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Description and results of cost-benefit and risk assessment

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

Description and results of cost-benefit and risk assessment

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Executive summary

PRIMA is a project of the 2013 Programme of the Conference of European Directors of Roads (CEDR) to study the use of pro-active techniques and novel technologies in the management of road traffic incidents, building upon previous regulations, specifications and assessment studies regarding Traffic Incident Management (TIM).

This is the deliverable of Task 3.3, forming part of WP3 which identifies and assesses the benefits, costs, risks and impacts. This Task assesses incident scenarios identified in Task 2.4, the enhanced TIM techniques identified in Task 3.2, drawing on extensive recent data on incidents.

Four incident scenarios are modelled assuming a range of traffic demand levels and initial response times, and applying different pro-active management techniques. Benefits of reduction of delay and secondary accidents are 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, including eCall, is 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.

Results suggest that pro-active techniques able to achieve substantial benefits include 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 BCR of 3.35.

New technology 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 difficult to assess because of high total installation costs especially of in-vehicle systems such as eCall which require high user penetration and service providers (e.g. PSAPs), and more marginal benefits where conventional technology like CCTV is already in place. 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.

1 Introduction

The purpose of the PRIMA project, 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 to analyse 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). The objectives include assessing the technical, economical and organisational feasibility of innovative incident management based on pro-active techniques and novel technologies. WP3 of PRIMA identifies and assesses the overall social benefits, costs, risks and impacts. This Task 3.3 has assessed incident scenarios identified in Task 2.4, Deliverable D 2.2 (Taylor, Nitsche *et al* 2015), the enhanced TIM techniques identified in Task 3.2, Deliverable 3.1 (Olstam *et al* 2015), and extensive recent data on incidents.

Four incident scenarios are modelled assuming a range of traffic demand levels and initial response times, and applying different pro-active management techniques. The impact of new technology is assumed to be on initial response times, and that of pro-active management techniques primarily on subsequent scene management. Benefits of reduction of delay and secondary accidents are assessed in monetary terms and compared with the costs of interventions where available, with evidence-based assumptions about accident rates and value of time.

The report draws from several additional sources:

- An assessment of technologies available for detecting incidents
- Operational and technology costs identified previously by CEDR Task 12
- A large recent incident database provided by Highways England (the project has also had access to German GIDAS data)
- Evidence on actual accident risks and costs and secondary accident risk.

Results are subject to the proviso that the effectiveness of any intervention can be difficult to verify for three reasons: counter factuality, as it attempts to measure something that has not happened because the intervention is assumed to have prevented it; variability, so it may require several years of operation to obtain reliable data; confounding, of the effects of different measures that cannot be separated experimentally. For these reasons there has been a strong emphasis on modelling and statistical analysis.

The report is organised as follows, in Section 2 some incident datasets are summarised, including a recent large dataset made available by Highways England, and a recommendation for the content of incident databases is included. In Section 3 evidence on incident frequencies and durations is assembled using the Highways England data. Section 4 gives some evidence on secondary accidents. Section 5 summarises modelling scenarios and results. Section 6 analyses costs and benefits from novel technologies and pro-active techniques based on the modelling results and external evidence. Section 7 considers operational and investment risks of pro-active techniques in general terms. Section 8 concludes.

2 Incident datasets analysed and recommendations

The data sets available are listed in Table 1, where in some cases ‘Incidents’ have been filtered to exclude events with no classification, or events lasting more than a day such as debris not needing urgent removal. ‘Accidents’ are those positively identified as such. There is considerable variation between the data sets as to incident types recorded, their classification, and what data are recorded or easily inferred ✓ or excluded ☒.

Table 1: Incident datasets with breakdown of attributes recommended and recorded

SOURCE	West Midlands	CIS	Carillion	NILO(M'ways)	Ireland NRA	Coverage	H/England
AREA	Midlands_2002	M25_2005	M25+_2005	M1-M6_2005	Ireland 2014-5	TOTAL	2013-5
NUMBER OF MONTHS	7(4-10)	12(1-12)	10(5-11)	2(10-11)	15(1-3)	27	29
Number of Incidents	1018	942	5277(*)	128	8322	15687	103359(#)
Of which Accidents	621	238	1059	112	1355	3385	21374
RECORDED ATTRIBUTES							
Road	✓	✓	✓	✓	✓	100%	✓
Date	✓	✓	✓	✓	✓	100%	✓
Start Time	✓	✓	✓	✓	✓	100%	✓
Response Time	☒	☒	✓	☒	☒	20%	☒
Cause	✓	✓	✓	✓	✓	100%	✓
Duration	✓	✓	✓	✓	✓	100%	✓
Severity	☒	✓	✓	✓	✓	60%	☒
Lanes Open	☒	✓	☒	☒	☒	20%	☒
Lanes Closed	✓	☒	☒	✓	☒	40%	☒
Heavy Vehicle Involved	✓	✓	✓	✓	☒	80%	☒
Delay/Effect on Traffic	☒	✓	☒	✓	☒	40%	(#)
No. of Vehicles Involved	☒	✓	☒	✓	☒	40%	☒
Number of Persons/Injuries	☒	✓	☒	✓	☒	40%	☒
Numerical Delay Estimate	☒	☒	☒	☒	☒	0%	✓
Directions Affected	✓	✓	☒	✓	☒	60%	☒
Diversion Information	☒	✓	☒	✓	☒	40%	☒
Keywords or Text	✓	✓	✓	✓	✓	100%	(#)

(*) This dataset actually contains 17937 records, but some incidents are represented by several record entries each with Receive, Start/Arrive and Stop times. This extra information complicates analysis but enables response time to be estimated.
(#) The Highways England 2013-5 dataset is excluded from the Coverage summary because it is much larger than the others and would bias the results. Effect on traffic is indicated for many events by estimated delay incurred by individuals to the nearest 5 minutes. Some records omit fields, and in some cases informal comments have been added, resulting in inconsistent format which complicates analysis.

Phases of an incident recognised by Highways England, PRIMA and earlier tasks are:

- Normality
- Discovery
- Verification
- Initial response
- Scene management (could be sub-divided)
- Clearance (could be delayed, e.g. until off-peak)
- Recovery (whole carriageway is available but queues are still dispersing)
- (Restoration to) Normality

The attributes listed in Table 1 also constitute a **recommendation** as to the data that should be collected and offered in a **consistent format** suitable for analysis in a spreadsheet. Issues for analysis or simulation or modelling are lack of information about the numbers of lanes available and blocked during the incident and the timings of initial response, scene management and clearance phases, accepting that lane availability may vary between or within phases of the incident, and it may not always be possible to record information accurately.

3 Evidence from Highways England database of incidents 2013-15

3.1 Incident duration and delay

Highways England gives the total number of incidents on its network as 430,000 annually (Highways England 2015). The dataset provided by Highways England covers more events than others analysed combined (see supplementary report Taylor 2015) and is highly current, containing data in 29 monthly files from January 2013 to July 2015. The dataset contains over 100,000 events covering the equivalent of about 28 months (two files being incomplete), which Highways England advises account for more than half of events longer than 15 minutes in duration (events shorter than 15 minutes are unlikely to be of interest to PRIMA). The data have been provided in the form of 29 Excel spreadsheets with the following attributes, some of which are unfilled in a few records:

- Identifier
- First reason
- Date [time] event confirmed
- Date [time] event completed
- Duration in hours (high precision)
- Location (road number, direction and other descriptive text)
- Maximum delay in minutes (resolved to 5 minutes)
- [Further data in no consistent format]

These files have first been converted to text format then analysed by a specially written compiled program, which can read all the files together. This has been used to generate frequency distributions of incident duration and user delay disaggregated between motorway and non-motorway and several incident types, a matrix of the relationship between delay and duration, and an analysis of site-to-site variation. Events without duration given have been skipped, but those without user delay have been retained. All months have been aggregated because little difference is expected between the years, and seasonal variations are not considered relevant to this project because investments would be long-term. The statistics of events retained are given in Table 2, where the aggregate cause ‘blockage’ includes all specific and other causes apart from accident and congestion.

Table 2: Highways England Jan 2013 - Jul 2015 dataset statistics (~28 months)

Road type	Cause	Events (per month)	Mean duration (minutes)	Mean user delay (minutes)
Motorway	All (3046 km)[1]	1764	90	21
Non-motorway	All (3867 km)[1]	1927	93	21
Motorway	Accident	466	104	24
	Blockages(*)	554	123	18
	Congestion	744	85	22
Non-motorway	Accident	297	134	22
	Blockages	337	182	16
	Congestion	1293	77	22

(1) Source: DfT Table RDL0202

(*) ‘Blockages’ are all events other than accidents and congestion

Congestion events dominate at 55% of all and 42% of motorway events. Accidents represent 21% of all and 26% of motorway events. The number of 'blockages' is broadly comparable with the number of accidents, but as many of these are classified as 'other events' their relevance is uncertain. However, the frequency distributions of incident duration are broadly similar for motorways and non-motorways, as shown by Figure 1, and those for different types of motorway incident are also similar as shown by Figure 2. Note that the graphs have been truncated at 6 hours but a few events have much longer durations.

