Paper Title: Traffic Modelling of Diverted Flow during the Wellington Tunnels Upgrade project

Authors: Tom Small – BE (Civil) (Hons), CPEng, MIPENZ, Civil and Transportation Engineer, TSmall@globalskm.com
Martin Peake – MEng (Hons), CEng, MICE, MCIHT, Traffic Engineering Leader, MPeake@globalskm.com

Presenters: Tom Small and Martin Peake

Abstract

The Wellington Tunnels Alliance (Alliance) was formed to undertake an upgrade of the Mount Victoria and Terrace Tunnels in central Wellington. These tunnels form an integral part of the Wellington Urban motorway network as a vital link between Wellington Airport, the Central Business District and southern, northern and eastern suburbs. A key part of the upgrades was the planning and management of traffic during tunnel closures to minimise the impact on motorists, whilst maximising the efficiency of work being undertaken in the tunnel.

The project presented a unique opportunity to predict the likely traffic re-routeing during the tunnel closures and examine the actual effects on the traffic flows in the short-term rather than attempting to forecast what happens years into the future. This required the development of a custom built Excel model as the only other tools available were network models of traditional peak periods. These network models were unsuitable as the time of interest for the tunnel upgrade was early evening and early morning (outside of the standard peak). The modelling was used to identify when would be the most appropriate time to close and open the tunnels.

This paper explains how the Excel spreadsheet was developed, how it was used and the success in forecasting diverted flows. It demonstrates the robustness of developing a cost effective and simple assessment tool from existing models and data without extensive preparation of new network models or data collection.

Introduction

The Terrace and Mount Victoria Tunnels are vital to the operation of the Wellington highway network. The Terrace Tunnel is the key link between the Wellington Central Business District (CBD) and the northern suburbs. It is a key link for commuters and freight. The Mount Victoria Tunnel connects the CBD and the southern suburbs to Wellington International Airport and the eastern suburbs.

The Wellington Tunnels Alliance (Alliance) was formed between NZ Transport Agency (NZTA), Leighton Contractors, Aecom and Sinclair Knight Merz (SKM) to undertake a fire life safety upgrade of each tunnel. Since the opening of the Terrace Tunnel in 1978 and the Mount Victoria Tunnel in 1931, there has been no significant safety upgrades. The key objective of the project was to bring the tunnels up to international fire life safety standards.

This paper focuses on the methodology and results observed for the modelling and operation of the Terrace Tunnel, although a similar procedure and results were observed for the closure of Mount Victoria Tunnel.

Background – Tunnels Upgrade

The Terrace Tunnel has been in operation for over 30 years without a significant safety systems upgrade. In recent times there have been a number of international incidents which have highlighted the importance of a high quality fire life safety system. In 2001, two trucks collided causing a fire in the Gotthard road tunnel in Switzerland, which killed 11 people (Henke and Gagliardi, 2004). In 2003 a truck caught fire in the Mont Blanc Tunnel connecting France and Italy, taking the lives of 39 people, the resulting fire was not put out for 53 hours (Bailey, no date).

As the tunnel is such a vital part of the Wellington road network, a key objective of the Alliance was to minimise any disruption to the travelling public. Initially consideration was given to closing both the Terrace and Mount Victoria Tunnels for five weeks over the Christmas period when traffic volumes in the city are at their lowest. Significant modelling was undertaken to determine the impact of such a closure. Initial results showed that during the first two weeks there would not be significant issues; however in the final three weeks traffic congestion was forecast to be extensive. As a consequence of the disruption predicted, consideration was given to other options for upgrading the tunnels. The preferred and chosen option was extended night-time closures that would be undertaken five nights a week for the duration of the works.

For many years the tunnel had been closed once a month during the night for regular maintenance. These closures generally occurred between 10pm and 4am. After consultation with the construction team it was concluded that a similar closure five nights a week would not be an efficient use of time. This was on the basis that each night it was anticipated that it would take approximately an hour to set-up for work, an hour at the end of the night to clean-up and perform safety checks before the tunnel could be opened to the public and a 30 minute break for the workers. This effective down time meant that only 3.5 hours of actual work would be undertaken in the tunnel. Such short working times would have significantly extended the programme of works and have significant cost impacts to the project. Therefore, it was decided to extend the closure period as much as possible to maximise the time available for productive work.

