MONEY WELL SPENT? THE CHALLENGE OF FINDING PRIMARY DATA TO DEMONSTRATE SOUND INFRASTRUCTURE INVESTMENT

Richard Young, MICE, MBA, MSc, BSc (Hons), Principal Project Manager Waikato Expressway, New Zealand Transport Agency. Richard.young@nzta.govt.nz – Presenter

Chris Vallyon MIR (Merit), LLB, PLSC, BA, Senior Transportation Analyst, Beca chris.vallyon@beca.com – Presenter

ABSTRACT
The government has announced a $7.5 billion dollar programme investing in major transportation projects.

This paper will discuss some of the challenges facing collecting data to support these projects, and how new technologies are assisting in meeting these challenges.

The paper will provide the Waikato Expressway project as a case study, with the New Zealand Transport Agency (NZTA) project manager’s perspective on the need for good data and reasons for the solutions chosen.

The paper will examine the effectiveness of one new technology and how this has been applied to the rapid assessment of the performance of a recently open section of the Waikato Expressway. In addition the paper will highlight additional uses for the chosen technology that have become apparent during its deployment.
INTRODUCTION

There is an increasing requirement for infrastructure providers to demonstrate that the benefits that projects were targeted to achieve are being delivered. With respect to major roading projects, these benefits are often long term and strategic in nature as the return on investment takes time, however as a profession we can seek proxy measurements that can rapidly be deployed to indicate that we are ‘heading in the correct direction’. These need not be substitutes for longer term monitoring but it would be desirable to establish pre and post-delivery assessment systems that provide both this rapid assessment whilst gathering data for longer term evaluation.

For roading schemes there are numerous methods for post-implementation assessment of the effectiveness of road infrastructure improvements. These are shown in Table 1.

Table 1 – typical assessment methods for evaluation of roading improvements.

<table>
<thead>
<tr>
<th>Metric</th>
<th>Measure</th>
<th>Strengths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Journey time saving</td>
<td>Floating car surveys</td>
<td>Accurate, readily measured.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Small sample size, infrequent. Lacks temporal coverage (ok for annual trends, but less suitable for assessing reliability or peak spread)</td>
</tr>
<tr>
<td>Crash reduction</td>
<td>Long term crash data (5 years)</td>
<td>Can identify trends, crashes are well documented.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Statistical methods are prone to distortion, long period needed for data collection</td>
</tr>
<tr>
<td>Diversion rates</td>
<td>Number plate surveys, stated preference surveys</td>
<td>Accurate, high quality data.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Expensive, potentially time and labour intensive as they have to be established for finite periods and then analysed. Concerns over privacy and law enforcement applications</td>
</tr>
<tr>
<td>Economic stimulus</td>
<td>Gross Vehicle Movements - Vehicle Counters (AADT), ANZ heavy and Light Traffic Index</td>
<td>High volume of data, cheap and easy to collect. Collected nationally.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No location intelligence within data. Are vehicle numbers a realistic proxy for economic stimulus? Little vehicle type data.</td>
</tr>
<tr>
<td>Migration away from car usage</td>
<td>Public transport utilisation</td>
<td>Relatively simple to collect.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>May be influenced by many extraneous factors (fare structure, timetabling etc)</td>
</tr>
</tbody>
</table>

MEASURING THE PERFORMANCE OF THE WAIKATO EXPRESSWAY

In the Waikato Region, the Waikato Expressway (Figure 1) will be a 102km length of continuous divided four-lane highway which will reduce the length of State Highway 1 by 6km. It will provide a further 12km of new or upgraded links and a new bridge over the Waikato River north of Hamilton. The stated benefits are to:

- significantly reduce the number of fatal and serious injury crashes,
- increase the highway's capacity and passing opportunities,
- reduce traffic congestion within smaller communities like Huntly, Ngaruawahia and Cambridge,
- reduce fuel costs and contribute to economic growth,
- improve economic growth and productivity for Auckland, Waikato and Bay of Plenty through more efficient movement of people and freight between Auckland, Hamilton, Tauranga and Rotorua
- improve the reliability of the transport network through a more robust and safer road between Auckland, Hamilton, Tauranga and Rotorua
- reduce travel times between Waikato and Auckland (Auckland to Tirau by 35 minutes)
- support the growth strategy for the central Waikato.

