WORKSHOP REMIT

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Presentation topic	**Please check the box to identify your topic area:**		
	1. Traffic management		☐
	2. Road and roadside design for safety		☐
	3. Meeting needs of principal road user groups		☐
	4. Integrating transport infrastructure and land-use		☐
	5. The transportation profession		☐
Presentation title	Calibrating trip distributions with Generalised Linear Models		

Presentation Remit

Trip distribution or gravity modelling is one of the four stages of a land use / transportation model. Generalised Linear Models (GLMs) are more flexible than standard transport modelling software for calibrating them from observations. GLMs have been used to study the fit of trip distribution in the Wellington Transport Strategy Model (WTSM) and its data, mainly car commuting and household interviews. GLMs are capable of addressing a wide range of issues in trip distribution with well established statistical methods.

Trip distribution combines the demand from land use, generated by homes and workplaces in each zone, with the supply of transport, described by a matrix of zone-to-zone costs through the network, to give the demand for travel from zone to zone. It depends on the extent to which the costs deter travel, which is calibrated from observation. The UK's VaDMA lists coefficients calibrated from different models, including NZ.

Generalised Linear Models have been in use over 30 years, and are available in many major statistical packages, sometimes as add-ons. They are a development of linear regression, but allow non-Normal errors, in particular the **Poisson** which can represent sampling error, and link functions, in particular the **logarithm** which allows multiplicative forms. GLMs are a broad family that are also used in accident analysis and simple modal split modelling.

GLMs can **simultaneously calibrate**: multiple household segments; separate constants (K factors) and cost coefficients by segment; and joint mode split and distribution. These can all be synthesized by Furness balancing; GLMs can recover the coefficients.

GLMs can fit a wide variety of **deterrence functions**: empirical or user defined, with either conventional steps, or sloped segments; analytical functions – Exponential, Power, Tanner; or polynomials or splines. Some functions like the Log-Normal and Box-Cox are not strictly linear, but may be fitted by non-linear extensions to a Generalised Linear Model packages.

More sophisticated functions than the Exponential do not show any clear improvements in **practical measures of fit**, such as screenline counts or scheme usage or benefits. The dataset is statistically very powerful, and the prime effect of cost deterrence is hugely significant. Sub-sampling showed that calibration on **smaller surveys** is possible, but with a wider spreads of results than estimated in GLMs, and some bias. Other purposes and modes will naturally have smaller samples than journey to work by car.

Marginal significances appear exaggerated, and encourage overfitting. **Statistical significance** can also be exaggerated by including zones with no observed trip ends in the calibration, and by simple averaging of varied expansion factors for weighting. It may also be exaggerated by including both outward and return trips. Data is sparse, so mean residual deviances are less than unity, which would otherwise be expected. Large 't' statistics are not as reliable as changes in deviance for distinguishing major differences, but appear consistent at the margins of significance.

In an Exponential model, separate constants (K factors) and cost coefficients **reproduce observed trips and total travel cost** respectively in the segments to which they apply. This is a property of the calibration method; it does not validate the model.

Generalised cost parameters can be fitted with distributions, in effect determining 'Values of Time' within the calibration. In Wellington, time gave a better fit than distance, but the difference was not great.

GLMs estimate cell accuracies in synthesized matrices; these correspond well with **Whittaker**'s approximation. These accuracies might be used to determine an optimal mix of synthesized and observed matrices for **matrix smoothing**, akin to the Empirical Bayes methods used for accident prediction.

Weighting can minimise the effects of errors in model fitting. Surveys with different sampling rates require different weights, and uneven sampling reduces efficiency. GLMs allow weighting, but weighting schemes need to be developed alongside the design and processing of surveys.

The order of mode split and distribution should be determined by the scale of their respective cost coefficients, otherwise results can be counter-intuitive and elasticities irrational. A minimal model demonstrated these effects, but also showed that they do not always occur when the order is 'wrong', and may only occur for quite extreme values.

Intrazonal costs can affect the fit of trip distributions. The Power deterrence function is much more sensitive to them than the Exponential. The Tanner is slightly more sensitive <than the Exponential>, but estimates travel between zones better than either. In conjunction with the Tanner, the WTSM formula for intrazonal cost (half of minimum external) works as well as any tried.

Advanced forms of GLM allow correlated error structures, like time series. These may help quantify **spatial patterns** beyond those related to travel costs, or fit the correlations between choices of mode found in **nested logit** models. Distribution models can be disaggregated from production zones to households, persons, or trips, where they become equivalent to **disaggregate multinomial logit** models. At the other end of the scale, trip distributions can also be calibrated from aggregate counts, like **matrix estimation**. Cube ME (MVESTM) has a distribution component that has been used for conventional calibration and synthesis in this study.

There are specialised routines for calibrating trip distributions. They are based on **Maximum Likelihood**, like GLMs, so their results should be the same, and the same issues will arise in their statistical fit.

- LOGEST, used in London and Scotland (CSTM3, not the more recent TMfS)
- John Bates' MAXL, used in Wellington
- George Skrobanski's GSLogitcal, used with OmniTrans in Dublin