AUTOMATIC CYCLE COUNTING PROGRAMME DEVELOPMENT IN HAMILTON

Authors:
Axel Wilke
BE (Hons), ME (Civil), GIPENZ
Director, Senior Traffic Engineer and Transport Planner, ViaStrada Ltd
(027) 2929 810
axel@viastrada.co.nz

John Lieswyn
BSc, MET (pending)
Transport Planner, ViaStrada Ltd
john@viastrada.co.nz

Steve Taylor
NZCE (Civil), AIPENZ
Transport Engineer, Hamilton City Council
steve.taylor@hcc.govt.nz

2 Walk and Cycle Conference, Hastings, 23 February 2012

Abstract

Prioritisation of land transport funding and justification of investment by mode has long favoured easily measured motorised journeys. The collection of data on active transport trips has traditionally been limited to manual counts.

Following on from the 2008 NZTA funded investigation by ViaStrada into methods of continuous cycle counting, this conference paper summarises the literature on the latest methods, count durations, how many sites are needed, and where they should be placed to gain a representative sample of the cycling levels throughout a given network.

This knowledge has been applied in the development of automatic cycle counting programmes for three New Zealand cities of a range of sizes: Christchurch, New Plymouth, and Hamilton. This paper presents the development process, planning, and implementation to date of the programme for Hamilton City.

The topics will be of interest to decision-makers and transportation planners working to quantify the effectiveness of investment in active transport networks.

Introduction

Prioritisation of land transport funding and justification of investment by mode has long favoured easily measured motorised journeys. The collection of data on active transport trips has traditionally been limited to manual counts.

Jones et al (2010) noted: "While funding for pedestrian and bicycle facilities is typically limited to 'transportation' functions only, funding for roadways, transit, and other systems make no such distinction. The result is a potential funding bias against non-motorized facilities, as well as a potential resistance to accommodate non-motorized modes in new projects..." To redress this and ensure the most effective allocation of resources, it is crucial that cycle traffic volumes, trends and distributions are understood. A monitoring programme is required to provide an accurate indication of cycling activity levels throughout the city and to monitor trends over time.

This paper gives an overview of the literature on cycle counting technologies and implementation methods. The subsequent sections describe how this research was applied in the development of an automatic counting programme for Hamilton City. It is then discussed how the counting programme was implemented and what the findings have been so far. The paper concludes with a commentary on applications for other cities. The paper builds on one that was presented at the March 2011 IPENZ Transportation Conference in Auckland (Lieswyn et al. 2011).

Cycle Counting Methods – Best Practice

Research objective

Cycle counting technologies have been rapidly advancing and research has yielded a wealth of information regarding the relative limitations, applications and operation of each (Alta 2009; Cope et al. 2009; Jones et al. 2010; Schneider et al. 2005; ViaStrada 2009).

However, less is known about the specification of a cycle counting programme, including how many counters are needed, how long to count for, and where to locate them on a network.

State of knowledge

Site selection to monitor a transport network, even for motor vehicles, is not a well documented topic perhaps due to the complexity of the task. Most guidance simply suggests something along the lines of 'a sufficient number of representative sites should be chosen'. For motor vehicle networks, Traffic Design Group (2001) suggested taking a sample of road links from road classification groupings.

For bicycle networks, a report on the regional bicycle count for Tucson, Arizona, USA (PAG 2008) states that "locations were chosen based on estimated levels of cycling activity and achieving a reasonable regional / geographic distribution." And an investigation into cycle monitoring in Hertfordshire, UK (Strong 2004) states "there is at present little or no guidance on the number of counters required in any given geographic area in order to provide robust data."

When questioned about the method employed by the UK's Sustrans in monitoring its national cycle network, Andy Cope, Sustrans' research and monitoring director, said: "In short, I don't think a formula exists to determine how many and where to situate counters. I think it needs to be a pragmatic judgement based on existing networks and proposed interventions". (A. Cope, 2009 *pers comm.*) ARTA[1] (2006) in its Regional Cycle Monitoring Plan Provisional Guidelines emphasised the importance of having consistency in terms of count programmes throughout the various local authorities in the Auckland region but did not suggest how the number, locations and durations of counts should be determined.

[1] Auckland Regional Transport Authority; now superseded by Auckland Transport

Monitoring cycling activity levels

The three broad types of (potentially complementary) data sources for cycling are surveys, crash data analysis, and cycle traffic counts (Cope et al. 2009; Davies et al. 1999).

Survey methods include national survey data (such as the New Zealand Household Travel Survey and the Census), local interview or destination surveys (which are often time consuming and unsuitable for time-series analysis), parked bicycle counts and school 'hand-up' counts (which can be influenced by external factors such as peer pressure).

Crash data analysis can reveal important clues about where cyclists are travelling, however under-reporting rates are at least 54% (NZTA 2010; Turner et al. 2009) and crash causation reporting is often biased (Wood 2008).

