Auckland Network Performance Monitoring and Reporting: Evolution through Collaboration

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ABSTRACT

The Auckland Motorway Alliance (AMA) and New Zealand Transport Agency (NZTA) have developed an evidence-based, data-driven method to objectively evaluate congestion levels on Auckland's motorway network. The extent of saturation of Auckland's motorway and arterial road network at peak times means that operational and infrastructure changes tend to redistribute congestion spatially and/or temporally. The developed method is well suited to assessing the impact of incremental changes in operational tactics, strategy or infrastructure by assessing the entire zone of influence – rather than estimated or arbitrarily assigned project extents. Depending upon the extent of network coverage and frequency of input data updating, the resulting Network Performance Measurement and Reporting System can provide valuable feedback to operations, planning and project level evaluations. Iterations developed so far by the AMA and NZTA apply large scale data mining algorithms to currently available traffic detector data. To date coverage has been expanded from selected motorway corridors to the entire Auckland Motorway network. Current development work in conjunction with Auckland Transport (AT) and Joint Transport Operations Centre (JTOC) is aimed at inclusion of motorway / arterial interchanges and selected connected arterial routes.

INTRODUCTION

Auckland's State Highway and arterial road network is routinely saturated at peak times resulting in extensive recurrent congestion. There is now widespread acceptance that continual unrestricted expansion of capacity for general traffic to address the congestion problem is neither affordable nor desirable. Therefore capital improvement projects and changes to network management systems such as ramp signals, traffic signals, and the Auckland Harbour Bridge tidal lane system usually result in a redistribution of congestion spatially and / or temporally to other parts of the network. Extensive traffic modelling is invariably carried out in investigation and design stages of major capital projects, along with monitoring of selected routes after implementation. Despite this, whether the final result is a net gain or loss in overall congestion delay at the network level is often indeterminate or subjective. The ultimate effectiveness (or otherwise) of the allocation of limited funding resources to maximise the use of available capacity and achieve stated strategic network goals is therefore often unclear.

Network Performance Measurement and Reporting (**NPMR**) is a process for collecting, analysing and reporting intelligence on how well existing network capacity is being utilised and in particular how well congestion is being managed. It is intended to clearly articulate the cause-and-effect relationship between inputs, actions, and outcomes. The primary purpose is to provide a clear "line of sight" for decision-makers in operations, management and planning to understand whether network capacity utilization and congestion management are in line with the strategic intent. Therefore this tool can provide a feedback loop to guide the development and review of network strategies and operating plans. As a result, reliance on perception or sample data from arbitrarily confined study areas can be replaced with objective, rigorous and consistent assessment across the network and over time, allowing consistent assessment of network effects and trends. As a secondary purpose suitable relevant and meaningful summaries should be extractable for use to inform the media and public of how the road network is performing.

BACKGROUND

For the last four years the Auckland Motorway Alliance (**AMA**) has been tracking network-wide motorway congestion using continuously collected speed and volume data from 38 Advanced Traffic Management System (**ATMS**) detectors on SH1 and SH16 as part of the AMA's agreed KRA-KPI framework. In the last 12 months the AMA Network Performance Team (**NPT**) has been working with the NZTA Auckland Traffic Operations Team (**TOT**) to develop network level performance reporting tools capable of providing the clear line of sight needed for operational strategy / plan formulation and progress monitoring. More recently the early prototypes have been shared with management and operations staff at the Auckland Joint Transport Operations Centre (**JTOC**) and with the network performance specialists at Auckland Transport (**AT**) with the express aim of further development towards a "one network" NPMR system.

AVAILABLE DATA SOURCES

To date two key constraints have underpinned the development of the NPMR tools:

1. The reporting system should use data that is already available from existing detection systems; and
2. The primary data sources should be owned, managed and maintained by NZTA or AT. Third party data should only be used in a supplementary role.

