Transportation modelling for model walking and cycling communities

Angus Bargh and John Kelly

Invited paper

A version of this paper was originally presented at the 2011 Transportation Group Conference of the Institution of Professional Engineers, New Zealand, where it won the NZAA Award for Best Paper. It is published here by permission at the Editor's invitation, with minor edits but without further review, to acknowledge the paper and to bring its subject to the attention of a wider audience. All papers presented at the IPENZ conference are accessible in their original form at www.hardingconsultants.co.nz/ipenz2011/.

Abstract

This paper discusses an innovative approach to the development and application of a multi-modal wide-area transportation simulation model of Hastings and Havelock North, New Zealand, built on behalf of Hastings District Council. This model formed a key element in Hastings District Council's successful bid to become the New Zealand Transport Agency (NZTA) Model Community for walking and cycling, for which they have been awarded $3.5m funding. The analysis undertaken using the simulation model was essential for the economic evaluation of the potential benefits of implementing cycling and walking schemes in and around Hastings. This paper provides a link between the what, how and why of designing a methodology for sustainable integrated land-use transportation modelling.

OVERVIEW

Making walking and cycling a more attractive choice for those who prefer to drive their cars requires a multifaceted approach. For Hastings District Council (HDC) in New Zealand this involves infrastructure improvements on their walking and cycling networks, cycle training programs for school children and organisational specific travel plans – to name just three of their many intended strategies. A primary problem for HDC is how to identify the specific organisations and parts of their active transport network to target first. This paper outlines the development and subsequent innovative application of a transport model which was used to highlight where infrastructure improvements would offer the greatest benefit in promoting real change in favour of active transport use in the Hastings urban area. The adopted methodology is considered to have several innovative aspects within the industry from both a domestic and international perspective. The core components of the innovation include:

- Scale of geographical extent of model coverage within a microsimulation environment (this is considered innovative in a New Zealand context).
- Development of a high level cycle distribution and assignment model to run in parallel with the traffic model (this is considered innovative on an international level).
- Linkage with Census data allowing select link interrogation of a microsimulation model to extract trip length distribution by trip purpose. This in turn provided prioritisation of network improvement schemes for movement by active mode (this is innovative within a microsimulation assignment model environment).

Land-use based four-stage transportation models are a well established part of the integrated transportation planning landscape in New Zealand. The nature and operation of these models have changed little in the 50 or so years since their basic form was conceived. These strategic level models which often cover large geographical regions are calibrated against extensive surveys which often include household travel surveys, driver roadside interviews, and potentially public transport surveys as well as integrating Census data. Furthermore, transport planning in New Zealand is commensurate with current overseas best practice in the application of a tiered modelling approach where the geographically larger strategic four-stage models are used to inform the construction of geographically smaller and more detailed operational transportation models such as micro-simulation models. These operational models are in effect sub-regional or corridor models which provide greater detail at the assignment level (the fourth stage) and also assist in the understanding of network constraints and detailed vehicle interactions.

One point of departure for this project with the existing modelling approach in New Zealand is the application of geographically extensive operational models – particularly with regard to models which delve into the detailed operation of the road network, representing merge, weave, lane utilisation, queue block-back and the type of dynamic assignment characteristics which we are all familiar with as drivers (I'll go *this* way because *that* way was congested yesterday). Our perception of tiered modelling within New Zealand often dismisses operational modelling approaches such as microsimulation on the false premise that their high level of detail precludes them from being able to practically (and cost effectively) represent a large sub-regional area. This represents a departure from overseas current best practice where models such as the UK M25 Widening model, Scotland M8 extension model, Scotland Forth Road Crossing model, Singapore City Centre model and the M30 Madrid model are all examples of large geographic areas being modelled in a detailed simulation environment.

In early 2010 Traffic Design Group completed a modelling commission on behalf of Hastings District Council of their complete urban area. This model was constructed using S-Paramics microsimulation software and was designed to provide 'a reliable, functional and efficient multi-modal modelling platform'…'allowing HDC to plan proactively and effectively for the sustainable growth of Hastings in the immediate and long term future'. The model as a whole was a tiered assignment model which included representation of private vehicle assignment, commercial vehicle assignment, public transport journey reliability modelling, pedestrian crossing opportunity assessment and pedestrian-vehicle interaction assessments in addition to an innovative cycling assignment model.

