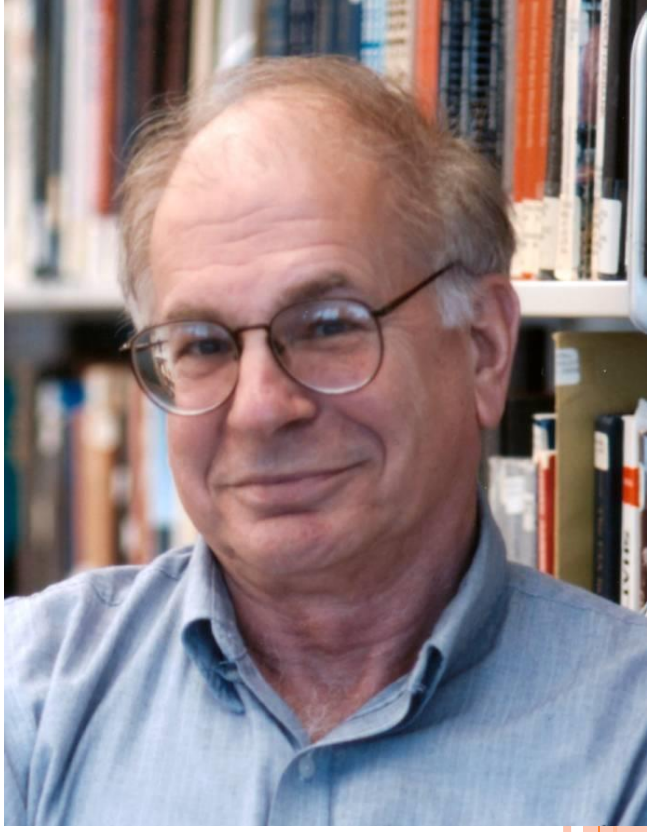
Randomising utility allows Umax to be applied very widely

- different people behave differently in apparently identical circumstances
- so if we believe in Umax, either
  - we haven't observed everything that is relevant

or

  - they have different utility functions
- the analyst can therefore only approximate the true function
- random utility models make the degree of approximation part of the model
- so we can attribute probabilities to choices

Really, behaviour is more complicated than this



- there are significant and consistent deviations from Umax behaviour (these imply that transitivity fails)
- for example concerned with risk
- but also with the relationship between alternatives, e.g.
  - losses > gains, i.e. relating to 'reference points'
  - the position of alternative in the market is relevant
    - regret, 'path size'
- an important research problem is to distinguish these effects from short-term phenomena
  - e.g. arising in stated preference experiments

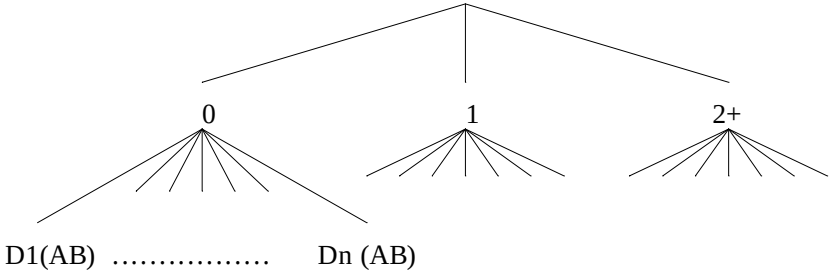
But long-term forecasting still relies on conventional RUM models

- WebTAG: tree-nested logit
  - so we get some generalisation of elasticity across alternatives
- generalising across trip types is essential
  - separate models for travel purposes (3-10)
- variation with trip length is a major issue
- sensitivity varies because of
  - self-selection and taste variation, e.g. income
  - but usually cannot afford to abandon nested logit
    - for quite a few reasons