Cycle traffic counts are the focus of this paper, and are used in three general ways:

- cordon counts give useful information, as they can capture all movements across a boundary, but only represent a proportion of city-wide cycling activity. For example, Hamilton has been undertaking central city cordon counts for cyclists for many years;
- screen line counts commonly follow natural or artificial barriers and if all potential crossing points are counted, they can be useful to check home interview or other transport survey data. For example, Hamilton's Waikato River and railway main trunk line are used as screen lines; and
- a sample of network locations are selected to be generally representative of the range of trip purposes and geographic areas.

Cycle traffic counts have historically been undertaken by means of manual (i.e. a human surveyor) counts. Sample sizes are necessarily limited by resource availability. For example, Hamilton has been undertaking small sample (one day per year) manual counts of cyclists since at least 1980.

Automatic cycle counters

Automatic cycle counters are the primary method of cycle monitoring recommended by most reviewed sources as they can generate larger sample sizes. A network of automatic count sites is required to build an understanding of cycle volumes and trends throughout a city. This is supplemented with manual counting, for example for turning counts at intersections.

The design of an automatic cycle counting programme is dependent upon the technology chosen, as counter performance varies depending on the facility type (e.g. on-road cycle lanes versus off-carriageway paths).

Jones et al (2010) describe a range of automatic traffic counters which are available worldwide. The principal types of counters are infrared (passive thermal contrast or active beam interruption), ultrasonic, radar, video imaging (computer analysis of pixel changes), piezometric pressure sensitive (above ground pneumatic tubes or in ground cables); and inductive magnetic field loops (in-pavement).

A web-based search and personal observations on study tours indicates that piezometric and inductive technologies are commonly used in western Europe. In North America, infrared counters have been used primarily off-road but there has been little development of on-road counting technologies (Alta 2009; Schneider et al. 2005). San Francisco has successfully trialled inductive loops and planned on implementing them at 33 sites city-wide throughout 2010 (SFMTA 2010).

In New Zealand, piezometric pneumatic tubes are commonly used for short term count sites. Based on previous automatic counter research (ViaStrada 2009), Christchurch City has plans to install in-ground inductive loops at 22 sites in Christchurch. Piezometric in-ground loops have become available but were not reviewed for this research. A prospective counter technology user is advised to consider new technological developments before selecting a product.

Number and location of counting sites

The authors' previous paper on cycle counting provided a literature review on the number and location of counting sites (Lieswyn et al. 2011). Davies et al (1999) recommended that at least one and preferably several sites with automatic equipment should be established for long term counting, so that background levels of cycle traffic can be established. Manual counts can only provide supplementary information, but are unsuitable as the main data collection approach. Sites with heavy flow (preferably over 250 cycles per day) free of future infrastructure changes spread between different route types should be aimed for. Site selection should be based on strategic and local criteria.

Perhaps one of the most intensive cycle monitoring schemes undertaken recently was by Cycling England for the Cycling Demonstration Towns, the project that inspired the Model Communities initiative in New Zealand. Monitoring, mostly with automatic counters, was considered key to determine the effectiveness of investment in measures to stimulate increased levels of cycling in six English demonstration towns (Cope et al. 2009). There was no scientific basis for the number and placement of automatic counters, but pragmatism achieving cordons and screen lines and budget constraints often determined what was done.

Strong (2006) developed an empirically based model which suggests a range of counters dependent on urban population, with some additional factors also to be considered.

Count durations

Counts do not need to be permanent to give an indication of yearly volumes. New Zealand's Cycle Network and Route Planning Guide (LTSA 2004) provides a method for estimating cycle AADT (average annual daily traffic) from counts done for part of a day at a specific site by factoring them for various influences. However, the resulting estimates cannot be assumed to be statistically reliable.

The coefficient of variation (CV) is a normalised measure of dispersion of a probability distribution, or simply the standard deviation (SD) of the daily count values divided by the mean of those values, multiplied by 100 (Wright & Hu, 1997). The CV is an indication of the degree to which variability in the data affects the precision of a scaled up estimate of the population (total cycles that would be counted in 365 days).

The CV is very sensitive to small changes in the mean if the mean is close to zero (as is common in cycle counting on low volume routes). Research shows that:

- Motor vehicle counts between 4,474 and 154,304 had associated CVs between 8% and 22%, and vehicles of minor classifications (e.g. semi-trucks) had much higher CVs (Wright & Hu 1997);
- Davies et al (1999) suggest count durations of seven days per year to achieve a 90% confidence of detecting a 20% change in volumes[2], assuming a CV of 0.15 for sites with 250 or more cyclists per day. Sites that vary less than most may require a smaller sample size to achieve the same desired accuracy;
- Christchurch automatic cycle counters are generating CVs around 35% (T. Hughes, 2010 *pers. comm*.) but show strong correlation between two of the three permanent count sites. This suggests that given a sufficient number of permanent count sites which exhibit good correlation and careful matching of site characteristics, a shorter duration for short term sites may still be possible; and
- Little River Rail Trail automatic short term (two-week) counters with low mean traffic (under 100 cyclists per day) have CVs no better than 28% and averaging 90% - consequently year on year comparisons are not statistically significant (unpublished analysis of the 2007-2011 dataset by the authors).

