Monitoring cycling:

you can't manage what you don't measure

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Abstract

For people managing a cycling network, there are over sixty different metrics to help evaluate the impact of engineering, education, encouragement and enforcement interventions. These range from mode share (as measured by the census question on the journey to work mode) to 'hands-up' counts in classrooms to measures of physical activity through the NZ Health Survey. The most direct measure is traffic counts – but the questions of where, when, how, and for what duration we should count requires careful consideration. This paper focuses on cycling traffic counts – primarily the trends in automatic count technology, crowd sourcing, 'big-data', and how manual surveys are still important. The Palmerston North Cycling Network Monitoring Plan is used as a case study to show how count data is managed to help identify what interventions are affecting cycling.

Introduction

Why monitor

Measuring the impact of investments in active transportation assists in telling a story of success and helps identify factors that will influence pedestrian and cycle use. Data collection can help in the pursuit of funding applications and the support of sustained development of capital and operational programmes to support pedestrian and cycle growth. Monitoring is also a requirement in order to receive National Land Transport Programme funding. According to the NZ Transport Agency (2014), “programme information needs to clearly identify …baseline figures on usage and safety and proposed monitoring of change”.

Range of indicators

For Palmerston North City, we identified 62 indicators categorised by importance, geography or availability:

- Key indicators designed to “headline” performance measured either continuously, annually or at least every two years (listed in Table 1)
- Secondary indicators that add nuances to the understanding of walking and cycling measured every 3 to 5 years
- Sub-indicators used in the production of the headline or secondary indicators
- Regional-level indicators available from the Household Travel Survey or NZ Health Survey
- Other measures which would only be collected and reported if available

Specific targets are planned to be set through an upcoming strategic plan update.

Table 1: Summary of key indicators

CATEGORY	INDICATOR
Volumes	Average annual daily cyclists at 6 permanent continuous counters is increasing
	Total pedestrians and total cyclists at 6 permanent continuous counters is increasing
Patterns	Walk and cycle mode share of journeys to school (all year levels) at a standardised set of participating schools (TBD) is increasing
Safety	Number of injury crashes involving pedestrians and cyclists is trending downwards
Network	Proportion of urban arterial and collector road network with cycle lanes
	Length of urban and rural cycleways, excluding rural shoulders
Health	Percentage of adult residents who are physically active (did at least 30 minutes of exercise on five or more days in the past week) is increasing

The three broad types of (potentially complementary) data sources are surveys, crash data analysis, and cycle traffic counts (Davies, Emmerson et al. 1999, Cope, Muller et al. 2009). Surveys include the New Zealand Household Travel Survey, the census, local interview or destination surveys, parked bicycle counts, and school “hand-up” counts. Crash data analysis can reveal important information about where cycle crashes are occurring and the safety risks on the network, however under-reporting rates are at least 54% for minor and non-injury crashes (Turner, Roozenburg et al. 2009, NZTA 2010), crash causation reporting is often biased (Wood 2008) and crash numbers may not reflect the reality that a given network element may be perceived as so dangerous that cycle trip making demand is suppressed.

This paper next focuses on pedestrian and cycle counting technologies and follows with a summary of the development of the Palmerston North City Council Cycling Network Monitoring Plan (unpublished, Dec 2017) that aims to harness recent equipment advances, better monitor activity, and inform future decisions.

Count technologies

State of practice

Cycle counting technologies have been rapidly advancing and research has yielded a wealth of information regarding the relative limitations, applications and operation of each (Cope, Muller et al. 2009, ViaStrada 2009). The NZ Transport Agency Cycling Network Guidance, or CNG, has an extensive summary of monitoring techniques. The 2013 revision of the US Traffic Monitoring Guide (TMG) even includes material on active transport such as data cleaning techniques (FHWA 2013). An extensive review of technologies including evaluation of performance was conducted in the United States produced the *Guidebook on Pedestrian and Bicycle Volume Data Collection* (Ryus, Ferguson et al. 2014). The usefulness of this guide to NZ practitioners is somewhat limited due to a prohibition on naming suppliers and the rapid advance of counting technologies since 2013.

