Safety Impacts of Incident Management at Incident Sites

Submission date: July 31, 2008

Word count: 5046 words + (9 figures and tables)*(250 words) = 7296 words

Authors:

Koen Adams MSc.
Arane Advisors in Traffic and Transportation
Groen van Prinsterersingel 43b
2805 TD Gouda, The Netherlands
Phone: +31 182 555 030
Fax: +31 182 555 039
k.adams@arane.nl

Victor L. Knoop MSc.
TRAIL Research School
Delft University of Technology
Stevinweg 1
2628 CN Delft, The Netherlands
Phone: +31 15 27 81723
v.l.knoop@tudelft.nl

Serge P. Hoogendoorn PhD.
TRAIL Research School
Delft University of Technology
Stevinweg 1
2628 CN Delft, The Netherlands
Phone: +31 15 27 81723
s.p.hoogendoorn@tudelft.nl

John A.A.M. Stoop PhD
Delft University of Technology
Stevinweg 1
2628 CN Delft, The Netherlands
Phone: +31 15 27 81723
j.a.a.m.stoop@tudelft.nl

ing. Alex van Loon
Rijkswaterstaat Centre for Transport and Navigation
Van den Burghweg 1
2628 CS Delft, The Netherlands
Phone: +31 88 7982 222
alex.van.loon@rws.nl

Abstract
Incident Management (IM) entails the collection of measured aimed at clearing the road as soon as possible after an incident has occurred. The rationale behind IM is to improve the safety of the different risk groups around the incident site, as well as to normalize the traffic stream as quickly as possible. In this paper, we investigate the effects of Incident Management on the safety of different risk groups. To this end, an overview is made of the effects of an incident on the safety, by conducting a Delphi. It is concluded that for all risk groups, an incident brings additional safety risks especially in the first stages of an incident. The effects of the individual IM measures were quantified and combined with the results of the Delphi, leading to an overview of the effect of IM combined with the risks of a secondary incident.

From this investigation it is concluded that IM has a positive effect on safety of all risk groups, especially in the later stages of incident handling. In the first stages the risks are relatively high, and the impacts of IM are relatively low. Therefore a gap between the two exists there. This shows that in the first stages of incident handling, there is still room for improvement in the safety of certain risk groups.

1. INTRODUCTION

A traffic incident is an unpredictable event which can cause extra delay to road users. Accidents, breakdowns, loss of cargo and calamities are examples of incidents. Whenever an incident occurs on the freeway this also has an effect on the safety of the people near the incident. In *(1)* it is shown that road users, victims of the incident, emergency services, and people living near the freeway are the most important risk groups who are exposed to additional risks when an incident occurs. By risk we mean the risk of being in a secondary incident (see section 5.1). Incident Management (IM) is the policy that through a set of measures aims at reducing both the effects on the traffic flow conditions and the effects on safety, by shortening the period needed to clear the road after an incident has happened. In the Netherlands, IM was introduced nationally in 1999. In terms of its organization, IM is a collaboration between Rijkswaterstaat (the Dutch Road Authority) and other emergency response services such as the fire department, the police department, ambulance services, salvagers, and insurance companies. Together they set up new guidelines and protocols in order to shorten the time which is needed to clear the road after incidents.

In this paper, we quantify the impacts of the IM measures which are implemented in the Netherlands on the safety of different risk groups. The main question of this paper is whether IM has had the intended positive effect on the safety of the different risk groups around an incident. We investigated where and when IM has had the most effect and where in the future the biggest gains in safety can be realised by new policy.

First, an overview is made of the risks which occur in different incident situations. Each incident comes with additional safety risks, that is, the possibility of a new, secondary incident. Then, by quantifying the effects of the different IM measures and summing them per time phase of the incident, an overview is obtained of where (in time) IM has had its biggest effect, and where the most room for improvement lies. In other words, in what phase of the incident the difference between the risk of a secondary incident and the effect of IM is the largest.

2. LITERATURE REVIEW

This section is divided into two parts. The first part provides insights in the international activities to increase increasing safety for workers and motorists in working areas in general. The second part shows the Dutch approach towards Incident Management.

2.1 Safety studies

The work falls in the general scope of the safety of both workers and motorists during exceptional conditions. The situation of workers on the roadway working on a roadway is studied in case of engineering works. The most general work published by the Federal Highway Administration is *(2)*. It raises the awareness of the risks that exist at work zone. It also lists possibilities to improve the safety situation: “traffic monitoring and management, providing traveler information, incident management, enhancing safety of both the road user and worker, increasing capacity, enforcement, tracking and evaluation of contract incentives/disincentives (performance-based contracting), and work zone planning.” For special projects a discussion on safety at the work zone is started, for instance for the Reconstruction of the I-25/I-40 in 2003 *(3)* or the construction on the Lake Springfield Bridge in Illinois *(4)*.

Planning the exact conditions is not possible for the working site at incidents, which are unpredictable by nature. However, also for the response to incidents plans are made; the least one can do is try to create a safe situation for both the workers and the motorists. For instance in Connecticut an overview is made of the possibilities that Intelligent Transport Systems give to improve the safety and to improve traffic flow when an incident occurs *(5)*. They summarize and assess the methods available, but do not carry out an extensive data analysis. Many road authorities acknowledge the problem need for proper Incident Management, and have plans that can be executed in case of an incident, for instance in Kentucky *(6)*.

No measures can be put into place when the incident is not detected yet. Therefore there is currently research going on to reduce the time between the incident and the (automatic) detection of the incident. An example of this can be found in Ossen et al. *(7)*, where the individual headways (rather than the aggregate flow values) are checked on consistency.