In Figure 1, there appears to be a plateau of frequency up to 1 hour duration, after which frequency declines systematically. When the frequency data are plotted logarithmically, the graphs are quite linear between 1 and 5 hours duration implying an exponential relationship. Over this range, incident frequencies are proportional to $exp(-0.0134t_{mins})$ on motorways with $R^2>0.98$ on motorways and $exp(-0.0105t_{mins})$ with $R^2>0.95$ on other roads. Above 5 hours duration, the rate of decline falls and levels out at around 10 hours, suggesting an underlying population of events with unpredictable durations. This pattern reflects that seen in other datasets. The one hour plateau, in particular, may reflect the spread of effective initial response times.

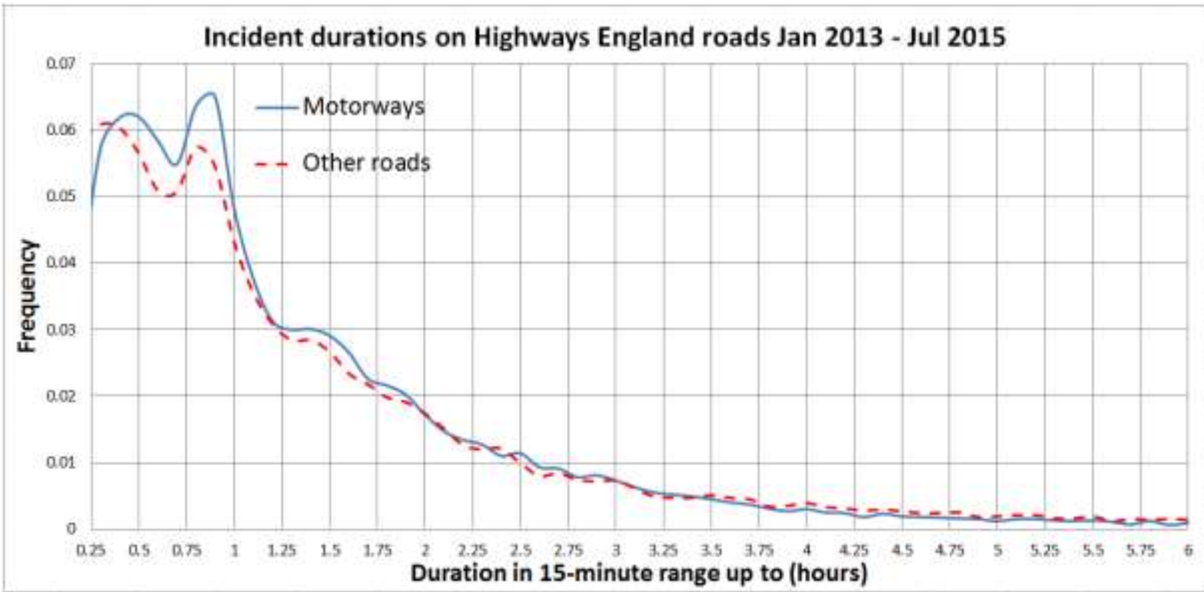

Figure 1: Frequency distribution of incident durations on Highways England roads

The form of the incident frequency distributions can be interpreted as follows:

- The 'plateau' in the first hour may reflect a range of response times depending on the location, nature and urgency of the incident. The peaks between 15 and 30 minutes and around 54 minutes exist in the data but could be an artefact of the way the data are recorded.
- While this part of the distribution actually gives the frequency of short incidents (53% of all incidents), including management and clearance, the sharp change to an exponential form is suggestive of a ceiling on response time.
- The exponential decline above 1 hour (42-43% of incidents) until around 5 hours indicates that the system is 'memoryless' in this range, that is the time remaining before an incident is cleared is independent of how long it has already been going on. During this period the incident duration is predictable only in statistical terms.

- The levelling off of the distribution after 5 hours total duration implies that for some incidents time to clearance is not even statistically predictable, although relatively few are represented (3.8% of motorway and 4.8% of other road incidents).

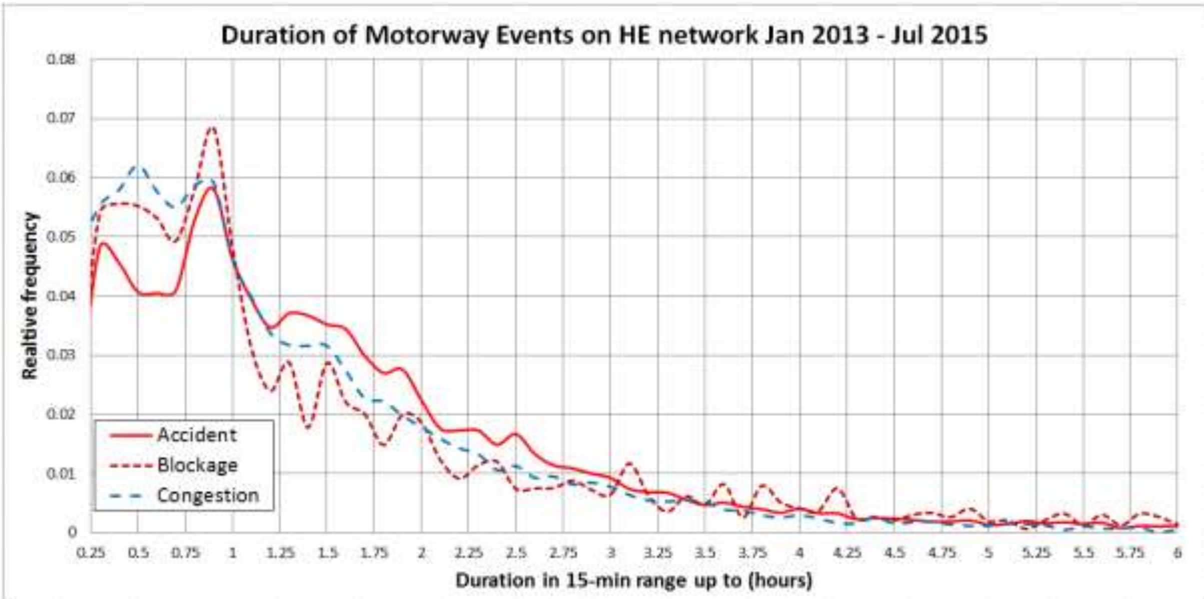

Figure 2: Frequency distribution of Highways England motorway event durations

Figure 3 shows the relationships between incident duration and maximum delay to individuals for the three incident categories, which are broadly similar. They indicate a linear rise in delay from 10 minutes for the shortest incidents, to around 40 minutes at 4 hours duration, after which it rises only slightly with increasing variability for longer duration events (it is not known whether remedial actions such as diversion may have affected the results).

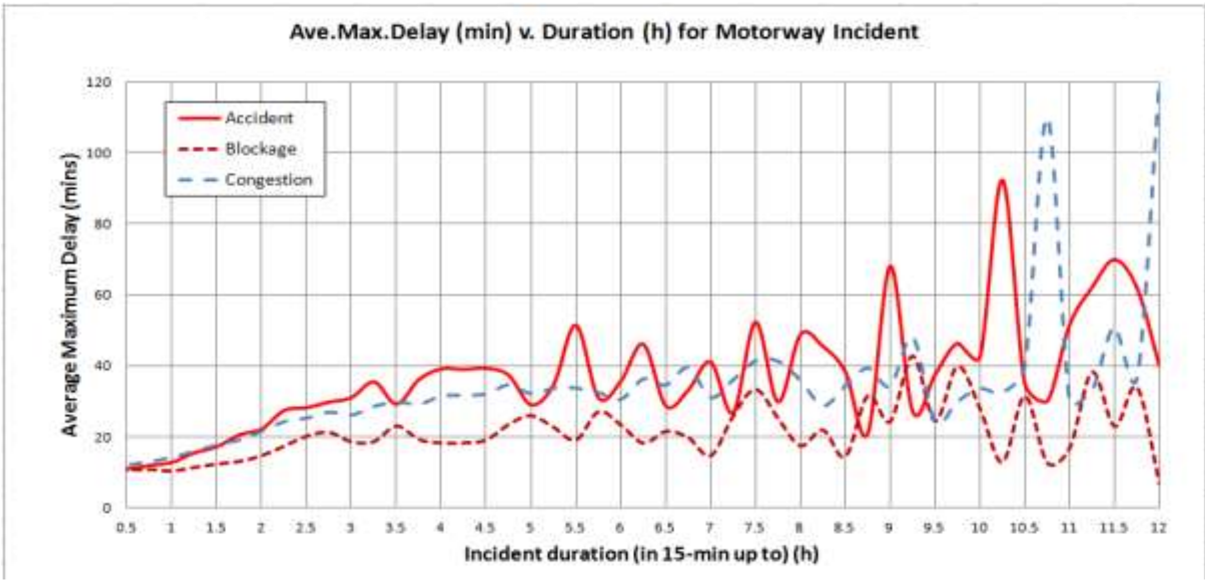

Figure 3: Relationship between individual delay and incident duration in HE data

Individual delay for accidents d_{ACC} is estimated by the following equation, where d_{ACC} and incident duration *T* are in minutes:

$$d_{Acc} = \min[10 + 0.1333(T - 15), 40] \quad (1)$$

For *blockages*, the slope is about half that for *accidents*, but with a similar minimum:

$$d_{Blk} = \min[10 + 0.0667(T - 15), 20] \quad (2)$$

Unfortunately, the Highways England database does not give an indication of the ambient traffic volume (in principle this could be estimated from road number and time of day, but project resources have not permitted this), nor of total vehicle-hours delay. Modelling results given later allow a relationship between incident duration and total delay to be estimated, but as this is based on special developed test scenarios there is no guarantee that this can be applied directly to the majority of incidents.

