THE WAIKATO REGIONAL TRANSPORTATION MODEL

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Abstract

The Waikato Regional Transportation Model was completed in February 2010, and is the first model in the country to attempt to include large urban and rural areas. The development of the model has been described as '..a major success story that positions the region well for future transport planning…'. The paper describes the unique organisational structure adopted by the client organisations, and gives an overview of the technical form of the models, highlighting the methodology adopted, including data collection, model calibration and validation. It details some of the issues that were faced during the build process, and discusses the ways in which problems that arose were overcome.

1. INTRODUCTION

1.1 History of Modelling in the Waikato Region

There has been a long history of modelling in the Waikato, beginning with the first transportation study of Hamilton in 1968. It was undertaken in an era of rapid urban expansion and development, and was prior to a period of economic downturn, the slowing of population growth, and the fuel crises of the 1970's. It envisaged a population of 133,000 by 1988, and recommended a transportation system commensurate with that population.

The Hamilton Transportation Review Study began in 1975 to review the earlier study. There was a more modest growth expectation of 104,000 population by about 1991, and 124,000 by 2001. Initially the analysis was undertaken by the then Roading Division of the Ministry of Works and Development. Later in the study (in 1979) the analysis and final reporting was undertaken by Gabites Alington and Edmondson, with Beca Carter Hollings and Ferner, and the NZ Institute of Economic Research responsible for the associated Public Transport studies. The final report was published in July 1981, and set the framework for the transport system that was largely in place by 2006.

From 1981 Hamilton City Council continued to use increasingly sophisticated modelling techniques as the technology changed. The all day models of the 1981 study gave way to morning, Interpeak and evening peak models, and the simple link based assignment techniques were converted initially to include simple intersection delay models, and later to use full intersection modelling within the assignment process.

In the wider region since the 1980's, a number of other transportation studies were undertaken, each using a variety of modelling techniques. Urban models were developed in Tauranga[1], Rotorua, Taupo, and Pukekohe, Cambridge and Te Awamutu[2]. A coarse regional assignment model was also developed.[3]

The last data collection exercise in Hamilton was the 1967 surveys from which the original model was built, and which was re-analysed when the 1981 review study model was built. That data was lost during the local authority and governmental reforms of the late 1980's, and all of the models validated after that essentially relied on either the old calibrated parameters, or on relationships imported from other studies.

1.2 The 2006 Scoping Study

This range of different models, operated by different Local authorities on different software platforms, and built from historic, or imported data gave rise to a view that a more consistent and comprehensive approach was required. Accordingly, a scoping study was commissioned in 2006 to undertake a review of the existing models in the Waikato Region, and to scope options for updating the model. In the event the review only looked at the Regional model and the Hamilton City models.

[1] Initially by Traffic Design Group, and later by Beca using Cube
[2] These five models were developed by Gabites Porter using Tracks
[3] An assignment model developed by Opus using Saturn

That study essentially recommended building a new model covering the whole of the Waikato Region, the collection of recent and robust data from which the causal relationships could be calibrated, and a model management structure that would ensure that there would be long term benefits for the model 'owners'.

While generically there was little that was new in this approach, the way in which the report was implemented has resulted in a technical model, and a model management structure that is unique in New Zealand.

2. OVERVIEW OF THE PROJECT

2.1 Objectives

The basic requirement of the project was to build a new Waikato Regional Transport Model that:

