Improving Road Safety through Integrated Process for Incident Traffic Management

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Abstract

Austroads has identified the lack of a mutually agreed incident management framework across the member organisations as a gap in the traffic incident management (TIM) practice in Australia and New Zealand. A research project has been undertaken to develop such a framework based primarily on a literature review of local and international incident management techniques. Based on Austroads (2017), this paper presents the review outcome and the proposed framework, underpinned by seven management principles and the integrated process for TIM, with a focus on advanced incident management techniques to minimise traffic disruption and road safety risks in a more systematic and harmonised manner.

Background

Traffic incident management is a process of managing multi-agency, multi-jurisdictional response to road traffic incidents. It encompasses the planning, management, operations and review of incident management activities. Safety of road users and responders is paramount. In FHWA's Traffic Incident Management Handbook (Farradyne, 2000), incident management is defined as:

> The systematic, planned, and coordinated use of human, institutional, mechanical, and technical resources to reduce the duration and impact of incidents, and improve the safety of motorists, crash victims, and incident responders (p. 1-1).

According to Dunn and Latoski (2003), a traffic incident can be defined as:

> An unplanned event creating a temporary reduction in roadway capacity that, in turn, impedes the normal flow of traffic (p. 5).

Emergency events (e.g. extreme weather, natural disasters and terrorism) as well as planned events (e.g. roadworks and special events) that impact safety and traffic flow can also be considered in the TIM process. In other words, a traffic incident refers to any event that degrades safety and/or traffic flow.

The responsibility of implementing TIM in Australia and New Zealand primarily lies with road and traffic authorities and private toll operators, who are vested with managing their respective road networks. Given its complexity in managing multiagency, multi-jurisdictional responses to road traffic disruptions and the emergence of intelligent transport systems (ITS) and other transport technologies (e.g. smartphone and connected vehicle technology), the practice of TIM is evolving. By reinforcing an aim to provide a quick, effective and coordinated incident response to safely return normal traffic flow, an integrated TIM process would improve traffic safety for road users and responders.

Development of traffic incident management framework

The primary goal of the framework is to present the many aspects of incident management in a systematic and harmonised manner. Incorporating existing and emerging incident management techniques, the proposed TIM framework is presented in Figure 1.

