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PRIMA
PRO-ACTIVE INCIDENT MANAGEMENT

Guidelines and Implementation Steps for Pro-Active Traffic Incident Management

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CEDR Call 2013: Traffic Management
PRIMA
Pro-Active Incident Management

Guidelines and implementation steps for future Traffic Incident Management

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1 Introduction

Non-recurrent events such as road accidents, vehicle breakdowns and extraordinary congestion – henceforth referred to as traffic incidents – affect travel times, safety and the environment and also generate unwanted costs associated with these impacts. Therefore, road administrations must manage incidents in a safe and efficient manner. Typically, every country has its own Traffic Incident Management (TIM) regulations and strategies, implying that there is a need for transnational practical guidance to achieve an optimal balance of cost and risk factors. In order to develop such practical guidance, appropriate tools for assessment need to be defined and applied and, existing tools need to be improved.

The purpose of the PRIMA (Pro-Active Incident Management) project, which is a 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 to develop a transnational practical guidance by analysing the benefits, costs and risks of pro-active management of road traffic incidents, building upon previous regulations, specifications and assessment studies regarding Traffic Incident Management (TIM).

This deliverable presents the final output of PRIMA, giving recommendations on pro-active traffic incident management techniques. The recommendations consider both novel technologies for decreasing the duration of the discovery, verification and initial response phases, as well as more traditional scene management techniques, such as optimal closing of lanes, towing options, etc. Additionally, implementation steps for the novel techniques are presented, either as a “to do” list or in the form of value networks.

The report starts with relevant PRIMA definitions, followed by a general description of the traffic incident management cycle and its phases in Chapter 2. Then a brief summary of the methodology and results of the qualitative and quantitative assessment of novel and traditional techniques is given in Chapter 4. Chapter 5 starts with the methodology for the recommendations and the implementation steps and continues with the PRIMA incident management techniques, described in a format that provides details on the benefits, cost elements and risks of applying a specific technique in the TIM cycle. Additionally, implementation steps are presented for the novel techniques. The overall conclusions and discussions are given in Chapter 6.

2 Definitions

Various definitions of what an incident is exist in literature. Based on existing definitions 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).

3 TIM cycle and phase descriptions

The CEDR report of "Best practice in European Traffic Incident Management" from 2011 describes that the management of an incident can be broken down into a cyclic sequence of phases (see Figure 1) which constitutes the timeline of an individual incident. The diagram shows the phases as a cycle that starts and finishes with a state of normality. The TIM cycle has been the basis upon which the PRIMA recommendations were built.

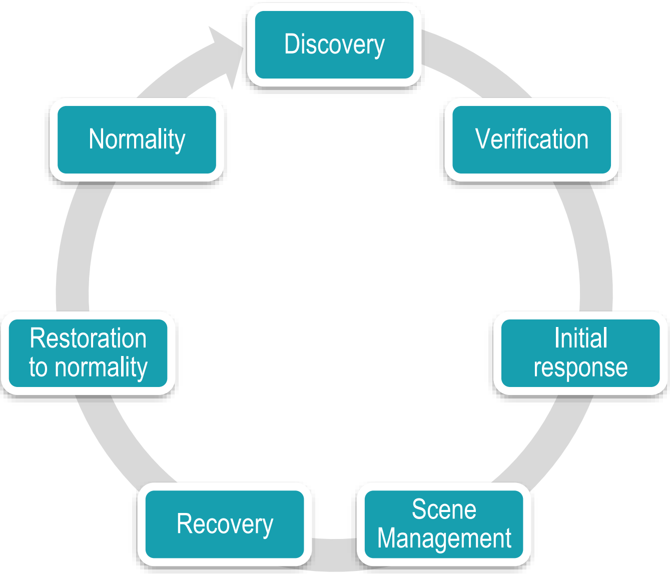


Figure 1: Illustrations of different phases in incident management (CEDR, 2011)

Discovery is the initial identification by any means of a potential incident by a responsible organisation or its staff. In this phase, CEDR recommends the following actions:

- Implement immediate safety measures
- Initiate early actions to protect the lives of road users
- Initiate early actions to prevent an escalation of the incident
- Obtain sufficient detail to enable an informed decision on the responder organisations to be involved and the type and level of response required
- Establish initial command, control, and coordination of the incident

Verification is the clarification and confirmation of the location, extent, and key details of an incident as far as is possible, enabling appropriate resources to be deployed. In this phase, the following actions are recommended by CEDR:

- Verify the nature and location of the incident
- Identify the resources and organisations required for an initial response to the incident
- Implement immediate safety measures
- Identify and tackle the aspects that require immediate attention
- Supply responders and their organisations with essential information
- Establish initial command, control, and coordination of the incident scene
- Plan the 'initial response' phase

Initial response is the dispatch of appropriate resources to the incident scene, the deployment of information, signing, and control measures to stabilise the scene and prevent escalation, and the securing of the scene for safety reasons and so that immediate attention can be paid to casualties and hazards. In this phase, the following actions are recommended by CEDR:

- Protect the scene
- Save lives
- Protect and preserve the lives of others
- Preserve the scene for investigation
- Safeguard property and infrastructure
- Protect the environment
- Commence initial investigation
- Mitigate congestion
- Plan the 'scene management' phase

Scene management is the management of activities that need to be completed at the scene before the incident location can be cleared, including protection of the scene, implementation of diversions or other traffic management measures, relief of trapped traffic, further treatment and evacuation of casualties, removal of hazardous chemicals, investigation of the incident, and collection of evidence. In this phase, the following actions are recommended by CEDR:

- Ensure that the activities at the scene are controlled and managed effectively by and through a clearly identifiable authority.
- Ensure the continued safety of the incident location.
- Preserve and protect life, property, and the environment.
- Prevent escalation of the incident and secondary incidents.
- Minimise disruption and congestion.
- Record details of the incident that are required for investigation.
- Secure and preserve evidence.
- Identify witnesses.
- Plan, prepare, and organise the 'recovery' phase.
- Ensure that there is a managed handover of the scene control when appropriate and ensure that all relevant parties are aware of it.

Recovery is the recovery of vehicles, loads, obstacles, and debris from the carriageway and the carrying out of essential repairs to the infrastructure before restoring the normal traffic condition. In this phase, the following actions are recommended by CEDR:

- Using safe work methods, quickly, effectively, and efficiently remove obstructions and return the road and other assets to a state allowing traffic flow to return to normality.
- Update traffic information to road users.
- Plan for the 'restoration to normality' phase.

Restoration is the restoration of the traffic conditions to those expected at the location for that particular day and time of day. In this phase, the following actions are recommended by CEDR:

- Restore the traffic conditions to the level expected for that location at that time of day.
- To minimize congestion, this should be done in stages as lanes become serviceable, provided it is safe to do so.
- Ensure the final update of information when normality is achieved.
- After clearing an incident, while traffic may be flowing freely past the scene, there could still be delays on the approaches in both directions. Normality is not restored until these also return to the conditions expected for that location at that time.

Normality is the traffic conditions expected at a location on a particular day and at a particular time of day.

The TIM cycle has been the basis upon which the work in PRIMA has been done. The assessment of techniques, the incident scenarios, as well as the analyses of risks and costs performed in WP3 used the incident phases in the TIM cycle as a starting point.

4 Assessment and selection of techniques

The assessment of different TIM techniques was conducted using a scenario-based approach. This chapter gives a brief summary of the assessment which is documented in detail in Olstam et al (2015) and Taylor et al (2015b). By using the information from the PRIMA best practice review and the stakeholder consultation as a base (Taylor et al, 2015a), a total of four different incident scenarios were developed during a comprehensive workshop held with the project team. The four traffic incident scenarios (all based upon motorways) are:

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

The assessment was conducted in three different steps:

1. Assessment of time savings and quality improvements from utilization of novel technologies
2. Assessment of traffic performance
3. Assessment of risks and costs

The first step was to assess novel and innovative technologies that can be utilized in incident management. This involved qualitative assessment of solutions for detecting, classifying and verifying incidents based on promising technologies that are likely to be wide-spread in the near future. The assessment showed that given relevant requirements such as communication networks available and appropriate penetration rates, vehicle-based systems provide good capability for the detection of incidents whereas video-based systems provide good capability for the verification of incidents.

Potential time savings due to overlapping of phases may result from direct communication links with involved or reporting persons. The actual time savings depend on the baseline conditions, which vary between countries, regions and road types. Urban motorways are in general more densely equipped with detectors and video monitoring compared with rural motorways and general roads. For the two urban motorways' scenarios investigated in PRIMA, namely scenario 1 and 3, the time savings were estimated to be around 4-5 minutes (80-97%) whilst for the inter-urban motorway scenarios the savings were estimated to be around 10-15 minutes (67-93%). However, these results come with some uncertainty and there is need for further investigation. However, an obstacle to further investigation is that most incident databases commonly only include total incident durations and rarely include information on the duration of the different TIM phases.

The length of the discovery, verification and initial response phases also depend on the type, quality and correctness of the information that novel technologies provide; therefore, quality indicators were also investigated as well as the feasibility of automatic incident severity classification. The assessment shows that an extension of Emergency Call (eCall) to Advanced eCall, i.e. including injury severity estimation, seems promising. To prove its suitability however, an extended investigation towards more cases (to account for the variation in human variability), other body regions (not only thorax) and different impact scenarios (not only frontal impacts) is needed. It should also be investigated how the injury risk information can be used in practice, for example to adjust the (emergency) response actions accordingly (e.g. is there a need to send an ambulance, or will only a police officer suffice; is specialized medical help required, or maybe even a helicopter?), or to estimate the impact of the incident on the traffic, which can in turn be used to take appropriate actions (e.g. how long is it expected for the road to be blocked, is redirecting of traffic needed?, etc.).

The amount of saved time by using innovative techniques was fed into the second step of the assessment, namely modelling and simulating the incident scenarios in order to estimate the traffic performance (e.g. travel time delay, queue length and incident duration) for different incident management techniques. Two different assessment methods were developed, one more advanced based on macroscopic traffic simulation using the Cell Transmission Model and one simpler but quicker based on a deterministic queue model. The queue model was proven to be useful to conduct quick comparisons for different techniques given the start time of the incident, the travel demand profile, speed limit, number of lanes, etc. The 'GUI' (Graphical User Interface) and the implementation needs to be enhanced if the model is to be used in operational incident management, but its simplicity for quick and rough estimates for scene management techniques makes it an interesting candidate as a supportive tool for incident managements centres. In addition, the macroscopic cell transmission simulation model was applied to investigate the effect of different scene management techniques in more detail. The cell transmission model has longer execution times but gives a more detailed description of changes in the traffic state due to an incident and different incident management techniques. The simulation model takes on- and off-ramps into consideration and can capture variations in the travel demand at a higher level of detail. Therefore, for more complex motorway sites with recurrent incidents, a local calibrated macroscopic traffic simulation model would be a more preferable decision support tool for scene management.