The model has been used extensively since its commission and was a core part of the bid for the model community award which HDC received from the New Zealand Transport Agency (NZTA) in June 2010. This paper sets out the core components of the model and presents a solid case for the importance of land-use based transportation planning in a tiered modelling environment. The paper highlights the effectiveness of large area microsimulation as an alternative to less-detailed assignment based modelling approaches and points to new and innovative modelling methodologies which seek to incorporate a wider range of transportation modes in the assessment basket.

STUDY OBJECTIVE

The Hastings Urban Area Transportation Study had three primary objectives:

- to determine the functionality of the existing Hastings urban roading network;
- to build a reliable, functional and efficient multi-modal modelling platform; and
- to allow HDC to plan proactively and effectively for the sustainable growth of Hastings in the immediate and long term future.

What was clear from the outset of the study was that no tools were available on the market to fully encompass what HDC wanted to achieve. Their desire for full representation of all modes could only be genuinely achieved through a four-stage model – which in turn was limited by the fact that the regional Heretaunga Plains Transportation Model was, at the time, only a three stage model with the omitted stage being that representing mode choice. HDC, however, required a modelling framework which went beyond simple demand and distribution forecasts of all modes – they wanted the ability to assess the detailed interaction between them. HDC rightly identified that the complexity of transportation planning cannot be simply reduced to a single modelling approach; traditional four-stage models are ideal at assessing present day demand and distribution and in turn forecasting this into the future but they are blunt instruments when it comes to the detailed understanding of the network which so often influences our behaviour as trip makers. At the other end of the scale detailed studies of factors such as urban form and network accessibility do not account for the very prescriptive nature of why we travel.

Extensive scoping work with HDC resulted in identifying the following outline scope for the model methodology.

- That the traffic model be representative of the existing AM and PM peak periods and therefore would be a suitable tool for assessing the effects of proposed network and land-use changes in the Hastings Urban Area.
- That the active mode aspect of the model, in the absence of industry calibration standards, would be:
    a) transparent in its construction and operation;
    b) a suitable basis for further refinements in the future as other surveys are undertaken, technologies developed and updates are made to the higher tier strategic model; and
    c) capable of providing a sensible interaction 'response' between modes – when there is an increase in the activity of one particular mode there is a logical and proportional effect on other modes. For example, if car use increases then bus journey-times would lengthen due to increased congestion on the roads or if pedestrian activity increases then car journey time would increase, due to increased pedestrian stages called at traffic signals.
- That the model would be used to identify deficiencies in the existing roading network.

The first of these points meant that whatever model was developed it was important to retain a link to the existing regional land-use transport model, the Heretaunga Plains Transportation Model (HPTM), and to ensure the model could be updated to match any proposed future updates of the HPTM. This was considered the overarching priority for the study as without this link the relationship between land-use and travel behaviour would be lost, which would limit the applications of the model.

THE MODEL

The resultant Hastings Area Transportation (HAT) model was constructed in the following form:

- An S-Paramics microsimulation model of the whole Hastings urban area which represented the following AM and PM peak periods:
- AM peak period: 7.30am – 9.30am
- PM peak period: 4.00pm – 6.00pm
- The network extent of this model is shown in *Figure 1*.
- The model simulated the behaviour of circa 60 000 vehicles in the AM peak period and circa 80 000 vehicles in the PM peak period.
- The model had a zoning system which is consistent with the Heretanga Plains Transportation Model and therefore capable of reflecting land-use driven changes in travel distributions.
- Separate assignment classes for private vehicles and heavy commercial vehicles;
- Fixed route bus service assignment with stop locations and a passenger loading model defined;
- Pedestrian sub-model where dynamic pedestrian demand is represented at signalised and non-signalised (zebra) crossing points. The pedestrian model also provides indices of crossing opportunities at informal crossing locations as a post-processed analytical method.
- Detailed cycle distribution and assignment model.