On this basis several different data sources exist, each with their own relative strengths and weaknesses as summarised in Table 1. In order to process the data from these systems and reduce them into clear concise performance reports requires large scale data mining using algorithms based on sound traffic engineering principles. For example, production of a single month motorway network report using mainline Ramp Metering System (**SRMS**) detector data requires the processing of in excess of 30 million individual pieces of detector data. Management of this amount of data in terms of collection, cleaning, storage and retrieval is in itself non-trivial.

Table 1 – Available Sources of Traffic Data for NPMR System

Detectors	Strengths	Weaknesses
Advanced Traffic Management System (ATMS) I detectors (Loops)	Accurate volumes Includes speed & length	Poor spatial coverage & temporal granularity No occupancy measurement
SCATS Ramp Metering System (SRMS) detectors (Loops)	Good coverage (area & density) 30sec update rate	Poor volume accuracy with some sites No speed measurement
Tyco Inductive Loop Detectors (TILDs) – ATMS II (Loops)	Good density of coverage Speed & occupancy measurement	Spatial coverage poor (CMJ + approaches only)
SCATS detectors (Loops) at traffic signals	Good density of coverage	Poor volume accuracy (especially during congestion); No speed measurement
Wavetronix (Radar)	Speed and occupancy Useable where loops are not	Poor volume accuracy Limited spatial coverage
Bliptrak units (Bluetooth)	Direct travel time measurement	No volume/occupancy; Low hits at quiet times Data access via 3rd party; Raw data not accessible;

Note: Occupancy refers to lane occupancy (traffic density) not vehicle occupancy

EVOLUTION TO DATE

One of the fundamental principles underpinning the development of the NMPR tools is that performance should be assessed at the link level and then aggregated to network level (i.e. working from the part to the whole) to allow interrogation of network trends while being able to establish the contribution of individual sections. Fortunately this complements the main available point sensor sources of data.

First Generation (NZTA) Report

The first generation report utilised the data from the 38 ATMS detectors already being used to evaluate the AMA network efficiency KPIs. This data was reinterpreted to provide an estimate of aggregate network travel time (vehicle-hours travelled, VHT, per month) in addition to an estimate of aggregate network level demand (vehicle-kilometres travelled, VKT, per month) for the southern, northern and northwestern motorways. This allowed the adoption of a network speed index (total demand divided by total travel time) as a single network congestion indicator. Figure 1 shows an extract from this monthly report.