Our study focuses specifically on improving safety at incident sites. Rather than naming the possibilities *(5)*, we quantify the risks in different phases of the incident. We do this by interviewing experts on this subject, all with a different background and based on their view we quantify the risks.

2.2 Incident Management in the Netherlands

In 2007 the Dutch Road Authority conducted research on the effects of the IM-policy, especially on the traffic flow around incidents and the safety of risk groups around incidents *(1)*. This work combined the findings and conclusions of earlier reports by the Road Authority, which will therefore not be discussed here. The study was mostly done by expert judgement without quantification. The conclusions were the following.

- At this moment there is no conclusive material indicating the influence of IM on safety;
- It is likely that the *decrease* in congestion due to IM also decreases the risk of secondary incidents and thus improves safety;
- It can also be argued that a better organization of emergency response to incidents (one of the goals of IM) significantly improves safety, as a result of training and guidelines.
- Further research into this matter is necessary in order to get more reliable results.

3. INCIDENT MANAGEMENT

As explained in the introduction, the first IM project was executed nationally in the Netherlands in 1999. The official goal of the policy is to clear the road as quickly as possible after an incident has happened *(8)*, especially taking into account the traffic safety, the interests of the victims of the incident and controlling the damages. On the scene of an incident however the safety of the emergency workers is rated higher than the situation of the victims of the incident and (delay/safety) of the road users *(9)*.

Studies have shown *(10-13)* that incidents and accidents also have a big impact on the capacity of the road and therefore often lead to congestion. Clearly, the sooner the road is cleared, the sooner the traffic flow will normalize again. When traffic is in congestion, the risks of a secondary incident, especially in the tail of the traffic jam, are higher. This is mainly because of the speed difference *(14)*.

In coming up with new IM measures, the attention of the policy makers was especially on the organization, communication, and co-operation between the several IM partners (the parties which work together on the site of an incident), and measures which will shorten the incident handling time. Below (table 1) an overview is given of the most important IM measures.

TABLE 1 – The Incident Management measures used for this study

Measure	Abbreviation	
National Passenger car Regulation	NPR	Improved organization of the salvage process. A salvager is send to the site immediately after the incident has been detected, instead of the police investigating the situation. This results in a reduction of handling time of 15 minutes *(15, 16)*
National Truck Regulation	NTR	A similar regulation to the NPR, but then for trucks and lorries. The reduction in handling time is 60 to 90 minutes *(17)*
Initial Safety Measures for Incidents on Motorways	ISMIM	Safety measures for the emergency workers on how to secure an incident situation *(18)*. Results in a lower probability of a secondary accident.
Coordination Team at Incident Sites	CTIS	A coordination team is formed with members of all emergency services to improve the organization and communication on the scene of bigger accidents,. It is assumed that this results in a lower handling time through more efficient work.
Red-Blue Booklet	RBB	Gives an overview of all tasks of the emergency services during the handling of incidents. It also states the questioning procedures used by emergency centrals and emergency workers *(19)*. This leads to more efficient work.
Project IM+	IM+	This project gave the road inspectors of Rijkswaterstaat additional authorities around incidents. Regulating the traffic flow around incidents is the most important one, which is a task for the police in normal situations. They are in direct contact with the traffic control centre, also controlled by Rijkswaterstaat.

4. RESEARCH APPROACH

In this section, we present the approach used in this research to quantify the impacts of IM on traffic safety in case of an incident. The research was conducted using a scenario-based approach. From these scenarios the impacts of IM are quantified subjectively in time and space.

4.1 Incident scenarios

For this research a *scenario-based* approach was chosen; the effects will be quantified using three distinct incident scenarios. Scenarios are often used for risk analyses. In that way a limited number of characteristic events is sufficient to cover all aspects of the problem. In this research, three characteristic incident scenarios were selected. By choosing the three scenarios carefully, it is possible to get a complete overview of all possible risks around an incident location. The scenarios are:

- A car breaking down on the hard shoulder (scenario 1);
- An accident on the main carriageway involving two cars and blocking one lane (scenario 2);
- An accident involving dangerous chemicals (scenario 3).

The scenarios are increasingly involved in terms of potential risks, population at risk and emergency services involved. Scenario 1 only requires an emergency breakdown services, whereas scenario 3 needs the involvement of large number of emergency responders.

To ensure that the experts were able to identify with the situation at hand and provide as realistic answers as possible, for each scenario a study area is identified in which they are located. A freeway segment in the middle of the Netherlands was selected, namely the A28 around the city of Zwolle. The scenarios were placed in the study area in such a way, that the relevant risk groups will have additional safety risks. For instance, scenario 3, an accident with dangerous chemicals, is situated near an inhabited area. If the truck was to explode or hazardous gasses escape, the people living in the surrounding area will have additional safety risks. Figure 1 shows the incident scenarios in the study area.

4.2 Risks in time and in space

The first goal of this study is to get an overview of the potential impacts of an incident on safety in time and space. So, for each scenario, risks will be categorized in time and space.
A typical incident is divided into five phases, starting from the incident happening to the normalization of the traffic stream after the road is cleared again. *F*igure 2 shows these phases *(20)* which are:

1. *Detection phase* – this is the time between the incident occurring and the incident being reported to the emergency centre.
2. *Response phase* – the time needed for the emergency units to respond, the time from the incident being reported until the emergency units arriving on the scene.
3. *First clearing phase* – this is the time it takes the emergency units to clear the main carriageway. The incident is moved towards the hard shoulder as quickly as possible.
4. *Second clearing phase* – the time it takes to clear the hard shoulder and with that the entire incident.
5. *Normalization phase* – this is the phase from the emergency units leaving the scene until the normalization of the traffic stream (towards conditions similar to before the incident occurred).

