CONGESTION: WHAT ARE CHRISTCHURCH'S WORST OFFENDING ROADS?

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ABSTRACT

As part of their mandate to "get the greatest efficiency out of the existing roading network", the Christchurch Transport Operations Centre installed Bluetooth sensors throughout the strategic road network in 2013. As well as providing real-time data for a host of operational uses, the data from these sensors have been monitored on a monthly basis to get a better understanding of the city's congestion hotspots. The large volume of data necessitated the development of sophisticated analysis tools and geospatial systems to present the results in a useful way.

The intention behind this project sits firmly in the "Smarter" theme of this conference. The Bluetooth sensors provide a vast amount of data about traffic congestion. The challenge of this project was developing methods of processing the data into meaningful information which can then contribute to smarter decisions being made about the transport network.

Results from July 2014 revealed that the roads with the highest costs of congestion were Fitzgerald Avenue, Brougham Street, Blenheim Road and Bealey Avenue, with congestion costs ranging from $140 - $1,700 per km/hr. The total cost of peak hour congestion for the monitored routes was calculated as $54 million per year. This paper describes the tools developed to monitor congestion in Christchurch, and presents further details of Christchurch's most congested roads, how bad they are and how much they are costing society.

1. INTRODUCTION

Travel patterns in Christchurch have been in a state of change since the Canterbury earthquakes. Changes to residential zones, employment areas, shopping centres and recreational facilities have resulted in changing travel demand. Damage to roads and bridges, and widespread capacity-reducing roadworks are constantly altering the routes people choose to take. As a result, congestion is regularly relocating and is difficult to predict.

In 2013 the Christchurch Transport Operations Centre (CTOC) installed a network of approximately 80 Bluetooth sensors throughout the strategic road network. These record an anonymous timestamp whenever they sense an active Bluetooth device, such as a vehicle's hands-free phone system, stereo, or a mobile phone. By matching the devices recorded by sensors installed at key locations throughout the road network, travel times can be calculated.

This system allows detailed analysis of actual network performance, providing traffic managers and policymakers with a better understanding of how the network is operating. Real-time monitoring of data can detect incidents quickly, and allow traffic managers to intervene to mitigate the impacts.

A Congestion Monitoring System (CMS) was developed to analyse the data on a monthly basis. Various measures of congestion have been developed which can be used to better inform investment, and has helped identify changes to congestion over time. It reflects the conference theme by allowing smarter management of the road network, and a stronger network that is more responsive to incidents.

The CMS has some similarities to traditional traffic models; however, it shows actual network congestion rather than predicted network congestion. This paper focuses on analysis of data collected in July 2014.

2. METHODOLOGY

Existing methods for measuring congestion were investigated. Austroads (Luk, Chin & Han 2012) has developed a methodology for comparative analysis of congested networks based on flow-weighted delay. This methodology gives each link a weighting based upon the volume of traffic using it. However this method requires highly detailed data, being designed to be used in conjunction with traffic modelling outputs. It was not considered suitable for use with the data being sourced from the Christchurch Bluetooth system. Another methodology is the Tom Tom Congestion Index (2013). This was developed to provide drivers with more accurate route information and arrival times to allow better route planning. The methodology compares travel times during non-congested periods (free flow) with travel times in peak hours. The difference is expressed as a percentage increase in travel time. It uses a simple weighting system to recognise the differing importance of local roads, arterials and highways.

A hybrid methodology has been developed to incorporate the more detailed road classifications used in the Austroads method, while having the basic data requirements of the TomTom Congestion Index method. It calculates the percentage increase in travel time (as the Tom Tom methodology does), and then applies a weighting procedure based on the traffic volume of each link (similar to the Austroads method).

The first step was to download the raw travel time data for each of the 186 monitored links in the strategic road network, and filter them to remove all Fridays, Saturdays, Sundays and public holidays (weekday peak periods were the focus of the analysis).

An example of the raw data obtained from the Bluetooth sensor system for one link (Memorial Avenue eastbound, between Grahams Road and Clyde Road) in July 2014 is shown in Figure 1 below. Each cross represents the average travel times recorded over a 15 minute period. The greyed out crosses are those which were removed by the data cleaning process (described later in this paper). The solid red line shows the average travel time, while the dashed yellow line shows the calculated free flow travel time (explained later in this paper).

