Detection of Incidents using Vehicle Detection Station Data

Abstract

The early detection of incidents on the motorway network can significantly reduce the additional travel time costs of our customers. Manual identification of incidents is undesirable on a busy motorway network, because manual detection puts unnecessary pressure onto traffic management centre operators. Implementation of automated systems to detect incidents quicker has become one of the best practices that traffic management centres implement internationally. The development of the standard sensor data format (SSDF) system has enabled the wider NZTA team to access data from various vehicle detection systems, including the data collected from the 5,000+ detectors of the ramp signalling system. The improvement in data availability and completeness allows the implementation of an automated system to detect unexpected disruption in vehicle flow on the motorway. This paper provides an overview of:

- Existing practice (incident detection, incident response)
- Benefits of implementing an automated detection system to speed up incident response
- Speed, volume and occupancy characteristics during an incident
- Importance of historic flow data profile establishment
- Statistical models used to distinguish recurring congestion from incident
- Methodology of testing and refining algorithms
- Development path

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Introduction

The early detection of incidents on the motorway network can significantly reduce the additional travel time costs incurred by our customers. Manual detection of incidents is not desirable on a busy motorway network, because manual detection puts unnecessary pressure onto traffic management centre operators.

Implementation of automated systems to enable faster incident detection has become one of the best practices that traffic management centres adopt internationally.

The development of the standard sensor data format (SSDF) system has enabled the wider NZTA team to access data from various vehicle detection systems, including the data collected from the 5,000+ detectors of the ramp signalling system. The improvement in data availability and completeness allows the implementation of an automated system to detect unexpected disruption in vehicle flow on the motorway.

This information paper provides an overview of existing practice of incident detection & resposne and progress that the AMA has made to date to realise the benefits of implementing an automated detection system to speed up incident response.

Existing Practice in Auckland

A number of stakeholders are involved with incident response in Auckland, including but not limited to, the Police, Traffic Management Unit, Auckland Motorway Alliance and other emergency services.

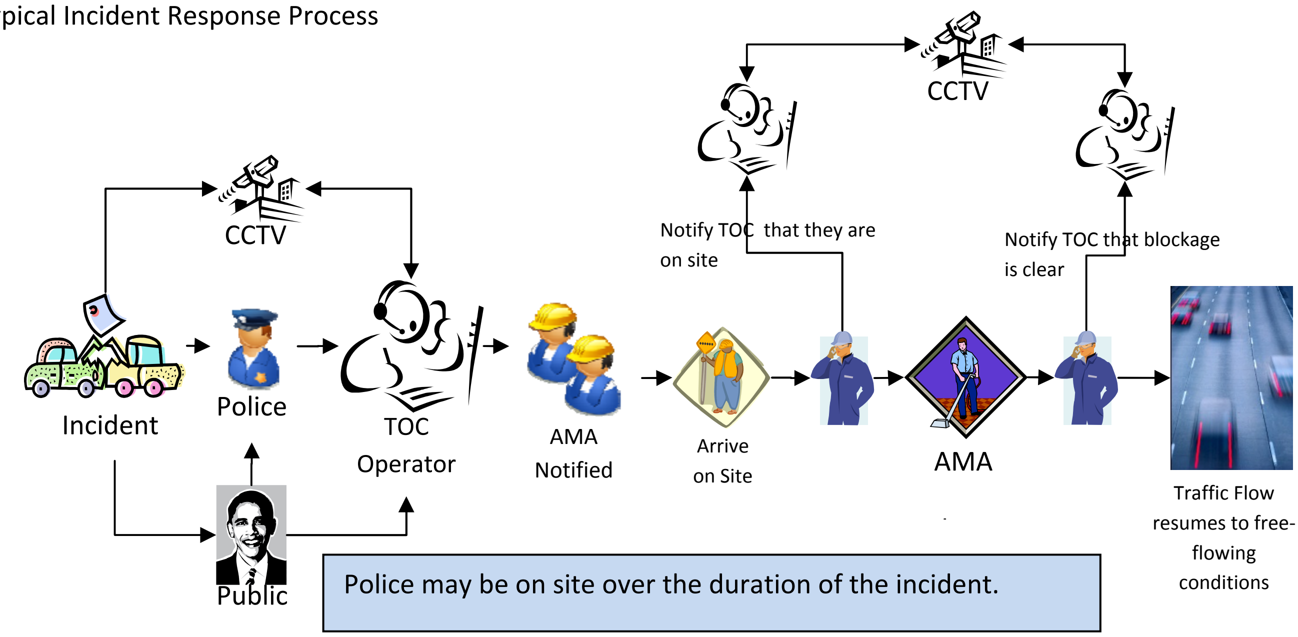
The current incident response process is illustrated in Figure 1. The current system works reasonably well; however, it relies heavily on visual detection, public reporting and/ or police notification. Visual detection is the only incident detection source managed by the road controlling authority, which is undertaken by traffic operation centre staff. The need to constantly monitor the ever increasing number of Closed Circuit televisions (CCTV) on the network is likely to have the following unintended consequences:

- number of operators required will need to be increased to maintain the same level of surveillance
- workload of operators is likely to increase
- detection time for secondary/ tertiary incidents is likely to increase
- high rate of staff turnover, as the visual incident detection task is not considered to be rewarding

It is anticipated that the recent law changes in relation to mobile phone use while driving may reduce the level of public reporting using mobile phones via *555 in the future. Hence, affecting the timeliness of this information source.

NZTA, like other road controlling authorities around the world, is gradually shifting from builders/ contractors to operators, adopting a customer centric and service oriented approach to traffic operations. Therefore, network efficiency is one of AMA's key performance indicators (KPI) and the prompt detection of incident is one of the critical factors contributing to the efficiency of the incident response process.

Typical Incident Response Process



Generalised Timeline	1 or 2 minutes	1 or 2 minutes	1 or 2 minutes	5 to 30 minutes (highly variable, depends on where the incident is)	5 to 30 minutes (highly variable, depends on how big the mess is)	5 minutes to 5 hours (highly variable)
Current Information Collection Practice	The time when Traffic Operation Centre (TOC) is aware of the incident is recorded generally			The time when AMA is on site is currently reported to TOC. Major incidents are entered in NZTA's Traveller Information System (TREIS)	Currently, the time, when AMA leave site, is usually reported to TOC and recorded.	This information is not recorded explicitly
				This duration is recorded on daysheets and subsequently entered into our tracking system.		

Likely Corresponding Traffic Conditions

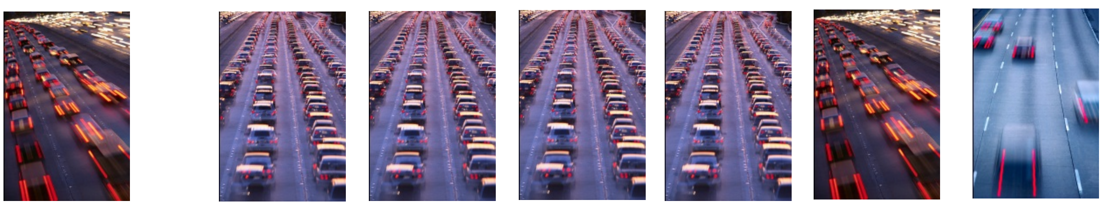


Figure 1. Typical Incident Response Process and Current Information Collection Practice [1]

The Anatomy of Incident Response

The typical incident response process can be simplified to four key stages (Figure 2. The anatomy of an IncidentFigure 2) and the duration of each stage can be reduced potentially.

- **Detection** – when the detection timeliness is improved, benefits will be generated in subsequent incident response stages
- **Plan** – present response plans which activates once an incident is detected allow less operator inputs to achieve the desired results
- **Action** – if an incident is detected more promptly, response crews can be dispatched earlier, reducing the risk of them getting stuck in traffic
- **Resolution** – getting to the incident response site quicker with the right equipment will allow

Therefore, it is considered that the reduction of detection time is one of the key measures to reduce the duration of incident.

Figure 2. The anatomy of an Incident, showing 4 key stages [2]

Benefits of implementing an automated incident detection system

Automatic incident detection (AID) is not a new idea; many road controlling authorities identified AID as one of the essential component of traffic incident management [3]. The key advantage of AID is that appropriate decision support system can be deployed to assist incident response operation with fewer inputs from traffic operation centre staff.

The NZTA ATMS II Odyssey[1] system implemented in early 2000's has a built-in automatic incident detection module. The module required significant calibration efforts and was turned off due to excessive false alarms being raised. Although this bad experience has made practitioners in the industry to be sceptical of AID, technologies have progressed considerably since then.

Two important game changers were implemented recently to make AID a more sensible incident detection mechanism than manual detection, i.e. Ramp Signals and Standard Sensor Data Format (SSDF).