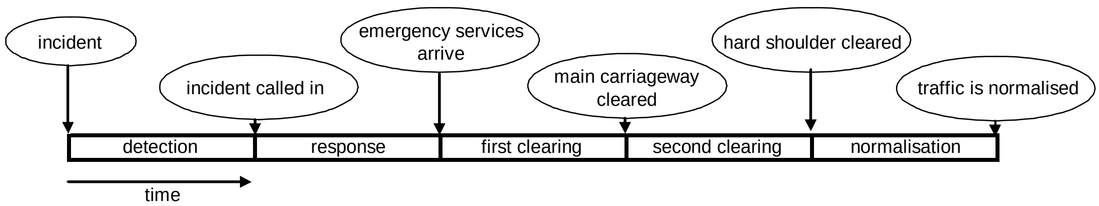

FIGURE 2 The time phases in an incident

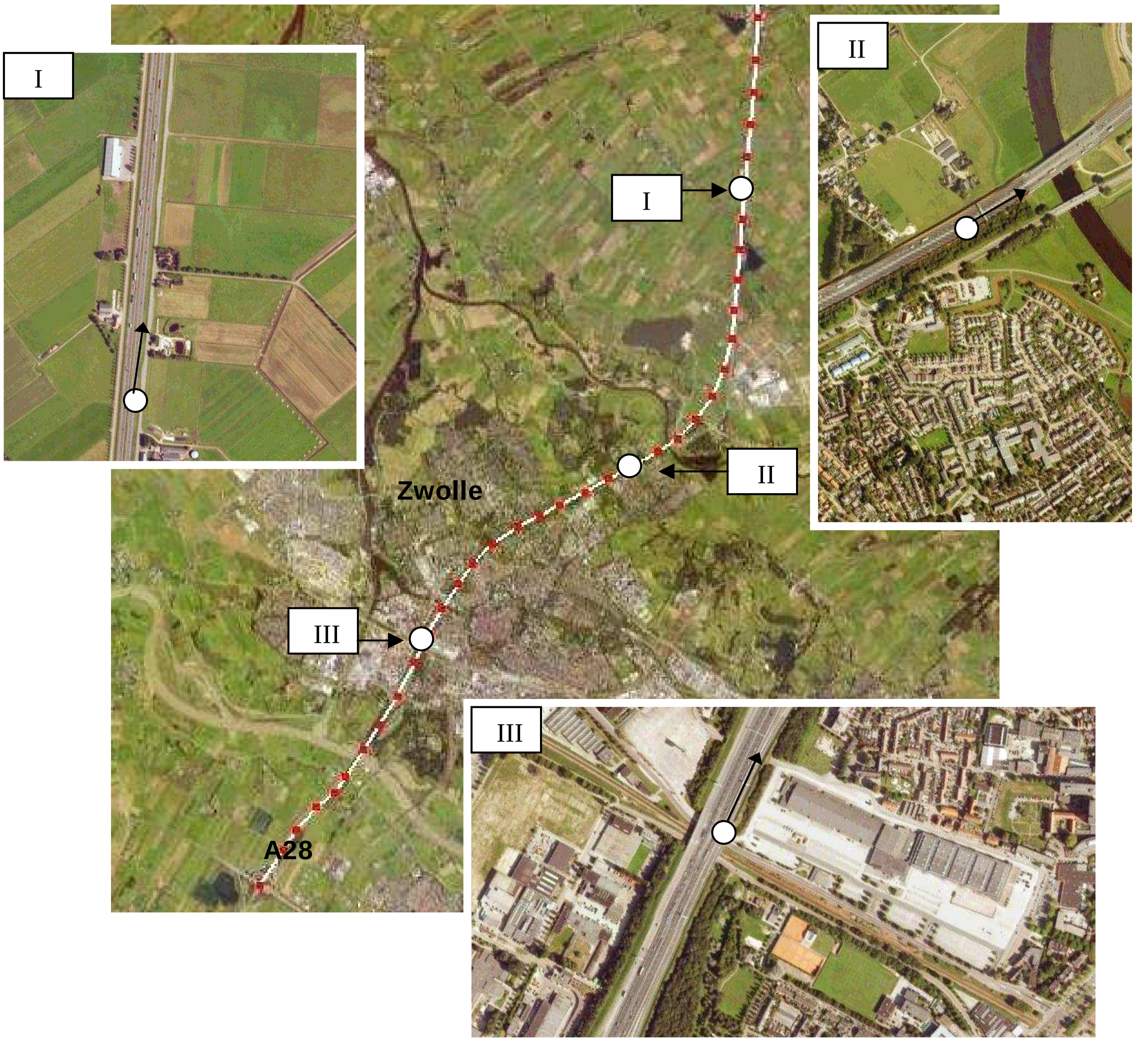

FIGURE 1 The different incident scenarios in the study area

Five risk groups were named, each of them populating the surrounding area of an incident.

- The victims of the primary incident
- The emergency worker(s)
- The road user upstream of the incident
- The road user on the other side of the road
- The people living around the incident

Whenever an incident occurs, it has an effect on the safety of a number of these risk groups. These risk groups are used to determine the group specific effect and the overall effect of an incident on safety and the impact of IM measures on safety.

The victims of the primary incident and the emergency workers are staying in the middle of the road during incidents, which increases the probability of a secondary crash. Road users on both sides of the road often have to deal with congestion around incidents *(21)*. The difference in speed at the interface between the tail of the traffic jam and uncongested traffic is a factor for the probability of a secondary incident *(14)*. And in big accidents with hazardous materials also the people living in the surrounding area have additional safety risks in case of a fire or explosion on the road.