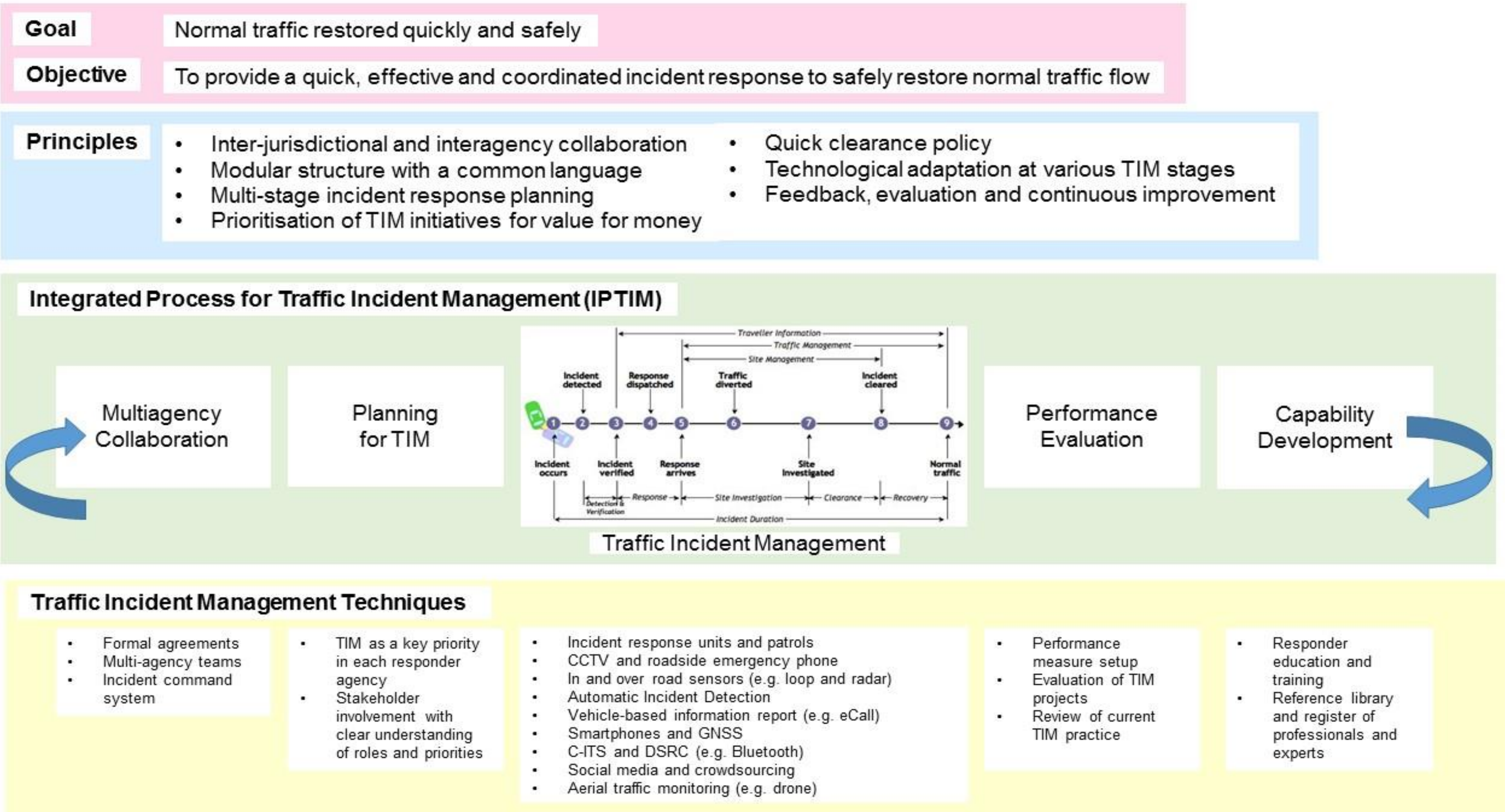
The framework developed as a result of Austroads research project NS1994 was based upon a review of current incident management practice in Australia and New Zealand with inputs from the jurisdictions. Further detail on the review and identification of contemporary leading TIM practices can be found in Austroads (2017).

The framework, underpinned by proposed principles, will provide road network managers and incident management service providers with an overarching guidance and a common understanding of the on-going processes for integrating traffic incident management approaches. Besides capturing the goal and objective of planning and implementing TIM activities, it incorporates contemporary leading-edge incident management techniques that can be employed to provide a quick, effective and coordinated incident response process to safely return normal traffic flow.

Incident management principles

The following management principles underpin the TIM framework within the broader scope of maintaining mobility and improving safety during an incident:

- Inter-jurisdictional and multi-agency collaboration – the importance of stakeholder coordination in order to establish a collective agreement for a quick response cannot be overemphasised. For example, a memorandum of understanding (MoU) on road clearance has been signed between Victoria Police and VicRoads (Victoria Government, n.d.). This MoU states the procedures to be followed at the time of incident clearance. To clear the incident in a timely and compliant manner, VicRoads Traffic Commander is required to be present at the incident site. After satisfactory completion of all statutory responsibilities, the most senior Victoria Police officer present at the incident site will hand over the site to the VicRoads Traffic Commander who takes responsibility for clearing the incident site. Clearly delineated roles and responsibilities between all the agencies before, during and after the incident are critical to ensure a sense of urgency to safely re-establish normal traffic conditions.
- Modular structure with a common language – it is important that the structure of the multi-agency response team can be adapted to suit different levels of incidents. A common language with consistent, agreed terminology is critical for effective communication during each stage of the TIM process.
- Multi-stage incident response planning – the recognition that TIM, from incident detection to traffic recovery, assists operational planning, performance evaluation and process improvements.
- Prioritisation of TIM initiatives for value for money – rather than focusing exclusively on the delay-reducing benefits, a process to evaluate net benefits (value for money) should take into account the ‘triple bottom line’ (Austroads, 2009) that includes economic (financial), social and environmental implications.
- Quick clearance policy – unless there is a justification otherwise (e.g. thorough investigation required after a major incident), quick clearance is a fundamental principle in traffic incident management. Relevant laws, policies and procedures should reflect this.
- Technological adaptation at various TIM stages – drawing upon advanced information processing, telecommunications and electronic technologies, ITS provides road user support services at different incident management stages, from user information, traffic management, advanced vehicle controls and data warehousing services.
- Feedback, evaluation and continuous improvement – a post-incident review, on-going process evaluation and capability building are equally important for improving TIM practice.



