Traffic incident management : a common operational picture to support situational awarenes of sustainable mobility

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TRAFFIC INCIDENT MANAGEMENT: A COMMON OPERATIONAL PICTURE TO SUPPORT SITUATIONAL AWARENESS OF SUSTAINABLE MOBILITY

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Abstract

Successful traffic incident management presupposes a multi-disciplinary approach. To meet appropriately the safety and mobility needs of all affected parties, traffic incidents call for a high level of collaboration and coordination of involved agencies. Effective traffic incident management activities rely in particular on flexible communications and information systems. Based on experiences from the military domain it is possible to develop strategic concepts that are related to the improvement of information sharing and collaboration. Such concepts can also be applied to enhanced traffic incident management information systems. The present paper aims to offer a review of the state of the art in this field and to illustrate the empirical usefulness and benefits of traffic incident management.

Keywords*: Traffic Incident Management, Common Operational Picture, Shared Situational Awareness, Context Awareness, Netcentric Enabled Capabilities*

1. INTRODUCTION

The goal of sustainable mobility is one of the biggest challenges in modern traffic management. Sustainable mobility refers to the social and ecological objectives of transport, in particular, the minimization of environmental damage, the maximization of transport throughflow and the minimization of fatalities in the transport sector. Steadily growing traffic volumes and traffic intensity since the early seventies have led to enormous congestion and mobility problems, especially during the rush hours. Irregular situations like traffic incidents, adverse weather conditions, road works and events increase these mobility problems.

Traffic Incident Management (IM) is "*a planned and coordinated process to detect, respond and remove traffic incidents and restore traffic capacity as safely and quickly as possible*" (US Federal Highway Administration, 2000). The IM concept is also gradually introduced in the EU. For instance, in the Netherlands, IM is defined as "*all measures that are intended to clear the road for traffic as quickly as possible after an incident has happened, to ensure safety for emergency services and road users, and control the damage*" (Dutch Ministry of Transportation and Water Management, 1999). Road networks are part of a country's transport infrastructure and are therefore subject to general transport policies.

Road traffic injuries in the European Union are a major public health issue, as they are claiming about 127 thousand lives per year (World Health Organization, 2004). Next to this intolerably high number of lives lost, about 2.4 million people per year are injured in road traffic accidents. Over 1.2 million people die each year on the world's roads, and between 20 and 50 million suffer non-fatal injuries. And most likely, road traffic injuries will rise to become the fifth leading cause of death by 2030 (World Health Organization, 2009). In terms of safety, this brings the topic of traffic IM high on the political agenda. The importance of IM, besides its direct impacts in terms of property damage, injuries and fatalities and road saftety for the road users, is also very relevant for safe and reliable mobility. In general, traffic becomes congested when the demand is larger than the supply, i.e. there are more travellers than the road can cope with. Incidents can quickly lead to congestion and associated travel delay, wasted fuel, increased pollutant emissions and a higher risk of secondary incidents. They are an important cause of congestion and the total cost of traffic congestion is high.

The handling of an incident can be described based on the duration of an incident. This serves to show where problems arise in the clearing of incidents and is useful for determining what measures are needed for specific situations. The duration is defined as the period of time in which a traffic flow is disrupted due to an incident. The amount of delay and impacts that result from the incident depends on the duration of the different distinct phases. In the literature there is no general agreement on the different process phases for IM (Özbay and Kachroo, 1999; Corbin and Noyes, 2003; US Federal Highway Administration, 2000; Dutch Ministry of Transportation and Water Management, 2005). In this paper we will use a more detailed description which in practice covers all the different process phases found in the literature. The following phases (or time periods) can be identified (based on Zwaneveld et al., 2000) (see also Figure 1):

- Phase 1: detection and verification time (Tl); the time elapsed between the occurrence detection and verification of the incident;
- Phase 2: warning time (T2); the time required to alert all necessary emergency services;
- Phase 3: respond, driving, and arrival time (T3); the length of time required by the emergency service alerted to reach the location of the incident;
- Phase 4: operation or action time (T4); the length of time required to move 'damaged' vehicles onto the hard shoulder. Lanes are free for normal traffic use;
- Phase 5: normalisation time (T5); the time required to take the damaged vehicles from the hard shoulder to a location out of sight of road users;
- Phase 6: flow recovery time (T6); the time elapsed between the moment that the incident has been fully removed and the disappearance of the tailback.