In New Zealand, the two most common automatic counters are the Metrocount pneumatic tube traffic counter and the EcoCount inductive loop cycle counter. Each have been used in varying ways around the country. In this paper we will discuss how they are currently used in Palmerston North and how a 2017 review of the count programme is guiding a change in approach.

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

- cordon counts around a central city or major trip generator give useful information but typically only represent a limited proportion of cycling activity occurring city-wide
- screen line counts commonly follow natural or artificial barriers such as a river. If all potential crossing points are counted, they can validate home interview or other transport survey data
- a sample of network locations selected to be generally representative of the range of trip purposes and geographic areas

Manual counts

Cycle traffic counts have historically been undertaken manually by a human observer. Sample sizes are necessarily limited by resource availability. For example, Hamilton City has been undertaking small sample (one day per year) manual counts of cyclists since at least 1980 (Wilke, Lieswyn et al. 2012). Manual counts enable the local authority to obtain information such as gender, age, riding behaviours (e.g. footpath cycling), e-bike and helmet use that cannot be monitored with automatic counts. Urban Cycleways Programme (UCP) recipients are required to report on gender.

In New Zealand, UCP participants and others conduct manual counts one day each March during the 7-9 am morning commute period at selected sites, which may include a central city cordon or screenlines such as bridges. Full day counts (with gaps for surveyor breaks) can help establish other peak hours during the day. Counts should always be taken on a fine day during the school term, as rain dampens ridership especially on recreational trails. Manual count data should be collated into a database such as an Excel workbook and maintained every year for trend analysis.

The UCP wider network monitoring form is used to report on the results of the annual manual count. Note that all manual count totals are aggregated before scaling up to account for the day of week and month of year seasonal variation. Ideally, scaling factors should be developed for each type of facility where manual counts might be undertaken (cycle lanes, paths, near the central city, along intercity routes) and then applied to similar sites (Abley Transportation Consultants 2016).

Based on the author’s experience administering the US National Bicycle and Pedestrian Documentation Project (Alta Planning + Design 2018) and training others how to conduct counts, it is important to ensure that all persons conducting counts are using the same classification system:

- If a person is seen walking with a bike, they are counted as a pedestrian
- If a person is seen cycling but then dismounts to cross a road, they are counted as a cyclist

- If two or more people are riding on one bike (e.g. child in a child seat or on a single-wheel ‘tagalong’, or two people on a tandem bike) then count the number of people cycling
- Count all people riding a bike as cyclists, regardless of whether they are riding in the road or on the footpath, with or contraflow to traffic
- Record in separate columns people’s gender, whether they appear to be school age, and whether riders are on the footpath

The key steps in preparing for the manual count are:

- Recruit staff and/or volunteers
- Set two back-up dates in case of bad weather, and a plan for postponement notification
- Hold a briefing the day prior to the count; for those who cannot attend the briefing, make copies of the materials available electronically

These principles were applied for the first time in Palmerston North in 2018 (refer page 8).

Big data, crowd-sourcing and app-based counting

Smartphone apps (active counts) and Bluetooth (passive counts)

With smartphones being ubiquitous, apps such as CounterPoint (http://counterpointapp.org/) make it easy for members of the public to contribute "crowd-sourced" counts. Researchers have also investigated the potential for capture and use of ‘big data’ from smartphones (Kim, Porter et al. 2014). In New Zealand some smartphone users are likely to have Bluetooth and Wi-Fi turned off or restricted. Bluetooth travel time counters are ubiquitous now in the industry, capturing roughly 10% of the traffic that passes a sensor (ibid).

Strava app

Strava is targeted at recreational and fitness riders and runners. It is an app-based tool that enables users to compile their exercise and other trip data and share it with others in a social-media platform. While Strava data probably has few utility-oriented trips, it is a useful quick tool for screening-level analyses.

Map views (Figure 1 shows a cropped area of Palmerston North) are free, while the underlying data is available to government agencies for a fee. The thicker and brighter the line, the more activity is being registered by the app.