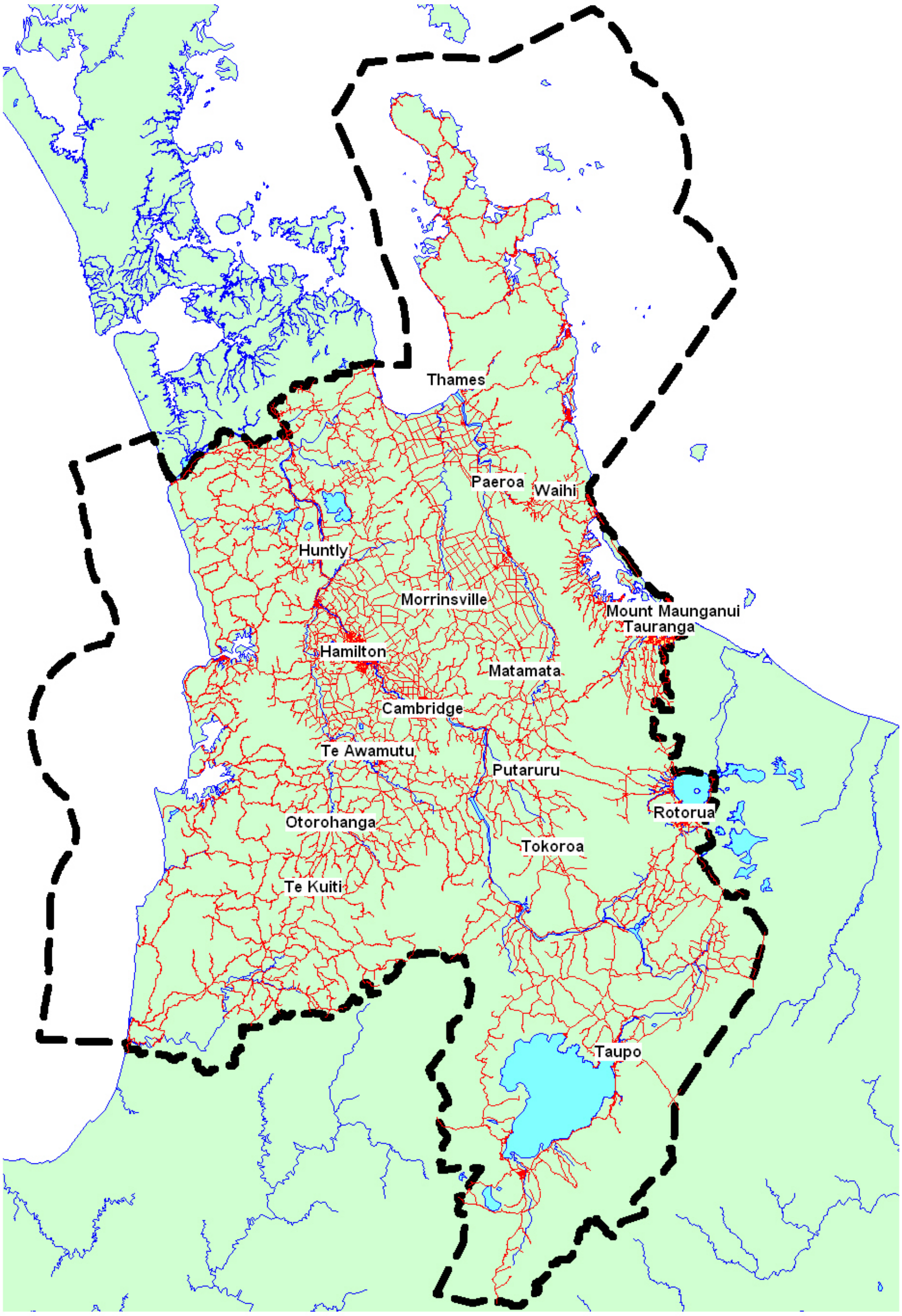
1. Provides a single model for use by project partners and 3rd parties within the Waikato Region.
2. Replaces a number of existing models including those for Hamilton City, NZ Transport Agency, Waikato District, Environment Waikato and Waipa District
3. Enables network level, inter-modal and project level evaluations to be undertaken to meet the legislative requirements of the LTMA and the RMA.

Accordingly, in addition to forecasting travel demands based on changes in land use, household structures and car ownership for planning future transport infrastructure and services, the model was developed to enable roading and public transport proposals to be analysed, and changes in transport policies, including travel demand management measures, to be evaluated.

2.2 Geographic Coverage

The geographic area covered by the model is shown on Figure 1, and extends from the Bombay Hills in the north, to Taupo in the south, and includes Rotorua and Tauranga to the east. While Rotorua, Tauranga and Taupo are included, the detail within these areas is reasonably coarse, and the model provides the 'boundary conditions' to feed the existing models of these three urban areas.

Apart from a couple of nationally oriented models some years ago, this is the first time in New Zealand that a detailed model including both a major urban area and an extensive rural area had been built. There was a degree of unease at the outset as to whether the approach would work, but in the event, there was insufficient difference in the travel patterns of urban and rural dwellers for separate models to be required.



Waikato Regional Transportation Model	**Waikato Regional Model Boundary**	**Figure 1**
Gabites Porter Consultants Traffic Design Group		

3. PROJECT MANAGEMENT

3.1 The WRTM as a Shared Service

The thirteen Councils of the Waikato Region have formed a limited liability company – Local Authority Shared Services Ltd with the purpose of providing a variety of shared services where the majority of Councils in the region will benefit. There are a number of services established under the LASS framework including the WRTM. Each service established has a variety of individual Council shareholders, and the WRTM shareholding includes:

Waikato Regional Council (Environment Waikato)
Hamilton City Council
Thames Coromandel District Council
Waipa District Council
Matamata Piako District Council
Taupo District Council
Waikato District Council

The shared service also includes NZ Transport Agency (by way of a term service agreement) as a significant contributor to transport outcomes in the Waikato Region.