The traffic performance assessment shows that alternative scene management techniques as quick clearance involving towing in off peak, contraflow, and closing a limited number of lanes can decrease delay and incident durations. However, the rank order of techniques depends on the start time of the incident in relation to the traffic peak, the assumptions for the duration of the different phases, the travel demand profiles, etc. The results show that there can be substantial differences between the total delay and the incident duration depending on which technique is applied for a given incident scenario.

The effect on traffic performance (step 2) and the estimated time savings (steps 1 & 2) were used in the last step of the assessment (step 3). The last step aimed to estimate the risks and costs of the different incident management techniques, given a specific incident scenario. Benefits of reduction of delay and secondary accidents were assessed in monetary terms and compared with the costs of interventions where available, with evidence-based assumptions about accident rates and value of time. Evidence on some technology and operational costs were presented, and risks that might be mitigated by the implementation of new procedures identified. While there is unavoidable uncertainty, there is evidence that pro-active techniques can deliver large absolute benefits.

The results suggest that pro-active techniques are able to achieve substantial benefits including quick clearance, assumed to mean also that final clearance is delayed until off peak, and optimisation of lane closures. Contraflow, where some traffic is diverted onto the opposite carriageway, can be effective but is not a short-term option. All scene management is assumed to reduce the effective capacity of running lanes, so where the capacity would be insufficient for demand, the emphasis should be on restoring normal flow as quickly as possible. Although operational costs are hard to assess when techniques are applied selectively, the potential benefits are sufficiently large that they are expected to exceed costs, with an estimated Benefit-Cost Ratio (BCR) of 3.35.

New technologies such as eCall and in-vehicle systems, or the further rollout of existing detection, monitoring and information technology, are expected to reduce initial response times, but benefits can be somewhat difficult to assess because of factors such as high total installation costs and variable penetration rates. On the other hand, the marginal cost to NRAs of exploiting data already available from third-party providers could be quite small. Estimated BCRs are in the range 0.56-1.13.

5 Recommended techniques and implementation steps

Based on the assessment results (see Chapter 4 or Olstam et al (2015) and Taylor et al (2015)), the most promising techniques were chosen to be included in the PRIMA recommendations. Expert judgement as well as consultations with the project officer and the PEB members was taken into account to yield the final list. It was also decided that the recommendations should not follow the scenario-based approach as discussed earlier in the assessment step of the project, but rather to show the most promising techniques for a generic incident scenario.

The techniques are presented in a simple and efficient profile format. The profile starts with a small description of the technique and the technologies that can be applied. The main benefits for TIM are presented in a graphic format, indicating the specific phases for which the technique is most beneficial. An overview of the cost components is given along with an estimation of the cost value size. The estimation of the costs is qualitative in nature and provides a simple, high-level indication of the potential additional costs for implementing a specific technique. The cost ratings are defined as minor (€), mid-range (€€) and high (€€€). While a minor cost rating indicates low investments such as equipment or maintenance costs, a high cost rating indicates e.g. large infrastructure investments or personnel hours for long-term projects. Of course, the rating might vary from country to country according to the legacy systems and the NRA's requirements.

The risks are also presented, giving a description of the elements that need to be taken into account when applying a specific technique. Additionally, implementation steps for the most novel techniques are presented either in the form of value networks (see Sub-chapter 5.2) or as a step-wise approach. It must be noted that the more traditional techniques (such as clearing or towing strategies, incident screens or dynamic speed limits) were considered as being already integrated into current TIM and therefore without the need for defining implementation steps.

The PRIMA recommendations are by no means a complete list of traffic incident management measures, since pro-active incident management is the focus of the project. This chapter presents the recommendations on traffic incident management techniques. The recommendations consider both novel techniques for providing benefits for the initial phases of TIM, such as video incident detection, hot spot localization or Advanced eCall, as well as more traditional scene management techniques such as optimal lane closing, incident screens, or contraflow. It must be noted that a number of assumptions were made when selecting the techniques, e.g. legacy systems are already in use for traffic incident management, such as CCTV (closed circuit television), inductive loops, use of Variable Message Signs, etc.)

5.1 Overview of PRIMA recommended techniques

Figure 2 shows an overview of the PRIMA recommended techniques for traffic incident management, grouped into the four PRIMA phases that were defined in the project's commencement:

Monitor & Anticipate:
In these phases, incident management techniques can be utilised to monitor and recognise changes in the traffic state, as well as to identify certain high risk locations on the road network. This can facilitate the anticipation of potential incident scenarios.

In these phases, pre-incident management techniques based on novel technologies are used, such as video incident detection systems, Probe Vehicle Data (e.g. Vehicle to Infrastructure communication – V2I, Floating Car Data – FCD) or the Simulation-based incident response strategy planning tool.

Prepare & Respond:
In these phases, incident management techniques can be utilised to best prepare and respond to an incident, thus minimising costs and risks as well as potential secondary effects. In these phases, incident management techniques can be used such as Advanced eCall, redirection strategy or the Model-based short term response planning tool.

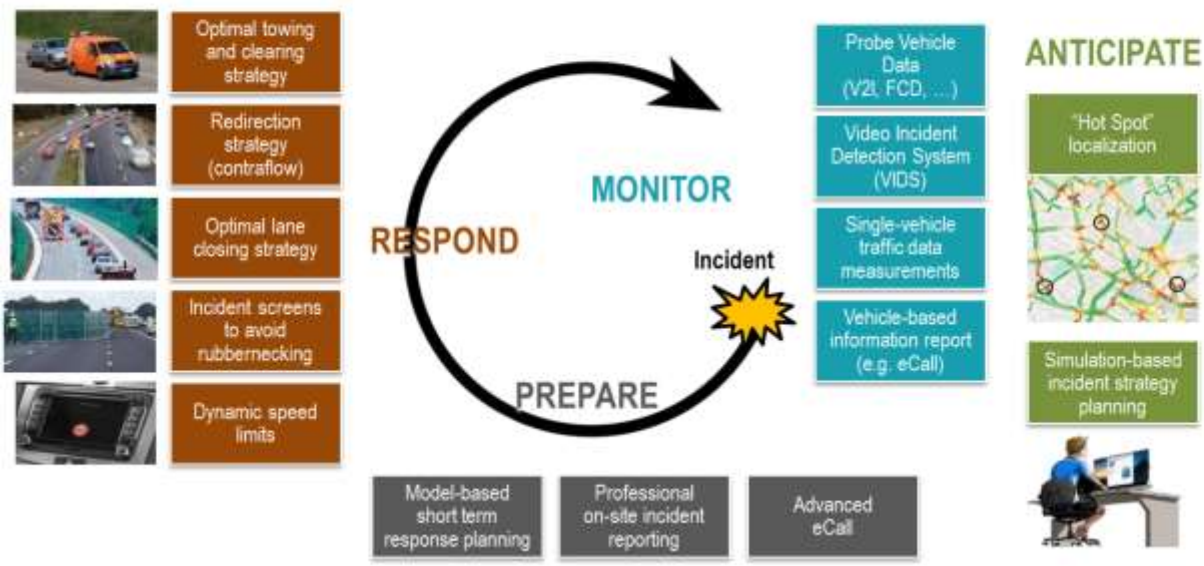


Figure 2: PRIMA recommended incident management techniques

5.2 Business models and implementation

To best show how to integrate the novel techniques recommended in PRIMA in traffic incident management, a two-fold approach was employed. For the three most innovative techniques, business models were developed. For the remaining techniques, lists of implementations' steps were defined based on the expertise of the project consortium.

A business model describes the method in which all the stakeholders involved exchange value for money. A positive business case means that the business model results in a positive cash flow for at least the commercial stakeholders involved, without which they are unlikely to participate. However, public stakeholders such as the road authority can also receive value in other forms, such as achieving specific goals in terms of network performance (e.g. reduction in the number of injury accidents, decreasing emissions, etc.). Therefore societal benefits can replace monetary gains.

Business models can be visualised in value networks (Faber et al, 2013). A value network is similar to a value chain; however it shows the relationships between the involved entities into a non-linear, non-sequential manner. It depicts the flows of services, money and other gains between the main stakeholders involved into a service (whether as a provider, user or beneficiary). Including societal benefits into a value network is not typical for a usual value network used for private companies' business cases. However, as the road authority has a definitive role in traffic incident management, it is appropriate to include societal benefits in this analysis.

5.3 Anticipate

5.3.1 Incident hot spot localization

RECOMMENDED TECHNIQUE

Incident hot spot localization

Similar to high risk accidents spots, incidents hot spots are defined as locations or road stretches where incidents are likely to occur. Those locations can include sections with recurring congestion, such as high-volume motorway intersections, spots with a high risk of road crashes or adverse weather conditions or spots where an incident would cause major impacts. The identification of hot spots can be seen as an anticipatory incident management technique to be prepared for optimum response. Hot spots must be carefully monitored (e.g. by CCTV) and possible incident response strategies must be prepared in advance. This technique is recommended to be used alongside a simulation-based incident response planning tool, where different response management options can be evaluated for the respective hot spots.

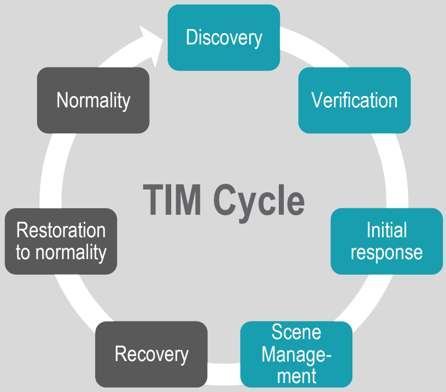
Apart from expert judgments by traffic managers, hot spots can be identified by 1) spatial clustering of incident locations from historical incident databases, 2) analysis of road side sensors or Probe Vehicle Data to detect congestion, 3) modelling the risk of road crashes based on historical crash or near-miss databases or 4) analyses of recurring weather events in combination with circumstances that lead to incidents (e.g. snowdrifts in combination with high road gradient).