The inclusion of Wider Economic Benefits in the infrastructure investment justification provides unique challenges in developing methodologies to directly relate the lead infrastructure investment to economic growth.

Three sections were completed prior to the announcement of the New Zealand Government’s Roads of National Significance programme (RoNS) in 2009, which includes the Waikato Expressway (and new projects in Pokeno, Mercer & Ohinewai).
The remaining construction is staged into eight sections, each of which has its own completion date, with the corridor target completion date of 2019. Of these eight sections the Te Rapa section was opened in December 2012 with the Ngaruawahia Section to open in late 2013 and three more sections scheduled for 2016.

Given the staged and long time frame for completion of the Waikato Expressway it was not considered acceptable to delay assessing its effectiveness into after 2020. The challenge was to collect data that could be utilised in assessing the incremental benefits as each section is opened whilst ensuring that this data could be aggregated until 2019 and compared with relevant data collected prior to the opening of each section.

Due to the limitations identified in Table 1, none of the conventional methodologies were considered ideal to provide early, regular, location specific and cost effective data. As a result the NZTA engaged Beca to extend the innovative Bluetooth based monitoring infrastructure that has been deployed at key locations within Auckland (and Wellington) to provide cumulative and near real-time data on vehicle routing and journey time.
The Innovative Technology Solution
The solution that the NZTA has adopted to capture journey time data relies on the fact that a statistically significant proportion of vehicles on the highway network are travelling with Bluetooth devices switched on. These devices operate using unique serial numbers (MAC addresses) which the Bluetooth roadside sensors detect as the vehicle drives passed them. By correlating the time each vehicle passes the roadside detectors with the detector’s location we can determine the following:-

- Journey time (between two or more sensors)
- Journey reliability (statistically meaningful data derived from 1000’s of results)
- Vehicle routings and timing (vehicles passing multiple roadside sensors)
- Near real-time performance (typically every 10-20 minutes, but various depending on route length and traffic volumes)
- Pre and post road opening data (all data is stored and can be retrieved for spreadsheet analysis)

![Figure 2 - Installed roadside Sensor](image)

Given the ease and relatively low cost of deployment of these roadside sensors (all they need is a power source to charge the battery and 3G signal coverage) a suite of nine roadside sensors was procured and deployed between the Bombay Hills and Cambridge covering SH1, SH1B and part of SH39. Through the occasional re-location of some of the sensors over a four year period sufficient data will be collected to establish pre-construction base-line travel times and journey reliability which could then be compared to post-construction data on each individual section of the Waikato Expressway.

International Bluetooth Systems
Bluetooth matching involves scanning for Bluetooth-enabled devices (such as cellular phones, hands free devices, some car stereos, GPS in-car navigation, etc) to identify unique devices passing a survey location. Every Bluetooth device contains a unique MAC address, which is used for the purposes of encrypting communication between devices once they “handshake”. This is so that a third device, while in range, will not be able to interpret the short wave Bluetooth communication. For example, a person talking on a Bluetooth hands-free kit does not need to worry about another nearby hands-free kit listening to the conversation.

By scanning for these devices it is possible to identify MAC addresses, record time stamps, and then match MAC addresses at another location. It is then possible to infer a journey has been made between two or more locations and an approximate travel time can be calculated. Unlike automatic number plate recognition (ANPR), the Bluetooth device volunteers its unique identifier number, without the need for expensive video analytics.

Bluetooth matching is an attractive technology because it is relatively cheap (compared to ANPR) and affords statistically significant sample of data (>10%) in real time and due to its anonymity can be stored indefinitely and data-mined. Where it is installed, it can be used to identify travel times year round. It can identify travel times during the day, and therefore identify changes to peak spread, congestion reliability, the effects of holiday peak loading, etc. Lastly, as it involves unique identifying numbers, it can be used to determine trip choice between Bluetooth matching units.