3.2 Incident rates and variation across sites

Incident rates are important for cost-benefit analysis. Based on Highways England's own figure of 430,000 incidents per annum (Highways England 2015), the annual incident rate per km of carriageway is between 31 and 62 (depending on whether dual or single carriageway). However, on the strength of the size of the Highways England 2013-15 dataset the definition of these incidents must be very wide. Considering only those in the dataset, the rate of non-*congestion* incidents is around 2.0 per km of carriageway per annum on motorways (6096 km) and 1.3 per km of carriageway per annum on other roads. The Highways England database represents covers *at least* half of incidents but not much more than half of all 'significant' incidents over the 28 effective months (personal communication by Highways England), so in the absence of complete data (promised at some future time) it may be reasonable factor up these figures by slightly less than 2.

When incidents at the same site are counted, where 'same' means that the text description of the location is identical, slight variations will result in incidents being ascribed to different sites. The pattern that emerges is one of great variation, and substantial differences between incident types. A 'site' can be a junction to junction section in one direction, but can also be within a junction or some other feature, so its 'length' is not possible to define without more detailed information. Although where there is great variability means are not very meaningful in themselves, the comparison of results in Table 3 quantifies the findings.

Table 3: Numbers of incidents per site (and ~ per km) p.a. in Highways England 2013-15 dataset

	Motorway			Other roads		
	Accident	Blockage	Congestion	Accident	Blockage	Congestion
Mean	1.90	2.00	5.87	1.30	1.36	4.26
Maximum	71	103	324	37	48	222

According to Table 3, the number of non-congestion incidents per site per annum is 3.9 on motorways and 2.66 on other roads. These per-site figures are almost exactly equal to the adjusted per-km figures arrived at earlier, so an estimate of 3.9 'significant' non-congestion incidents per kilometre of carriageway per annum may be representative.

Figure 4 shows incident rates on a logarithmic scale of number of sites within each incident count range. The form of relationship is broadly logarithmic but with a notably elevated rate of congestion events recurring at the same sites, as might be expected. It is also seen that accidents and blockages are more likely to recur at the same sites on motorways than on 'other' road types. These results are instructive but not directly relevant to what follows.

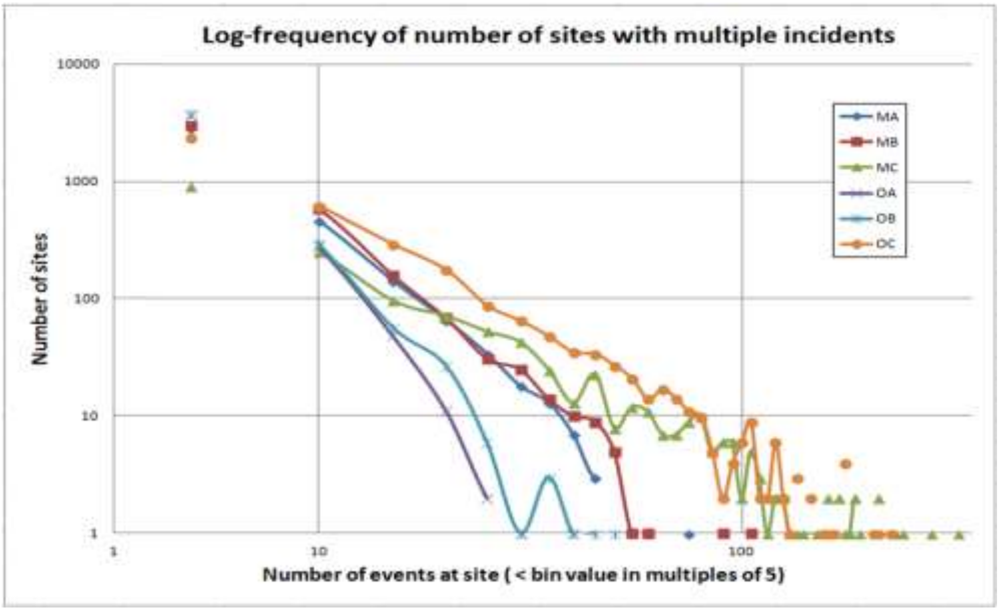

Figure 4: Incidents variation site-by-site (M=Motorway, O=Other, A=Accident, B=Blockage, C=Congestion)

3.3 Other data sets

The other smaller data sets listed in Table 1 lead to similar conclusions, except for the TRL 1995 and US data, which appear to give a similar and much steeper decline of incident frequency with duration. Why there should be this difference is unclear as both of these datasets show signs of a few randomly distributed long duration incidents, suggesting that selection is not the issue (Taylor 2015). Be that as it may, the Highways England data set is felt to be sufficiently comprehensive that it may be taken as representative of conditions on English major roads, which may be applicable to busy fairly densely monitored networks elsewhere.

4 Secondary accidents

4.1 Frequency of secondary accidents

PRIMA does not address incident prevention, so primary incident cost is not considered. However, the frequency and cost of secondary accidents are relevant because management can influence incident duration, and the risk of a secondary incident is related to duration of queuing. There is little information about the risk of secondary accidents, which are assumed primarily to take the form of rear-end collision with an unexpected queue. Pande and Abdel-Aty (2006) find that rear-end crashes can be placed into two mutually exclusive groups: first, those that occur under extended congestion and, second, those that occur under relatively free-flow conditions. It is the former that constitute secondary accidents where the congestion is itself caused by an incident, although the primary cause of congestion is likely to be relevant only to the extent it affects the speed and density of the queue and the motion of its tail-wave. The paper does not give actual risk values but claims that surveillance via loop detectors can not only distinguish between rear-end and other types of collision, but could identify the conditions leading to three-quarters of rear-end collisions 5-10 minutes before the collisions occurred, although with a significant false-alarm rate, which the authors point out would not be as detrimental as for incident detection algorithms.

Abdel-Aty et al (2012) discuss pro-active collision risk assessment where the risk is visibility-related, and give several references concerned with accident risk assessment more generally. While these sources fall into the area of accident prediction, which is outside the project's remit, they might contain information relevant to pro-active TIM. Lowe and Summersgill (1999, 2000, unpublished) reviewed queue-tail accidents on the most congested western section of the 4-lane M25 motorway between Junctions 10 and 16 over a total three-year period, as part of assessment of the benefits of MIDAS variable mandatory speed limits (VMSL). While VMSL was not expected to reduce the number of queue-tail accidents associated with 'regular' queues, it was found to reduce the number associated with unexpected queues, including secondary accidents. The sample of accidents in the data set was relatively small, 10 damage-only and 7 personal injury accidents per carriageway per year, of which around 3 and 2 respectively were associated with unexpected queues. MIDAS was estimated to give a statistically significant overall benefit of 57% composed of a significant 72% reduction in unexpected queue-tail accidents, and a 46% reduction in 'regular' queue-tail accidents, which while not significant was considered to be real.

On the 4-lane M25 controlled section, the average rate of queue-tail accidents was estimated to be one damage-only accident per 72 hours of queuing and one injury accident per 144 hours of queuing. VMSL was in operation for slightly less than half the study period, but three-quarters of queue-tail accidents occurred while it was not in operation. This suggests that accident rates on the motorway when signals are not operating should be increased by a factor of around 1.5. However, driving style on 4-lane roads, which in the UK have to be controlled, tends to be different than on 3-lane roads, with improved lane discipline and less speed differential between lanes, so this factor may not apply to conventional 3-lane motorways. Motorway speed limits and signals are considered to reduce incidents by discouraging speeding and lane-changing, and improvements in vehicle technology are likely to further reduce read-end shunts.

On a more conventional motorway, the 3-lane M1, with only advisory speed limits, the risk of accidents both at the queue-tail and within the queue was estimated to be one damage-only accident per 17 hours of queuing and one injury accident per 25 hours of queuing, signals delivering an 18% overall reduction in injury accidents. These much higher rates than on the

M25, with a relatively higher rate of injury accidents, may reflect lower volumes and higher speeds as well as greater differentials between lanes. As accidents within a queue are also relevant to pro-active TIM, the M1 rates are probably the ones to adopt. However, it is clear that traffic management and queue warning can give a significant benefit.

Summersgill (1985) looked at accidents associated with road works and found a much larger average ratio of 3.7 between damage-only and injury accidents, possibly because of reduced speeds. He estimated that in the vicinity of road works the national average injury accident rate is increased by 50% from 0.15 to 0.22 per million vehicle-km. This is likely to reflect the complexity of manoeuvring and general slowing of traffic, but the extent of primary and secondary queuing was probably moderate, and it is not clear how rates in terms of vehicle-km could be used.

As most of the interest of PRIMA is focused on motorways, the approach here is to adopt conservatively a figure of one secondary accident per 30 hours of queuing (see also CEDR 2011), and assume also conservatively that secondary accidents have the same pattern of severity as the primary incident. While in practice they might involve more minor shunts than primary incidents that occur at high speeds, severe accidents can result from running into a stationary queue produced by an earlier incident.