- Ramp signals were installed to manage inflow onto the motorway network, thousands of induction loops were installed as part of the system, increasing geographic coverage and density of the detection system – the data collected can readily be used for other purposes, including but not limited to AID, once the data quality issues are addressed
- Standard Sensor Data Format (SSDF) database collects data from various detection devices on the roadside (Figure 3) and currently feeds a flat table database (Figure 4), making detecting incident possible providing a continuous and reliable data feed is established to feed the detection algorithm module

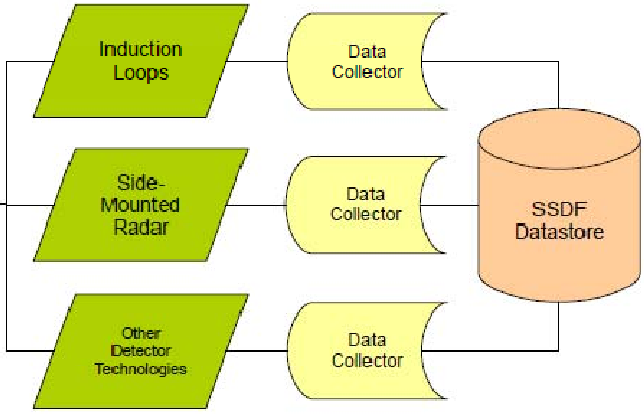



Figure 3. Relationship between SSDF and roadside equipment

[1] developed by Tyco Electronics

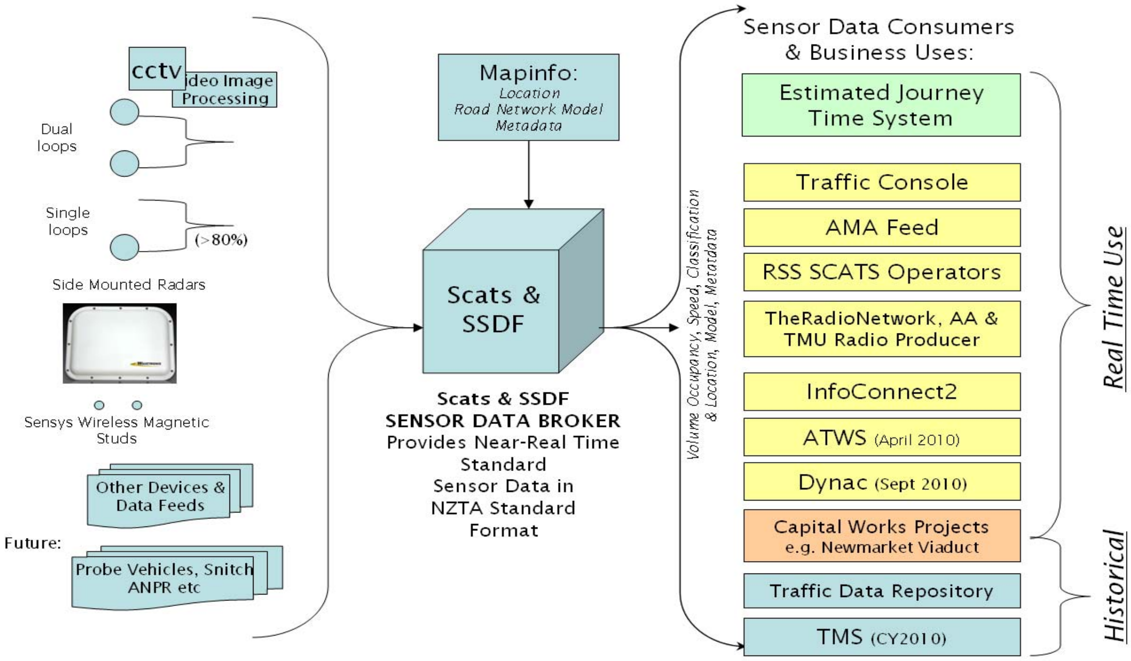


Figure 4. SSDF architecture and data consumer

Implementing an effective incident detection system can benefit traffic operation centre, network manager, road users and the wider economy in various ways:

Traffic Operation Centre (TOC)

- Reduced reliance on manual detection
- Improved job satisfaction of operators
- Operators can spend more time to provide better traveller information to travelling public using Variable Message signs (VMS)

Network Manager (Incident Response)

- More timely mobilisation of incident response crew, which will reduce the chance of the incident response crew getting stuck on the motorway network
- Providing better value for money for road controlling authority

Customers

- Reduced duration of incident response, leading to more reliable travel
- Reduced level of congestion due to incidents
- Improved traveller information

Economic Benefits

- The economic benefits of reducing duration of every incident on the motorway by 1 minute is estimated to be around $500,000 per annum [2]

Speed, volume and occupancy characteristics during an incident

During an incident, the operating speed of the motorway segment drops, volume reduces and detector occupancy increases. The characteristics of traffic flow during an incident display certain characteristics that are very similar to those during recurring congestion both upstream and downstream of an incident. It is therefore, essential to have a technique to distinguish incidents from recurring congestion.