[2] Refer to pages 13-15, in particular Table 3.1 and Figure 3 of Davies et al (1999) for a more in-depth description.

Increasing the sample size (number of days) to obtain a larger number of observations (bicycles counted) is one way to improve the precision of scaled up values and the reliability of year on year comparisons. The greater the variability in the observations, the larger the sample of days must be. It is the authors' experience that for lower traffic volume sites, two weeks of counting is not enough to provide a statistically reliable time-series comparison for individual sites. Rotating count equipment between sites should thus be based on longer counting periods.

Hamilton Cycle Counting Programme – Phase 1

Background and method

The previous Hamilton City Council (HCC) annual manual count programme included 20 intersections around the central city (undertaken annually since 1980), with three pathway sites and six suburban intersections added to the programme in 1996. HCC required an automatic counting programme to augment or replace the manual counts.

Counting programme development may be divided into three broad phases. Phase 1 would include determination of the number of counters, strategic site locations, counter types, time frames and indicative costs. Phase 2 would be to specify exact site locations and installation details required for contractors. Phase 3 would be the collection and analysis of data. HCC commissioned ViaStrada to undertake Phase 1, while equipment suppliers Integrated Traffic Solutions (ITS) completed Phase 2.

In developing the programme, factors had to be considered somewhat simultaneously and iteratively as they involve many interdependent relationships. These factors, which are also the heading titles of the next sections of this paper, are:

- Number of sites required
- Strategic site criteria
- Counting equipment types
- Counting durations
- Counting methods
- Site locations
- Programme costs
- Implementation options

Number of sites required

The work of Strong (2006) suggests a city of Hamilton's population (approximately 140,000) should have around six to nine counting sites. In addition to this population based method there should be enough counter sites to represent a mix of geographic areas and facility/user types (Davies et al. 1999). Considering these factors in an iterative process, twelve count sites were recommended for Hamilton.

As an automatic count programme recently developed for Christchurch (unpublished ViaStrada report for Christchurch City Council) used a similar analysis to recommend 22 sites, it is useful to compare the two cities (Table 1).

Table 1: City size comparison

Criteria	Hamilton	Christchurch
City population (2009)	141,504	386,100
City area (km^2)	98	240
Cycleways on and off street (km)	101	154

In a mix of geographic and population terms, the city of Hamilton is between a third and half the size of the city of Christchurch. This comparison indicates a consistency between recommendations for the minimum number of sites.

The project identified more sites than the minimum to enable flexibility based on the outcomes of Phase 2. A further increase in the number of sites may be justified as budgets permit, new facilities are developed, or to satisfy other monitoring objectives.

Strategic site criteria

Based on the literature review and previous experience, inputs to the Hamilton strategic site selection process included the cycle network map, cycle and general traffic count data, the road hierarchy map, and major trip generators (e.g. schools, tertiary institutions, hospitals, and the central city). These inputs were considered along with strategic criteria including:

- network coverage criteria including the selection of locations with high cycle volumes to maximise the data accuracy and principal origins / destinations, and screen lines;
- a mix of on-road and off-road facilities, especially considering potential impacts from the proposed completion of contiguous off-road routes;
- a mix of tidal directions based on peak period considerations; and
- site specific factors including pavement surface, the effect of curves, parking and lane lines upon the typical line taken by riders, and intersections.

Counter types, durations and methods

A total programme cost analysis showed that using in ground inductive loops at all sites was not significantly more expensive than a mixed system employing above ground piezometric tubes at short term sites. Further reasons to employ a full inductive loop system were the Boundary Bridge active warning sign (where an inductive loop is employed to activate the sign) and the ability to integrate with pedestrian counters on shared path installations.

The programme development included a review of existing manual programme peak periods. Automatic counting durations were divided into permanent (full-time) and short term (two-week) counting sites, with suitable counter types as per Table 2. Permanent sites are especially important for establishment of locally appropriate factors to be used in scaling as per the CNRPG method mentioned previously.

As a result of the iterative development process, it was determined that the short term sites could actually be counted for longer periods (up to ten weeks each) due to the number of counters required. This would improve the sample sizes and data reliability.

The previous manual intersection cycle count programme gathered behaviour, gender, age, and turning movements. Manual counts were also required for calibration of the automatic counters. The addition of an automatic count programme provided an improved estimate of cycle traffic throughout the city's network and should make it possible to reduce the existing manual counting programme. Subsequent steps identified opportunities for this.