Figure 1: Strava 'heatmap' of walking, running and cycling activity in Palmerston North

Ride Report app

Perhaps one of the most promising datasets grew out of the Aotearoa Bike Challenge promotion of the Ride Report app (Stokell 2017). This runs in the background and uses the smartphone accelerometer to detect whether the user is walking, running, cycling, or driving. Users do not have do anything at all to capture and report their travel totals. Errors are easily reported and help to refine the algorithm. Once the user enables the app, it records active transport trips in the background and sends the data for aggregation to a server that can be accessed by the NZ Transport Agency for planning purposes. The app is being used globally and as of late 2017 had over 248,000 participants logging 4.6 million trips (ibid). In New Zealand the 2018 Aotearoa Bike Challenge reported 37,823 people logging 1,015,523 trips, many of which were logged with Ride Report. There is strong potential for this data to be used to determine the usage level of favoured routes, with privacy concerns addressed through data aggregation.

Internet of Things (IoT)-based sensing

Across most of the developed world (including in NZ) the ultra-low power Sigfox Wireless Access Network (WAN) enables the deployment of low-cost sensors with miniature yet long-life batteries. Such sensors are ubiquitous, detecting the rubbish level in a public bin, the number of cars in a parking building, and the number of people walking through the doors of a mall. Because there is not cellular modem-draining power, IoT sensors can provide data for years within a very small chassis. One manufacturer is now marketing a device in New Zealand that uses active infrared sensor and IoT communications to obtain a count of persons passing within 2.0 m of the device (Pipiot).

An example of an IoT based sensor is the parking management sensors used in Palmerston North. They are solar powered with a 12-hour running time and four-minute recharge time. Similar sensors recognise traffic and this technology may well be utilised in live traffic lanes to count cars and other modes of transport. This technology has the potential to be a low-cost alternative or supplement to current counter systems for pedestrians and cyclists.

Bike sharing datasets

In another application of IoT technology, the latest generation of bike sharing works by GPS-equipped “smart lock” dockless bicycles. Operators can easily obtain large datasets indicating how many trips are made and where, and share this with the local government agency. Figure 2 is a screenshot from the back-end system of one operator.

Figure 2: Real-time cycling activity monitoring using bike share (source: Mobike)

The data that could be mined from such systems could be used for:

- Network management applications such as cycleway corridor planning and the provision of cycle parking and
- Planning studies of how weather affects ridership across an entire city (or service area), user demographics such as gender and neighbourhoods, and even travel time competitiveness with other modes (Carpenter 2018)

Automatic counters

In addition to manual counts, there are two main types of cycle traffic counters: permanent automatic counters (typically inductive loops in the pavement, with the option of a thermal infrared sensor for pedestrians) and short-term automatic counters (pneumatic tubes).

These types of automatic cycle counters are the primary method of cycle monitoring as they can generate larger sample sizes. Video data collection is typically only conducted for short durations (e.g. one day) and therefore insufficient for scaling up to an annual value and monitoring over time. A network of automatic count sites is required to build an understanding of cycle volumes and trends throughout a city. 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 offcarriageway paths). According to Ryus, Ferguson et al. (2014), the principal types of counters include 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). Each technology has different applications and accuracy considerations.

While Ryus et al. have a good summary of this information, the authors have found guidance on on-road short term cycle count technologies to be limited and the application in New Zealand to be generally problematic. Figure 3 and Figure 4 provide two examples of how cycle counting with tubes on-road can significantly undercount ridership.

Figure 3: tubes miss all right turning cyclists (Christchurch)

Figure 4: tubes miss most riders due to parking lane alignment (Christchurch)

A prospective counter technology user is advised to (a) clearly state the goals of the automatic count programme and (b) carefully assess each proposed site and consider new technological developments before selecting a product for each site.

Data analysis

The authors have found that many local authorities do not consistently maintain cycle count data and do not annualise the data. Traffic data should be reported in annualised terms in order to account for seasonal and weather variations. New Zealand's Cycle Network and Route Planning Guide (CNRPG) (LTSA 2004) provides a method for estimating cycle AADT (average annual daily traffic) from counts done for part of a day, and more recently the Transport Agency has developed a spreadsheet-based scaling tool for two-week short term counts (Abley Transportation Consultants 2016).

For cars, a one or two-week duration is generally sufficient to reliably compare year-on-year flows and detect relatively small trends because there are thousands of vehicles counted and there is a small variation from the mean traffic volumes. But with few riders counted at a given site, a longer duration is needed to enable statistically reliable comparisons. Davies, Emmerson et al. (1999) suggest a duration of seven days per year to achieve a 90% confidence of detecting a 20% change in volumes, assuming a coefficient of variation (CV[1]) of 0.15 for sites with 250 or more daily riders.