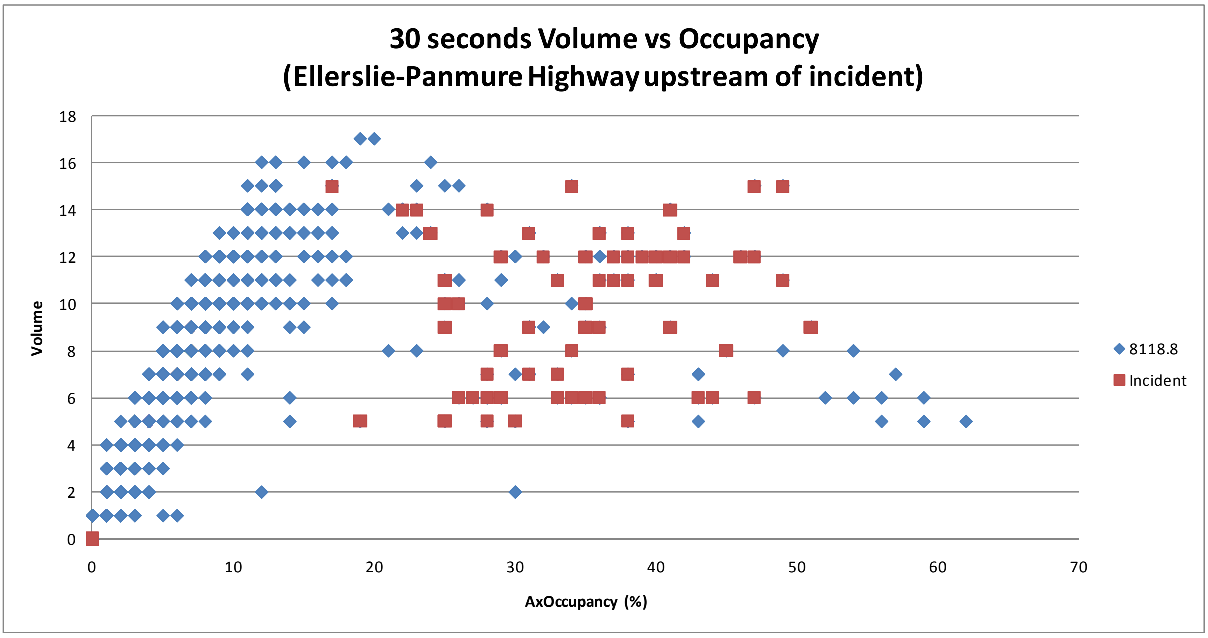


Figure 5. Volume, occupancy plot upstream of an incident (values blend in with data points during recurring congestion)