Undertaking tunnel closures over an extended time period and over several months was always going to be contentious. Therefore, to determine the effects of the closure, modelling was undertaken to demonstrate that the tunnel could be closed earlier in the evening and open later in the morning than the traditional maintenance closure times. The results were used to determine suitable hours, demonstrate that they could be achieved without significant disruption to the road network and to identify any measures required to accommodate diverted traffic.

The Alliance worked closely with Wellington City Council (WCC) to agree the hours of closures and the diversion routes. In the lead up to and during the closures WCC assisted by adjusting traffic signals along the routes to assist in the management of traffic. The communications and consultation teams from both organisations undertook extensive advertising campaigns to ensure the public was aware of the proposed closures and diversion routes. Extensive communication was also undertaken with emergency services, taxis, public transport providers and Wellington International Airport. Figure 1 provides details of the road network and signed diversion routes.

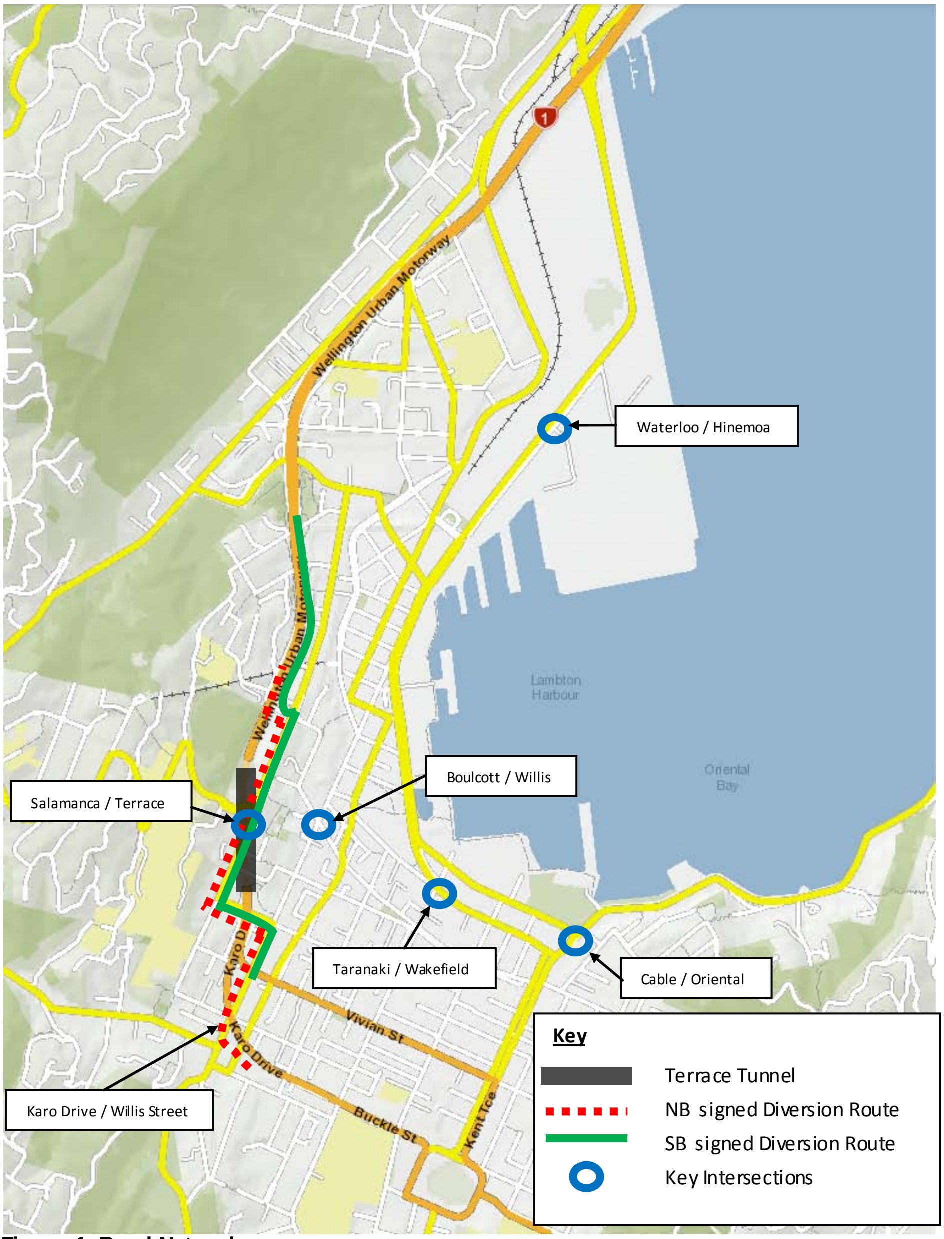

Figure 1: Road Network

Modelling Challenges

In order for the Alliance to reassure and provide confidence to its stakeholders that extended tunnel closures would be acceptable, traffic modelling was required. Unfortunately all the available models were peak period models with nothing available for modelling traffic outside of the peak commute times. Furthermore the Wellington Transport Strategic Model only covers traffic patterns for peak times so developing a defendable SATURN model would have been very difficult.

Although it was possible to develop an S-Paramics model based on traffic counts, to satisfactorily model the diversion routes a very large model would have been required. It was highly likely an S-Paramics model of the size required would be difficult to validate and not necessarily provide the Alliance with the confidence in the outputs it was after. Developing either model would have added significant cost to the project and unlikely to be used for any other project. Furthermore, the demanding project programme would have posed a significant risk to the project in developing a fully calibrated model that could have been used for the assessment.

Through discussions with various modelling specialists it was determined that the most appropriate approach was to develop an Excel spreadsheet model utilising data outputs from the available SATURN model, SCATS data and the NZTA data counters for tunnel traffic.

The intent in using the SATURN model was to develop an understanding of where tunnel traffic diverted to when the tunnels were closed and to apply the modelled proportions to actual tunnel volumes at the times of the closures. These diverted tunnel volumes were added to SCATS data at critical intersections along the various diversion routes to assess how each of these intersections would operate with a tunnel closure.

SCATS data was used as this provided a readily available source of turning count data across the whole of the time periods being considered at intersections through the Wellington road network. This also avoided the need for extensive data collection. Data was used for both peak periods and for the times to be assessed for the tunnel closure, with a comparison being drawn between peak period volumes and tunnel closure volumes at each of the critical intersections.