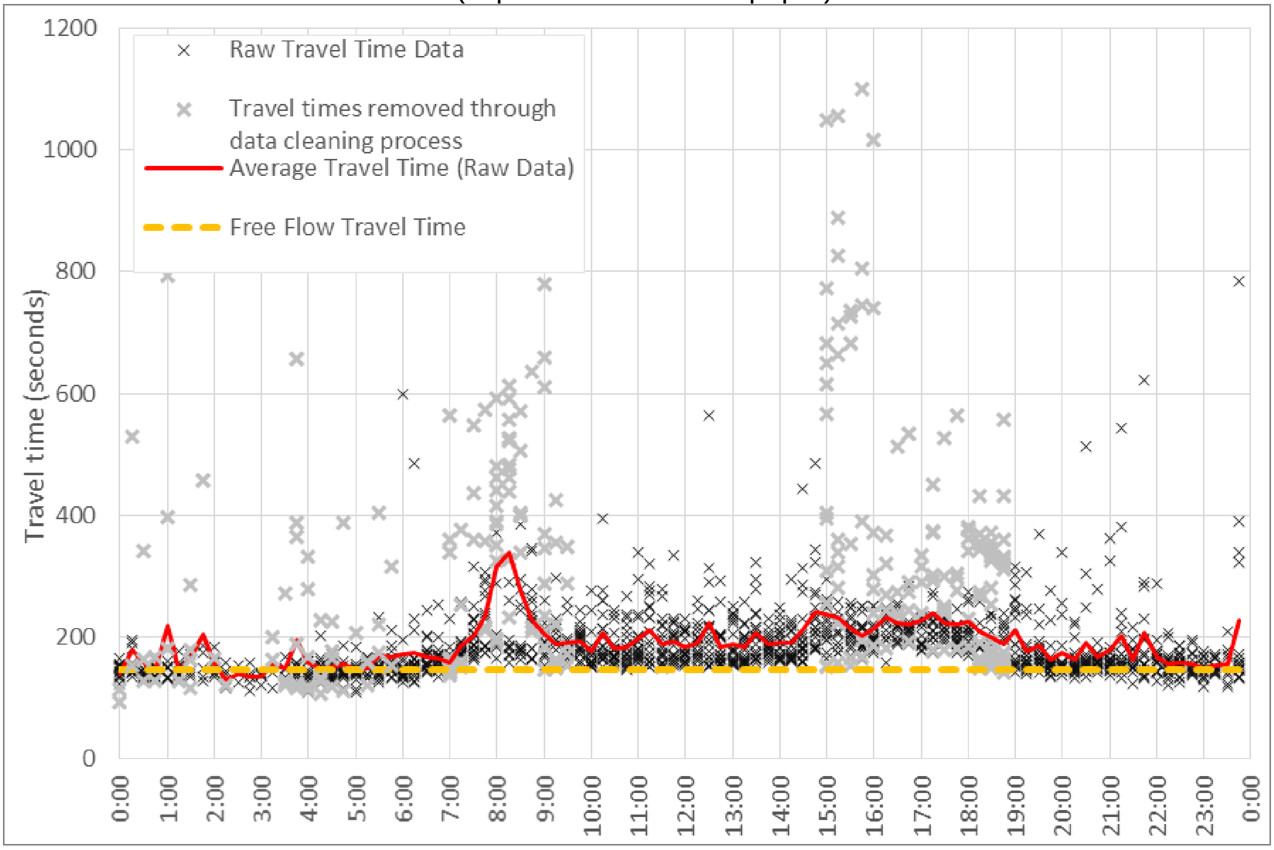

Figure 1: Eastbound Travel Times on Memorial Avenue (between Grahams Rd and Clyde Rd), July 2014

It can be seen that travel times are closely bunched in the lower part of the graph, but there is considerable scatter in the upper regions of the graph. Outlying travel time values could be caused by a number of factors:

- A vehicle not travelling from an origin sensor to a destination sensor along the shortest path. An alternative destination between the two sensors would lead to travelling a longer distance and creating a longer travel time regardless of the impact of congestion.
- A vehicle not travelling from an origin sensor to a destination sensor in a continuous journey. If a driver chooses to stop at an interim destination along the route it would lead to a longer travel time regardless of the impact of congestion.
- Collection of data from a Bluetooth device not travelling in a car. Devices being carried by pedestrians, cyclists, or buses using a bus lane may record faster or slower travel times.

These outlying travel times made it necessary to clean the data before processing. For each separate night period (00:00 – 06:00) on each separate link, the recorded journey times were averaged. The standard deviation was calculated and an acceptable minimum and maximum range was created of one standard deviation shorter or longer than the average journey time. Any results with a travel time outside of the acceptable range were removed from the data. This process was repeated for the morning period (07:00 – 09:30) and evening period (15:00 – 19:00).