Localizing incident hot spots bring benefits for the discovery, verification, initial response and scene management phases of an incident.

BENEFITS FOR TRAFFIC INCIDENT MANAGEMENT

Benefits for Discovery:

Since the hot spots are monitored thoroughly, incidents can be discovered more quickly. The detection rate is expected to be increased for the monitored sections. False alarm rates depend on the applied monitoring technology.



Benefits for Verification:

The quality of verification is not directly affected by localizing hot spots, since this depends on the verification technology applied. However, the duration of this phase is expected to be reduced due to a higher coverage of monitoring technologies at the hot spots. Hence, the response phase can be initiated earlier.

Benefits for Initial Response:

For hot spots, the initial response can be proactively prepared by setting appropriate actions for the expected incident types. This involves the warning of following traffic e.g. by VMS or the efficient placement of response services such as fire workers or towing vehicles as well as ensuring easy access for the responders. This can shorten initial response time in terms of an earlier arrival of response services.

Benefits for Scene Management:

For hot spots, scene management can be proactively prepared by setting appropriate actions for the expected incident types. The duration of this phase can be reduced due to optimum placement of response services, and in combination with a simulation-based incident strategy planning tool, the most efficient response actions can be applied.

COST CONSIDERATIONS

€€	Costs for collecting and processing Probe Vehicle Data
€	Costs for collecting and processing historical accident data
€	Personnel hours for analysing historical incident databases and weather events
€€	Costs for implementing a hot spot mapping tool within the NRA
€	Cost for software maintenance of the mapping tool

Assumptions: Historical incident records exist within the NRA. National accident data is available in the country.

RISKS

By carefully selecting the right incident hot spots, risks regarding inefficient or needless upgrading of monitoring equipment and response services can be kept low. There are no other direct risks expected by applying this recommended technique.

RECOMMENDED IMPLEMENTATION STEPS

1. Consult motorway service personnel for their expert judgement on incident risk spots.
2. Establish a centralized incident database, to be populated with historical incident records from sources such as police, emergency and rescue services or motorway service and maintenance depots.
3. Analyse historical traffic measurements and identify locations with a high-risk of road congestion
4. Analyse the road network in terms of hazardous road geometry characteristics, e.g. gradients, curve radii etc.
5. Identify locations where incidents may cause major impacts (based on historical incident data), e.g. at sections with high traffic volume or in tunnels.
6. Identify locations with recurrent extreme weather events, e.g. snow drifts, ice, fog.
7. Identify high-risk accident locations (accident hot spots) from historical accident data
8. Collect Probe Vehicle Data (see technique “Probe Vehicle Data”) for real-time hot spot identification
9. Implement a hot spot mapping tool (geographical information system) within the NRA
10. Establish an interface to a simulation-based incident response strategy planning tool (see technique “Simulation-based incident response strategy planning tool”).

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5.3.2 Simulation based incident response strategy planning

RECOMMENDED TECHNIQUE

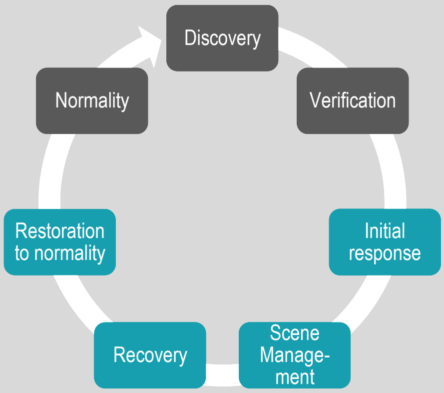
Simulation based incident response strategy planning

Simulation-based incident response strategy planning can be categorized as a prevention incident management technique used to anticipate the best scene management techniques for different types of incidents at specific hot spot locations and traffic conditions.

By setting up and calibrating traffic simulation models for relevant road sections or parts of the road network, it is possible to conduct scenario based evaluations of different scene management techniques for different types of incidents, traffic conditions and time of the incident occurrence. Examples of such techniques include optimal clearing strategies; dynamic traffic control (via VMS); optimal redirection strategy (contraflow); incident screens to avoid rubbernecking; optimal lane closing strategy)

The technique requires traffic engineers to set up and calibrate traffic models for the most important road stretches. The calibration requires a comprehensive amount of traffic and incident data.

BENEFITS FOR TRAFFIC INCIDENT MANAGEMENT



The technique has been assessed by applying it to a set of common incident types and scene management techniques on two and three lane motorways.

Benefits for Initial Response:

Simulation-based incident response strategy planning may help to shorten the initial response phase since the set of scene management techniques to be considered for a specific incident can be limited based on the simulation results for a similar type of incident. Furthermore the strategy planning will give guidance on which techniques can be most beneficial for the current type of incident depending on when it occurs and under which traffic conditions.

Benefits for Scene Management:

Simulation-based incident response strategy planning will increase the chance of applying the most beneficiary scene management technique in terms of capacity, delay, duration, risk for secondary incidents, etc.

Benefits for Recovery:

Decreased congestion in scene management consequently gives less delay during the recovery phase.

Benefits for Restoration:

Decreased congestion in scene management and recovery consequently results in less congestion and delay during the restoration phase. The duration of the restoration phase is directly proportional to the upstream congestion and the traffic demand. A decreased duration of the restoration phase will also reduce the risk of secondary incidents

COST CONSIDERATIONS

€€	Costs for data collection (travel demand, speed-flow-density relationships, capacity at normal and incident conditions, durations of the initial TIM phases)
€	Costs for buying a license and/or developing a suitable traffic model
€	Costs for setting up, calibrating and validating the traffic model for each hot spot
€	Costs for conducting the scenario based simulation experiments
€	Costs for documentation and integration of the results in the traffic control centre
€	Costs for keeping the traffic models up to date (changes in the road design, travel demand, speed limits, etc.)
€	Costs for training of personnel

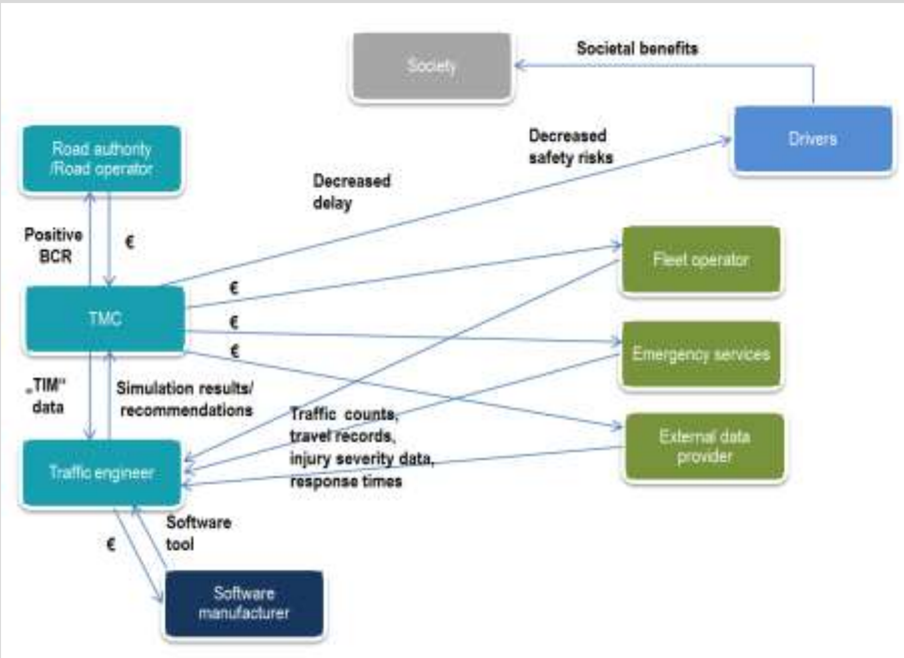
Assumptions: Some basic traffic data is already collected by the traffic management centre; nevertheless, additional measurements and data processing are needed.

RISKS

- If the set of incident scenarios, TIM techniques, time of incident occurrence, traffic demand, etc. is too limited, there is a risk that few actual incidents are similar enough to any of the evaluated scenarios.
- There is also a risk that suitable techniques are discarded by mistake in the process of limiting the number of potential techniques for a given type of incident, time of incident occurrence and traffic demand. It is important to continuously keep the traffic models up to date, redo the analysis and revise the results and the recommendations to ensure that the recommendations correspond to the current road and traffic conditions.
- A not well enough calibrated and validated traffic model is another risk that can lead to faulty results and recommendations.

RECOMMENDED IMPLEMENTATION STEPS

As this is one the most novel techniques (as well as being developed in PRIMA), it was decided to develop a business model and present it under the form of a value network.



The Traffic Management Centre (TMC) orders specific traffic data from data providers (e.g. fleet operators, emergency services or other external providers). Data such as incident response times, traffic counts, travel records, incident severity data and historical weather data goes directly to the Traffic engineer (who either belongs to the NRA or is a third-party contractor). The TMC also provides the Traffic engineer with other types of data, which is collected by the TMC, such as: historical incident data, scene management, incident techniques data, traffic data, etc. The software manufacturer, who developed the Simulation-based incident response strategy planning tool, sells the license to the Traffic engineer, who uses the data and sets up and calibrates traffic simulation models for relevant road sections or parts of the road network and then provides the TMC with the simulation results, i.e. recommendations for the optimum scene management techniques. The TMC (who either belongs to the NRA or is a third-party receiving budget from the NRA) can provide the benefits of this technique to the road authority in the form of positive benefit cost ratios, decreased costs of incident management as well as societal benefits (e.g. behavioural changes in drivers). The driver benefits from this technique by having decreased travel delay as well as decreased safety risks.

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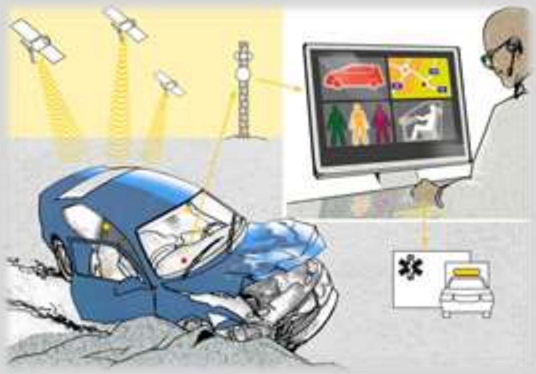
5.4 Prepare

5.4.1 Advanced eCall

RECOMMENDED TECHNIQUE



Advanced eCall

Advanced eCall (emergency call) is an improvement on the eCall system (For more details, see the profile of eCall). eCall is a system installed in a vehicle that automatically dials the emergency services in the event of a serious road accident. In Advanced eCall, injury risk information is added to the standard eCall message that contains the location of the crash site. This has the potential to further improve emergency response, both in quality and time as rescue personnel dispatched at the scene are better informed and thus better prepared on how to deal with the incident.