Bluetooth matching is still an emerging technology in New Zealand, but has a growing presence for analysis of travel times and trip choice to study the impact of major capital projects.
Overseas, a number of vendor solutions and government developed systems are being used not only for historic analysis, but are also being used for such things as real time incident detection and real time traveller information. Permanent Bluetooth matching systems have been established in a number of locations, including in Adelaide, Brisbane, Calgary, Barcelona, Houston, Denmark, etc.

**Privacy**

Unlike number plates or cell phone IDE numbers (the unique number embedded in all phone handsets used by cellphone companies to identify where to route phone calls and texts), there is no way of tracing the MAC number back to the owner, as there are a variety of types of device with Bluetooth, and no database matching these devices to their owners.

Although there may be potential sensitivities for using Bluetooth, in theory, the MAC address numbers can only be identified / observed if the Bluetooth device is on and the privacy settings have been set to allow it. (i.e. the Bluetooth is set to ‘visible’), although anecdotally some vendors have claimed to detect devices even when privacy modes are active, although this may aggravate potential privacy sensitivities. These MAC addresses are unconnected with any phone number or IMEI (International Mobile station Equipment Identity).

When Bluetooth ‘discovery’ is turned on by the user, the MAC address is identifiable in order to allow the ‘pairing’ of Bluetooth devices. The roadside Bluetooth sensor detects the MAC address number from devices carried by passing vehicles. To further protect privacy sensitivities, the “BlipTrack” hardware deployed in the Waikato is equipped with further features. The anonymous MAC address numbers scrambled using a rotating sequence which produces a ‘hash code’ and it is this ‘hash code’ that is transmitted to the vendor who collates it into median journey times for groups of vehicles (further anonymising the data) to provide the journey time data via a secure internet connection to the NZTA. The MAC address numbers are not stored. Further details relating to privacy can be found in the vendor’s publication. iv

**Effectiveness: Initial Waikato Expressway Findings**

To be an effective tool to be utilised for post-implementation assessment it is essential that that the data collected is both reliable and representative. To assess these areas, a comparison between conventional methods (Floating Car Survey) was undertaken.

A comparison between the Bluetooth journey time data recorded over a two month period along the project area for the Waikato Expressway was undertaken and compared with a floating car survey undertaken during the same period. (Table 2)

<table>
<thead>
<tr>
<th>Journey</th>
<th>Floating Car (obeying ALL speed limits)</th>
<th>Google Maps</th>
<th>Bluetooth traffic sensor (median)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bombay Hills to South of Cambridge</td>
<td>1 hour 29 minutes (off peak) 1 hour 34 minutes (peak)</td>
<td>1 hour 30 minutes</td>
<td>1 hour 31 minutes</td>
</tr>
</tbody>
</table>

The Bluetooth sensor data is based on 293,728 individual records over a three month period. As Bluetooth tracks continuously, the result covers both the peak and off peak Floating Car results. The Bluetooth data can, however, provide a far greater quantity of data than the Floating Car method. With close to 300,000 results the Standard Deviation (S.D.) of 4.5 is determined which, when shown graphically (Figure 3) demonstrates not only the clear median duration but also the journey reliability fluctuation about that median.
The median journey time closely correlates with Floating Car survey and the vast number of data provides for the first time a meaningful assessment of reliability, such that to have a 95% confidence of arriving at a given time a driver would need to leave $91\text{mins} + 1.96 \times 4.5\text{mins} = 100$ minutes. Or in real-world language ‘It should take an hour and a half but I’ll leave an extra ten minutes early in case I get delayed!’

![Distribution of Journey Times between the Bombay Hills and South of Cambridge](image)

Figure 3 - Distribution of Journey Times between the Bombay Hills and South of Cambridge

It is accepted that not all vehicles contain Bluetooth devices, so the data collected using this methodology is a sample of all traffic. It is therefore of interest to identify the size of the sample.

Between two of the Waikato Bluetooth sensors (3684-3677) the NZTA has a dual Loop traffic detector Ref 01N10477 which records the total traffic volume. The most recent published data for this detector (2011) in an AADT are shown in Table 3.

