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PRIMA - Pro-Active Incident Management

Report on best practice, needs and derived incident scenarios

Deliverable D2.2
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CEDR Call 2013: Traffic Management
PRIMA
Pro-Active Incident Management

Report on best practice, needs and derived incident scenarios (D2.2)

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Executive summary

The purpose of the PRIMA project, which forms part of the Call 2013 Programme of the Conference of European Directors of Roads (CEDR), is broadly to analyse the risks and costs of managing road traffic incidents. The project work will build upon previous regulations, specifications and assessment studies regarding Traffic Incident Management (TIM). The objectives can be summarized as follows:

1. Provide clear guidance and recommendations for handling incidents and monitoring management performance and benefits, based on the assessment of risks and costs.

2. Assess the technical, economical and organisational feasibility of innovative incident management based on novel technologies.

3. Provide implementable solutions to facilitate proactive incident management for high-level road networks, at a transnational level.

TIM methods and best practice have been studied in previous CEDR and other programmes. PRIMA aims also to update these studies by analysing pro-active measures which envisage the use of technology or methods such as optimal response timing to enhance the performance of traffic incident management, adding the pro-active features of Monitor, Anticipate, Prepare, Respond.

This is the report of Work Package 2 of PRIMA, which includes a review of the current practice in traffic incident management (TIM), a discussion of the needs and techniques for pro-active TIM, as well as a description of traffic incident scenarios to be assessed in the subsequent PRIMA Work Packages. The results of the Stakeholder Consultation with its associated Questionnaire are contained in a separate Stakeholder Consultation Report (D2.1, Taylor 2015).

This report details Incident Scenarios which will help to identify the scene management techniques and novel techniques and technologies for discovery and verification that can actively and pro-actively improve the performance of Traffic Incident Management. Issues to be addressed by PRIMA guidelines can be grouped into the three categories of needs, priority incident types, and tools or measures.

TIM Guidelines issued by NRAs tend to be specific to their conditions and the agencies they employ and tend to be detailed and prescriptive, while those developed in CEDR Task 13 allow for a wide range of capabilities and methods of organisation in TIM practice. PRIMA guidelines while more general will extend these to include pro-active techniques at the incident scene, and additionally address preparedness and systems-in-place. It is proposed also to follow the examples of the English Highways Agency and Task 13 by producing a compact Aide Mémoire summarising the guidelines. Depending on how pro-active measures fit into the conventional TIM timeline, guidelines may be couched in the form of an action checklist. It is anticipated that the Project Final Report and guidelines will be supported by slide presentations and conference and journal papers.

1 Introduction

The purpose of the PRIMA project (PRIMA 2015), which forms part of the Call 2013 Programme of the Conference of European Directors of Roads (CEDR), a body formed by European National Road Administrations (NRAs), is broadly to analyse the risks and costs of managing road traffic incidents. The project work will build upon previous regulations, specifications and assessment studies regarding Traffic Incident Management (TIM). The objectives can be summarized as follows:

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This is the report of Work Package 2 of PRIMA, which includes a review of the current practice in traffic incident management (TIM), a discussion of the needs and techniques for pro-active TIM, as well as a description of traffic incident scenarios to be assessed in the subsequent PRIMA Work Packages. Previous CEDR projects in incident management, that are the forerunners of this work, are outlined, followed by a summary of TIM experience and guidance in individual countries and regions. The rest of the report discusses the character of incidents, aspects relevant to cost-benefit analysis, and the use and potential use of pro-active incident management and the enhancements and scenarios proposed by the PRIMA project.

The results of the Stakeholder Consultation with its associated Questionnaire are contained in a separate Stakeholder Consultation Report (Taylor 2015).

2 Current best practice in traffic incident management

2.1 Previous CEDR projects on traffic incident management

CEDR's Strategic Plan 2009-2013 defined a number of tasks for harmonisation and standardisation of best practice across Europe, three of which are directly relevant to this review: Task 5 Traffic Incident Management; Task 13 Best Practice in European Traffic Incident Management and Task 12 Traffic Management. Other related Tasks include T14 NRAs' Roles in ITS and T16 Adaptation to Climate Change. See http://www.cedr.eu .

2.1.1 Task 5 Traffic Incident Management

CEDR Task 5 reviewed current practice in six European countries (see Table 1) with NRAs responsible for traffic incident management (TIM). It identified similarities in the approaches of the different NRAs and the benefit of coordination and partnership between different responders. It also proposed the use of multi-capable responders, but this has not been acted upon because of the specialist skills and equipment required by different responders such as police, fire, ambulance and clearance agencies. However, two kinds of responder with some multi-capability are a Traffic Officer Service (TOS) and Incident Support Units (ISU) as deployed by the English Highways Agency (HA), and the Weginspecteur and Officier van Dienst roles of the Netherlands Rijkswaterstaat (RWS). The Task 5 report (CEDR 2009) consisted mostly of the NRAs' own questionnaire-initiated descriptions of their systems and activities, and was dominated by material provided by the HA, based on its TIM framework and Aide Mémoire (HA 2007, 2009a,b), with contributions from the RWS that issues formal guidelines for responders in its 'Red/Blue Book' and Directives for Incident Safety Measures (VCNL 2010a,b,c).

2.1.2 Task 13 Best Practice in European Traffic Incident Management

The follow-on CEDR Task 13, led by the English HA in the overall project groups ITS (PG-ITS) under the leadership of the Rijkswaterstaat, brought together more NRAs to analyse TIM practice in more detail, to identify its essential elements and consider how these could evolve in countries with different levels of urbanisation and investment, road and traffic density, and distances responders would have to travel. Table 1 lists the countries and NRAs signed up to both projects (inactive in brackets). Task 13 maintained a relationship with Task 12, Traffic Management, through the PG-ITS lead, with related eCall projects through its Slovenian representative, and with the EasyWay ESG2 Incident Warning and Management consortium and its Guideline (EasyWay 2012) through a Memorandum of Understanding. A questionnaire was circulated and received responses from a number of other organisations as listed in Table 2. CEDR Task 13 results consist of a main report CEDR (2011a) and an Aide Mémoire, and are summarized by Steenbruggen *et al* (2012) in Proceedings of the 2012 Transport Research Arena conference.

Table 1. Countries and NRAs involved in CEDR TIM Tasks 5/13

Country	Organisation	Task 5	Task 13
Austria	ASFiNAG	✓	✓
Belgium-Flanders[1]	Agentschap Wegen en Verkeer	✓	(✓)
Denmark	Vejdirektoratet	✓	✓
England	English Highways Agency	✓	✓
Finland	FINNRA	-	✓
Italy	StradeANAS (concessionary)	-	✓
Netherlands	Rijkswaterstaat	✓	✓
Norway	Statens vegvesen	✓	✓
Slovenia	Slovenian Roads Agency	-	✓
Sweden	Trafikverket[2]	(✓)	✓
Iceland[3]	Vegagerdin	-	(✓)

Table 2. Other countries and NRAs that provided information to CEDR Tasks 5/13

Country	Organisation
Australia (State of Victoria)	VicRoads
Czech Republic	Road and Motorway Directorate
Estonia	Estonian Roads Administration
France	Ministère de l'Écologie, du Développement Durable et de l'Énergie
Germany	Bundesministerium für Verkehr, Innovation und Technologie
Latvia	Latvian Road Administration
Republic of Ireland	Road Safety Authority
Scotland	Transport Scotland
Switzerland	FEDRO/ASTRA

The documents issued by Task 13 and published on the CEDR web site are intended not just as reports of work done but as guidance to best practice. The main output (CEDR 2011a) contains (after a short general report) three sections styled as appendices that cover the following three topics:

Table 3. Targeted sections (Appendices) of CEDR Task 13 report

A	Framework Guide for Traffic Incident Management
B	Concepts for Effective Traffic Incident Management
C	Developing Capability as a Traffic Incident Manager

The second output is a 'pocket' Aide Mémoire (CEDR 2011b) similar in layout and structure to that of the Highways Agency (HA 2009) but adapted for the more varied requirements of European responders.

In Task 13, the high-level cycle of TIM is visualised by Figure 1, where it interacts with general traffic management (operator initiative) and the provision of information (user initiative).

[1,3]Belgium and Iceland did not participate in workshops, but had the opportunity to contribute.
[2] Formerly Vägverket, before incorporating Rail.

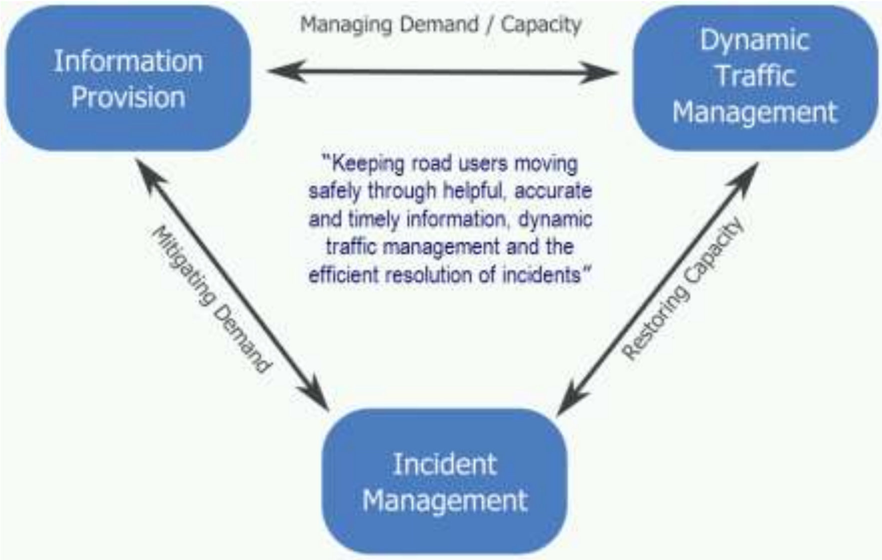

Figure 1. The relationship of incident management to other traffic management services

The 'TIM cycle' can be visualised in several ways (CEDR 2011a) including as in Figure 2 where the stages through discovery of the incident to restoration of normality are indicated. The actual length of these stages and their degree of overlap, if any, will depend on the particular circumstances of the incident.

Figure 2. The TIM Cycle of stages from discovery of an incident to restoration of normality (adapted from CEDR 2011a)

Developing TIM capability is a theme throughout the Task 13 report and is visualised by the 'cube' and ''towers' in Figure 3, where NRAs are characterised at three possible levels: Network Maintainer, Network Operator, and Network Manager.

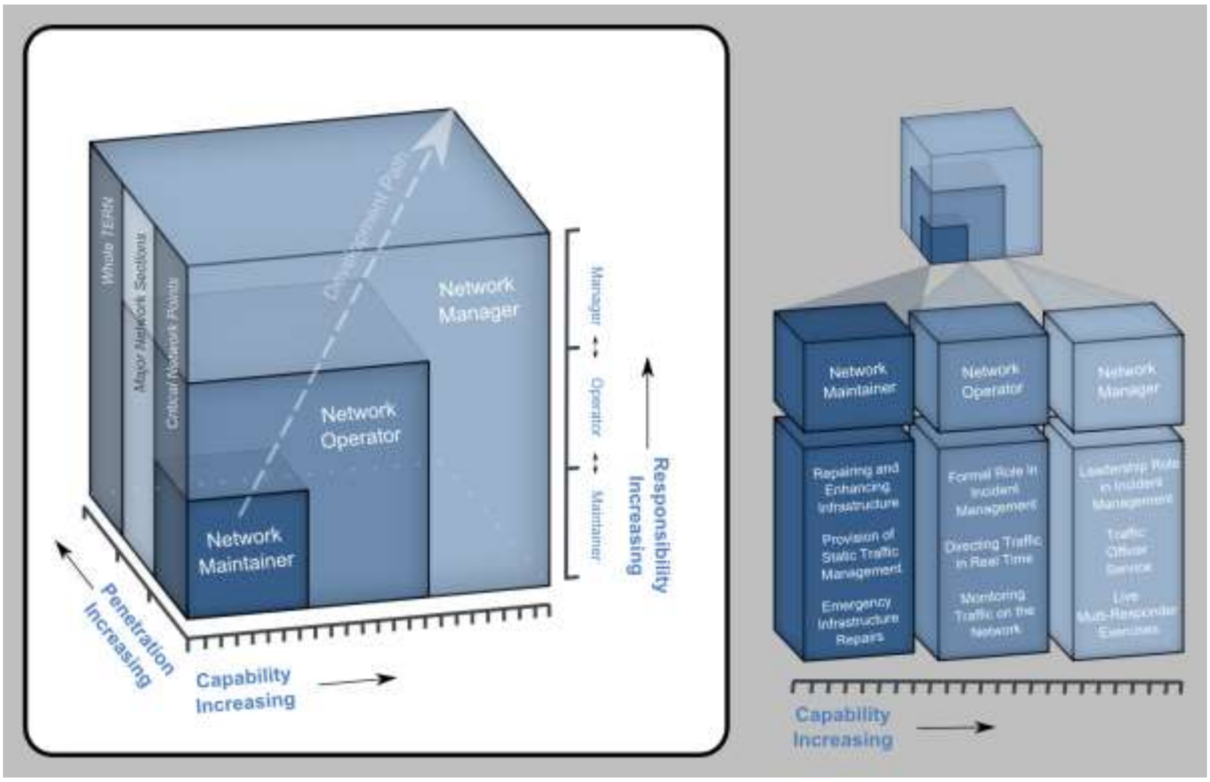

Figure 3. A model of the process of developing TIM capability [Graphics: PETER OWLETT]

2.1.3 Task 12 Traffic Management

Task 12 covered several traffic management measures, including Incident Management, and the TRL team was involved in both Tasks 12 and 13 in support of the English HA. The participating NRAs provided some country data as given in Table 4.

Table 4. Country statistics reported by CEDR Task 12

Country	Area Km_sq	Population	All road Km	NRA road Km	Freight BT-Km	Passenger BP-Km	Incidents	Deaths	Year
Austria	83,871	8,214,160	106,817	12,106	34.33	73.28	39,173	679	2008
Cyprus	9,251	838,897	12,380	2,443	1.31	5.75	1,250	71	2011
Denmark	43,094	5,515,575	73,197	3,866	19.48	52.86	5,020	406	2008
Finland	303,893	5,401,267	78,162	78,162	30.34	63.40	6,072	272	2010
France	551,500	63,504,500	1,027,183	20,819	206.33	720.17	74,487	4,275	2008
Germany	357,022	82,282,988	644,480	53,014	341.53	852.27	320,614	4,477	2008
Italy	301,340	58,090,681	487,700	24,670	306.65	863.89	215,405	4,237	2009
Netherlands	41,543	16,783,092	137,347	3,081	*54.69*#	147.00	21,832	677	2008
Sweden	450,000	9,500,000	425,400	15,325	42.37	98.42	18,309	397	2008
Switzerland	41,285	7,870,130	71,510	1,801	10.28	83.57	24,564	327	2010
UK (GB)	229,848	60,800,000	394,400	11,736	*180.16*#	504.00	218,924	2,222	2009

#: these figures are estimated

These data are hard to interpret because there is no consistent definition of what constitutes an 'incident', and the relationship between incidents and passenger-km is weak. However, the relationship between deaths and passenger-km appears strong (r=0.99) as seen in

Figure 4 (a), so deaths may be a reliable indication of 'significant' incidents. Note that this relationship would not necessarily be expected to extend outside the countries listed. Also freight ton-km are quite well correlated with passenger-km, with r=0.975, so any effect of the proportion of freight traffic cannot be determined here. Another difficulty is what constitutes the network of interest. The proportion of whole network ascribed to NRAs varies greatly, and it is not known what proportion of traffic and incidents are within NRAs' remits. However, some sense of traffic density can be obtained by comparing passenger-km with network length, as in Figure 4 (b). Here, Sweden has a very low relative traffic density as expected, while Germany and Italy have much higher than average values, but Britain and the Netherlands, perhaps surprisingly, are barely above average.