The formalized shared service framework is a particularly innovative feature of the WRTM project. In this situation the LASS has acted as the client for the model build and subsequent maintenance and management of the model, with each individual Council able to use the model for its own purposes.

The advantages of using a shared service approach for the Waikato project partners are:

- Retention of intellectual property. The WRTM is owned and operated by LASS with Gabites Porter as the model build and operations contractor. Intellectual property created is held solely by LASS for use by project partners.
- Collaboration on land use and network investment decisions. The building and maintenance of a significant strategic model has required project partners to collaborate on land use and network investment decisions. The shared investment in the model has promoted this collaboration, which has flowed into programmes of work such as the Regional Policy Statement review and the Regional Land Transport Strategy.
- Sharing of modeling outputs. The project partners have agreed to share not only the modeling resources, but also the model outputs. Previous barriers around different model results, model ownership and differing consultant advice have largely been removed from discussions amongst project partners.
- Financial cost savings and cost recovery. The capital cost of building and maintaining the WRTM has been apportioned across eight separate funding partners, each with their own shareholding in the service. The cost saving provided to each project partner has been considerable. For example, Waipa District Council has secured a full 4 step model that considers every route on their network for $100k. The forecast maintenance and management cost of the WRTM for the 2010/11 financial year is similar to the level anticipated for a single model provided for one Council, however this cost is now shared by all project partners.

- Administrative efficiency. Figures two and three provide an illustration of the management changes since 2007 when the WRTM was first tendered. The project partners have transitioned from five models run by two consultants with a project manager within each Council to a point where a single entity (LASS) contracts one agreed modeling platform and employs one project manager to support all eight project partners.