Table 3 – Correlation between measured vehicle numbers on detector loops and Bluetooth sensor

<table>
<thead>
<tr>
<th>Location</th>
<th>Loop Detector 01N10477(2011)</th>
<th>Average count / day from Bluetooth Roadside Sensor</th>
<th>Approximate sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northbound</td>
<td>10304</td>
<td>1984.82</td>
<td>19.25%</td>
</tr>
<tr>
<td>Southbound</td>
<td>10370</td>
<td>1864.5</td>
<td>17.98%</td>
</tr>
</tbody>
</table>

That fact that both readings are within a 1.5% of each other would indicate that approximately 18% of vehicles have some form of Bluetooth device enabled. This figure is slightly lower than Danish Research which recorded a 27% Bluetooth saturation in October 2012, although it is unsurprising that the wealthier Denmark had a slightly higher level of market saturation. Based on these findings, we are able to reasonably conclude that for every journey the Bluetooth sensors record there are roughly four similar journeys between each sensor. This provides a very high sample rate, and suggests inferences drawn from the sample are likely to be robust.

With the effectiveness of the Bluetooth system validated, the sensors are now collecting significant quantities of data which is being utilised for a growing number of applications. These applications include the original objective of demonstrating journey time savings, however the data usage is being broadened to include the validation of regional traffic modelling, integration into city wide traffic planning (Hamilton), Inter-Regional (Upper North Island) and National (Wellington) traffic monitoring and planning and also the real time management of the State Highway network.
Journey Time Savings

The opening of the Te Rapa section of the Waikato Expressway has been the first time a major ‘before’ and ‘after’ opening assessment using Bluetooth sensors has been undertaken in New Zealand. The new road alignment takes State Highway traffic away from the congested Te Rapa commercial / industrial area to the north of Hamilton. To measure the effectiveness of the new Expressway Bluetooth sensors recorded traffic flows for approximately three months prior to its opening and after opening they were configured to not only detect the journey time changes but also the relative proportion of traffic using the new and old routes. Figure 5 shows the Expressway alignment together with the locations of the three Bluetooth sensors that were deployed. A summary of the data recorded in provided in Table 4.
Table 4 – Summary of vehicle volumes and journey times before and after the opening of the Te Rapa Section of the Waikato Expressway.

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Bluetooth Sensors in use (Fig 4)</th>
<th>Date To</th>
<th>Bluetooth matches</th>
<th>Median Journey Time (Minutes)</th>
<th>Median Time saving after opening (median mins)</th>
</tr>
</thead>
<tbody>
<tr>
<td>New road under construction, all traffic on Old SH1 (Te Rapa Road)</td>
<td>1,2</td>
<td>21/9/12-2/12/12</td>
<td>29,847</td>
<td>22.2</td>
<td>-</td>
</tr>
<tr>
<td>Pre Opening Total Count (Not AADT)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expressway open, counting traffic on Expressway and avoiding Te Rapa Road</td>
<td>1,3,2</td>
<td>3/12/12-29/01/13</td>
<td>26,131</td>
<td>18.9</td>
<td>3.3</td>
</tr>
<tr>
<td>Expressway open, counting traffic on Old SH1 using Te Rapa Road</td>
<td>1,2 not passing 3</td>
<td>3/12/12-29/01/13</td>
<td>34,584</td>
<td>20.1</td>
<td>2.1</td>
</tr>
<tr>
<td>Post Opening Total (Not AADT)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note, as the route has only very recently opened at the time this data was collected, there may be a number of new, induced trips, as people investigate the new road. The number of observations is likely to settle as traffic behaviour stabilises. Based on this large data set it has been possible to demonstrate that journey time savings averaging 3.3 minutes have been obtained by the vehicles that have diverted onto the Waikato Expressway and a 2.1 minute saving by vehicles that are continuing to use the Old SH1 Te Rapa Road. Whilst these savings may not appear substantial, when the NZTA assessment of ‘NZ Inc.’ time saving of $21.7/hour is allowed for and the 2011 AADT of the Te Rapa area factored in (38,700 on Te Rapa Road, 19,900 at Horotiu). The daily saving to the New Zealand economy can be estimated as:-

- 19,900 vehicles saving 3.3 minutes x $21.7/hour = $23,750 plus
- (38700-19900) vehicles saving 2 minutes x $21.7/hour = $14,280
- Totalling $38,000/day or some $7.6M in weekday travel time savings each year.