Conventional RUM has given many benefits to transport analysis

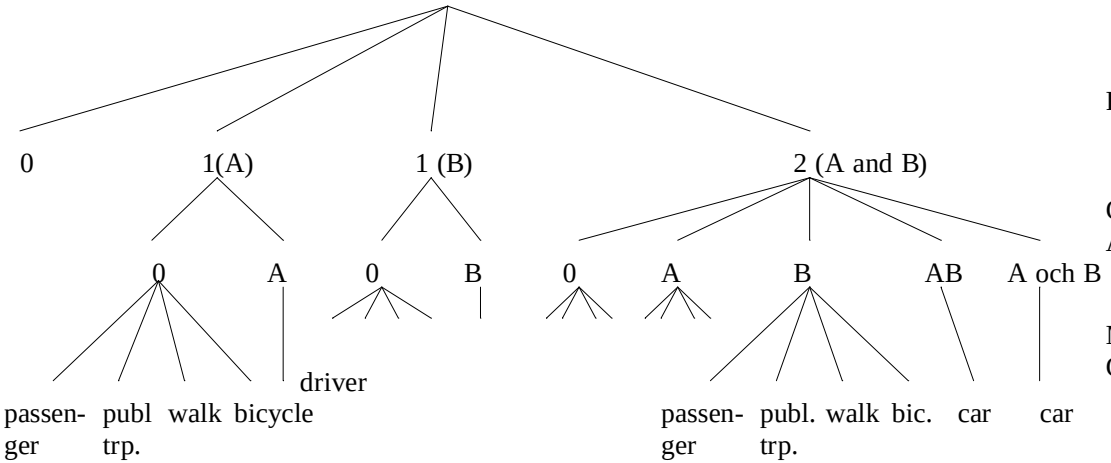
- unifying *all* models on the same basis
  - explaining, forecasting, valuing with same approach
- rigorous econometric basis for model estimation
  - nearly always using maximum likelihood
  - significance tests, confidence limits etc.
- rationale for model forms and generalisations
  - multinomial logit
  - tree and cross-nested logit, within GEV family
  - probit
  - mixed logit
  - you name it
- many of these models are yet to be used in practice

COMPLEX SYSTEMS OF CHOICES CAN BE MODELLED IN TREE-NESTED LOGIT



CAR OWNERSHIP

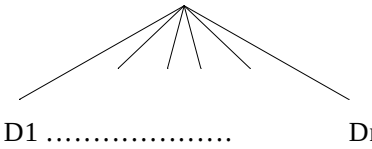
DESTINATION



FREQUENCY

CAR ALLOCATION

MODE CHOICE



SECONDARY DESTINATION

The next step may be extended Activity Based Models

- model out-of-home (sometimes in-home) activities of household
- explain travel (as 'derived demand') from activities
- ABM are already used quite extensively in US (and Israel)
- first large-scale Euro model in Copenhagen
  - more public transport, bike and walk than in US
- lead to very detailed models, but additional data requirements are quite modest
- application in UK has not yet been funded