Without significant interventions (such as the UK's Demonstration Towns or the UCP), a 20% increase per year in cycle volumes may be overly optimistic for most New Zealand urban areas and thus a longer count duration will be required. On the other hand, higher cycle traffic sites in New Zealand will have volumes in the up to around 1000 daily riders, thus a lower CV can be used.

To achieve a 90% confidence of detecting a 10% change in volumes, a CV of 0.10 is required. An analysis of permanent count sites in Christchurch gives a CV of around 0.35 (Hughes 2010), but shows strong correlation between two of the three permanent count sites. This suggests that given sufficient

[1] Coefficient of Variation – a measure of the relative variation of data, taken as the standard deviation of the cycle volume divided by the mean cycle volume. CV is normally lower for sites with higher volumes

permanent count sites which exhibit good correlation and careful matching of site characteristics, a shorter duration for temporary sites may still be possible. In the absence of a statistical analysis, two-week durations for temporary sites should be the absolute minimum and longer durations are preferable to more accurately apply seasonal and weather adjustment factors.

The Palmerston North Cycling Monitoring Plan (PNCMP)

The Palmerston North Cycling Monitoring Plan (PNCMP) has grown from early lists and service level agreements with contractors to a full and detailed plan in the following stages.

Initial automatic counts with pneumatic tubes (2002–2011)

Palmerston North City Council had been monitoring cycle use on its roading network since the early 2000s. Initially, technology was not readily available, so only a few key sites were selected for monitoring with standard pneumatic tube counters. A classification scheme based on wheelbase and speed was applied to the count data in order to ‘filter’ for bicycle traffic. The counting programme was managed through Excel-based collation of the annual daily traffic values contained in exported results from the classification software, as well as stored in the Road Assessment and Maintenance Management (RAMM) database used by all New Zealand authorities. Instructions were given to the contractors via Service Level Agreements (SLAs), but the actual details of counting cyclists were often unspecified – later leading to some questions about the accuracy of counts.

Expanding the monitoring programme with inductive loops (2012–2016)

As technology improved and counting budgets were increased, the number of sites grew together with the addition of inductive loops and infrared pedestrian sensors on shared paths. By 2017, the city had planned 10 (7 existing, 3 proposed) continuous count sites and 46 (20 existing, 26 proposed) short-term count sites.

Prior to equipment selection, PNCC staff researched technology that could monitor pedestrians and cyclists, with a focus on the former. Phase one was to (a) select a supplier, (b) install counters onto shared paths, (c) check and analyse the data and (d) refine the automatic count programme. Suppliers were interviewed before final selection of EcoCount technology that can differentiate cyclists and pedestrians, and has two types of on-road counters suitable for mixed traffic.

Reviewing and rationalising the sites (2017)

A review of all sites was conducted to determine whether site-specific factors such as on-street parking were likely to render standard tubes inaccurate. Figure 5 shows count sites to remain in relation to the cycle network, where solid lines indicate existing cycleways and dashed lines show proposed cycleways and the colours refer to the type of facility. The analysis has identified that six sites (out of 33 existing sites) can be retired with another 13 to be monitored with another technology.