It is accepted that this preliminary finding is a simplification of an exceedingly complex economic evaluation process that the NZTA applies, however the Bluetooth sensor data collected in real-time enable these types of assessments to be undertaken very rapidly and to gather statistically significantly data reliably and efficiently using year round data. These initial results compare favourably to the time savings predicted in the project investigation stage. The initial findings can be re-evaluated later in the year to compare data unaffected by seasonal variance / holiday traffic.

In more detail the Peak hour (7-10am, 4-7pm) time savings are greater than the 3.3 minutes average saving with savings of 3.6 and 4.1 minutes recorded for the morning and evening Southbound traffic. When the increase in journey reliability provided by the Te Rapa Section of the Waikato Expressway the 95% confidence level rises to 4.8 and 5.1 minutes respectively.

<table>
<thead>
<tr>
<th>Journey</th>
<th>Before Te Rapa Expressway Opened (mins)</th>
<th>Standard Deviation</th>
<th>Before Te Rapa Expressway Opened (Number of journeys recorded)</th>
<th>After Te Rapa Expressway Opened (mins)</th>
<th>Standard Deviation</th>
<th>After Te Rapa Expressway Opened (Number of journeys recorded)</th>
<th>Average Saving (minutes)</th>
<th>95% confidence level of Journey Time saving (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morning Peak</td>
<td>22.7</td>
<td>SD 1.67</td>
<td>(3911)</td>
<td>19.1</td>
<td>SD 1.07</td>
<td>(3175)</td>
<td>3.6</td>
<td>4.8</td>
</tr>
<tr>
<td>Evening Peak</td>
<td>22.6</td>
<td>SD 1.40</td>
<td>(4519)</td>
<td>18.5</td>
<td>SD 0.88</td>
<td>(3768)</td>
<td>4.1</td>
<td>5.1</td>
</tr>
</tbody>
</table>
Money Well Spent? Richard Young, Chris Vallyon

Or in real-world language ‘Te Rapa Section of the Waikato Expressway means I can bank on a 5 minutes peak time saving north from Hamilton’. The ability to use the large sample sizes to assess reliability is the first time this approach has been utilised in New Zealand.

The Bluetooth network in the Waikato also allows for an assessment of both the local impacts and the effects on the corridor as a whole. This enables cumulative benefits to be calculated, and also reduces the likelihood that downstream congestion is ignored when calculating benefits.

**Further Work and Potential**

The deployment of the Bluetooth sensors on the Waikato Expressway project is in its fifth month of an eight to ten year project. The data that has been collected to date has enabled the technology to be validated for ‘before’ and ‘after’ assessments of roading projects and will be updated.

The collection of data and subsequent analysis will continue throughout 2013-15 to provide baseline information along the Expressway route as well as post implementation data.

The biggest single test of the technology will be late in 2013 when the Ngaruawahia Section of the Waikato Expressway opens and the NZTA revokes significant lengths of SH1 and SH39. Not only are we anticipating significant journey time savings but also substantial re-routing of existing SH1B and SH39 traffic.

There is considerable interest in both accessing the existing data as well as extending the network on both State Highways and Hamilton City roads. As such this project, which was originally conceived to provide data related to the Waikato Expressway is likely to become a strategic regional tool. With regards to the information, the team has only started scratching the surface and the system lends itself to data mining to further examine trends. This analysis can include extended assessments of Bluetooth penetration and in collaboration with other techniques to better identify vehicle types.

**COMMERCIAL GPS Data**

Another technology being developed by the NZTA to assist with identifying the effectiveness of investment involves GPS data. This is explained as follows.