It must be noted that this technique is based on the assumption that eCall is already implemented in the vehicle. The European Parliament has voted that all new cars will be required to be equipped with eCall from April 2018.

BENEFITS FOR TRAFFIC INCIDENT MANAGEMENT

Benefits for Discovery:

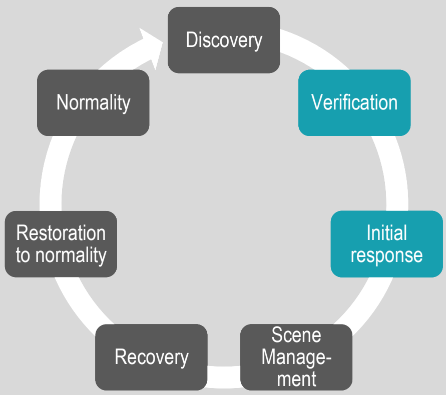
The benefits of this technique would be similar to those of eCall, as the detection capabilities of the system are identical.

Benefits for Verification:

Advanced eCall will provide injury risk information which is added to the eCall message. This data is highly beneficial in providing the TMC with information regarding the severity of the incident.

Benefits for Initial response:

Since injury risk information is provided, benefits can be achieved in the time for providing the initial response, as well as in its quality. By having reliable information on the injury risk levels, the appropriate initial response can be prepared.



COST CONSIDERATIONS

- € Interfaces between PSAPs (Public Safety Answering Points – where calls from equipped vehicles would be directed) to Police Control Offices, to Traffic Control Centres, etc.
- € Equipment for the data transfer between the involved entities

Assumptions: Any systems such as eCall, bCall or Advanced eCall are implemented by the vehicle manufacturers and hence do not bear additional costs for the national road authorities. Nevertheless, in order for the NRA to get the full benefits of these systems, some costs would occur to establish interfaces.

RISKS

- The False alarm rate could be of concern, especially in the early stages of implementation
- Incorrect estimation of the injury severity could trigger an inappropriate initial response, deployment of unnecessary equipment at the scene, etc.

RECOMMENDED IMPLEMENTATION STEPS

PRIMA did not focus on the implementation of Advanced eCall, which is of course necessary to prove its worth for Traffic Incident Management. It should be investigated how the injury risk information can be used in practice, for example to adjust the (emergency) response actions accordingly (is it needed to send and ambulance, or will only a police officer suffice; is specialized medical help required, or maybe even a helicopter), or to estimate the impact of the incident on traffic, which can in turn be used to take appropriate actions (how long is it expected for the road to be blocked, is redirecting of traffic needed, etc.).

More elaborate research, potentially followed by pilot studies are required to gain trust in the injury risk prediction and to gain insight in the effect of response scenarios based on the Advanced eCall information.

REFERENCES

Broos J.; 2016; Injury Risk Functions for Anthropomorphic Test Devices in Omnidirectional Loading Cases; TNO report TNO-2016-R10514"

Fimcar Project 2012. Frontal Impact and Compatibility Assessment Research. www.fimcar.eu.

Laan, E. V. D. 2009. Seat Belt Control, From Modeling to Experiment, Eindhoven University of Technology. ISBN-13: 978-90-386-2086-2

5.4.2 Professional on-site incident reporting

RECOMMENDED TECHNIQUE

Professional on-site reporting

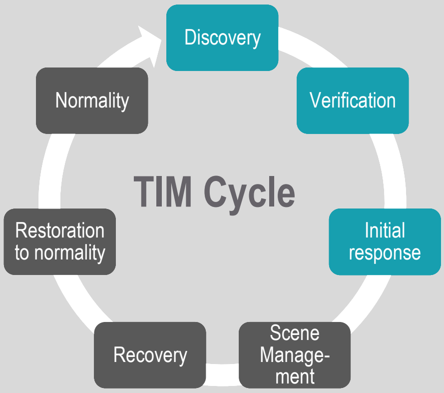
Professional reporting of traffic incidents supports incident management with detailed, accurate and reliable information regarding an incident. The reports may come from either the emergency services or a traffic officer on patrol, who are specifically trained and have experience in providing the necessary information regarding the respective occurrence. Professional reports can be given through the use of mobile phones or through portable radio communication devices. Ideally, traffic officers for professional reporting are located near incident hot spots and may be part of the motorway maintenance and service depots.

Professional reports can be used for the discovery, verification and initial response to an incident by verifying the nature and location of the incident on site in a professional manner, providing sufficient detail on the incident to enable an informed decision on the responder and by providing support on the level of response required, the type of organizations (e.g. ambulance, fire service, towing service etc.)

BENEFITS FOR TRAFFIC INCIDENT MANAGEMENT

Benefits for Discovery:

Professional reporting normally applies after an incident is discovered, so the rate of detected incidents may not necessarily improve. However, the reliability of discovery is high, e.g. for secondary incidents, with a low false alarm rate.



Benefits for Verification:

Professional reports provide accurate information through direct communication, thus lowering the false classification rate, while also giving details on the number and classes of vehicles involved in the incident, as well as the injury levels if necessary. Moreover, a first estimate of the expected incident duration can be given.

Benefits for Initial Response:

Response performance can be increased due to high quality of verification as well as preparation and information of response organisations. Due to the overlap of Verification and Initial Response phases, time savings can be achieved from direct communication channels with the reporting persons.

COST CONSIDERATIONS

€€€	Personnel hours (for Police or Traffic Officer)
€€	Costs for work places or integration into existing service centres
€	Investment costs for communication equipment
€€	Investment costs for patrol vehicles and safety equipment
€	Costs for training of personnel
€	Maintenance costs for patrol vehicles, communication and safety equipment

RISKS

- False alarm or a misleading reporting of the nature of a traffic incident. However, due to the training and experience of police or traffic officers, this risk is considered low
- The optimal placement and location of traffic officers is crucial for quick response, e.g. near sites where incidents are likely to occur ("hot spots"). Inadequate or sparse distribution of traffic officers along the road network results in a risk of higher response durations due to long journey times
- Potential of missed incidents due to a low penetration rate compared with other techniques. This would result in a poor discovery rate
- Traffic officers on site are exposed to a risk of being hit by vehicles passing by, as they are in charge of protecting the scene at normal traffic conditions. Patrol vehicles with blue lights and adequate clothing such as high visibility vests minimize the risk

RECOMMENDED IMPLEMENTATION STEPS

1. Identify hot spots with high incident density or "blind spots" in the road network with gaps of coverage by monitoring technologies
2. Identify number of necessary personnel on site, including working hours
3. Identify amount of equipment, e.g. vehicles, communication units etc.
4. Define working tasks, responsibilities and authorization of the traffic officers on patrol, incl. interfaces to emergency services
5. Recruitment and training of personnel
6. Decide on the work locations:
   a. Integrate new personnel into existing locations near the road, e.g. service and maintenance depots
   b. Build new service centres near incident hot spots
7. Implementation in dedicated smaller regions (test areas, single hot spots)
8. Testing phase for several months
9. Evaluate effectiveness and added value (benefit cost ratio)
10. Implement professional reporting on a larger scale

REFERENCES

Owens, N. D. et al, 2012. Training of Traffic Incident Responders. SHRP 2 Report, Transportation Research Board, Washington, www.trb.org

5.4.3 Model-based short-term response planning

RECOMMENDED TECHNIQUE

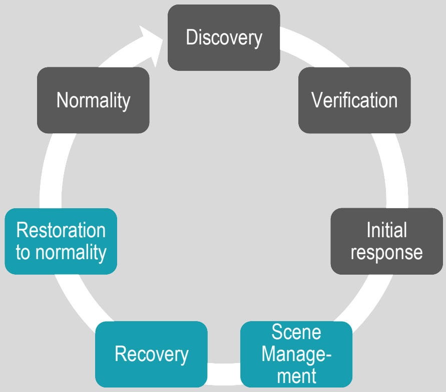
Model-based short term response planning

Model-based short term response planning can be categorized as an initial response incident management technique used to evaluate the best scene management techniques for an occurring incident. Given real time information on the type of incident, pre-estimations of durations for securing and clearing the scene, number of lanes blocked, current traffic conditions, etc., a queue model can give quick estimations of delay and duration for different scene management techniques, such as optimal clearing strategies; dynamic traffic control (via VMS); optimal redirection strategy (contraflow); incident screens to avoid rubbernecking; optimal lane closing strategy.

The technique requires traffic engineers who can set up a generic queue model that can be adjusted quickly by the traffic control centre staff to the current incident location, i.e. speed limits, number of lanes, traffic demand, durations of incident phases, etc.

BENEFITS FOR TRAFFIC INCIDENT MANAGEMENT

The technique has been assessed by applying a spreadsheet based implementation in an off-line context for a set of common incident types and scene management techniques on two and three lane motorways.



Benefits for Scene Management:

Model-based short term response planning will increase the chance of applying the optimal scene management technique while taking into account relevant data in terms of capacity, delay, duration, risk for secondary incidents, etc.

Benefits for Recovery:

Decreased congestion in scene management consequently gives less delay during the recovery phase.

Benefits for Restoration:

Decreased congestion in scene management and recovery consequently results in less congestion and delay during the restoration phase. The duration of the restoration phase is directly proportional to the upstream congestion and the traffic demand. A decreased duration of the restoration phase will also reduce the risk of secondary incidents.

COST CONSIDERATIONS

€€	Costs for data collection (e.g. travel demand, speed-flow-density relationships, capacity at normal and incident conditions, durations of the initial TIM phases)
€	Costs for interface for real time data exchange with other technologies and techniques
€	Costs for buying a license and/or developing a suitable queue/traffic model
€	Costs for settings up, calibrating and validating the traffic model for each hot spot
€	Costs for documentation
€€	Costs for education of TMC staff and integration of the model in the traffic control centre operational work

€ Costs for keeping the queue/traffic models up to date (changes in the road design, travel demand, speed limits, etc.)