Table 2: Counter types, durations and methods

Method	Counter	Duration
Permanent	Automatic counter (in ground)	Year-long
Short-term	Automatic counter (in or above ground)	2 weeks minimum
Manual	Manual counter	Peak periods

Strategic site locations

One on-road and one off-road permanent count site plus ten short term count sites were identified. Each site was tabulated against the aforementioned criteria, possible equipment type, and relationship to existing manual count sites. All sites were rank ordered, with sites 13 to 20 retained as 'alternatives' for future consideration.

Site locations were initially mapped in a web-based programme which could be edited by HCC staff to obtain feedback. Subsequently, a more detailed 'fixed' map with colour coding corresponding to direction, facility type, and implementation programme was produced. An example of the latter map is shown in Figure 1. The colour of the rings was correlated to a full table of count sites not provided for this overview paper.

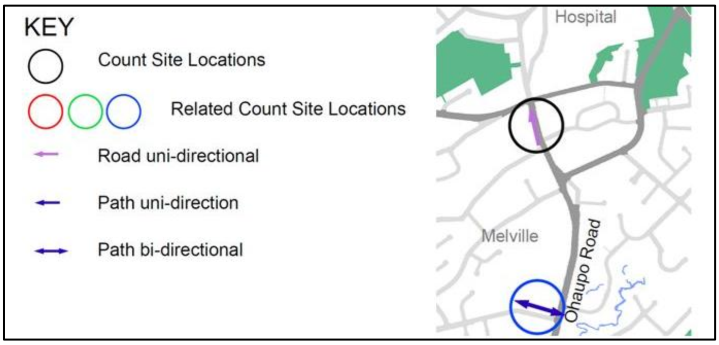

Figure 1: Excerpt of Hamilton count site map

Programme costs

Capital and operational cost estimates for various count types were collated. To reflect uncertainty in cost estimates, upper and lower bound estimates were used. For two permanent sites serviced by two counters and ten short term sites serviced by two counters on rotation, the start up capital cost was estimated as $43,800. The annual operational cost including data collection was estimated to be $4,200. To inform HCC budget allocations, the upper bound capital and operational costs were projected over a 20 year programme duration including an assumed replacement of all loops at year ten (Figure 2).

Based on an analysis of the existing and recommended count locations, eight of the 29 manual count sites were recommended to be eliminated, saving about $4,800 per year.

Implementation options

Four options for programme implementation were proposed (Table 3).

Table 3: Programme implementation options

Implementation timeframe	Programme size	
	Full (12 sites)	Partial (6 sites)
Immediate (1 year)	Option 1	Option 3
Staged (3 year)	Option 2	Option 4

Costs per site year (i.e. cost per survey) analysis showed that the full programme, immediate implementation option (option 1) was the most cost effective over the long term and generated the most data (Figure 3). The programme cost range represents the upper and lower bound estimates as previously mentioned.