The microsimulation model was calibrated to surveyed turn count movements, queue length surveys and most notably to calibration criteria presented in the UK Design Manual for Roads and Bridges (DMRB) (Department for Transport 2009) which far exceeds the requirements of NZTA's Economic Evaluation Manual. Therefore, this model not only presents a detailed picture of the peak hour traffic on the road network but does this with an extremely detailed level of calibration. Rather than viewing the geographical extent of such a large microsimulation model as a barrier to higher levels of calibration, it has become common experience amongst practitioners that the very detailed level of microsimulation allows for nuances which influence behaviour (and in turn lead to better calibration) to be teased out throughout the study. This challenges the general retort that microsimulation cannot be used for large areas, is too data hungry and is more expensive. The HAT model was developed in a similar time frame and a similar budget to traditional wide area assignment models using the same level of data input.

Cycle model

The cycle model was developed to provide both distribution and assignment assessment capabilities. While not being a 'true' demand model (in that it lacks the ability to forecast demand without an associated private vehicle demand matrix) it does provide a proxy demand methodology which is partially calibrated to observed cycle counts.

The distribution function for the cycle model is based on a combination of a cycle probability density function (gamma function) described by the Federal Highways Administration (Harkey et al. 1998) and the *a priori* distribution of the vehicle demand matrix. The basic form of the density function is shown in *Figure 2*.

This allowed for the production of a cycle demand matrix which could then be assigned to the network. The assignment aspect of the HAT cycle model utilised a geodatabase to provide an indication of the relative attractiveness (or deterrence) of each route through the Hastings road network from the perspective of a cyclist. The 'bicycle compatibility index', BCI, (Harkey et al. 1998) was used to provide these link cost factors using *Equation 1*.

$$BCI = C + a1*BL + a2*BLW + a3*CLW + a4*CLV + a5*OLV + a6*SPD + a7*PKG + a8*AREA + AF \quad (1)$$

where:

BL = Presence of a bicycle lane or paved shoulder (No = 0, Yes = 1)

BLW = Bicycle lane or paved shoulder width (metres)

CLW = Curb lane width (metres)

CLV = Curb lane volume (hourly)

OLV = Other lane volume (hourly)

SPD = 85th percentile speed of traffic

C = Constant

PKG = Presence of a parking lane with more than 30% occupancy (No = 0, Yes = 1)

AREA = Presence of residential roadside development (Yes = 1, No = 0)

AF = ft+fp+fn

ft = Adjustment factor for truck volumes

fp = Adjustment factor for parking turnover

fn = Adjustment factor for right turn volumes

and:

C = 3.67

a1 = −0.966

a2 = −0.125

a3 = −0.152

a4 = 0.002

a5 = 0.0004

a6 = 0.035

a7 = 0.506

a8 = −0.264

S-Paramics was used to assign the cycle matrix to the network. This allowed the link cost factors from *Equation 1* to be included in the route choice calculation within the microsimulation model. Cycle speeds were limited to 20 km/h and cycle link counts were used to calibrate the assignment aspect of the model. Although there was no specific validation of the cycle model undertaken, extensive sensitivity testing demonstrated the bicycle model was responsive and produced anticipated outputs. For example, the addition of a cycle lane on a road would lead to an increase in the number of cyclists on that road. An output from one of these tests is shown in *Figure 3*.

Model communities award

In early 2010 NZTA announced $7m funding was to be awarded under a competitive process between Local Councils to define a framework to become New Zealand's first walking and cycling model community. Of the 22 Councils who submitted expressions of interest, four were shortlisted (Hastings, New Plymouth, Nelson and Taupo) and eventually Hastings and New Plymouth shared the award.

At the heart of HDC's vision for their active modes network was the linkage between their four main activity centres of Hastings, Flaxmere, Havelock North and Whakatu. Along these links HDC wanted

