

# PATREC PERSPECTIVES

## Sensing Technology Innovations for Tracking Congestion

Drivers have increasingly been using inexpensive mapping applications imbedded into mobile devices (like Google Maps, MapFactor, Navmii and TomTom) to find their way in the city, to avoid congestion and find faster routes. In turn, by using these technologies drivers act as sensors providing up-to-date information to the service systems on real-time travel time along roads and congestion hotspots. Innovations in sensing technology have opened the window for government bodies and researchers to affordably use this type of data for congestion measurement and transport policy in many cities around the world. A research study testing the use of the Google Maps traffic function to measure travel time along segments of two highways in Perth, Western Australia, has found that this technology can be used as a viable alternative data source for measuring traffic congestion.

### MEASURING CONGESTION

Commuters living in large and growing urban areas, such as the Perth metropolitan region, face increasing traffic congestion. This represents a major daily transport problem causing a wide range of effects, from stress and frustration, longer journey times, increased air pollution and fuel consumption rates, to decline in business productivity. Several current planning and transport policy publications have recognised the need to reduce congestion along Perth roads. In doing so, measuring and evaluating congestion in urban areas, using traffic information from various sources is critical to the successful implementation of congestion mitigation and management strategies.

Vehicle travel time and speed are commonly used as standard measurements for quantifying congestion. Travel time and speed data are traditionally collected from several sources such as number plate recognition systems, Bluetooth detectors, inductive loops, traffic counters, CCTV cameras and probe vehicles. Each data source has its limitations in terms of availability, cost, coverage, sample size and accuracy.

### PLACE-BASED SENSING TECHNOLOGY

Over the past decade technological advances in place-based sensory devices have played a significant role in overcoming some of these limitations. In-vehicle Global Positioning System (GPS) receivers, together with smart phone applications such as Google Maps, Apple Maps, Waze, Navmii and Garmin Navigator, have made crowd-sourcing traffic information a reality. Similarly, the TomTom Traffic Index is based on sensing technology, as the measure integrates real travel time data captured from customer GPS devices (TomTom 2013<sup>1</sup>). Ratti and Townsend (2011<sup>2</sup>) have suggested the Google Maps traffic function as a good example of a sensing technology that can be harnessed to plan a smarter city through a bottom-up approach. Transit data sourced from Google Maps has been used for analysing the connectivity of public transport systems in three large cities (Hadas 2013<sup>3</sup>).



## CASE STUDY TRAVEL TIME SURVEYS

Travel Time surveys were conducted during May 2014 along two road segments of similar length (6.6-6.7km), on Stirling Highway and Canning Highway in Perth (Figure 1) to test the potential use of Google Maps traffic data. Both highways are classified as primary distributor and have a speed limit of 60km/h. The live travel time estimate to travel from the start to the end of the selected road segments in an eastbound direction (towards the city centre) were obtained by inputting each end of the road segment as the origin and destination to Google Maps, which then calculates the travel time (Figure 2). The operation was repeated at 10 minute intervals during the weekday morning peak period and off peak period (8:30pm – 9:30pm). The weekday morning peak period along the Stirling Highway segment was during 7:45am – 9:15am, and on the Canning Highway segment it was between 7:30am – 9:00am. Over a two-week period a Travel Time survey obtained 200 records, representing average times for traversing the two links.

