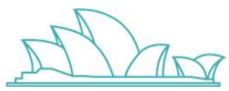
First presentation to be made by Andrew Daly and James Fox. Andrew will give a general introduction and describe the inception of the Sydney model, then James will talk about the specifics of that model.

We are pleased to be able to present our work and hope it is of interest.

The photo is taken in the Sydney CBD.

Three Webinars on Transport Modelling in Australia and Europe

RAND Europe will discuss their work:



1. Introduction and Sydney model (24 September)
2. Models of European cities and countries (22 October)
3. Long-distance Models (19 November)

We are describing a practice developed over 35 years and adapted to meet a wide range of local circumstances

RAND EUROPE

2

The series of studies described in these webinars has its ultimate roots in work by Cambridge Systematics in the Bay Area (related to McFadden's famous BART study) and in Holland, together with work by Andrew Daly and his colleagues in England, all of these around 1975. Through intermediate studies 1977-82, the major step was taken in the commissioning of the Netherlands National Model in 1983, operational from 1986 to the present date and currently the subject of a major update and improvement focussing on the treatment of rail in the model. In the current webinar we introduce the main features of this work and then describe the model we have developed of Sydney (New South Wales) which is in a number of ways the best of our models. In the second webinar we describe several comparable models we have developed in Europe, particularly describing the ways in which these models differ from the Sydney model. In the third webinar we talk about the Long-Distance Model we developed for Great Britain, showing how the particular characteristics of long-distance travel and the relevant policy affect model design and implementation, possibly relating that model to other long-distance models we have developed.

The development of the models in the period 1985-2000 was undertaken by Hague Consulting Group, for which all the presenters worked. Following the purchase of that company by RAND Europe in 2001 (the European offshoot of the RAND Corporation) the work has been done under the flag of RAND Europe.

Webinar 1: Background, Overview and Sydney example

- Background
- Overview
- Sydney example

The Notes to the slides give more background information.

RAND EUROPE

3

Background gives the context in which we are asked to do the work. **Overview** describes the general characteristics of the models we are developing.

Webinar 1: Background, Overview and Sydney example

- Background
- Overview
- Sydney example

RAND EUROPE

4

Background gives some general principles and the context of client requirements in which we have been asked to undertake this work.

Our clients have several objectives in modelling travel demand

- to support transport and other policy
  - this work is done under contract to government at various levels
    - local, regional/conurbation, state, national, supra-national
  - i.e. not pure research but we maintain contact with university work and exploit its practical aspects

1. in many countries, input to formal cost-benefit procedures is needed to satisfy government funding requirements
   - equity between modes, regions, sectors
   - civil servants are concerned to ensure quality and accuracy
2. or the model may contribute to the design of infrastructure or policy
3. in other cases, a more general understanding of likely future developments is required

RAND EUROPE 5

It is important at the outset to clarify the objectives of the work so that we can tailor the models to meet clients' requirements.

Supra-national refers to the European Commission, which maintains models to support its policy on Trans-European Networks and other international policy. The Transtools model covers Europe from the Atlantic to the Urals, about 50 countries.

Our clients expect rigorous validation

- to confirm that the model represents their area, they require good base-year fit, including trip length distributions and mode split
- elasticity values must be reasonable
  - in the UK, the government publishes ranges which models must meet
- parameter values, e.g. values of time, must be plausible
- an important contribution to accuracy can be the use of 'pivoting', where the model is used to predict *changes* relative to an accurately known base-year trip matrix
- a base matrix is not always available, or may be available in different ways
  - e.g. from census journey-to-work data
  - for public transport, from ticket sales and/or on-board counts
  - for highways, from matrix estimation based on roadside interviews and/or manual or automatic counts

RAND EUROPE

6

Validation means that the components of the model must be reasonable, in particular values of time and elasticities are inspected closely. Base-year validation, e.g. matching of flows, is more an issue of the base matrix (if present), although trip length distribution is an important indicator of validity.

Philosophy: model the key aspects of behaviour

- "Everything should be made as simple as possible, but not simpler" attributed to Albert Einstein
  - model the aspects of behaviour with the greatest impact on traffic
- the focus is on tours as units in the model
  - journeys from home to home, with a number of destinations en route
  - traffic as a derived demand
- tours offer a substantial improvement on trip modelling with only moderate increase in complexity
  - consistency of mode and destination choice with production and attraction
  - logical treatment of timing choices, primary and secondary destinations
  - car availability can be modelled with sophistication
  - can always obtain trips from tours for assignment
- further sophistication can be obtained by modelling person or household activity patterns but this adds a lot of complexity
  - important only for limited range of policy issues

RAND EUROPE 7

The models need to be able to distinguish between scenarios in a range of policy contexts and therefore need the features to focus on those differences.

These talks focus on travel demand models

- the final output is trip matrices for assignment
- route choice forms part of some of our models, but we ourselves do not usually deal with capacity-restrained assignment procedures
- our clients usually require standard packages such as EMME or VISUM
- of course, these form an important part of the modelling process and our models are therefore linked to assignment models
- the linking of demand and assignment models has implications:
  – meets government requirements for equilibrium
  – requires output of ‘full’ traffic flows
    - with segmentation significant for assignment, e.g. tolling
  – requires equilibration which in turn has major run-time implications
  – which impose necessity for efficiency in coding

RAND EUROPE 8

This is just a note to indicate a limitation of what we are going to talk about. We have not worked much on assignment because our clients have typically already been committed to an assignment package (EMME2/3/4, VISUM..). However, for the Dutch model LMS, we developed an advanced highway assignment program to meet specific client requirements.

Our clients typically require equilibration between demand and assignment. The UK govt. even gives specific criteria to define the precision that must be achieved – see WebTAG Unit M2: https://www.gov.uk/government/publications/webtag-tag-unit-m2-variable-demand-modelling, section 6.3.

Webinar 1: Background, Overview and Sydney example

- Background
- Overview
- Sydney example

RAND EUROPE

9

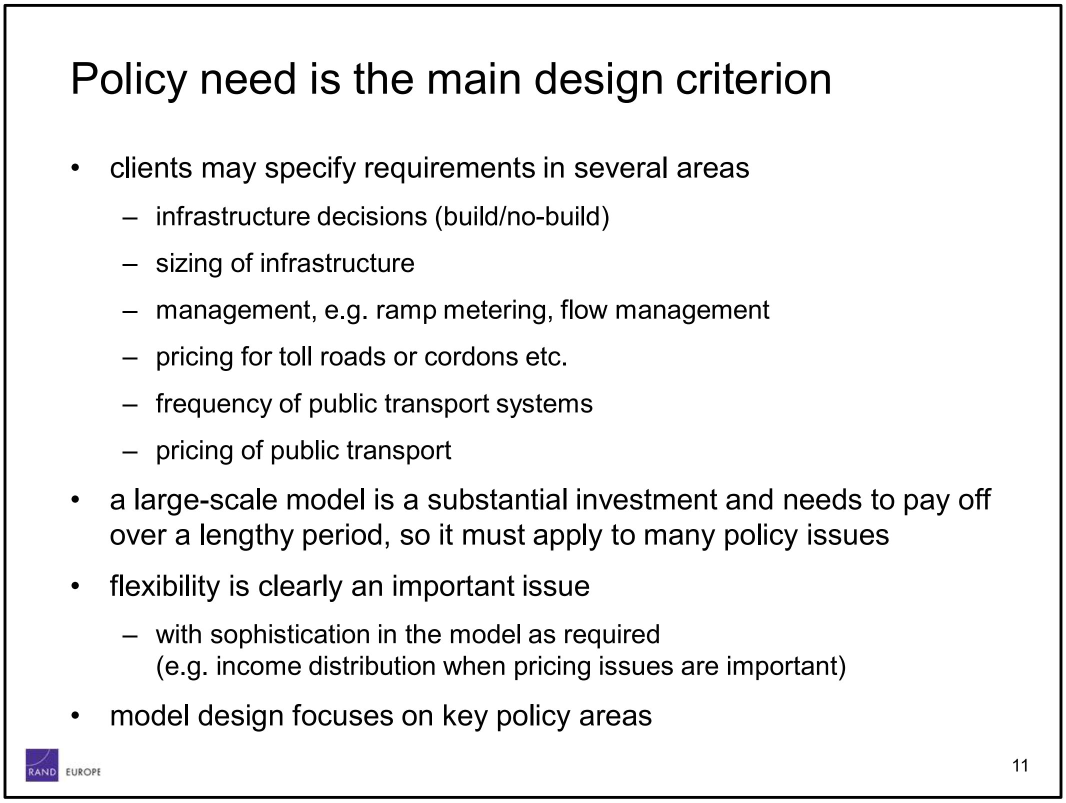
Overview gives a general description of RE's models, of which Sydney is a typical example

Introduction to our models

- criteria for model design
- flexibility to meet (changing) client needs
  - the models include a study-specific set of choices
  - not just four stages!
- behavioural ambition balances sophistication and practicality
  - tour-based analysis, not a model of all-day activities
  - detailed segmentation of the population, adjusted to each travel purpose
- utility-based models with consistent linkages
- rigorous statistical estimation
- the models predict *expected* demand
- population forecasting

RAND EUROPE 10

In this introductory section I want to try to show how our models have a family resemblance but nevertheless have grown up differently to meet the needs of the environments for which they have been developed.



The concept here is that we do not come to a client with a fixed model, which their policy, data and budgets must fit, rather we adjust the model to the local circumstances. This is slightly more expensive than some consultants' approaches, but we believe it gives a better service to clients.