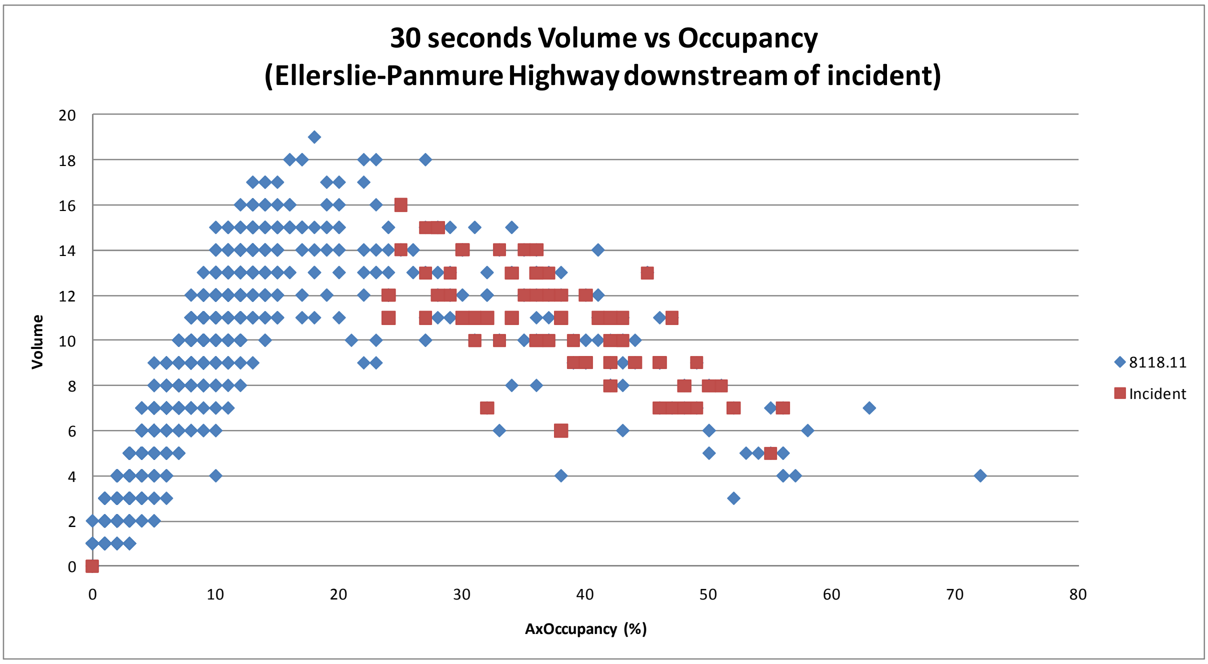


Figure 6. Volume, occupancy plot downstream of an incident (values blend in with data points during recurring congestion)

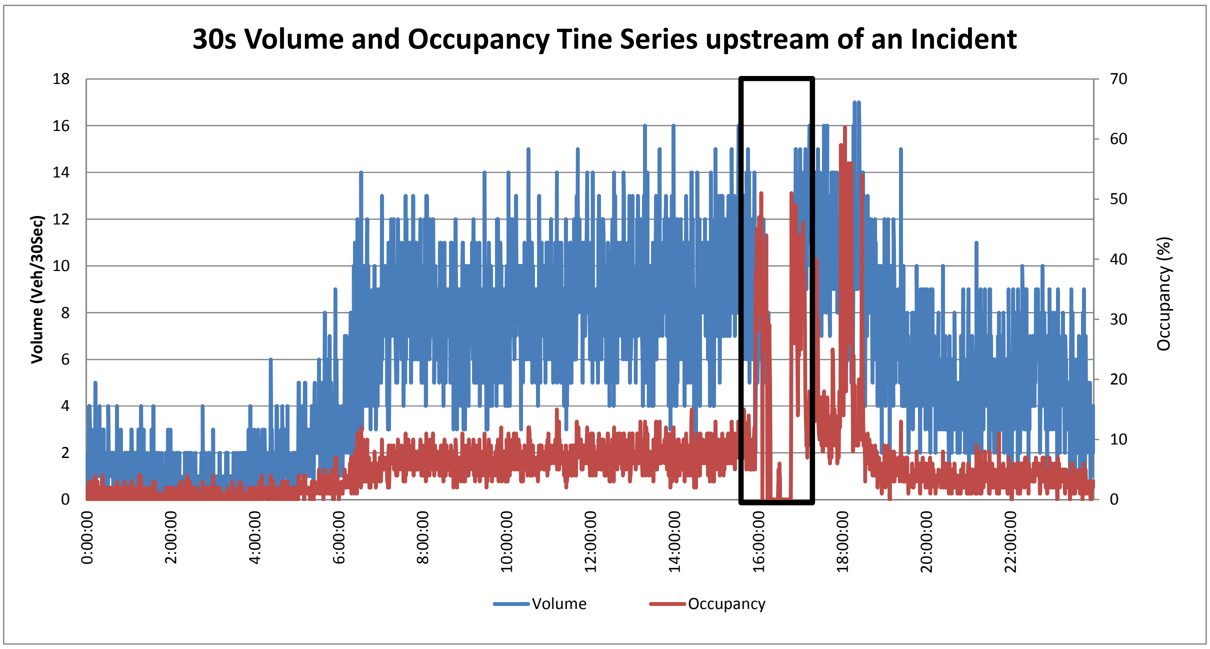


Figure 7. Time series showing volume and occupancy upstream of an incident, note abrupt changes in volume and occupancy