5. INCIDENT MANAGEMENT AND RISKS

This section describes the approach used to determine the safety impacts of incidents and IM. The goal is to see where and when IM has had the most effect and where in the future the most gain in safety can be accomplished by new policy. First, using an expert panel, the risks around three typical incident scenarios are quantified. Then, using these results, the impacts of the individual IM measures are qualified subjectively, leading to an overview of the impact of IM. Combining the results of both researches, we get an overview of the risks around an incident and the impact of IM. From these figures it is concluded that IM is most effective in the later stages of the incident and is most effective for the emergency workers.

5.1 Risks around incidents

Research has shown that quantification of the risks mentioned in the last section is not possible, because the available data on incidents and accidents is not detailed enough. So a subjective quantification of risks was made, which leads to an overview of relative risks between risk groups, scenarios and incident phases.

The best way to conduct this research was to form an expert panel. The expert panel consisted of people who have an affiliation with safety and/or risks around incidents. The diversity of the panel is important; not all the members of the panel should for instance work in governmental agencies. The panel members should all have their own connection to IM. For this research, eight panel members from different disciplines were selected.

The expert panel was questioned using a Delphi method *(22)*, were the experts individually answer questions from the research leader on the matter. The individual answers are then averaged by the research leader and if necessary another iteration round is done. This process is continued until a sufficient amount of consensus amongst the experts is reached. In this study, the Delphi was done in one preliminary round and one iteration round. For the three incident scenarios (see section 4.1), the experts had to name all possible risks for the risk groups, for every incident phase. This gave the experts a 5x5 matrix, where each cell represents an incident phase and a risk group for a distinct incident scenario. They received three matrices (for each scenario one) with in every column the time phases and on the rows the risk groups.

$$\text{Risk} = \text{probability of occurrence x consequences}$$

For this study, risk is defined by the probability of a secondary incident multiplied by the possible consequences of a secondary incident. The consequences are measured in injured victims. The iteration round was all about applying their knowledge about risks and safety to the previously determined risks in the incident tables. They were asked to point out in every cell of each table, what the most probable risks is and for that risk state a probability of occurrence and a magnitude of the consequences. For this, a scale from 1 to 10 was made for probability and consequences. The maximal risk in this study is thus 100, the minimal risk is 0.

As mentioned before, quantifying risks using an expert panel is a subjective effort. Each expert has his own interpretation of the given scales, although a interpretation of the scales was given (see figure 3). The results from the iteration round also showed this. There was a relatively large spread in the answers of the experts. To cancel out the influence of consistently larger (or lower) answers on the average, all answers from the experts were scaled to a row maximum (per risk group). Per row of each table, the scores were scaled to the maximum of that row. After that, the average score of all experts was taken again.

After the scaling the results were presented in three graphs, one for each scenario. The graphs show for each scenario, in which incident phase the risks of a secondary accident are the highest, for every risk group. With that, an overview of the possible risks resulting from an incident is obtained.

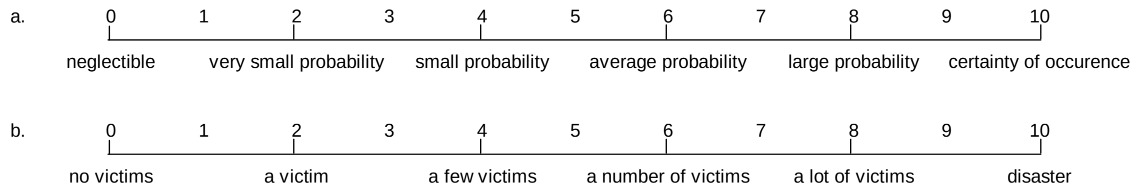

FIGURE 3 Scales for probability of occurrence (a) and for the consequences (b) of an incident

5.2 Impact of Incident Management

Incident Management consists of organisational measures for dealing with incidents. Most of the measures were introduced simultaneously, which makes it very difficult to quantify the effect of one single measure. Therefore, in this part of this study the effect of IM as a whole is qualified. This is achieved by looking at the societal risk in terms of victims, that is the damage society has in case a risk group is involved in an incident. In the previous section, risk was defined as the probability of occurrence times the consequences. In order to calculate the societal risk, the risk has to be multiplied by the total exposure to the risk, so

Societal risk = risk x exposure = probability x consequences x exposure

This means that, in order to have a positive effect on the total damages to society (safety), an IM measure has to have a positive effect on the product of the three elements. The available IM measures have either an effect on the probability of occurrence or on the exposure to risks. None of the measures result in lowering the consequences of an incident.

Since there are no statistics available on this matter, another approach was selected. There were some statistics available on the effects of the individual IM measures *(15-17).* However, these statistics are in terms of the gaining of time (in the incident handling process), or in terms of a change in capacity on the road. Some relevant relations had to be analysed in order to go from ‘a lower incident handling time’ to ‘a loss in total damages’. We formulated the following statements:

- When the societal risk drops as a result of IM, IM has had a positive effect on safety.
- A lower handling time has a positive effect on the exposure to risks for the victims and emergency workers, and an even more positive result for the road users. A shorter handling time of an incident obvousily leads to shorter congestion time.. Dependent on ration between the queue build-up rate and queue discharge rate, this time reduction can be larger than the reduction in handling time. This shows that a shorter handling time has a bigger effect on the exposure of road users than that of emergency workers.
- Measures which as a result have a higher road capacity, or result in a shorter incident handling time, have a positive effect on the risk exposure.
- A higher road capacity and a shorter incident handling time have a positive effect on the risk of a secondary incident happening.

With these statements, changes in incident handling time and capacity can be translated into changes in probably of occurrence and exposure. This was done qualitatively, because the effects differ per risk group. The individual IM measures were analysed (table2).