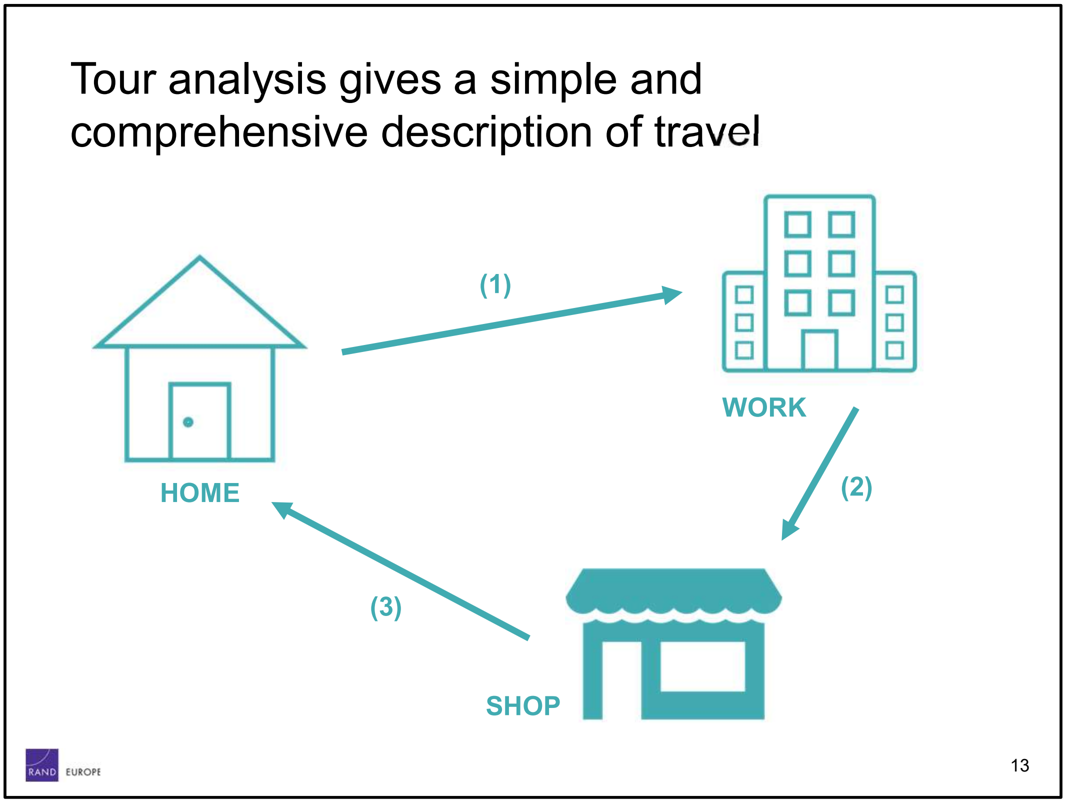
The design of the models varies

- components and/or segmentation can be added or simplified depending on client's expectation of policy issues
  - or time/money budgets or data availability
- e.g. in West Midlands, original model had no income segmentation but this had to be added to consider tolling options
- e.g. in Netherlands, original model had no time period choice, added to facilitate time-dependent road user charging
- in Stockholm, there was a considerable focus on the use of cars within households because of local family structure
- very often, we have components in the model additional to the basic 4-step concept, though those stages are consistently included
- sometimes we need special surveys (e.g. Stated Preference) to include specific behavioural impacts of important policy

RAND EUROPE

12

The design needs discussion with model stakeholders and thought.



A tour is a sequence of trips beginning and ending at home. Additionally, in some models, we defined work-based (or occasionally education-based) tours beginning and ending at specific locations.

Each tour has a primary destination, defined by a purpose hierarchy and/or the activity time. The models then represent primary destination choice, primary mode choice and timing for travel to that destination. Secondary destinations, for both detours and work-based tours, are modelled conditional on the primary destination and modes for secondary trips are conditional on primary modes.

Trips are extracted from the tours for assignment.

Utility-based models with consistent links

- the models form nested logit structures
  - can be quite complicated nesting, depending on local model design
  - always use simultaneous estimation where possible
- linkages between choice types are formed by logsum variables
  - this is the technically correct form for utility maximising models
  - structures are NOT specified *a priori* but estimated from data
- each alternative has a utility function containing its cost and time
  - may be several dimensions of time, e.g. walking, waiting, in-vehicle
  - socio-economic variables can also be introduced
- these functions may be non-linear, but need to be consistent with micro-economics
- rigorous framework allows new variables or behaviour to be added
  - several instances described with detailed models later
- and ensures predictions are consistent with micro-economic theory
  - e.g. elasticities always have the right sign!

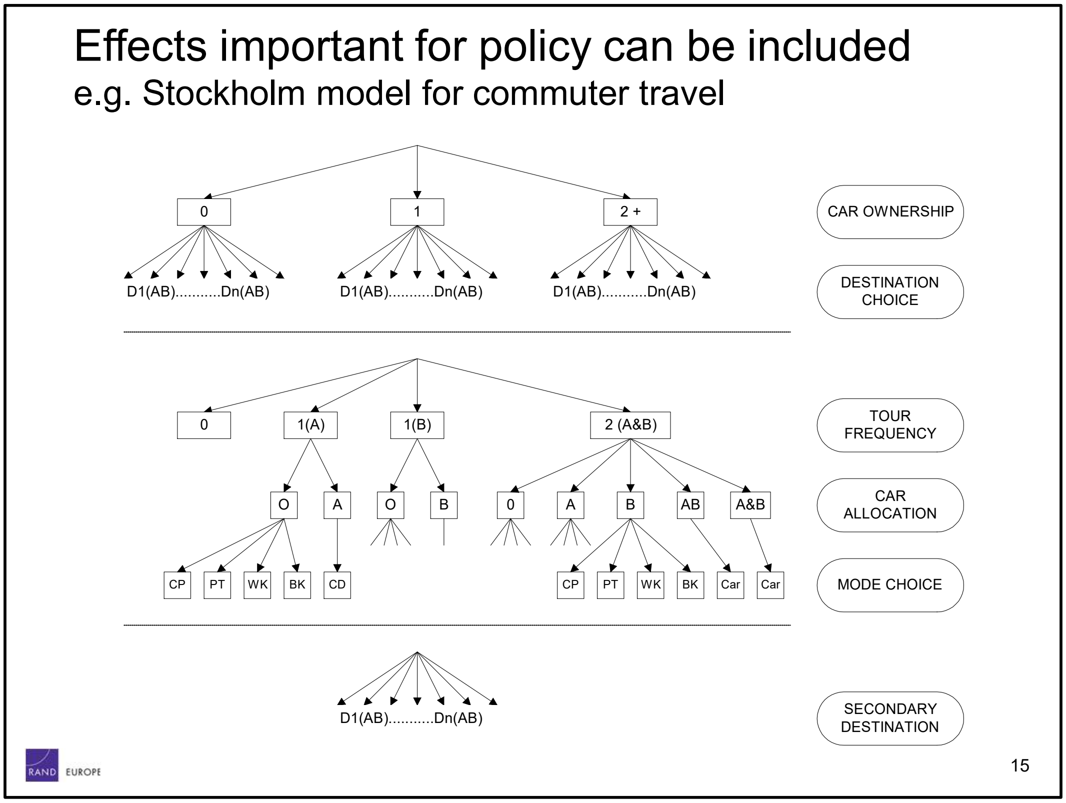
RAND EUROPE

14

Consistency with micro-economics requires strictly increasing generalised cost functions (disutility functions) with respect to cost and time components. Variables relating to the same type of disutility should appear in the same functional form for each alternative. Functions for one alternative should not depend on attributes of other alternatives (e.g. as they do in regret models). Failure to observe these criteria may cause counter-intuitive results, such as wrongly-signed elasticities and difficulty in formulating consistent appraisal measures.

Additionally, not strictly microeconomic but rather common sense, the kilometrage test (mileage test) can be applied, whereby increasing cost per mile does not cause an increase in total mileage. Criteria for this test are given in http://assets.dft.gov.uk/publications/pgr-economics-rdg-costdamping-pdf/costdamping.pdf.

Because of this consistent basis of the models, it is often possible to introduce new variables or aspects of behaviour into the models and this has often been done, as we shall show later today and in the following webinar.



This is the structure for the commuter model of Stockholm (SIMS) which is one of the more sophisticated models we have done (and was completed 20 years ago, so we had computer limitations that would not be a problem now). The car allocation model was introduced to deal with specific local conditions of high female employment and licence holding but largely single car ownership.

Other modelling concerns would of course give different model structures.

Statistical estimation procedures

- the models are estimated from local data
  - using maximum likelihood methods
  - estimating all the parameters
- data as disaggregate as possible, i.e. usually individual tour records
- allows all kinds of tests based on statistical process
  - significance, accuracy
- but it's important to balance fit against plausibility
  - for example, it may be necessary to constrain some of the parameters to values obtained earlier or from elsewhere
  - non-linear functions also allow flexibility to meet multiple criteria
- note, in particular, that model structures (e.g. whether mode is 'higher' or 'lower' than destination) are derived from estimation on local data
  - and may vary by purpose

RAND EUROPE

16

Software is needed for maximum likelihood estimation and for a wide range of model tests. It has to be efficient because of the large size of some models.

Elasticity is the key

- Differentiation between alternative policies is given by the model elasticities and these are therefore central to the assessment of model quality
- International comparisons of elasticity exist, but they are limited, though we have our own experience
- Elasticity is a measure of more general sensitivity, which is what it is really about
  - not a very good measure, because it depends on market shares
  - but the only available measure for international comparisons

RAND EUROPE

17

Elasticity is key because the model are intended to show the differences between scenarios.

There is international literature and within-country meta-analysis etc.. There are always reasons why elasticities should vary, but it is usually possible to get a reasonable indication of whether a model is performing within the expected range. The UK government indicates ranges for elasticities, based on previous UK experience, including time-series modelling and analysis of other data.