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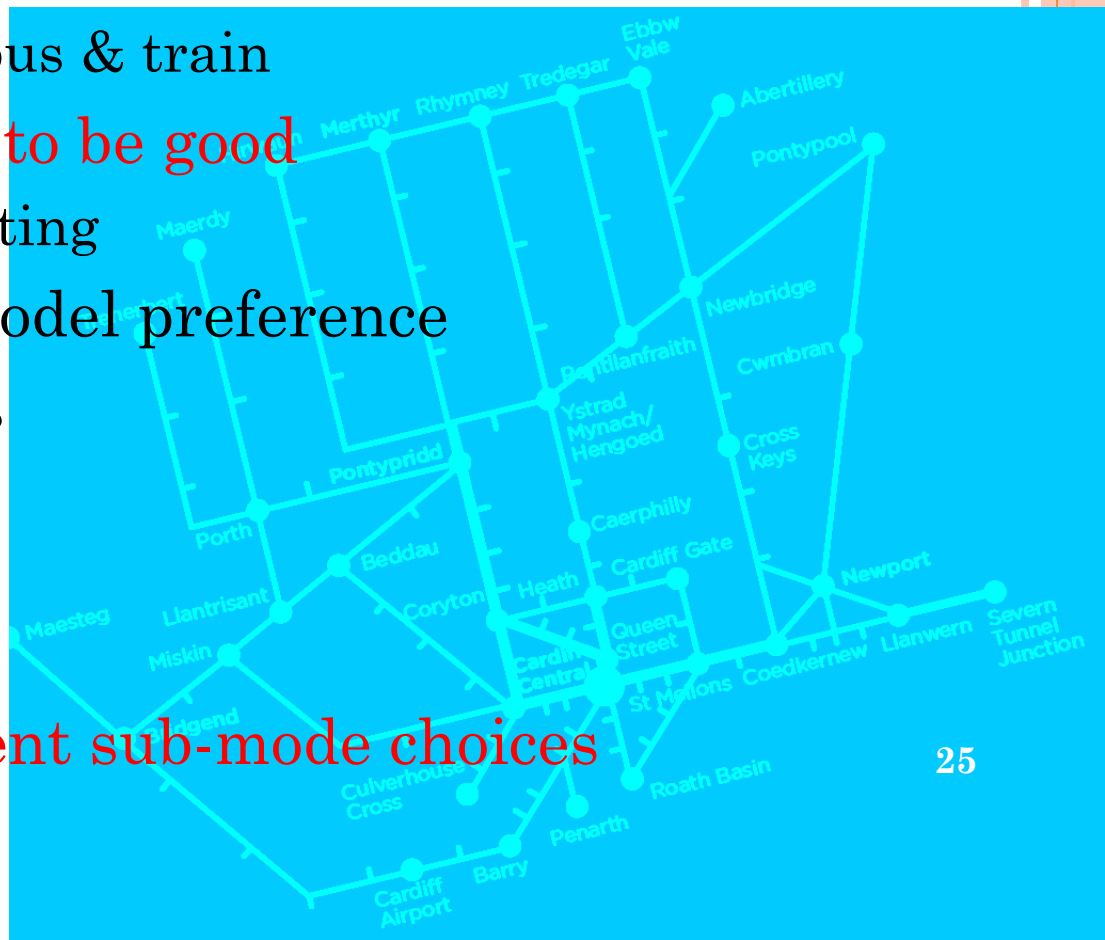
Design model to meet local requirements

- e.g. for a metro covering a region
  - how does it compete with cars?
  - how does it relate to bus & train
- network models need to be good
  - to get multi-mode routing
- but we also need to model preference
- 'softer' characteristics
  - reliability
  - apparent safety
  - image
- use nesting to represent sub-mode choices