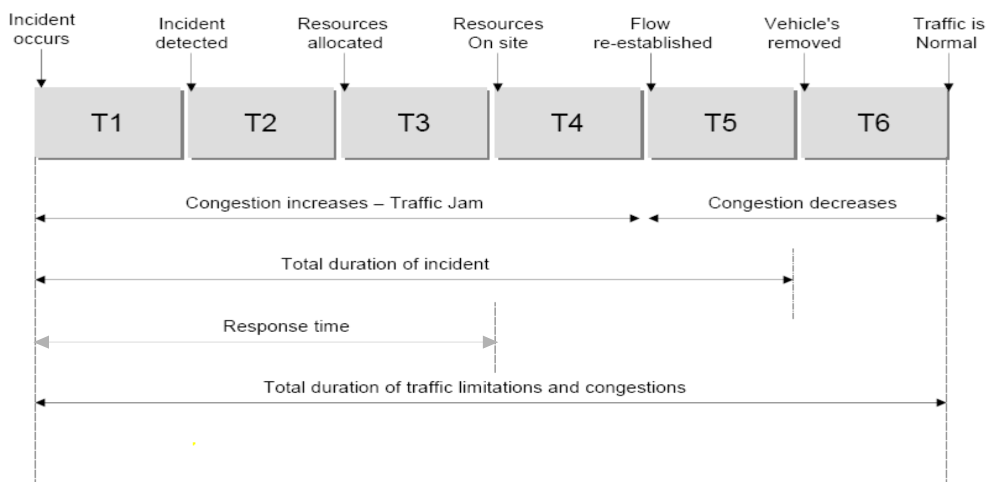

Figure 1: Different Phases Incident Mangement process (Zwaneveld et al., 2000)

The objective of this paper is to discuss how the innovative concepts of a Common Operational Picture (COP), shared Situational Awareness (SA) and netcentric working can be applied to traffic Incident Management (IM) to improve the situational interface and the quality of cooperation between the IM actors. First, we describe the importance of IM and the mobility consequences in Section 2. Then we analyze the role of information systems to support IM in Section 3. Netcentric working, originally introduced in the military domain, is a new way to support daily work processes and the collaboration of chainmembers of IM. This is decibed in Section 4. The introduction of a netcentric working is strongly related a Common Operational Picture (COP). This will be discussed in Section 5. The main challenge is which minimal data set need to be shared and which context variables define an accurate, operational and understandable picture of reality. This will be analyzed in Section 6. The use of a COP needs to improve the situational interface of a traffic management central which leads to better information sharing and decisions which have a positive effect on actions and IM policy goals. This will be discussed in Section 7. In Section 8 some implementation options for the introduction of a COP are discussed. Finally, the main problems and issues are analyzed in Section 9.

2. THE IMPORTANCE OF IM AND MOBILITY CONSEQUENCES

2.1. Providing reliable travel times to road users

Due to the large number of road users on the Dutch network congestion occurs frequently, particularly at the regular bottlenecks. This leads to congestion and travel time losses partly because it is difficult for the traveler to estimate how long the journey will take. Congestion caused by regular bottlenecks travellers can globally indicate how much time losses due to congestion on most routes. Much more difficult is to estimate the travel time losses caused by irregular and unexpected situations such traffic incidents, adverse weather conditions, road works and events. It is, especially for road users, often difficult to predict in advance when these situations occur and how long the delay will be associated. It is precisely these characteristics that make irregular situations a large contribution to the unreliability of travel times. This largely depends on how often irregular situations occur and what is the impact of the situation (loss of capacity and reliability of travel times).

From 10 per cent in 1995 (McKinsey and Company, 1995) nowadays aproximatetely 12-13 per cent (Knibbe et al. 2004; Dutch Ministry of Transportation and Water Management, 2004; TNO, 2006; KIM, 2010) of all traffic jams on Dutch roads are the result of traffic incidents. Figure 2 shows the division between regular and irregular congestion for the situation in the United States. 55 per cent of this congestion is caused by the less predictable irregular situations. There is a big difference between the Netherlands (13 per cent) and for example the US (25 per cent), Germany (33 per cent) and France (12 per cent) (see ECMT, 2007).