Alternative methods were considered, such as comparing the same 15 minute segments across all the days in the month and removing any values that were more than one standard deviation away from the average travel time. However this may have removed days where there were legitimately high travel times caused by particularly bad congestion. The process chosen was considered to be the most suitable for removing unusually high or low travel times, while minimising the chance of removing travel times which were legitimately high.

Using the cleaned data, the average travel time between midnight and 6am was calculated for each link. This was deemed to represent the free flow travel time.

The morning and evening peak hours were calculated based on when each link's average travel times were the highest. The percentage difference of this peak hour average travel time from the free flow travel time was calculated and mapped using a geographic information system (GIS).

The percentage difference is a raw measure of additional delay, and does not take into account the importance of the road or the number of vehicles using it. To account for this, a congestion index was calculated, using a weighting procedure to reduce the importance of less heavily trafficked roads, while increasing the importance of more heavily trafficked roads (traffic volumes were sourced from the Christchurch Assignment and Simulation Traffic model). From this congestion index, maps were produced which gave an indication of the roads with both high delays and high traffic flows.

The cost of congestion was calculated for each link. The difference between the free flow travel time and the peak hour travel time was used to represent delay. This was multiplied by the approximate traffic volume of each road, to give the total delay. This was multiplied by $23.90/hour in the morning peak period, and $23.60/hour in the evening peak period, based on values given by the Economic Evaluation Manual (NZTA, 2013) for base value of travel time, additional congestion cost, and update factors. The additional vehicle operating cost was also calculated following the procedures set out in the Economic Evaluation Manual (NZTA, 2013), and added to this figure to give a total cost of congestion. Travel time costs accounted for approximately 86% of the total cost of congestion, with vehicle operating costs accounting for the remaining 14%. The total cost of congestion was divided by the link's length and mapped, to give a diagram showing the roads in Christchurch costing society the most in congestion.

3. KEY FINDINGS

Maps showing the cost of congestion for monitored roads in Christchurch in the morning and evening peak hours are shown in Figure 2.