4.2 Cost of secondary accidents

At one point it was considered whether TRL's INCA model for costing incidents could be used in PRIMA. INCA recognises 12 types of incident and provides for specifying their rate, duration and number of lanes blocked, essential for estimating delay and cost in both 'do-minimum' and 'do-something' scenarios. However, the program is designed for long-term assessment of incident management over the whole network rather than the more targeted approach of pro-active TIM with its focus on techniques and technologies to reduce incident duration. For this reason it has been decided to assume a 'generic' secondary incident risk with an associated cost and a proportional effect on delay.

Apart from delay, which is of course related to incident severity but also depends on other factors, there is the cost of material damage, injury and even death. Dealing with injury and incident investigation are specialist tasks and the severest cases are rare, and it is not clear where pro-active TIM would impact these. On the other hand, by reducing incident duration, pro-active TIM could have a direct impact on the risk of secondary accidents and the associated costs. Relative rates and absolute costs of injury accidents on motorways and other roads are available as given in Table 4, and to first approximation it can be assumed that the values relevant to PRIMA match them.

Table 4: Injury accident statistics example (DfT 2012)

Accident severity	GB[1] motorway accident count 2012	GB average cost per accident 2012	Total cost (£M)
Damage only	*85,375*[2]	£2,048	*£544.5*[1]
Slight Injury	4,989	£23,336	£257.7
Serious Injury	546	£219,043	£251.7
Death	80	£1,917,766	£337.5

1: GB=Great Britain, the geographical main island including England, Wales and Scotland 2: estimated

The number of damage-only accidents is not given in the source but has been inferred from the average costs, although this may be an overestimate for motorways. The total costs of the different severities are otherwise remarkably similar. Accident counts and costs follow a power law; that is, there is a descending linear relationship between the logarithm of frequency and the logarithm of impact (cost), with a slope close to unity. A characteristic feature of a power law with a finite range such as this is that the mean is close to the minimum.

Based on Table 4, the average damage and injury cost of a motorway accident can be estimated as around £15,300 or €20,600. More serious accidents tend to get more attention from a road safety viewpoint, but from an economic viewpoint all accidents are important, as the rightmost column in the table indicates.

It is estimated that 29% of incidents lead to 'rubbernecking' queues on the opposite carriageway, with consequent additional delay and risk, but it does not appear possible to quantify this as the persistence of such queuing is unknown.

5 Summary of modelling and results

Four incident scenarios have been developed and two or three management techniques explored, in addition to a 'do minimum' baseline case. These are summarised in Table 5. Details of the scenarios are given in Olstam et al (2015).

Table 5: Summary of modelled Incident Scenarios and Techniques simulated

Scenario	Baseline response	>>>>>	Pro-Active Technique	
S1: Collision	1.1 Close all lanes	1.2 Incident screen	1.3 Close some lanes	1.4 Tow in off-peak*
S2: Bad weather	2.1 Close all lanes	2.2 Contraflow	2.3 VMS and speed limit*	
S3: LGV breakdown	3.1 Close extra lane	3.2 Repair on-site*	3.3 Tow in off-peak*	
S4: Obstruction	4.1 Close all lanes	4.2 Contraflow	4.3 Close blocked lane	

* Includes a 'respite' period between initial response or management and final clearance in the off-peak – see below

For each combination of scenario and technique, the following may be varied:

- Demand peak amplitude - Light, Medium or Heavy
- Demand peak length - Short or Long
- Technology level in early phases (Sections 5.2-5.3) – High, Medium or Low
- Speed limit applied

In total, 177 cases are identified. Scenario/Technique combinations marked with * in Table 5, namely 1.4, 2.3, 3.2 and 3.3, all involve a 'respite' period or delay between scene management and final clearance, which is assumed to take place at the beginning of the off-peak. Figure 5 and Figure 6 show the demand profiles used in modelling, which represent AM peak of various weight and duration.

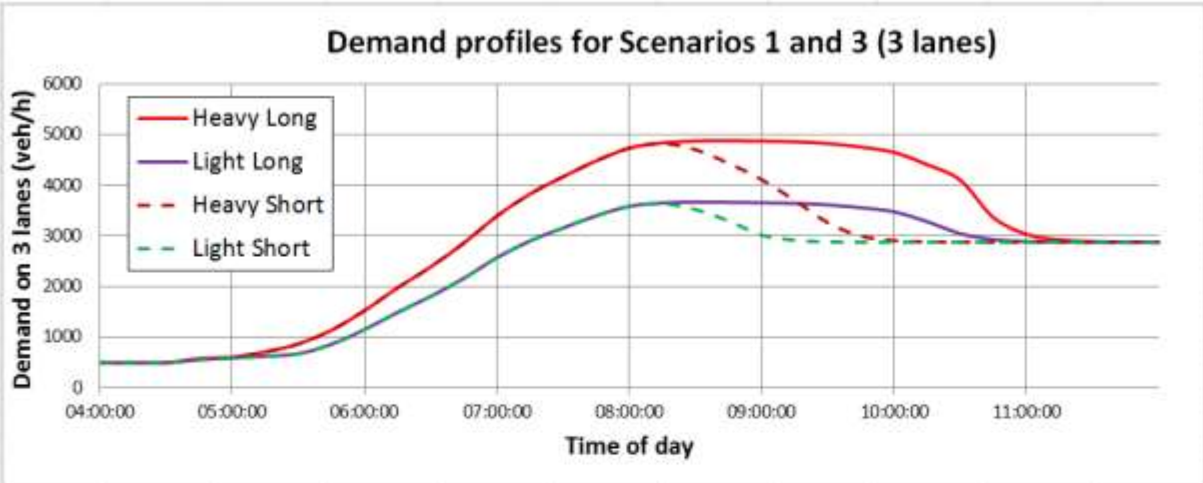

Figure 5: Demand profiles used for modelling 3-lane Scenarios 1 and 3

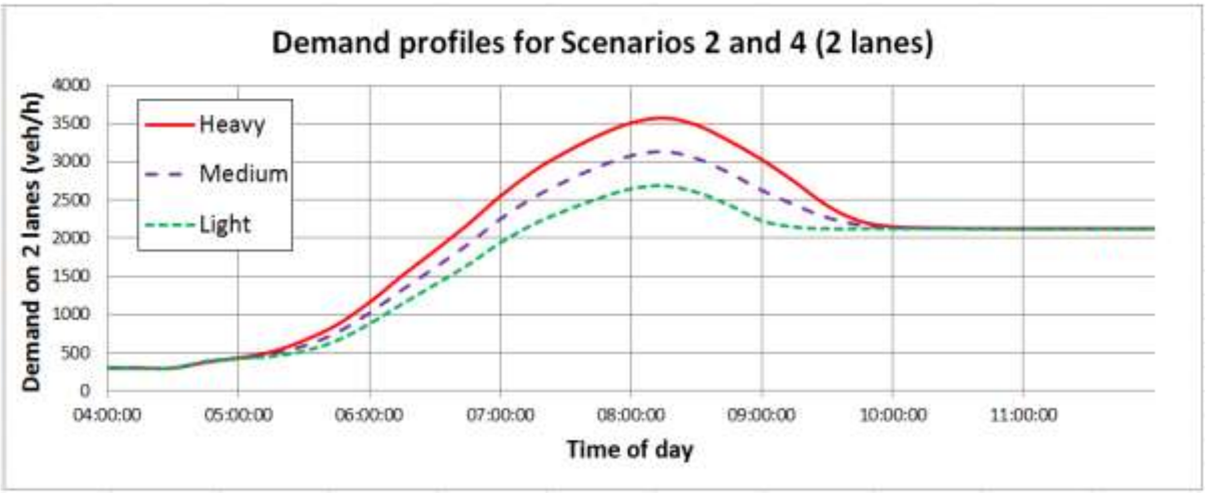

Figure 6: Demand profiles used for modelling 2-lane scenarios 2 and 4

The distribution of modelled incident durations is given in Figure 7, which includes the time required to disperse queues and restore normal flow, but excludes any time when traffic is assumed to be free-flowing in a 'respite' period. The distribution is quite different from Figure 2. This is because the cases modelled are intended to explore the effect of various combinations of technologies and management techniques under different conditions. Consequently, they do not reflect the pattern seen in the Highways England dataset.