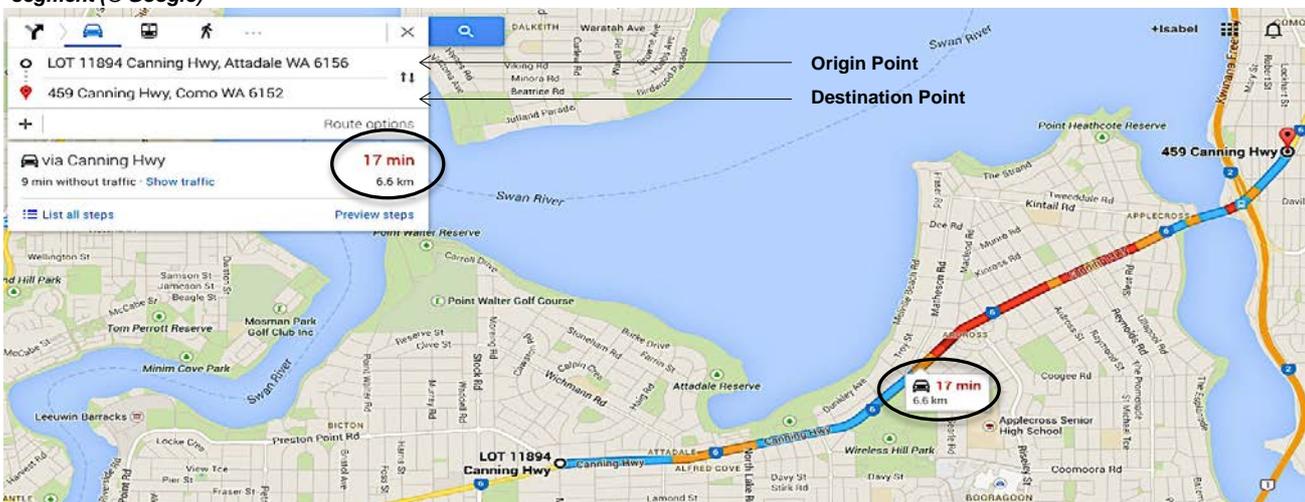
**Figure 1. Stirling Highway and Canning Highway travel time survey segments**



**Key:**

- Stirling Highway segment (Irvine Street to Hackett Drive)
- Canning Highway segment (Preston Point Road to Henley Street)
- Highway routes

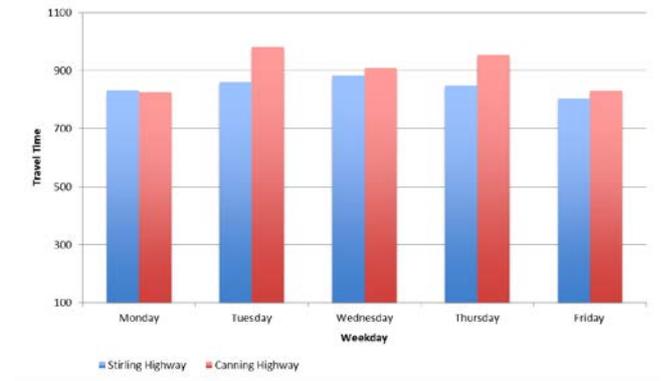
**Figure 2. Travel time of 17 minutes computed by Google Maps after entering the origin and destination points of the Canning Highway segment (© Google)**



In relation to daily morning peak travel time, results provided graphically in Graph 1, show:

- Average daily morning peak travel time on the Canning Highway segment was higher than on the Stirling Highway segment across all weekdays except Monday. This may be partly attributed to a geographic characteristic on the Canning Highway segment which incorporates a major intersection connecting Canning Highway to the Kwinana Freeway.
- There are differences between days of the week, with average travel time on Monday and Friday being lower than on Tuesday, Wednesday and Thursday for each segment. This trend is similar to the TomTom Traffic Index weekly congestion pattern reported for Perth (TomTom 2013), and is typically exhibited in daily traffic patterns for many cities.
- The longest travel time occurred on Tuesday in the case of Canning Highway and on Wednesday in the case of Stirling Highway.

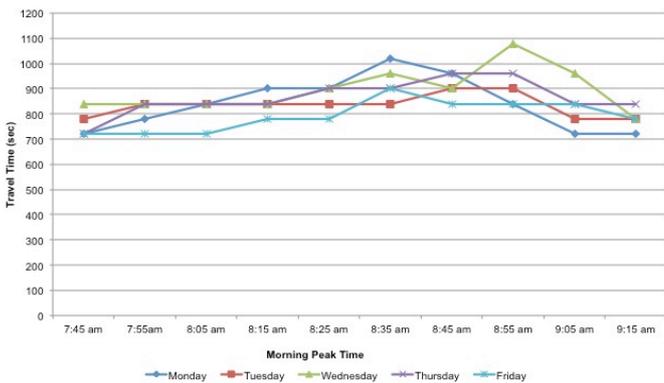
**Graph 1. Average daily travel time during the morning peak period along the Stirling and Canning Highway segments**