Currently, there are a variety of companies that provide GPS in vehicle navigation or GPS based fleet management systems, including NavmanWireless, Snitch, Argus Tracking, etc. Even vehicles without a specific vehicle navigation or fleet management system may have a working GPS on-board if an occupant has a Smart-phone with the right software installed. Information collected from GPS on Android based cellphone operating systems is used to inform and update Google Traffic, although the harvest rate depends on whether the phone is idle or actively being used for navigation.

There are now several webpages available to New Zealand drivers with real time traffic conditions derived from using some form of vehicle navigation system.

Unlike floating vehicle surveys, which use a controlled sample of survey vehicles travelling a specific route, fleet GPS analysis involves GPS data from vehicles that may be travelling through some or all of the study area.

**Strengths**

A primary strength of this technology is that the information can be collected anywhere on the transport network, without the need for new infrastructure. However, the primary limitation is that there is no guarantee that the vehicles will remain on the desired route or travel without stopping for unknown reasons. Unlike vehicle matching – whereby a vehicle is known to have passed two or more points – real time monitoring systems collect data from vehicles anywhere on the network, but as with matching technologies, have no control over what the vehicle does along the way.

Commercial GPS data has several attractive features. Firstly, it requires no new hardware
infrastructure to be installed. Secondly, the data is being collected all the time by commercial vendors. It is therefore possible to identify a route and then obtain data from prior to the identification process – something which has not previously been possible due to the inability to travel back in time. Lastly, the use of GPS offers the potential to identify travel behaviour, as specific vehicles can be traced individually or collectively, although this in turn raises significant privacy sensitivities.

Typically, vehicle navigation systems and online congestion pages require a precoded network. GPS data is then utilised by identifying an average speed / time for all vehicles passing through a specific route segment. This is then aggregated spatially for any given route by adding the travel times for each route segment. This method resolves privacy issues as the vehicles remain anonymous and are merely sampled to derive speeds /times at specific locations. This is very similar to aggregating for point speed technologies, but covers the entire network. However, this process resolves privacy issues as the source data is effectively anonymous. For this type of system, it is possible to store all GPS data points or just to store a record of aggregated times/speeds for individual segments, derived using the fleet GPS data.

Limitations
One downside of using commercial GPS data is that, currently, there are so many vendors that while a good proportion of vehicles will carry some form of GPS device, sample rates are influenced by the market share of individual vendors, and are significantly smaller than for Bluetooth matching. There is also the risk of introducing an unintentional sample bias if, for instance, the sample includes a large portion of vehicles that engage in atypical behaviour (taxis, courier vehicles, etc). This risk can be an unknown factor if the composition of the fleet is unknown to the analysts.

The total cost for establishing a system using private/commercial GPS is a very expensive process as it requires in-vehicle GPS for every vehicle being tracked, and then an extensive investment in software and data storage. For the most part, these systems are almost exclusively developed by private companies, which can recover the costs by selling products and services to organisations which rely on the data, (e.g. fleet management and navigation tools). Government access to this data is therefore typically by entering into a commercial arrangement with an existing vendor, which in turn requires a vendor with realistic financial expectations, a suitable business model and reliable level of service. The quantity of the available data is then limited by the market share of the chosen vendor.

Data for Electronic Road User Charges (eRUC)
The NZTA has investigated several potential sources of private GPS data. Of these, perhaps the most interesting relates to data collected for the purposes of electronic road user charges (eRUC). All vehicles over 3,500kg and all diesel vehicles pay a per kilometre road user charge (RUC). Historically, this road user charge has been paid in advance as a license for a specific vehicle to travel a specific number of kilometres. A mechanical odometer then counts the number of times an axle rotates to calculate mileage for the purpose of identifying when the license expires and needs to be renewed. However, manual odometers can be tampered with, and can also become faulty of their own accord. As a result, drivers are required to keep log books which can then be cross referenced against odometer readings. Enforcement typically involves a random audit of vehicles to determine if any are driving with an expired RUC license, and log books checked to identify signs of tampering of fraud.