Model structures vary

- For example, while we find mode 'above' destination in most European and Australian models, this is not always so
  - and models of this type estimated on North American data mostly give the opposite result
  - sometimes we get variation by purpose in the same study
- The primary decision criterion on model structure is the explanation of the data, but elasticities are also tested
- Additionally, we often include time period choice in the model and this has to be placed in the structure
  - usually below mode and approximately at the same level as destination
- Other choices are sometimes also included and need to be entered into the structure
- It becomes difficult to estimate all of the structural parameters because of collinearity

RAND EUROPE

18

Model structure is an empirical question, as we always model simultaneous choice.

Elasticities are not often very useful in determining structure, as other coefficients in the model adjust to the structure.

Outputs are expected demand

- like all practical choice models, the primary output is choice probabilities
- these are used to obtain *expected demand*
  - i.e. the expected number of tours (and hence trips)
- this approach is simple, yielding matrices that can be assigned
  - can aggregate over person types and (to some extent) purposes before output
- we do not use simulations, which introduce complications
  - simulation error
  - need for approximation, which clients would require to be tested
- research is needed on the balance of these approaches
  - either forecasting approach would require the same model estimation

RAND EUROPE 19

The models yield probabilities for each possible choice. These can be exploited either: to calculate expected demand as either

a. the probability times the number of people making the choice; or
b. as a basis for sampling, when a random number is drawn for each person and choice is assigned on the basis of the probability and the random number.

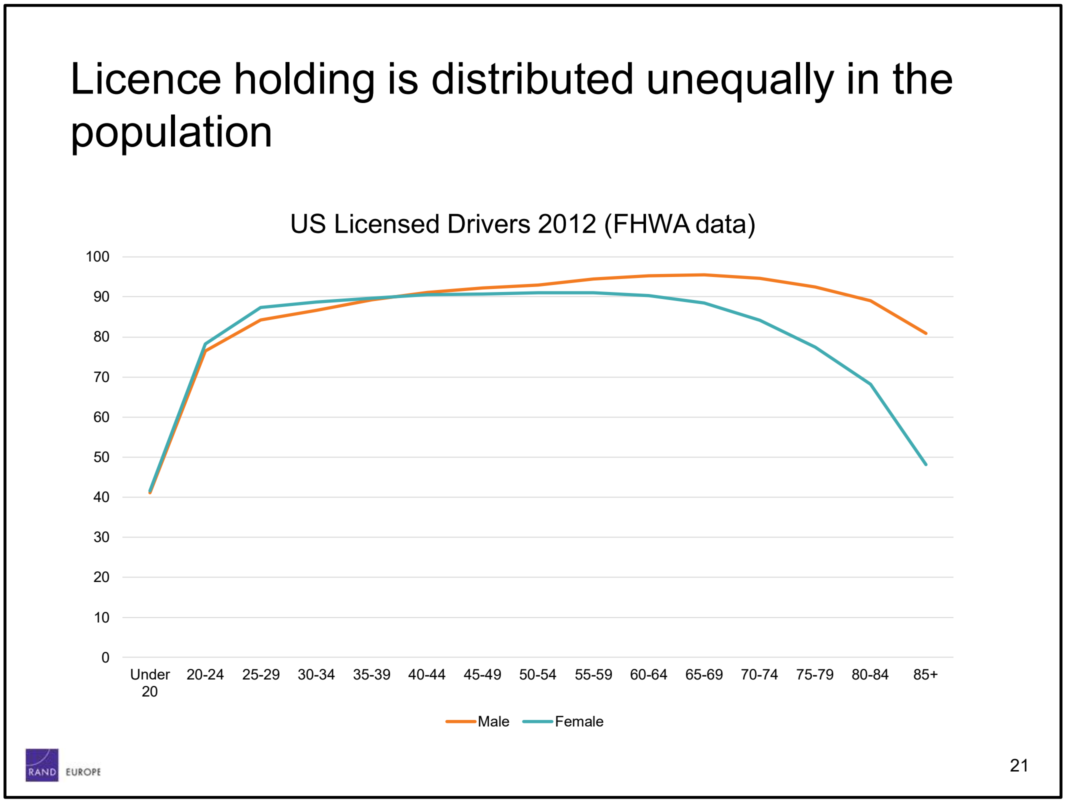
The sampling approach is typically used in activity-based modelling, but it seems that there is no absolute requirement to use sampling or expected demand in ABM or tour-based models.

Population forecasting

- population forecasting is required in sufficient detail to operate the models
- we use the quadratic minimisation approach, which balances
  - fit to expected marginal statistics for the forecast year
  - distribution of cell values as observed in the base year
- balancing the errors means that we accommodate uncertainty in the forecasts with the extent of change in the structure of the population
  - in contrast, Iterative Proportional Fitting (IPF) fits future marginals exactly
- licence holding can be modelled as part of this process
  - cohort models give the development over time
  - cross-sectional models give the distribution within the population

RAND EUROPE 20

IPF is used more widely than quadratic minimisation, particularly in the US. Detailed simulation of population development is also used.



This graph is fairly typical of developed countries, though the US has slightly more older licence holders, particularly women, and slightly fewer middle-aged licence holders than in most such countries. Licences under 25 seem to be declining but we don’t know if this is true in the US.

Information for Sydney appears later in the webinar.

Cohort modelling is particularly suitable for licence holding, because of the long-term nature of the decision.

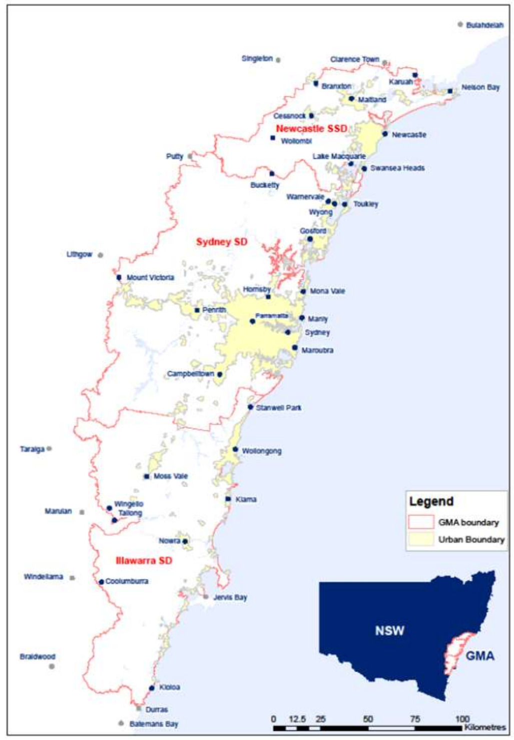
Webinar 1: Background, Overview and Sydney example

- Background
- Overview
- Sydney example

Sydney is an excellent example of our work – the modelling was greatly helped by the good local data and a capable client.

Sydney is a large isolated conurbation

population 5.2 million
area 0.3 million sq.m.



RAND EUROPE

Australia is very urbanised and the population is mostly located near the coast. The state of New South Wales on the eastern side of the continent is typical of that pattern – it's a bit larger than Texas with ¼ the population. The nearest substantial city to Sydney is Canberra, 175 miles away, population 350,000, and 500 miles to another city over 100,000. NSW is the most populous state of Australia and about 70% of the state population live in our study area. External land transport is not a major issue!

Transport networks in the study area are extensive, with a large suburban rail network and a number of tolled roads. However, continuous network development is needed to meet population development.

In 1996, NSW decided to upgrade its transport data and modelling

- previous modelling used a 4-stage trip model developed by US consultants from 1971
  - state of practice at the time and carefully developed
- updated from time to time based on one-off home interview surveys
- but latest update in 1991 was getting out of date
- no longer suitable for the relevant policy concerns

- network and land use data of generally high quality
- EMME used for assignments

RAND EUROPE

Rapid growth of population from migration and rapid spread of development. Car ownership increasing and very intensive development in CBD.

Rolling data collection

- the decision to develop an entirely new model was taken at the same time as a major change in data collection
- instead of 'big bang' occasional home interview surveys, a rolling programme was started in 1997
  - allows trends in all sorts of travel to be followed closely
  - maintains consistency
  - cost-efficient by maintaining a permanent workforce
  - but there are issues for modelling
- initial new modelling had to use the 1991 big bang in addition to new data, but later there was sufficient new data to use that alone
- networks were also gradually updated

RAND EUROPE 25

Rolling data presents problems for modelling as there may not be enough data in the early stages. Moreover, it is difficult to maintain network data for every year, so some degree of approximation is needed.