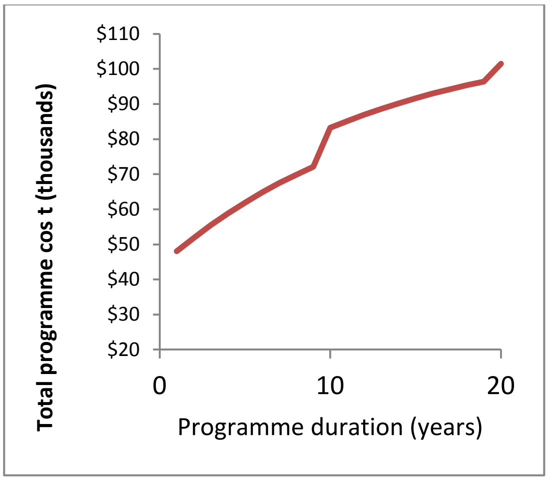

Figure 2: Cumulative programme cost estimate over various durations

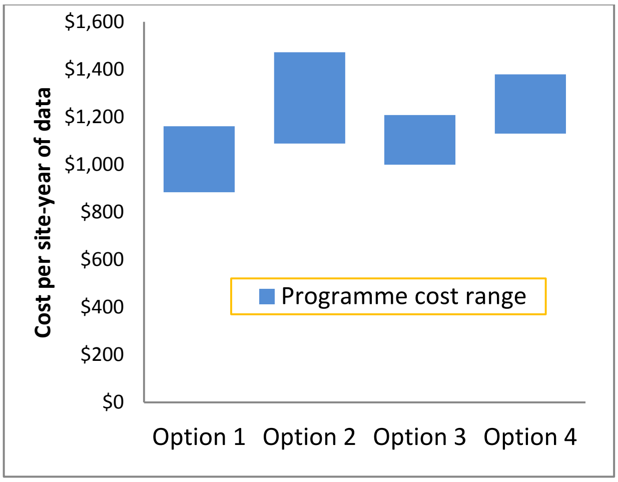

Figure 3: Cost per site-year of data for various implementation options

Hamilton Cycle Counting Programme – Phase 2

Local detailed site investigations

Following the initial strategic report, Hamilton City Council and equipment suppliers ITS visited the recommended sites to undertake detailed investigations focusing on the technical aspects of counter installation. This is a critical step as the path of a cyclist is dependent on many factors such as surface conditions and path or road user interactions. These site specific factors were considered at every location to establish sensor placement and data logger configuration, with Figure 4 showing an example output from the field work. The installation of permanent and short term count sites will be completed by the end of the 2012/13 financial year.

Figure 4: Example outputs from the field work prior to counter installation

Sites chosen

Six counters (data loggers) were purchased, of which two get circulated around the six short term count sites. Only five data loggers are shown in Figure 5 because the counter which is to be connected to the active warning sign inductive loops on the Boundary Road bridge carriageway is currently being upgraded. Table 4 below identifies the count site locations, outlines whether a location is for a permanent or a short term counter, and whether pedestrians are also counted by the equipment.

Table 4: Site locations and related details

site ID	location	duration	pedestrians
2	Rifle Road underpass	permanent	yes
3	Waikato River path	permanent	yes
6	Bridge Street	short term	no
7	Fairfield Bridge	short term	no
8	Flagstaff	short term	yes
9	Clyde Street	short term	no
10	Hukanui Road	short term	no
12	Pembroke Street	short term	no
13	Boundary Road path	permanent	yes
13	Boundary Road carriageway	permanent	no

Data management

Since the original programme development, a new data logger has become available with telemetry, which uploads data to a server owned by the equipment manufacturer on a daily basis. Data management is done via a web-based user interface as shown in Figure 5. The user can produce a range of analyses and reports such as movement data per direction per mode of transport to an analysis of the citywide data for chosen date ranges.