Source: Austroads, 2017.

Figure 1. Traffic incident management framework

Integrated process for traffic incident management (IPTIM)

The integrated process for traffic incident management (IPTIM) is an iterative process, incorporating the following five key management phases:

- multi-agency collaboration
- planning for traffic incident management
- traffic incident management (TIM)
- performance evaluation
- capability development.

The multi-agency and inter-jurisdictional collaboration phase is a critically important first step in the framework as it establishes a relationship and interaction among the jurisdictions and the various agencies (police, transport agency, fire and rescue, medical emergency and towing and recovery) and stakeholders (media and user groups) to support one another. A formal agreement is required to guide the development of a modular team structure with common objectives and language, clear command hierarchy and designated responder roles and responsibilities.

The second phase is the planning process. To improve the resource efficacy and deliver greater community benefits, it is imperative to plan incident response procedures and prioritise TIM programs and initiatives. Benefits can be realised by a wide range of means such as improved safety, reduced congestion and reliable incident-related information. A multi-stage planning for TIM can be instigated by identifying the needs and establishing desired objectives and outcomes at each TIM stage from incident detection to traffic recovery. A strategic framework and setting up performance measures should also be considered at the planning phase.

During the TIM stages, it is important to adapt new technologies and to automate procedures to enable quick and safe clearance. The application of technology (e.g. the use of Bluetooth technology and automatic incident detection algorithms to detect and verify incidents) can be observed in the findings of the literature and jurisdictional review. Performance evaluation and capability development are the last two phases of the IPTIM. They are essential for an ongoing process and procedural improvement, especially with the adaptation of advanced TIM technology.

Literature review methods

As part of the development of the TIM framework and principles for Austroads, a literature review was also undertaken to better understand how new and emerging technologies can contribute to the improvement in TIM processes and techniques. The literature review encompassed a variety of reference databases and sources such as peer-reviewed journals, published reports and documents provided by the project working group (PWG). The PWG members are representatives from government transport agencies across Australasia.

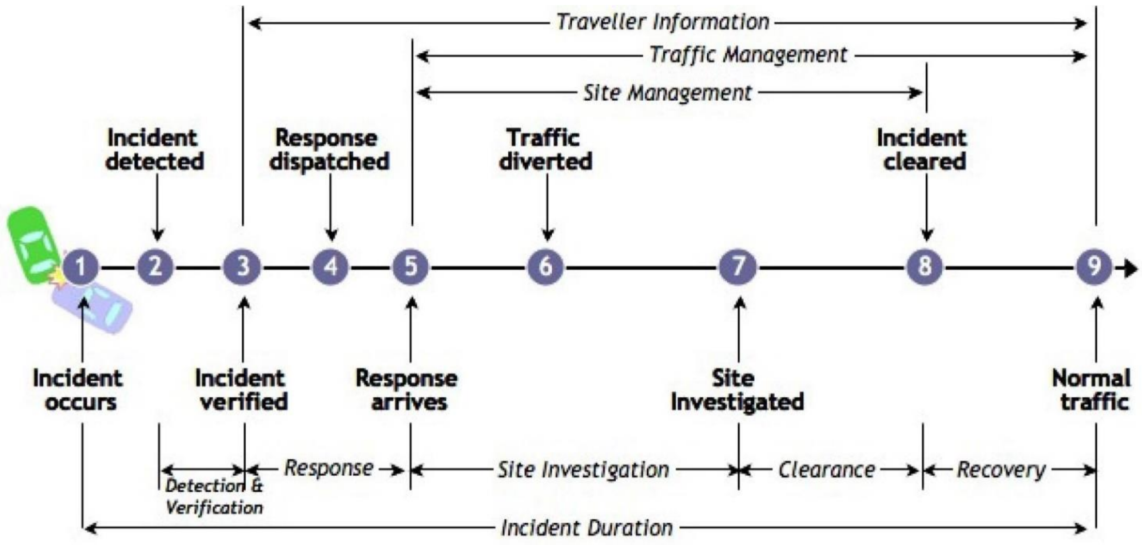
The literature review involved the following activities:

- A search for peer-reviewed literature using a variety of reference databases. These included those accessible through the M.G. Lay library, located at ARRB, and university databases accessible to the authors.
- General Google searches were used to identify relevant non peer-reviewed monographs and sources (e.g. ‘grey’ literature), industry-related research reports and other literature.
- Use of the following key search terms: ‘traffic incident’, ‘incident management’, ‘safety’, ‘traffic management’, ‘technology in traffic incident management’, and ‘incident management framework’.

- A review of policy, practice and procedural documents obtained from the PWG members in relation to contemporary leading TIM techniques.
- An ancestry approach to obtain other relevant documents; that is, using the references within the literature obtained to lead the authors to other relevant documents.

Traffic incident management steps

Within the IPTIM, the TIM process can be characterised by incident management activities from detection and verification to site management and traffic clearance. Figure 2 illustrates the temporal development of a traffic incident from occurrence to return of normal traffic conditions (Austroads, 2007b). The aim of these components is to provide a quick, effective and well-coordinated response in order to minimise the duration and impact of a traffic incident.



Source: Austroads, 2007b.

Figure 2. Traffic incident management steps

Detection is the process of collecting information or 'intelligence' about the occurrence of an incident. Verification is the process of confirming that an incident has really occurred. Incident verification is required before responding and is especially important if the source of incident information is unknown, incomplete or contradictory. With an aim to minimise traffic disruption and safeguard responder safety, traffic management is the application of traffic control devices at the incident scene. Traveller information is the activation of various means of communications to relay incident related traffic conditions to travellers.

The review of technologies focused on TIM techniques relevant to the management of transport services and network users during an incident (rather than processes and stakeholder management for incident response) and specifically from incident detection to traveller information (excluding site management, investigation and clearance).

Literature review results

Existing traffic incident management techniques

Existing TIM techniques for incident detection and response can be established based generally on the TIM practices discussed in the research reports published by Austroads (2007a; 2007b). As shown in Table 1, incident detection and verification techniques include emergency phones, service patrols and incident response units. The majority of detection and response practices utilise road and traffic sensing technology. In the area of traffic data collection technologies, infrastructure-based detection systems with stationary measurement devices distributed across the network have dominated. Such static sensing systems can be classified into in-road or over-road (Klein, Mills, & Gibson, 2006). Examples of these devices are inductive loops, infrared, pneumatic tubes, radar, CCTV and in-vehicle emergency sensors.

Table 1. Table 1. Incident detection and verification techniques

Source	Technique	Description
General public	Emergency call	▪ Incidents reported to emergency call centre, and subsequently to emergency services who then advise transport agency
		▪ Most common means of detection with 24/7 operation
	Traffic report hotline	▪ Incidents reported to transport call centre
		▪ Fast detection and verification if CCTV is available
	Roadside emergency phone	▪ Direct connection to transport agency call centre
		▪ Accurate phone location and 24/7 phone availability
Professional driver	Traffic incident watch	▪ Incidents reported by a network of professional drivers e.g. buses, trucks, taxis and couriers in collaboration with transport agency staff and police patrols
Road patrol	Police motorcycle patrol	▪ Peak period patrol or high-risk road sections
	Incident response unit	▪ Special or towing vehicle to patrol high incident locations during peak periods
Vehicle	Mayday	▪ When triggered, distress signal transmitted automatically to private call centre
		▪ Accurate location with Global Positing System (GPS)
Camera (CCTV)		▪ Use of pan-tilt-zoom cameras in a traffic control centre to monitor major traffic routes and tunnels
Automatic incident detection (e.g. STREAMS, SCATS and Addinsight)		▪ Software algorithms to detect change in speed and flow characteristics from normal traffic
		▪ Infrastructure requirement of detection devices (e.g. detector loops at an adequate interval)
Aerial traffic monitor		▪ Use of aircraft during peak periods by traffic reporting services

Source: Based on Austroads, 2007b.