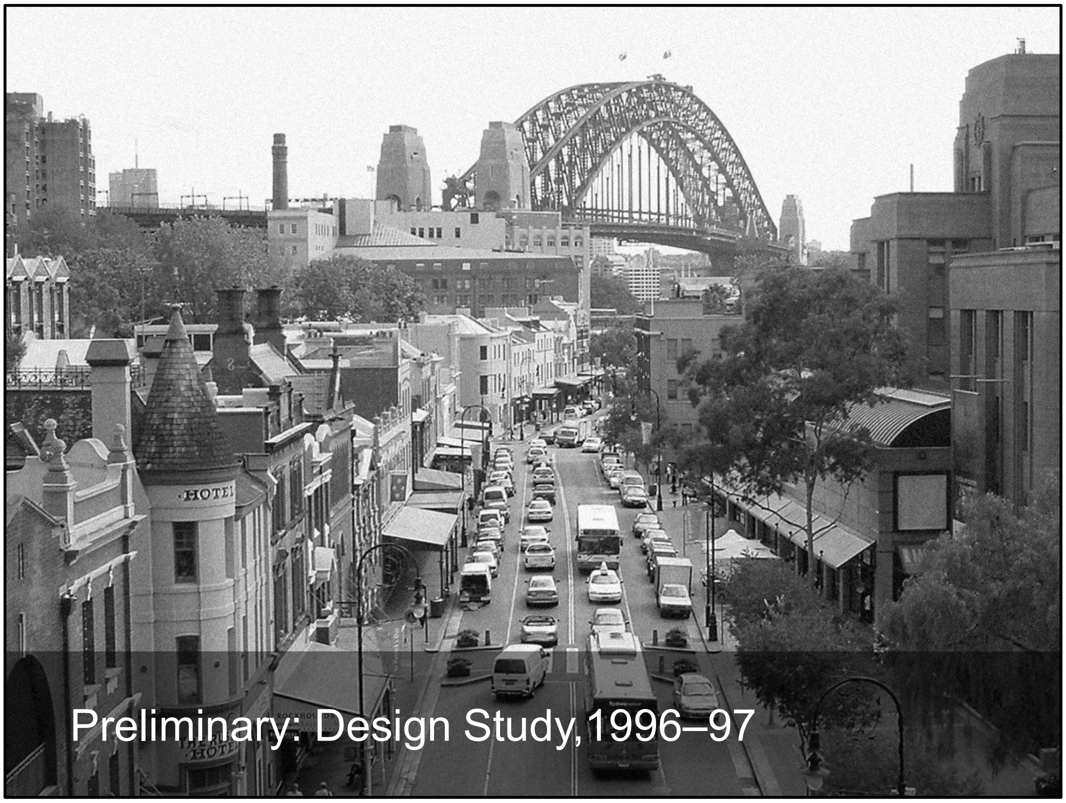
The Sydney Model was developed in stages

- model design study, 1996–1997
  - design to get model operational quickly and keep it working
- stage 1 and 2 of model development, 1999–2001
  - followed plan set out in design study
  - estimation of a number of linked disaggregate demand models, incorporating wide range of socio-economic segmentation
  - development of an operational demand model implementation
- model validation, 2004–2005
  - generally reassuring but some areas for improvement identified
- model development, 2009–present
  - more recent data, extended model area
  - enhancements to model specification to address evolving policy needs and findings from validation study

RAND EUROPE 26

Staging of model development was primarily a financial issue. The model development team did not know how much money they would have for the model on a long-term basis, so they had to proceed in relatively small steps. Nevertheless a certain core budget was needed to get an operational model.

The remainder of the presentation is structured into four sections covering these four stages, the second section describing the core of the model is the largest section.



This is the oldest part of the city (The Rocks), where the first European settlement of Australia took place in 1788.

The study was commissioned by international competition, won by Hague Consulting Group based in Holland.

Design study produced both 'end state' design and a development plan

- reviews were made of the current model
  - US-style 4-stage model last updated in 1991
- reviews were made of Sydney data and a decision taken to conduct a rolling household survey
- reviews were made of world practice in transport modelling
- stakeholder consultation provided a summary of policy requirements
- to prioritise and schedule improvements, a cost-benefit type approach was used that considered the resources required for each option alongside the benefit it offered
  - not always a suitable approach but in this context it proved intuitive and insightful
- a programme was written for model development to obtain the greatest improvement first for a planned expenditure stream
  - getting an operational model as early as possible and keeping it

RAND EUROPE 28

Following reviews of the current model and data and of world-wide modelling practice, interviews were held with a dozen State agencies to determine their requirements. The model features and components were then prioritised to get a plan of development that would get an operational model as soon as possible, then develop the features that were considered important in the appropriate priority given by notional cost-benefit.

The existing model was strong in its data base, particularly networks, so these were retained. The focus was then on the policy-sensitive aspects of the demand model.

Interviews and a workshop obtained each agency’s preferences for model enhancements

- Each agency’s preference was recorded on a scale of 1 to 4
- Cost was assessed in estimated person-months of work
- A spreadsheet made the calculations (this is part of it)

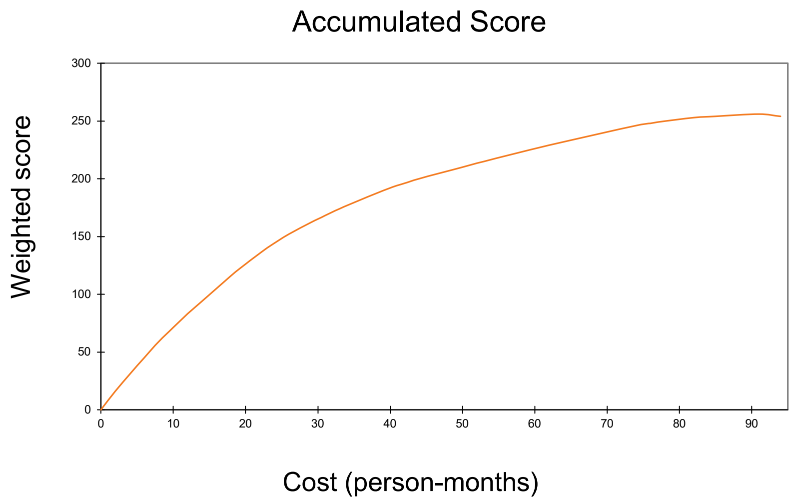
				DoT	Treas	MUIM	CityR	RAC	STA	RTA	EPA	DUAP	W'shop	Rep1	Gen
Modelling issue	Ben:cost	Cost	Benefit	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	4.0	2.0	2.0
Parking availability & pricing	8.0	2.0	16.0				2.0	2.0		2.0			2.0		1.0
Model multiple modes	7.5	2.0	15.0								1.0		3.0	1.0	
Better pt access	7.0	2.0	14.0				2.0		1.0		1.0		2.0	1.0	
Detailed generalised cost	7.0	2.0	14.0				2.0		1.0	1.0			2.0	1.0	
Include freight	6.0	2.0	12.0							2.0			2.0	1.0	
Land use variants	6.0	2.0	12.0	1.0	1.0						2.0		2.0		
Elastic generation	5.5	2.0	11.0					2.0	2.0	2.0		1.0	1.0		
Extend time periods	5.5	4.0	22.0					2.0	2.0	2.0	2.0		3.0	1.0	
External traffic	5.0	2.0	10.0										2.0	1.0	

RAND EUROPE 29

About 10 state agencies were recognised as having relevant views about the model and their views were collected by personal interviews and through a workshop. These views were then used to make concrete and prioritise model features that could be added to the basic design, at a specific cost for each feature.

Quantifying these preferences as points goes a bit far, but it illustrates the general ideas of picking the low-hanging fruit and balancing the requirements of the different agencies.

Balance between effort and benefit



RAND EUROPE 30

Benefit is defined in terms of the notional scoring system, cost in terms of estimated person-months of work. Then the logical approach is to do the high benefit/cost ratio tasks first. But this has to be constrained by the logic of the modelling.

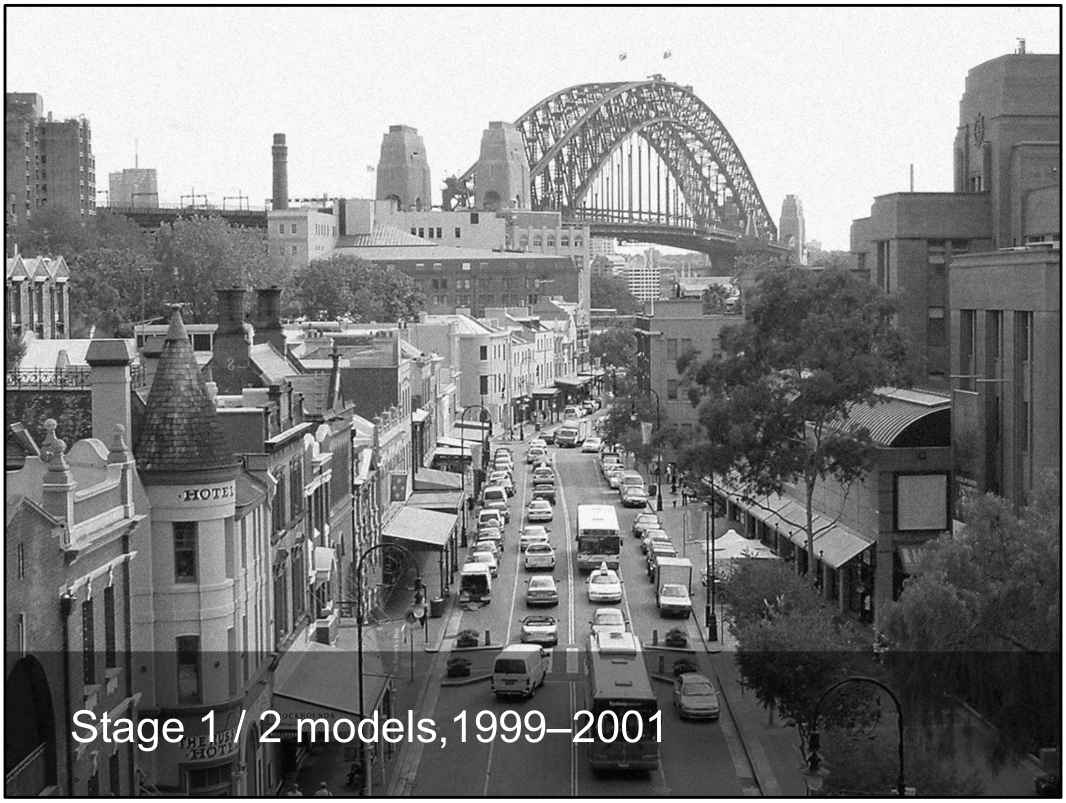
This approach appears naïve, but it did turn out to be insightful and to help with explanation of the approach to the agencies.