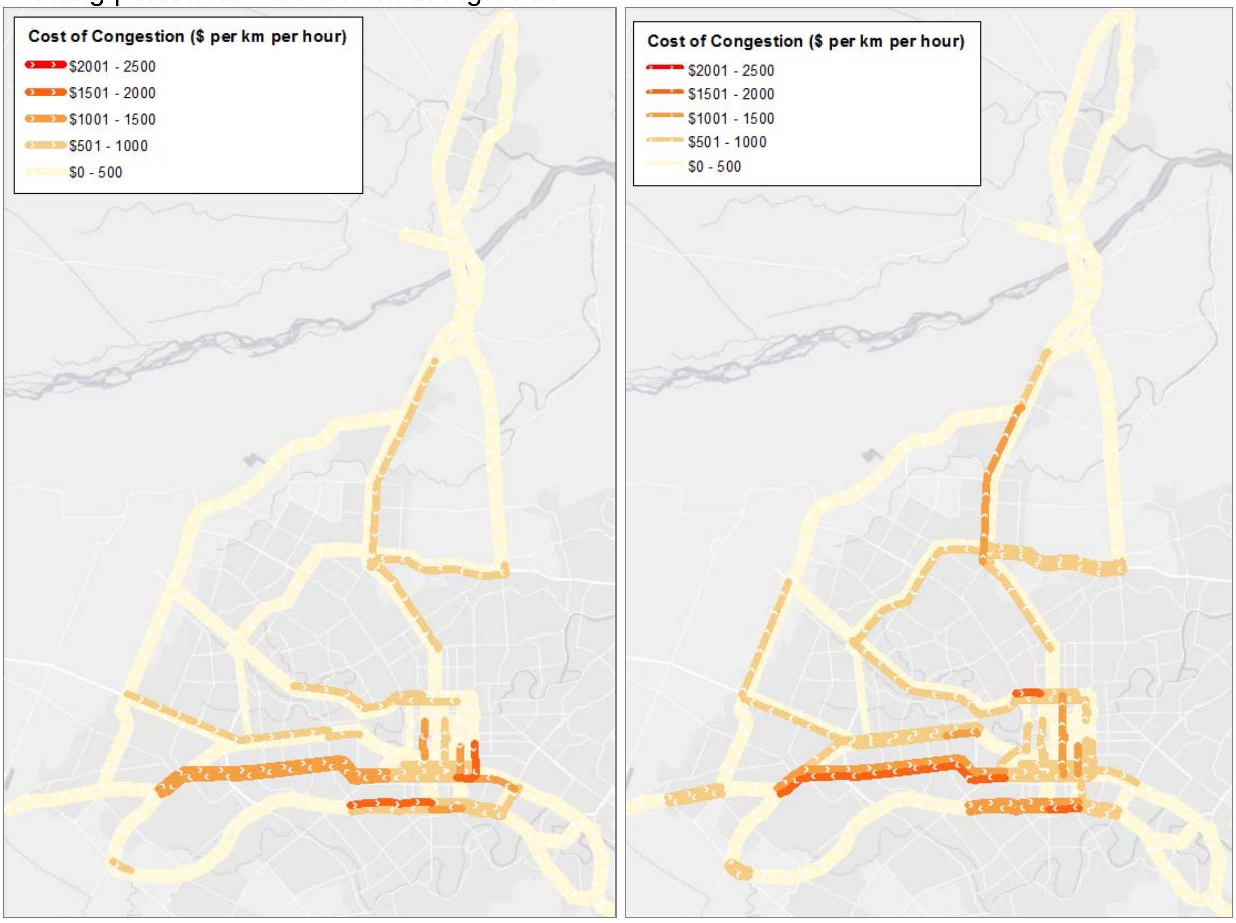

Figure 2: Cost of congestion in Christchurch in July 2014, morning peak (left) and evening peak (right)

Roads which had the highest cost of congestion in the morning peak hour in July 2014 were:

- Fitzgerald Avenue southbound ($140 - $1,600 per km/hr)
- Brougham Street both directions ($600 - $1,500 per km/hr)
- Barbadoes Street southbound ($300 - $1,300 per km/hr)
- Blenheim Road both directions ($400 - $1,200 per km/hr)
- Durham Street southbound ($700 - $1,200 per km/hr)

Roads which had the highest cost of congestion in the evening peak hour in July 2014 were:

- Blenheim Road both directions ($500 - $1,700 per km/hr)
- Bealey Avenue eastbound ($230 - $1,700 per km/hr)
- Brougham Street both directions ($600 - $1,700 per km/hr)
- Madras Street northbound ($1,200 - $1,400 per km/hr)
- Main North Road northbound ($800 - $1,200 per km/hr)
- Riccarton Road westbound ($900 - $1,200) per km/hr

The peak hour travel times on these roads were between 80% and 230% higher than their free flow travel times.

The total cost of the recorded congestion was valued as $96,000 in the morning peak hour and $123,000 in the evening peak hour. These were multiplied by 245 working days per year, to give an annual cost of approximately $54 million. It is noted that this does not include congestion experienced outside the morning and evening peak hours, on weekends and public holidays, or on roads which are not monitored by the Bluetooth system.

The close proximity of monitored routes within the central city provided an opportunity to study the properties of the congestion on adjacent routes in more detail. A daily analysis of congestion on four parallel North-South routes through the central city was carried out. The southbound travel congestion indices are plotted for each weekday in Figure 3 below.