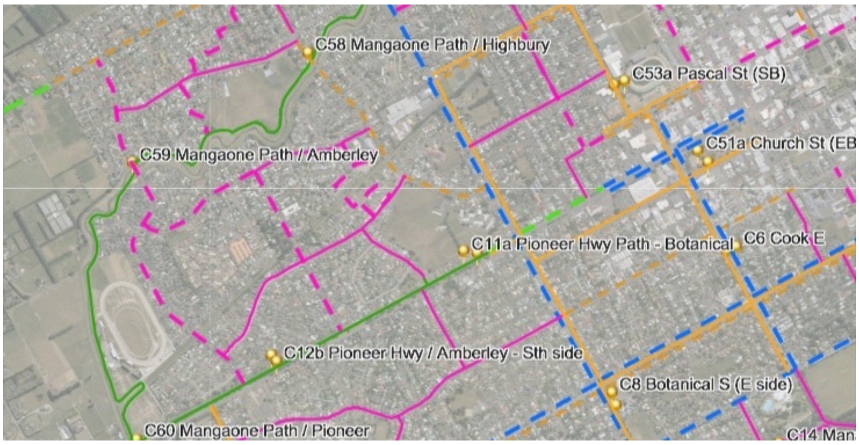

Figure 5: map (cropped) showing revised short term tube count programme

The preparation of the PNCMP included a cleaning and analysis of previously collected data, yielding important insights. Figure 6 presents a comparison of weekend versus weekday cycle traffic, showing that some sites are strongly recreational (e.g. the recently installed Linton path, which is as yet a no-exit facility, and the Te Matai Road pathway). Conversely, the Tennent Drive path is strongly commuter-focused with a 77% weekday bias, with four times higher traffic during the week than on weekends.

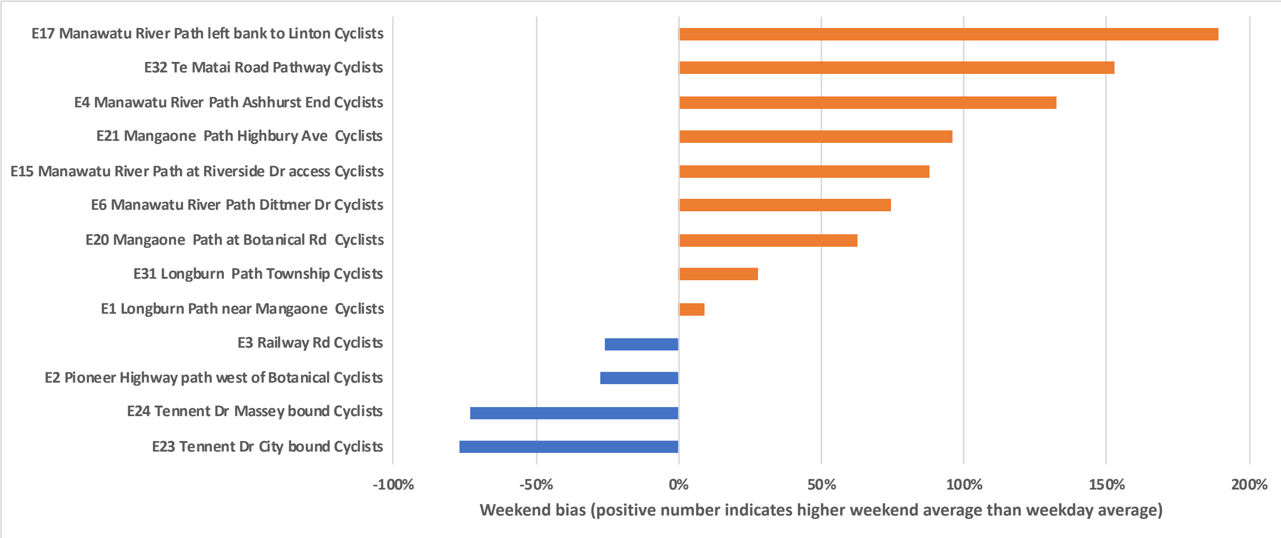

Figure 6: recreational versus commuter bias at various path sites

The contractor has been trained on how to 'rotate' an inductive loop logger between permanently installed count stations every two months. This will maximise the site-hours of data collected while still achieving a robust count duration and leveraging the previous equipment investments.

Next steps will include the procurement of mobile pedestrian/cycle counters and the installation of a real-time display on Fitzherbert Avenue. The real-time display is intended to raise the profile of active transport and create some interest and buy-in from the community.

Manual counts

One-off manual counts have been continued as necessary capital project development components. Palmerston North conducted its first annual manual count in March 2018 at 17 sites forming a cordon around the central city. The results are summarised in Table 2 and show that while there is a fair amount of cycling going on, it is dominated by males which is a potential indicator of the perceived safety of the network (Aldred and Dales 2017). This kind of insight is not possible solely with automatic counters. The annual cordon count may therefore be augmented by simultaneous manual counts on other key corridors such as the route to Massey University.