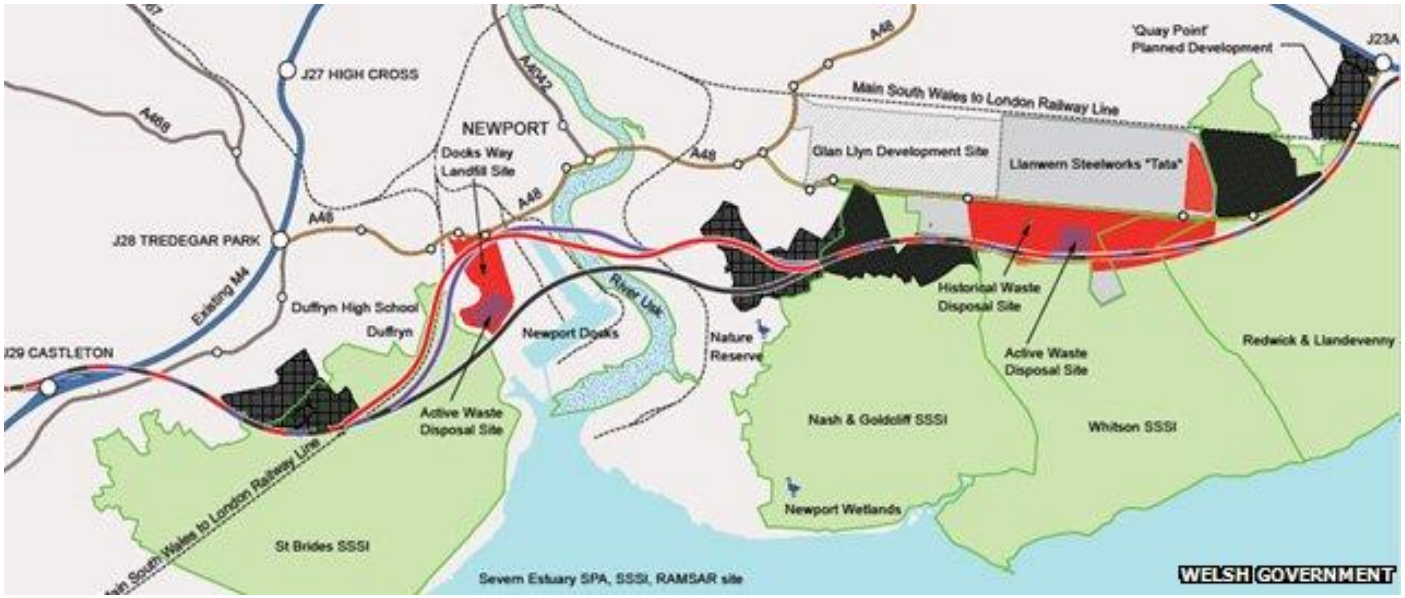


URBAN/PERI-URBAN PUBLIC TRANSPORT

- key issues are likely to be
  - access, frequency and need to interchange
  - service to important destination areas
  - fare (through ticketing)
  - speed and integration
  - comfort and image
- these require accurate geographical modelling and sophisticated behavioural modelling
  - probably SP is needed
    - depending on importance of soft factors
- may or may not need detailed choices in modelling

Road alternatives also raise detailed issues

- who benefits?
  - needs detailed model: geographic and socio-economic
- is toll the answer?
  - tolls would change flows and congestion
  - values of time vary continuously in the population
  - more complicated models needed



Long-distance road travel

- key issues are likely to be
  - congestion and peaking
  - variations with trip length
    - value of time increases
    - overall sensitivity decreases (cost damping)
- these can be accommodated in conventional 5-stage models
  - i.e. with time period choice
- but investigating toll means we have to think about distribution of value of time
  - travel purpose, trip length, income
  - but also within these segments
  - separate alternative for toll may be the solution
- again SP may be desirable

Models should be estimated from local data as far as possible

- fair degree of transferability has been found
  - but local attitudes and network performance vary, so local adjustment is essential
    - e.g. mode shares, trip lengths as a minimum
- home interview trip diaries remain the gold standard
- intercept surveys (roadside, in-pt) are more difficult to use because of inherent biases
- mobile phone records may offer a way forward
  - if privacy concerns can be allayed
- stated preference is OK for trade-offs and essential for new alternatives
  - but remains subject to biases

Pivoting is often a good way to exploit local data

- use model to predict changes relative to well-measured base situation
- often in the form of a matrix or matrices
- can be more aggregate than the model
- procedures are quite well understood, though sometimes problems remain in practice
  - particularly when model far from matrix!