TABLE 2 Effects of the individual IM measures on the probability and exposure

Abbreviation	Effect on probability of occurrence	Effect on exposure to risks
NPR	-	positive
NTR	-	positive
ISMIM	positive	positive
CTIS	positive	positive
RBB	-	positive
IM+	positive	negative

One typical incident was selected for analysing the effects of IM. We choose scenario 2, an accident on the main carriageway, because in this scenario all IM measures are operational. For this scenario a qualification of effects will be made per incident phase and per risk group.

The last step in the analysis is linking the effect of the measure (table 2) to the risk group and the incident phase. Keeping in mind in which phases the individual IM measures are operational for the different risk groups, an overview was made of the effects of the measures. A scale was introduced te quantify the effect on exposure: 5 minutes loss in handling time equals an effect of +1. The effect on the probability of occurrence was processed subjectively, keeping in mind the figures in table 2. This results in an overview of the impacts of IM per risk group and per time phase.

5.3 Discrepancy between Incident Management and risks

The final step in this research was combining the results of sections 5.1 and 5.2. Here we have an overview of the risks around an incident on the one hand, and an overview of how IM made the process of incident handling saver. When these results are combined (risks vs. effects), the following questions can be answered:

a. Where IM has had the most effect
b. If this has been useful for all risk groups
c. Where in the future the biggest gains in safety can be realised by new policy.

In order to compare the results of both studies, the correct results were selected. For the risks, the results of scenario 2 were used (the scenario where all IM measures are operational). These risks, together with the effects of IM, were then rescaled in order to compare the results. The scaling was done to row maximum, which means that for each risk groups the maximum risk and effect were made 1 and the rest of the results were scaled to that number.

6. RESULTS

In this section the results of the research are presented. In the first section, the results from the Delphi method with an expert panel are shown. In the second section, the effects of IM are qualified. In the last section of this chapter, the results of both studies are combined.

6.1 Risks around incidents

The Delphi was conducted in one iteration round. For all three scenarios, the experts gave their view on the effects of an incident on the safety of the five risk groups through the time phases of an incident by filling out matrices.

The results of the Delphi method are shown in figure 4. In these figures, the horizontal axis represents the time phases of the incident; the vertical axis represents the relative risk. The figure also shows what risk the experts viewed as most important. Consider for instance the second clearing phase (the clearing on the hard shoulder) in scenario 1 (a breakdown on the hard shoulder). The experts saw the risk of ‘a collision with the safety zone’ as the major risk for the victims of the primary incident, and gave it a relative risk of 8.2.

Note that (as explained in section 5.1), the results were rescaled. The scaled results showed no big deviations from the original results, which led to the conclusion that the interpretation the experts have of the scales had no effect on the results. To better show the relative risks of the incident scenarios, the original results are presented here instead of the scaled results.

A number of observations can be made from the graphs in figure 4. First of all, it shows that for all risk groups in all scenarios, an incident gives additional risks. Only a certain risk groups is not present on the scene of the incident, the risks is equal to zero. Also, people living in the near surroundings of the incident only have additional risks when there is an incident with hazardous materials (scenario 3). The graphs also show that bigger incidents involve bigger risks. The risks of a car breaking down are judged lower than those of an accident on the main carriageway.

Secondly, the figures show that for most risk groups, the largest risk of being in a secondary incident, are in the first stages of the incident (phases 1 and 2). These are the critical phases before the emergency services arrive. This is especially risky for the victims of the primary incident and the road users upstream of the incident. In the next phases, when the emergency services have arrived, the risk of other risk groups are the highest, namely for the emergency services and the road users on the side of the road. This is likely to be related with the distraction of road users looking at the incident and unwillingly adjusting their driving behaviour to the situation.