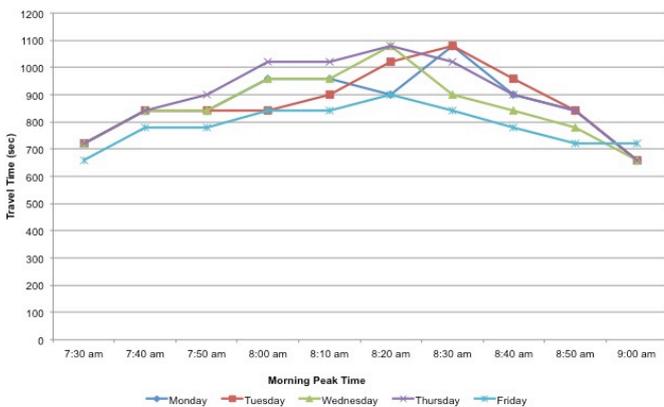
Travel time results across the morning peak period (Graphs 2 and 3) show:

- As expected, travel time gradually increases from the beginning of the period, climaxes and then decreases towards the end of the period.
- On the Stirling Highway segment, the daily travel time climaxed between 8:35am and 8:55am across most weekdays, with the highest peak occurring on Wednesday.
- On the Canning Highway segment the daily travel time reached a maximum between 8:20am and 8:30am across all weekdays with a peak occurring on Tuesday.

**Graph 2. Travel time per 10 min time interval during the morning peak period by weekday along the Stirling Highway segment**



**Graph 3. Travel time per 10 minute time interval during the morning peak period by weekday along the Canning Highway segment**



One-way Analysis of Variance tests were conducted to assess the statistical significance of the observed variation in travel time in relation to day of the week, route and time of day (before and after 8:30am during the morning peak). At the 5% significance level, it was found that:

- There are statistically significant differences in the congestion conditions across day of the week and between the two highway road segments ( $P < 0.001$ ).
- There is no significant difference between the travel time before and after 8:30am ( $P = 0.817$ ).

## USING THE TRAVEL TIME SURVEYS TO TRACK CONGESTION

There are a number of different traffic congestion measures that can be used to quantify the level of congestion. For the purposes of this study the Congestion Index (CI) developed by Hamad and Kikuchi, (2002<sup>4</sup>) was applied for the following reasons:

- The index value is simple and easy for professionals and the general public to understand.

- It can describe the existing congestion conditions and act as a baseline once subsequent studies in the future are conducted.
- It has been used in Australian transport studies and also internationally.
- It can describe a range of congestion conditions from low to high.
- It allows the comparison across different road segments and routes.
- It can be used across different timeframes either during the whole day or only at the congested periods of the day.
- Earlier transport studies have applied the index to different road types like freeways, motorways, arterial roads and different geographical settings.

The main limitation of this ratio type of index is that its use is limited for a particular road and it cannot be used to effectively describe the level of congestion over a whole geographic area (Rao *et al.*, 2012<sup>5</sup>).

The CI gives an overall indication of the level of congestion on the road by calculating the difference between the actual travel time being evaluated to those free-flow travel time conditions between two points. Free-flow travel time is defined as the period of non-congestion, usually occurring at nighttime when vehicles experience no delays or interruptions on the road and travel at the posted speed limit. The index can be expressed by the following equation:

$$CI = (T - T_0) / T_0$$

Where:

CI = congestion index value

T = actual travel time

T<sub>0</sub> = free-flow travel time

The value of a CI can range between 0 and infinity, and a higher index value corresponds to a higher congestion level. A CI value equal to 0 indicates low congestion levels because the actual condition is close or equal to the free-flow condition. A CI of 1 indicates high congestion levels, as the actual travel time is double the free-flow travel time.

Using the travel time survey results, CIs were calculated according to the above equation for both highway segments (Table 1). In terms of this equation T was represented by travel times recorded during the weekday morning peak period and T<sub>0</sub> was represented by the lowest travel time recorded during the off peak period for that particular road segment. On the Stirling Highway segment T<sub>0</sub> was 10 minutes and on the Canning Highway segment it was 9 minutes.