- required by WebTAG

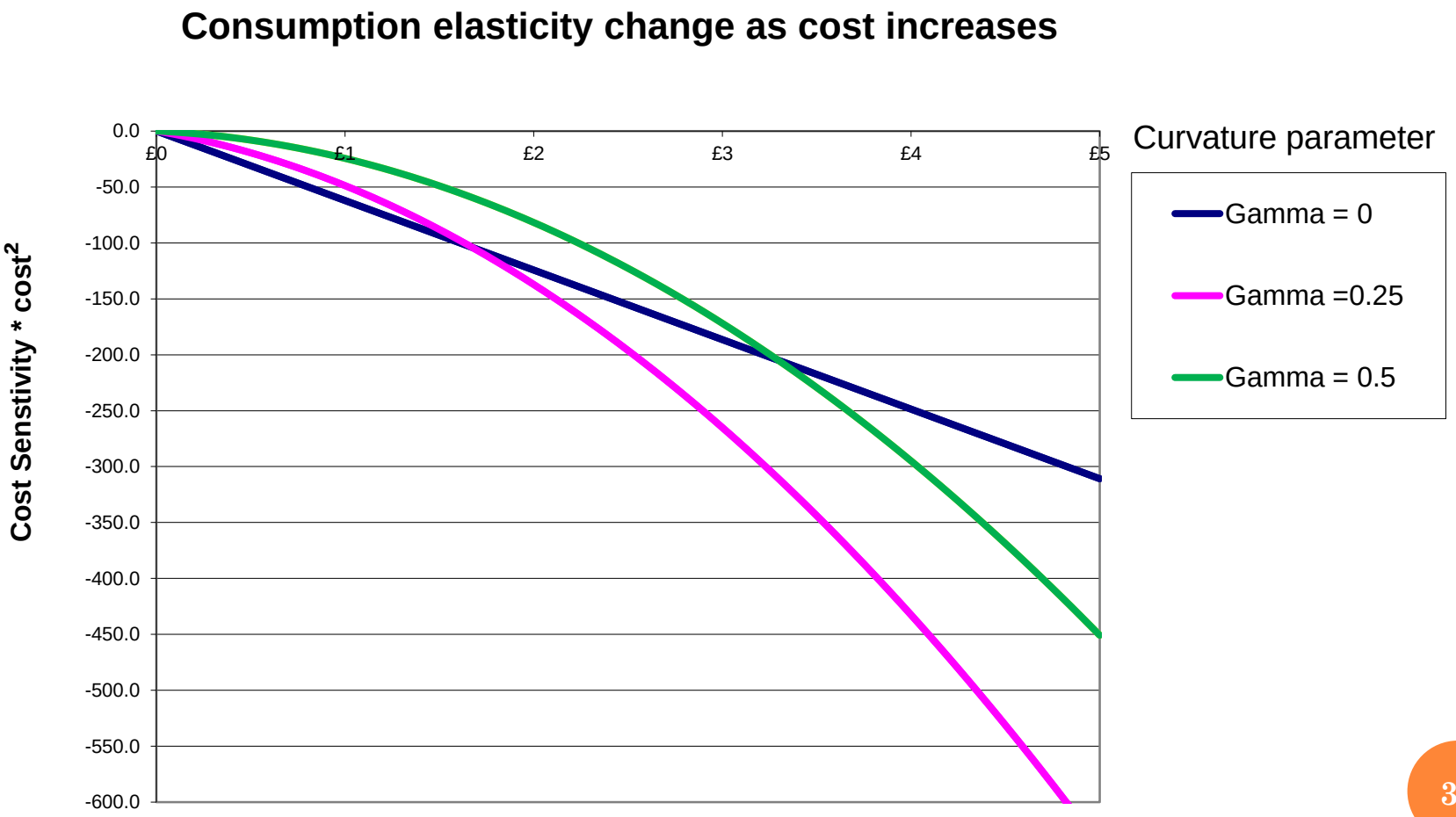
Non-linear functions offer improvements within standard models

- this is 'cost damping'
  - or amplification, but not plausible
  - maybe damping is an approximation
- gives freedom to obtain better fit to observed data and/or VOT and/or elasticity
- in practice, may mean abandoning strict criterion of maximum likelihood
  - but likelihood may not give strong discrimination between models when other criteria do discriminate
  - we may need to fix curvature coefficients on the basis of experience

Elasticity is a useful test of performance

- not ideal, but values are widely published
  - allows models to be compared across areas and time
  - required by WelTAG/WebTAG
- it could be argued that this is the most important test of a demand model
- and good results help enormously in building the credibility of the model
- cost, time and income elasticities