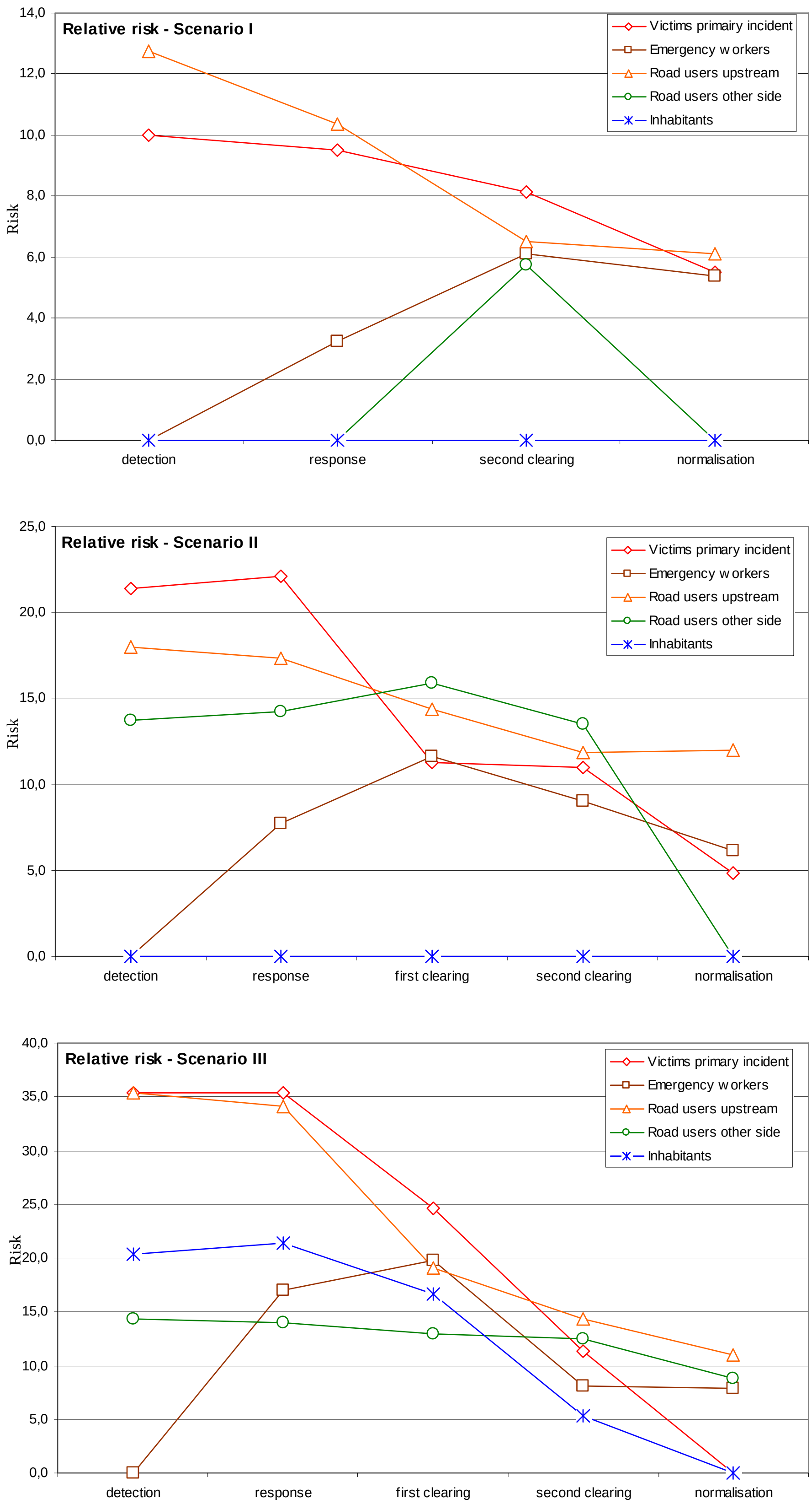

FIGURE 4 The relative risks for the scenarios per time phase as determined by the expert panel

6.2 Impacts of Incident Management

By connecting the effect IM measures have on handling time, capacity and the probability of occurrence to a certain risk group and incident phase, the total damages to society were qualified. This resulted in the figures shown below. The figures show:

- On the horizontal axis the time phases of the incident, on the vertical axis the different IM measures.
- Per time phase, the most prominent risk (coming out of the Delphi method) is shown.
- The colored bars show how big the effect of IM was in the particular time phase. The colors are linked to a certain degree of how big the effect was. This is done by naming the effect of a measure subjectively, as explained in section 5.2. The scale runs from +5 to -5, and is shown in figure 5. The value of the bars are the sum of the two last columns of the figure, which represent the effect a certain measure has on the probability of occurrence (ΔC) and exposure to the risk (ΔE).
- Below each figure, the effects of the individual measures are summed to get the total effect per time phase.

+5	very positive effect
+4	clear positive effect
+3	positive effect
+2	moderate positive effect
+1	small positive effect
0	no noticable effect
-1	small negative effect
-2	moderate negative effect
-3	negative effect
-4	clear negative effect
-5	very negative effect
?	effect unknown

FIGURE 5 The scale of the qualitative effect of the IM measures

Note that since for this part of the research only scenario 2 is used, the people living in the surrounding area of the incident have no additional risks, therefore they will not be included in this part of the research. The results are shown in figure 6.

From these figures, some observations can be done. In general, the figures show that IM has had a positive effect on the safety of the risk groups. On the level of an individual measure, for some risk groups negative effects are found, but the end result of IM is positive in all phases of the incident where IM is active, as can been seen in the last row of the graphs of figure 6.

Furthermore, the figures show that IM has had the biggest effect in the later stages of the incident. In fact this is logical. Because most IM measures are of organizational nature, these measures only start taking effect when the emergency services have arrived.

Relatively the biggest effect of IM is seen in the clearing stages for the emergency workers and the victims of the primary incident, the people on the scene of the incident. This goes back one of the goals set by IM, to improve the safety of the incident location.

Victims primary incident

incident phase	detection phase	response phase	first clearing phase	second clearing phase	normalisation phase	effects	
identified risk(s)	new accident collision w. passenger	new accident collision w. passenger	crash into safety zone death by injury	crash into safety zone death by injury	crash leaving location	ΔC	ΔE
NPR/NTR		+3	+3	+3		0	+3
CTIS			+2	+2		+1	+1
ISMIM			+4	+4		+3	+1
RBB		+1				0	+1
IM+			+2	+2		+2	0
Total	0	+4	+11	+11	0		

Emergency workers

incident phase	detection phase	response phase	first clearing phase	second clearing phase	normalisation phase	effects	
identified risk(s)	no risks	involved in an accident	incident during work crash into safety zone	crash into safety zone	crash leaving location	ΔC	ΔE
NPR/NTR			+3	+3		0	+3
CTIS			+2	+2		+1	+1
ISMIM			+4	+2	+1	+3	+1
RBB		+1				0	+1
IM+			+2	+2		+2	0
Total	0	+1	+11	+9	+1		

Road users upstream

incident phase	detection phase	response phase	first clearing phase	second clearing phase	normalisation phase	effects	
identified risk(s)	secondary accident	secondary accident	secondary accident crash into safety zone	secondary accident crash into safety zone	secondary accident	ΔC	ΔE
NPR/NTR			+4	+4	+4	0	+4
CTIS			+1	+1	+1	0	+1
ISMIM			+2	+2	+2	0	+2
RBB			+1	+1	+1	0	+1
IM+			-1	-1	-1	+1	-2
Total	0	+1	+7	+7	+7		

Road users other side

incident phase	detection phase	response phase	first clearing phase	second clearing phase	normalisation phase	effects	
identified risk(s)	accident by viewers secondary accident	accident by viewers secondary accident	accident by viewers secondary accident	accident by viewers secondary accident	no risks	ΔC	ΔE
NPR/NTR			+3	+3	+3	0	+3
CTIS			+1	+1	+1	0	+1
ISMIM			+2	+2	+2	0	+2
RBB			+1	+1	+1	0	+1
IM+			+1	+1	+1	+1	0
Total	0	+1	+8	+8	+8		

FIGURE 6 The qualitative effects of the IM measures per scenario and time phase

6.3 Discrepancy between Incident Management and risks

In section 6.1 it was shown that the biggest risks for the identified risk groups occur in the first stages of the incident, whereas the previous section showed that IM had the biggest effect in the later stages of an incident. From these observations, the risks and effects were combined in one figure. To this end, the results from both studies had to be put in the same scale for them to be effective in a combined figure. This was done for the risks and the effects of IM. Figure 7 shows how risks and effects of IM were combined.