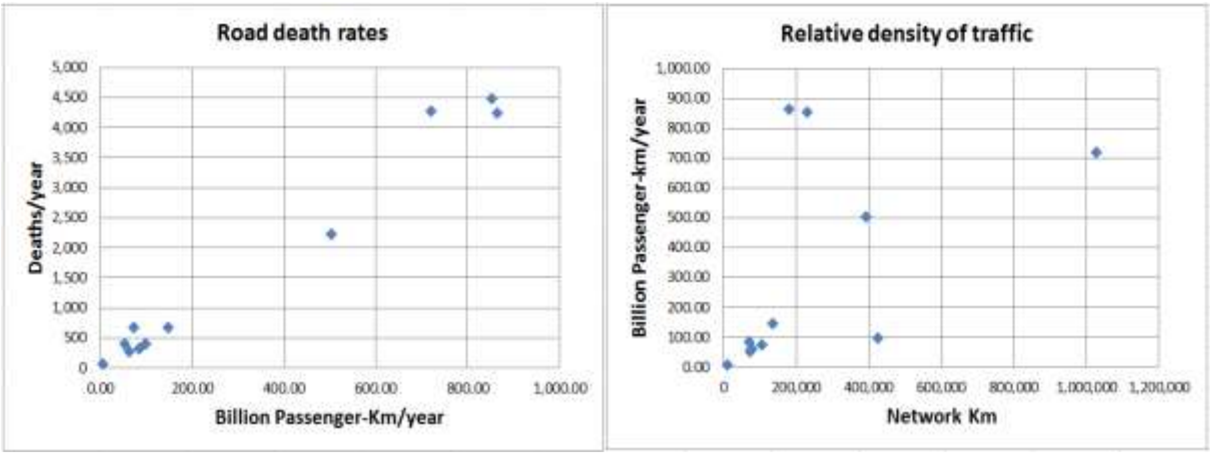

Figure 4. (a) Road accident death rates (left) and (b) relative traffic densities (right) from Task 12 participants

2.2 National TIM Guidance and experience

In this and the following section, the incident management situation in the consortium member countries, and some represented in the Programme Executive Board (PEB), is considered in more detail. This section focuses on NRAs that have issued substantive Guidance documents, while the next summarises European practice as found by CEDR Task 13 and EasyWay, and assembles some evidence from outside Europe.

2.2.1 England

The English Highways Agency can be characterised as a Network Manager, according to the definition in Figure 3 earlier. The HA is responsible for incident management on its strategic network and is actively engaged on motorways and some trunk roads through its Traffic Officer Service (TOS) and its responder-coordinating activities and exercises. The TOS was established in 2004 as a body dedicated to patrolling motorways with some legal powers to stop and direct traffic. This recognised that traffic management is a specialised task and where it becomes intensive, it does not make best use of the more general enforcement and public safety skills of the Police. Thanks essentially to the high traffic levels and the justifiable investment, enforcement on motorways is increasingly automated, while incidents can cause serious disruption requiring rapid and coordinated response.

Between 2004 and 2009, the HA developed its methods and capabilities through its TIM Unit, formulated its Guidance Framework and Aide Mémoire for responders (HA 2007, 2009), issued regular TIM Bulletins and conducted a number of live and simulated multi-agency exercises on which reports are publicly available (see CEDR 2013, Section 17). The Guidance and Aide Mémoire detail phase-by-phase roles and actions divided between the Police and the HA, plus Shared and Common Roles. Further documents provide guidance for managers. The TIM Unit has since been disbanded, the TIM Bulletin is no longer produced, and the exercise reports have been archived. The HA is continuing to develop traffic management through its Smart Motorways programme, aimed at relieving capacity bottlenecks on existing motorways, and the TOS, Incident Support Units and other responders who continue to deal with incidents in a coordinated manner.

2.2.2 The Netherlands

The Rijkswaterstaat (RWS) can be characterised as a Network Manager. In the Netherlands, most of the strategic network is controlled by the Motorway Traffic Management (MTM) variable speed limit system, various capacity-enhancing methods such as narrow or ‘plus’ lanes are used, and Weginspecteur and Officier van Dienst have a broadly similar role to that of the HA’s Traffic Officers. Detailed guidance to responders of the several agencies involved in TIM is provided in the form of the ‘Red/Blue Book’ together with ancillary documents (VCNL 2010). Each of six types of agency, further divided between control centre and on-site responder, is given a page of detailed phase-by-phase instructions. In addition, the TrafficQuest expertise centre, run by TNO and Delft University of Technology in cooperation with the RWS, was founded in 2010 to develop and apply new knowledge on traffic management.

2.2.3 Austria

In Austria, the ASFINAG is responsible for the operation, management and maintenance of all motorways and expressways. The ASFINAG network currently comprises around 2,200 km of roads, including about 350 km of tunnels and 340 km bridges. ASFINAG's tasks include construction and planning of new road projects, operation and maintenance of the existing network, collecting tolls and developing telematics' services. The priorities with regard to construction and planning are increased road safety, improved international connections between Austria and bordering countries, and the implementation of necessary road network upgrades. Therefore, incident management has always been an essential part of their processes.

For a consistent and safe operation, several handbooks have been used within ASFINAG, e.g. for tunnel operation and management, for traffic and road user information as well as for incident management. In the following, the latter one is summarized to briefly discuss ASFINAG's approach. According to their handbook, the following incident groups must be reported: congestion, crashes, vehicle breakdowns with partial or full lane blocking as well as any other road safety hazards.

In general, there are three incident management phases mentioned in the handbook:

1. Phase 1: Alerting: Process incident information, initial response, inform and send out incident manager

An incident can be detected and reported by persons (e.g. citizens, police, service staff etc.) or by various systems (e.g. video, eCall, roadside emergency phone, wrong-way driver warning etc.). However, an appropriate first response initiated by the regional ASFINAG traffic management and monitoring centre is of highest priority. This includes as an example, lane or tunnel closure via VMS as well as immediate advice of emergency services, of the national traffic management centre and of the nearest "Autobahnmeisterei" (local service and maintenance station). Subsequently, the "Autobahnmeisterei" sends out an incident manager to the incident location.

2. Phase 2: Handling: Situation report, Scene management, clear incident spot and open lane(s)

Supported by the ASFINAG traffic management centres, the incident manager is responsible for all on-site management actions until the clearance of the incident location. The incident manager has to make a quick initial incident report (including the incident type, location, blocked lanes, involved vehicles or persons, injuries/fatalities, expected duration until clearance etc.) to the regional traffic management centre, which then informs the national traffic management centre. The national centre distributes the incident information to internal and external partners, e.g. the press office or radio broadcasts. At intervals of 30 minutes or less, or at certain event milestones (e.g. helicopter landing, successful recovery etc.), the incident manager has to make an update of the incident situation report.

3. Phase 3: Post-processing: Documentation and reporting, analysis

In the third phase, when the restoration to normality is completed, the incident response is evaluated in terms of compliance of internal processes. Furthermore, incident statistics are analysed and management actions are documented.

In summary, according to their handbook, ASFINAG's current incident management is based on reactive procedures. However, a new internal incident management software tool has recently been rolled out to improve response time and information quality. Proactive features comprise a more accurate estimation of incident and congestion duration as well as the use of hotspots in the road network, where incidents (congestions) are likely to occur and hence the response can be ameliorated in advance.

2.2.4 Republic of Ireland

The Republic of Ireland's National Road Administration can be characterised as a Network Maintainer. The separate Road Safety Authority was consulted during Task 13 and since then the Irish government has issued Guidance to emergency management on major roads (DECLG 2013). Apart from the practicalities of securing the scene and dealing with hazards, diversion, collection of evidence etc., the Guidance specifies the responsibilities of the Principal Emergency Services, namely:

- Gardai
- Fire Services
- National Ambulance Service

Supported by:
- National Roads Authority
- Towing services
- Aero-medical services

2.2.5 Status of national guidance and initiatives in TIM

Traffic Incident Management with its formal Guidance in England, the Netherlands and substantially in the Republic of Ireland and Austria can be considered mature. However, while it may be efficiently reactive it is not necessarily pro-active. There is a move towards a more pro-active system through the group of Common Highways Agency Rijkswaterstaat Model (CHARM) projects sponsored jointly by the HA and the RWS (CHARM 2014), whose objectives are:

1. Advanced distributed network management
2. Detection and prediction of incidents
3. Support of cooperative ITS functions
4. Development of an open, modular architecture for Advanced Traffic Management Systems (ATMS)

The formal inclusion of statistical analysis in ASFiNAG's guidance in addition to logging of data is interesting. While other NRAs include de-briefings and multi-agency exercises (see CEDR 2011a), and statistics are generated (as e.g. in the UK by the DfT including from Police STATS19 logs) these tend to be 'add-ons'. The aims of PRIMA do not extend to prediction but embrace technological and other solutions to enhance incident management performance, nationally and transnationally, on motorways and primary roads. Secondary roads will be taken into account during the execution of this project, however this will be limited to incidents requiring the diversion of traffic onto non-primary roads and incidents on secondary roads and the impact on primary roads.

2.3 *Other international TIM studies and experience*

2.3.1 Task 13 survey of TIM in Europe

Table 5 is a highly condensed summary of the findings of the CEDR Task 13 questionnaire, which obtained responses (in variable depth and detail) from 19 countries, including Australia (State of Victoria) as an 'honorary European'. The current roles of NRAs and their responsibility for incident management are highlighted (**Mt**=Maintainer, **Op**=Operator, **Mg**=Manager).

Table 5. Summary of selected response to CEDR Task 13 questionnaire

Country	Aus[1]	AT	BE(Fl)	CZ	DK	Est	FI	DE	IE	IT	LV	NL	NO	SE	UK
Role / Responsibilities	**Mt**	**Mt**	**Op**	**Op**	**Mg**	**Mt**	**Op**	**Mt**	**Mt**	**Op**	**Mt**	**Mg**	**Mg**	**Op**	**Mg**
Incidents	Some	No	No	No	No	No	Major	State	No	Yes	No	Yes	Major	Yes	Yes
Traffic	Yes	Yes	Yes	No	Yes	No	No	State	No	Yes	No	Yes	Yes	Yes	Yes
Information	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Taking More Responsibility[2]	Yes	Some	No	No	Yes	No	No	No	No	No	No	Yes	Yes	No	Yes
Formal TIM Guidance	Yes	No	No	No	No	No	No	No	Yes	No	No	Yes	Yes	No	Yes
Focus on Incidents Safety	Yes	Yes	No	No	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Agreed Responder Roles	Yes	No	No	No	Yes	No	Some	No	No	No	No	Yes	Yes	Yes	Yes
Integrated Communications	No	Yes	No	No	No	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Policy Group/Exercises	Yes	Yes	Yes	No	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Performance Measures	No	No	Yes	No	No	No	No	No	No	No	Yes	Yes	No	Yes	Yes
Primary Prevention	No	No	No	No	No	No	No	Yes	No	Yes	Yes	No	No	No	No
Focus on Traffic Flow	Yes	Yes	Yes	No	Yes	No	Yes	No	No	Yes	No	Yes	Yes	Yes	Yes
Integration with Urban	No	No	No	No	No	No	Some	No	No	No	Data	Data	No	Data	No
Strategic Plan	No	Some	No	No	Yes	No	No	Some	No	No	Safety	Yes	No	No	Yes

1: The State of Victoria, Australia 2: Switzerland also has indicated a desire to take on more responsibility

Three NRAs that do not take full responsibility for TIM indicate they intend to do so more in the future. However, an NRA can issue guidance on TIM practice without taking full responsibility for TIM. Sometimes the issues are complicated by division of responsibilities between different organisations. For example, in the Republic of Ireland the Road Safety Authority is distinct from the National Roads Authority, in Germany responsibility for roads is devolved to the Länder, and in Italy the autostrade are 'Design Finance Build Operate' (DFBO) projects of the private company ANAS. In many countries the Police have primary responsibility for responding to an incident, although they may hand over quickly to the roads operator. This is a significant point, because in the absence of statutory Traffic Officers, only the Police normally have the power to stop or direct traffic and collect evidence. Conversely, the employment of Traffic Officers represents a significant specialised investment that can be justified only where there is a sufficiently extensive network carrying high levels of traffic. This criterion is unlikely ever to be met in many countries with sparse networks, e.g. Finland and the Baltic States. Furthermore, the systems required to take even secondary responsibility for incident response may not be justified in countries with moderately sparse networks like Norway. It therefore seems logical for Finland and Norway to concentrate on dealing with critical emergencies involving tunnels and bridges. Sweden employs a mobile assistance service VägAssistans, which has vehicles equipped with a crash cushion, variable message sign, video recording and a small crane to assist clearance.

2.3.2 Conclusion of CEDR Task 13

Task 13 identified ten criteria for successful TIM practice:

1. Speedy detection and response
2. Good information about location, severity and any attendant hazards
3. Protection of the scene, and ensuring safety of responders, victims and the public
4. Coordinated response with a clear structure of authority, roles and responsibility
5. Reliable communications between responders and with the public
6. Provision of appropriate equipment, facilities, access paths, and management
7. Sufficient backup services to ensure speedy clearance to minimise congestion
8. Information exchange through training and debriefing systems
9. Written guidelines and formal agreements where necessary
10. Monitoring, performance assessment and feedback into practice.

In addition, it made several recommendations for the way forward:

1. Dissemination of best practice
2. Pursuing a development path (as in Figure 3 earlier)
3. Exploiting learning loops (e.g. Capability→Assessment→Intelligence→Policy↲)
4. Monitoring and feedback
5. Exploiting developments in technology and communications (e.g. DATEX2)
6. Lowering institutional barriers
7. Engaging the Police (including internationally)

Prevention of incidents was of course also highlighted, with the conclusion that incident prevention is a natural companion of incident management. Just as incidents arise from combinations of factors, so successful incident prevention may depend on a combination of measures: analysis and intelligence, driver information and education, and physical measures. Some measures identified are shown in Figure 5, with indicators of current success or future priority.

Figure 5. Primary incident prevention measures in use and planned from the Task 13 Survey

2.3.3 EasyWay's Guideline on Incident Management

EasyWay is a large European umbrella project partly funded by the European Commission whose purpose is to deploy ITS core services. The participants are more wide ranging than in CEDR, involving academia and industry as well as government agencies. So far EasyWay has progressed through two project phases, EW I in 2007-2009 and EW II in 2010-2012. EW I was roughly contemporaneous starting slightly ahead of CEDR Task 13, and after some high-level discussions a Memorandum of Understanding between the two projects was agreed to avoid duplication. There was also a more direct link through the Norwegian member of Task 13, who was also active in the VIKING group that existed at that time, embracing the Nordic countries together with several north German states, which joined EasyWay in 2007.

Task 13 had available an early version of the Guideline for the Deployment of Incident Management, one of 19 guidelines issued. Task 13 was mildly critical of this on the grounds that whatever might be recommended, NRAs would have to be the ones to implement it. The original guidelines (EasyWay 2010) resembled Task 13's assessment of best practice in tabulating actions and methods appropriate to various roles and functions at three service levels (see Section 19 of CEDR 2011a), though EasyWay's approach focused more on technology than on organisation:

- A (Basic): covering critical points such as bridges or tunnels
- B (Enhanced): also covering major roads with daily traffic or critical weather problems
- C (Intensive): covering 100% of the TERN network'24/7'.

EasyWay Guidelines are currently available from its web-based ITS Deployment Guidelines Library. The current Guideline (EasyWay 2012) is quite different from the earlier version and much more prescriptive, almost legalistic, in its tone, with particular emphasis on harmonization and standards requirements for technology, signing etc. This is stated explicitly in its introduction:

"A certain level of strictness in compliance is required to achieve the intended goal of … harmonisation and interoperability in Europe – the guideline documents are written in a way that clearly defines criteria that deployments have to fulfil in order to claim overall compliance with the guideline. Although not legally binding in any sense, compliance may be required for the eligibility of deployments in future ITS road projects co-funded by the European Commission. Deviation from compliance requirements may nevertheless be unavoidable in some cases and well justified. It is therefore expected that compliance statements may contain an explanation that justifies deviation in such cases. This is known as the 'comply or explain' principle."

This didactic approach differs from that of NRAs, whose procedures will accord to their areas of responsibility and the working relationships they have developed with service providers. NRAs may choose to address aspects of harmonisation, for example signing to improve user comprehension, but this is unlikely to be a principal operational concern except where they subscribe to specific international services such as eCall, DATEX II/TPEG etc.

2.3.4 Other European projects relevant to TIM

The **e-Call** project, part of the EC's ITS Action Plan now enshrined in a Directive, could in principle alert responders automatically, although at present it is envisaged to work through Public-safety answering points (PSAPs). Projects looking farther ahead include **SAFESPOT** (Brignolo *et al* 2010, SAFESPOT 2010), which envisages collaborative V2V as well as infrastructure-supported hazard warning to reduce incidents. Although such developments could not be expected to completely eliminate incidents they could affect the circumstances in which they occur, and the provision of information directly to responders could affect their distribution and for example reduce the risk of unnecessary deployment.