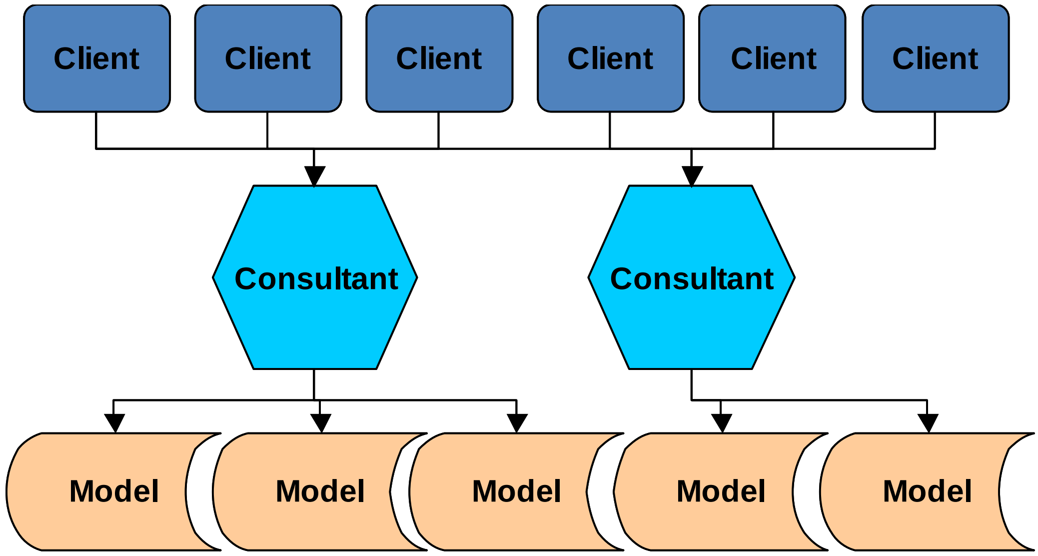


Figure Two: Model Management Structure Pre-WRTM

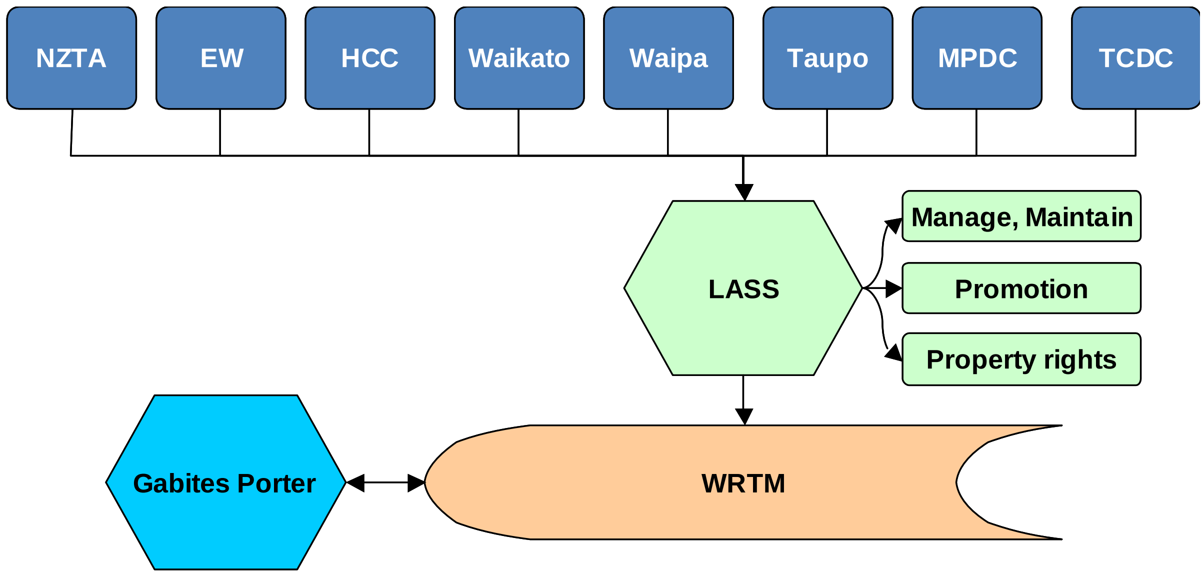


Figure Three: Model Management Structure for WRTM

To assist with the collaborative effort amongst project partners, two groups were formed to guide the model build, maintenance and management efforts:

- The Project Control Group (PCG) provides the main governance function, and is the means by which the project partners exercise control over the scope, budgets and timeframes.
- The Technical working Group (TWG) provides the intellectual leadership and 'local' understanding of technical aspects such as model details, implementation, network and project testing and survey requirements.

Supplementing the TWG was a peer reviewer who took oversight of the detail of the model, and signed off each stage of the build process. The peer reviewer was brought in early in the study and assisted with development of the Request for Tender (RFT), and appointment of the Consultants.

3.2 The Procurement Process

In July 2007, LASS issued a (RFT) for a model supplier to *'…develop a robust Transportation model that the project partners can have confidence in for a wide range of land use and planning issues, and then operate the model on behalf of the project partners providing expert opinions in an unbiased manner'*[4]

The 'target price' tender closed in August, and Gabites Porter Consultants in conjunction with Traffic Design Group were commissioned in October 2007 following evaluation of five tenders. The specific tasks listed as part of the contract were

- Contract management
- Model design and specification
- Data collection - survey design and management
- Development of model components and inputs
- Model Calibration
- Model Validation
- Model Implementation and forecasting
- Model Reporting

The model build component was expected to take 18 months, followed by a three to five year model operation contract. In the event, for reasons which will be discussed later, the completed model was signed off in January 2010.

[4] Excerpt from the RFT

4. GENERAL MODEL FORM

4.1 Model Structure Envisaged by the RFT

The general method described in the RFT comprised a hierarchical approach to modelling with a region wide strategic demand model which contains the Hamilton, Rotorua, Taupo and Tauranga areas at a coarse level, so that there is consistent precision over the whole region. The greater Hamilton area was also to be modelled as a sub-area with very much greater detail, including public transport, travel demand management (TDM) and the option of a parking model. The existing models of Rotorua, Taupo, and Tauranga would remain unchanged, except that flows by trip purpose at the boundaries would interface with the higher level regional model.

It is important to appreciate that the output of this study was intended to be a single modelling tool consisting of integrated models of the Region and Hamilton City, but with the urban areas being modelled at two different levels of detail. The time periods, road network, land use activity would be common to both levels, and the interface between them seamless.

The higher level model was to be a vehicle driver model only, (a three step model) while the Hamilton model was to include public transport (a four step model). Both were to be built using generalised cost so that TDM initiatives (such as tolling) can be tested.

4.2 The Resultant Model Structure

However, the conceptual approach to the model changed radically once the Household Interview Survey (HIS) data became available, and showed there was little significant difference between the trip rates within the Hamilton model area and the wider region. As a result, there was no need to continue with a separate, more detailed model of Hamilton to be windowed from the full regional model. Instead the necessary detail was included within Hamilton; meaning only one model was required.

Accordingly, there were two models built covering the whole of the Region. Both have the same network and zone structure, but there is a now a three step (vehicle driver) model and a four step model that incorporates public transport where it exists, and a mode choice step that separates out car drivers, car passengers, public transport and walk and cycle. The model flow chart for the four step model is shown on Figure 4.