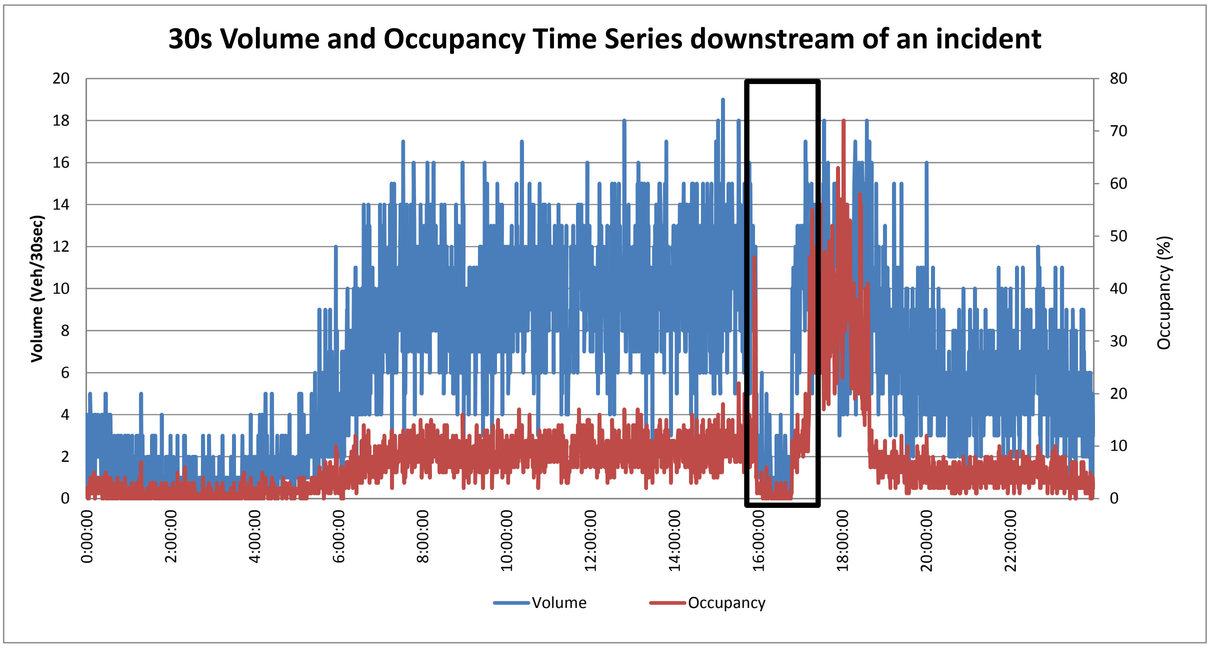


Figure 8. Time series showing volume and occupancy downstream of an incident, note abrupt changes in volume and occupancy

It appears that the volume/ occupancy values during an incident blends in with data points during recurring congestion and there are no particular volume/ occupancy characteristic displayed during an incident (Figure 5, Figure 6). Therefore, purely using empirical relationships would generate false alarms during periods of recurring congestion.

It was found that the key difference between recurring congestion and incident is the abrupt change in volume and occupancy as opposed to a more gradual change (Figure 7, Figure 8). The rate of change of volume and occupancy are now included in the detection algorithm.