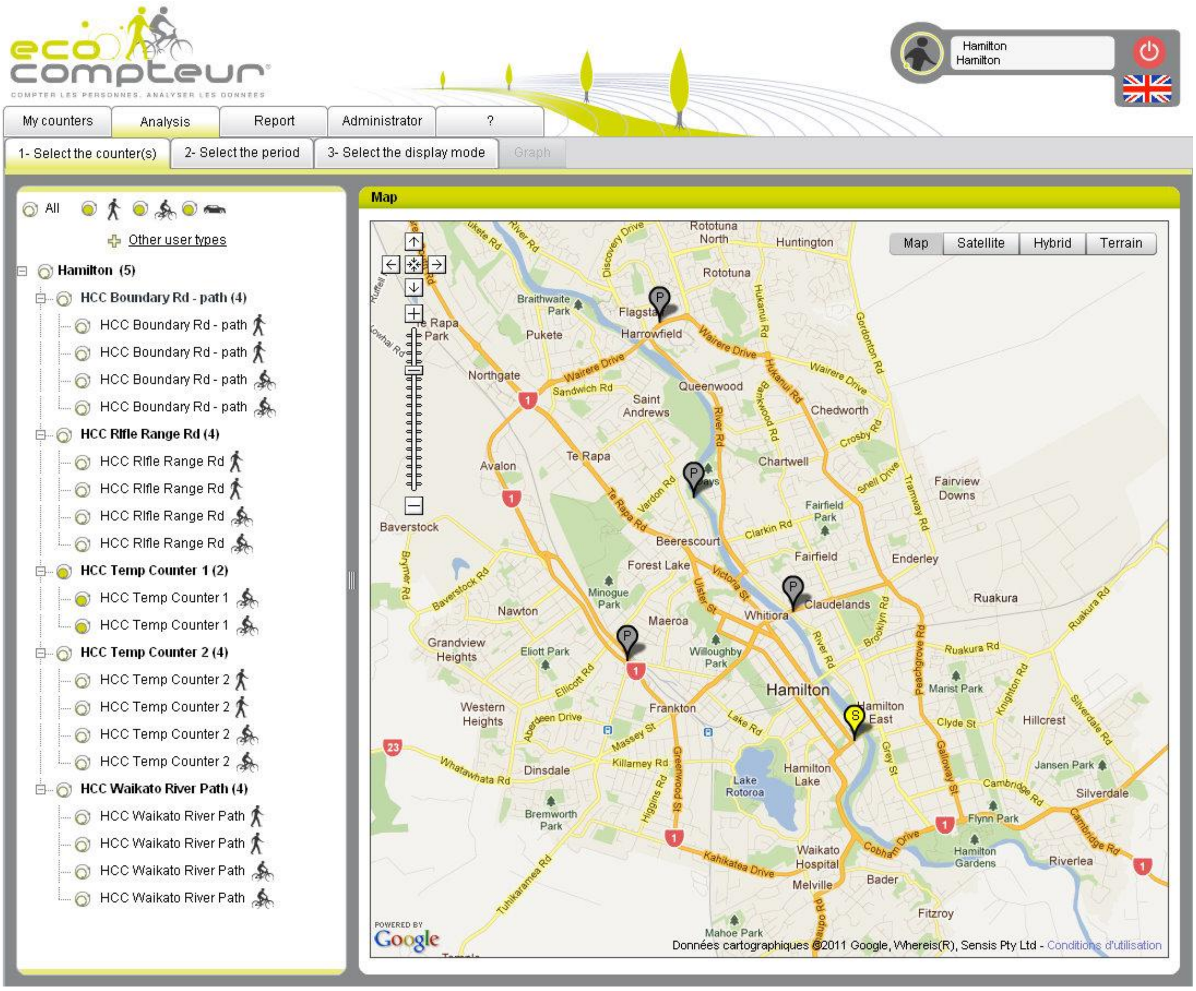

Figure 5: User interface for the web-based count database

These data analysis tools and reports are most useful for longer time series reporting. For each counter, the site names, directions, and travel mode must be clearly differentiated to ensure that the outputs are readily understood.

For this paper, the software was used only to export raw data because of the limited amount of data available and the need for further calibration before relying on the software reporting tools.

Initial results

The initial traffic count data (both directions) for three permanent count sites is presented in the following two charts showing pedestrian (Figure 6) and cycle traffic (Figure 7), respectively. Only the Rifle Range site shows any notable trend over the six month period. Longer term data will be required along with notations of any potential external factors (e.g. network changes) before any further conclusions can be drawn.

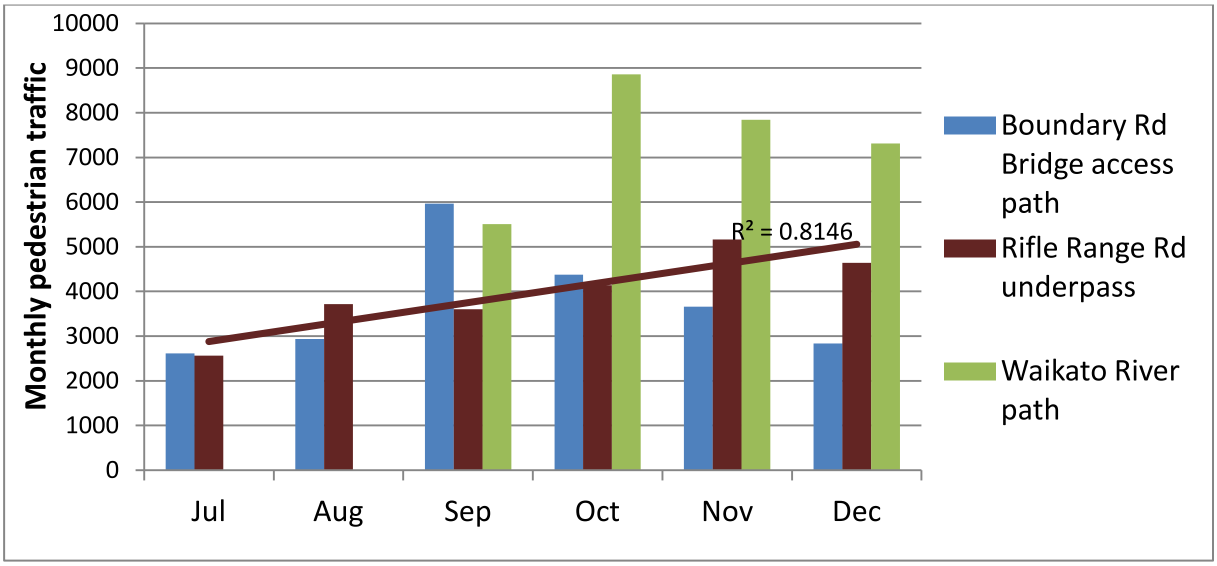

Figure 6: Monthly pedestrian traffic at three permanent count sites (trend line for Rifle Range only)

All sites carry more pedestrians than cyclists. The Boundary Road (Whitiora) Bridge is a key network link for cyclists. Currently, the Boundary Road access path connects to River Road and is more of a pedestrian site; the soon to be implemented bridge carriageway counter is anticipated to collect more cyclist traffic. All sites report lower usage in December than November, which follows the usual annual profile of lower traffic volumes leading up to the holiday season.

It should be noted that the Waikato River path site was not online for July and August, and failed to upload data for parts of September, October and December (the data that were uploaded have been factored up to get an estimate of the monthly total).