It was recognised in developing the approach that SCATS data can vary from actual counts due to the mechanism in which SCATS counts identifies demands. However, it was considered that the approach enabled a sufficiently robust method of comparing the traffic volumes during a tunnel closure with those during a peak period as similar anomalies in the data would be present between the different times.

Methodology

The following high level methodology was used for undertaking the modelling for the tunnel closure:-

1) The SATURN model was run with the tunnel open and closed during the AM and PM peaks.
2) A select link analysis was undertaken for the tunnel traffic to determine the percentage of this traffic that was long distance (i.e. travelling through the CBD through both Mount Victoria and Terrace Tunnels) and the percentage that had an origin or destination within the CBD. This was important as this could affect the potential for route choice.
3) In consultation with key stakeholders the signed diversion routes and those routes which motorists would be encouraged to use during the tunnel closures were identified. The outputs from the model on the likely diversion routes assisted in these discussions.
4) Intersections along the diversion routes that were considered key intersections were identified and agreed with key stakeholders (as shown in Figure 1).
5) For each diversion route, for the AM and PM peaks, the percentage of tunnel traffic which would travel along each of the diversion routes was identified. A logic check was undertaken on these results to ensure that illogical routeing was taken into consideration.
6) For the identified key intersections, traffic volumes from SCATS data were extracted for each intersection in the AM and PM peak and at the times between the proposed new closing times and the standard maintenance closing times.
7) Using NZTA's Traffic Monitoring System (TMS) the volume of traffic travelling through the tunnel between the proposed closure times and the standard closure times was extracted.
8) The volume of traffic travelling along each of the diversion routes was calculated by applying the percentage split for each route from the SATURN model (5 above) for either long distance trips or those with an origin or destination in the CBD (as per 2 above) to the actual tunnel traffic volumes (from 7 above). This was carried out on an hour-by-hour basis to reflect the variation in traffic flows. The proportional split from the PM peak was applied to the evening tunnel volumes and the AM peak split to the morning tunnel volumes to reflect the more likely travel patterns.
9) The diverted tunnel traffic derived from step 8 was added to the normal throughput at the equivalent time segment of the key intersection to get the total throughput of the intersection over the various times examined for the tunnel closures.
10) The ratio between the "peak hour" throughput and the tunnel closure throughput was calculated to determine if the traffic conditions during the tunnel closure would be any worse than those during a normal peak hour period (an example of this is shown in Figure 2).
11) An economic analysis was undertaken to determine the economic impact of various closure times against the effects on lengthening the construction time period. This analysis considered the length of working each night, the number of vehicles affected and the increase in journey times for tunnel traffic due to the diversion.