2.3.5 TIM in the USA

Practice in the USA can be considered relevant at least for information for three reasons: the involvement of the Federal Highway Administration (FHWA), the variety and large number of bodies with some interest in TIM (around 200 according to the FHWA), and the increasing deployment of quick-clearance laws. One source identified is a report for the I-95 Corridor Coalition (Delcan 2010). I-95 runs along or near the east coast from the Canadian border with Maine to Miami, Florida. The report draws information from a number of States, including many not on the I-95 route, identifying a response cycle with components similar to those in Figure 1. The following recommendations are identified, which correspond quite closely to those identified by Task 13 and emphasised by established network managers like the HA:

1. Post-incident reviews
2. Clear leadership, and agency and stakeholder coordination
3. Use of incident response patrols and vehicles
4. Clearance time goals (30, 60 or 90 minutes depending on incident severity)
5. Dissemination of guidance and training
6. Outreach to significant outside bodies and institutions
7. Planning and consultancy support
8. Performance measures
9. Photogrammetry and location coding
10. Strategic plan

These recommendations are consistent with the elements identified as significant by Task 13 and already present in the most advanced TIM practice in Europe. In addition to clearance time targets there is emphasis on adequate towing provision and contracts and quick clearance, a significant aspect of which is the existence in many states of Driver Removal and Authority Removal laws which allow vehicles or casualties to be removed quickly while complying with legal requirements for investigation and protecting responders from any ensuing legal liability (FHWA 2008). The FHWA has conducted an intensive SCAN study of European TIM practice (FHWA 2006). It identified several recommendations including:

1. National unified goal for incident response
2. Formal agreements between incident responders
3. Integration of research and practice, particularly in data analysis
4. Performance measures
5. Incident response training
6. Pro-active role of agencies (e.g. TOS) including powers to direct traffic
7. Clear lines of command and control, and TMCs
8. Coordination of responders
9. Making use of private sector organisations (e.g. for clearance)
10. Use of variable speed limits and queue protection where appropriate

The FHWA was critical of TIM practice found in 2006 on a number of counts, as summarised below:

1. TIM is not always at the centre of an agency's mission
2. It may be a fragmented, reactive activity with divided responsibilities
3. As a 'lower tier' activity it is often limited by resources sourced from unrelated budgets
4. Participating agencies can have different cultures leading to role conflicts
5. Secondary accidents, representing 14-20% of total, are not adequately considered
6. Traffic control is inconsistent
7. Quick clearance may require special legislation

Many of these criticisms can be said to have been addressed already by the English HA, which at the time (as recognised in the FHWA report) was developing its capability, and by the Netherlands RWS, and all are considered by Task 13. There is no reference to pro-active features as proposed by PRIMA, but it should be recognised that fragmentation of TIM in the USA is a natural consequence of the large size of the country, the great length of rural roads with relatively low traffic levels and the disaggregated nature of governance in the USA with most responsibilities delegated at State, County and Metropolitan level. In 2013 the FHWA, under the National Cooperative Highway Research Program, specified a project NCHRP 03-108 'TIM Program Assessment Framework', whose objective is to coordinate measures of performance across the approximately 200 agencies involved in TIM. This would be a first step to harmonising practice, apart from guidance documents issued by the FHWA (2009a, 2010a,b) and several technical documents including FHWA (2009b), but it suggests there is some way to go.

As a final point, the National Highway Traffic Safety Administration (NHTSA) has identified that in 2012 rural areas in the USA experienced a road death rate per population five times higher, and per vehicle-km 2.4 times higher, than in urban areas, although the disparity has been decreasing (NHTSA 2012). However, the percentages of deaths considered to be related to speeding are almost identical (31% of rural, 30% of urban), which is highly suggestive of traffic speed being a critical factor in anticipating serious accidents.

2.3.6 TIM in the rest of the world

Australia appears to be relatively advanced in TIM. The national Austroads body has issued reviews (Austroads 2007a,b) supported by guidelines (Austroads 2007c). However, actual implementation is the responsibility of the individual states and territories. In its report on improving TIM (Austroads 2007b) it states:

"There is an emphasis to adopt a more pro-active approach to managing incidents, not only through in-house means such as service patrols, incident response units, coordination of incident response/traffic management centres, but also to use policy and legislative tools to provide more powers to the responding agencies (quick clearance and authority to tow laws)".

This interpretation of ‘pro-active’ essentially reflects existing practice in the UK and Netherlands. However, the report makes several references to Balke *et al* (2002), who recommend more attention to the ‘demand aspect’ including surveillance and control, but also emphasise the need for performance measurement. Clearly there is considerable cross-fertilisation from the ‘big players’ like the FHWA, HA and RWS to smaller bodies or those less far ‘along the curve’.

Dubai Roads and Transport Authority issued a TIM Manual (RTA 2008) but this was developed by a consortium of Hyder and TRL and relied significantly on material already cited as well as some more technical sources.

Singapore emphasises the roles of TMC, ITS and VMS in its Expressway Monitoring Advisory System (EMAS 2014). When operators see an incident on their screens they dispatch a Recovery Vehicle, which is estimated to arrive within 15 minutes. The recovery crew have legal powers to tow away vehicles, and the emphasis is on rapid clearance. Where there is a need to direct traffic or collect evidence, this is done by dedicated Traffic Marshals, but accidents involving injury are handled by the Traffic Police.

Hong Kong, another densely populated city, announced in 2011 a proposal to develop a TIM System by 2015 (Telematics News 2011). This is also technology based with CCTV and traffic and incident detection. It proposes a knowledge-based system to evaluate incidents and launch responses, linking all responders and generating appropriate traffic information. It is unclear what level of operator intervention is envisaged.

Japan views traffic management as predominantly ITS-based, with emphasis on accident prevention through vehicle control and information plus a mixture of local metropolitan and national systems (MLITT 2010). However, there appears to be little information about incident management as such, suggesting it is mostly handled locally.

2.4 Other issues affecting TIM best practice

2.4.1 Emergency medical response

When life-threatening injuries occur there is a 'rule of thumb' that medical attention is required in the first 'Platinum 10 minutes', with follow-up care in the remainder of the 'Golden Hour'. In the US, the Centers for Disease Control and Prevention (CDC) issued Guidelines for Field Triage of Injured Patients in order to provide optimal emergency medical service (CDC 2011). Response within 10 minutes implies a pro-active approach in the medical emergency services, which will depend on their policies. For this reason it seems superfluous to specify it as part of pro-active TIM. However, assuring rapid situation assessment and communication channels to mobilise emergency medical teams may be considered part of pro-active TIM.

2.4.2 Quick clearance

Quick clearance policies are currently more in evidence in the USA than anywhere else. The FHWA finds that quick clearance is the most effect method to decrease responder injuries and secondary crashes, improve mobility, and improve the public image of response agencies. It is recommended to be a policy supported by laws that reduce liability for responders taking aggressive actions to open roadways (NCTIM 2002) and also empowering them to, for example, remove dead persons from the scene, since the legal and other sensitivities of road death can considerably lengthen incident clearance. Practice in the USA is extensively described in NCHRP (2003) and I-95 (2003). The FHWA has reported on SCAN visits to Europe where these issues are still under negotiation (FHWA 2005, summarised in World Highways 2005). However, they report that EMS personnel in Germany (usually including a doctor) and the Netherlands are empowered to officially declare a victim deceased. In the UK, road death investigation is governed by a manual issued by the Association of Chief Police Officers (ACPO 2001) which includes procedures for securing and collecting evidence that emphasise thoroughness rather than speed. Quick clearance will usually require the items listed below, while a 'softer' approach is the use of Driver Removal Laws, which apply in around half of US States (Chowdhury *et al* 2007), requiring a driver to "make every reasonable effort to move the vehicle or have it moved so as not to obstruct the regular flow of traffic", or signs requiring drivers to move crash vehicles to the shoulder if there is no serious injury.

- Legislation for rapid clearance and towing
- Legislation for traffic direction (e.g. by responders other than police)
- Removal of vehicles containing deceased person before attending to casualty
- Empowering EMS responders to declare victim dead at scene
- Streamlining of investigative processes (e.g. use of laser scan photogrammetry)
- Clarification of liability and insurance law
- Public information about these policies
- Benefit analysis including institutional awareness of costs of delay and congestion
- Clearance time targets
- Training of responders
- Cross-border coordination where relevant
- Possible dispatch of salvage experts to minimise collateral damage
- Efficient ways of dealing e.g. with chemical spills, heavy vehicles

2.4.3 Dealing with lane blocking incidents

In addition to lanes blocked by the incident itself, best practice is to close the minimum number of lanes necessary to protect victims and responders, bearing in mind the need for access. This number could vary during the incident management process. There is a further loss of capacity from closing a lane for safety reasons. Although the numbers do not follow a consistent pattern, closing an additional lane for safety will cost broadly 20-30% of total normal capacity (see later section on duration of incidents). FHWA advice is to:

- Move closure from full to directional to multi-lane to single-lane to shoulder
- Seek the quickest route to clearing a lane, e.g. removing debris is relatively quick
- Open individual lanes as soon as they are cleared or otherwise possible
- Clear from offside to nearside
- Shrink the scene gradually, preferably towards the nearest exit
- Hold back complex vehicle load transfers or repairs until all lanes are cleared.

The FHWA has estimated the effect on capacity of blocked lanes (FHWA 2000), which is discussed in the later section on costs and benefits.

2.4.4 Weather

Although weather is not consistently associated with incidents, poor visibility as in fog, or poor surface condition such as produced by snow are bound to have an impact. Given the prevalence of weather forecasts, pro-active responses are possible, such as the use of variable warning signs or speed limits, gritting, and mobilisation of snow ploughs. In Iceland, the road administration (ICERA) also has to be prepared to cope with volcanic ash. However, these investments must be balanced against the prevalence of conditions, for example snow is much more common in central Europe, the highlands of Scotland and parts of North America than in England. In these cases, pro-activity could include an element of demand management, for example through the 511 phone information service in North America. In a group of articles on rural ITS solutions (TTI 2014), the comment is reported that “It’s not the weather that closes the roads; it’s the people who go out and get stuck or spin sideways and end up blocking the carriageway”.

2.4.5 The role of information to road users

The European Commission (2014) announced in December 2014 that it has:

“adopted new rules which will help provide road users across the EU with more accurate, accessible and up-to-date traffic information related to their journeys (Real-Time Traffic Information). This can include information about expected delays, estimated travel times, information about accidents, road works and road closures, warnings about weather conditions and any other relevant information. Such information can be delivered to drivers through multiple channels: variable message signs, radio traffic message channels, smartphones, navigation devices, etc.” It points to the existing market for Real-Time Traffic Information services as influencing the objective of the new rules “to make existing information services available to more users, facilitate the sharing of digital data, and foster the availability of more and accurate data.”

Optimising information provision channels in anticipation of need could therefore be interpreted as an indirect element of pro-active TIM. At first sight, information appears not to have a direct role in pro-active TIM, because information about an incident cannot be available until after it has unfolded. However, Lindsey *et al* (2014) argue that the benefit, and in some cases disbenefit, of information that might enable travellers to avoid delay caused by an incident depends on the alternative paths available. Benefits are expected to be greatest when alternative paths are most similar in type, capacity and risk of shocks, while disbenefits may arise if the alternatives are very different in character. This issue has arisen in practice. Anecdotally, in the event of an incident on a motorway causing a substantial blockage, the policy of police or traffic managers may be to keep traffic on the motorway, in preference to diverting it onto an unsuitable network where further incidents might be caused. The pro-active element in this would be recognising in advance whether providing information would be beneficial in any given cases and preparing systems accordingly.

2.5 Commercial products

As web, big data and digital analysis and presentation technologies evolve, there is an increasing market for general software tools that organise data or support traffic management. Examples of the former are produced by companies like TomTom and INRIX. An example of the latter is GEWI (2015), which markets traffic software under the generic brand TIC, including an incident management function.

2.6 Discussion

There are clearly two different TIM philosophies involved in this review - ‘local targeted’ and ‘global organisational’, in a context of moves towards technology-based systems like e-Call and SAFESPOT. The first concentrates on sites where incidents have or are more likely to have more serious consequences. Bridges and tunnels are obvious sites, and may be managed by a local TMC coordinating with Police or, if justified, using their own patrols, and local emergency and clearance services. The second is justified for dense heavily-used networks where jurisdictions effectively merge through proximity and inter-dependence. Reliance on technology is likely to be greater in the first case because incident scenarios can be more precisely defined and the high cost of critical infrastructure makes investment more justifiable, for example in a high density of vehicle detectors, cameras or other sensors linked to a permanent dedicated TMC. The second type of situation is likely to favour coordinated mobile response supported by more distributed technology.

These philosophies broadly match what exists in countries like Norway, Sweden and Finland (first type) and the United Kingdom and Netherlands (second type) with countries like Austria and Italy somewhere in between. German practice is complicated by its federal organisation, but the approach of the Länder is broadly of the second type. However, in some countries it is difficult to establish exactly how incidents are managed, especially where motorways are privately operated. In south-east Asia, with its dense and growing cities, the starting point seems to be an integrated technological, possibly automated, solution.

Although CEDR Task 13 laid out a development path for NRAs, with the implication that each country’s current practice represents a stage on a natural progression, it did not attempt to match benefits with costs, and consequently did not recommend an optimum level of deployment for any particular country or type of network. In that regard, EasyWay’s three levels of service approach may be more realistic, while Task 13’s Maintainer, Operator, Manager sequence represents organisational reality on the ground. Both of these can evolve according to need and resources, but whether there is a natural progression path may be questioned.

3 Pro-active incident management

3.1 *Evidence from previous work*

The Task 13 report includes Figure 6 where a linear model of the 'TIM cycle' has been modified to allow for the possible overlapping of stages, each being started at the optimum moment instead of only when the previous stage is complete. Incident prediction is not part of this so to that extent it remains reactive to the original incident, but it is envisaged that optimising the response pro-actively could improve performance.

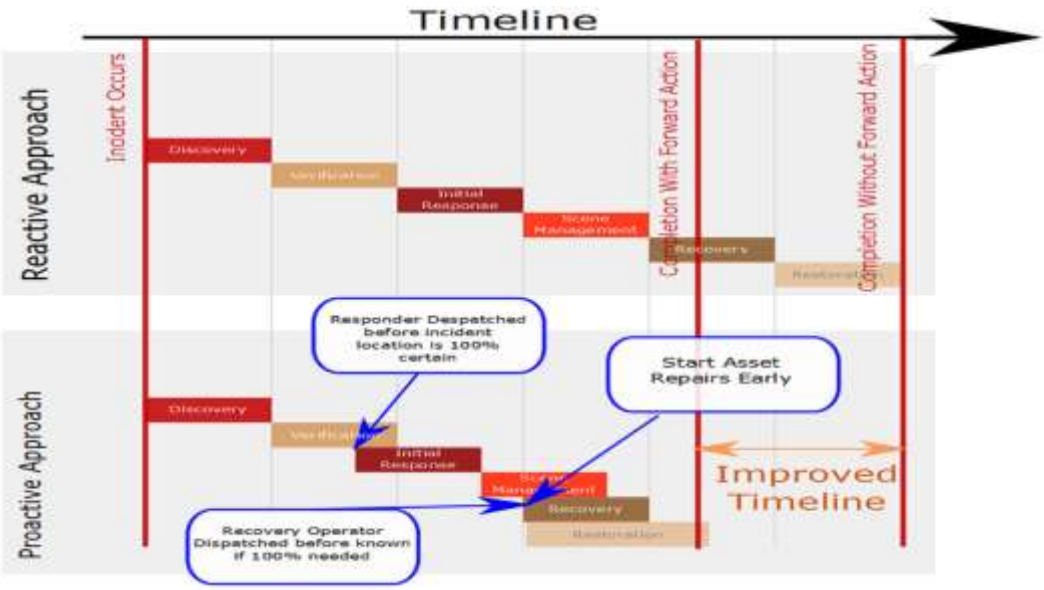

Figure 6. Pro-active incident management measures as proposed by Task 13

Figure 7 shows an enhanced TIM Cycle incorporating generalised pro-active elements whose specification is one of PRIMA's objectives, plus aspects of implementation and performance that the project will address.

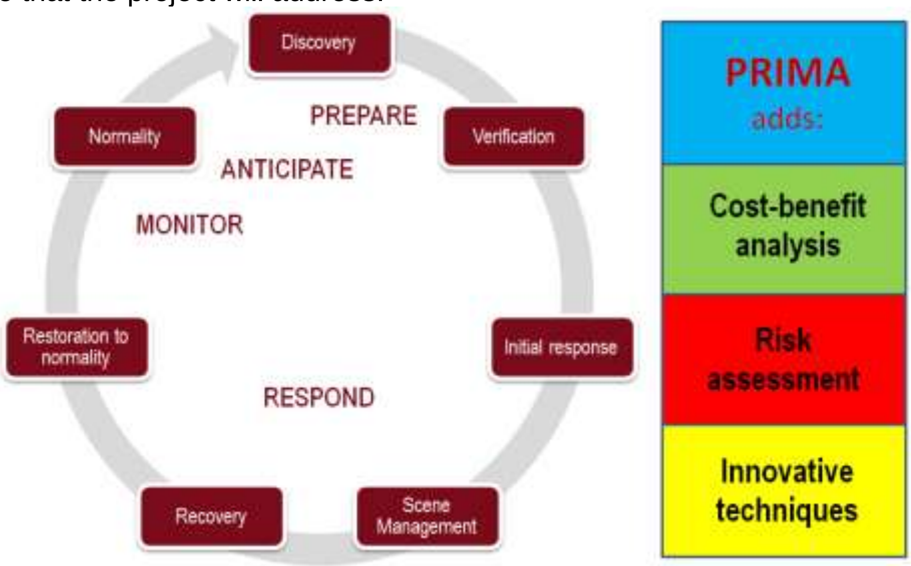

Figure 7. TIM cycle enhanced by pro-active elements and assessments

However, this still gives no indication of the durations of the incident stages, which are reflected in a simplified manner in Figure 8. It is clear from this that the initial response stages are very short compared with subsequent management stages. However, a rapid initial response is essential to (1) reach, stabilise and, if necessary, evacuate seriously injured casualties, and (2) protect the scene and avoid secondary accidents. It can therefore make a substantial contribution to improved TIM performance. Early initiation of clearance and recovery may in some cases be able to reduce the duration of blockage and so reduce queues, bearing in mind that total delay is proportional to the square of queue size (CEDR 2011a, EasyWay 2010). Studies by WADOT (2011a,b) look at factors affecting TIM performance with particular focus on delays. Two of its conclusions are that regular TIM is justified only where at least 45 crashes per year occur in one direction on a typical highway segment (8-11 km), and 'roving' response only where traffic flow is at least 60-70% of capacity.