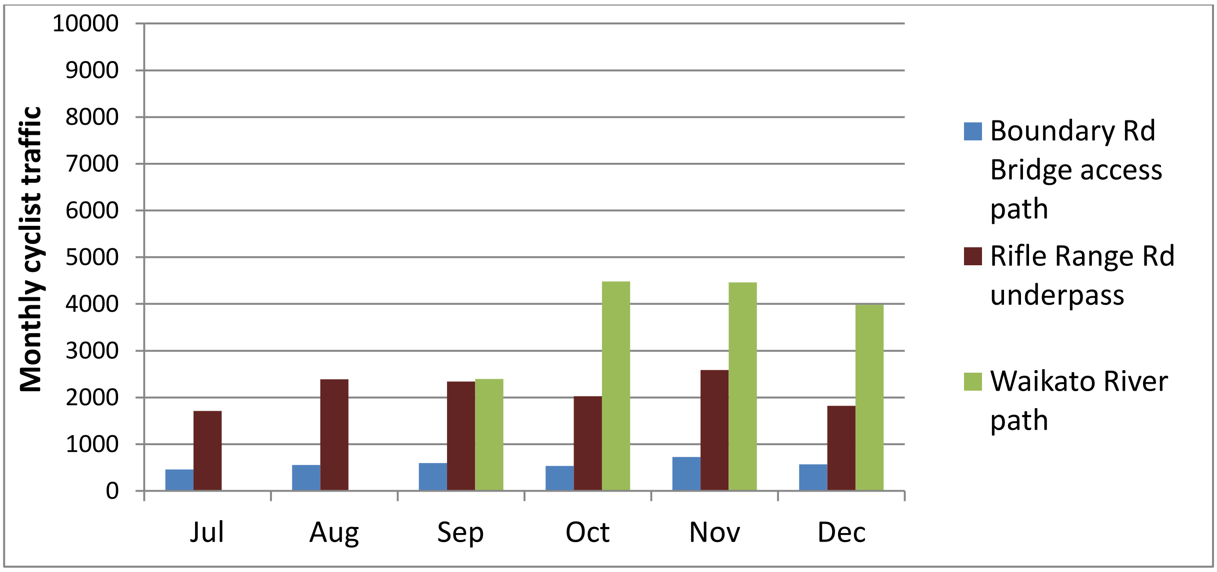

Figure 7: Monthly cyclist traffic at three permanent count sites

Next steps

The next steps that have been identified are as follows:

- To reduce data processing time and take full advantage of the web based software analysis and graphing facilities, the permanent counter description setup needs to be edited to include direction of travel and mode (pedestrian or cycle).
- The sites need to be calibrated with manual counts to determine any site-specific correction factor that may be necessary.
- After all short term sites have collected several weeks of data, an analysis needs to be undertaken to determine what count durations give statistically reliable data at each site. Some high usage sites might need only two weeks of data collection at a time, whilst other sites should have data collected for four weeks or more. Knowing what count periods result in statistically reliable data helps optimise the counter use and maximises data capture with the hardware available.
- An analysis of the first full year of data from the permanent sites will determine Hamilton specific scaling factors for short term (manual) counts based on the methodology given in the CNRPG (Gravitas 2009; LTSA 2004). This will be useful for specific projects in locations where no count hardware is installed, and can be used to obtain AADT estimates for the short term automatic sites.
- For the first time in New Zealand, it will also enable those scaling factors to be developed for pedestrian activity. The count locations are mostly in suburban areas, but one site is close to the central city and a different flow profile can be expected for the latter site compared to the others.

Conclusions and other New Zealand applications

Good bicycle traffic volume data can aid strategic planning, transport system modelling, and network management. Larger sample sizes offered by automatic counting technologies enable robust time series data analysis.

The literature includes limited explicit guidance on cycle counting programme development. For Hamilton, a minimum of 6-9 automatic counters was estimated based on the work of Strong (2006) and comparison with the recently developed Christchurch City Council cycle counting programme. After consideration of a range of strategic criteria, 12 sites were recommended with at least two of these to be permanent count stations. Capital and operational costs of an automatic count programme for Hamilton were estimated to be $43,800 and $4,200, respectively. Comparison of the existing and proposed sites showed that a reduction of eight (out of 29) manual count sites would yield savings of about $4,800 per year.

The project demonstrated that an iterative, step by step approach is a useful method to develop a cycle counting programme. Careful strategic site selection is required to ensure that a range of facility types, geographic features, and key cycle trip generators are included. The development of implementation options will also be specific to each city, as will the selection of equipment.

Hamilton's telemetry-enabled data loggers and internet based data management have proved useful to monitor equipment operating characteristics and obtain real time data. After some time of collecting data, statistical analysis will be required to develop site specific minimum count duration periods and city wide scaling factors for annual daily traffic estimation at short term automatic and one-off manual count sites.