The schedule was developed based on these preferences

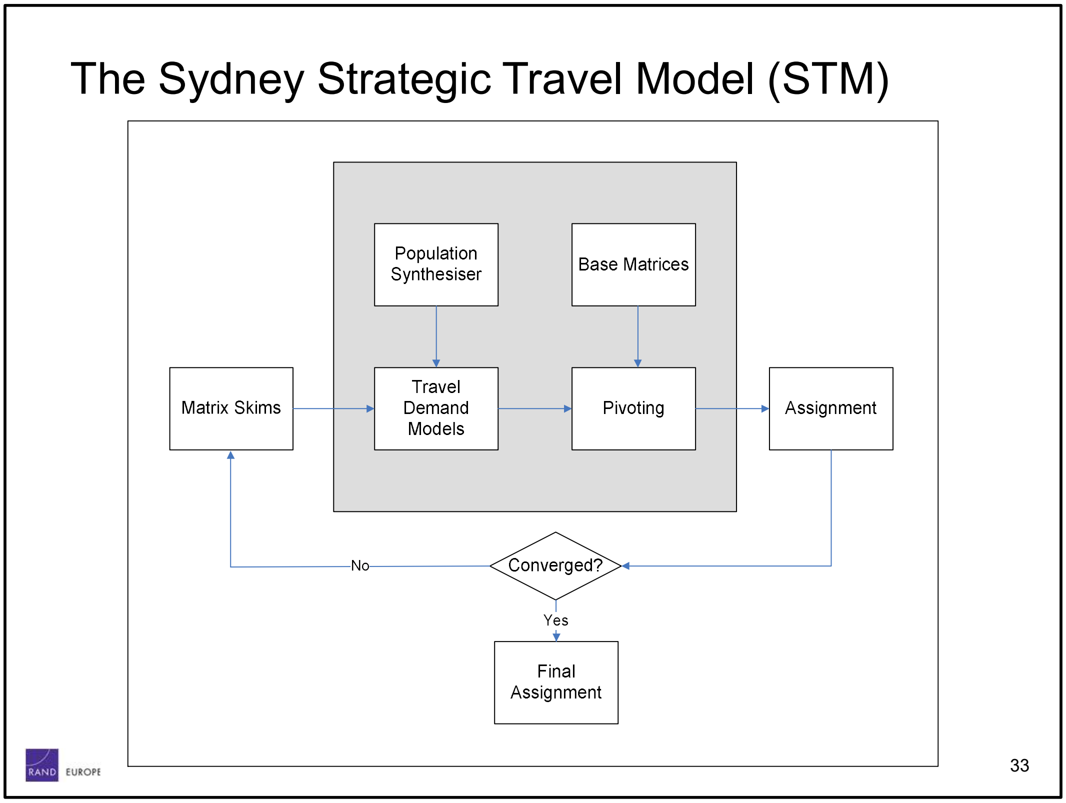
- and on the logic of modelling
  - module can be used only if the module providing its input is operational
- Stage 1 built an operational journey-to-work model
  - allowed peak hour analyses using the new model
- Stage 2 added the other travel purposes
  - completed the peak and extended to off-peak analyses
- further developments added non-core features
  - car access to rail (including park and ride)
  - more sophisticated treatment of toll roads
  - improvements from validation of initial model
  - updates from 2001 to 2006 and 2011 (census every 5 years)

RAND EUROPE 31

Note that the Australian census is equivalent to US Long Form for every person.



This work was done while the client was distracted by the 2000 Olympics, when many people were seconded to Olympic transport duty.



The presentation is focussed on the modules in the grey box, which together constitute the demand model, and which we will describe in turn.

The diagram illustrates that the demand model is run in iteration with networks, however population model does not depend on skims and therefore is run once per demographic scenario

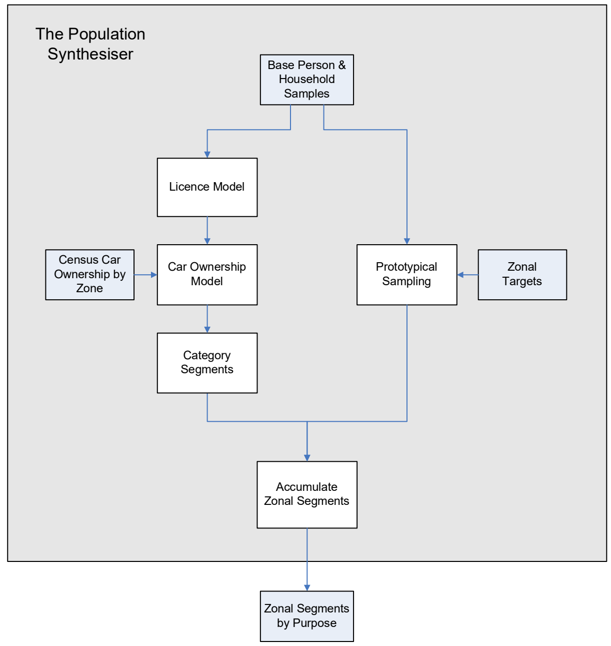
Population Synthesiser

- the Population Synthesiser generates predictions of the future Sydney population by socio-economic segment
- it includes disaggregate models of licence holding and car ownership, which are used to predict changes in car availability
- it also includes a 'Prototypical Sampling' approach, where the Household Travel Survey data is used to form a 'base sample' of persons and households which is re-weighted to meet target totals in each model zone
- the output is population totals by zone and segment
  - in contrast, most activity-based models generate individual records for the base and future populations

RAND EUROPE 34

Andrew noted that more work is needed to compare expected demand and AB approaches.

Population Synthesiser



RAND EUROPE

35

Aim is to produce forecasts of the population by zone and segment for input into the Travel Demand models

Will talk through each of the model components shown in the white boxes in turn…

Forecasting car availability is key to predicting changes in mode share

- licence holding predicted using a two-stage approach
  - cohort models predict changes in licence holding over time
  - cross-sectional licence holding models predict distribution of licence holding across different socio-economic segments given the cohort predictions
- car ownership is predicted using cross-sectional models estimated at the household level
- individual licence holding, household licence holding and household car ownership are used to define different car availability levels in the mode-destination choice models

RAND EUROPE

36

This is a key feature of our models

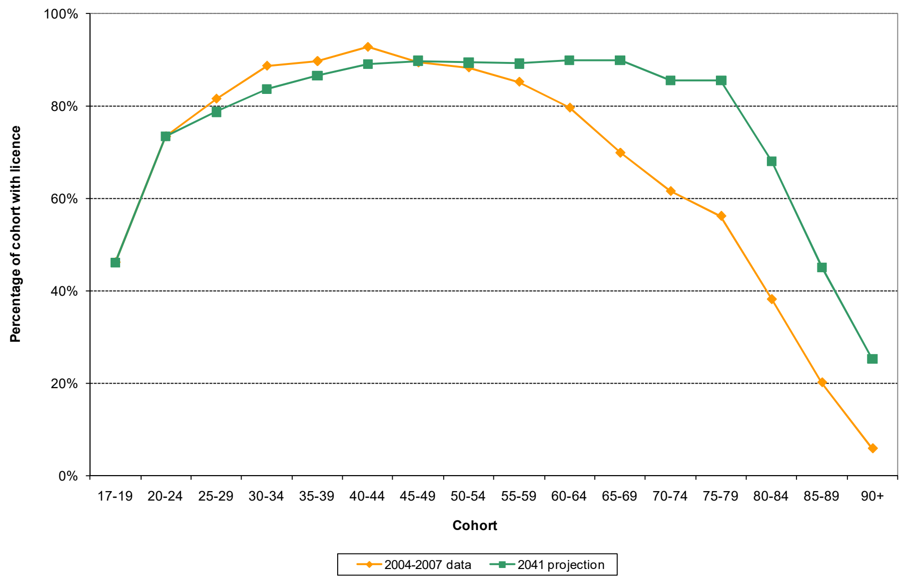
Longitudinal licence cohort models

- predict licence holding by age-gender cohort as function of:
  - licence holding for that cohort 5 years back
  - acquisition/loss rates, depending on age
- calibrated using repeated cross-section data, dating back to 1971
- approach accounts for lower licence holding of migrants, and can be run for different forecasts of future migration

RAND EUROPE

Focus on acquisition rates when talking through

Licence cohort models – predictions for females



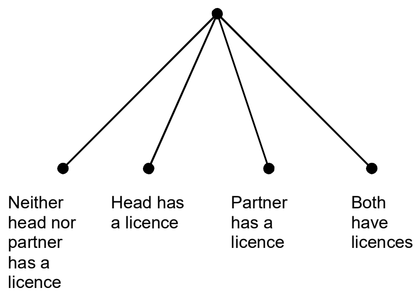
RAND EUROPE

38

Females retaining licences into retirement -> will impact upon travel patterns

Cross-sectional licence holding models

Model is applied to head of household and their partner, if they exist:



Model variables

- household income
- age
- work full or part time
- gender
- number of children
- whether married
- whether born in Aus.

Second ‘other adults’ model applied to each other adult in the HH

Predictions adjusted to take account of cohort model

RAND EUROPE

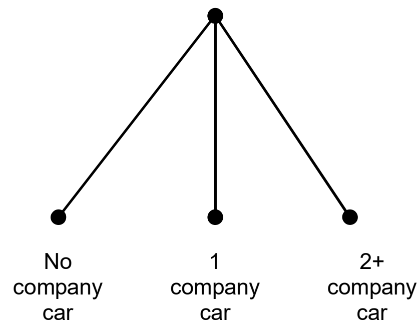
39

Explain why model head & partner together – significant correlations.