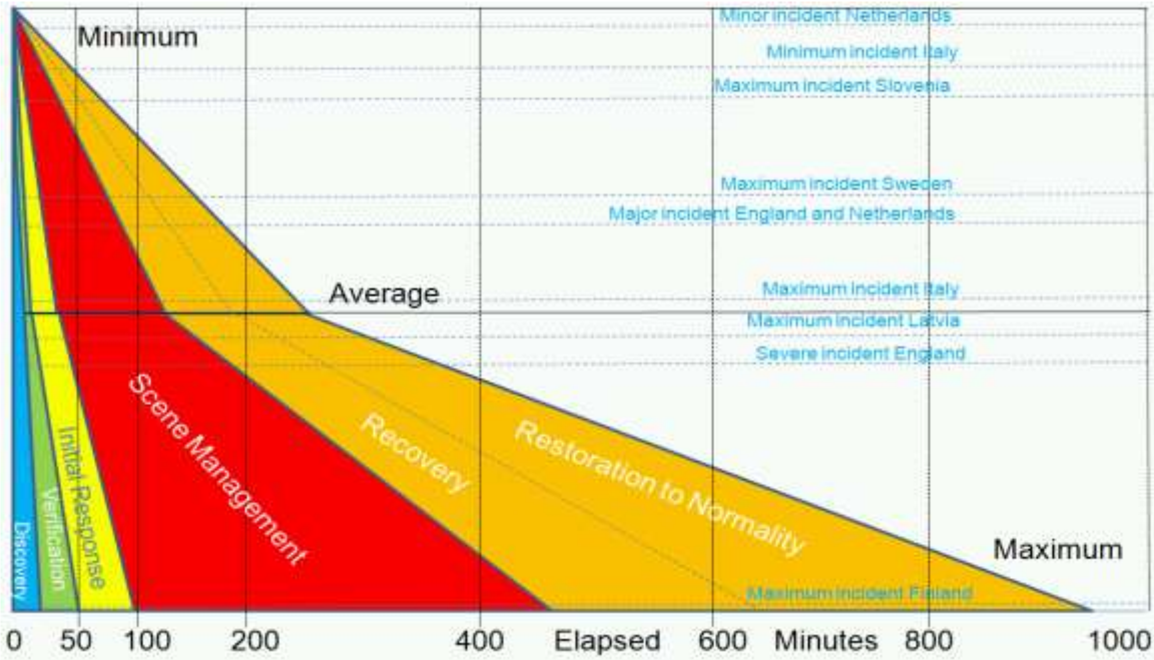

Figure 8. Sketch showing absolute and relative durations of TIM stages

Where the network is sufficiently dense to be monitored constantly by CCTV, as in Singapore (EMAS 2014), a pro-active approach can consist of early response plus dispatch-readiness of services. Hou *et al* (2014) describe a regression model of incident clearance times as a function of circumstantial factors on the I-5 near Seattle, WA, which also allows estimation of remaining duration at any point, raising the possibility of 'pro-active review' throughout the TIM process. They identify debris, abandoned vehicles, heavy truck involvement, time of day/night, time of week, traffic control as factors associated with what in laymen's terms would be unpredictability or a 'heavy tailed' distribution of incident duration, with collisions, injury, fires and lanes blocked having a more even and predictable effect.

3.2 Enhancements proposed by PRIMA

The potential benefits of timely and appropriate response are recognised by PRIMA's proposed Prepare and Respond features. Another aspect of pro-activity is contained in the broader Anticipate and Monitor features. These additions are sketched in Figure 9. None of them is actually *predictive* of incidents. They are focused less on the probability of what will happen than on the likelihood that a particular response will be required. Each implies readiness based on experience and recognition of current conditions.

PRIMA characterises these features in the following terms:

Monitor and Anticipate: Monitoring and recognising changes in traffic state (level of service) and identifying high-accident-risk locations on the road network in order to facilitate anticipation of potential incident scenarios. In particular, novel pre-incident management methods based on promising technologies can be used.

Prepare and Respond: Based on incident anticipation, and particularly based on risks and costs of certain TIM methods, the most efficient response activities can be planned ahead. In other words, the coordination of the phases - Initial response, Scene management, Recovery and Restoration - can be established in advance. Minimising costs and risks as well as secondary effects is of major importance.

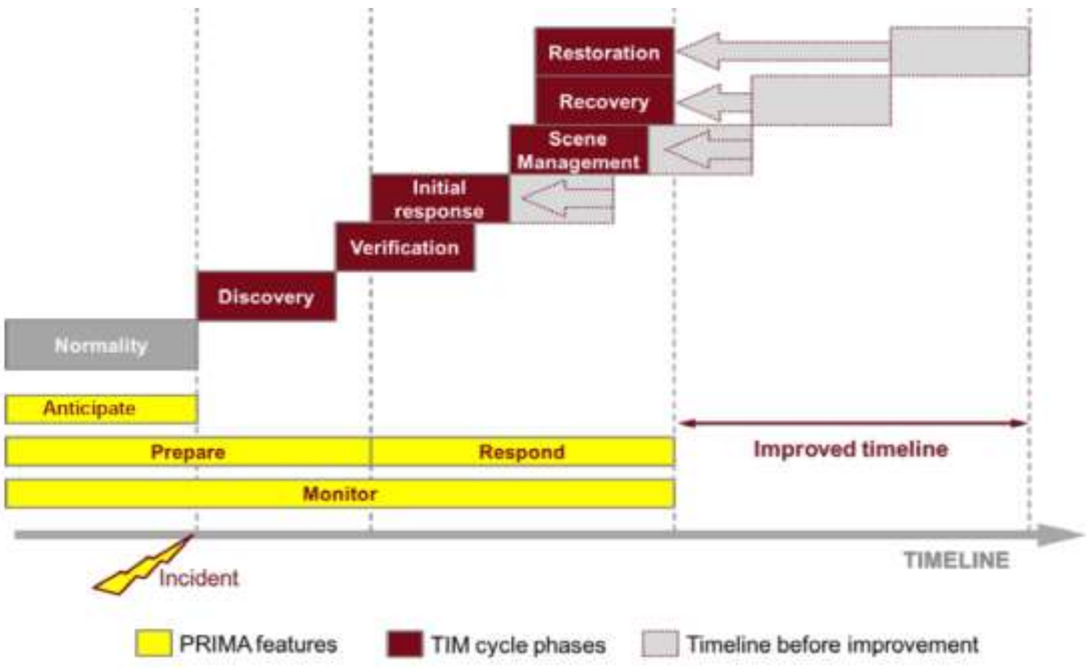

Figure 9. Additional pro-active TIM features proposed by PRIMA

While prediction and detection are outside the remit of PRIMA, they nevertheless may be expected to play a major and increasing part in TIM. One of the TIM cycle stages is labelled 'Verification', which implies that without direct visual assessment by either an operator or the Police there can be a delay in deciding whether an incident has occurred and if so how serious and what the response should be. Deployment of systems like e-Call, SAFESPOT dynamic cooperative networks (SAFESPOT 2010) (see earlier in Section 2), image processing and recognition, and even acoustic disturbance monitoring (Pinchen et al 2014) may provide automated input to speed up this stage.

4 Incident definition classification and valuation

4.1 Definition of an incident

Various definitions of what an incident is exist in literature. Among them are mentioned:

- "An incident is any unplanned event, other than a vehicle breakdown on the hard shoulder that may adversely affect the capacity of a road and hinder traffic flow, including accidents, spilled loads and stranded vehicles." (CEDR 2011a)

- "An incident is a situation on the road that is not expected or foreseen by the road user and which may, or may not, lead to an accident. An incident impacts the safety and/or the capacity of the road network for a limited period of time. Incidents range from breakdowns, to debris on the carriageway, road works, collisions between vehicles or with obstacles and accidents involving hazardous materials." (EasyWay 2012)

- "Any non-recurring event that causes a reduction of road
- way capacity or an abnormal increase in demand, such as traffic crashes, disabled vehicles, spilled cargo and debris, special events, or any other event that significantly affects roadway operations." (RAIDER 2013)

- "A traffic incident refers to any event that can degrade safety and/or slow traffic, including disabled vehicles, crashes, maintenance activities, adverse weather conditions and debris on the roadway." (Austroads 2007b,c)

- "An 'incident' is defined as any non-recurrent event that causes a reduction of roadway capacity or an abnormal increase in demand. Such events include traffic crashes, disabled vehicles, spilled cargo, highway maintenance and reconstruction projects and non-emergency events (e.g. ball games, concerts or any event that significantly affects roadway operations)." (FHWA 2000)

- "An unexpected intrusion that detracts from normal traffic flow resulting in immediate consequences on traffic flow or traffic safety affecting a road section over a long period." (ASFiNAG 2011).

Based on the definitions above and the discussions within the project team, the definition that will be used in PRIMA is:

> A **traffic incident** is any unplanned event that may adversely affect the safety or the capacity of a road and hinder traffic flow.

In addition, two other definitions were developed and will be used as such in PRIMA:

> A **technique** is a way of conducting a series of traffic incident management actions (e.g. close lanes, secure workspace, tow vehicle and reopen lanes), eventually by applying a certain technology (e.g. Variable Message Signs, Probe Vehicle Data, etc.)

A **scenario** is an internally consistent (verbal) picture of a situation or a sequence of events, based on certain assumption and factors (variables).

4.2 Classification of incidents

A planning workshop was organised in PRIMA, as part of the project kick-off meeting. A brainstorming exercise was carried out to identify main incident types, based on the project team's knowledge and expertise. The exercise resulted in a first list of incident categories. Furthermore, relevant and influencing factors leading to specific incident scenarios were determined as follows and detailed further in Table 6:

1. Collisions
2. Stranded vehicles
3. Unpredictable congestion
4. Crime
5. Weather events
6. Natural disasters
7. Obstructions on the road
8. Road infrastructure damage and distress

Table 6. Factors relevant to and influencing incidents

Location	Circumstances	Day and time
On a ramp	Involving fire	During peak hours
On a shoulder	Involving heavy goods vehicles/dangerous goods vehicles	Off-peak
In a tunnel zone (before or after)	Amount of involved passengers	Just before high peak (morning or evening)
On a bridge	Involving fatalities	During Daytime/Night-time
On the motorway road, blocking lane(s)	Involving slight/serious injury	During another TIM phase
Next to a toll plaza	Involving damage only	Peak characteristics
Local speed limits	Direction of impact	Traffic demand pattern
Driver information systems available	Type of emergency response needed	etc.
Available infrastructure for monitoring and control	Towing vehicles required	
Distance to and between ramps	Traffic demand patterns	
etc.	Number of lanes blocked	
	Opposite direction lanes blocked	
	Number of vehicles involved	
	Involving infrastructure damage	
	Weather condition	
	etc.	

Further discussions and input provided by members of the Programme Executive Board (PEB), as well as the results of the literature review of TIM best practice yielded a final list of incident types, which was included in the questionnaire for the stakeholder consultations. The incident types identified are presented below along with their definitions:

1. **Collision involving injury and/or damage**
   An incident involving a collision between two or more vehicles, one vehicle and roadside object or a vehicle and a pedestrian or animal, which may resolve in injury (slight, serious or fatality) or only material damage and cause other secondary incidents.

2. **Incidents before or early in peak period**
   An incident occurring shortly before and within early peak hours which can lead to congestion, collision and/or other secondary incidents.

3. **Incidents involving Large Goods Vehicles (LGVs)**
   An incident involving a heavy vehicle (i.e. over 3.5 tons maximum permissible gross vehicle weight) transporting goods, which can lead to secondary incidents, e.g. stranded LGV, collision with another vehicle or with road side infrastructure.

4. **Weather events**
   An incident caused by a weather event such as wet road, fog/mist, snow, sleet or ice that can lead to congestion, collisions and/or other secondary incidents.

5. **Stranded vehicles**
   An incident involving a vehicle stranded on the road, usually caused by a vehicle breakdown (i.e. operational failure of a vehicle that it is stationary), that in most cases will require the vehicle to be towed away. This type of incident can lead to congestion or secondary incidents.

6. **Congestion caused by incident in opposite direction**
   An incident involving congestion, due to distraction of drivers (i.e. the “rubbernecking” phenomenon – see e.g. Knoop 2009) caused by a separate incident in the opposite direction which can lead to secondary accidents, such as rear-end collisions.

7. **Obstructions on the road**
   An incident caused by obstructions on the road, such as vehicle/road debris, animals or spilled substances that can lead to congestion, collisions and/or other secondary incidents.

8. **Crime**
   An incident involving a crime such as a traffic offense (e.g. vehicle driving on the opposite-way), a car chase (e.g. a vehicle exceeding the speed limit followed by law enforcement) or terrorism that can lead to congestion, collisions and/or other secondary incidents.

9. **Road infrastructure damage and distress**
   An incident caused by road infrastructure damage and distress, such as pavement surface issues (e.g. potholes, cracks) or cracked walls that can lead to congestion, collisions and/or other secondary incidents.

10. Unpredictable congestion

An incident involving congestion caused by an unpredictable event (such as a traffic accident) which can lead to secondary incidents.

11. Environmental pollution (e.g. involving Hazardous Materials)

An incident involving Hazardous Material spills that can lead to environmental pollution, which can cause congestion, clearance of whole area and/or other secondary incidents.

12. Natural emergencies (e.g. floods, landslides)

An incident caused by a natural disaster such as flood, earthquake or lightning, which can result in congestion, collisions, as well as secondary incidents.

4.3 Severity of incidents

The most common classification of incidents is by severity, which generally relates to the nature of injuries, these commonly being classified into death (or 'fatality'), serious injury, slight injury, and damage-only. A more detailed scale of use to physicians and researchers is the Abbreviated Injury Scale (AIS) (AAAM, 2015). Although the standard of reporting and what is taken to constitute an 'accident' may differ between countries, given that a road accident is recorded, the reported risk of death in a road accident varies greatly. UNECE figures for 2004 (UNECE 2007) illustrate the amount of variation, expressed in Figure 10 as the percentage risk of a death in a recorded accident for 48 countries in and bordering on Europe plus North America. While the exclusion of the Middle East, except for Israel, would be a serious omission if accident rates and risk were at issue, it probably does not have serious consequences for incident classification. Those countries normally considered to have less developed road traffic management, have a notably higher risk of death, which probably reflects contributory factors and not just possible omission of minor accidents. In Figure 11 the relative risk of accident severity on different types of road in Great Britain in 2012 (DfT 2012a) is shown.

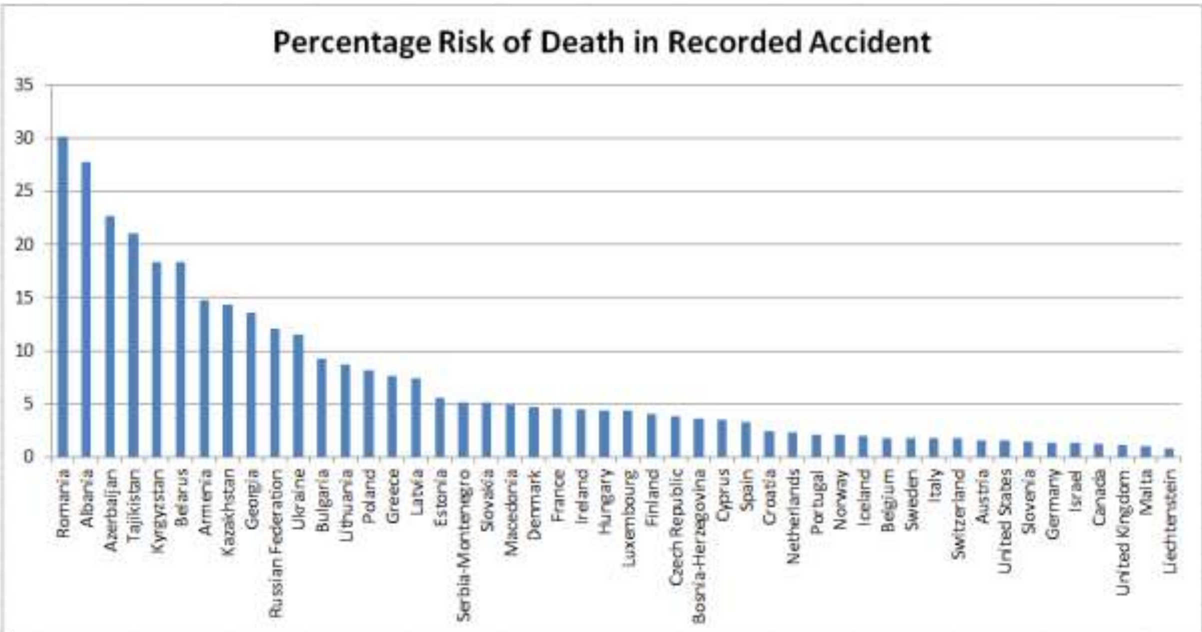

Figure 10. Risk of death in (recorded) road accidents in different countries

Bearing in mind that the numbers and relative risks (per kilometre) of accidents differ between the types of road, it can be seen that given that an accident is recorded, the risk of death on motorways is intermediate between those on the other road types, and the risk of serious injury the smallest of all. This can be ascribed to the higher standard of motorways compared with other roads, despite their higher speeds, and in particular to the absence of the combination of low road standard with high speeds, which makes rural single carriageways the most dangerous roads of all. Accident risk falls by around an order of magnitude for each step in severity, while the cost of an accident goes in the opposite direction, as shown in Table 7.