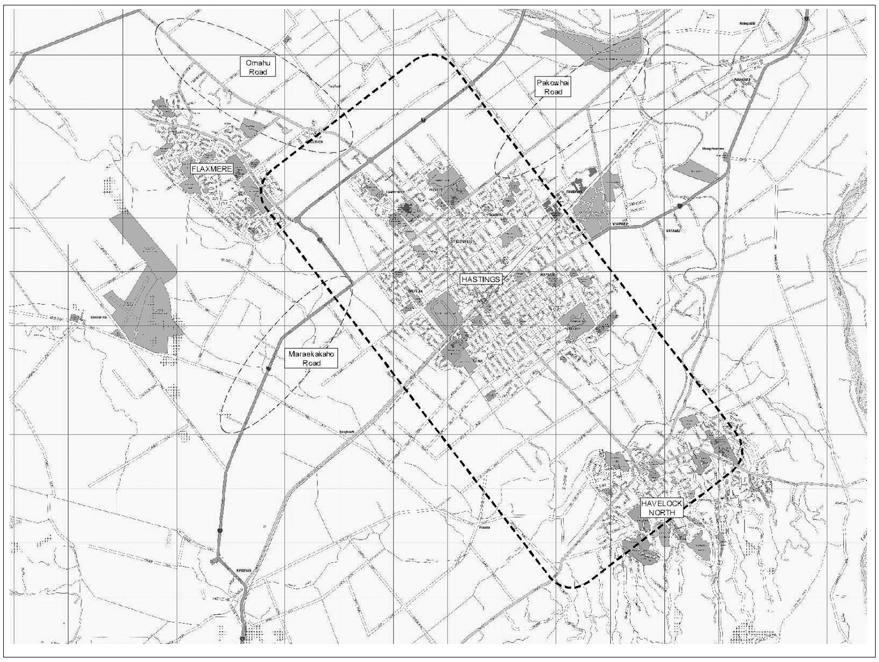

Figure 1
Geographic extent of HAT model

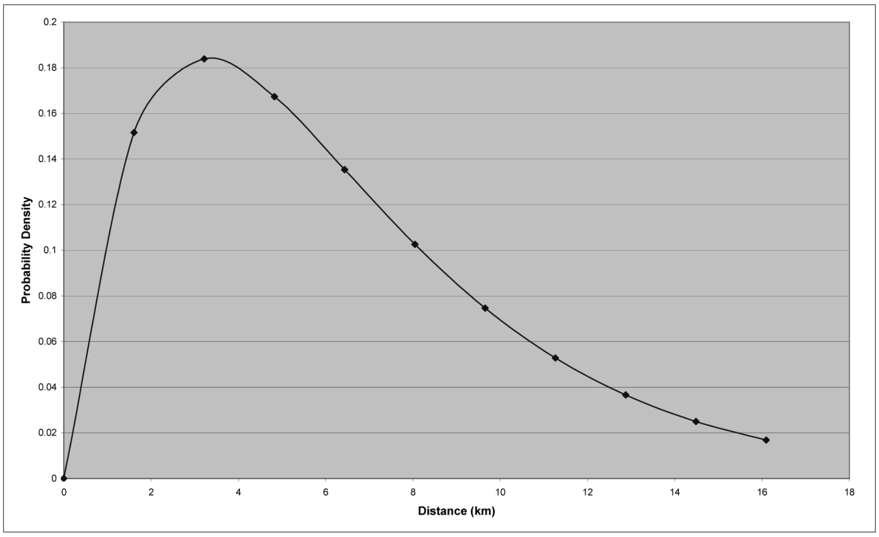

Figure 2
Cycle probability density function (distribution)

to specifically target four main groups. These were those who potentially could walk and cycle:

- to work;
- for fun;
- to shop; and
- to school.

HDC requested that the HAT model be used to determine the nature and scope of how the NZTA funding could be most effectively spent and the impact it would have on their transportation network. The initial challenge for HDC was to determine who were the people that needed to be convinced to give up their car keys and either walk or cycle.

The HAT model was interrogated by undertaking a select link analysis of the primary routes of interest to HDC. The specific origins and destinations of each vehicle on these links was extracted from the HAT model which, coupled with Census land-use data, was used to estimate trip purpose. The trip length distribution of vehicles along each of the selected links was also extracted. This analysis allowed for the identification of two items of crucial importance when planning improvements to the active mode network. The first was an estimate of the proportion of drivers currently using these strategic links who are completing journeys within a range that could be readily replaced by a cycling or walking trip (typically 1–3 km for walking and 2–7 km for cycling). The second was an indication