Cohort adjustment takes account of differences between gold and green lines in previous chart, e.g. licence holding for seniors adjusted upwards in 2041

Company car ownership models

Household level model for households with at least one worker:



Model variables

- household income
- age
- gender
- household size
- number workers
- licence holding
- married couple
- whether born in Aus.
- parking cost

taxation is not a variable but changes can have a significant impact

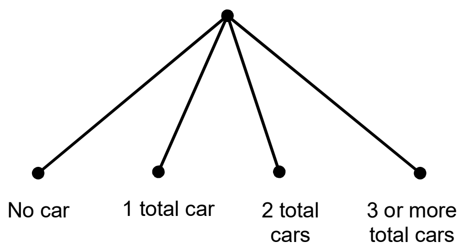
RAND EUROPE

40

Taxation – experience from a number of contexts is that this plays a key role, but the impact is difficult to represent in a cross-sectional model, and it is hard to predict future changes

Total car ownership models

Best of two alternative structures – total cars predicted conditioned on company, alternative was company predicted conditional on non-company:



accessibility term accounts for the impact of increased accessibility on car ownership, and varies spatially

Model variables

- HH income less ownership costs
- age
- gender
- number of children
- number FT & PT workers
- licence holding
- married couple
- whether born in Aus.
- parking cost
- company car ownership
- mode-destination accessibility
- distance from CBD

RAND EUROPE 41

Operating cost has an influence on the accessibility variable
Explain accessibility term in terms of improvements in areas with poor PT provision

Prototypical sampling

- prototypical sample is re-weighted for each zone to best meet 19 zonal targets for the future year:
  - eight age-gender cohorts (0–19, 20–39, 40–59, 60+)
  - five household types (couples with/without children, single person, single parent, other types)
  - workers (manufacturing, non-manufacturing)
  - income (four personal income bands)
- the approach used balance seeks the best fit to the zonal target variable while minimising the deviation from the base prototypical sample

RAND EUROPE

42

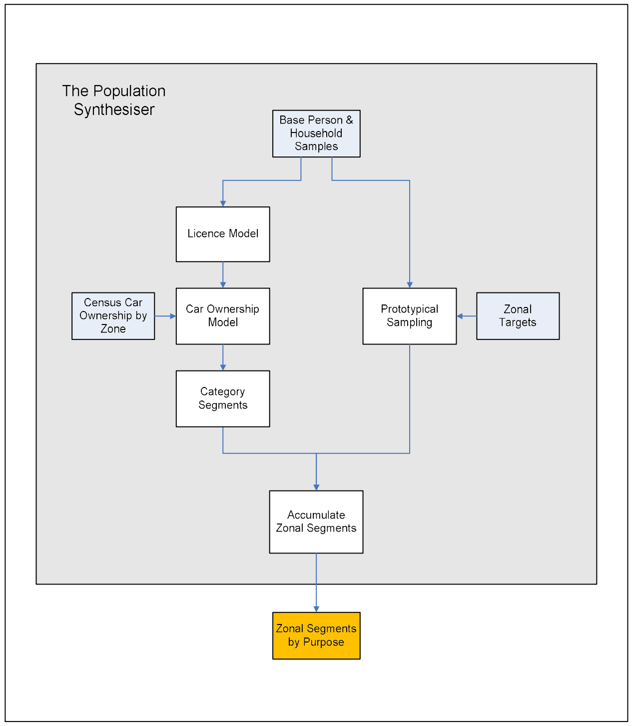
Mention IPF seeks to just best fit zonal targets

Accumulate zonal segments

- the segments are specified in the demand model estimation
  - define all key socio-economic terms
  - e.g. for commute, car availability, job type and income
- output from the process is zonal segments by purpose
  - give population totals by home zone
  - segments vary by purpose, reflecting different segmentations used for different journey purposes
  - the zonal segments by purpose form inputs into the Travel Demand models
- thus models work with numbers of people classified into a particular segment combination, rather than tracking a single individual through the whole process

RAND EUROPE

Population Synthesiser

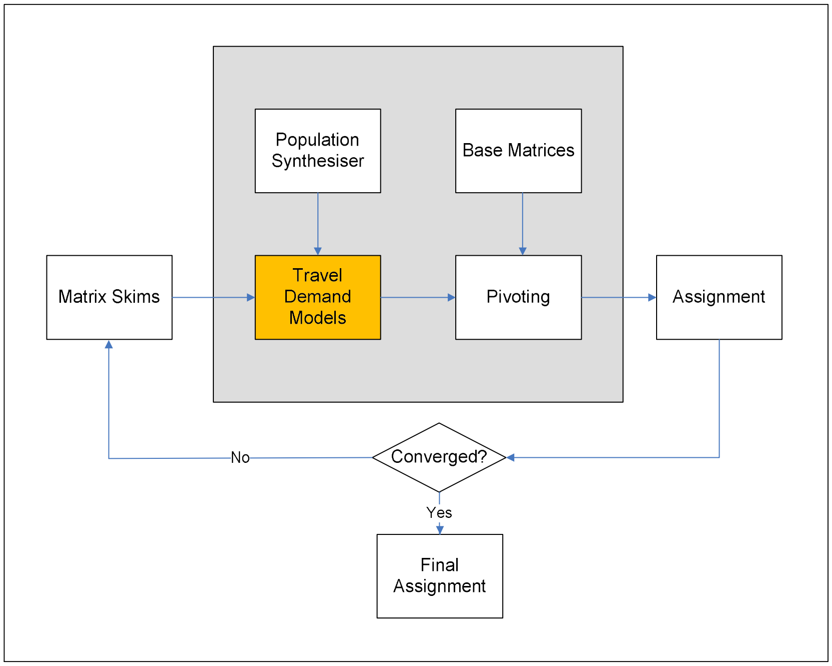


RAND EUROPE

44

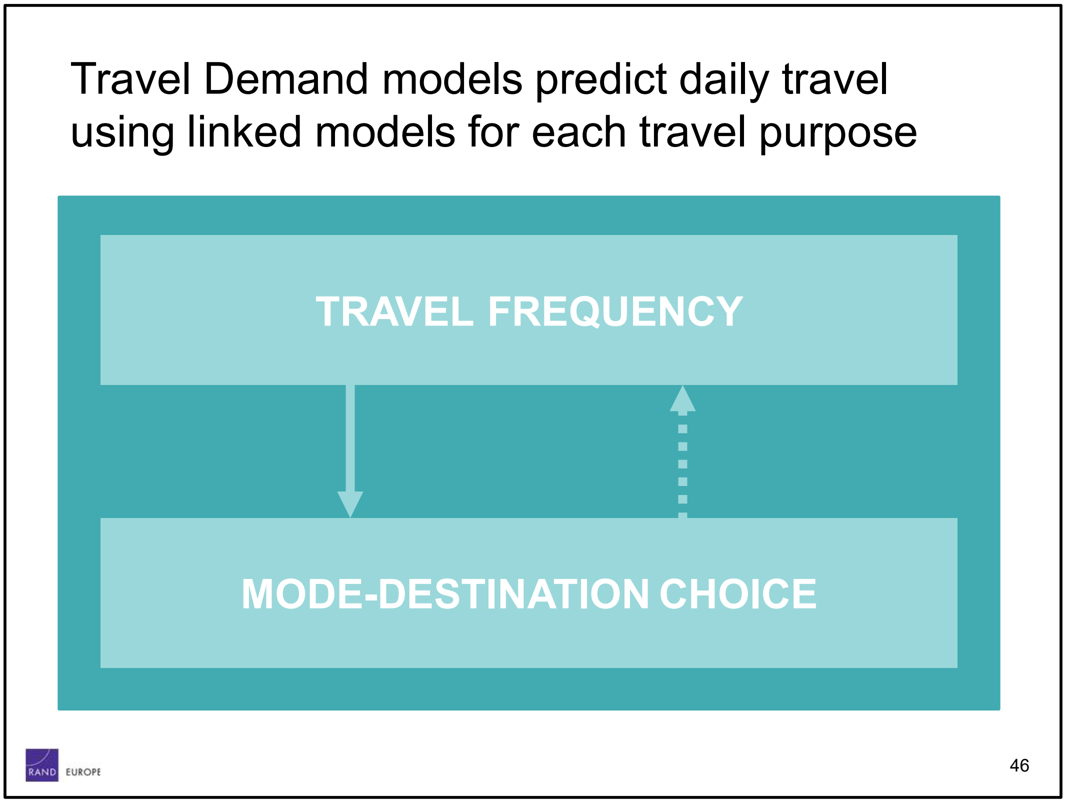
Output from the process is predictions of Population by zone and segment, ready for input to the Travel Demand models

The Sydney Strategic Travel Model (STM)



RAND EUROPE

45



The travel frequency models predict how many tours an individual in a give zone makes, then the mode-destination choice model predicts where those tours go and by what mode. In turn, the mode-destination logsum measures accessibility of mode and destination alternatives and is used as a variable in the frequency models. The Sydney model does not currently include a model of time-of-day choice, however the client is currently are considering whether to add to the model system.

Travel purposes

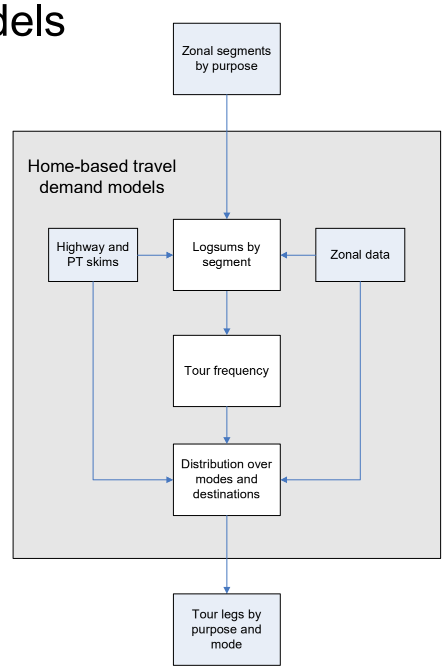
- home-based
  - commute
  - business
  - primary education
  - secondary education
  - tertiary education
  - shopping
  - other travel
- non-home-based
  - work-based business tours
  - business detours during home-based tours
- main category missing is non-home-based other (i.e. non-business)
  - currently this is forecast using a matrix factoring approach rather than with behavioural models
  - client did not prioritise funding for modelling these trips

RAND EUROPE

47

Explain difference between tours and detours at this point, also explain work-based tours clearly.