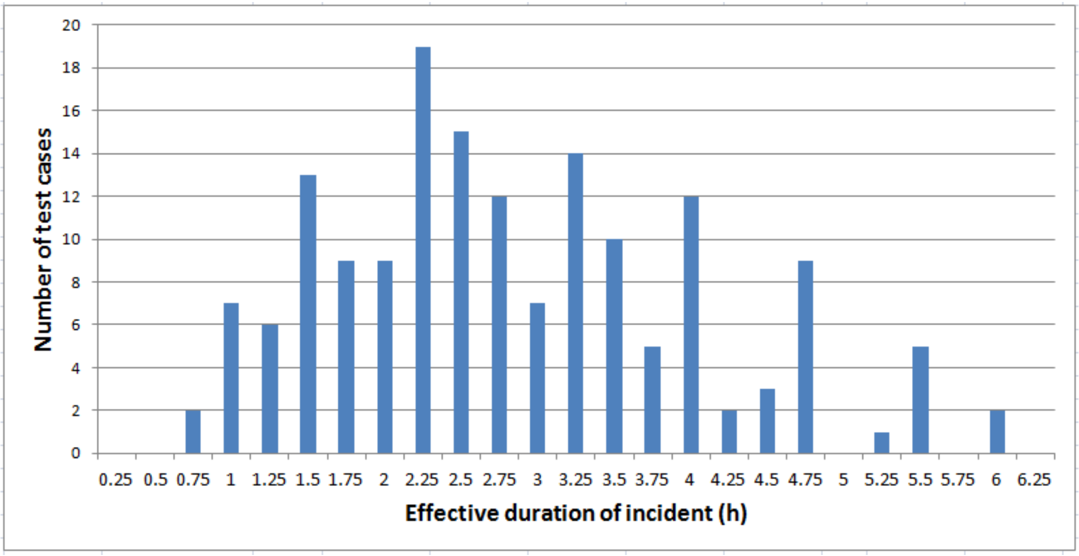

Figure 7: Distribution of total duration of modelled incident scenarios

The total of delay and secondary accident costs in any case is the maximum that could *potentially* be saved by pro-active management, although in practice only a partial saving could be achieved. This is referred to here as the 'value' of the example, because 'cost' has to refer to the cost of technology or interventions, The formula used to estimate the undiscounted (see later) total value of a case is given in equation (3), the variables being defined in Table 6.

$$E = a\left(cD(1+p)+Sp\right) \quad (3)$$

The positive benefit of a given technique is then given by:

$$B = \max\left(E_{baseline} - E_{technique}, 0\right) \tag{4}$$

Table 6: Variables and assumed values in value calculation

Variable	Description	Value or units
E	total value (cost to users) of delay and secondary accidents	(€)
a	annual incident rate per kilometre of carriageway	3.9
c	average value of delay time	€10/h
D	veh-h total delay	(veh-h)
S	average cost of a secondary accident	€20,600
T	duration of queuing	(h)
H	average hours of queuing per secondary accident	30 h
p	probability of a secondary accident = T / H	

Figure 8 plots the estimated benefits per km per annum of all 126 Scenario and Technique combinations relative to their respective baseline cases in sorted order. Assuming the mix of scenarios is representative, 61 (48.4%) of cases confer benefit compared to baselines. However, the plot indicates that techniques need to be applied selectively because some measures that increase delays could result in substantial disbenefits.

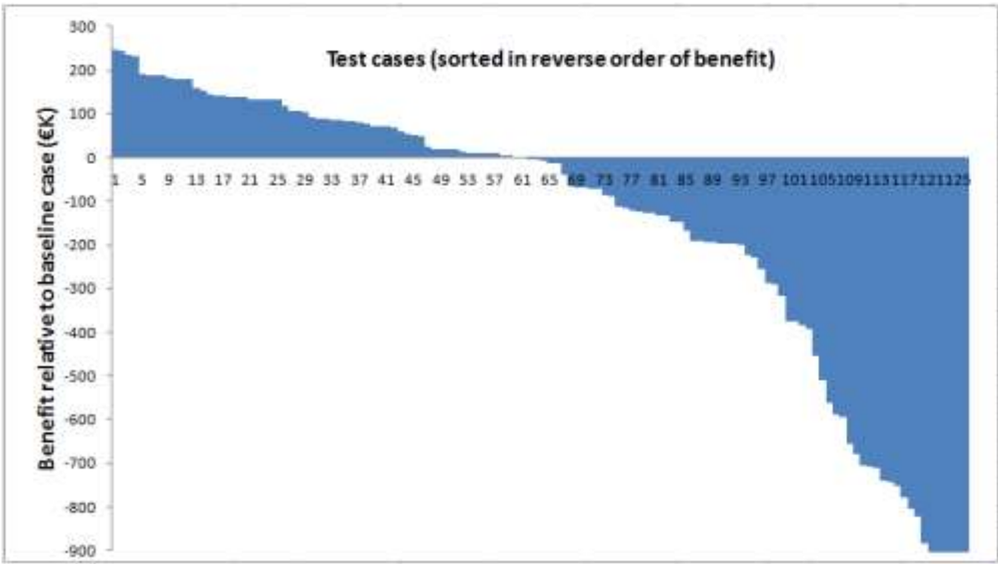

Figure 8: Modelled annual benefits per km for Scenario/Technique cases

The average pattern of results is not dissimilar to that from the Highways England data. Although the delay to each individual affected, Figure 9 does not appear to level off with duration, its average magnitude of 40 minutes at duration 4.5 hours is comparable. Figure 10 plots total vehicle-hours delay, showing a square-law increase with duration as expected from queuing theory. This includes delay to the opposite carriageway, which can arise from ‘rubbernecking’ and can be considerable where contraflow is used. Crosses in Figure 9 and Figure 10 represent cases where clearance is delayed until off-peak.

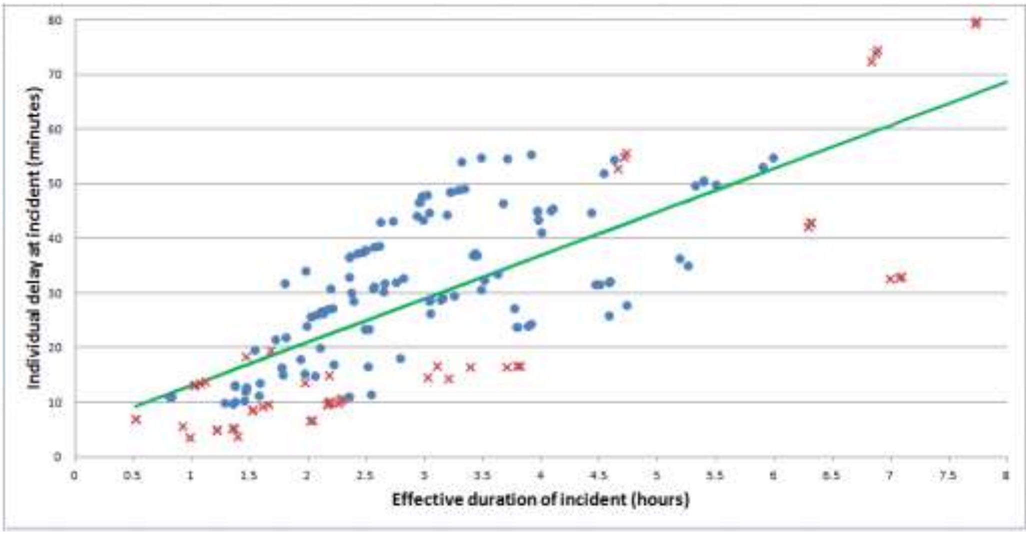

Figure 9: Relationship between individual delay and incident duration in modelled cases

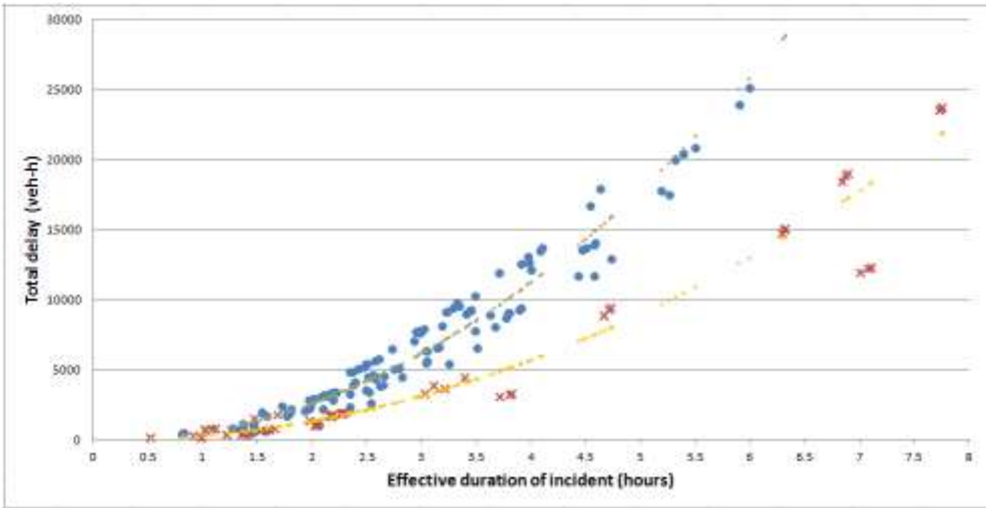

Figure 10: Relationship between total delay and incident duration in modelled cases, with square-law trends

Incident duration excludes time when traffic is free-flowing during ‘respite’ periods where clearance is delayed until off-peak. Where this applies during the whole period, delay is below average. However, in some cases reduced capacity in the period results in some delay, and an extended total duration is assessed. The modelled incident scenarios are designed to be on the severe side, and no diversion is enabled. Their average duration, *excluding* cases with delayed clearance, is 176 minutes compared to 90 minutes for Highways England motorway incidents from Table 2. Based on Figure 10, this would imply that modelled total delay should be discounted by a factor around 4. However, average individual delay in modelled cases is 30 minutes compared to 21 minutes in the HE dataset, a factor around 1.4, much less than the factor of almost 2 suggested by Figure 9. Therefore we assume conservatively that in translating from the scenarios to more typical cases modelled values should be discounted by the factor 3.