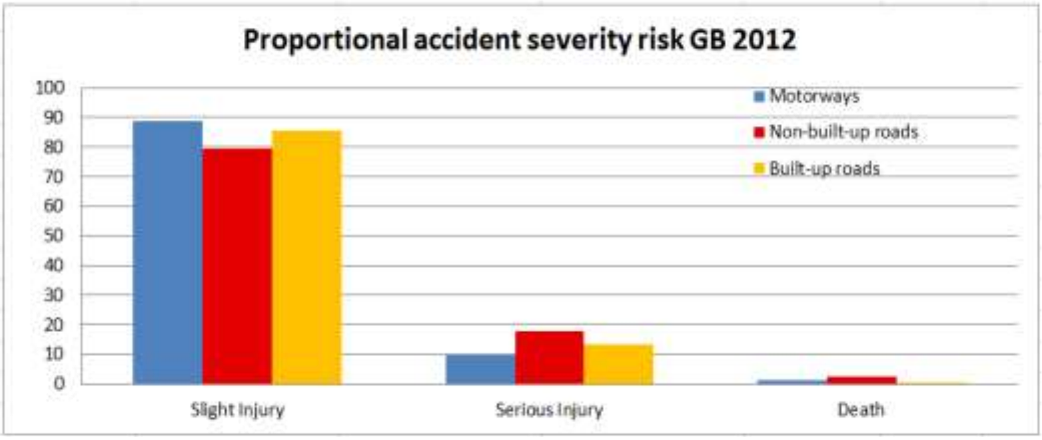

Figure 11. Relative severity of road accidents in Great Britain according to road type (DfT Table RAS40002)

Table 7. Costs of accidents calculated by DfT (2012a) and FHWA (RMIIA 2014)

Severity	**GB per accident 2012**	**GB per casualty 2012**	**USA 2005**
Damage only	£2,048	-	$2,950
Slight Injury	£23,336	£14,760	-
Average Injury	*£72,739*	*£50,698*	*$68,170*
Serious Injury	£219,043	£191,462	-
Death	£1,917,766	£1,703,822	$3,200,000

The UK Department for Transport's STATS19 database classifies injuries as slight or serious, as well as 'fatal' (DfT 2012b). Police may use terms like 'life threatening' and 'life changing'. Each classification is associated with a range of specific injuries, but these ranges are broad. There is a move to extend the number of formal injury types to include Very Serious, Moderately Serious and Less Serious. These are defined in terms of specific medical conditions: unconsciousness, head injury or breathing difficulty, multiple injury but conscious, loss of limb, serious internal fracture; limb fracture, laceration or other head injury respectively (Ward *et al* 2010). While these conditions are likely to influence the early casualty-management stages of TIM, and may be broadly associated with the severity of the incident, they are unlikely to be strongly related to other aspects of TIM or even necessarily evident to traffic managers.

4.4 Causes and factors in incidents

The causes and characteristics of significant incidents have been studied for many years. A few references are given below, which may contain many further references that may be useful. UK DfT statistical publications (DfT 2012b) tend to concentrate on behavioural factors like speeding, which might be measured indirectly by analysing traffic data, but express their involvement in terms of percentage of accidents, which is relevant to prevention but not to pro-active TIM as such. These data and data on injuries, location and circumstances are collected at the scene by Police in the STATS19 form. However, no information about incident management, clearance or duration is collected. An extension to the principle of incident information is the German In-Depth Accident Study (GIDAS, 2015) which reconstructs incidents in simulated detail.

Steenbruggen *et al* (2012) tabulate numbers of incidents by broad cause, as recorded by towing services employed by the five TMCs in the Netherlands over the period 2000-2009, although risk in relation to total traffic is not given. There is both year-on-year increase and year-to-year variation, and it is not possible to tell how much of this is related to non-reporting or mis-classification. A major change appears to occur around 2005. Percentages of incidents by type as well as total annual incidents are given in Table 8. These suggest roughly equal numbers of breakdowns and accidents, although the original data appear to show breakdowns rising steadily from 2005 while accidents remain fairly stable.

Table 8. Percentages of incidents of broad types in the Netherlands

	2005-9 average %	2009 %
CAR All Incidents	**93.2**	**93.0**
Car Breakdown	35.7	43.5
Car Accident	51.3	36.4
Car Unknown	6.2	13.1
TRUCK All Incidents	**6.8**	**7.0**
Truck Breakdown	4.7	5.3
Truck Accident	2.1	1.7
TOTAL INCIDENTS	**45014**	**56481**

Giuliano (1988/89) found (in reviewing earlier work) that only 6-9% of urban freeway incidents qualified as accidents, though it is not clear what the other incidents were, for if they were breakdowns their frequency may have fallen since as vehicles have become more reliable. Among lane-blocking incidents however, 25-49% were caused by accidents. Furthermore, these caused a more than proportional loss of capacity, for example blocking one lane of a three-lane carriageway reduced capacity to 55-60% of normal rather than 67%. An important variable in incident impact and duration is therefore the number of lanes blocked. A broadly similar conclusion was reached in relation to the effect of lane-filling abnormal loads (Taylor *et al* 2009).

An important factor is the involvement of Large Goods Vehicles (LGV), which are disproportionately involved in injury accidents leading to disproportionately long delays (TRL 2008). Bi *et al* (2014) find that incidents involving trucks are more likely when there is congestion, whereas for other traffic free-flowing traffic conditions are safer. Both Giuliano (1988/9) and Golob *et al* (1987) found that the involvement of trucks tends to increase incident durations, which are Log-Normally distributed. Garib *et al* (1997) reviewed previous work on and models of incident durations, and again found (perhaps not surprisingly) that the number of lanes blocked is an important factor, another strong predictor being the number of vehicles involved in the incident, with response time also being important and again truck involvement increasing delay.

Khattak *et al* (1995), in their abstract, make the interesting statement that “initially, after an incident is detected, information at a Traffic Operations Center is often acquired at a high rate, then information acquisition levels off and towards the end of an incident the acquired information may decay. Accordingly, the incident duration models grow in terms of their explanatory variables at first, then they are sustained during the middle stages and begin shrinking toward the end when information starts decaying.” In the main paper they discuss the implications of this for prediction.

4.5 Duration of incidents

Measurements in the State of Virginia over a period of one year show considerable variation in incident duration, and also that the distribution is 'heavy tailed', indicated by the mean of 285 minutes (s.d. 77) being much greater than the median of 91 (Tarnoff *et al* 2008). This behaviour is difficult to relate to any common frequency distribution, indeed it may be that the statistics of longer-duration incidents are determined by complex factors (e.g. load type in an LGV accident or mix of vehicle types in a multi-vehicle accident) that are less influential in short duration incidents. The same source suggests that active patrolling can reduce incident durations by around 20%, but this relates to US freeways with a relatively high proportion of rural character.

Chowdhury *et al* (2007), using data from South Carolina, illustrate a typical feature of accidents which is that their severity and frequency behave oppositely in relation to the number of lanes blocked, and each graph exhibits a geometric dependence on number of lanes blocked, that is to say an approximately constant ratio between degrees of severity, with an inverse or power law relationship between frequency and severity, as shown by Figure 12. Similar relationships are found between injury cost and frequency, where there is typically a 5-10x factor between each severity band (see Figure 11 and Table 7 earlier). Chowdhury *et al* (2007) find further that TIM measures deliver broadly similar levels of total benefit for each incident type, but that patrols increase benefits for multiple-lane blocking incidents.

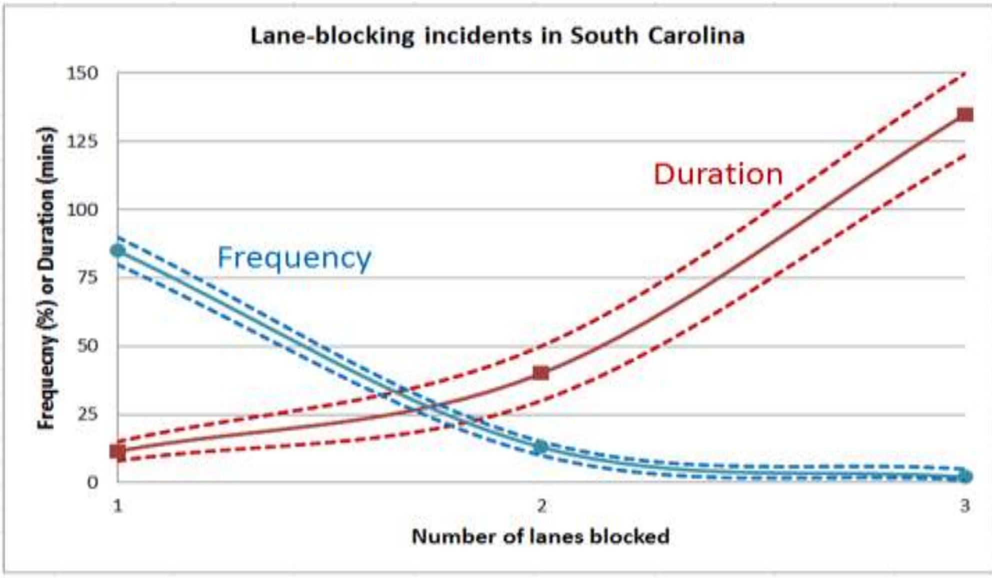

Figure 12. Example of the relationship between frequency and severity of lane-blocking incidents

The English Highways Agency HA analyses individual and collective accidents on its network, see for example HA (2014). A model combining STATS19, network and traffic data is used to identify accident clusters for remedial action. Data on incident duration collected by the HA are published and updated monthly (UKGov 2014). The mean incident duration over the whole period is around 28 minutes, while the median is just over half that at 16 minutes, considerably shorter and less 'heavy tailed' than the Virginia data. The distribution of HA incident durations is illustrated in Figure 13, though caution is needed in interpretation because data on number of incidents in each duration band have been plotted at the median points of ranges which expand from 10 minutes in the first hour to 1 hour and then 2 hours plus (interpreted here as 90 and 180 minutes respectively). The results suggest that there is no minimum incident duration. This and the values of mean and median duration depend on how ‘incident’ is defined. Arguably, PRIMA’s concern with very short incidents should be to recognise them early so as to avoid mobilising unnecessary pro-active TIM effort. However, Giuliano (1988/89) emphasises that quick clearance of disabled vehicles is an effective way to reduce overall delays at least in the circumstances in which she conducted her research.

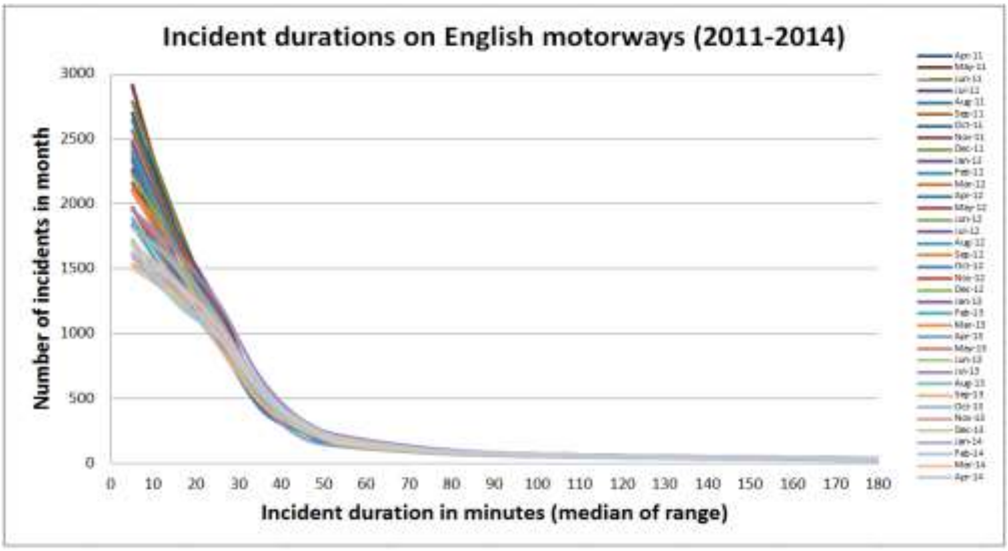

Figure 13. Recorded incident duration frequencies on English motorways

In Figure 14, the *total* time taken up by incidents peaks at around 25 minutes duration, which is also the median of the frequency distribution. However, this is not a reliable measure of total delay because if a queue occurs the number of vehicles affected will increase steadily, so as long as capacity remains constant total delay tends to rise in proportional to the square of duration. Nevertheless many incidents of moderate duration, which make a large contribution to total delay, will be particularly mitigated by rapid response.

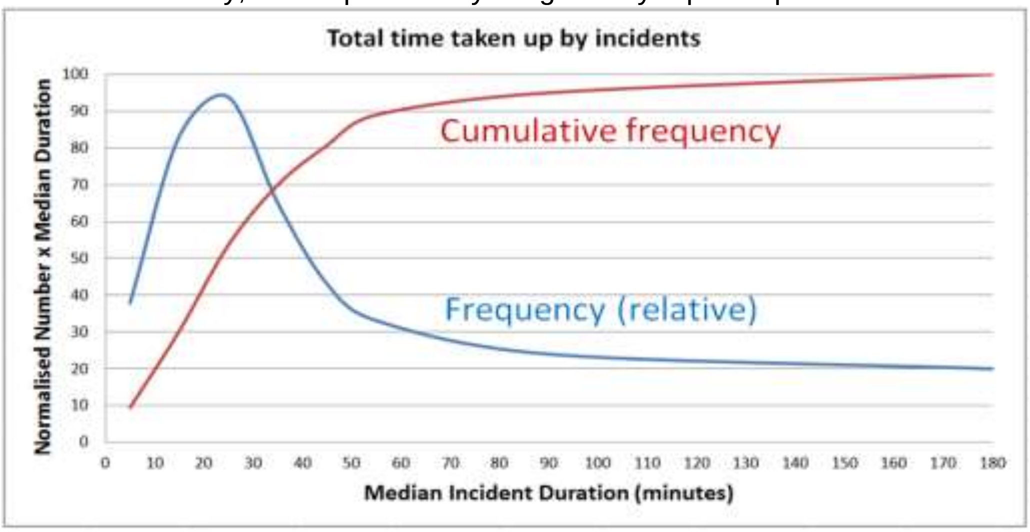

Figure 14. Total time taken up by incidents on English motorways as a function of duration

Nam and Mannering (1997) consider the allocation of duration between detection, response and clearance in Washington State. For clearance time, they estimate a model based on a hazard function, the ‘rolling’ probability density of clearance at each point in time divided by the cumulative probability that it has not happened by that time. This is *no*t a normalised probability distribution because it exaggerates the 'tail' at long durations, but it may be easier to calibrate for long-duration incidents because of their low frequency. The general form of hazard function arrived at is Log-Logistic as in Figure 15. The authors take account of a large number of variables some of which are purely local, such as what county the incident occurred in, so it may not be useful to a general model except for indicating possible variability. Although the function values are small, and despite the distorting effect of the method, the range of durations seems remarkably wide, with the upper end of the scale representing duration of nearly 23 hours. While such incidents can occur, it seems unlikely that they can be modelled with any degree of accuracy.