eRUC is a system whereby the NZTA grants permitted vendors a license to provide road user charges through an electronic GPS based system. Instead of a manual odometer, approved GPS devices are fitted to a vehicle to calculate distance travelled. The NZTA has approved two features which make this more attractive. Firstly, purchasers of eRUC no longer have to pay for mileage that occurs outside of publicly owned roads, i.e. if a vehicle is driving on a farm road, driveway, logging road, or manoeuvring within a yard, the GPS identifies that this is not a public road and the mileage accrued does not get charged RUC. Secondly, the NZTA has authorised eRUC systems to be closer to a pay-as-you-go system, meaning that operators pay for RUC monthly, rather than
purchasing mileage that may take some time to work through. Additionally, eRUC providers will typically also be selling other fleet management tools, and operate an online dashboard to reduce the effort of managing RUC for individual vehicles.

There are several benefits to the NZTA. Firstly, in terms of RUC, the voluntary adoption of approved tamper-proof GPS systems improves the rate of RUC compliance. The NZTA can then direct its enforcement toward higher risk enterprises. Secondly, the presence of large numbers of GPS on commercial vehicles provides the NZTA with a highly desirable source of data, specifically for commercial vehicles. In the past, understanding commercial/heavy vehicle behaviour has involved stated preference surveys, which although expensive, provide only a limited dataset.

**eRUC Data Explored**

Over the past 12 months, the NZTA have been involved in developing a pilot eRUC analysis system using eRUC data from a commercial eRUC supplier who pioneered the concept and development of eRUC, and was therefore a logical choice for initial exploration of the potential applications for the new technology.

A number of tools have been developed as part of this pilot study, to aid in interrogating data collected for the purposes of eRUC. While the tool currently consists of one data set, the intention is to add other sources of eRUC GPS data as these become available.

The eRUC data has been compared against both floating vehicle surveys and Bluetooth matching data to identify if travel times can be estimated accurately. The Bluetooth matching provides significantly higher number of observations (thousands of sample matches across a month) to compare against, so this is seen as a good source for comparison. To achieve the comparison between eRUC and Bluetooth, both data sets were sampled for the month of March 2012, for an SH1 route through the Central Motorway Junction in Auckland. The data for the month of March 2012 was aggregated to identify an average (representative) travel time flow profile during the day. One would expect to see eRUC data to be slightly slower, as heavy vehicles may travel slightly slower due to the topography of the route, particularly in the northbound direction. In open road locations, commercial vehicles towing trailers of any size are required to travel at 90km/h, however this is not an issue for the CMJ route as the speed limit is only 80km/h.

![Figure 6 Comparison of March 2012 flow profiles, eRUC and Bluetooth matching](image-url)
Figure 6 compares roughly 800 weekday data points for eRUC and roughly 66,000 Bluetooth matches across the month of March 2012. Despite the difference in sample rates, the resulting flow profiles are very similar.

The eRUC data can also provide some idea of reliability along a route. While fleet GPS provides a significantly lower sample rate than Bluetooth, it provides a much greater sample rate than floating vehicle surveys. Additionally, the data is gathered all the time, so it will be possible to identify year round reliability. One example is that it will soon be possible to identify the proportion of commercial vehicle trips between Auckland and Wellington that come close to or exceed 11 hours (the legislated maximum driving time), and how this improves as a result of investment such as the Waikato Expressway, which have the potential to reduce delay along the way. Similarly, the data can be used to assess travel times & reliability for strategic freight routes, freight hubs, port access, etc.

Another significant advantage of the eRUC data is that it is possible to identify a route significant to commercial vehicles and then harvest historic data. Essentially, this provides road operators the ability to “go back in time,” a function impossible with floating vehicle data, and a function which will improve with time as more data is collected.

The eRUC also offers the possibility of identifying trip/route choice, as it is possible to interrogate the raw GPS data directly (something that is currently problematic with other sources of fleet GPS data). The prototype eRUC “screen line” tool makes it possible to not only identify travel times, but also investigate the number of trips crossing specific multiple screen lines. By having a common origin and/or destination and shifting the location of secondary screen lines, it is possible to identify route preference for vehicles contained within the eRUC data set.