5. DATA COLLECTION AND ANALYSIS

5.1 Surveys

One of the key strengths of the model is the data on which it is based. In this project, two major data collection exercises were undertaken – namely a Household Interview Survey (HIS) from which to calibrate the generation, distribution and mode split step of the models, and a Roadside Interview Survey (RSI) to calibrate the external components of the model, enable checking and adjustment of any under-reporting of the household interview survey, and to assist with validation

In addition to these two major surveys, there was also a Bus Passenger Intercept Survey and a series of journey time surveys.

The specification for the data collection contracts was contained in the 'Survey Specification Report' drafted in January 2008 and finalised in June 2008. There are also survey reports for each of the specific surveys.

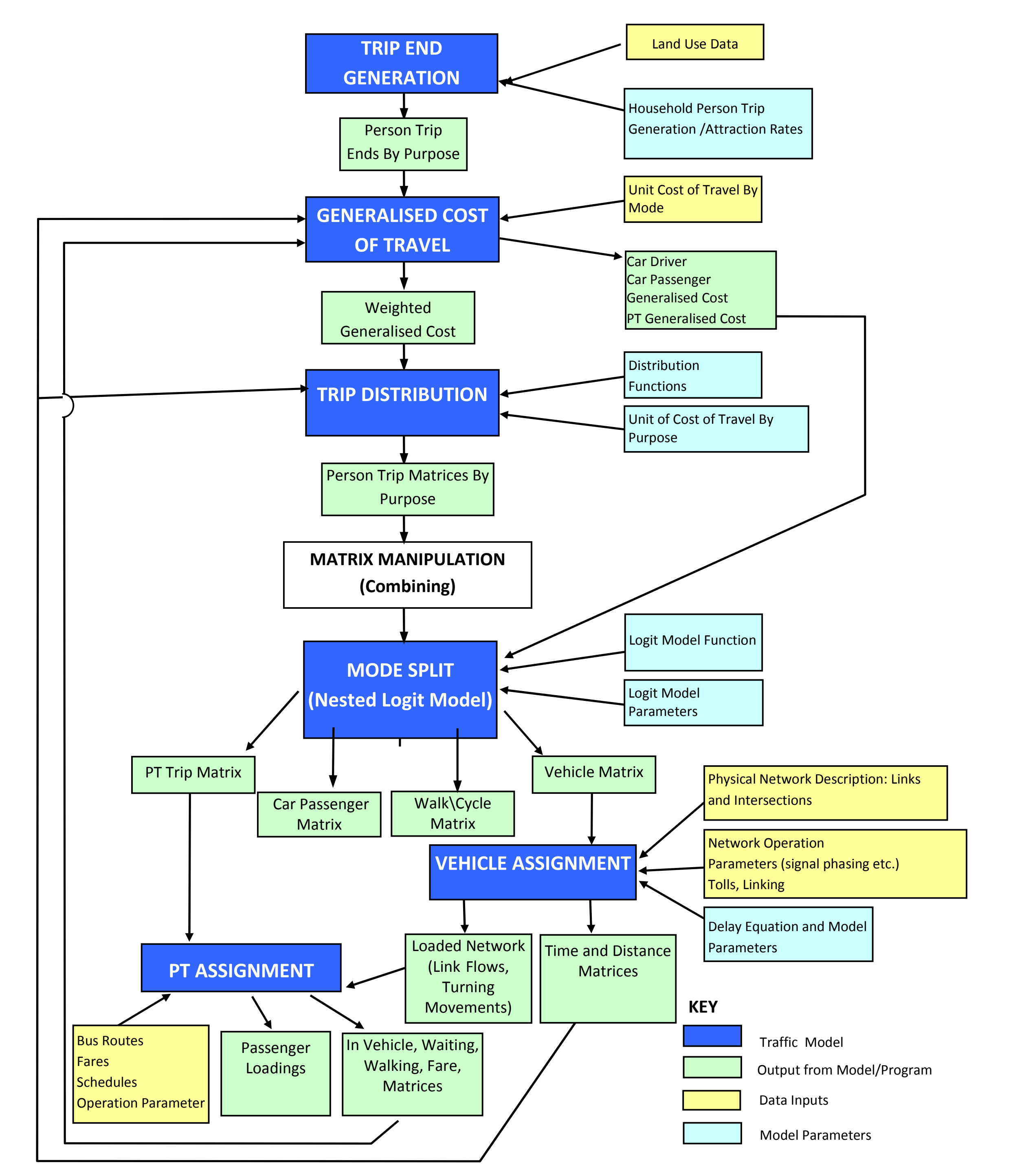
In summary, however, the HIS covered just over 2000 households, of which 1074 were in the Greater Hamilton area, and the 938 were in the wider region. The sample achieved was a little under 1.4% over the region – 1.5% in Hamilton and 1.2% over the balance of the region. It included some 20,000 daily person trips representing an expanded total of a little over 1.6 million trips per day. Data was collected for both weekday and Saturday travel, although the Saturday data has not yet been analysed.