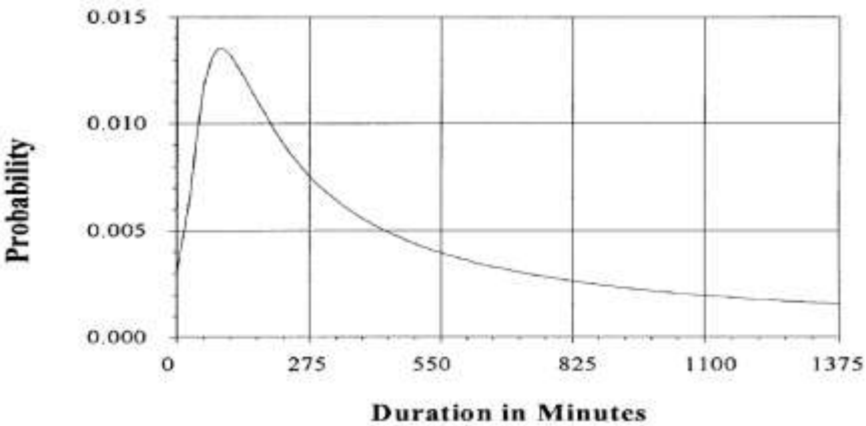

Figure 15. Log-Logistic hazard function example for incident clearance (Nam and Mannering 1997)

Ozbay and Noyan (2006) propose a Bayesian network approach to estimating delay from incident statistics, that could be applied on a local basis, listing some references later than those cited earlier. They also include a large number of variables, the essence of which are type of incident (death, injury, fire etc.), number of vehicles and trucks involved, number and type of emergency vehicles responding, and number of lanes blocked and available. Circumstantial variables like type of roadway, weather, light and time of day can also be included. All the modelling approaches apart from the hazard function (and even that to some extent) are based on analysis of observational data from particular sites and so may be difficult to generalise, but there appear to be no factors other than those that are intuitive and measurable.

4.6 Impact of lane blocking on capacity

The FHWA has estimated the effect on capacity of blocked lanes (FHWA 2000), which is discussed in the later section on costs and benefits. While these may not be the most recent data, or even representative of other countries, they give an indication of impact. In particular, blocking one lane of a 2-lane carriageway reduces the capacity of the remaining lane by about 1/3 and that of the remaining two lanes on a 3-lane carriageway by about 1/2. The relationship is not quite linear, as shown by Figure 16. A similar effect was found when observing slow abnormal loads (Taylor *et al* 2009) and could be ascribed to various causes including extra caution by drivers resulting in reduced speeds and increased clearances, as well as the presence of police (escorts in that instance) which had a marked effect compared with commercial escorts. Knoop (2009) further estimates that rubbernecking can reduce own-lane capacity by 25-40%, although he reports other sources as giving lower figures.

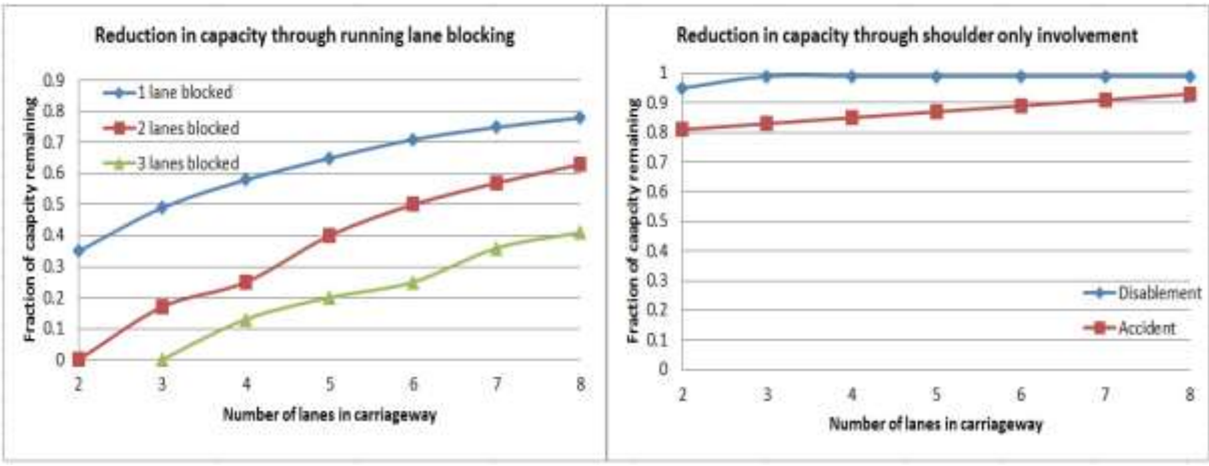

Figure 16. Effect of lane blocking on carriageway capacity from FHWA (2000) data

4.7 Costs of incidents and potential benefits from delay saving

The National Traffic Incident Management Coalition (NTIMC 2006) reports benefit/cost ratios of highway patrols in various parts of the USA between 2:1 and 36:1, average 11:1. Moss (2012), using a different data set, itself composed of averages from 17 sources with a range of 2.3:1 to 38:1, averages around 13.5:1. While the benefits to cost ratio (BCR) is clearly highly dependent on circumstances, it is uniformly positive. However, it is likely that highway patrols are targeted at those locations where incidents are more frequent or costly, so this probably means that each case needs to be considered on its merits. Estimating the cost of patrols should be fairly straightforward based on km-hours that can be patrolled per team per day, but estimating the saving in congestion and other incident costs is likely to be more difficult, even if a 'rule of thumb' of 20% is applied (23% reported by the State of Maryland according to NTIMC 2006). Furthermore, as pointed out earlier, relying on figures from the USA is risky because of the different nature of its freeway system compared with Europe. NTIMC (2006) also gives dollar benefits in Maryland, and while their absolute values are not useful because no baseline is given, they show that congestion-related delay cost dominates at 92% of total cost, with emissions at 7% and fuel saving just under 1%. Similar dominance of congestion cost at 90% was found for 'induced incidents' caused by large slow abnormal loads, with nearly all the remainder down to health and environmental costs (Taylor *et al* 2009).

EasyWay (2010) and CEDR (2011a) calculate benefit from delay saving assuming linear growth of a queue from the start of the incident as in Figure 17, where the impact of TIM is assumed to save the amount of delay represented by the area ABCD. Moss (2012) gives formulae for estimating delay based on the length of road segments occupied and the traffic density, which in turn is estimated by dividing volume by speed according to the 'fundamental relationship of traffic'. Taylor *et al* (2009) use this approach to take account of the speed and density of traffic in a moving queue and to calculate the rates of growth and discharge of the queue in a manner consistent with the observed 'shock wave' speed. These could be practical methods for real-time estimation where surveillance is extensive and volume and speed are measured directly by vehicle detectors. Scenario evaluation in PRIMA will rely mainly on simulation.

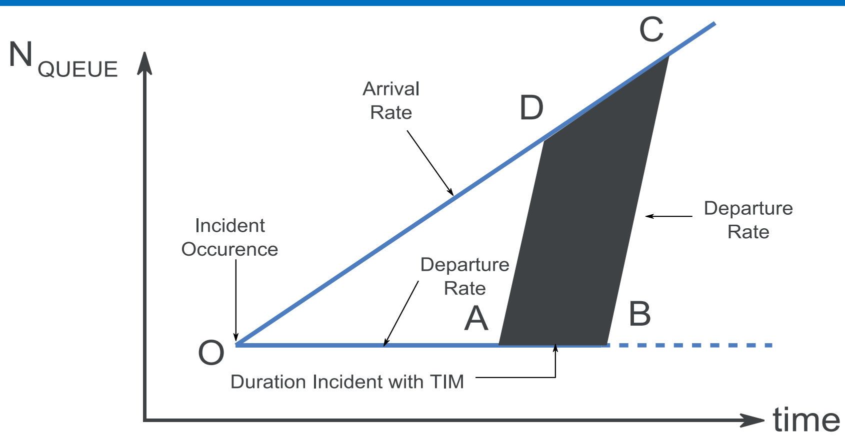

Figure 17. Simplified rendering of queue growth after an incident and potential delay saving

Where delay is estimated, e.g. by modelling, from a relationship between demand and delay, it is necessary to know how capacity is related to lane availability (see Figure 16 earlier). The final component in incident cost is the assumed value of time which will vary by country, vehicle type and journey purpose. Average costs for the UK estimated by the DfT, converted to Euros and quoted in CEDR (2011) are given in Table 9. It should be noted that the concept of value of time has suffered increasing criticism in its application to scheme appraisal, as summed up by Metz (2014), on the grounds that time budgets are more or less fixed, so saving time translates into increased distance travelled with knock-on effects on distribution, land use, environmental impact and car-dependence. However, it is probably legitimate to use conventional value-of-time in estimating the benefits of managing individual incidents because of their short-term nature, but a long-term impact of wider deployment of TIM could be an effective increase in network capacity leading to traffic generation, an effect highlighted by SACTRA (1994). The cost of remedial actions will depend on the extra staff, equipment and infrastructure investments. As a general rule, it is difficult to measure the benefits of such deployments, especially where they interact with other changes, one way around this being to estimate a high Benefit-Cost Ratio (BCR), typically at least 3.

Table 9. Cost of motorway lane closures based on estimates by DfT (from CEDR 2011a)

Flow (% of capacity)	Lanes closed (out of 3)	Duration of Incident Closure			
		15 minutes	30 minutes	1 hour	2 hours
80% (Busy)	1	€ 517	€ 2,068	€ 8,272	€ 33,088
	2	€ 3,619	€ 14,476	€ 57,904	€ 231,616
	3	€ 9,306	€ 37,224	€ 148,896	€ 595,584
60% (Moderate)	2	€ 1,034	€ 4,136	€ 16,544	€ 66,176
	3	€ 3,490	€ 13,959	€ 55,836	€ 223,344
40% (Quiet)	2	€ 173	€ 690	€ 2,758	€ 11,030
	3	€ 1,551	€ 6,204	€ 24,816	€ 99,264

[In the above, comma separator indicates thousands. No delay assumed if not busy and only one lane is blocked]

On the strength of the results reported in this section, it is hard to see how any costs of pro-active TIM deployment, excepting major investment in heavy infrastructure like networked gantries carrying electronic signs, being supplanted on new sections by roadside mounted variable message signs, could approach the conventionally-calculated benefits of delay saving. The practical issues may then be the potential marginal delay saving from optimisation of existing procedures, and whether it is real and can be guaranteed.

4.8 Modelling and Cost-Benefit Analysis of TIM and enhancements

Walker *et al* (2010) describe methods and results of cost-benefit analysis of eCall, which distinguish between internal benefits like staff time saving and external benefits which most amount to delay saving. They find that over 10 years, and depending on assumptions about penetration etc, the internal Benefit-Cost Ratio (BCR) is generally low, around 1, but the external BCR averages around 45, implying benefits are dominated by delay saving.

DfT (2014) lays out the methodology of cost-benefit analysis as applied to transport in the UK. This is mostly concerned with scheme appraisal which covers a wide range of environmental and social impacts. However, incidents are appraised separately using the INCA program (INCA 2009). INCA is configured only for grade-separated dual carriageways, and optimised for long-term appraisal. Most of the impact of incidents is on delay, which simplifies that side of the equation, but wider aspects may need to be considered when designing remedial systems, including the effects of variability, future changes in road geometry. traffic growth and discounting over the analysis period which INCA takes account of plus LGVs and diversion.

INCA contains a database of twelve incident types, with their relative rates per million vehicle-km, number of lanes blocked, and durations of queue build-up associated with them. The modelling in INCA uses demand profiles based on ‘flow groups’ representing distinct segments of daily traffic. Default values of flow have been adopted by the DfT, which vary by time of day and by day of the week. Demand flows are assumed constant during the incident itself, although a proportion of traffic can be diverted. Queues and delays are calculated using deterministic queuing theory, which is considered sufficient for high-capacity roads because any random contribution depends only on the ratio of demand to capacity, independent of volume, and is therefore negligible in such cases. Speed/flow curves are used to provide input for day-to-day variability calculations. These methods do not make use of ‘bent-back’ speed-flow relationships based on the ‘fundamental relationship of traffic’, nor do they calculate the physical length of queues as a function of speed and density.

A situation specifically covered in the INCA User Manual is of an incident on a Dynamic use of the Hard Shoulder (DHS) section, where there is no hard shoulder available in the usual sense during peak periods, although emergency refuge areas are provided. The use of DHS, as well as permanent All-Lane Running (ALR), is increasing in the UK and the Netherlands as a way of increasing peak capacity without having to build extra lanes. Incident management needs to take this into account, as the absence ofa hard shoulder lane will reduce the scope for storing vehicles, diverting traffic or accessing the incident site. While INCA allows for more complex scenario definitions than a single road section as in the proposed Incident Scenarios (see Section 5 later and Appendix), including feeder links and associated O-D matrices, it is not clear that the Incident Scenarios merit this complexity, so a simpler bespoke model supported by simulation may suffice, possibly making use of some of INCA’s standard parameters, although these strictly apply only to the UK.

5 Development and specification of incident scenarios

5.1 Development of incident scenarios

The PRIMA guidelines will be customized according to some specific traffic situations. These specific situations are identified according to the stakeholder consultation performed in this Work Package 2 (Taylor 2015) and consultations with the CEDR Program Executive Board (PEB). A minor number of incidents were developed with primary target to cover a large variety of different incidents and include the highest ranked incidents according to the stakeholder consultation. The following incidents were ranked as most important:

- Incidents before or early in the peak period
- Incidents involving Large Goods Vehicle
- Collision involving injury and/or damage
- Weather events

In addition to the highest ranked incidents, it was of major interest to identify suitable technologies to be applied on the incident scenarios. The following technologies were highest ranked according to the stakeholder consultation:

- Floating vehicle data
- Incident screens or other passive measures
- Quick clearance techniques

By using the information from the stakeholder consultation as base, a total of four different incident scenarios were developed during a comprehensive workshop held with the project team. The main target was to get a large variety of scenarios and at the same time satisfy the desired requests from the stakeholder consultation. Most of the highest ranked incidents and technologies were covered in the developed scenarios. The following traffic incident scenarios have been developed.

Scenario 1: Car to car collision involving injury, before traffic peak
Scenario 2: Unsafe road conditions due to adverse weather leading to congestion
Scenario 3: Large Goods Vehicle stranded on a motorway
Scenario 4: Unpredictable congestion due to obstruction on a motorway

Each scenario is described in more detail in the upcoming sections.

5.2 Incident scenario and TIM techniques specification

Each Scenario definition is an internally consistent description of a phenomenon, sequence of events, or situation, based on certain assumptions and variables (factors). The use of the Scenarios is in estimating the probable effects of one or more of the variables. They are considered to be an integral part of situation analysis and long-range planning.

Variable factors are added to these basic Scenario definitions, leading to a set of sub-scenarios, assessment of possible impacts, and a list of potential TIM techniques to be applied. Each scenario is briefly described in the following sections and a more detailed description can be found in Appendix A.

5.2.1 Scenario 1: Car to car collision involving injury, before traffic peak

Description of incident

On a weekday just before the morning peak, a serious crash between two passenger autos occurs on an urban motorway with three main lanes plus hard shoulder. The weather conditions are clear and dry when the incident occurs. The crash has caused injuries and is blocking 1-2 lanes in at least one directional (inbound morning commute) lane of travel. See visualization in Figure 18. At the moment when the incident occurs the required number of resources are assumed to be available (police, ambulance, fire fighters, towers).

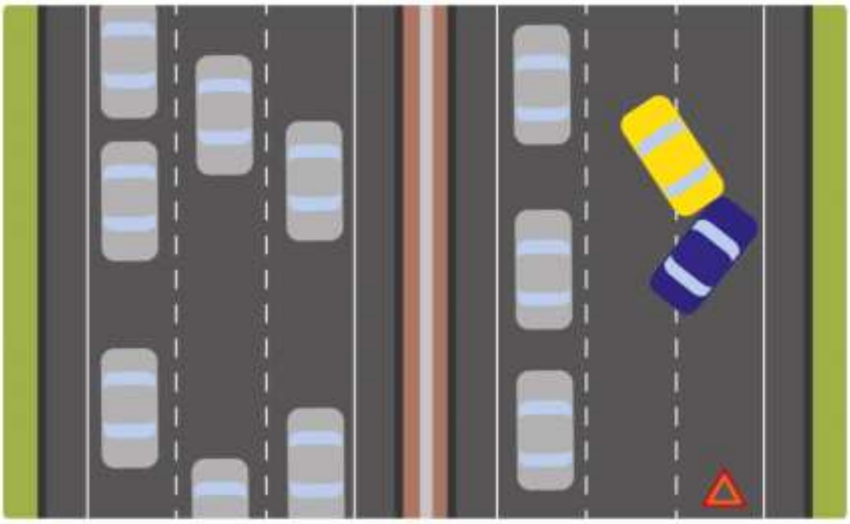

Figure 18. Illustration of the incident scenario with car to car collision involving injury, before traffic peak. 2 out of 3 lanes are blocked in the illustration, but the number of lanes blocked may vary between 1-2 in the simulations

Considered scene management techniques

The different scene management techniques considered for this scenario focus on ensuring a safe operating environment for the emergency responders and at the same time recover the scene to normality and prevent unnecessary delays for remaining traffic. The following techniques are planned to be evaluated in PRIMA for restoring the capacity to normality.