Travel Demand models



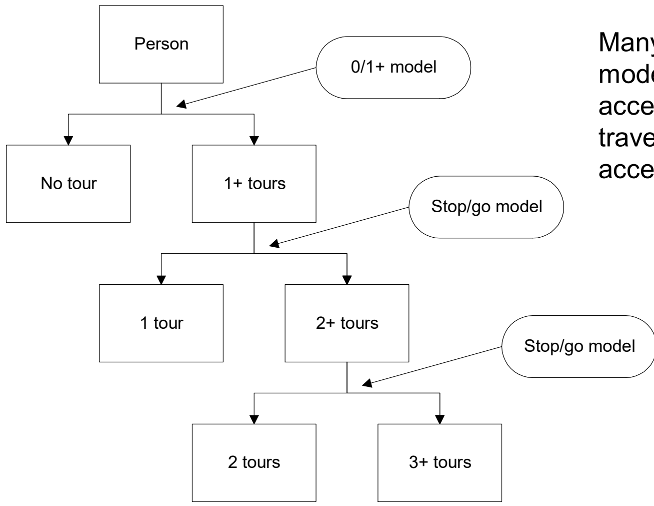
RAND EUROPE

48

Logsums calculated first so allow calculation of frequency{accessibility}.
Important point is that output is not split by segment.
Note that highway and PT skims incorporate some variation by TP.

Frequency models

Estimated at the person level, separate models by purpose



Many models incorporate mode-destination accessibility terms – more travel in zones with higher accessibility

RAND EUROPE

Frequency - zero/one-plus models

	Commute	Business	Primary	Secondary	Tertiary	Shopping	Other
Constant	√	√	√	√	√	√	√
Adult status	√	√			√	√	√
Occup. type		√					
Age	√	√		√	√	√	√
Gender	√	√				√	
Car availability	√	√				√	√
Education type			√		√		
Children							√
Income	√		√		√	√	√
Accessibility	√	√	√		√	√	√

RAND EUROPE

Frequency – stop/go models

	Commute	Business	Primary	Secondary	Tertiary	Shopping	Other
Constant	√	√	√	√	√	√	√
Adult status							√
Occup. type	√						
Age		√					√
Gender							
Car availability	√	√					√
Children							√
Income	√	√					
Accessibility				√	√	√	√

RAND EUROPE

51

Less data for stop/go, so specification sparser

Mode-destination (MD) choice models

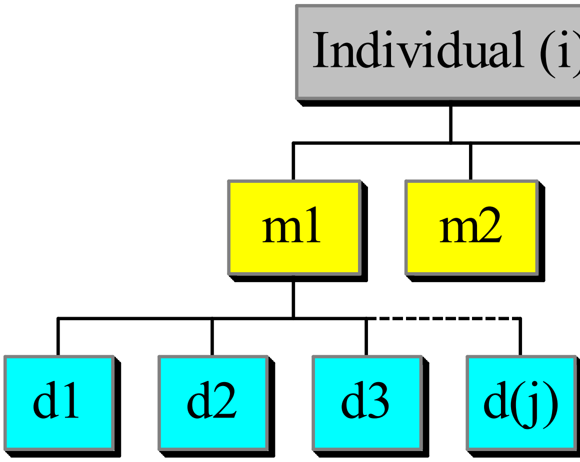
- modelled using tours and detours
- mode alternatives
  - car driver, car passenger, taxi
  - train (and other PT modes), pure bus, plus school bus for education
  - bike, walk
- destination alternatives are 898 model zones
- alternative structures tested to determine the relative sensitivity of the two choices
  - modes above (less sensitive than) destinations
  - destinations above modes
  - for most purposes we found that modes above destinations had a better fit, consistent with European experience, which means that …..

RAND EUROPE

52

Toronto commute results (PhD) in line with US.

MD models – modes over destinations



RAND EUROPE

Key utility components and their impact on policy

Terms	Policy or demographic impact
Cost	infrastructure and pricing policies
Level-of-service	infrastructure and PT management policies
Car availability	reflects increases in licence holding and car ownership
Attraction	land-use policies
Destination constants	land-use policies

RAND EUROPE

54

..now go on to talk through these five utility groups in turn

MD models – cost and level-of-service terms

- cost terms
  - usually some non-linear component, e.g. log of cost, so VOT increases with distance (observed in a number of countries)
  - sensitivities vary by income band for some purposes
  - for car, distance-based costs plus parking
  - for PT, fares taking account of pass ownership
  - for taxi, fare calculated from fare schedule
- level-of-service terms
  - in-vehicle time terms for car (including taxi), rail and bus
  - for PT, access times, wait times, interchanges
  - walk and cycle use uncongested distance skims

MD models – car availability terms

Segment	Cars in HH	Individual licence?	Household licences	Description
1	zero	any	any	No car in HH
2	1+	no	1+	No licence, at least 1 car
3	1+	yes	2+	Competition for car (HH licences > HH cars)
4	1	yes	1	Free car use, 1 car (HH licences ≤ HH cars)
5	2+	yes	2+	Free car use, 2+ cars (HH licences ≤ HH cars)

- car driver is available to segments 3, 4 & 5 and more likely to be chosen by segments 4 & 5 than by segment 3
- car passenger is more likely for segments 2, 3 & 5 as another HH member can offer a lift

RAND EUROPE

56

Key is to condition avail(CD) and P(CD), P(CP)

MD models – socio-economic terms

Terms	Commute	Business	Primary	Secondary	Tertiary	Shopping	Other
Gender	√	√	√	√		√	√
Age	√	√	√			√	√
Income	√			√			
Adult status	√					√	
Occup. type	√						

most terms are mode constants, however some all-mode distance terms are used, e.g. manufacturing distance term in commute to reflect that these trips are shorter on average than non-manufacturing trips

RAND EUROPE

MD models – attraction terms

Terms	Commute	Business	Primary	Secondary	Tertiary	Shopping	Other
Manufact./non-manufact. emp.	√						
Total employment		√					
School enrolments			√	√			
Education employ.					√		
Retail employ.						√	√
Service employ.							√
Population							√

RAND EUROPE

58

Probability choosing a zone proportional to attraction term all other things being equal.
Models singly, not doubly, constrained.
For other, relative contribution of different size terms is outcome from model estimation.

MD models – destination effects

Terms	Commute	Business	Primary	Secondary	Tertiary	Shopping	Other
C.B.D. terms	√	√				√	√
Ring terms			√	√		√	√
Shopping centres						√	
Pop. density						√	√

RAND EUROPE

59

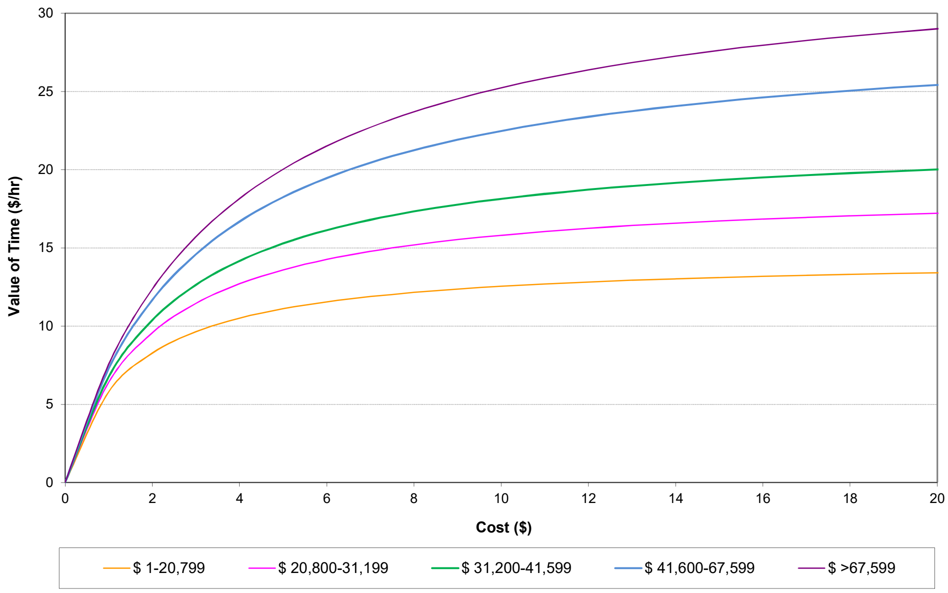
CBD – Central Business District
Rings – inner, middle, outer, interacted with mode-choice

MD models – validation

- validation at estimation stage is a balance between different criteria
  - fit to the observed choices
  - model elasticity
  - implied values-of-time – these vary with distance if cost in non-linear
  - match to observed trip length distributions
  - relative parameter values, e.g. PT out-of-vehicle components
- professional judgement required, informed by local circumstances

RAND EUROPE

MD models – commute values of time

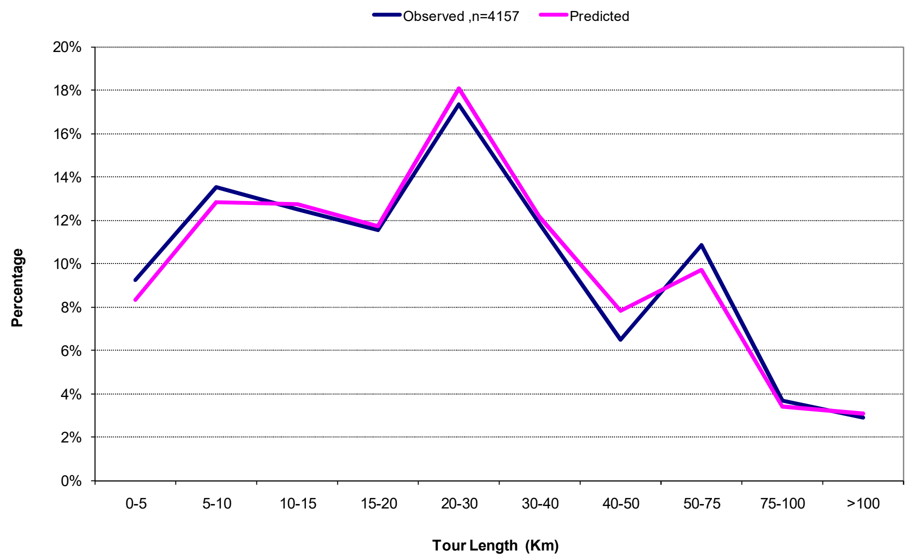


RAND EUROPE

61

For car-driver – from latest model.