Table 2: Palmerston North manual count summary

Female %	Adult %	Footpath riding %	Total riders
17%	59%	8%	561

Areas for improvement

Through our multi-year effort, we have learned:

- Installation of permanent counters is technically challenging and, in most cases, should be guided by the manufacturer's representatives rather than local contractors. Where local products have been substituted (such as off-the shelf bollards for the pedestrian sensors) and not properly concreted in place, higher error rates have resulted
- Pneumatic tube counts are likely to have substantial error rates and there is a need to validate existing technologies and potentially adopt new ones

- More effort needs to be allocated to data management, cleaning, analysis and reporting or else the investment in counts is not leveraged

In addition to the raw data collected through manual and automatic counts, the following metrics have not been well-tracked in Palmerston North and it is hoped that this will change with the use of the Monitoring Plan and rollout of a city-wide school travel planning effort. In addition to activity level monitoring, the Monitoring Plan calls for surveys that will help give a better indication of what influences people to ride:

- How many people would like to bike versus how many have got on a bike and tried it?
- How many have used new infrastructure and who likes a new facility, project or idea?
- What schools have we worked in and how has mode share changed?

Getting the word out

Report cards

The first known annually-issued monitoring and progress report was Copenhagen's 2006 Bicycle Account (Urban Systems 2013). Since then, numerous cities including Portland, San Francisco and Minneapolis have released their own annual reports.

New Zealand's best example is Auckland's glossy, info-graphic laden Cycling Account (Auckland Transport 2018).

For Palmerston North, the Monitoring Plan recommended a simple annual report card. The first version of this is provided in Appendix A; it is planned to have this formatted by a graphic designer and published on the council's website to inform the public.

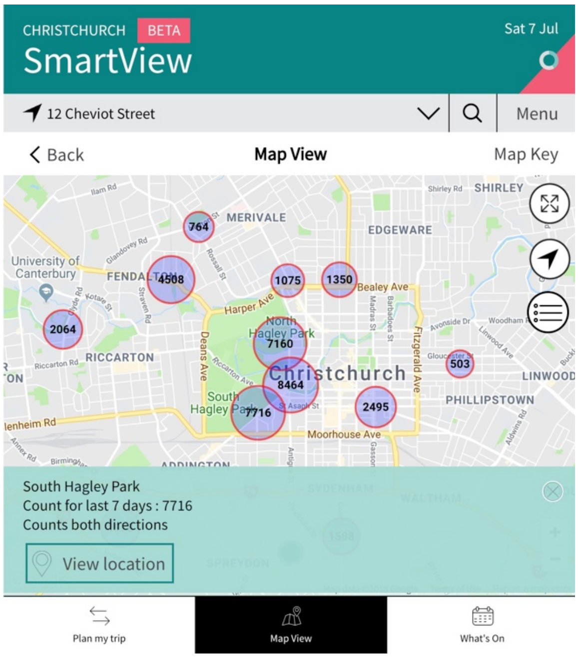

Figure 7: Screen capture of the SmartView app in Christchurch

Online reporting

Christchurch is pioneering a new public interface for cycle counts (amongst a range of other transport datasets) called SmartView (Christchurch City Council 2018). The SmartView app permits users to pan around a map of the city and interrogate cycle count data (illustrated by the blue filled red circles in Figure 7). From the home page, a viewer clicks through 'on the go', then 'cycle counters', then can pan around the city and click on count sites for the most recent data. It also has layers for other transport modes such as the bus network and route planning assistance.

Real-time displays at specific locations

Real-time displays of daily and annual cycle traffic at a particular point are now present in at least three locations across New Zealand: Auckland, Napier, and Christchurch (Figure 8). Such displays encourage cycling by communicating to cyclists that they are a priority while 'suggesting' cycling to those not currently riding. An area for further research is the impact of such displays on rider and non-rider attitudes.

Figure 8: a real-time display on the Antigua Street bridge, Christchurch

Conclusions and recommendations

While we are investing in infrastructure and promotion we want to know that we are making a difference and that we are investing in the right places at the right time. Monitoring is one way of determining what is making a difference in our effort to provide a more multi-modal, safe environment for all road users. By gauging the gender, age, and geographic distribution of people on bikes we can better assess if we are delivering for all our residents (and visitors). By implementing the PNCMP, it is anticipated that data quality will improve so activity levels can be utilised in the prioritisation and justification of future investments. So far, the data indicate that the number of cycling trips on pathways is increasing while cycling trips on roads is decreasing. This suggests that Palmerston North's rapid expansion of the path network is paying dividends, while the on-street lanes still require improvement (and/or promotion).