Most data is for short trips, but long trips are more important for elasticity



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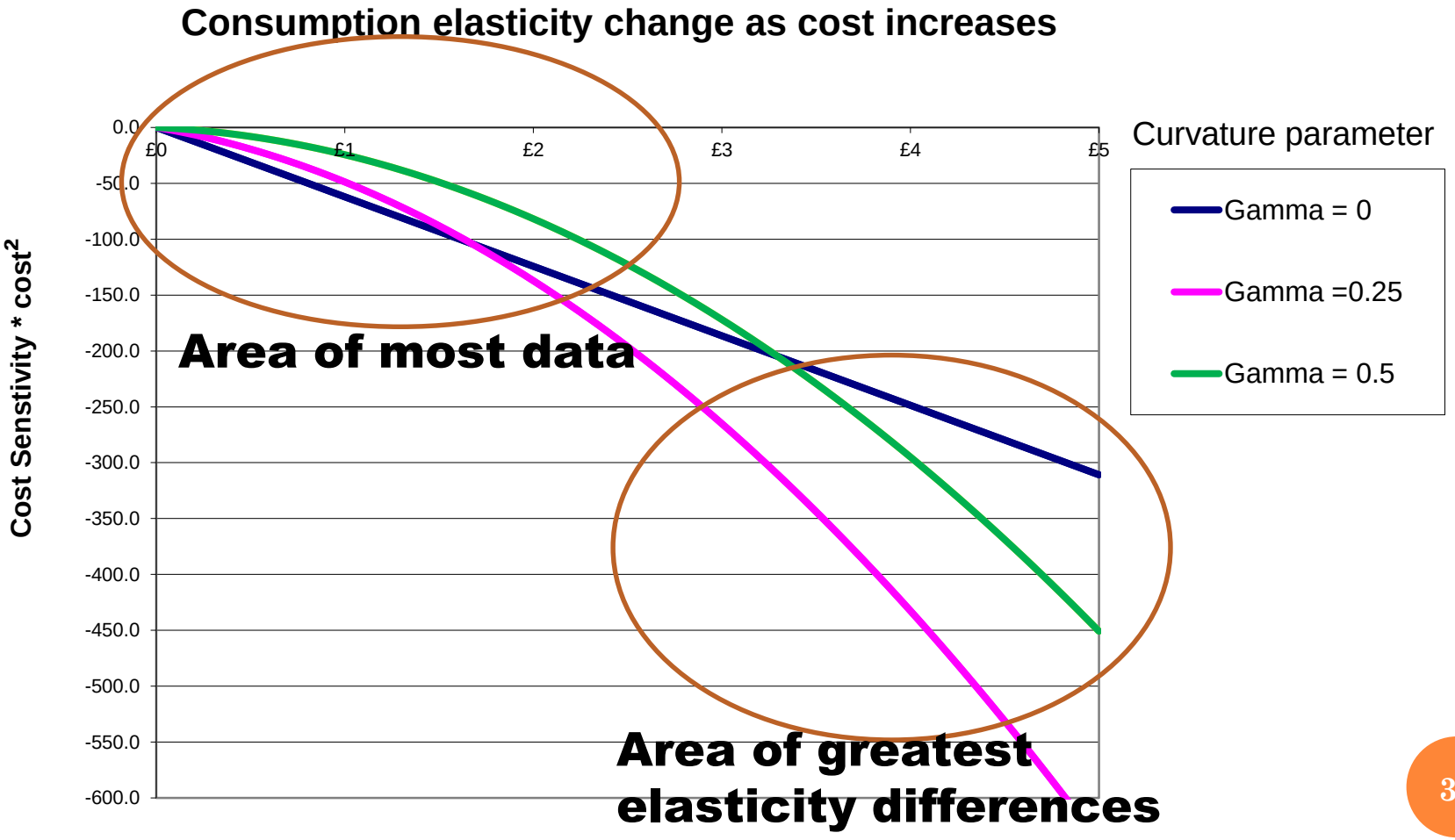

So we need a balanced view of model specification for forecasting

- to get the best model we need to use as much information as we can
- this means experience and information that may not be strictly quantified
  - e.g. on elasticity and VOT
  - and theory, e.g. on model specification (relationship of time values to each other)
- the goal of modelling is to derive the most objective view possible, not necessarily to advance the state of the art
  - at least not directly

But models are never right!