With automatic counting programmes now being launched in cities including Hamilton, Christchurch, Auckland and New Plymouth, results will soon become available to help establish guidelines for minimum short term count durations and develop locally appropriate scaling factors.

Acknowledgements

The initial literature review and count programme development method was developed by Megan Fowler (formerly of ViaStrada) and Jeanette Ward of ViaStrada in an unpublished report to the Christchurch City Council in 2008. Research on developments since 2008 and application of the method to Hamilton was primarily undertaken by the authors. The sites are now managed by Hamilton City Council and equipment supplier ITS.

References

Alta 2009, *National Bicycle and Pedestrian Documentation Project: Automatic Count Technologies*. from www.bikepeddocumentation.org/index.php/download_file/-/view/22

ARTA 2006, 'Regional Cycle Monitoring Plan Provisional Guidelines 2006-2008'. Auckland Regional Transport Authority, Auckland.

Cope, A, Muller, L & Kennedy, A 2009, *Cycling Demonstration Towns Monitoring project report 2006 to 2009*, Cycling England. from http://webarchive.nationalarchives.gov.uk/20110407094607/http:/www.dft.gov.uk/cyclingengland/cycling-cities-towns/results/

Davies, DG, Emmerson, P & Pedler, A 1999, *Guidance on Monitoring Local Cycle Use. TRL Report 395*, Transport Research Laboratory.

Gravitas 2009, *Manual Cycle Monitoring in the Auckland Region*, Auckland Regional Transport Authority. from http://www.aucklandtransport.govt.nz/about-us/publications/PlansProgrammes/Documents/AT-ARTA-Report-Regional-Cycle-Monitoring-%20Summary-2009.pdf

Jones, MG, Ryan, S, Donlon, J, Ledbetter, L, Ragland, DR & Arnold, L 2010, *Measuring Bicycle and Pedestrian Activity in San Diego County and its Relationship to Land Use, Transportation, Safety, and Facility Type*, Institute of Transportation Studies - UC Berkeley Traffic Safety Center, University of California. from http://www.path.berkeley.edu/PATH/Publications/PDF/PRR/2010/PRR-2010-12.pdf

Lieswyn, J, Wilke, A & Taylor, S 2011, 'Automatic Cycle Counting Programme Development in Hamilton', *IPENZ Transportation Conference*, Harding Consultants,, Auckland. http://www.hardingconsultants.co.nz/ipenz2011/downloads/Lieswyn__John.pdf

LTSA 2004, 'Cycle Network and Route Planning Guide'. Land Transport Safety Authority, Wellington.http://www.nzta.govt.nz/resources/cycle-network-and-route-planning/

NZTA 2010, *Economic Evaluation Manual*, New Zealand Transport Agency. Retrieved May/10/2010, from http://www.nzta.govt.nz/resources/economic-evaluation-manual/volume-1/

PAG 2008, *2008 Tucson Metropolitan Region Bicycle Count*, Pima Association of Governments. from www.pagnet.org/documents/bicycle/2008TucsonMetropolitanRegionBicycleCount.pdf

Schneider, R, Patton, R, Toole, J & Raborn, C 2005, *Pedestrian and Bicycle Data Collection in United States Communities*, Pedestrian and Bicycle Information Center, US Department of Transportation Federal Highway Administration. from www.pedbikeinfo.org

SFMTA 2010, *City of San Francisco 2009 Bicycle Count Report*, San Francisco Municipal Transportation Agency. from http://www.sfmta.com/cms/rbikes/3172.html

Strong, M 2004, *Monitoring of Cycling in Hertfordshire: Report on the Current Situation and Proposals for Improvement*, Transport Initiatives. from http://www.hertsdirect.org/infobase/docs/pdfstore/cycmonguidept1.pdf

Strong, M 2006, 'Practical Monitoring of Cycling', *Transport Practictioners' Meeting*, Transport Inititiatives, LLP. www.transport-initiatives.com

Traffic Design Group 2001, *Transfund Research Report 202: Update and Enhancement of Traffic Count Guide*, NZTA. from http://www.nzta.govt.nz/resources/research/reports/202/index.html

Turner, S, Roozenburg, A & Binder, S 2009, *Cycle safety: reducing the crash risk*, NZ Transport Agency, 389. from www.nzta.govt.nz/resources/research/reports/389

ViaStrada 2009, *Continuous Cycle Counting Trial*, NZT Agency. from http://www.nzta.govt.nz/resources/continuous-cycle-counting-trial/

Wood, K 2008, *Bicycle Crashes in New Zealand: Revised Web Version*, Lincoln University. http://viastrada.co.nz/sites/viastrada.co.nz/files/Wood-thesis.pdf

Wright, T & Hu, P 1997, *Variability in Traffic Monitoring Data: Final Summary Report*, Center for Transportation Analysis, Oak Ridge National Laboratory. from http://www.fhwa.dot.gov/ohim/flawash.pdf