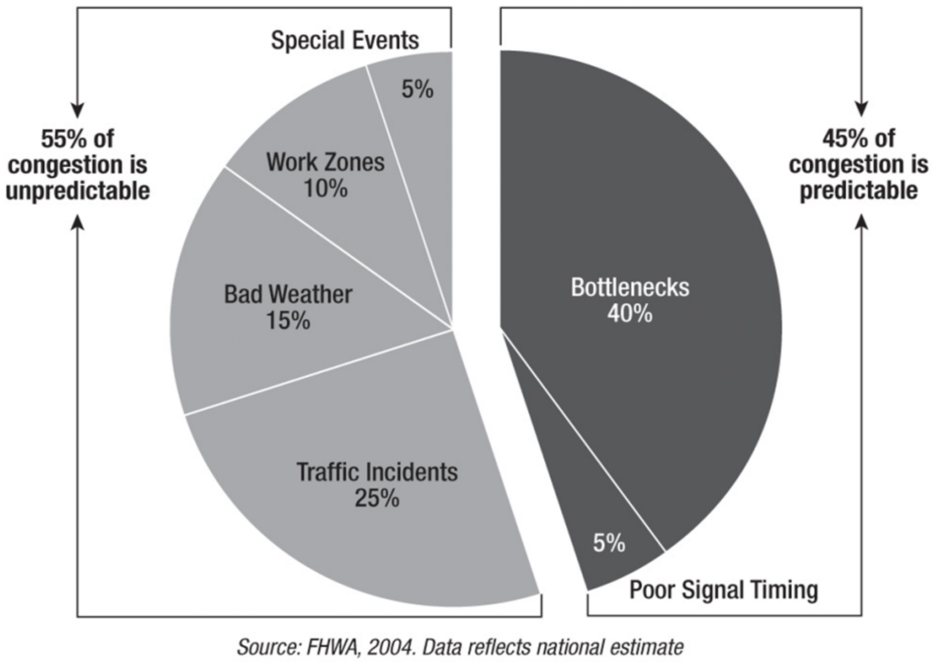

Figure 2: Causes for the existing congestion (US FHWA, 2004)

2.2. Increasing discrepancy between mobility and capacity

The importance of ramping up the application of IM on the road network is shown by Figure 3. This Figure shows both the trend in mobility in the Netherlands and the growth in the length of the highways network since 1980. The growing discrepancy between the trend in mobility and the increase in capacity since 1980 is striking. The increasing weight of traffic jams (vehicle kilometres per kilometre traffic lane, strain on the highways network) is the consequence of this. In turn, the increasing imminence of jams means less is required to trigger a disruption (even small discontinuities can result in a traffic jam). Moreover, the consequences of a disruption (hours lost by vehicles) become much greater. Through the application of IM the negative effects of incidents can be reduced considerably (Dutch Ministry of Transportation and Water Management, 2003).

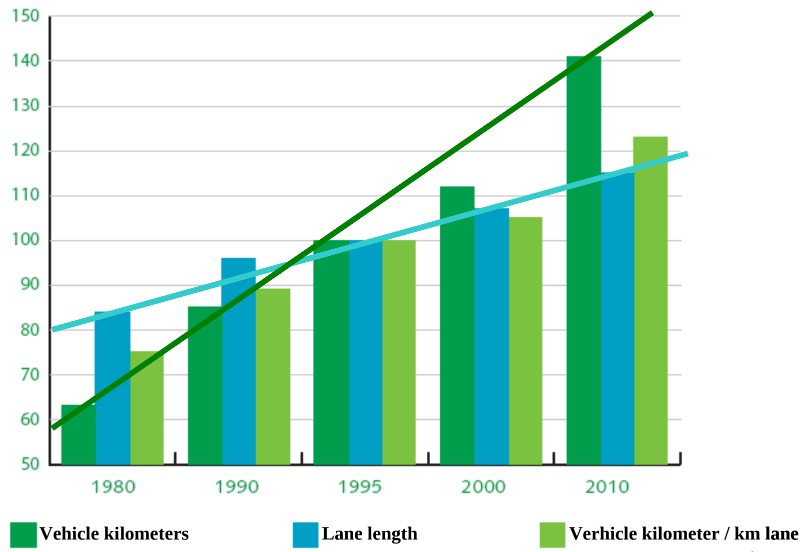

Figure. 3: Developments vehicle kilometers and lane length in the Netherlands (index 1995=100), (Dutch Ministry of Transportation and Water Management, 2003)

From 2000-2008, traffic volumes increased by an average of 2 per cent. In 2009, traffic volumes fell by 1 per cent. Apparently, then, a small increase in traffic volumes leads to a large increase in traffic congestion; or, conversely, a relatively small decrease in traffic volumes consequently lead to a relatively large increase in traffic congestion. In recent years, this relationship between traffic volumes and traffic congestion has intensified. Presumably, the reason for this is that the maximum capacity of the main motorway network is reached at increasingly more places and during an increasingly larger share of the day. The Dutch road network is very heavily loaded, especially compared to neighboring countries (see Table 1). The heavy load means that during large parts of the day little spare capacity available. Consequently, incidents have a big impact.