A key component of the assessment was the use of the ratio of tunnel closure throughput to peak throughput at the key intersections. The intent of the ratios was to readily identify if the key intersections may be problematic during the tunnel closures. As it was known how each intersection performed during a typical peak period, a ratio approaching or greater than one indicated that an intersection required closer examination of its performance. For those intersections which were near or at the peak time capacity, further SIDRA modelling was undertaken to confirm the performance and if necessary, test options for improving the intersection.

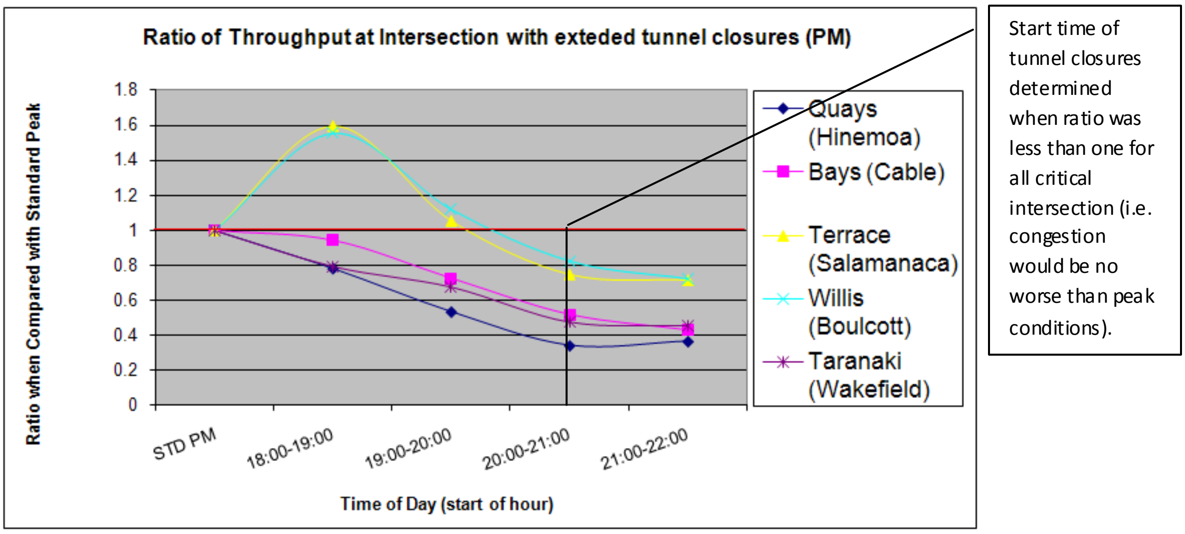

Figure 2: Example of Plot Showing Ratios of Intersections

The analysis was used for discussions with WCC regarding timings of the proposed closures and measures required to be implemented prior to work starting to offset the effects of the closures or as contingency measures should the actual network operation be different from that determined by the assessment.

The closure times that were determined to be the most appropriate were 8pm to 6am. These closures were for Sunday night through to Thursday nights inclusive.

Execution of the Tunnel Closure

For the tunnel closure to be successful, traffic needed to use the most desirable alternative routes. The assessment indicated the theoretical routeing of traffic which could be adequately accommodated. The Alliance therefore needed to ensure that from the first closure of the tunnel at the earlier time of 8pm, that motorists used these routes. The forecasting indicated that the signed diversion route would be most heavily used and was thus most critical. It was therefore important that the actual distribution of traffic had no more traffic than that forecast for the signed diversion.

As part of this process the Alliance undertook a significant advertising campaign to maximise the number of motorists aware of the tunnel closures. The advertising campaign included radio advertisements, newspaper articles and adverts and Alliance sponsorship of travel bulletins.