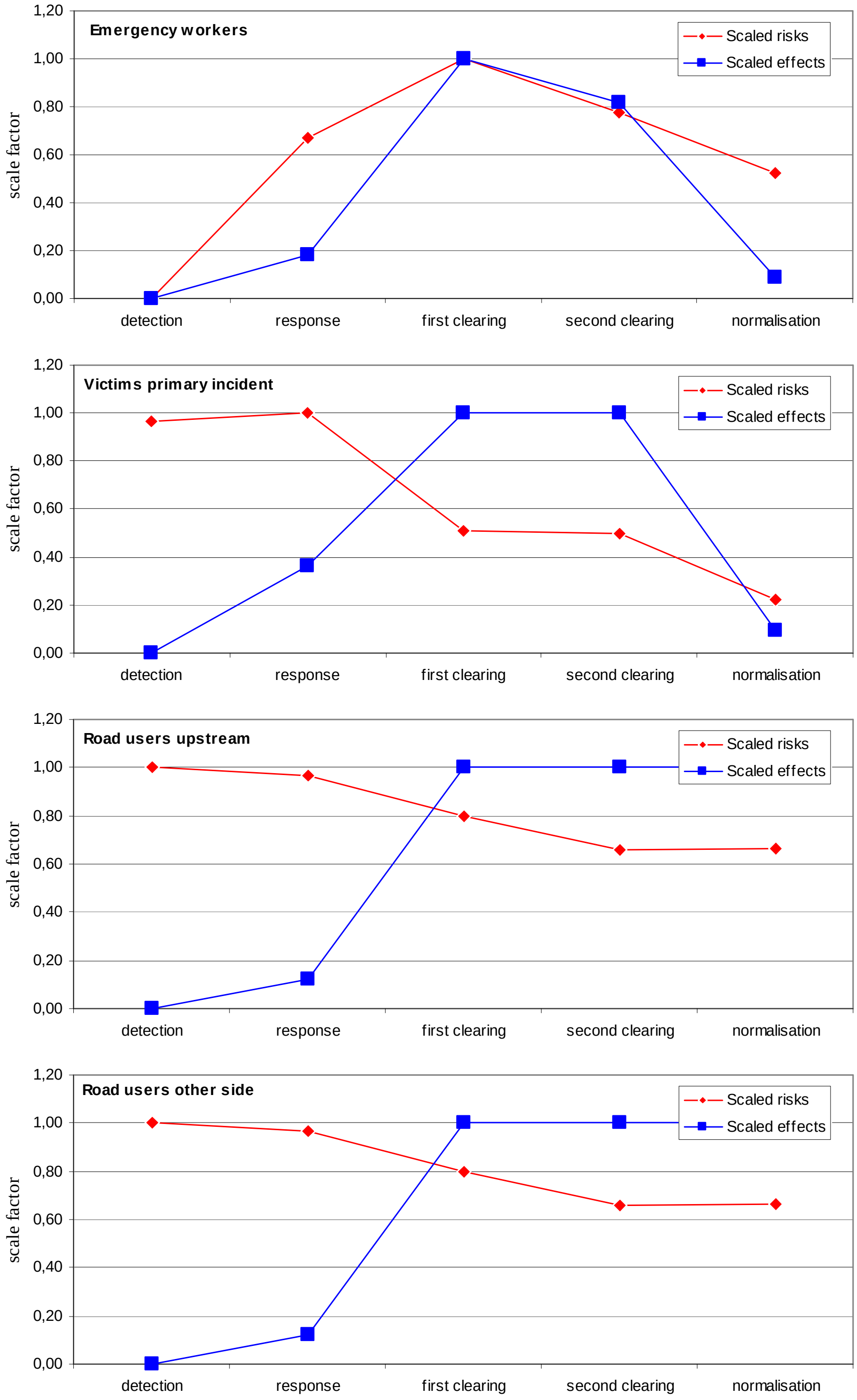

FIGURE 7 The risks as a result of an incident and the effects of the IM measure in one figure

For all risk groups, except for the emergency workers, the effects of IM are the largest in the time phases were the risks are the smallest. For the emergency workers both curves are taking a similar shape. This means that for this risk group IM was effective; note that when on the scene of an incident, the safety of the emergency workers is the first priority before the safety of the victims and the road users.

For the other risk groups the figures show a lot of space between the two curves, in other words there exists a ‘safety gap’ in the first stages of an incident between the effects of IM and the risks of a secondary incident.

7. CONCLUSIONS

The goal of this paper is to find out which effect Incident Management has the on the safety of the different risk groups around an incident. Hereto, it was studied to what extent IM has been effective in time (through the phases of the incident handling) and for different risk groups. Also from this research, an idea could be formed on where in the future new policy could realize a bigger safety gain.

In the first place, the impacts of an incident on safety were investigated. Our research showed that for all considered risk groups, an incident brings additional safety risks. This especially holds for the first phases of an incident. It also showed that the bigger the incident is in terms of involved vehicles and emergency services, the bigger the additional safety risks are. The paper then showed that Incident Management has a positive effect on the safety around incident for all risk groups. This effect is most prominent in the later phases of the incident. These are the phases of the incident handling when the emergency services are on the scene.