MD models – commute car trip lengths

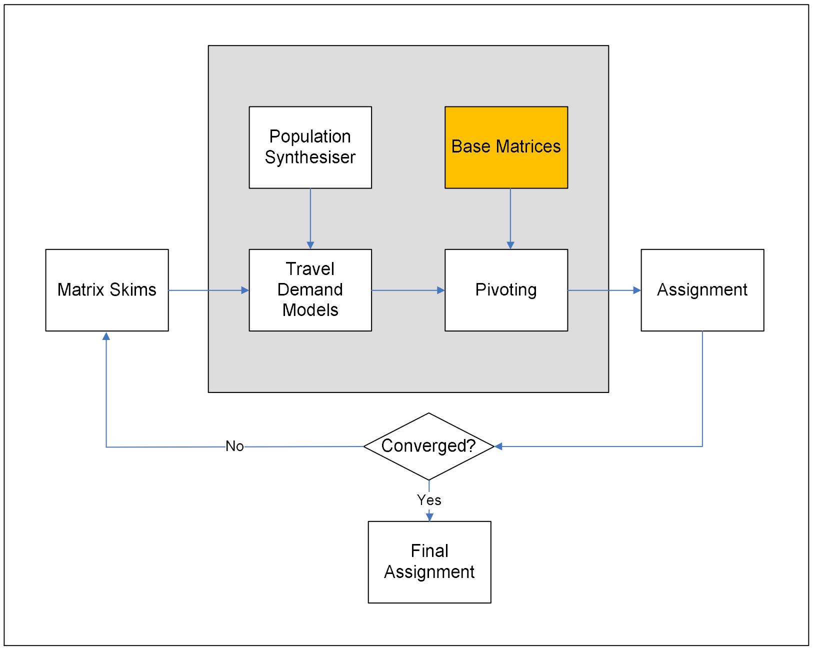


RAND EUROPE

62

For car-driver – from latest model. Note tour length is round trip – out plus return. Fit is good.

The Sydney Strategic Travel Model (STM)



RAND EUROPE

63

Base matrices aim to provide the best description of base year flows

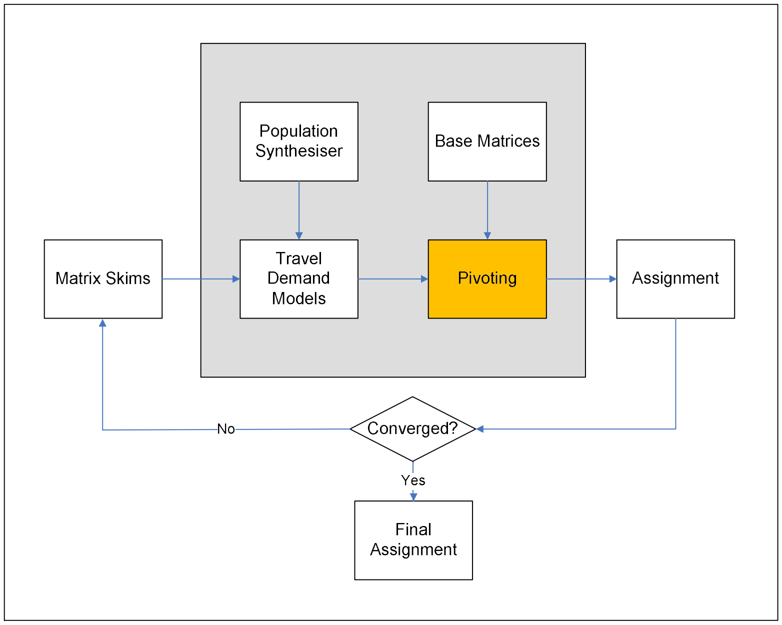
- 'base matrix' information (B) is assembled that provides the best description of base year flows, and is separate to the predictions of the demand model for the base year
  - this approach is typical to UK transport planning
  - in contrast, in the US typically the model predictions for the base year are adjusted to match the sort of information used in the base matrices
- changes relative to the base matrices are then predicted by the 'pivoting' process
- creating good base matrices is key to this process – not the focus of this presentation, but in summary for car and PT modes:
  - for commute, Census Journey to Work matrices used (full sample)
  - for other purposes, expanded Household Travel Survey data used

RAND EUROPE

64

Expect Census JTW to be good quality
HTS data also well regarded but clearly expansion introduces some error

The Sydney Strategic Travel Model (STM)



RAND EUROPE

65

The models are applied to define changes relative to an established base matrix

- pivoting is a technique for combining model forecasts in base and future year (S_b and S_f) with 'base matrix' information (B) that provides the best description of base year flows
- the approach requires good base matrix information, split by mode and time period
- two types of pivoting employed:
  - multiplicative pivoting: $P = (S_f/S_b)\,B$
  - additive pivoting: $P = B + (S_f - S_b)$
- approach that is used in based upon 30 years of practical experience from Dutch National Model onwards
- more detail in Daly, Fox & Patruni (2011) Pivoting in Travel Demand Models, presented at European Transport Conference

RAND EUROPE

66

Explain that multiplicative pivoting is the standard, but additive is used for greenfield cases, and other cases where one of the matrices is zero. Multiplicative pivot gives lower error when error is proportional; additive pivot gives lower error when error is constant across cells.


Model validation, 2004–2005

Validation findings

- overall, Population and Travel Demand models performed well
- however, some areas for improvement were identified
  - company car ownership increased significantly post-2000 due to tax changes – model was recalibrated using post-2000 data
  - while both licence holding and car ownership models validated well overall, both models were unable to fully replicate spatial variation in licence holding and car ownership – a car ownership pivot was subsequently added to address this
  - spatial distribution of students was poorly predicted, with tendency to spread evenly over study area rather than in known student areas – student target subsequently added to model to address this

RAND EUROPE

68

IPF techniques typically used in US just seek best fit to targets

Model development, 2009–present

Summary of model development

- models re-estimated using more recent data, and with more detailed zoning system that covered are larger area
- improvements to model specification made drawing on findings from validation work, client experience and changes in local travel patterns
- new sub-models added to address evolving policy requirements
  - toll road choice model
  - park-and-ride model

RAND EUROPE

More detailed zones give better representation of PT, walk & bike

Improvements to licence and car ownership models

- licence cohort model updated to reflect recent trend for young people to delay licence acquisition
- term added to total car ownership model to reflect lower car ownership around the Central Business District
- terms added to both licence holding and car ownership models to reflect lower ownership levels by migrants (after accounting for socio-economic differences)

RAND EUROPE

More detailed zones give better representation of PT, walk & bike

Toll road choice models

- a number of toll roads opened across Sydney in the 2000s
- option of modelling in highway assignment – problem is 'lumpy' choice depending on whether travellers predicted to choose a tolled route
- therefore modelled as a probabilistic choice in the demand model
  - highway skims generated with and without tolled routes available
  - model predicts choice between two options, taking account of differences in travel time and travel cost
  - results highlighted strong distance relationship, with long-distance travellers much more likely to use toll routes than short-distance travellers

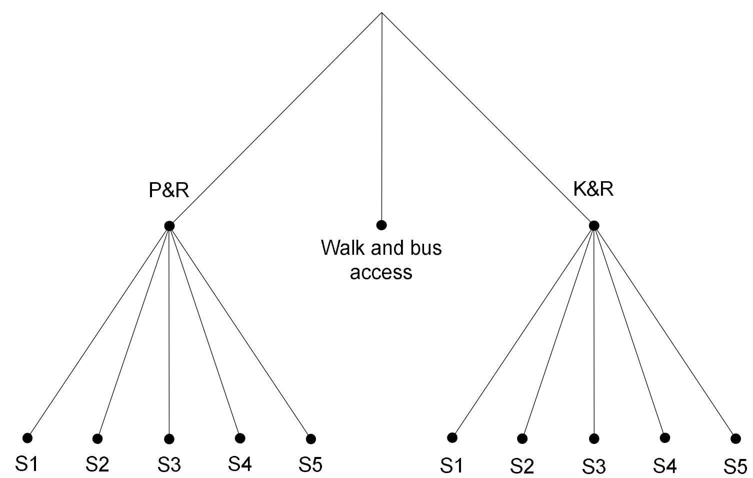
RAND EUROPE

Train access mode & station choice models

- to better represent demand for suburban rail services, where car access is key, and also demand for new lines
- model two linked choices
  - access mode to train: P&R, K&R, and 'other' (walk and/or bus)
  - for car access, choice between 5 possible access stations
- for car access, approach considers level-of-service on both the access and train legs, e.g. choice between
  - nearby station with a stopping service
  - or a more distant service with an express service

RAND EUROPE

Train access mode & station choice models



S1 to S5 identified in a pre-processing step that loops over all possible station alternatives
For walk and bus access, single station option is identified by Emme

Summary

- detailed representation of behaviour, using linked choice models that incorporate a wide range of socio-economic segmentation
- model design was driven by policy makers' needs
- the model has evolved over time, with initial development followed by incremental improvements
  - validation study informed improvements to model design and specification
  - models enhanced to meet new policy requirements, e.g. toll roads
  - models updated using more recent data

RAND EUROPE

RAND EUROPE