- internal statistics based on estimation give minimum error
  - even this is not usually considered
- more important is that inputs will also be wrong
  - e.g. what will be the growth in national income? (and hence in employment, car ownership etc.)
- and models omit variables that will become important in future
  - don't know what these are
- there is research on temporal transfer but many uncertainties remain

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Concluding: Achievements

- fundamental insight that travel demand arises from choices
- utility maximisation gives a single framework for explaining behaviour, forecasting and appraisal
  - consistent with WelTAG-WebTAG approaches
- random utility allows the framework to cover the behaviour of the whole population
- explicit error distributions allow rigorous statistical method to be applied
  - most often maximum likelihood
- the choice framework provides for model generalisations (and alternative paradigms)

Concluding: Achievements (2)

- simple models (e.g. tree-nested logit) can explain quite complex behaviour
  - covering many aspects of choice (e.g. activity analysis)
- non-linearity in the models often gives better results
  - in particular, concerning elasticity
- statistical method allows 'internal' error to be estimated
- the choice framework gives a method for investigating detailed behavioural effects
- can focus on specific policy issues for each study
- using appropriate data collection procedures

Concluding: challenges

- can alternative paradigms substitute or complement Umax?
  - need to cover forecasting and appraisal as well as understanding behaviour
- can we forecast how an alternative will sit in the future market?
  - relationship to other alternatives
  - history of changes to network
- can we use less formal background data to improve model estimation?
  - e.g. on VOT or elasticity

Concluding: challenges (2)

- how should we exploit local data?
  - matrices or disaggregate data
- do we need more sophisticated models for practical forecasting?
  - e.g. cross-nested or mixed logit
- are the advantages of activity-based models sufficient for the investment in them to be made?
- what's the best way to forecast population changes?
- can we get equilibrium or other solutions more quickly?

Concluding: challenges (3)

perhaps most importantly:

- how can we get our models used more appropriately?

- i.e. with regard to errors in forecasts

Objectives of talk

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- thank you

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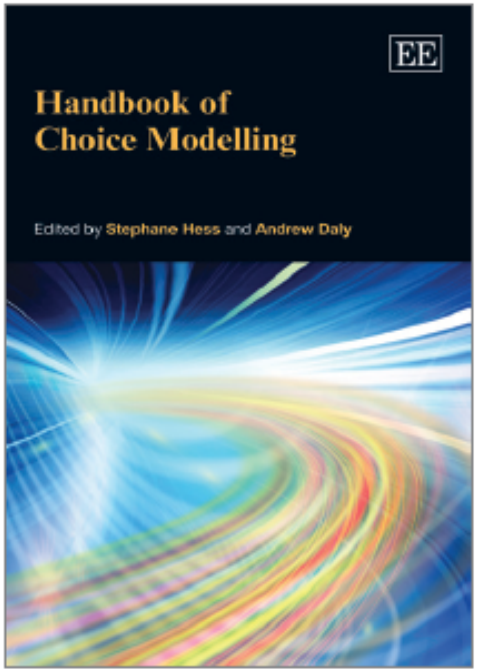
HANDBOOK OF CHOICE MODELLING

Edited by **Stephane Hess**, University of Leeds, UK and **Andrew Daly**, University of Leeds, UK and RAND Europe



'There have been some exciting developments in choice modeling, but much of this work is only accessible to those attending conferences like the International Choice Modeling Conference where researchers from many different fields can share their work. This Handbook brings the best of this new work to a wider audience. The editors have convinced many of the top researchers in choice modeling to contribute essays, and the resulting Handbook is the only reference I know that comes close to covering the current state of the art in choice modeling.'

– David Brownstone, University of California, Irvine, US

This book proposes a fantastic consolidation of these recent developments, written by the major actors in the field, including Daniel McFadden, Nobel Laureate. The good balance between fundamental topics and applied considerations, as well as the coverage of area-specific aspects, make it an exceptional reference for researchers and practitioners interested in human choices.'

– Michel Bierlaire, EPFL Lausanne, Switzerland

'A truly astonishing collection of papers. This book is the new place to go for learning the latest and greatest in choice modelling.'

– Kenneth Train, University of California, Berkeley, US