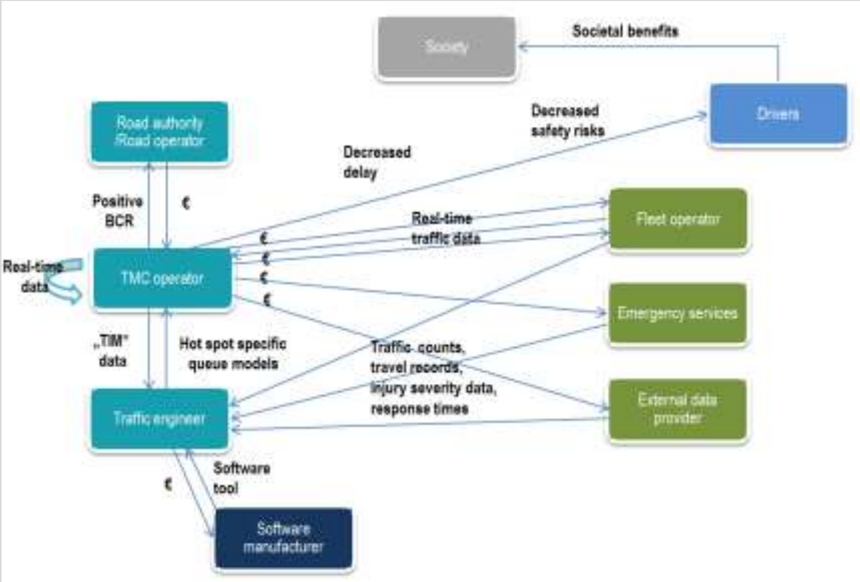
Assumptions: Some traffic data is already collected by the traffic management central, but additional measurements and data processing is needed.

RISKS

- The technique may imply a slightly longer duration of the initial response phase compared with always choosing a standard scene management technique
- There is a risk that waiting too long for the results will prolong the initial response past its optimal time

RECOMMENDED IMPLEMENTATION STEPS

As this is one the most novel techniques (as well as being developed in PRIMA), it was decided to develop a business model and present it under the form of a value network.



The Traffic Management Centre (TMC) orders specific traffic data from data providers (e.g. fleet operators, emergency services or other external providers). Data such as incident response times, traffic counts, travel records, incident severity data and historical weather data goes directly to the Traffic engineer. In addition, real-time data is needed that can be provided from either the TMC itself or from a fleet operator. The TMC also provides the Traffic engineer with other types of data which is collected by the TMC, such as: historical incident data, scene management, incident techniques data, traffic data, etc. The software manufacturer, who developed the Model-based short term response planning tool, sells the license to the Traffic engineer, who uses the data and sets up a generic queue model and then provides the TMC with hot spot specific queue models. The TMC (who receives its budget from the Road authority), through an operator, can use the queue model and adjust it to a specific incident, by feeding the models with real-time incident information, e.g. speed limit, number of lanes, type of incident, location, traffic demand, etc. The benefits of this technique to the road authority come in the form of positive benefit cost ratios, decreased costs of incident management, societal benefits (e.g. behavioural change). The driver benefits from this technique by having decreased travel delay as well as decreased safety risks.

REFERENCES

Menendez, M. and C. Daganzo, 2004. Assessment of the Impact of Incidents near Bottlenecks Strategies to Reduce Delay, Transportation Research Record: Journal of the Transportation Research Board, No. 1867.

Dougald, L. Goodall, N. and Venkatanarayana, R., 2016. Traffic Incident Management Quick Clearance Guidance and

Implications, Final Report VTRC 16-R9, Virginia Transportation Research Council.

Olstam, J. Bernhardsson, V. van Dam, E., Uittenbogaard, J. Reinthaler, M., Ponweiser, W. Taylor, N. B. Nitsche, P.et al, 2015. Assessment results of incident management procedures. PRIMA, Deliverable 3.1, CEDR

5.5 Respond

5.5.1 Optimal clearing strategy

RECOMMENDED TECHNIQUE

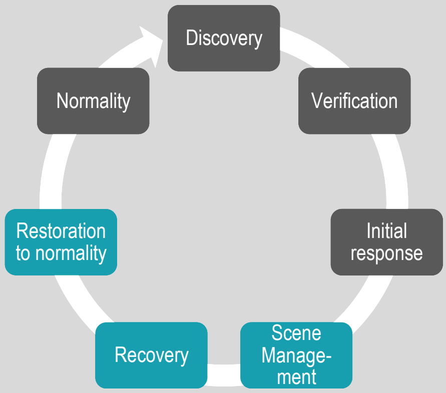
Optimal clearing strategy

Optimal clearing strategy is a scene management technique used at incident locations in order to maximize traffic flow at the incident scene. The objective is to minimize total delay and duration of the incident by deciding when and how to close lanes in order to optimally clear the scene. Clearing the scene may include actions such as towing stranded vehicles, removing obstructions on the road or cleaning the surface of hazardous substances.

Depending on circumstances such as traffic demand and current available flow, different types of clearance techniques can be used. Examples include: wait and tow during off-peak, or closing additional lanes before the traffic peak and repairing a stranded vehicle to make sure it can run to the closest emergency refuge area or off-ramp.

Rescue vehicles or traffic managers will close the required number of lanes when needed. Additional service vehicles may be required; however repairmen or towing services are a part of the technique.

BENEFITS FOR TRAFFIC INCIDENT MANAGEMENT



Optimal clearing strategy may already be initiated during the initial response phase since required resources may be ordered to the location. Largest benefits are achieved during the last phases in the TIM cycle as a consequence of increased capacity during the most critical time period of the TIM cycle (peak demand).

Benefits for Scene Management:

Applying optimal clearing strategy to scene management usually means higher flow and capacity, shortened queues and minimized delays. But it must be kept in mind that optimal clearing strategy aims to minimize the duration and delay caused by the incident, not optimizing each phase. The consequence may be that the optimal solution increases delay or duration for individual phases. A potential benefit is decreased rubbernecking due to limited incident clearing activities and less presence of rescue vehicles.

Benefits for Recovery:

Optimized clearing strategy in scene management should bring benefits to the recovery phase in terms of decreased queues and delays, but as already mentioned; optimal clearance is not focused on individual TIM phases and may not necessarily bring benefits to all phases.

Benefits for Restoration:

By optimizing the clearing strategy it would be natural to have less congestion and delay in the restoration phase. That is dependent on how the optimal clearing strategy is applied in relation to the traffic demand profile. As already mentioned, optimal clearance strategy is not specific to individual TIM phases and may not necessary bring benefits to all of them.

COST CONSIDERATIONS

- € Additional personnel cost for traffic officers. These costs can increase depending on the complexity of the clearing strategies.
- € Additional operational costs for rescue vehicles
- € Costs for dedicating service vehicles required for towing, moving or repairing vehicles

Assumptions: Since clearing an incident is a common task, costs for the NRA apply in the business-as-usual case. Depending on the optimal clearing strategy, e.g. computed by a simulation-based response planning model, additional costs may apply.

RISKS

- The risk of secondary accidents may increase since the duration of the incident may increase even if the total delay may decrease, e.g. if waiting with tow activities until off peak.
- The risk of secondary accidents may also increase since there may be several phases when the queue is building up, when capacity reductions are spread out in order to maximize flow during the most critical periods (high traffic peak)
- Underestimation of the incident clearing or repairing time may increase the total duration and delay. The technique is sensitive to miscalculations of durations for operations since the aim is to maximize flow during critical moments in the TIM cycle. Also misjudgements of the traffic demand profile may imply serious consequences as increasing congestion and delay

RECOMMENDED IMPLEMENTATION STEPS

It is considered in PRIMA that traditional scene management techniques are already well known and implemented by the road authority. Therefore, no implementation steps were defined for Optimal Clearing Strategy.

However, PRIMA suggests applying a simulation-based incident strategy planning model as decision-support for the optimal clearing strategy.

REFERENCES

NCHRP, 2003. Safe and Quick Clearance of Traffic Incidents - A Synthesis of Highway Practice, NCHRP Synthesis 318, Transportation Research Board, http://i95coalition.org/wp-content/uploads/2015/03/NCHRP-Synethesis318.pdf?dd650d.

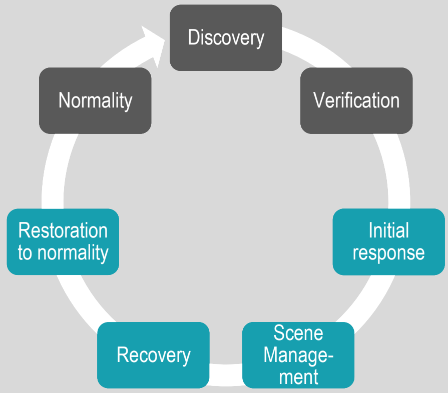
5.5.2 Incident screens to avoid rubbernecking

RECOMMENDED TECHNIQUE

Incident screens to avoid rubbernecking

Incident screens are a scene management technique used at incident locations in order to protect the scene and retain full capacity utilization from the remaining lanes by preventing rubbernecking. Multiple screens are placed around the scene at an incident in order to obscure the view and prevent rubbernecking in the remaining lanes of the incident direction but also for the opposite direction. The technique requires professional traffic management providers erecting the incident screens in a safe way. Rescue vehicles are required in order to close the blocked lanes at the scene and additional service vehicles may carry the incident screens.

BENEFITS FOR TRAFFIC INCIDENT MANAGEMENT



Incident screens may only be beneficial if the incident duration is long enough in relation to the time required to establish the screens.

Benefits for Initial Response:

Incident screens may be initiated already during the initial response phase since required resources may carry some simple view protection or screens. Vehicles carrying screens may also be ordered to the scene during the initial response. During the initial response, some benefit may occur depending on the severity of the incident. The most important action during the initial response is still to protect the scene.

Benefits for Scene Management:

Incident screens may be put up during the scene management phase preventing motorists being distracted by the actions at the incident location. By using incident screens, the capacity utilization may increase towards normal conditions and the effect on congestion and total delay may decrease.

Benefits for Recovery:

Decreased congestion in scene management consequently gives less delay during the recovery phase. Some additional capacity reductions may be required when removing the incident screens before reopening all lanes. The total delay and queue length will still decrease during the recovery phase compared with not using incident screens.