The HIS data was collected using face to face interviewers with laptop computers. These wre loaded with custom written software, and interviewee responses entered as they were given and the software performed the range and logic tests on the data as it was entered. This process went a long way to ensuring the integrity of the data, and was largely instrumental in removing the need for a correction for under-reporting that was evident in the recent Auckland and Christchurch HIS surveys.

Procurement of a contracter to carry out the HIS was difficult. The first attempt in January of 2008 elicted no tenders. On the second attempt, one tender from Opus International consultants was accepted, and surveying began in July 2008. The final data was delivered in late January 2009, and the model was delivered a year later in January 2010. The delay in the delivery of the model was almost entirely due to the delays in appointing Opus.

The Roadside Interview Surveys covered 18 sites in one direction only. Thirteen of these were at or near the boundary of the model area, inbound into the Region. The Waikato River is a natural screenline, and five sites were set up on the bridges, for traffic travelleing twoard the CBD.These sites were supplemented by surveys that had been carried out by the Auckland Regional Council for the ART3 model build, and by Tauranga City Council for the Tauranga model build.

Conventional survey techniques (stopping drivers and questioning them) were used for all of the sites except for the river screenline where setting up physical interview stations would have caused major traffic disruption. On these stations, videos were taken of vehicle number plates, and using character recognition software, the numbers were identified and driver addresses obtained. A 'mail back' interview form was posted to all drivers and some 41% of all forms were returned – an unusually high response rate. The river screenline data was important for checking that there was no significant under-reporting.



Waikato Regional Transportation Model	**Four Step Model Components**	**Figure 4**
Gabites Porter Consultants Traffic Design Group		

5.2 Household Survey Data Expansion

Following delivery of the Household Interview Survey data, this sample needed to be expanded to match the region 'population'. Five expansion factors were required Including

- A geographic expansion factor calculated separately for Rural and Urban Households
- A factor to adjust for household type to match Census data totals
- A factor to adjust for total population to match Census data totals
- A factor to adjust for car ownership to match Census data totals
- A factor to convert from the survey day to an average March weekday

Although the model represents traffic conditions for an average weekday, the evaluation of options requires conversion to Annual Average Daily Traffic (AADT), and then conversion of that to yearly figures.

Once these factors were applied, the following statistics were derived from the 147,100 households in the HIS survey area.

Trips by Mode		Table 1
Vehicle Driver	989,607	60.8%
Vehicle Passenger	397,398	24.4%
Bus Passenger	18,221	1.1%
School Bus Passenger	30,442	1.9%
Bicycle	26,501	1.6%
Walk	156,877	9.6%
Other	7,443	0.5%
Total	***1,626,489***	***100%***

This produces 11.06 person trips per household.

In order to check the level of under-reporting, (if any) the 24 hour trip matrix extracted from the HIS was compared against the manual classified counts taken at each of RIS stations. Only light vehicles were compared. At the inner cordon (around Hamilton), the comparisons were 98% inbound and 100% outbound. At the outer cordon, the comparison were 87% outbound and 92% inbound, but these stations are likely to be affected by externally generated trips which of course are not included in the HIS data. From these figures, there was no basis on which to apply a further factor to correct for under-reporting.

6. SPECIFIC COMPONENTS OF THE MODEL

6.1 Zone detail

As noted earlier, initially, the concept was to have two models, with one at a relatively coarse zonal level over the whole area, and the second with a more detailed model of the greater Hamilton area.

That concept changed radically once the HIS data became available, and there was no need to continue with a separate, more detailed model of Hamilton to be windowed from the full regional model. Instead the necessary detail was included within Hamilton, meaning only one model was required. As more experience was gained in running the model, detail also was also added in Tauranga, Rotorua, Taupo, and the smaller towns of Tokoroa, Putaruru and Matamata.