6 Intervention costs and benefits

6.1 Equipment and system costs obtained from CEDR Task 12

CEDR Task 12 on Traffic Management (TM) studied a number of TM measures, including Traffic Incident Management (TIM) which was dealt with in depth by Task 13. The final report (CEDR 2012) gives costs for a number of interventions and facilities in various European countries. Definitions and costs vary between countries, sometimes minima and maxima being given rather than single values, and in some cases costs are totals for a fixed period of time, e.g. 15 years and it is not possible to separate initial and ongoing costs. In some cases the timescale over which costs are incurred is unclear or described only as 'ongoing'. This makes it difficult to provide precise figures for CBA. Table 7 interprets all the data into a consistent structure. Some items are unlikely to be relevant to pro-active TIM, but have been included for completeness and to give a sense of the range and scale of possible costs.

Table 7: Costs of equipment and systems interpreted from CEDR Task 12 and COBRA

Equipment or facility	Capital €K	Annual €K	€K (years)	Per	Country
Traffic information	2790	160		city/region	USA
Travel planning	700	40		city/region	USA
Travel planning			140-169 (15)	city/region	NL
Travel planning	300	110		city/region	FI
Dynamic diversion			137-280 (15)	km	NL
Dynamic lane management			418-550 (15)	km	NL
Incident management	279-434	30		km	NL
Incident warning			279-312 (15)	km	NL
Interchange lane management			307-441 (15)	km	NL
Interchange lane management system	1300			km	D
Signal gantries			201-340 (15)	km	NL
Signal gantries	295	15		km	UK
Signs (LGV overtaking ban)	8.8			km	NL
Traffic management and loops	174			km	NL
Traffic information			115-121 (15)	km	NL
Use of hard shoulder			477-576 (15)	km	NL
Wireless beacons (3.33 units/km)	53.3	1.67	(10)	km	COBRA
CCTV camera	4.4	0.17		unit	UK
Incident Control Centre	378		773 (#)	unit	UK
Incident screen (75m)	20.3			unit	UK
Incident Support Unit	28.4		232.2 (#)	unit	UK
Lane control gantry	130-170			unit	NL
Movable guard rail	200-300			unit	NL
Network subsystem	170	57		unit	UK
Police camera		24		unit	UK
Police/Traffic Officer		43.7		unit	UK
Ramp metering	200			unit	F
Speed camera	122	0.901		unit	UK
Staff		28.7-31		unit	UK
Control centre/office for wireless alerts	200	20		unit	COBRA
VMS sign	409	1		unit	COBRA
Wireless beacon	16	0.5	(10)	unit	COBRA
Standby recovery vehicle	*19.15-39.15*			*€/hour*	UK

Assumed to be annualised costs

6.2 Improved detection/response times from new technology

Table 8 presents estimated ranges of possible detection and response times based on consideration of possible scenarios (for details of the estimation see Olstam *et al* (2015). For completeness these include the time to detect and verify congestion, which will be longer than for an incident. Table 9 estimates the ranges into which detection times fall using various technologies, where there are slight differences between the Scenarios. Initial Response times are unfilled as these do not depend on the technologies but on the nature and deployment of responder facilities. Any effect on initial response is assessed as part of verification. No detection or verification time is assessed 'High' as this is considered to apply only under adverse circumstances. The table therefore is intended to represent typical circumstances while allowing for the spread of performance represented by Table 8.

- **Technology 1:** Citizen report is the most basic and can be done e.g. via phone call or dedicated smartphone apps.
- **Technology 2:** represents a pro-active presence such as Police or Traffic Officers on patrol, whose professional experience and communications network help them to detect a problem, but there can be some delay in reaching an incident scene and verifying the situation.
- **Technologies 3-5**: represent various low resolution traffic measurements, all of which are expected to result in 'high' detection times according to the definition in Table 8.
- **Technology 6:** Vehicle-based trajectory data, comparable to GPS/GNSS reports, could reduce detection and verification times but are likely to be subject to some uncertainty or error, and delay in compilation.
- **Technology 7:** Video monitoring is often available in busier parts of networks monitored by a Traffic Management Centre, but may depend on detection by a human operator.
- **Technology 8:** Vehicle-based information assumes an advanced electronic data 'V2I' (Vehicle-to-Infrastructure) reporting system that with central collation can identify significant changes in traffic flow and pinpoint them to some level of accuracy with GPS/GNSS.
- **Technology 9:** Incident detection based on image processing is potentially the quickest to react and is precisely located, but whether a system is in place will depend on whether the traffic volume and risk of incidents justifies the cost, and the false alarm rate is acceptable.

The impact of technology in practice depends on what is chosen as the base level technology. The nine technologies are grouped broadly into 'low tech' methods 1-4, 'medium tech' 5-7, and 'high tech' 8 and 9. In order to assess benefits, timings from Table 9 are applied and these can differ between the scenario types. In principle, timings should be weighted according to the likelihood of the different scenarios, but in view of the approximate nature of the exercise, a simple average is used. As technologies move from low to high they are likely to become more dependent on global services: regional TMC, GPS/GNSS, V2I equipped vehicles and processing or control centres, eCall PSAPs etc. While the total roll-out costs of these systems may be high, the cost to NRAs of exploiting data from third-party providers could be quite low, and it is conceivable that insurers would see value in NRAs' investments.

Table 8: Definition of ranges of detection and response times

TIM Phase	Symbol	Low Time	Medium Time	High Time	Very High Time
Detection Time (Accident/Breakdown) (Scenario 1,3)	t_D	< 10 sec	10 sec < t < 1 min	1 min < t < 5 min	>= 5 min
Detection Time (Congestion) (Scenario 2,4)	t_D	< 1 min	1 min < t < 5 min	5 min < t < 15 min	>= 15 min
Verification Time	t_V	< 1 min	1 min < t < 3 min	3 min < t < 10 min	>= 10 min
Initial Response Time	t_{IR}	< 5 min	5 min < t < 10 min	10 min < t < 30 min	>= 30 min
Overlapping of TIM Phases:					
Detection and Verification	$t_{D\&V}$	< 5 min	5 min < t < 10 min	10 min < t < 15 min	>= 15 min
Verification and Initial Response	$t_{V\&IR}$	< 5 min	5 min < t < 10 min	10 min < t < 30 min	>= 30 min

Table 9: Detection and response time ranges for various technologies

		Scenario 1			Scenario 2			Scenario 3			Scenario 4		
Nr	**Subcategory**	Det.	Ver.	I.R.	Det.	Ver.	I.R.	Det.	Ver.	I.R.	Det.	Ver.	I.R.
1	Citizen Report (partial and draft Information)	<- $t_{D\&V}$ ->			<- $t_{D\&V}$ ->			<- $t_{D\&V}$ ->			<- $t_{D\&V}$ ->		
2	Professional Report (full and reliable Information)		<- $t_{V\&IR}$ ->		NA	<- $t_{V\&IR}$ ->		NA	<- $t_{V\&IR}$ ->		NA	<- $t_{V\&IR}$ ->	
3	Cross-sectional Traffic Data Measurements		NA			NA			NA			NA	
4	Sectional Traffic Data Measurements – overall		NA			NA			NA			NA	
5	Sectional Traffic Data Measurements –single veh.		NA			NA			NA			NA	
6	Vehicle-based (Trajectory) Data Measurements												
7	Video Monitoring (visual , CCTV)				NA			NA			NA		
8	Vehicle-based Information Report (eCall)	<- $t_{D\&V}$ ->			NA	NA		NA	NA		NA	NA	
9	Video Incident Detection System (VIDS)												

Abbreviations: NA… not applicable; I.R. … Initial Response

6.3 Improvement in initial detection and response times

Table 8 above classifies Initial Response times on a scale independent of technologies and scenarios as they depend on different services (fire, ambulance, TMC operators etc.) and how these are deployed. The net effect of improvements in detection and verification times through technology is assessed in Table 10, and savings corresponding to step changes in response time are given in Table 11.