Benefits for Restoration:

Decreased congestion in scene management and recovery consequently results in less congestion and delay during the restoration phase. The duration of the restoration phase is directly proportional to the upstream congestion and the traffic demand. A decreased duration of the restoration phase will also reduce the risk of secondary incidents.

COST CONSIDERATIONS

€	Additional personnel costs for officers on site
€€	Costs for buying, storing, maintaining, transporting, installing and removing incident screens

Assumptions: Putting up incident screens is not a common task of the NRA. There will be costs for increased duration of the incident, since establishing and removing incident screens may require some extra time. However, these are rather societal costs than direct costs for the NRA.

RISKS

- The incident screen itself can decrease the risk of secondary incidents due to rubbernecking, while the extra time needed to establish the screens can increase the total incident duration and thereby the risk for secondary incidents
- An overestimation of the incident clearing time can imply that incident screens are applied in cases when it is not beneficial

RECOMMENDED IMPLEMENTATION STEPS

It is considered in PRIMA that traditional scene management techniques are already well known and implemented by the road authority. Therefore, no implementation steps were defined for Incident screens.

REFERENCES

Colon, N., 2013. Temporary barriers reduce rubbernecking and distraction on roadways, HIM 1990-2015. Paper 1391. University of Central Florida.

Masinick, T. and Jonathan, P., 2004. An Analysis on the Impact of Rubbernecking on Urban Freeway Traffic, Report No. UVACTS-15-0-62, Center for Transportation Studies, University of Virginia

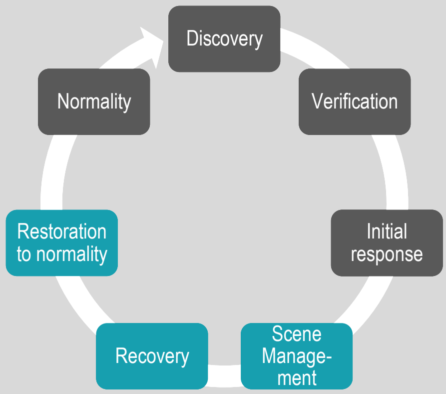
5.5.3 *Redirection strategy (contraflow)*

RECOMMENDED TECHNIQUE

Redirection strategy (contraflow)

Contraflow is a scene management technique used at incident locations in order to retain some traffic flow in the incident direction even when all lanes are blocked. When the incident occurs, some lanes in the opposite direction may be dedicated for contraflow. Vehicles in the incident direction are directed to cross the median barrier and travel in the opposite direction, passing the incident location and then are directed back to their own direction. The technique requires professional traffic management in order to establish a contraflow in a safe way. Rescue vehicles need to close all lanes in the incident direction while simultaneously taking care of dedicating lanes in the opposite direction. The action may require speed limit changes and additional information to the drivers in the opposite direction. Additional service vehicles may be required if the road segment is equipped with a median barrier.

BENEFITS FOR TRAFFIC INCIDENT MANAGEMENT



Contraflow may only be beneficial if the incident duration is long enough in relation to the time required to establish the contraflow. Contraflow may be initiated already during the initial response phase since required resources may be ordered to the incident location. But the benefits may be achieved as a consequence of increased capacity in the incident direction during the last phases in the TIM cycle.

Benefits for Scene Management:

Contraflow increases capacity in the incident direction which decreases queue length and total delay. The potential benefit is large and increases with the increasing duration of the incident. The scene is protected since all lanes may be closed but there may still be some traffic flow in both directions.

Benefits for Recovery:

Decreased queue length in scene management consequently results in less congestion and delay during the recovery phase. When the scene is cleared and lanes may be opened, the contraflow needs to be removed which may require some temporary capacity reduction. The total delay and queue length are often still shorter for the recovery phase compared with not conducting the contraflow technique.

Benefits for Restoration:

Decreased queue length in scene management and recovery consequently results in less congestion and delay during the restoration phase. The duration of the restoration phase is directly proportional to the upstream congestion and the traffic demand. The duration of the restoration phase will decrease which also reduces the risk of secondary incidents.

COST CONSIDERATIONS

- € Additional personnel costs for officers and workers on site
- € Costs for opening and closing the median barrier to put up the contraflow

Assumptions: Contraflow is not a common task for the NRA. There will be costs for increased duration of the incident, since establishing and removing incident screens may require some extra time. However, these are rather societal costs than direct costs for the NRA.

RISKS

- Increased risk for collisions with oncoming traffic since there may be no formal separation of the traffic directions on the contraflow sections
- Increased risk of secondary accidents in the opposite direction since contraflow introduces a bottleneck in the “no incident” direction
- An overestimation of the incident clearing time can imply that contraflow is applied in cases when it is not beneficial

RECOMMENDED IMPLEMENTATION STEPS

It is considered in PRIMA that traditional scene management techniques are already well known and implemented by the road authority. Therefore, no implementation steps were defined for Contraflow.

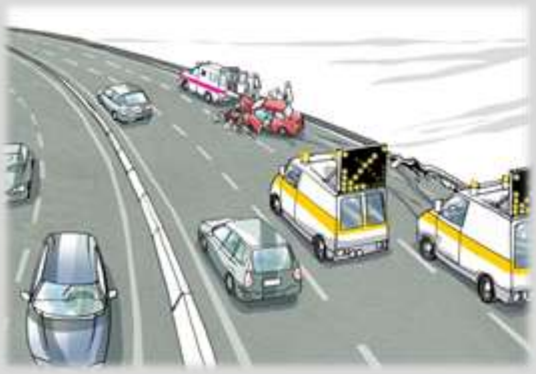
However, PRIMA suggests applying a simulation-based incident strategy planning model as decision-support for the optimal redirection strategy.

REFERENCES

Policy and Procedure for Contra-Flow Traffic Management - F3 Freeway, TMC-POL-402012, http://www.dpc.nsw.gov.au/__data/assets/pdf_file/0009/95778/Attachment_14.pdf

5.5.4 Optimal lane closing strategy

RECOMMENDED TECHNIQUE

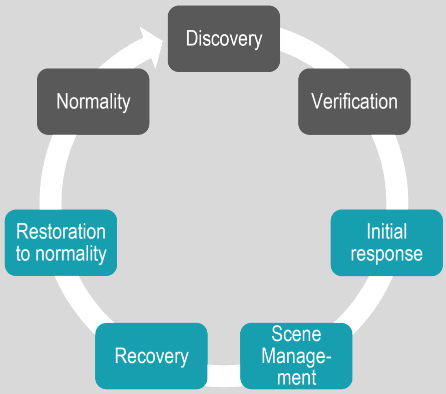


Optimal lane closing strategy

Optimal lane closing is a scene management technique used at incident locations in order to maximize traffic flow at the incident scene. When the incident occurs, only the minimum number of lanes will be closed in order to maximize the capacity at the location of the incident.

The technique requires professional traffic management officers in order to make the right decision and close only the required number of lanes but still protect the scene. Rescue vehicles and/or service vehicles are required when protecting and clearing the scene before reopening all lanes. The severity of the incident may affect the number of rescue vehicles required; however optimal lane closing technique is possible. Utilizing monitoring infrastructure such as VMS and speed limit changes may be useful when applying optimal lane closing.

BENEFITS FOR TRAFFIC INCIDENT MANAGEMENT



Benefits for Initial Response:

Optimal lane closing strategy may be established during the initial response phase depending on the level of information and the severity of the incident. There is always a trade-off between traffic performance and security at the scene, especially during the initial TIM phases which are most critical since there may be crucial need of medical care and protection of the scene. Depending on the severity of the incident, the risk assessment may give permissions to establish optimal lane closing which brings benefits in terms of reduced delay and congestion.

Benefits for Scene Management:

Optimal lane closing will increase capacity at the bottleneck which reduces congestion and delay during the scene management. The technique still requires sufficient lane closures in order to provide enough distance to secure the scene.

Benefits for Recovery:

Optimal lane closing will bring benefits to recovery in terms of reduced congestion and delay as a consequence of increased capacity at the bottleneck. The technique still requires sufficient lane closures in order to provide enough distance to secure the scene.

Benefits for Restoration:

Decreased queue length in scene management and recovery causes less congestion and delay during the restoration phase. Optimal lane closing will reduce the duration of the restoration phase which will reduce the risk of secondary incidents.

COST CONSIDERATIONS

€ Additional personnel costs for officers and workers on site

€ Additional operational costs for service vehicles to block the lane safely

Assumptions: Since lane closing is a common task, costs for the NRA apply in the business-as-usual case. Depending on the optimal lane closing strategy, e.g. computed by a simulation-based response planning model, additional costs may *apply. Reducing closures may require more rescue vehicles in order to protect the scene. Increasing the number of rescue vehicles may increase rubbernecking, which results in a cost of congestion and delay in the opposite direction.*

RISKS

- Keeping some lanes open increases the risk for the emergency workers at the scene compared with closing all lanes
- Increased risk of secondary accidents in the incident direction since the duration of the incident may increase when there is decreasing protection at the scene
- Increased risk of secondary incidents in the opposite direction due to rubbernecking caused by an increased number of rescue vehicles to protect the scene

RECOMMENDED IMPLEMENTATION STEPS

It is considered in PRIMA that traditional scene management techniques are already well known and implemented by the road authority. Therefore, no implementation steps were defined for Optimal lane closing.

However, PRIMA suggests applying a simulation-based incident strategy planning model as decision-support for the optimal lane closing strategy.

REFERENCES

FEMA 2012, Traffic Incident Management Systems, FA-330, https://www.usfa.fema.gov/downloads/pdf/publications/fa_330.pdf

Verkeerscentrum Nederland, 2010, Directive initial safety measures for incidents with a one-sided collision risk - for all roads with divided carriageways, https://www.incidentmanagement.nl/Portals/0/Documenten/DirectiveOne-sided.pdf.

5.5.5 *Dynamic speed limits and driver information*

RECOMMENDED TECHNIQUE

Dynamic Speed Limits and Driver Information

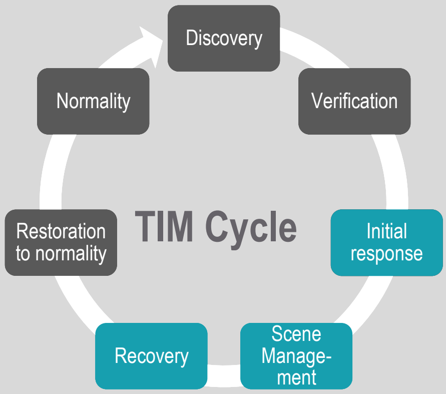
The reduction of the driving speed in advance of the location of the incident allows the reduction in the risk of secondary incidents as well as improving capacity management.