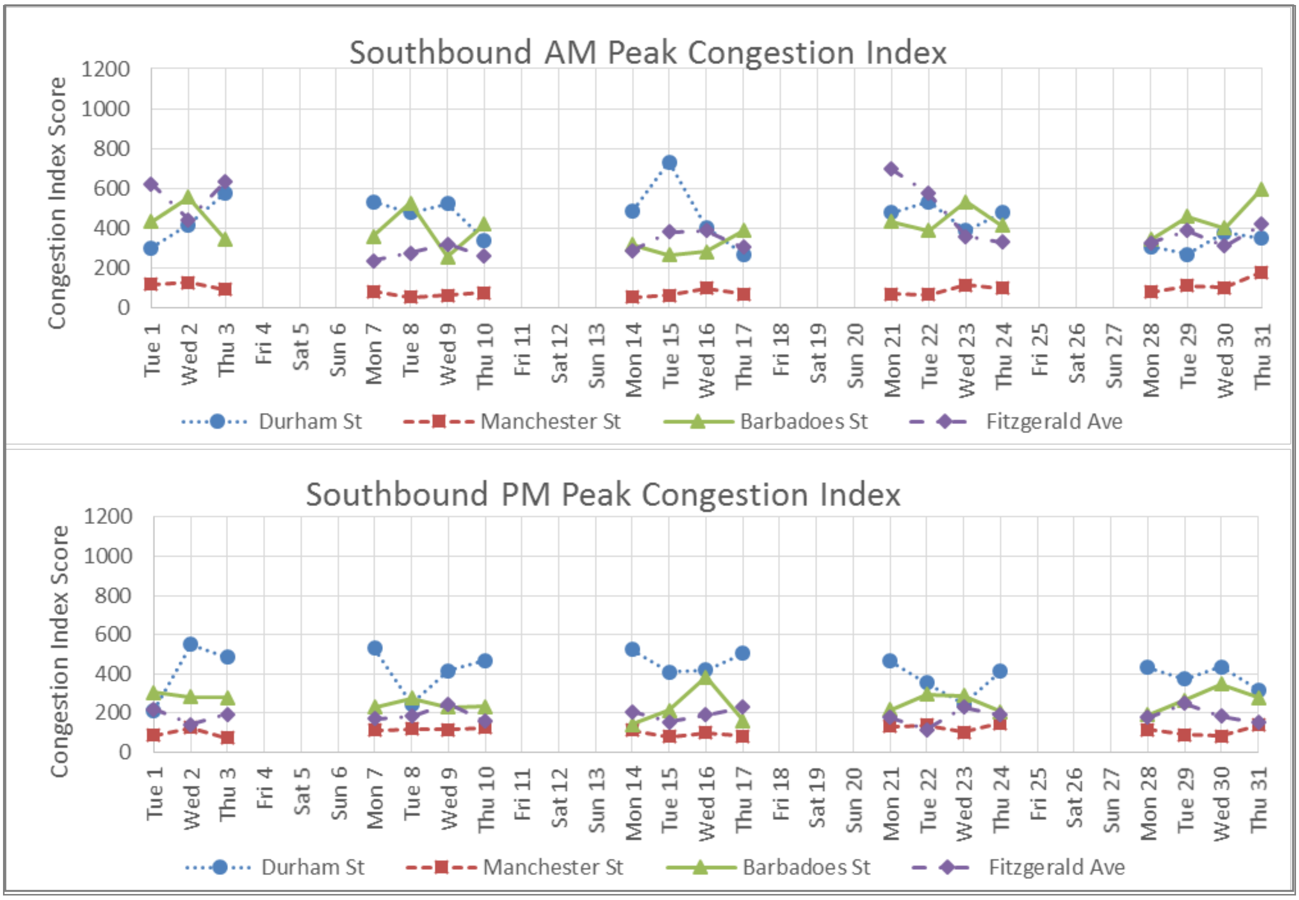

Figure 3: Congestion indices for southbound routes through central city in July 2014, morning peak (top) and evening peak (bottom)

There are some instances where congestion decreases or increases simultaneously on multiple routes. For example, in the AM peak hour, travel times on Manchester Street and Barbadoes Street generally show the same shape, both increasing or both decreasing on the same days. This pattern would be produced when congestion on one route causes drivers to re-route to the other route, in turn increasing congestion there. A driver's route choice may be based on visible congestion at the beginning of the route, advance warning of congestion or knowledge of congestion from the previous day. This relationship is not seen consistently throughout the month or across all four routes, and further analysis is required to completely understand it.

The identification of the most costly congestion in Christchurch has provided information to help inform smarter investment. Many of the routes identified as having high costs of congestion have been subject to optimisation investigation to improve travel times.

4. CONCLUSION

The CMS was developed to provide information on congestion in Christchurch. It involved extracting data from the network of Bluetooth sensors installed in 2013, cleaning this data to remove outliers, and calculating a free flow travel time for each of the 186 monitored links. The difference between this free flow travel time and the travel time during the peak periods was calculated as a percentage. Each link was categorised according to its traffic volume, and a weighting procedure was used to combine this with the travel time percentage differences to produce a congestion index. Economic analysis was conducted to determine the cost of congestion on each link. These results were displayed spatially using GIS.

Results from July 2014 revealed that the roads with the highest costs of congestion were Fitzgerald Avenue, Brougham Street, Blenheim Road and Bealey Avenue, with congestion costs ranging from $140 - $1,700 per km/hr. The total cost of peak hour congestion for the monitored routes was calculated as $54 million per year.

The system allows monitoring of actual congestion over time, to identify changes and emerging trends. The hybrid method developed gives suitably detailed results using data easily extracted from the Bluetooth monitoring network. It has developed objective measures of congestion which can enable smarter operational and investment decisions to be made for the Christchurch transport network.

5. REFERENCES

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6. ACKNOWLEDGEMENTS

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