**Table 1. Average daily Congestion Index during the morning peak period along the Stirling and Canning Highway segments**

Road Segment	Mon	Tue	Wed	Thu	Fri
Stirling Highway	0.39	0.44	0.47	0.42	0.32
Canning Highway	0.53	0.82	0.68	0.77	0.54

- Average daily morning peak CI values on the Stirling Highway segment range from 0.32 to 0.47, which represents a 32-47% greater travel time than under free-flow conditions. This finding is consistent with the TomTom Traffic Index reporting a 45% CI during the morning peak period across the entire Perth metropolitan road network (TomTom 2013<sup>1</sup>).

- Congestion was greater on the Canning Highway segment with average CI values ranging from 0.53 to 0.82. This result is significantly higher than the 45% increase in the morning peak travel time reported by the TomTom Traffic Index for Perth. As previously highlighted these trends may be due to the presence of a major intersection connecting onto a freeway.
- When the CI values are broken down to 10 minute time segments during the morning peak period, the values fluctuate considerably depending on the time (Table 2 and 3).
- Daily CI values increase to a maximum and then decrease, reflecting a similar pattern to the daily travel times displayed in Graph 2 and 3.
- All the maximum daily congestion indices for the Stirling Highway segment remained below the value of 1 (Table 2). In comparison, congestion levels on the Canning Highway segment were higher with a majority of the CIs having a maximum value of 1 (Table 3).

**Table 2. Congestion Index during the morning peak period by days of the week along the Stirling Highway segment at 10 minute intervals**

Morning Peak Time	Mon	Tue	Wed	Thu	Fri
7:45 am	0.2	0.3	0.4	0.2	0.2
7:55 am	0.3	0.4	0.4	0.4	0.2
8:05 am	0.4	0.4	0.4	0.4	0.2
8:15 am	0.5	0.4	0.4	0.4	0.3
8:25 am	0.5	0.4	0.5	0.5	0.3
8:35 am	0.7	0.4	0.6	0.5	0.5
8:45 am	0.6	0.5	0.5	0.6	0.4
8:55 am	0.4	0.5	0.8	0.6	0.4
9:05 am	0.2	0.3	0.6	0.4	0.4
9:15 am	0.2	0.3	0.3	0.4	0.3

**Table 3. Congestion Index during the morning peak period by days of the week along the Canning Highway segment at 10 minute intervals**

Morning Peak Time	Mon	Tue	Wed	Thu	Fri
7:30 am	0.3	0.3	0.3	0.3	0.2
7:40 am	0.6	0.6	0.6	0.6	0.4
7:50 am	0.6	0.6	0.6	0.7	0.4
8:00 am	0.8	0.6	0.8	0.9	0.6
8:10 am	0.8	0.7	0.8	0.9	0.6
8:20 am	0.7	0.9	1.0	1.0	0.7
8:30 am	1.0	1.0	0.7	0.9	0.6
8:40 am	0.7	0.8	0.6	0.7	0.4
8:50 am	0.6	0.6	0.4	0.6	0.3
9:00 am	0.2	0.2	0.2	0.2	0.3



## COMPARISON WITH AN ALTERNATE DATA SOURCE

Floating car survey results from Main Roads WA were used to compare with the Google Maps data. The survey was conducted on Thursday 19<sup>th</sup> September 2013, with two vehicles travelling in an eastbound and westbound direction along the Stirling Highway segment during the morning (6:30am – 9:30am) and afternoon (3:30pm – 6:30pm) peak periods.

Given their different structure, the two data sources were compared in aggregated form using the morning time period of the same weekday and road segment. Key findings from the comparison are:

- Keeping in mind the smaller sample size in the case of the floating car survey and that the Google Maps data represents average travel times for all vehicles on the segment, a two sample t-test assuming unequal variance derived a P-value of 0.187, which is greater than the 5% significance level, confirming that there is no significant difference in the average travel times for the two data sources. Google Maps results were thus reasonable consistent with the floating car survey.
- The average travel time sourced from Google Maps was however 6.82% lower than the floating car survey results yielding a 23.37% lower CI value. These findings provide a good indication that Google Maps is a useable data source, yet could be slightly under representative of the travel times exhibited on a road.