Because actual and perceived safety is a key barrier for people to choose to cycle, it is important to collect and analyse safety data (e.g. crashes reported in the Crash Analysis System and other proxy measures). However this paper focuses on volume data collection and analysis.

While collecting and analysing data is important, it is even more important to make it accessible to the general public and to use it when planning new or upgraded facilities. Annual report cards, real-time displays, and live web applications are now being used around New Zealand and should be emulated more widely to communicate that cycling in particular is not a fringe activity but happening everywhere.

To manage an effective count programme, it is recommended that practitioners:

- Use a site ID and maintain accurate count location information to help others who either get involved in the programme or need to use the data
- Regularly review the sites where data is collected to ensure that a representative sample of locations is being monitored, within the available budget
- Conduct automatic counts for a minimum of 14 days to allow scaling up to annual averages, reduce variability, and enable the identification of trends
- While automatic counting is becoming more affordable and reliable, continue to conduct annual manual counts to collect age, gender, and behavioural information (e.g. footpath and/or contraflow cycling)
- Publish an annual report card on the local authority's website, including progress in developing the network as well as volume data and trends

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Declaration of competing interests

The authors declare no competing financial interests. Metrocount and EcoCount are providing loan equipment to the lead author for a planned update to the referenced Continuous Cycle Counting Trial.

Appendix A: Palmerston North Cycle Report Card 2017/18[2]

The following is a simple report card example that is planned to be formatted for public distribution and will be built upon in future years with school and public survey data. Footnotes will be simplified.

561	**People cycling in the *central city* on an average *morning* (2h)[3]**
667	**People cycling along *Tennent Drive* on average *weekday*[4]**
540 (-21%)	**People cycling at nine *on-street* count stations *daily*[5]**
129,480 (+3.1%)	**People cycling at four *path* count stations *yearly*[6]**
1.7 million	**Estimated cycling *trips* per *year* in Palmerston North[7]**
5%	**Decline in reported cycle crashes from 2012 to 2017**
Future metric	**Palmerston North residents interested but concerned about riding to work or school**
To be reported in 2018/19	**Walk and cycle mode share at participating schools**
70 km	**Length of cycle lanes and shared paths in Palmerston North[8]**

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[2] Refer to Monitoring Plan 2017 for all sources

[3] A manual count of people riding bikes across a complete 17 station cordon around the central city is taken one 7-9am morning peak period every March. In March 2018, there were 382 riders counted riding into the central city and 179 out of the central city; it is acknowledged that some people may be counted twice (e.g. Boy's High riders entering from Fitzherbert Avenue and exiting via Rangitikei Street). A manual count captures a snapshot of gender and age. In Palmerston North, these metrics for 2018 were 83% male and estimated 59% adult (vs. school age riders).

[4] Sum of both directions; excludes holiday period (i.e. from 15/01/18 to 18/04/18). Permanent continuous counters were installed in 2017; trends will be reported in future years.

[5] Sites are C03 Ruahine St, C04 Milson Line, C05 Rangitikei St, C06 Cook St, C07 Broadway, C34 Fitzherbert Av, C35 Victoria Av, C50 Summerhill Dr, C53 Pascal St. Percentage change compared with average from previous 5 years.

[6] Sites are E1 Longburn Path (Maxwells Line end), E2 Pioneer Path (Botanical end), E6 Manawatu River Path (Dittmer Dr end), E31 Longburn Path (in township). Percentage change is 2017 vs 2016; feasible to compare one year to previous year (rather than a rolling average of several previous years) because the sample size is much larger (nearly continuous). For some sites, gaps in the data have been smoothed.

[7] Refer to monitoring plan for calculation method.

[8] In addition to the 26 km of cycle lanes (measured from the road centerline, not both sides of a road) and 43 km of shared paths (both sealed and unsealed), there are 27 km of 'quiet streets' with low volumes and speeds and 9 km of designated rural road shoulders meeting Austroads guidelines for cycling width.