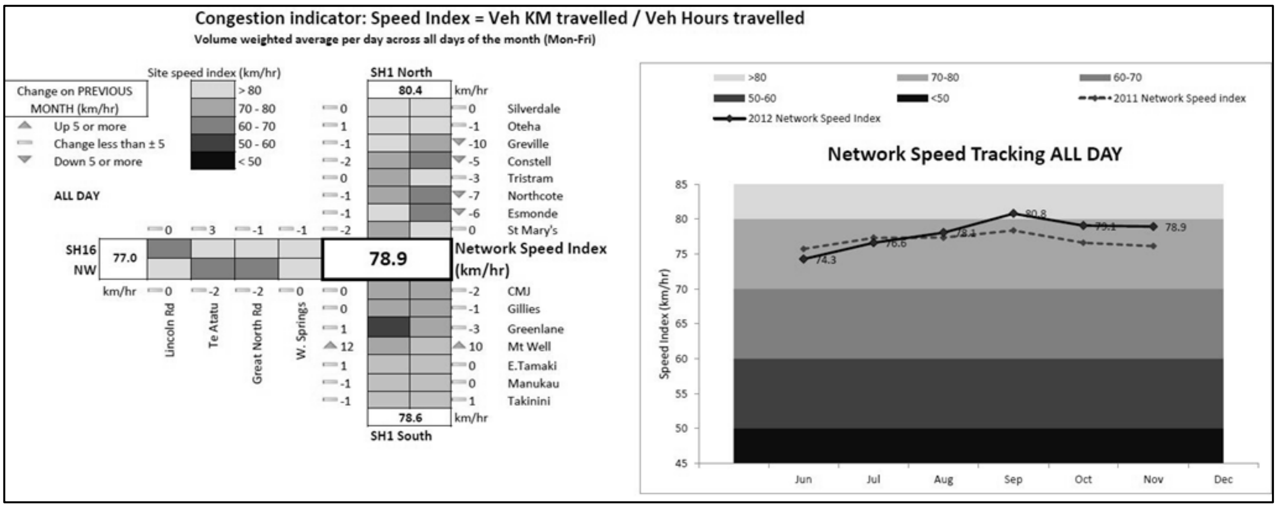

Figure 1: Extract from First Generation (NZTA) Report

Corridor Bottleneck Assessment Tool and the Second Generation (JTOC) Report

The Corridor Bottleneck Assessment Tool (**CBAT**) uses data from all available SRMS mainline detectors to summarise the pattern of congestion along an entire motorway corridor by: location; time; extent; duration; and frequency of recurrence. It is based on the concepts used by Chen, C., Skabardonis, A. and Varaiya, P. (2004) and utilises a flow-occupancy binary congestion discriminator based on the method of Kosmatopoulos, E., et al. (2006). This is applied to 30 second SRMS detector data aggregated for all sites on a corridor over one month. The result is presented based on the principles of Wiezczorek, J., Fernandez-Moctezuma, R. J. and Bertini, R. L., (2010).

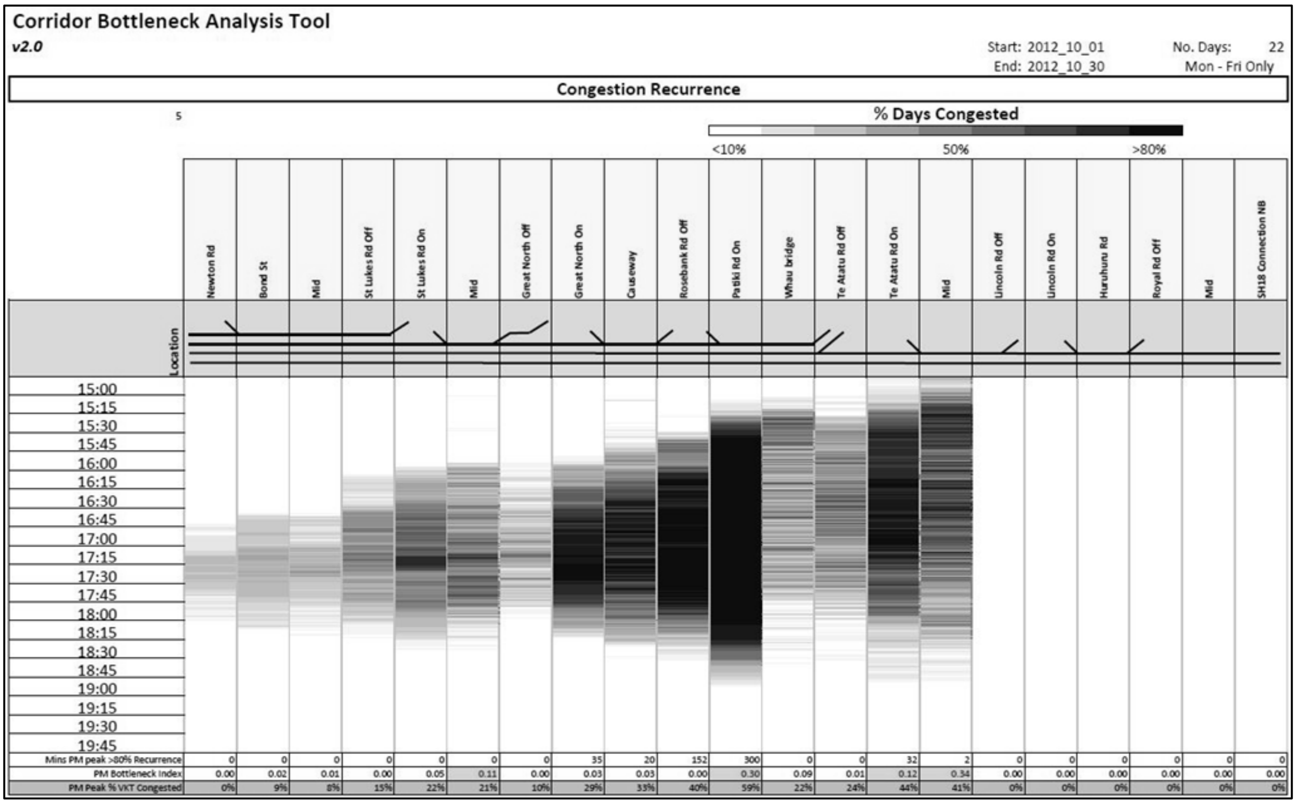

Figure 2: Extract from Corridor Bottleneck Analysis Tool (PM Peak)