By using the channels of VMS (Variable Message Signs) or more specifically VSL (Variable Speed Limits), drivers are informed not only about the incident, but also about the new traffic measures. Additional to road side systems, speed limit information can also be distributed via cooperative traffic systems like traffic message channel using in-vehicle and nomadic devices as front-end. Dynamic Speed Limits can be used for Scene Management and Recovery by the reduction of the risk of secondary incidents and their severity, and management of capacity via limitation and harmonization of speed.

BENEFITS FOR TRAFFIC INCIDENT MANAGEMENT

Benefits for Initial Response

Dynamic speed limits installed as part of the initial response can help reduce the risk of secondary incidents, as well as provide a first warning to drivers etc.



Benefits for Scene Management:

Dynamic speed limits are essential for the reduction of the risk of secondary incidents and their severity. Furthermore, it is a technique that helps to deal with reduced highway capacity due to the reduction of available lanes at the incident location during scene management.

Benefits for Recovery:

The capacity bottleneck at the incident location can be managed pro-actively via dynamic speed limits to create a harmonized flow of vehicles; this partially compensates the effect of lane closures.

COST CONSIDERATIONS

Elements of the costs that need to be considered:

- €€ Costs for road side equipment (e.g. VMS and/or VSL) consisting of acquisition, installation and operation/maintenance costs
- € Costs for the communication link to additional information channels (cooperative systems, TMC, etc.) highly depend on the availability of communication units

Assumptions: There is existing roadside infrastructure for VMS and traffic sensors, incl. power and network supply.

RISKS

- Only areas, which are well covered by road side units in terms of the location and density, can be managed by dynamic speed limits
- Although speed limits may be in place, the compliance of the drivers to the respective signs is not ensured. Hence the compliance rate is key, which can be increased by enriching the speed limit with additional information (the cause for speed limiting) and enforcing measures

RECOMMENDED IMPLEMENTATION STEPS

1. Perform an inventory of existing infrastructure, e.g. VMS and traffic sensors
2. If necessary, provide additional information signage on existing VMS for incident information
3. Build up I2V communication interface from the TMC to the driver (either via cellular network or ITS-G5)
4. Establish interface to real-time incident database
5. Implement algorithms for suggesting signage:
   - Dynamic speed variation ("gradual" speed reduction)
   - Optimal lane closures
   - Type and content of incident information
   - Duration of how long information is given
6. Manual plausibility checks by the operator and final approval for signage

REFERENCES

Kessels, J., 2009. Dynamic speed limits. Rijkswaterstaat

Texas A&M Transportation Institute, n.d. Variable speed limits. http://mobility.tamu.edu/mip/strategies.php

5.6 Monitor

5.6.1 Video Incident Detection systems

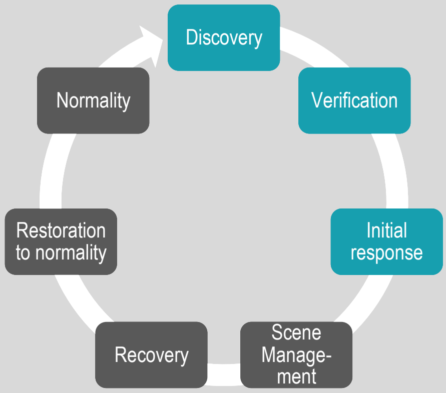
RECOMMENDED TECHNIQUE

Video Incident Detection Systems

Video Incident Detection Systems (VIDS) provide automatic incident detection and traffic data in real time. This technology supports optimal surveillance of the road network by automatically detecting incidents based on processing image data. It is based on CCTV cameras installed at different points on the road network. As opposed to regular CCTV monitoring, the system automatically notifies (by visual or auditory alarm) the traffic management centre and its operators. VIDS can detect events such as a stopped vehicle, speed drop, traffic congestion, smoke and flame detection, debris on the road, etc.

VIDS can be used for the discovery, verification and initial response by: automatic discovery of traffic incidents; reliable visual verification of the nature and location of incidents and initial details of the traffic incident nature.

BENEFITS FOR TRAFFIC INCIDENT MANAGEMENT



Benefits for Discovery:

VIDS have the highest detection rate among all assessed techniques, with a medium false alarm rate. Depending on the detection algorithm, the reliability of discovery can vary.

Benefits for Discovery:

Full and reliable verification of traffic incidents is a high advantage for VIDS. The technique can provide detailed and accurate information on the location, number of vehicles, vehicle classes, etc. Low false classification rate.

Benefits for Discovery:

The response performance will be very high, conditional of the quality of the verification. Moreover, through visual monitoring, the injury risk or the injury level of the incident participants could be estimated. This will ensure an optimal preparation of the level of initial response required.

With regard to time-related indicators, potential time savings, due to the overlapping of discovery and verification phases, can be achieved.

COST CONSIDERATIONS

€€	Costs of equipment: CCTV cameras retrofit or supplement, video image processor, method of communication (network), system software
€	Cost of equipment installation and maintenance
€	Cost for training of TMC staff

Assumptions: There is a sufficient coverage of CCTV to be used for VIDS.

RISKS

- CCTV and automatic incident detection are already in use. The risks associated with these could be related only to investment and operational cost versus benefit
- The risk of false alarm rates should also be considered.

RECOMMENDED IMPLEMENTATION STEPS

1. Perform inventory of existing CCTV network
2. If required, retrofit or supplement the existing CCTV network through investments, e.g. infrared cameras for detection during darkness
3. Develop image recognition software (either internal or through an external software developer)
4. Testing phase of system, incl. feedback loop by the NRA to the developer
5. Quality assurance of the software
6. Training of the TMC staff
7. Roll-out of the VIDS
8. Regular Software maintenance
9. Keep a hardware maintenance plan

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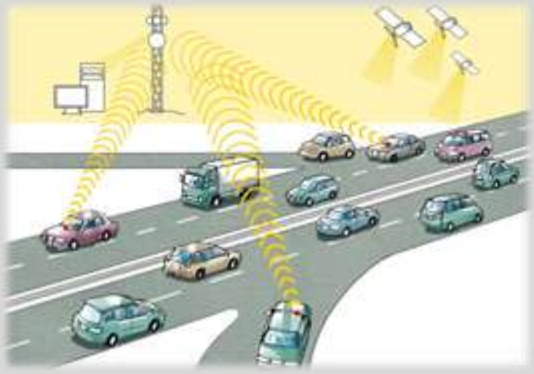
5.6.2 Probe Vehicle Data for traffic monitoring and incident detection

RECOMMENDED TECHNIQUE



Probe Vehicle Data for traffic monitoring and incident detection

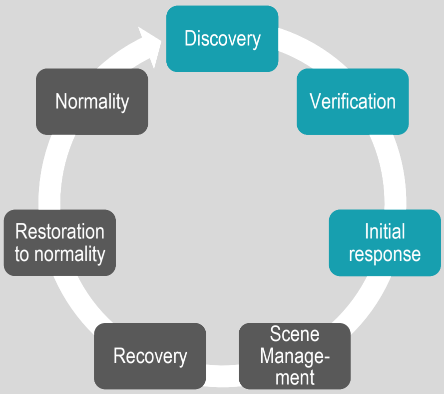
Probe Vehicle Data (PVD) through vehicle to infrastructure (V2I) communication supports direct and indirect detection of incidents. Vehicles are equipped with on-board devices (e.g. sensors) to perform as probe vehicles measuring data of their actual situation and surroundings. The data is transferred to road side IT Infrastructure via cellular network.

Roadmaps for deployment of C-ITS applications stimulate numerous projects, field trials and demonstrations utilizing PVD. These projects also push for the strong need for a standardized framework for PVD collection. In this framework, flexibility, security, privacy protection mechanisms and open access of PVD are essential for the success of probe data systems.

PVD can provide information about:

- Vehicle conditions – Direct information about the real-time situation and information about incidents with direct involvement of the probe vehicle can be derived (e.g. accident, breakdown)
- Network conditions – Depending on the penetration rate, the data enables the analysis of driving patterns at certain locations, such as acceleration, velocities and journey times. This data can be used to build a real-time dynamic network model to estimate traffic conditions, which enables indirect detection of incidents.

BENEFITS FOR TRAFFIC INCIDENT MANAGEMENT



Benefits for Discovery:

Depending on the penetration rate, a low detection rate can be expected initially, but if a high reliability of detection can be achieved with a low false alarm rate as a consequence, the discovery phase would be well supported.

Benefits for Verification:

Data from equipped vehicles allows for the utilization of information such as the number and type of involved vehicles. Furthermore the exact location of the incident is known via on-board localization technologies (e.g. GPS).

Benefits for Initial response:

The response performance, especially the routing and travel time estimation can benefit from the knowledge of the exact location of the incident and the driving direction.

With regard to time-related indicators, potential time savings, due to the automated data measurement and transmission can be achieved in discovery and verification phases.

COST CONSIDERATIONS

€/€€	Purchase of Probe Vehicle Data
€	Communication equipment (installation and operation)
€€	IT centre for data management and data analysis (development and operation)

Assumptions: Probe Vehicle Data with sufficient coverage is available in the country.