Table 10: Estimated Detection/Verification time saving from technology step-change

Technology step-change	Time Saving (minutes) Minimum	Average	Maximum
Low→Medium	2.8	6.0	9.2
Medium→High	0.5	1.4	2.4
Low→High	3.3	7.4	11.6

Table 11: Estimated Initial Response time savings based on Table 8 (minutes)

Response time step-change	Time Saving (minutes) Minimum	Average	Maximum
High→Medium	5.0	12.5	20.0
Medium→Low	2.5	3.8	5.0
High→Low	7.5	16.3	25.0

Improving Initial Response time may require deploying additional services, for example having more patrol officers, or more depots for Incident Support Units (ISU). An ISU is a special vehicle operated by NRA staff or accredited contractors with equipment needed to set up scene protection, and perform some clearance and recovery, so its primary impact will be on Scene Management with some impact on Initial Response. We might consider, for example, that a given facility, such as an ISU, has only limited capacity to deal with incidents. If the maximum number of serious incidents that can be planned for it to attend in one day is n then the minimum number N of facilities for dealing with incidents that occur at an annual rate a per km over a network length L is:

$$N_0 = \frac{aL}{365n} \tag{5}$$

If a=3 and n=2 this implies one unit for every 243 km of carriageway. However, assuming an average travel speed V in response of 80 km/h, and a start-up time R_0 (which we neglect for the sake of simplicity), the average response time given by:

$$R = R_0 + \frac{L}{4NV} \tag{6}$$

would imply an average response time of around 45 minutes. Although this is within the 'plateau' of incident durations up to 60 minutes found earlier, it is on the long side considering the '10 minutes to save life platinum rule'. Ideally facilities would be located optimally according to the varying incident rates in the network, though this would be subject to practical constraints. If availability of locations means facilities are placed randomly with a given *average* spacing, then actual spacing must be *halved*, so the factor 4 in (6) is replaced by 2 in (7)[1]. Conversely, assuming that there is already the minimum provision, to achieve a given average response time *R*, the number of new facilities required is:

$$N_{+} = \frac{L}{2V\left(R - R_{0}\right)} - N_{0} \qquad (7)$$

Using the same parameters, Table 12 estimates the additional provision of services needed to achieve average response times in terms of average spacing between 'depots' in km. Spacing is *halved* to allow for random variation in available depot location while ensuring response time at the assumed speed. The annual cost of the additional services can be estimated from Table 7. For example the additional cost per km of providing ISUs can be estimated by dividing the annual unit cost estimated at €232.2K by the spacing figure in Table 12.

Table 12: Estimated provision to achieve average Initial Response times in Table 8

	Initial Response average in time band			
	Low	**Medium**	**High**	**Very High**
Average response time (min)	<5	7.5	20	>60
Average depot spacing (km)	11	24	95	N/A

6.4 Benefits of new technology and improved response

The effect of novel technology alone is modelled by changing only the assumed duration of Detection, Verification and Initial Response phases based on the ranges in Table 8 earlier, 'other things being equal'. The effect on the total value of each case is generally positive, as shown in Figure 11.

The average benefits per km per annum, relative to a 'Low-tech' baseline, are €90.9K and €67.3K for 'High-tech' and 'Medium-tech' respectively. However, many roads and especially motorways are equipped at level 3 or 4 and 7 according to Table 9, and Smart Motorways incorporate a queue protection and alert system, so a more conservative figure may be the €23.6K difference between Medium-tech and High-tech. Applying the discount factor from Section 5 this falls to €7.9K per km per annum. Assuming this applies to all 6,092 carriageway-km of motorway on the HE network, potential annual benefit is €48.1M. Saving on non-motorway roads is difficult to estimate partly because of the lower incident rate (Table 3) and partly because of lower volumes, but is probably much less than the above figure, against which there is no reason to expect the cost of deployment to be less.

[1] This is analogous to the average waiting time for buses that arrive according to a Poisson random process, which is equal to their average timetabled interval, not half of this as one might expect.

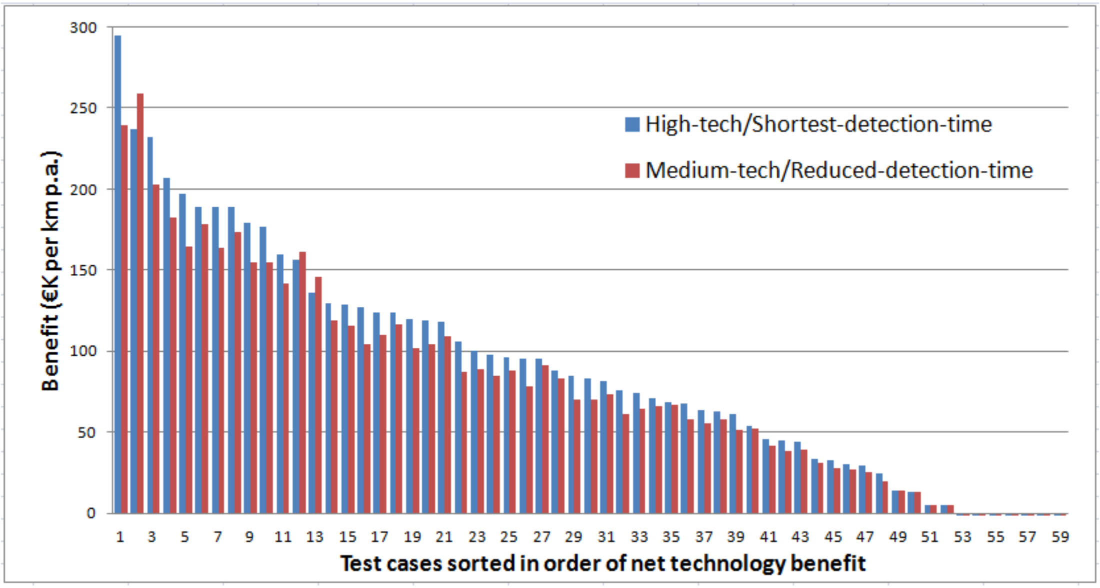

Figure 11: Benefits of Novel Technology in modelling tests relative to 'low-tech'[2]

eCall

While new technology may reduce Initial Response time by locating an incident more accurately, the gain could be marginal where there is already a high level of instrumentation, as on the HE network. If eCall achieves only the average medium-to-high saving of 1.4 minutes from Table 10 only, then discounted saving per incident falls to €209, corresponding to €818 per km p.a. By comparison, the cost of deploying eCall over the whole UK network has been estimated at up to €360M per annum for full regulatory deployment (DfT 2014). Assuming this is spread over 245,000 miles of roads, it amounts to around €1,470 per km p.a, suggesting a BCR of 0.56 before including the cost to the NRA of obtaining and processing eCall alerts (although this could be relatively insignificant – see below). This is similar to the UK DfT's estimate of 0.52. Therefore, given the uncertainty surrounding these figures, if new technology is deployed on a background of existing technology, overall benefits could be marginal. However, by the argument at the end of Section 5.2 earlier the costs to NRAs of receiving eCall alerts should also be marginal, so the BCR of their investment should be greater, provided the response is appropriate.

Wireless data and traffic information

The COBRA project has estimated costs and benefits for a number of scenarios for deploying cellular or beacon-based wireless Vehicle-to-Infrastructure data collection, processing and information or hazard warning across Highways England and Rijkswaterstaat motorway networks, one objective being to replace Variable Message Signs with their attendant costs. The calculation includes direct benefits including primary accident reductions, which are not comparable to more marginal incident management costs and benefits. Some item costs are given in Table 7 earlier. According to the COBRA scenarios, setup or renewal costs are incurred at the start and after every 10 years, so if these are annualised over 10 years, the cost of equipping a 'back office' and developing an application would amount to €80K p.a. However, the cost of installing roadside wireless beacons on the whole motorway network would be orders of magnitude greater at around €42.7M per

[2] There are three 'anomalous' results where 'Medium-tech' appears to improve upon 'High-tech'. These occur because demand is particularly sensitive to timing in these cases, but for the sake of consistency they are left 'as found'.

annum, although they would be expected to be deployed over many years up to 2030 and then with coverage not exceeding 30%. Provision of information through personal cellular phones appears to avoid the need for roadside equipment but incurs a similar cost to users for in-vehicle equipment, which while modest at €100-250 per unit and €30 annual subscription, has to be multiplied by an estimated 32M vehicles at assumed 65% maximum penetration by 2030. With these provisos, the cost of beacon deployment is similar to the annual benefit calculated for improved detection and response time, giving a BCR of 1.13. COBRA itself estimates maximum BCRs ranging from 0.8 for 30% deployment of a beacon-based V2I system, to 4.0 for local cellular phone based event warnings.

6.5 Benefits of pro-active scene management

For the Techniques (interventions) that deliver benefit relative to the baseline 'Close all lanes', the statistics are given in Table 13, ordered by average benefit. Of the total of 177 test cases, 126 represent interventions (non-baseline) and of these 61 (48.4%) deliver a benefit.

Table 13: Benefits of Techniques and cases where they are applicable

Pro-Active Technique	% of cases	Ave. benefit €K/km p.a.	Cases in which model suggests the Technique may give benefit
Part clear and tow in o/p	18.6	126.1	Collision or LGV repair on site
Partial closure	6.8	91.8	Collision in light peak
Close blocked lane only	3.4	67.9	Obstruction, e.g. due to debris
Contraflow	5.7	46.6	Weather/obstruction in light peak
Repair LGV (tow in o/p)	5.1	10.0	Light peak only
VMS+speed limit (tow o/p)	-	-	(model insufficiently sensitive)
Incident screen	-	-	(model insufficiently sensitive)

If the mix of scenarios is considered representative and pro-active measures are used appropriately, i.e. the discounted modelled average benefit of having techniques available is €33.5K per km of carriageway per annum where intervention is appropriate and benefit is achieved, or €16.2K spread over all non-baseline cases assuming intervention does not increase delay. Nevertheless, this would amount to the substantial sum of €98.8M over the whole English motorway network of 3046 km of dual-carriageway or 6092 carriageway-km.

Quick Clearance, referred to earlier in this report, is essentially equivalent to the Tow in Off-Peak technique, but would require a legal framework and liability cover. The technique has been modelled conservatively in the sense that although all running lanes have been assumed open, a reduction in their effective capacity has been assumed in the respite period between initial Scene Management and final Clearance, ranging from zero under the most favourable conditions to 57% reduction on a 2-lane road with a 50 km/h speed limit.