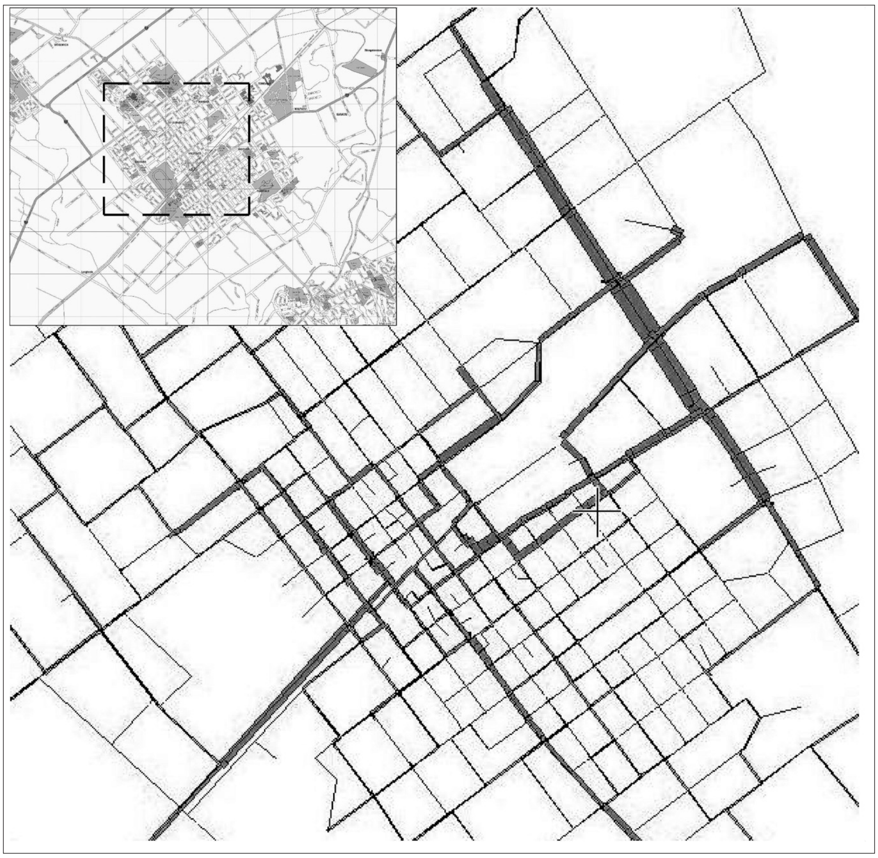

Figure 3
Cycle volume link plot forecast based on network improvement program

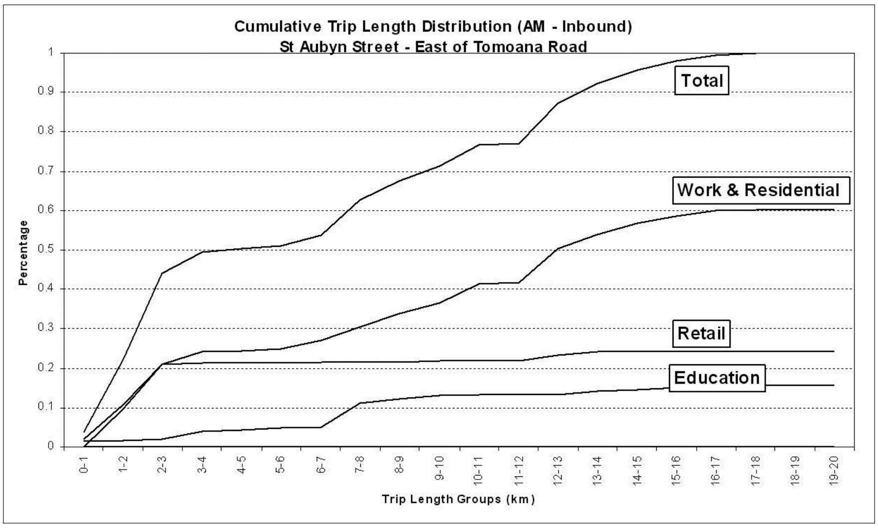

Figure 4
Trip length distribution by trip purpose – St Aubyn Street

of trip purpose within each of these 'catchment ranges'. This was crucial to HDC as it would allow for targeted, land-use specific travel plan strategies to be levied on individual organisations.