Emerging traffic incident management techniques

New and emerging techniques for managing incident traffic falls within the scope of advanced traffic management tools and techniques that are employed in road network operations. These techniques include:

Smartphones and global navigation satellite systems

The continuing improvement of location-aware mobile devices (such as smart phones and purpose-built navigation system receivers) with affordable high-bandwidth communications is considered a significant milestone in traffic data collection technology for traffic system planning and management, including traffic incident management, now and in the foreseeable future (Geers & Karndacharuk, 2016).

The majority of smartphones have access to Global Navigation Satellite System, of which GPS is a part, and are equipped with accelerometers, gyroscopic sensors and a compass. Mobile phone positions (to cell level) are routinely collected by service providers via call data records. They are, therefore, incredibly versatile sensing platforms because the sensors can be used to provide not only the position of the phone and the mode by which it is travelling, but also origin-destination travel patterns (Bekhor & Shem-Tov, 2015) and road network and traffic conditions (Demissie, Correia & Bento, 2013; Janecek, Valerio, Hummel, Ricciato, & Hlavacs, 2015). The smartphones, consequently, enable service providers, device manufacturers and mobile app owners to send traffic incident information to the users that is specific to their locations.

Cooperative-ITS and dedicated short range communications (DSRC)

Cooperative-ITS (C-ITS) involves specialised vehicle-to-vehicle/infrastructure communications (V2X, vehicle to anything). It can be any of: Dedicated Short Range Communications (DSRC), 802.11p, 5.9 ITS (which references the frequency of operation – 5.9 GHz), WAVE (Wireless Access in Vehicular Environments) in the US, or CALM G5 (Communications Access for Land Mobiles Geo-networked 5 GHz) in Europe.

There are two essential physical components: on-board units and road-side units (RSU). Ultimately, transport agencies would be responsible for RSU deployment because of their use in traffic network control, both as a means of collecting traffic data (up to 1 km from the RSU) and for sending information to vehicles.

DSRC forms the primary communications component of C-ITS. To make better control decisions, both locally and in a coordinated fashion, it is important to obtain a much clearer picture of the traffic state, particularly by locating DSRC systems at intersections. In due course, they will transmit control information directly to approaching vehicles. This is an active area of research around the world (e.g. Cai, Wang & Geers, 2012; Seredynski, Arnold & Khadraoui, 2013) but they are yet to be deployed.

A unique Australian example of the utilisation of traffic data obtained from Bluetooth devices (e.g. in-vehicle systems as well as smartphones) for traffic management and traveller information is South Australia’s Addinsight Bluetooth system (Cox, n.d.). Bluetooth sensors are cost-effective devices that can be used on signalised and freeway corridors to detect abnormal travel times and throughput (Cox, 2013). They can also be used as point sensors to detect slow-moving traffic because probe vehicles stay in range of the receivers for longer. Given the probes can be tracked wherever coverage is available, the Bluetooth traffic data can be used in real time to monitor traffic patterns and route choice in response to the incident. Post-assessment of the incidents is also possible to obtain a better understanding of driver behaviour in response to incidents and to quantify the impact of the incidents.

Social media, participatory sensing and crowd sourcing

To detect traffic incidents, real-time social media such as Twitter can play a vital role. Many minor incidents such as non-injury crashes and vehicle breakdowns are reported earlier via social media than traditional methods. Moreover, social media analysis can help to inform congestion and safety hazards.

Major technology-oriented companies such as Google and Apple have been taking participatory sensing to a new level. Participatory sensing is an approach to data collection and interpretation in which individuals provide information to service providers either voluntarily or involuntarily. Apps such as Waze (bought by Google), which encourage users to provide information in order to support a community (drivers in this case) are novel, and perhaps fit into the 'sharing economy' ideal more so than traditional navigation aids. Even though relatively simple information is collected and shared by Waze, it is perhaps a key innovation with extremely clear and easy-to-read user interface with very large buttons. If it is found to offer minimal visual distraction to the drivers, this type of sensing data could eventually replace all others because of the ability to provide additional insight into their journeys by the users of apps such as this.