- Close all lanes and clear the incident scene completely before reopening the motorway.
- Close all lanes and clear the incident scene completely before reopening the motorway. Put up incident screen in order to avoid unnecessary capacity drops due to rubbernecking.
- Close minimum number of lanes in order to remain as much capacity as possible for remaining traffic. Clear the scene totally before reopening any of the closed lanes.
- Close minimum number of lanes and move the crashed vehicles to the shoulder. Reopen cleaned lanes as fast as possible and tow the vehicles later during off-peak.

The performance measures planned to be used for evaluation of the scene management is mainly focusing on level of service. It does not mean that safety aspects are not taken into consideration, they are instead used as requirements constituting the scene management techniques rather than involved as a performance measure. The level-of-service performance measures planned for this scenario are:

- Total waiting time (travellers multiplied by waiting time)
- Shockwave speed
- Queue length

Considered novel techniques and technologies for discovery and verification

In addition to the scene management techniques the following groups of promising novel techniques and technologies will be considered for this scenario:

- Vehicle/Nomadic device based information systems: the characteristics of technologies, like floating vehicle data, cooperative systems and nomadic devices with accurate point- and sectional- traffic information will be assessed. Furthermore the feasibility of the European in-vehicle emergency call (ecall) service will be analysed.
- Visual traffic/incident monitoring: reports of citizens and professionals on-site as well as CCTV available in a traffic management centres are capable techniques to discover and verify e.g. type, location and traffic impacts of accidents.

There are distinct factors that define performance of novel technique or technologies in order to support the incident management process. Performance Indicators that will be considered for assessment include:

- Time relevant Indicators
- Quality based Indicators

Based on the findings of the project RAIDER, the definition for performance indicators for incident detection will be extended to include as well time relevant indicators such as availability and timeliness of data/information and quality based indicators such as accuracy and reliability.

5.2.2 Scenario 2: Unsafe road conditions due to adverse weather leading to congestion

Description of incident

During daytime, the weather conditions cause reduction of the safe operating speed on an inter-urban motorway with two lanes and hard shoulder. This may be as an effect of e.g. heavy rain causing high risks for aquaplaning, intensive snow in combination with wind causing snowdrifts or a minor landslide causing mud on the road (assumed to affect safe operating speed on both lanes in the influenced direction). See visualization in Figure 19. The reduction of the safe operating speed leads to some upstream congestion. At the moment when the incident occurs the required number of resources are assumed to be available (police, fire fighters, snow ploughs, water pumps, Truck Mounted Attenuator (TMA)3).

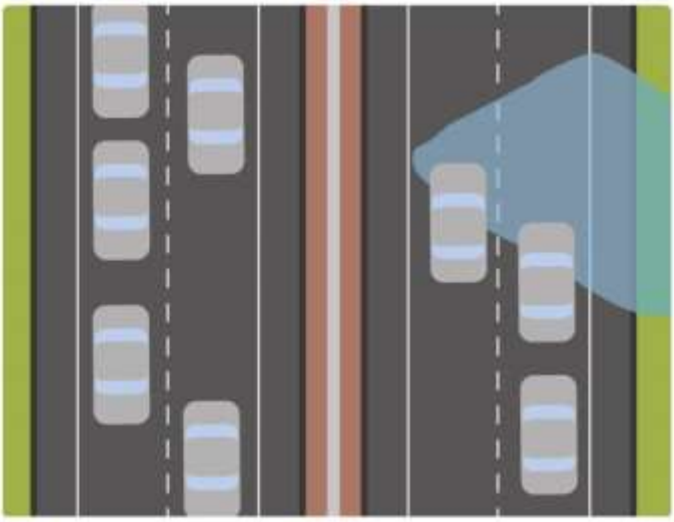

Figure 19. Illustration of the incident scenario with unsafe road conditions due to adverse weather leading to congestion. No lanes are blocked, operating speed is decreased.

Considered scene management techniques

The different scene management techniques considered for this scenario focus on enabling maximum capacity and at the same time also approve safe operating conditions for the motorists as well as for the emergency responders. The following techniques are planned to be evaluated in PRIMA for clearing the incident scene and restoring the capacity to normality:

- Close all lanes and clear the scene totally. Do not reopen any lane before the scene is totally restored to normality, i.e. all water is pumped away, all mud or snow is removed.
- Close all lanes and clear the scene totally. Do not reopen any lane before the scene is totally restored to normality, i.e. all water is pumped away, all mud or snow is removed. Redirect all traffic to the opposite direction in order to have some remaining capacity at the scene.

[3] A TMA is a truck fitted with flashing lights, speed limit and/or lane-closed or change-lane sign. Potentially several TMAs can be deployed across all lanes to create a ‘moving block’ to slow traffic or create a temporary working space ahead.

- Do not close any lanes. Put out information signs/use VMSs in order to keep the road totally open but decrease the operating speed at the scene by a temporary lower speed limit. Close the road and clear the scene during low traffic/off-peak.

The performance measures planned to be used for evaluation of the scene management is mainly focusing on level of service. It does not mean that safety aspects are not taken into consideration, they are instead used as requirements constituting the scene management techniques rather than involved as a performance measure. The level-of-service performance measures planned for this scenario are.

- Total waiting time (travellers multiplied by waiting time)
- Shockwave speed
- Queue length

Considered novel techniques and technologies for discovery and verification
In addition to the scene management techniques, the following groups of promising novel techniques and technologies will be considered for this scenario:

- Vehicle/Nomadic device based information systems: technologies such as floating vehicle data, cooperative systems and nomadic devices with accurate point- and sectional- traffic information in combination with measurements of road conditions and weather data can deliver valuable information for incident management.
- Visual traffic/incident monitoring: reports of citizens as well as CCTV available in a traffic management centres are capable techniques to discover and verify e.g. type, location and traffic impacts of incidents due to adverse weather conditions.

There are distinct factors that define performance of novel technique or technologies in order to support the incident management process. Performance Indicators that will be considered for assessment include:

- Time relevant Indicators
- Quality based Indicators

Based on the findings of the project RAIDER, the definition for performance indicators for incident detection will be extended to include as well time relevant indicators such as availability and timeliness of data/information and quality based indicators such as accuracy and reliability.

5.2.3 Scenario 3: Stranded Large Goods Vehicle on a motorway

Description of incident

Due to technical failure, a Large Goods Vehicle (LGV) gets stranded on the lane closest to the road side on a motorway with three main lanes without hard shoulder. The incident occurs during daytime when the weather and road conditions are clear and dry. Due to the size and location of the LGV, the capacity is reduced on the motorway, but since the vehicle is not loaded with dangerous goods there is no need of immediate evacuation. The LGV is only blocking one lane, which leads to reduced capacity causing congestion and travel time delays. See visualization in Figure 20. At the moment when the incident occurs the required number of resources are assumed to be available (police, Truck Mounted Attenuator (TMA), heavy towers, repairs).

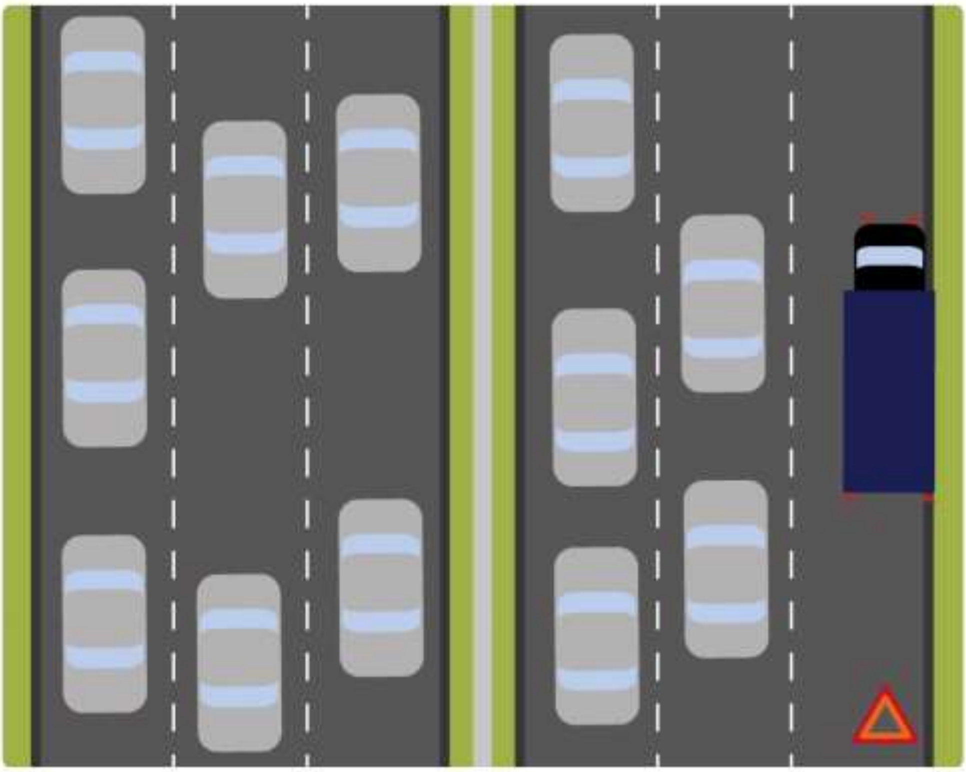

Figure 20. Illustration of the incident scenario with stranded LGV on a motorway. 1 of 3 lanes are blocked

Considered scene management techniques

The techniques considered for this scenario focus on maintaining the highest level of service and capacity at the roadway, motorists will probably not attempt any major diversion or change of plan due to the stranded LGV since this kind of incident is quite common.
The main purpose is to minimize the distraction for the motorists, in order to maximize the capacity at the scene, since the largest risk concerns rear end collisions as a consequence of decreased operating speed at the scene. The truck driver is assumed to remain inside the cabin of the truck. In case towing is necessary, the risk level for the road works has to be minimized, which requires closing additional lanes.

The following techniques are planned to be evaluated in PRIMA for removing the stranded LGV and restoring the capacity to normality:

- Close the blocked lane and the centre lane and tow the stranded heavy goods vehicle to the nearest downstream off-ramp
- Close the blocked lane and the centre lane in order to repair the vehicle so that it can drive to the next safety pocket or downstream off-ramp. Wait and tow the vehicle during off-peak.
- Close the blocked lane using a TMA and wait to close additional lanes and conducting towing to off-peak (and then close the blocked lane and the centre lane in order to tow the stranded vehicle)

The performance measures planned for evaluating scene management mainly focus on level of service. Safety aspects are also taken into consideration, but safety aspects are instead used as requirements constituting the scene management techniques rather than involved as a performance measures. The level-of-service performance measures planned for this scenario are.

- Total waiting time (travellers multiplied by waiting time)
- Shockwave speed
- Queue length

Considered novel techniques and technologies for discovery and verification

In addition to the scene management techniques, the following groups of promising novel techniques and technologies will be considered for this scenario:

- Vehicle/Nomadic device based information systems: assumed that there is no direct information from the stranded LGV, e.g. based on eCall, the assessment will focus on the feasibility of technologies such as floating vehicle data, cooperative systems and nomadic devices available through other vehicles.
- Infrastructure-based traffic data measurements: the LGV is blocking one lane which leads to reduced capacity and causes congestion and travel time delays. Therefore novel technologies for sectional traffic data measurements (e.g. ANPR, Tolling Systems) can at least indicate such incidents by suddenly changed traffic parameters.
- Visual traffic/incident monitoring: reports of citizens as well as CCTV available in a traffic management centres are capable techniques to discover and verify e.g. type, location and traffic impacts of incidents due to stranded vehicles.

There are distinct factors that define performance of novel technique or technologies in order to support the incident management process. Performance Indicators that will be considered for assessment include:

- Time relevant Indicators
- Quality based Indicators

Based on the findings of the project RAIDER, the definition for performance indicators for incident detection will be extended to include as well time relevant indicators such as availability and timeliness of data/information and quality based indicators such as accuracy and reliability.

5.2.4 Scenario 4: Unpredictable congestion due to obstructions on a motorway

Description of incident

During dry and good road conditions, an obstruction appears on the motorway as a consequence of e.g. spilled load, debris or tire cap. The obstruction objects are blocking one lane on a two lane Inter-urban motorway with hard shoulders, which causes reduction of the safe operating speed and the consequence is reduced capacity. See visualization in Figure 21. At the moment when the incident occurs the required number of resources are assumed to be available (police, tractors, loaders, TMA).

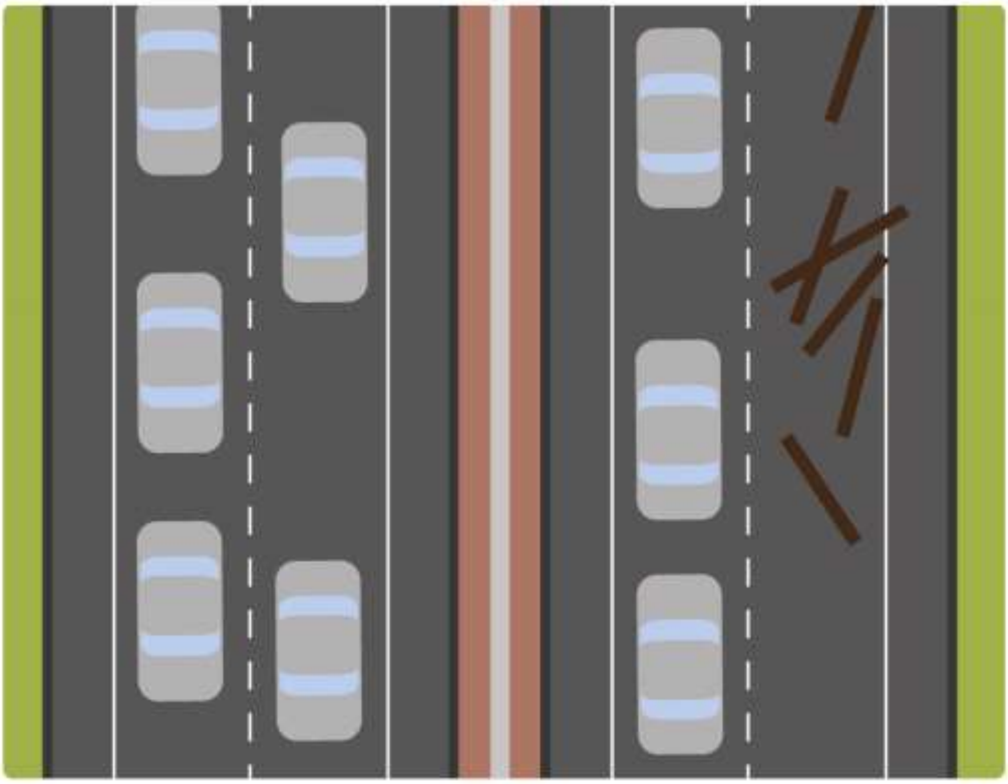

Figure 21. Illustration of the incident scenario with unpredictable congestion due to obstructions on a motorway. 1 of 2 lanes are blocked

Considered scene management techniques

The techniques considered for this scenario focus on maintaining the highest level of service and capacity at the roadway, due to the congestion since this kind of problem is quite common.

The main purpose is to minimize the distraction for the motorists, in order to maximize the capacity at the scene, since the largest risk concerns rear end collisions as a consequence of decreased operating speed at the scene. Where road works are needed to remove the obstruction the risk level for the road works has to be minimized, which requires closing additional lanes.

The following techniques are planned to be evaluated in PRIMA for removing the obstruction and restoring the capacity to normality:

- Close all lanes and clear the scene totally before reopening any lane.
- Also redirect all traffic to the opposite direction in order to maintain some capacity at all times.
- Close the blocked lane and immediately clear the scene.

Considered novel techniques and technologies for discovery and verification
In addition to the scene management techniques the following groups of promising novel techniques and technologies will be considered for this scenario:

- Vehicle/Nomadic device based information systems: the assessment will focus on the feasibility of technologies such as floating vehicle data, cooperative systems and nomadic devices in order to observe changes in traffic parameters or obstacle avoidance maneuvers.
- Infrastructure-based traffic data measurements: the obstruction objects are blocking one lane which causes reduction of the safe operating speed and the consequence is reduced capacity. Therefore novel technologies for sectional traffic data measurements (e.g. ANPR, Tolling Systems) can at least indicate such incidents by suddenly changed traffic parameters.
- Visual traffic/incident monitoring: reports of citizens as well as CCTV available in a traffic management centres are capable techniques to discover and verify e.g. type, location and traffic impacts of incidents due to obstructions on a motorway.

There are distinct factors that define performance of novel technique or technologies in order to support the incident management process. Performance Indicators that will be considered for assessment include:

- Time relevant Indicators
- Quality based Indicators

Based on the findings of the project RAIDER, the definition for performance indicators for incident detection will be extended to include as well time relevant indicators such as availability and timeliness of data/information and quality based indicators such as accuracy and reliability.