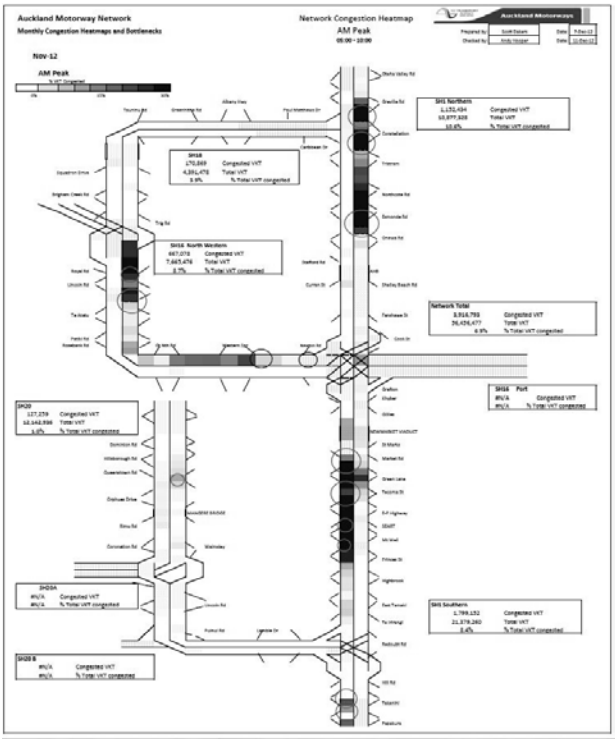

Figure 3 – Extract from the Second Generation (JTOC) Report (AM Peak)

Figure 2 shows an example output for one month of data for SH16 westbound in the PM peak. The horizontal and vertical axes display location and time respectively, and the density scale indicates how frequently over a one month period congestion occurs around each detector site. The darker the colour the more frequently the location is congested at the indicated time. Active bottlenecks are identified by the tool where congestion occurs at a location concurrently with non-congested conditions at the next detector downstream. The severity of a bottleneck is expressed by an index that accounts for both overall duration of congestion at the site and what proportion of that congestion is as an active bottleneck.

The JTOC report takes the data

behind the CBAT for each peak period on each corridor and uses it to quantify the overall amount of congested travel (expressed in VKT) as a proportion of total demand (also in VKT) for each corridor and also for the network as a whole. An extract of this monthly report is shown in Figure 3. The darker areas on the graphic indicate an increasing proportion of demand congested and the circles indicate the major bottleneck locations (with diameter proportional to their bottleneck index score).

Use of the CBAT and review of the JTOC report confirms that with the level of saturation experienced on Auckland's motorways, the performance of the entire network is governed by a handful of key bottleneck locations. The CBAT visually indicates how these interact at the corridor level and quantifies which of these are the most significant. However as the data analysis is performed at the corridor level, assessment of network level interactions between bottlenecks on different corridors (often via motorway links through Central Motorway Junction) requires aggregation of individual corridor results.

FUTURE DEVELOPMENT: TOWARDS A ONE NETWORK TOOL

The genesis of development work on a third generation report was the need to capture network level effects on congestion intensity and distribution from major network changes. In particular before/after assessment in relation to the impact of Victoria Park Tunnel, and subsequent changes to the timing of shifts in the extended Auckland Harbour Bridge / St Mary's Bay Moveable Lane Barrier system.