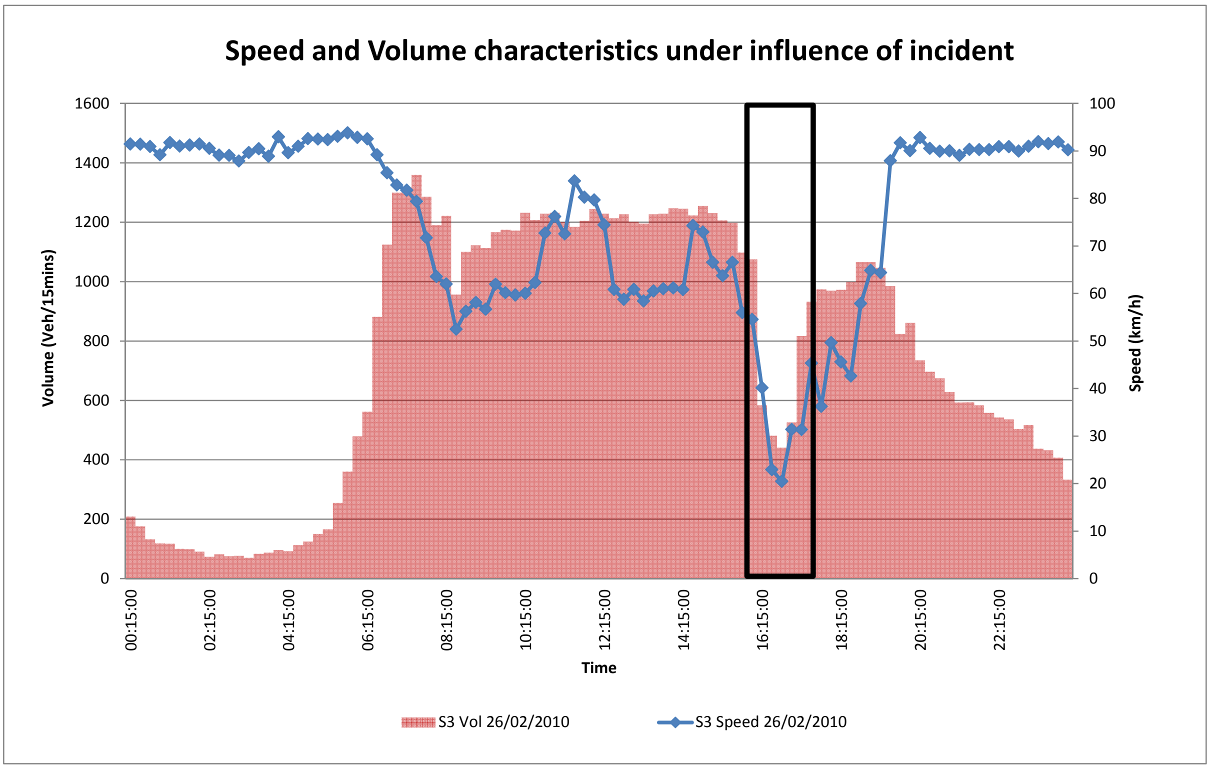


Figure 9. Volume and speed during an incident, showing reduced throughput and speed.

The volume and speed time series also react to an incident differently to recurring congestion (Figure 9).

However, due to the limited coverage of measured speed data on the network, the speed and volume relationship will only be used as a supplementary element in the detection algorithm.

Importance of historic flow data profile establishment

Archived historic flow data is now available through Traffic Data Repository (TDR) and SSDF. With the use of these data, the AMA is able to establish flow, occupancy and speed characteristics at individual detector stations. The historic flow data enabled development of statistical models to underpin tools such as:

- AMADEUS temporary traffic management plan traffic impact assessment module (under development)
- Automatic Incident Detection module (under development)
- Bottleneck management (under development)
- Time series Motorway Traffic View diagrams (under development)
- Automatic reporting system highlighting changes in traffic patterns (under development)

Further to the initiatives described above, having a spatially enabled historical traffic flow dataset will also allow the network managers to overlay other datasets geospatially, e.g. maintenance or flooding records to enable quantification of benefits for minor improvement works (Figure 10).

Figure 10. Effects of flooding incidents on traffic flow presented spatially

Statistical models used to distinguish recurring congestion from incident

The nature of events causing traffic congestion on the motorway network can broadly be classified into three categories (Figure 11):

- Known recurring conditions – these tend to occur regularly on the network, e.g. activation of bottlenecks and recurring congestion
- Planned activities – these are planned activities for undertaking maintenance, capital work activities
- Incidents – these are unplanned events that disrupt traffic flow, create congestion and reduce travel time reliability