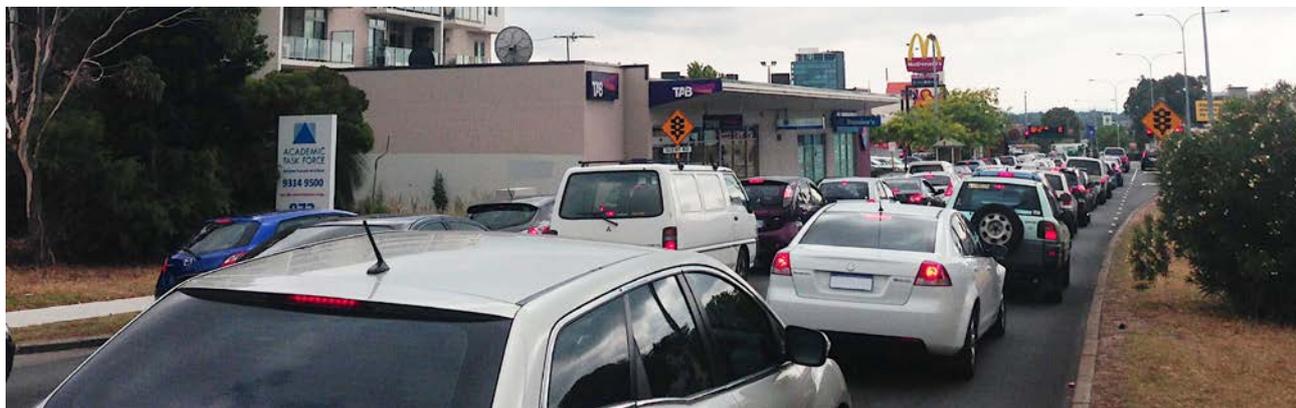
## LIMITATIONS

- The Google Maps travel time is rounded to the nearest minute, whereas floating car data sourced from Main Roads WA is recorded to the nearest minute and second, therefore the Google Maps data are less precise.
- There is limited information available about sample size, as privacy protection concerns require Google Maps to gather data from anonymous mobile devices (Barth 2009<sup>6</sup>).
- For research purposes, data from Google Maps needs to be manually extracted by an analyst. Its programming interface (Google Maps API) does not currently support using historical data for analytical purposes.
- In this research the origin and destination points were manually inserted into Google Maps to record the travel time for each road segment at 10 minute intervals during the morning peak period and off peak period. As a result, there is the possibility of human error with the manual extraction of the travel time data from Google Maps.
- Concerns have been expressed regarding the accuracy of Google's mobile phone sourced data. Critics argue that it is difficult to separate pedestrians, cyclists, public transport passengers and drivers, especially during congested times. When GPS information is not available, Androids phones could switch to lower accuracy signals such as mobile network and WIFI for location information, which is a further concern.

## FURTHER RESEARCH OPPORTUNITIES

As an initial investigation the findings from this study provide a foundation for future research in congestion measurements. In particular, research in this field should focus on five specific areas:

1. Compare Google Maps data with other pure GPS data sources such as Suna Traffic, HERE and TomTom;
2. Investigate the potential of integrating multiple sources;
3. Extend the data collection period over a longer timeframe, in order to explore monthly or yearly trends;
4. Use Google Maps to collect travel time data on different roads such as freeways and arterials.
5. Assess the interactions between location, time of the day and day of the week, applying multiple-way ANOVA with an extended sample size.



## References

- <sup>1</sup> TomTom, 2013. *TomTom Australia and New Zealand Traffic Index*. TomTom International. <<http://www.tomtom.com/lib/doc/pdf/2014-05-14%20TomTomTrafficIndex2013annualAUNZ-km.pdf>> (viewed 23 August 2014).
- <sup>2</sup> Ratti, C., Townsend, A., 2011. The Social Nexus, *Scientific American*, pp. 42-48.
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- <sup>4</sup> Hamad, K., Kikuchi, S., 2002. Developing a Measure of Traffic Congestion: Fuzzy Inference Approach. *Transportation Research Record* 1802(1), pp. 77-85.
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- <sup>6</sup> Barth, D., 2009. The bright side of sitting in traffic: Crowd sourcing road congestion data. Google: Official Blog. <http://googleblog.blogspot.com.au/2009/08/bright-side-of-sitting-in-traffic.html>

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