In the week prior to the tunnel closures, Variable Message Signs (VMS) were also utilised warning motorists of the upcoming closures. Throughout the tunnel closures, strategically placed VMS (mobile and permanent) were also used to warn motorists of the tunnel closures and suggest alternative routes. The Alliance continued to sponsor the travel bulletins and provided announcements on a regular basis to provide information to the public.

During the initial few weeks of the tunnel closures on street monitoring was undertaken to confirm the acceptable operation of the network. Alliance staff were located at key locations to observe the operation of the network and to identify any issues.

In addition to the onsite presence, WCC monitored the operation of the traffic signals remotely and altered the signal timings and phasings to optimise the revised distribution of traffic, particularly along the signed diversion route.

Special attention was paid to the overall safety of the network and where necessary modifications were made. For example at the Karo Drive / Willis Street intersection at the start of the signed diversion route northbound, the phasing was amended together with adjustments to the traffic management to better manage traffic and improve safety.

Results and Operation

Comparison with forecast diversion flows

Once the tunnel closures had commenced and enough time had elapsed for travel patterns to settle down, analysis was undertaken to determine how well the spreadsheet model assessment reflected actual travel patterns. This section compares the forecast throughput ratios derived from the modelling and the actual ratios seen on site and compares the forecast and actual distribution of traffic. This analysis is derived from the second week of the tunnel closures (week commencing 13 December 2010) and utilises the average of the peak hour flows (when the tunnel was open) and the throughput whilst the tunnel was closed for this particular week. The data was derived from SCATS and is therefore consistent with the data used to develop the models.

Data is only presented here for the evening period as during the week the evaluated tunnel re-opened earlier than the time periods originally envisioned in the morning. This was due to the initial works phase of the works not requiring as long a closure as that required in later phases.

A comparison of the throughput ratios between those forecast and actual ratios are presented in Table 1.

Table 1 – Comparison for PM Peak forecast and actual ratios of intersection throughput with diverted traffic to peak period intersection throughput

	Forecast Ratio		Actual Ratio		Difference between forecast and actual ratios	
Intersection	20:15	21:15	20:15	21:15	20:15	21:15
Waterloo Quay / Hinemoa	0.3	0.4	0.40	0.40	-0.10	0.00
Cable Street / Oriental Parade	0.5	0.4	0.47	0.45	+0.03	-0.05
Terrace / Salamanca	0.7	0.7	0.83	0.75	-0.13	-0.05
Willis / Boulcott St	0.8	0.7	0.58	0.54	+0.22	+0.26
Taranaki / Wakefield	0.5	0.5	0.60	0.57	-0.10	-0.07

The comparison shows that the forecast ratio was largely similar to the actual ratio. In the case of The Terrace / Salamanca and Willis Street / Boulcott Street it is evident that the forecasts indicated that the Boulcott Street route was more favourable than The Terrace; in actuality it was the reverse situation. This is likely to be because the signed diversion route was along The Terrace which would have encouraged motorists to use this route rather than continue along Boulcott Street (which they may have done had they been left to choose their own route).

It is concluded that from examining this data that on the whole the forecasts were within around 10% of the actual traffic distribution. Although the forecast ratios for Willis / Boulcott were higher, this route and The Terrace route can be considered to be interchangeable and hence considering them together, these would, by-and-large, fall within the 10% range.

Traffic Distribution

The diverted tunnel traffic volumes were examined along the key alternative routes to determine the proportional distribution of traffic around the network. These were compared to the forecast diversion flows and these are summarised in Figure 3.

The actual distribution of traffic on the key routes was obtained by comparing the “with” and “without” tunnel closure SCATS volumes at key intersections along the routes. The percentage distribution has been obtained from the total change in traffic volumes at these locations. The north and southbound directions have been treated separately as different routes are affected. The total change in traffic along the routes examined, closely correlated to those traffic volumes that would normally have used the tunnel when it was open. This provides confidence that the distribution observed related to actual tunnel traffic.
The figure shows that the main routes that were forecast and were actually used by diverted traffic are The Terrace and the Quays and Waterfront.