Precision levels

A report by Foster (1994) prepared for Auckland City Council defined three levels of precision for models arising from the way in which intersections were treated during assignment. These were:

- *Level 1 – The traditional level of precision whereby network supply functions occur on the links or partly on the links and at the intersection as a whole*
- *Level 2 – Intersection delays are calculated on each approach to the intersection*
- *Level 3 – When delays occurring on the network are calculated lane by lane on the links and according to each turn at the intersections.*

It went on to say:

> *The principles of consistency and uniformity in model formation require the general level of activity in terms of the number of trips generated and attracted at each traffic zone to be similar and at a precision level consistent with the remainder of the model.*

and

> *It is necessary that both the present and any future set of traffic zones contain the same level of activity according to the precision levels detailed below*
> - *Level 1 – 1000 equivalent households*
> - *Level 2 – 400 equivalent households*
> - *Level 3 – 250 equivalent households.*

In the almost twenty years since those comments were made, technology has moved on significantly, with levels 2 and 3 virtually becoming coincident in terms of intersection modelling during the assignment process

Zone Definitions

The Waikato model was built to about level 2 for the rural areas and finer than level 3 for the urban areas, but as discussed later; the assignment includes full intersection modelling over the whole model.

There are currently 702 zones in the model with 484 in the Hamilton urban model and the balance in the rest of the region.

6.2 Time Periods

The models have common time periods of 0700-0900, 1100-1300, and 1600-1800 for generation, distribution and mode split (where applicable). Network validation was undertaken against two hour flows.

All day (24 hour) flows were derived by factoring the three period assignments and these were also compared against 24 hour flows during validation.

6.3 Trip End Generation – Category Derivation

Conventional practice in New Zealand has been the use of a household category model for trip generation, usually as a cross classification of the number of people in the household against car ownership. The more recent urban models (outside of Wellington, Auckland, Christchurch and Tauranga) have had 5 persons categories (1,2,3,4,5+) against 4 car ownership (0,1,2,3+) giving 20 categories in all. The three step models have category trip rates calibrated for vehicle driver trips, and the four step model total person trips by all modes.

While this model form has performed well and has been relatively easy to calibrate, and to use in forecasting mode, it does not necessarily reflect the aging population, and changing social structure that has occurred and is continuing to do so. A third cross classification was initially proposed such as to separate household with and without children.

In the event, this classification was difficult to calibrate, and a slightly different approach was taken with the finally adopted categories shown below

Households without children	**Households with Children**
One Adult working	Two Persons
One adult not working	Three Persons
Two Adults working	Four Persons
Two adults not working	Five or more persons
Two adults one working	
Three or more adults	

These categories were cross classified with four car ownership categories, but with a constraint that the number of cars available could not be greater than the number of adults.

The number of households in each of the categories for a zone depend on the average persons per household and cars per household giving a combined probability, $\rho i,j$, where i and j are category model variables. Thus for any life cycle category k

$$\rho_{I,j,k} = \rho_{I,k} \times C_{j,k}$$

e.g. $\rho_{1,\ 3+,1} = \rho_{1,1} \times C_{3+,1}$

where

$\rho_{1,\ 3+,1,1}$ = proportion of households in the category with 1 person, and 3+ cars in life cycle category 1

$\rho_{1,1}$ = proportion of households with one occupant in life cycle category 1

$C_{3+,1}$ = proportion of households with 3+ cars in life cycle category 1

The probability curves (that is the proportion of households in each category given a zonal average) were calibrated from the 2006 Census data, as were the average number of vehicles and persons per household in each life cycle category.

6.4 Trip Distribution

Trip distribution was undertaken using a standard gravity model, with the three-step model having distribution functions based on time, while the four-step model is generalised cost based to enable the effects of fares, tolls and other travel demand management measures to be included, and to represent the differing values of time perceived for each mode of travel. The functions are represented by negative exponential equations of time or cost. Different functions were used in specific parts of the region. All were validated against observed inter-sector movements, and trip length (time or cost) frequency distributions.

6.5 Mode Split

The mode split model used a series of binary choice logit models with following structure

Split One – All **person** trips into **Active modes** (walking/cycling) vs **Other**
Split Two – **Other trips** into **Public Transport** vs **Vehicle occupants**
Split Three – **Vehicle occupants** into **car driver** vs **car passenger**

Home Based Work and Home Based Education were kept separate with all other purposes aggregated prior to the mode split step.

6.6 Assignment

TRACKS is one of the few transport planning software packages where intersection delays are explicitly modelled during the assignment process as opposed to being externally calculated and iteratively fed back into a further assignment. As a result, the delay at an intersection is a function of both the approach flow and the conflicting flows. This is true also of signals as the cycle time and phase splits are internally calculated, rather than being user defined. An assignment technique which has a unique solution needs to be used. An incremental assignment is the only available technique, as the mathematical constraints of an equilibrium assignment are violated by the use of conflicting flows.

a) Link Travel times

The volume delay relationships used in this study were for delays on links only and were based on those analytically derived by Akcelik (1991) using a time dependent Davidson model. As a result, these curves give ‘link only’ delays, allowing intersection delays to be separately calculated. The JA parameter, or friction factor, in Akcelik's equation for travel time was set for each link type so that Vcapacity/Vfree flow = 0.5. This is consistent with standard traffic theory and Fisk's behavioural model and matches data surveyed in Wellington. As a result these curves give ‘link only’ times, allowing intersection delays to be separately calculated. Each link in the network is given a volume delay curve depending of the speed limit, function and characteristic of the road the link represents. A steady state period of one hour was used.