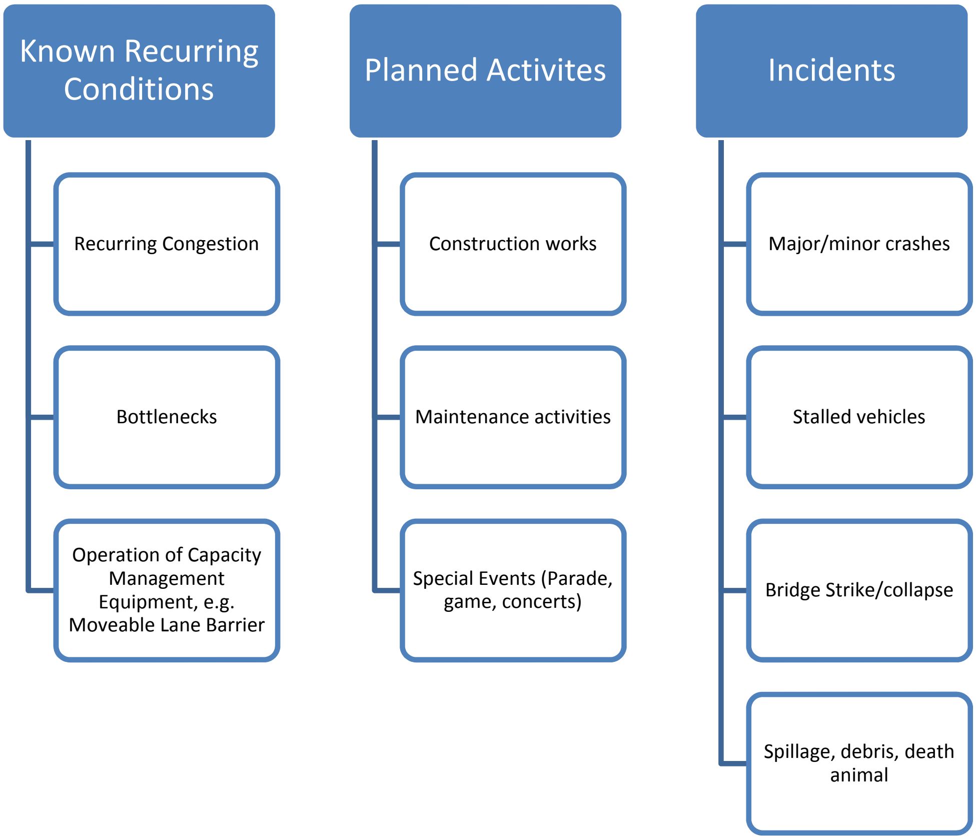


Figure 11. Events causing traffic congestion on the motorway network

A statistical model, developed from historic detector data is necessary to distinguish incidents from planned activities and known recurring conditions. It is considered that a statistical approach would yield significantly better results than relying solely on empirical relationships.

The advancement in database infrastructure and increasing processing power of servers have enabled the use of large volume of historic data to underpin statistical models that are being developed in the AMA.

Using data from SSDF, the upper and lower bounds of volume and occupancy characteristics will be determined for individual detector stations. These bounds will be used to calibrate the detection algorithm at individual detector stations.

Methodology of testing and refining algorithms

A number of algorithms are being reviewed as part of this initiative, including:

- Rule based
- Time series
- Artificial intelligence
- Area detection
- Combinations of the above

A section of the motorway network was selected as study length, historic incident and traffic datasets were obtained for the selected study length (Figure 12).

Figure 12. Study Length on SH1 Southern Motorway from Market Road to Mt. Wellington Highway

Individual incidents were geospatially located and various algorithms are applied to a simulated data stream from both upstream and downstream detector stations. The algorithms will first be tested and refined using fixed calibration factors until minimum incident detection rate of 80% and maximum false alarm rate of 10% is achieved on all test locations. Then the algorithms will be gradually refined by adjusting calibration factors to a target incident detection rate of 90% and target maximum false alarm rate of 1%.

Conclusions

It is concluded that:

- The change in the law to prevent mobile phone calls while driving is likely to reduce the number of calls from the public to alert the authorities about incidents on the network.
- The reduction of detection time is one of the key measures to reduce the duration of incident and there are significant cumulative benefits to be attained.
- Implementing an effective incident detection system can benefit traffic operation centre, network manager, road users and the wider economy significantly.
- For network efficiency, an automated system is essential to provide timely warning of breakdown in traffic flow and alert operators to the situation.
- The key difference between recurring congestion and incident is the abrupt change in volume and occupancy as opposed to a more gradual change. Hence, a statistical approach of establishing “base network loads” would yield significantly better results than relying solely on empirical relationships.
- A clear development path has to be implemented to ensure the appropriate outcomes are delivered to all stakeholders.

Development Path

In the next few months, more progress will be made on this initiative and it is envisaged the following will be undertaken in the not too distant future:

- Network wide algorithm verification
- Linkage with live SSDF data feed
- Development of production algorithm
- Incorporation into production server
- Publish incident detection information as a service for use by wider NZTA

Reference

1. Cheung, H., Lin, A. (2009), *Duration of Incidents on the Auckland Motorway network and recommendations for way forward*, Auckland Motorways.
2. Van der Walt, M. (2002), *The 60 Seconds Challenge,* NZIHT Conference 2010, Christchurch.
3. Austroads (2007) *Traffic Incident Management - Best Practice*