Forecast distribution of diverted traffic flows on the Quays were very similar to those observed with the tunnel closed. The forecast northbound proportion of tunnel traffic along the Waterfront included traffic that could have reached the motorway via Aotea Quay, Hawkestone Street, Molesworth Street on ramps or via Hutt Road. These forecast flows were all included in this figure as it represented a worst case in terms of total diverted traffic volume along the route, whereas it was recognised that in reality some traffic was likely to use only part of this route before filtering through other roads to reach these ramps.

As for the Quays, the forecast northbound traffic along Willis Street closely correlated to the actual tunnel diverted volumes (68% compared with 66%). This traffic has a choice when travelling to the motorway via the Everton Terrace on-ramp of either travelling along The Terrace or continuing straight along Boulcott Street. Along these routes, there was a difference in balance between forecast and observed flows.

For southbound traffic, more traffic was observed to use the Terrace off-ramp than forecast, which correlates to lower flows travelling along Wakefield Street. This shows that less traffic chose to use the off-ramps at Molesworth Street and Hawkestone Street than was originally anticipated.

Overall the traffic distribution was similar to that forecast.

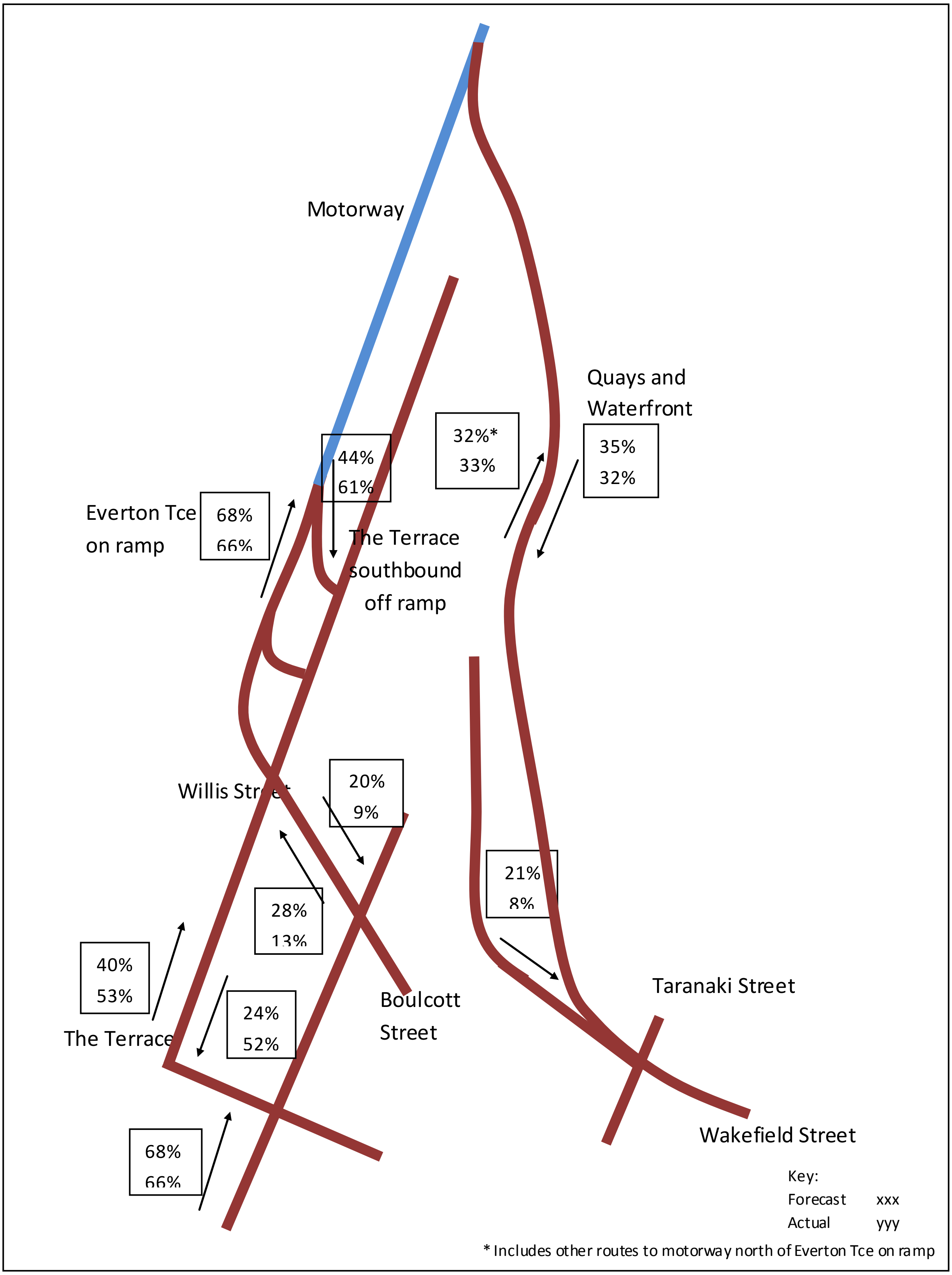

Figure 3 - Distribution of diverted tunnel traffic along key routes

Discussion

The distribution of traffic along The Terrace shows there were differences between the forecast and actual flows. The forecast distribution was based on the strategic SATURN model split of traffic between the two routes at peak times. However, The Terrace was the signed diversion route and therefore it appears as though motorists tended to follow this signed route rather than selecting their own preferred route based on either actual or perceived journey times. There may be a number of reasons for this.

Motorists travelling along the route during the times of the closures may be more occasional users and so not as familiar with the local road network as commuters or those that travel into the city on a daily basis. Similarly, those motorists that use the tunnel, particularly those travelling a longer distance (e.g. to the airport) would not normally be using The Terrace off-ramp and so have greater reliance on the signage to guide them due to poorer knowledge of the local road network. It may also be that motorists at this time of night are not as sensitive to longer travel times as those during the day who may be travelling to work and therefore are more willing to accept a slightly longer travel time rather than seeking a quicker alternative which has lower traffic flows.

Regardless of the reason it is evident that the majority of the motorists that travelled through this section of the network chose to follow the signed diversion route rather than choose their own alternative.