Twitter feeds can be mined to obtain relevant road and traffic data. Work by Kosala, Adi and Steven (2012) and Elsafoury (2013) have applied this technique to reporting on road congestion and traffic incidents. Many transport agencies throughout the world maintain a strong presence on social media to receive feedback on operations from the general public.

Drones for traffic data and incident management

Drones can be used as a potential tool to collect data and information on traffic movements. Laser scanning drones can expedite clearance by collecting data quickly, with good survey accuracy and in 3D to permit incident reconstruction and investigation by police and road agencies. Trials are taking place in the Czech Republic to collect real-time traffic data using drones (Evolving Systems Consulting, n.d.). The Civil Aviation Safety Authority and Airservices Australia have restricted their use in Australia. Drones for traffic data collection can be fitted with navigation systems with pre-set flight time, high-resolution cameras and high-capacity data collection links.

Summary matrix of incident management techniques

Table 2 shows the role and relevance of the variety of incident management techniques and practices for collecting and processing road and traffic data in response to incident management needs. The 'enable' or 'support' terms are assigned to each technique to differentiate its role in traffic management during an incident from detection to traveller information dissemination (Austroads, 2017).

It can be observed that all of the new and emerging techniques have an ability to carry out or support the implementation of all traffic management steps whereas only the manual operation of service patrols and incident response units did in the existing practice.

In addition, the interconnectivity of technologies renders it more difficult to differentiate one technique from another. An example is that traffic data on a smartphone with incident information in a connected vehicle is transmitted to roadside infrastructure via C-ITS vehicle-to-infrastructure (V2I) communication technology, which is subsequently detected and responded to using an integrated AID and emergency response system with an incident warning broadcast to other travellers through social media.

The increasingly more people-centric techniques using mobile connected devices with location-aware technologies reflect the shift to provide real-time data on current conditions for immediate service delivery and informed decision making. A TIM solution for a successful incident management process is therefore potentially an array of interoperable and interconnected technologies that best utilise available data sources.

Table 2. Role and relevance of traffic management techniques in the traffic incident management process

Practice	Traffic Incident Management Step					Note
	Detection	**Verification**	**Response**	**Traffic Management**	**Traveller Information**	
New and emerging technique						
Smartphones and GNSS	Enable (Link)	Enable	Enable	Support	Enable	Features of a smartphone enable incident management and traveller information
C-ITS and DSRC	Enable (Lane)	Support	Support	Enable	Enable	C-ITS using DSRC enables traffic management by providing traffic control information to approaching vehicles
Social media and crowdsourcing	Enable (Link)	Support	Support	Support	Enable	Examples are Waze and Twitter
Drones for traffic data and incident management	Enable (Lane)	Enable	Support	Support	Support	Restricted use is allowed in Australia
Existing technique						
Emergency phone call and hotline by general public	Enable	Support	–	–	–	–
In-road sensors (e.g. inductive loop)	Enable	Support	–	–	–	Sensors provide traffic data to AID for incident detection
Over-road sensors (e.g. radar and infrared)	Enable	Support	–	–	–	
Automatic Incident Detection (algorithm)	Enable	Support	Support	–	–	AID analyses traffic data from other sources
Traffic incident watch (by professional drivers)	Enable	Enable	Support	–	–	Participants collaborate with transport agency and the Police for incident verification
In-vehicle emergency (e.g. Mayday and e-Call)	Enable	Enable	Enable	–	–	Voice link enables proper incident response
CCTV	Enable	Enable	Enable	Support	–	–
Static traffic and road space management devices	–	–	Enable	Enable	Support	–
Adaptive traffic control and communication devices (e.g. VMS and VSLS)	–	–	Enable	Enable	Enable	–
Service patrol and incident response unit	Enable	Enable	Enable	Enable	Support	–

Source: Austroads, 2017.

Conclusions

This paper presents the development of a proposed TIM framework. The framework, underpinned by seven principles, has incorporated the overarching TIM goal and objective of maintaining mobility and improving road safety during an incident. The framework provides incident management guidance at various IPTIM stages, ranging from inter-agency collaboration, planning and traffic incident management through to performance evaluation and training.

The adoption of emerging transport technologies, particularly those related to the use of smartphone, Bluetooth and drone technology, for incident detection, verification and response, could help minimise traffic disruption and road safety risks and improve the traffic incident management process.

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