Closing blocked or selected lanes only rather than all lanes is likely to be already common practice at various stages of incident management, but could be optimised provided safety is not compromised. Because risks to road users and victims are likely to be sensitive to precise circumstances, this may require more detailed analysis or simulation.

Incident Support Units (ISU)

If an ISU is able to achieve the medium response time 7.5 minutes in Table 12, or an equivalent reduction in scene management time, bearing in mind that they will be deployed mostly on the motorway network, implying deployment of one ISU per 24km of motorway, or 48 km of carriageway assuming both sides are accessible to it, the potential benefit is €4,238 per km of carriageway per annum compared with an outlay of €4,838 per km p.a, giving a BCR of around 0.88. Again, this would depend on the current level of provision, and BCR could be higher if facilities are targeted at higher-risk sites.

The benefit of **Incident Screens** is not measurable in the modelled cases, but this can be ascribed to the modelling being insufficiently sensitive. Also, while rubbernecking on the opposite carriageway in the absence of incident screens is modelled by a moderate capacity reduction on the running lanes, the potential for flow breakdown leading to queuing is not represented because of its probabilistic nature.

The modelling suggests that in collisions and incidents which immobilise and LGV, the objective should be to restore carriageway capacity as soon as possible, and quick clearance may achieve this even if full capacity is not restored. Delayed clearance may be counter-productive if significant delay to traffic occurs during the ‘wait time’, for example because of heavy demand or because a speed limit has to be imposed.

Apart from deployment of Incident Screens and Incident Support Units whose costs are known, the costs of pro-active tactical measures for Scene Management are hard to assess. Closing or opening lanes should not involve any extra cost, while quick clearance will require sufficient deployment of specialised equipment at depots sufficiently closely spaced to enable rapid access to the scene. However, Table 13 suggests that the benefits of successful application of pro-active measures could exceed substantially extra equipment costs.

6.6 Summary of benefit-cost

The results from above are summarised in Table 14.

Table 14: Benefit-Cost Ratios of Technologies and Techniques

Intervention	Method	Cost (€/km/year)	Benefit (€/km/year)	BCR
Detection/Response	eCall	1,470	818	0.56
Detection/Response	Intensive V2I system	7,000	7,900	1.13
Scene protection	ISU or equivalent	4,838[3]	4,238	0.88
Quick clearance	ISU or recovery vehicle	4,838	16,200	3.35

There is considerable uncertainty underlying these figures, and even if a more detailed analysis like that of COBRA were applied it would still be necessary to account for the large variability in incidents and impact of interventions in individual cases.

[3] This figure is based on the assumption that one vehicle is deployed on average for every 24 km of bi-directional motorway and is able to attend up to 2 incidents daily.

7 Risk assessment

7.1 Identifying risks and their possible impacts

Risks identified in project team workshop exercises are tabulated below in Table 15, assessed by estimated likelihood and impact on a coarse scale of 'low-medium-high', with overall evaluation – broadly the product of likelihood and impact – being indicated by colour coding.

Table 15: General qualitative risk assessment

Likelihood – High	Wrong deployment of resources (impact on BCR)	**Excessive traffic speed or other unsafe driver behaviour**	**Secondary Incidents in queue**
Likelihood – Medium	People on carriageway Poorly positioned vehicles causing obstruction	Emergency access blocked Overload requiring diversion Road damage (esp. LGV) Rubbernecking	**Danger to workers where lanes remain open**
Likelihood – Low	False alarm Overreaction of TMC	Special equipment unavailable Late evaluation of situation (increased queuing and delay) New technology does not work as expected	Danger to workers where all lanes are closed Fire or chemical spillage

Many different types of incident are possible, which have been summarised by this project into four generic scenarios, and many possible approaches for a response have been reduced to three or four techniques in each case with some aspects specific to the scenario. Even so, the number of possible combinations makes it impractical to give a full assessment for each. However, it is possible to identify those risks that may be elevated or mitigated relative to the generic risk as in Table 16. This table relies on fairly intuitive assumptions about the effect of different scenario/measure combinations. For example, accidents involving a heavy vehicle (LGV) risk road damage because of high axle and load weight, total closure of the opposite carriageway will attract more attention than slow traffic, and a contraflow would be expected to require a temporary speed limit to be applied, reducing risks associated with traffic speed.

Table 16: Scenario and technique dependent variations in risks or risk factors

Closure Clearance	Maximum Prompt	Maximum Prompt	Minimum Delayed	Minimum Prompt
Technique	1.1 Close all lanes	1.2 Incident screen	1.3 Close some lanes	1.4 Tow in off-peak
Scenario 1 Collision	↑Rubbernecking	↓Rubbernecking		
Technique	2.1 Close all lanes	2.2 Contraflow	2.3 VMS and speed limit	
Scenario 2 Bad weather	↑Emergency access blocked	↑Emergency access blocked ↓Traffic speed	↓Traffic speed	
Technique	3.1 Close extra lane	3.2 Repair on-site	3.3 Tow in off-peak	
Secnario 3 LGV breakdown	↑Poorly positioned vehicles causing obstruction ↑Road damage ↓Secondary incident ↓Danger to workers	↑Poorly positioned vehicles causing obstruction ↑Road damage ↓Secondary incident	↑Poorly positioned vehicles causing obstruction ↑Road damage	
Technique	4.1 Close all lanes	4.2 Contraflow	4.3 Close blocked lane	
Scenario 4 Obstruction	↑Road damage	↑Road damage	↑Road damage	

7.2 Risks to road authorities versus risk to investment

Provided interventions do not increase the exposure of workers there should be no additional risk or cost above that proportional to activity. The risk to investment depends on the success of interventions, which can only be assessed by rational analysis or modelling, and may require several years of operation to verify experimentally. PRIMA D3.1 (Olstam *et al* 2015) propose the following techniques, to which this report adds optimal location of resources according to cost-benefit analysis:

- Advanced eCall
- Rapid detection through central monitoring
- Rapid detection through cooperative systems
- Incident screen
- Minimising number of closed lanes
- Quick clearance
- Rapid recording of scene for legal/insurance purpose

Central monitoring by CCTV and incident detection systems, as well as automatic queue detection, are already in use, as are incident screens and rapid scene recording using 3D laser scanning (CEDR 2011). The risks associated with these appear to be related only to investment and operational cost versus benefit and should be possible to assess from historical incident rates, using for example the methods of Section 3 earlier.

Minimising the number of closed lanes can be expected to be a priority for any incident manager provided that safety of responders and road users is not compromised. However, it may not be a priority for the police who tend to emphasise safety and order, so employing traffic officers and other dedicated responders can be considered pro-active. CEDR Tasks 5 and 13 describe how many NRAs already conduct desktop or live exercises to help plan optimal response to incident scenarios (CEDR 2009, 2011). The practical risks of being less cautious in establishing buffer zones and time intervals are somewhat imponderable and there would likely be resistance to such changes from workers. Any new advice would certainly require specific proposals based on careful observation of actual incident management operations followed by consultation with responders.

Quick clearance has been referred to earlier in the project (Taylor, Nitsche *et al* 2015) and as practised in the USA requires laws to be enacted that relieve responders and police of liability for unforeseen consequences of moving vehicles off the carriageway, either when they contain casualties or when evidence is thereby lost or property damaged. Therefore risk in this case falls upon legislature and government, as well as operators for compliance. The practical extent of risk can be assessed only through consultation of medical emergency personnel, police, scene management workers and insurers.

Past experience of incidents being reported by road users on mobile phones is that locations are often given inaccurately, and with any autonomous system such as eCall or V2I, as with automatic incident detection (AID), the risk of false alarms would need to be assessed according to the characteristics of the system.

8 Conclusion

The results of this analysis, based on a recent large Highways England incident database and modelling of selected incident scenarios and management techniques, suggest that Pro-Active measures may be able to achieve substantial benefits, the most effective being quick clearance, which is assumed also to imply delaying full clearance until demand is reduced, e.g. in the off-peak. Optimal closure of lanes taking account of traffic demands could also be beneficial. Contraflow can be effective in some cases but may not qualify as a tactical technique because of the time needed to set it up. In the incident scenarios it is applied only where an obstruction such as snow or a spill would take a long time to clear. Incident conditions are assumed to reduce the effective capacity of running lanes, and techniques may exacerbate this, for example if a speed limit is applied, which can be disadvantageous in a heavy peak. Overall, a BCR of 3.35 is estimated for pro-active scene management.

The benefits of new technology or other interventions aimed at more rapid initial response may be more marginal, and their BCR from the viewpoint of a road operator could depend on what costs are taken into account. For example this might be only a small part of the collection, processing and dissemination costs of data from systems like eCall or V2I systems (floating-car data), most of which would be incurred by road users via third-party providers (PSAPs), as well as by government responsible for regulation. On this basis a high BCR might be achievable. On the other hand, if the road operator is responsible for installing and maintaining equipment such as wireless beacons or extra response vehicles, BCR could be more or less marginal depending on how intensively data and driver information are managed, estimated values lying in the range 0.56-1.13.

9 Acknowledgement

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10 References

10.1 PRIMA deliverables (in Task order)

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