RISKS

- A risk that may occur with PVD is the potential of missed incidents, depending on penetration rate. Low penetration rates probably result in low detection rates
- Probe vehicles are usually organized by fleet operators. There is an organizational risk in the availability and dependence on these operators
- Depending on the underlying technical structure, considerable delays in the information transfer from the vehicle to the fleet operator to the road operator may occur

RECOMMENDED IMPLEMENTATION STEPS

1. Conduct a feasibility study and cost-benefit analysis, preferably for a public-private partnership between the NRA and a third-party data provider
2. Implement data server infrastructure and interfaces for receiving PVD in real time
3. Collect PVD
4. Aggregate probe data in real-time for the purpose of incident management, in terms of location and time
5. Plausibility checks and quality assurance
6. Generate relevant information
   a. network information, e.g. congestion level and delay, travel times and speeds
   b. vehicle-reported incidents, e.g. accident, breakdown

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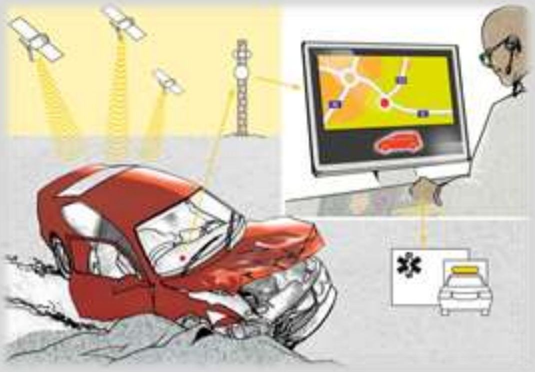
5.6.3 Automated vehicle-based information report

RECOMMENDED TECHNIQUE



Automated vehicle based information reports

Vehicle based information reports can be based on eCall. eCall is a European based system which can be installed in vehicles and which automatically calls the nearest emergency centre, in the event of a road crash. An automatic line of communication is then established between the vehicle and the centre. In the event that no passenger is able to speak, a minimum set of data, such as the location of the crash site will be sent. Moreover, other road users that witness an accident can report it automatically and give the precise location of a crash.

eCall is expected to reduce the response time of emergency services, thus reducing the number of fatalities, injury level, as well as the number of secondary accidents and road congestion. The European Parliament voted that all new cars will be required to be equipped with eCall from April 2018.

Vehicle based information reports can also be based on other technologies such as dedicated smartphone apps or bCall (i.e. Breakdown call).

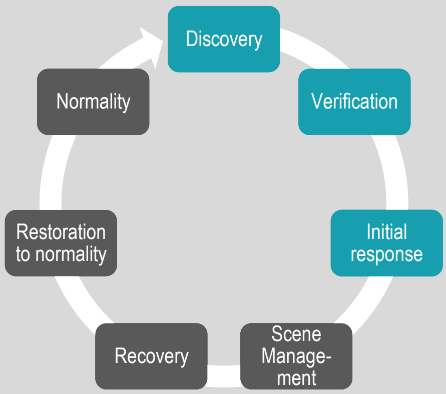
BENEFITS FOR TRAFFIC INCIDENT MANAGEMENT

Benefits for Discovery:

Vehicle based information reports have a medium detection rate; however as the penetration rate will increase (due to the mandatory introduction in all new vehicles), the detection rate will improve. Both the false alarm rate and classification rate are low, due to the high accuracy of data of the eCall system.

Benefits for Verification:

Due to the communication link established between the vehicle and the emergency service, data can be easily transmitted regarding number of vehicles, vehicle class, injury level etc.



Benefits for Initial response:

The initial response can be highly improved, in terms of emergency services. Nevertheless, savings can also occur due to a faster response of the other entities involved.

COST CONSIDERATIONS

- € Interfaces between PSAPs (Public Safety Answering Points – where calls from equipped vehicles would be directed) to Police Control Offices, to Traffic Control Centres, etc.
- € Equipment for the data transfer between the involved entities

Assumptions: Vehicle based information reports based on systems such as eCall, bCall or smartphone apps do not bear any costs for the NRAs. Nevertheless, in order for the NRA to get the full benefits of these systems, some costs would occur to establish interfaces.

RISKS

- The False alarm rate could be of concern, especially in the early stages of deployment
- False positives, e.g. manual activation of the system when no accident has happened

RECOMMENDED IMPLEMENTATION STEPS

In April 2015, the European Parliament voted in favour of the eCall regulation, which requires that all new cars to be equipped with the eCall systems from April 2018.

As eCall technology has been under research and development for more than 10 years, it is considered that there is significant literature on the implementation of this system. The European eCall Implementation Platform Task Force 3 published a study in 2011 that analyses the needs and benefits towards eCall from the road operators' perspective. The literature provided in the references provides ample details on the implementation of eCall.

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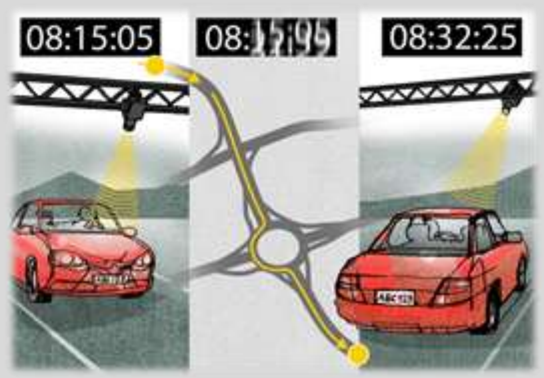
5.6.4 Single-vehicle traffic data measurements

RECOMMENDED TECHNIQUE



Single-vehicle traffic data measurements

Single-vehicle traffic data measurements relates to infrastructure based systems such as Automatic Number Plate Recognition (ANPR), tolling systems, Bluetooth or Wi-Fi delivering detailed traffic data for specific road sections.

Automatic Number Plate Recognition is a technology that uses CCTV to read vehicle registration plates. Electronic toll systems use automated vehicle identification to determine if a vehicle is subject to tolls. Similarly, Bluetooth and Wi-Fi signals can be reliably used for measuring travel times.

However, these technologies can also monitor the movement and flow of individual vehicles around the road network and therefore could be used to highlight problem areas and possible traffic incidents.

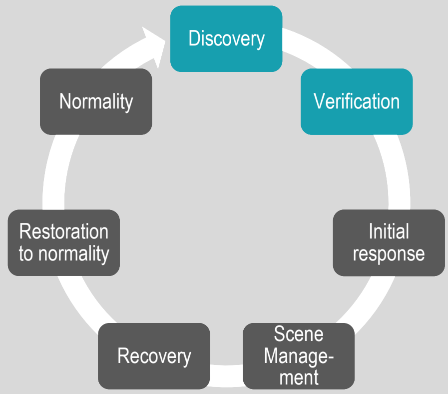
BENEFITS FOR TRAFFIC INCIDENT MANAGEMENT

Benefits for Discovery and Verification:

As a standalone TIM technique, single-vehicle traffic data measurements do not bring substantial benefits to TIM. However, the technologies that support it (ANPR, tolling, etc.) are in most cases already implemented on motorways, i.e. the penetration rate is high. Therefore, the benefits for incident management are a by-product.

This technique can bring benefits to the discovery and verification phases; however, its accuracy is not high.

It is therefore recommended that this technique should be used in combination with others in order to increase the accuracy and reliability of incident discovery and verification.



COST CONSIDERATIONS

- € Analysis software implementation
- € Software maintenance
- € Costs for training of TMC staff and software roll-out

Assumptions: As the technologies that support this technique (i.e. ANPR, tolling) are already installed on the roads for their main purpose, the costs for TIM are only marginal.

RISKS

- The technique can bring benefits only when accompanied by other TIM techniques
- Not all the road network is equipped with the technologies supporting this technique, especially when taking into account the transnational level

RECOMMENDED IMPLEMENTATION STEPS

1. Inventory of existing roadside and sensor infrastructure and feasibility study on the benefits of using the existing infrastructure
2. Decide on data interface, architecture and graphical user interface:
   a. Accumulated data provision (e.g. only travel times or detected incidents)
   b. Raw data provision for analysis within the NRA
3. Implementation of analysis software for detection incidents
4. Testing phase of analysis software, incl. feedback loop by the NRA to the developer/provider
5. Roll-out of analysis software
6. Training of TMC staff
7. Software maintenance and updating procedure

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6 Conclusions

The objectives of PRIMA were to develop a guide with recommended TIM techniques based on risks and costs and to define implementation steps and business models for the most innovative ones, providing clear guidance on pro-active incident management to road authorities. This was achieved by synthetizing all inputs provided by the previous project work and presenting the most effective techniques for handling different types of incidents, across the whole TIM cycle.

The report gives an introduction on Traffic Incident Management and PRIMA, by providing background information on the TIM cycle and each of its phases, as well as giving a short overview on the previous work conducted in the project that led to the PRIMA recommendations. The recommendations present 14 selected incident management techniques that are based on both novel technologies and traditional scene management measures.

The novel techniques based on technologies such as eCall, Probe Vehicle Data (PVD) or CCTV can bring a large benefit in decreasing the discovery, verification and initial response phases. Problems can arise though, due to uncertainties regarding deployment and penetration rates. For example, the implementation of eCall in all new European cars has been delayed several times in the last ten years. As it stands now, 2018 is the date at which all new cars will have to be equipped with eCall technology. Moreover, the extension of eCall to Advanced eCall seems promising, however more research is needed to prove its suitability. Unavoidable uncertainties also arise in the case of PVD and driver information provided through cooperative V2I, as the business case is still unclear for either technology.

The traditional scene management techniques are not based on technologies, but on the optimal use of incident management measures, such as optimal closing of lanes, different towing options and installing incident screens to avoid rubbernecking. These techniques although not novel, can bring substantial benefits in terms of decreased delay and decreased incident duration, contributing to the overall optimisation of the TIM cycle.

One result of PRIMA is that it brings forward two pro-active incident management techniques developed within the project. The model based short term response planning tool can be useful to conduct quick comparisons of different incident management techniques for a real-time occurring incident. On the other hand, the simulation based incident response strategy planning tool can be useful to investigate the effect of different scene management techniques in more detail, as an anticipatory measure. This tool is best suited for more complex road networks with recurring incidents. The two tools can be an added support for incident management centres.

Further development, in terms of refining the models (i.e. the deterministic queue model and the simulation-based model, respectively) as well as enhancing and developing the user interfaces would make each an attractive decision support tool for traffic incident management.

7 Acknowledgement

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List of abbreviations

ANPR	Automatic Number Plate Recognition
bCall	Breakdown Call
BCR	Benefit Cost Ratio
CCTV	Closed Circuit Television
CEDR	Conference of European Directors of Roads
C-ITS	Cooperative Intelligent Transport Systems
eCall	Emergency Call
FCD	Floating Car Data
GUI	Graphical User Interface
I2V	Infrastructure to Vehicle Communication
ITS	Intelligent Transport Systems
NRA	National Road Authority
PEB	Programme Executive Board
PRIMA	Pro-Active Incident Management
PSAP	Public Safety Answering Point
PVD	Probe Vehicle Data
TIM	Traffic Incident Management
TMC	Traffic Management Centre
V2I	Vehicle to Infrastructure Communication
VIDS	Video Incident Detection System
VMS	Variable Message Signs
VSL	Variable Speed Limits