Akcelik's formula is:

$$t = t_o \left\{ 1 + 900\, r_f \left[(x - 1) + \left((x-1)^2 + (8 J_A x) / (Q t_o r_f) \right)^{1/2} \right] \right\}$$

Where:

t	=	travel time per unit distance (secs/km)
t_o	=	minimum (zero flow) travel time per unit distance (e.g., secs/km)
J_A	=	delay (side friction, level-of-service(LOS)) parameter
x	=	q/Q = degree of saturation
q	=	demand (arrival) flow rate (veh/sec)
Q	=	capacity (veh/sec) per lane
r_f	=	ratio of flow period T_f, to minimum travel time t_o

b) ***Priority Intersections***

Delays at priority intersections are calculated at the movement level. That is, left, right and through movements on all legs have delays calculated specifically.

A queuing theory model is used to calculate the delays. The queuing theory formulation adopted is that described by Fisk and Tan(1989) which uses an M/M/1 model (indicates a queuing system with negative exponential distributions for arrival headway and service times, with one service channel) and a coordinate transformation approximation to allow for over-saturated conditions. This work was extended by Gabites Porter (1991) to cover all 23 different intersection types.

The formulation is:

d	=	$r/\mu\ (1 - r)$	steady state conditions, $r<1$
		$(r - 1)\ T/2$	deterministic conditions, $r>1$

Where:

$$r = q_2 / \mu$$

$$\mu = \frac{q_1 e^{-q_1 t}}{1 - e^{-q_1 b}}$$

T	=	duration of time period over which a steady state is assumed
q_1	=	major road flow rate
q_2	=	minor road flow rate, always defined as approach being delayed
t	=	critical gap
b	=	move-up time for minor road traffic.
μ	=	mean service rate
r	=	traffic intensity

Fisk shows that the delay equation can be written:-

$$d = \frac{-(2 + \mu t - r\mu t) + \sqrt{(2 + \mu t - r\mu t)^2 + 8 r\mu t}}{4\mu} + \frac{1}{\mu}$$

when the coordinate transform is included. This is the formulation used.

c) Roundabouts

Delays at roundabouts are calculated using the formulae described in the SIDRA 5 User Manual. Akcelik and Besley (1996).

d) Signalised Intersections

Delays at signalised intersections are calculated according to turning movements using the formulations in Akclik(1981), including equations 6.4, 6.3 and 6.1 shown below. While ARR123 is the basis for SIDRA it does not give exactly the same results, especially for the more recent versions of SIDRA.

6.7 Run Time Considerations

The WRTM has been built using TRACKS – a New Zealand developed package that has been widely used in New Zealand, Australia and Malaysia since the mid 1970's. The model has 900 zones (with 200 of these 'spare'), with 8,400 nodes and a little over 20,000 links in the network. There are 13 trip purposes. On a reasonably new PC, the three step model takes around 6 minutes (generation, distribution and assignment) while the mode split and public transport assignment of the four step brings the total run time to around 25 minutes.

7. CONCLUDING COMMENTS

The Waikato model project is a major model 'build and operate' exercise which began with a scoping report in 2006, with the model build phase completed in January 2010. The operational phase of the project is schedule to continue until 2013, with optional extensions through to 2015. There is expected to be an update in 2012 following release of the 2011 national census data.

The management of the project is unique in New Zealand, with the client body being a commercial enterprise comprising a private company of Local Authority shareholders, with a significant input from the New Zealand Transport Agency.

For the first time since the late 1970's, Hamilton has a model that has been built from well conducted surveys, providing extremely good data that has been essential in the model build phase of the project. Indeed, the more the data was used, the more confidence could be placed in it.

While the model form has deliberately been kept simple, it has used the latest available proven technology for trip generation mode choice and assignment. The end result is a model that has been well validated, and which will be used extensively in the years to come. One of the key tasks during each operational project is a 'local area validation' exercise that will mean continual improvement if the model, and the confidence that can be placed in the results.

Finally, the model has been extensively peer reviewed during the build process, with the peer reviewer involved in development of the original brief and with sign off at each step of the build. The results of several operational projects have also been reviewed.

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