The tool has already been used to identify the commercial vehicle split between SH1 and SH1B within the area of the Waikato Expressway RoNS. Based on March 2012 data, the split at Taupiri is roughly 2/3 SH1 and 1/3 SH1B. Beyond this, a significant portion of trips on SH1B head east toward Morrinsville, rather than south toward Cambridge.

It will soon be possible to compare this against data collected more recently to identify the proportion of commercial vehicles travelling on the new SH1 Te Rapa Bypass.

Adding further screen lines makes it possible to identify where vehicles within the sample set travel once this initial choice has been made (for instance, how this split is affected by vehicles travelling to vs travelling passed Hamilton). Within the current data set, only 15% of vehicles travelling on SH1B travelled as far south as Cambridge. However, this is still a work in progress as the current filters mean that a trip “ends” whenever a vehicle comes to a stop (e.g. for refuelling), which makes long distance comparisons problematic. Future iterations will have a choice of filters to make it easier to distinguish between trips and journeys, which may include multiple trip-chains (i.e. the vehicle may stop at intermediary points along the way). This will improve the ability of using eRUC data for inter-regional commercial vehicle analysis.

However, the benefit of access to raw GPS data for thousands of commercial vehicles across the country also creates significant privacy and commercial sensitivities. Currently these are being managed through the use of three-party confidentiality agreements, which govern the use of the information and require privacy and commercial sensitivities to be respected. With the exception of monitoring RUC, the data may not be used for enforcement purposes, as this would potentially act as a deterrent to voluntary uptake of eRUC systems, which in turn would undermine the core benefit to the NZTA of having a low-risk high-compliance revenue gathering system.

eRUC therefore offers significant opportunities for assessing where to invest (through assessing travel behaviour), and then as a further tool for identifying the benefits of intervention on the network, i.e. demonstrating money well spent. Most importantly, this new source of data provides opportunities to identify information specifically relating to commercial & heavy vehicles, allowing directly targeted investment, and providing opportunities to identify benefits for this key road using demographic, in a manner that has never before been possible.
Conclusions

- The use of Bluetooth sensor has proven to be a reliable and exceptionally cost effective method of gathering anonymous traffic flow data that was previously impossible to achieve economically.
- The utilisation of Bluetooth sensors along the Waikato Expressway has proved their effectiveness at gathering quantities of travel time and routing data that was previously inconceivable.
- Sample rates of up around 18% of all vehicles using the corridor have been achieved. No other technique deployed in New Zealand can provide such a high percentage of location and routing specific data for the same cost and longevity.
- The validity of the data has been demonstrated and correlated to more conventional journey time assessment tools.
- The Bluetooth technology and data is truly anonymous and should not cause any privacy issues.
- Due to the statistically significant quantity of data collected, meaningful assessments of journey reliability can be made (95% confidence level). This level of confidence over this geographic area and time period was not cost effectivewithout this technology.
- The data and technology are providing significant opportunities outside of the original scope through widening of the data collection network. This widening is permitting validation of city and regional traffic modelling utilising ‘real world’ data.
- Additionally the real time nature of the data availability is permitting its use in network monitoring in a rural area where more traditional monitoring systems are difficult to justify.
- Analysis of eRUC data, while still evolving, provides a significant additional tool for prioritising funding and assessing effectiveness of investment. The ability to identify travel time and reliability for commercial/heavy vehicles is a significant step forward, as are the tools which allow us to further understand commercial vehicle trip choices and behaviour.
- The ability for the NZTA to collect data from Bluetooth matching and commercial vehicle GPS provides more opportunities to assess its impact on the network than ever before. Along with the standard travel time changes, the NZTA now has more options for assessing travel time reliability, trip choice, peak spread, model validation, etc. This has the potential to significantly improve the information available to engineers, planners, economists, modellers and operational staff.

REFERENCES

vi BlipTrack, 2012, Bliptrack Penetration Studies, version 1.0 http://issuu.com/blipsystems/docs/bliptrack_penetration_case_study_new/1