It is also of interest to note that a higher proportion of motorists continued southbound to The Terrace off-ramp rather than exiting the motorway earlier, as forecast, even though drivers were given sufficient warning of the tunnel closure via variable message signs along the southbound motorway. These signs encouraged the use of Aotea Quay off-ramp and alternative routes. Thus as The Terrace off-ramp is the last usable exit from the motorway when The Terrace Tunnel is closed, this ramp caters for all traffic that has not chosen an alternative exit from the motorway as advised.

As noted above, variable message signing warned motorists of the tunnel closure southbound along the motorway. Similar signage was provided for northbound traffic via temporary variable message signs strategically located so that motorists had ample opportunity to re-route. In addition, particularly during the initial stages of the project, extensive advertising was provided to warn motorists of the tunnel closures and that they should use alternative routes; one suggested route was the Waterfront and the Quays. Based on the observed traffic distribution of tunnel traffic it appears that the variable message signs and advertising resulted in around one third of motorists electing to use an alternative route to completely avoid the tunnel and the official diversion route.

Conclusions

The simple modelling technique used to determine distribution of traffic provided results with an accuracy of around 10% providing a basis that could be used to assess the effects of the closures.

The approach was cost efficient, sufficiently robust and saved significant time when compared to developing a new SATURN and / or S-Paramics model which would have had little use for other projects.

The radio advertising and the use of variable message signs assisted in re-routeing of around one third of tunnel traffic away from the closure points of the tunnel.

It appears that when presented with diversion route signage, for an on-going closure, that around 80% of motorists follow the signed route rather than choosing to find their own alternative route.

References

BAILEY, C (No date), Infrastructural Fires http://www.mace.manchester.ac.uk/project/research/structures/strucfire/CaseStudy/HistoricFires/InfrastructuralFires/mont.htm

HENKE, A., GAGLIARDI, M., (2002). The 2001 Gotthard Road Tunnel Fire, *Tunnel Management International*, Col 7, No. 1, 2004 pp33-39

Acknowledgements

NZTA as Owner participant in the Wellington Tunnels Alliance
AECOM as a Non Owner participant in the Wellington Tunnels Alliance
Leighton as Non Owner participant in the Wellington Tunnels Alliance
WCC for providing input into the diversion routes and working alongside the Alliance; and also for providing SCATS data for use in pre and post analysis
AECOM peer reviewers of the model