However, when the impact of IM through the phases of incident handling is investigated, our research shows that for most risk groups IM has been less effective. Especially in the first phases of the incident, the risks are high, while IM only appears to have a small effect. In the later stages the opposite is seen, the risks of a secondary incident are lower, whereas the effects of IM are higher. We therefore conclude that additional measures are needed here to make the handling of incidents safer for all risk groups.

The goal of IM is to clear the road as soon as possible after an incident, especially taking into account the safety of the victims, the emergency workers and the road users. On the scene, the first priority is the safety of the emergency workers, before the victims and the road users. From the results presented in the paper it becomes clear that in this IM has been effective in achieving its goals. For the emergency workers risk-reducing effects of IM take place in the same phase as the identified risks.

Future research should show weather other measures can effectively reduce the risk in the first phases and thus be a useful addition to IM. An example Other measures exist to improve the safety in the first stages, such as video-monitoring in combination with incident detection algorithms *(23)* and dynamic signaling on DRIPS.

ACKNOWLEDGEMENT

The research presented in this paper was performed on within the ITS Edulab, a collaboration between Rijkswaterstaat Centre of Transport and Navigation and the Delft University of Technology in the Traffic Management research field.

REFERENCES

1. *Inventarisatie beleidseffecten incidentmanagement*. Rijkswaterstaat Adviesdienst Verkeer en Vervoer, 2007, in Dutch (English summary).
2. Federal Highway Administration, *Intelligent Transportation Systems in Work Zones: a Cross-Cutting Study. Integrated Work Zone Systems for Improving Travel Conditions and Safety*. Publication FHWA-OP-02-025, 2002.
3. Hall, J.W. and E.W. Rutman, *Work Zone Safety: Analysis of Crashes, Speeds, and Traffic Flow During the Reconstruction of the I-25/I-40 Interchange.* Publication NM00SAF-01. New Mexico Department of Transportation, 2003.
4. Federal Highway Administration, *Intelligent Transportation Systems in Work Zones - a Case Study: Real-Time Work Zone Traffic Control System. Using an Automated Traffic Information System to Reduce Congestion and Improve Safety during Reconstruction of the I-55 Lake Springfield Bridge in Illinois*. Publication FHWA-HOP-04-018, 2004.
5. Fang, C., *Information Technology Systems for Use in Incident Management and Work Zones.* Publication FHWA-CT-RD-222-39-06-1. Federal Highway Authority, 2006.
6. Barrett, M.L., J.D. Crabtree, J.G. Pigman, and J.R. Walton, *Kentucky's Highway Incident Management Strategic Plan*. Publication KTC-05-11/SPR288-05-02F. Kentucky Transportation Center University of Kentucky, Lexington, Kentucky, 2005.
7. Ossen, S., S. Hoogendoorn, T. Alkim, and W.J. Knibbe. Incident Detection Based on Microscopic Double Loop Detector Data. In *Proceedings of 87th Annual Meeting of the Transportation Research Board*, Washington D.C., 2007.
8. *Website Incident Management in the Netherlands*. 2007 [cited 2008 21st July]; Available from: http://www.incidentmanagement.nl/.
9. *Course reader: Introductie Incident Management*. Verkeerscentrum Nederland, 2006.
10. Goolsby, M.E. Influence of Incidents on Freeway Quality of Service. In *Proceedings of The 50th Annual Meeting of the Transportation Research Board*, Washington D.C., 1971.
11. Blumentritt, C.W., D.W. Ross, J. Glazer, C. Pinnell, and W.R. McCasland, *Guidelines for selection of ramp control systems*. Publication 232. Transportation Research Board, 1981.
12. Qin, L. and B.L. Smith, *Characterization of accident Capacity Reduction*. Publication STL-2001-02 University of Virginia. University of Virginia, 2001.
13. Toorenburg, J.A.C.v. and T.A. Nijenhuis, *Capaciteitsbeperking door incidenten*. Transpute, 2007.
14. Aarts, L.T., *Snelheid, spreiding in snelheid en de kans op verkeersongevallen*. Stichting Wetenschappelijk Onderzoek Verkeersveiligheid SWOV, 2004.
15. Immers, L.H., *Visie Incident Management*. Verkeerscentrum Nederland, 2007.
16. Feenstra, N., R.C. Krommenhoek, J.H. Leopold, M.A. Loos, and R.C.v.d. Mark, *Landelijke evaluatie Incident Management*. Berenschot, 2002.
17. *Incident Management, Vrachtautoberging*. Projectbureau IM, 1997.
18. *Initial Safety Measures for Incidents on Motorways*. Verkeerscentrum Nederland, 2004.
19. *Het Rood-Blauwe boekje*. Verkeerscentrum Nederland, 2007.
20. Zwegers, A., *Capaciteit bij incidenten: verkennend onderzoek naar de mogelijkheden van het opstellen van een methode voor het bepalen van decapaciteitswaarden bij incidenten.* Rijkswaterstaat: Adviesdienst Verkeer en Vervoer, 2000.
21. Knibbe, W.J. and L. Wismans, *Voertuigverliesuren door incidenten*, in *Verkeerskunde DVM congres 2007*. Rijkswaterstaat: Adviesdienst Verkeer en Vervoer, 2006, in Dutch.
22. Linstone, H.A. and M.Turoff, *The Delphi Method - Techniques and Applications*. New Jersey Institute of Technology, 2002.
23. Ven, L.R.W.v.d., *Automatische incident detectie met behulp van meetlusgegevens*. ITS Edulab, 2007.