6 Conclusion and outcomes

6.1 Guidelines for practice

Evaluation of the Incident Scenarios detailed in this report will help to identify the scene management techniques and novel techniques and technologies for discovery and verification that can actively and pro-actively improve the performance of Traffic Incident Management. The format of Guidelines adopted particularly by the HA and RWS consists of general advice plus sections aimed at specific responders. However, the previous CEDR projects recognised that it is difficult to dictate detailed rules to agents in different countries, who are likely to have different conditions, statutory duties, ways of working and access to resources. Therefore the Task 13 Final Report focused more on general principles, objectives and experience, while providing a toolkit of measures organised by level of technical detail. Practical guidelines were embodied in a compact Aide Mémoire organised by the stages of the TIM timeline. This is the general approach proposed for PRIMA but with appropriately different content as described below.

6.2 Relevant outputs for TIM best practice

The issues for PRIMA can be grouped into three categories: needs, priorities and tools or measures. Recalling that three out of the four pro-active PRIMA features (Monitor, Anticipate, Prepare, Respond) involve appraisal and readiness, as opposed to response as such, the following may be relevant:

Needs for pro-active TIM

- Realistic scenarios to be prepared for (examples in this report)
- Identification of appropriate technologies and techniques
- Ability to assess incident risk by location, time, weather, traffic conditions etc.
- Ability to rapidly (re-)assess incident situations and their likely impact and duration
- Having necessary resources in readiness

Prioritisation of incident types based on the best practice review and stakeholder consultation

- Incidents before or early in peak period, especially with heavy traffic and/or few alternative routes
- Lane blocking incidents
- Incidents with potentially long duration, e.g. involving LGVs, fires, oil spills
- Incidents affecting critical sites like bridges and tunnels

Tools and measures that may assist pro-active TIM

- Novel techniques and technologies to be assessed (in Scenarios and WP3) including Floating Vehicle Data and other real-time data sources and traffic pattern recognition
- Other existing techniques identified in Stakeholder Consultation including:
  - Passive measures like incident screens (used to hide the incident scene to avoid distraction and rubbernecking by passing drivers), trucks with lane-closed or change-lane signs, cones etc.
  - Rapid clearance provided legal issues are resolved
- Risk analysis and decision support tools
- Scene recording to evidential standard, e.g. by laser scanning
- Specialised units in place where appropriate, e.g TOS, ISU.

6.3 Expected outcomes of PRIMA

TIM Guidelines issued by NRAs tend to be specific to their conditions and the agencies they employ and tend to be detailed and prescriptive. The guidelines developed in CEDR Task 13 allow for a wide range of capabilities and methods of organisation in TIM practice. PRIMA guidelines will extend these to include pro-active techniques at the incident scene, and additionally address preparedness and systems-in-place.

The CEDR Task 13 Main Report was structured as a short summary report followed by three appendices titled: A framework guide to traffic incident management; Concepts for effective traffic incident management; Developing capability as a traffic incident manager. The first deals with 'every day' tactical matters like timeline, responsibilities, experience, training and performance indicators (the EasyWay Guideline contains much the same information). The second looks more strategically at international comparisons, targets, safety and economic costs, prevention and governance. The third deals with paths of development and institutional issues.

This comprehensive structure may not be suitable for pro-active TIM, and a more general approach may be more appropriate given local conditions and resources available, which will vary between countries. A possible structure for PRIMA guidelines may be to follow the scenario-priented form (see Section 6.2 above) plus advice on how best to develop capability to achieve the maximum benefit, with an appendix or links to background information like incident characteristics and current best practice.

Past experience suggests it will be useful to complement this with an Aide Mémoire similar in format to the TIM European Best Practice Aide Mémoire developed by Task 13. This document, which is 'pocket size' in a compact A5 format, has a layout based on the TIM Guidance Framework Aide Mémoire produced by the English HA for its various responder agencies. Because of the diversity of countries and their levels of TIM deployment and capability, the TIM European Aide Mémoire could not be so specific or detailed, so follows a simplified pattern as illustrated by Figure 18, where each phase of the incident management timeline is broken down into Objectives, Shared and Common Roles, and Other Actions where the responsible agent could vary. In addition, it incorporates two mnemonics developed by the HA, shown in Figure 19. Finally, it summarises some useful Additional (physical) Resources.

The layout of the TIM European Aide Mémoire can be a helpful guide, but for the reason given at the start of this section, the content of the PRIMA equivalent will necessarily be different, and it may not be appropriate to follow a timeline-based structure, as it may make little sense to divide up a single 'pro-action' between several timeline phases, but each should rather indicate those phases it is relevant to. It remains to be determined to what extent TIM guidance as such should be included. Although simpler than the HA equivalent, the Aide Mémoire format still contains a large amount of information, and because the approach is prescriptive there is no explicit indication of what elements are most critical.

A possible alternative would be to make the PRIMA guidelines more in the form of an explicit checklist, distinguishing between READ-DO items, to be actioned and checked off immediately, and DO-CONFIRM items, to be done at some convenient time and confirmed at a review point (Gawande 2011). The emphasis will however be on clarity, simplicity, portability and ease of reference. We also recognise that simplicity will aid translation into different languages. The Final Report and guidelines could also be backed up by slide presentations and conference and journal papers.

Figure 22. Appearance and layout of CEDR Task 13 TIM Aide Mémoire (compact A5 document)

AIDE MEMOIRE 1

SAD CHALETS

Survey the scene.
This should be done as quickly as possible without putting yourself at risk.

Assess what has occurred / is occurring.
An accurate overview is required

Disseminate the information, informing the NRA/TMC of:

Casualties; approximate number and, type.
This should include an estimation of severity, numbers and their current situation e.g. trapped, lying in the carriageway, injured but mobile.

Hazards; present and potential.
If the hazards include hazardous substances or fire, ensure the basic safety measures included in the relevant procedure are followed whilst reporting to the NRA/TMC e.g. keep upwind of fumes and smoke.

Access routes for Emergency Services.
Include a safe approach route into the incident, and take into account which lanes are involved or closed

Location - exact - of the incident.

Emergency Services present / required.

Type of Incident - be specific.
Include whether the opposite carriageway is affected. Can the NRA/TMC take action now that will prevent escalation or further incidents, e.g. deploy other resources to close roads?

Safety of all persons at the scene.
Risk factors to be reported include: weather conditions including poor visibility, slippery surfaces, poor lighting, infrastructural damage (particularly damage to barriers on elevated sections) and hazardous spillages

AIDE MEMOIRE 2

IIMARCH

The IIMARCH acronym may help to structure your information gathering process; the incoming information can be used to assist with decisions and briefings.

Information - (Picture Compilation)
What is known factually about the incident/operation so far?
What tactical information is required for a complete overview of the incident?
What is the anticipated timeframe of the incident/operation?

Intention
What is the command desired outcome?
What is the objective of the incident/operation?

Method
What are the tactics that the command is adopting?
How will the objective be achieved?
What support from higher-level Command is required?

Administration
What additional support does the command need?
Is a Log being maintained of the incident/operation?
What obstacles is tactical command facing? (e.g. Financial)

Resources
What resources are required for the duration of the incident/operation?
What plans for resource sharing are in place?
Is any formal process being used as a means of support?
What can the senior staff do to assist tactical Command?

Communications
Which organisations are involved in the incident?
Who do you need to talk to?
What contingencies are in place to ensure continual operation during breakdowns or blackouts?

Health and Safety
Have all risks associated with the operation/ incident been addressed?

Figure 23. Example of the use of mnemonics in CEDR Task 13 TIM Aide Mémoire

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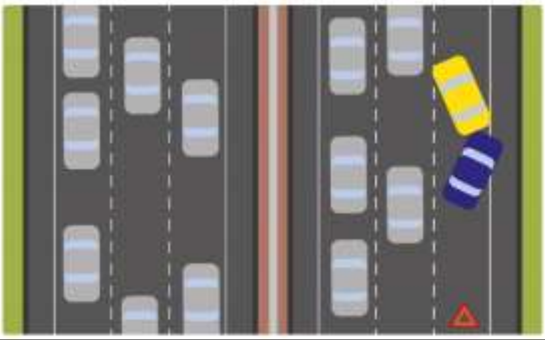
Annex A: Incident Scenarios

TRAFFIC INCIDENT SCENARIO 1

Car to car collision involving injury before traffic peak

Description

On a weekday just before the morning peak, a serious crash between 2 passenger autos occurs on an urban motorway with 3 main lanes plus hard shoulder. The crash has caused injuries and is blocking at least one directional (inbound morning commute) lane of travel. See illustration to the right.



Assumptions

High priority urban motorway with 3 lanes plus hard shoulder

Speed limit is 80 km/h

Average distance between ramps is 2 km

Clear weather conditions with good visibility, daytime

Good road conditions, the roadway is dry

The location of the incident is between two intersections

Crash type: Rear-end collision

Involved vehicles are out of order and must be towed/pushed away (not on fire)

Only 2 vehicles are involved in the collision, no fire occurs as a consequence of the incident

One injured passenger

Variable factors

3 levels of Injury (*slight, serious, fatal*)

4 combinations of traffic demand patterns (*peak amplitude high and low, peak duration short and long*)

2 different cases of blocked lanes (*between 1 to 2 number of lanes blocked. Either the lane closest to the shoulder and the centre lane, or only the lane closest to the shoulder*)

2 different crash members (1x striking vehicle, 1x struck vehicle)

2 levels of available monitoring and controlling/informing infrastructure.(*Either available or not*) (The systems are: floating vehicle data, cooperative systems and nomadic devices with accurate point- and sectional- traffic information, citizen reports, professional reports, CCTV, eCall)

Possible impacts

Major queues and travel time delays.

Risk for secondary incidents and rear end collisions.

Reduced capacity in opposite direction due to rubbernecking.

Potential TIM techniques (Scenario 1)

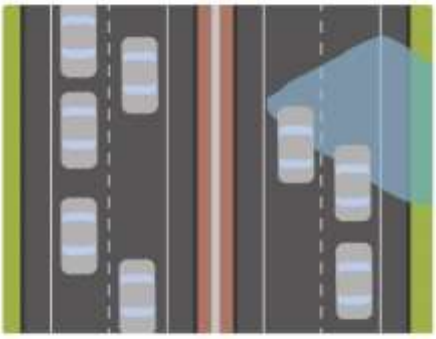
1. **Close all lanes and clear the incident scene completely before reopening**
2. **Technique 1 but put up incident screens in order to avoid reduced capacity in opposite direction due to rubbernecking**
3. **Close number of blocked lanes + 1 additional lane in order tow all crashed vehicles (clean the incident scene completely)**
4. **Close number of blocked lanes + 1 additional lane and move crashed vehicles to the shoulder and tow them later during off-peak**

TRAFFIC INCIDENT SCENARIO 2

Unsafe road conditions due to adverse weather leading to congestion

Description

The weather conditions causes reduction of the safe operating speed on an inter-urban motorway. This may be as an effect of for example heavy raining causing high risks for aquaplaning, intensive snowing in combination with wind causing snowdrifts or a minor landslide causing mud on the road. See illustration to the right. The reduction of the safe operating speed leads to some upstream congestion.



Assumptions

Inter-urban Motorway with 2 lanes plus hard shoulder.

Speed limit is 120 km/h

Average distance between ramps is >2km, here set to 5 km.

The situation appears during daytime

No lanes are blocked, but the weather condition is affecting all lanes in one direction

The safe operating speed is limited to 50 km/h

No collisions or single vehicle accident has occurred (although the probability is high).

Variable factors

3 levels of traffic demand flow (*low, middle, high*)

2 levels of visibility (*good, poor* = reduced sight distance, late braking, higher shockwave speeds)

2 levels of available monitoring and controlling/informing infrastructure.(*Either available or not*) (The systems are: floating vehicle data, citizen reports, CCTV, weather data, measurements of road conditions, cooperative systems and nomadic devices with accurate point- and sectional- traffic information)

Possible impacts

Major queues and travel time delays.

High risk for incidents and rear end collisions due to large difference in speed upstream of the incident location and the possible safe operating speed at the incident location.

Additional comments

In this scenario a relevant question is, do we need to perform any action besides broadcasting informing to the motorists over radio? The alternatives is to close lane(s) and remove the water/mud/snow/etc. and then reopen the lane.

Potential TIM techniques

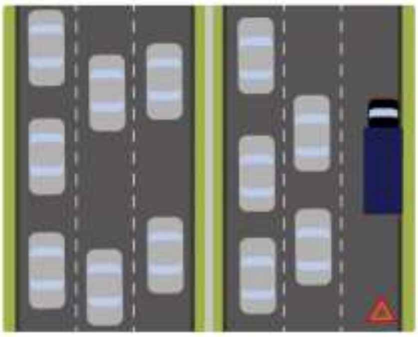
1. **Close all lanes and clear the scene, i.e. pumping away water, removing mud or snow. Reopen lanes when clearance is finished**
2. **Technique 1 but redirect all traffic to the opposite direction so that the accessibility is not totally blocked**
3. **Put out information signs/use VMSs if available and keep road open with limited speed limit. Close and clear road at off peak/low traffic.**

TRAFFIC INCIDENT SCENARIO 3

Stranded Large Goods Vehicle on a motorway

Description

Due to a technical reason, a Heavy Goods Vehicle (HGV) gets stranded on the lane closest to the road side on a 3-lane without hard shoulder, see illustration to the right. Due to the size and location of the HGV the capacity is reduced on the motorway, but since the vehicle is not loaded whit dangerous goods there is no need of immediate evacuation. The HGV is only blocking one lane which leads to reduced capacity which causes congestion and time travel delays.



Assumptions

Motorway with 3 lanes without hard shoulder

Speed limit is 80 km/h

Average distance between ramps is 2 km

General clear weather conditions with good visibility, daytime.

Good road conditions, the roadway is dry.

Only 1 one lane is blocked, the lane closest to the road side

The incident occurs during peak time

Variable factors

4 combinations of traffic demand patterns (*peak amplitude high and low, peak duration short and long*)

2 levels of available monitoring and controlling/informing infrastructure.(*Either available or not*) (The systems are: floating vehicle data, cooperative systems and nomadic devices available through other vehicles, traffic measurements (ANPR), citizen reports, CCTV)

Possible impacts

Queues and travel time delays.

Risk for secondary incidents and rear end collisions, maybe due to dangerous overtaking or merging close to the stranded vehicle. If closing lane and towing directly there is risk for the tow workers. If closing the lane and waiting to tow until after the peak there is an increased risk for secondary incidents.

Reduced capacity in opposite direction due to rubbernecking.

Potential TIM techniques

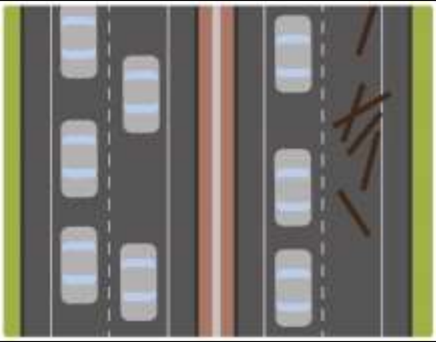
1. **Close the blocked lane +1 additional lane in order to tow the stranded HGV to the nearest downstream off-ramp.**
2. **Close the blocked lane + 1 additional lane and repair the vehicle so that it can drive to the next safety pocket or next downstream off-ramp and tow the HGV during off-peak.**
3. **Close the blocked lane using a TMA and wait to close additional lanes and conducting towing to off-peak (and then close the blocked lane + 1 additional lane and tow the stranded HGV).**

TRAFFIC INCIDENT SCENARIO 4

Unpredictable congestion due to obstructions on a motorway

Description

Obstruction appears on the motorway as a consequence of for example loss load, debris or tire cap. The obstruction objects are blocking one lane on the Inter-urban roadway, which causes reduction of the safe operating speed and the consequence is reduced capacity on the motorway. See illustration to the right.



Assumptions

Inter-urban Motorway with 2 lanes plus hard shoulder

Average distance between ramps is > 2 km, here set to 5 km.

Good road conditions, the roadway is dry

Constant off peak traffic demand pattern

Speed limit: 120 km/h

Only 1 lane blocked, the lane closest to the shoulder

Variable factors

2 different levels of visibility due to of weather condition (*either good or bad visibility*)

2 levels of operating speed depending on the visibility (60, 120)

2 different locations on the motorway (*1x close after the on-ramp, 1x further away from the on-ramp?*)

2 levels of available monitoring and controlling/informing infrastructure.(*Either available or not*) (The systems are: floating vehicle data, cooperative systems and nomadic devices, , traffic measurements (ANPR), tolling system, citizen reports, CCTV)

Possible impacts

Major queues and travel time delays.

Risk for incidents and rear end collisions.

Reduced capacity in opposite direction due to rubbernecking.

Potential TIM techniques

1. **Close all lanes and clear the scene totally before reopen any lane**
2. **Technique 1 but redirect all traffic to the opposite direction in order to remain some capacity at all time**
3. **Close the blocked lane and immediate clear the scene**