Figure 4 shows the trip length distribution by trip purpose for St Aubyn Street in the centre of the Hastings CBD. This graph shows that approximately 60% of the vehicles along St Aubyn Street in the PM peak are journeys to and from work of which approximately half are less than 7 km in length. In total nearly 70% of all journeys which route along St Aubyn Street are less than 7 km in length. HDC intend that by improving pedestrian and cycling facilities along St Aubyn Street and by placing organisation specific travel plan targets (to get people to move from cars to walking or cycling) within a geographical catchment identified by the HAT analysis, the people driving along this route will embrace a significant shift towards sustainable modes of travel.

Similar analyses were undertaken for several other key routes in and around Hastings and these routes are now the subject of infrastructure upgrade programs, utilising the NZTA funding.

CONCLUSION

The Hastings Area Transportation (HAT) model has been used to effectively demonstrate that there is a place for large area microsimulation modelling within the New Zealand transportation planning landscape. This is particularly true when it is coupled with a tiered modelling hierarchy which includes a strategic four-stage land-use driven model.

The integration of microsimulation with other innovative sub-models, including pedestrian models and in particular with cycling distribution and assignment models, presents unprecedented opportunity to determine both the impact and staging of proposed network improvements. Unfortunately, with active mode transport the mantra 'build it and they will come' does not always hold true. Therefore, New Zealand's commitment to integrated transport planning should continue by following an integrated modelling approach which cascades from a land-use transportation model. This ensures that the need (distribution), desire (demand) and execution (mode choice and assignment) of travel by all modes can be adequately assessed.

REFERENCES

Harkey, DL Reinfurt, DW Knuiman, M, Stewart JR and Sorton, A 1998, *Development of the Bicycle Compatibility Index: A Level of Service Concept, Final Report*, Report No. FHWA-RD-98-072, Federal Highway Administration, Washington, DC, August 1998, by the Highway Safety Research Center at the University of North Carolina, viewed 22 July 2011 at <www.hsrc.unc.edu/research/pedbike/98072/techrep/techrep.html>.

Department for Transport (UK) 2009, *Design Manual for Roads and Bridges, Volume 12 Section 2 part 1 – Traffic Appraisal in Urban Areas*, Chapter 4, Traffic Model Development, pp. 4-29..

Angus Bargh

Angus is a Principal Transportation Planner at Traffic Design Group, Christchurch, New Zealand. Angus holds a BSc in Physics from the University of Durham, UK and a MSc in Remote Sensing and Image Processing from the University of Edinburgh. Angus is a Member of the Institution of Professional Engineers New Zealand (MIPENZ), is an International Professional Engineer (IntPE) and a Chartered Professional Engineer (CPEng). Angus is currently Vice Chairman of the New Zealand Modelling User Group (NZMUGs) – which represents the interests of the transportation modelling industry in NZ. Angus is also a member of the Sustainability Society – a technical interest group of IPENZ. Angus has a particular interest in active mode transportation planning and the use of spatial modelling tools to engineer real-world change on our transport networks. Angus has 17 years professional experience including 8 years in transportation. He was formerly employed by SIAS, the developers of S-Paramics microsimulation.

John Kelly

John is a Senior Transportation Engineer for Traffic Design Group, Christchurch, New Zealand's largest specialist transportation consultancy. John holds a Bachelor of Engineering degree from University College Dublin, Ireland. He is a Graduate Member of the Institution of Professional Engineers New Zealand (GIPENZ) and a member of Engineers Ireland (MIEI). John has over 9 years experience working as a transportation engineer in Ireland and New Zealand. John has been developing S-Paramics microsimulation transportation models for the last 6 years. During this time he has gained extensive experience in all aspects of the model development process.

CONTACT

Angus Bargh
Traffic Design Group, Christchurch
angus.bargh@tdg.co.nz

ACKNOWLEDGEMENTS AND DISCLAIMER

We would like to acknowledge Hastings District Council and in particular the Transport Asset Management Team for their assistance and permission to publish this paper. Where the content of this paper expresses an opinion it is solely that of the authors unless otherwise stated.