No journeys originate or terminate on the motorway network itself – this simple fact highlights the importance of migrating ultimately to an NPMR system that incorporates arterial routes with motorway routes to truly capture network impacts. Indeed the performance of the motorway in "processing" traffic is ultimately governed by the exit flow rate achievable (Papageorgiou et al. 2003) and as such the receiving capability of arterial routes is a key factor. The limit to exit flow can have a major bearing on the allowable inflow and therefore the how restrictive the required on-ramp metering will need to be to manage mainline congestion. The extent of queuing generated by the ramp signals in turn will be a major determinant of delay to non-motorway bound cross arterial traffic at motorway interchanges.

Work is already under way on a number of third generation tools which draw on the concepts and output elements presented in Xie and Hoeft (2012). Development work so far is yielding promising results in the following areas:

1. Network level motorway analysis within a single module (as opposed to multiple corridor analyses that then have to aggregated);
2. Off and On ramp congestion frequency, severity and impact on mainline motorway and arterial routes, respectively;
3. Signalised motorway interchange module (likely to be integrated with 2. above); and
4. Arterial corridor analysis.

Development in areas 2-4 is requires extensive use of SCATS data which introduces a number of challenges to enable analysis results that will allow an "apples-with-apples" comparison with the motorway analysis. Development in area 4 in particular will require extensive liaison with AT to identify suitable arterial corridors feeding to / from the motorway and any further "zones of influence" to include. The NZTA TOT and AMA NPT have already commenced discussions with the AT Network Performance Team and JTOC management / operations personnel to ensure development progresses in a way consistent with AT network performance measurement strategy, to yield tools that will be of practical use to NZTA, AT and JTOC.

As the tool is refined a number of issues related to data sources, data quality and associated cost will need to be addressed: to date the cost has been minimised by re-use of data sources that already exist for other purposes. In addition there is a growing desire to move towards tools that measure movement of people rather than vehicles. The NPMR tools currently under development will have the capability to do this if fed with suitable vehicle classification and vehicle occupancy data. However, in order to do this a reliable source of vehicle occupancy measurement is required that can be deployed at a large number of locations network wide relatively frequently (a maximum of three months to allow suitable feedback regarding the impact of initiatives aimed at encouraging mode change). Such a system would also have to be practical and cost effective. A vehicle occupancy measurement system with these attributes is not currently available.

The use of vehicle occupancy assumptions or data collected less frequently (e.g. bi-annually) or at only a limited number of locations would need to be used with caution, as this will take the NPMR system away from being a continuous data collection tool and weaken its evidence-based approach. Ultimately this would reduce its responsiveness to changes in the short term and therefore its usefulness as part of an operations feedback loop. Additionally any assumptions used in lieu of data need to be critically examined: a network wide multiplier (e.g. 1.2 occupants per vehicle) will not change the results produced by the NPMR system, but merely express them in different units (oranges instead of apples). Assumptions that vary by location around the network need to have a sound evidence basis otherwise they will act only to skew the results.

In the meantime the third generation tools may still be able to play a vital role in evaluating prioritisation decisions related to non-private vehicle modes. Before /after assessments where capacity (lanes, phase time) is reallocated to prioritise other modes (bus, cycles, pedestrians) could utilise a vehicle measurement based NPMR system to assess the network (or defined sub-network) impact. This would allow a trial or post-implementation evaluation of the marginal cost of additional delay to general traffic imposed, to achieve a desired marginal benefit for other modes.

CONCLUSIONS

The extent of saturation of Auckland's motorway and arterial road network at peak times requires an evidence-based method to objectively evaluate the success of incremental changes in operational tactics, strategy and infrastructure on addressing congestion levels. This needs to be across the entire zone of influence – rather than estimated or arbitrarily assigned project extents. Depending upon the extent of network coverage and frequency of input data updating, the Network Performance Measurement and Reporting System can provide valuable feedback to operations, planning and project level evaluations. Iterations developed so far by the AMA and NZTA have utilised currently available traffic detector data and have expanded from coverage of selected motorway corridors to the entire Auckland motorway network. Current development work in conjunction with AT and JTOC is aimed at inclusion of motorway / arterial interchanges and selected connected arterial routes.

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