Table 1: Comparison intensities HWN Netherlands and surrounding countries (Dutch Ministry of Transportation and Water Management, 2011)

Country	Road	Day-intensity	Year
Belgique	R0 Brussel: Woluwe Zuid – Diegem	190.708	**2008**
	R1 Antwerpen Borgerhout – Berghem	186.480	**2008**
England	M25 – Western links from A1(M) to M23	213.000	**2009**
	M60 – Manchester West	186.000	**2009**
Germany	A3 AD Heumar – Nordrhein Westfalen	187.860	**2009**
	A100 Dreieck Funkturm – Kurfürstendamm	191.400	**2005**

Netherlands	A1 Muiden – Muiderslot	184.964	**2009**
	A4 Kp. Pr. Clausplein – Delft Noord	241.719	**2009**
	A4 Hoofddorp – Kp. De Hoek	208.287	**2009**
	A10 Kp. Nieuwe Meer – Amstelveen S108	202.591	**2009**
	A12 Utrecht – Nieuwegein Noord	207.021	**2009**
	A15 Kp Ridderkerk – Hendrik Ido Ambacht	239.728	**2009**
	A16 Kralingen – Pr. Alexander	205.098	**2009**
	A27 Kp. Rijnsweerd – Kp. Lunetten	190.652	**2009**
	Etc.		
	In total 15 road lanes > 180.000 vtg.		

Congestion occurs when the demand question arises (the number of vehicles per unit time to pass) is greater than the capacity (number of vehicles per unit time by a road can be processed). If the network is heavily loaded, more incidents occur (due to limited residual capacity for long periods of the day) which leads to more congestion and more inreliable travel times. This is a compelling argument to apply professional IM to the Dutch road network.

2.3 Costs of traffic jams and delays

Growing from annually 30 million hours lost through traffic congestion in 1990 to approximately 44 million hours in 2000, nowadays many hours are lost due to congestion in the Netherlands. For car drivers, between 2000 and 2008 the number of delays caused by traffic jams and congestion rose by 55 per cent. In 2009, the economic crisis caused that figure to fall by 10 per cent. Time loss due to traffic jams and congestion increased by 40 per cent from 2000 to 2009.

Table 2: Time loss due to traffic congestion (KIM, 2010)

	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Travel time losses (2000 = 44 mln vehicle lost hours	100	118	110	113	122	131	143	153	155	140
Traffic volume (number of kilomtres	100	102	104	105	108	109	111	114	114	113
Avarage travel time		100	98	99	100	101	103	104	104	102
Unreliable		100	94	94	101	102	105	115	114	104

The total congestion costs on the Dutch main road network for 2009 estimated at 2.4 à 3.2 billion euros. Between 2000 and 2009, these costs with 50 to 60 per cent. It is striking that in 2009 the first time since 2000 the congestion costs compared to the previous year decreased. Congestion costs in 2009 were roughly 10 per cent below 2008. This decline is entirely attributable to the decline number of vehicle hours lost. In 2009, the total costs due to traffic jams on the Dutch main motorway network was estimated at 2.4 to 3.2 billion euros, which is 10 per cent less than in 2008. Had various measures, including peak-hour and extra lanes, roadwidening works , traffic information systems and traffic IM, not been undertaken during this period, travel time loss would have increased by 13 per cent (KIM, 2010).

2.4 Incident numbers and time reduction

On a yearly basis there are about 100.000 incidents (Berenschot 2009), varying from small accidents to major multi-vehicle incidents causing casualties and vast damages to the road and its supporting structures. While relatively few incidents involve trucks, these incidents cause immediate, large-scale traffic jams that catch public attention. All these traffic jams contribute significantly to the economic damage that The Netherlands suffers each year from traffic jams. A traffic jam also creates an unsafe traffic situation, while in many cases collisions occur in the tail of the jam. This entails the risk of further material damage as well as injury. Therefore, there is sufficient reason to limit as far as possible the length and duration of such traffic jams.

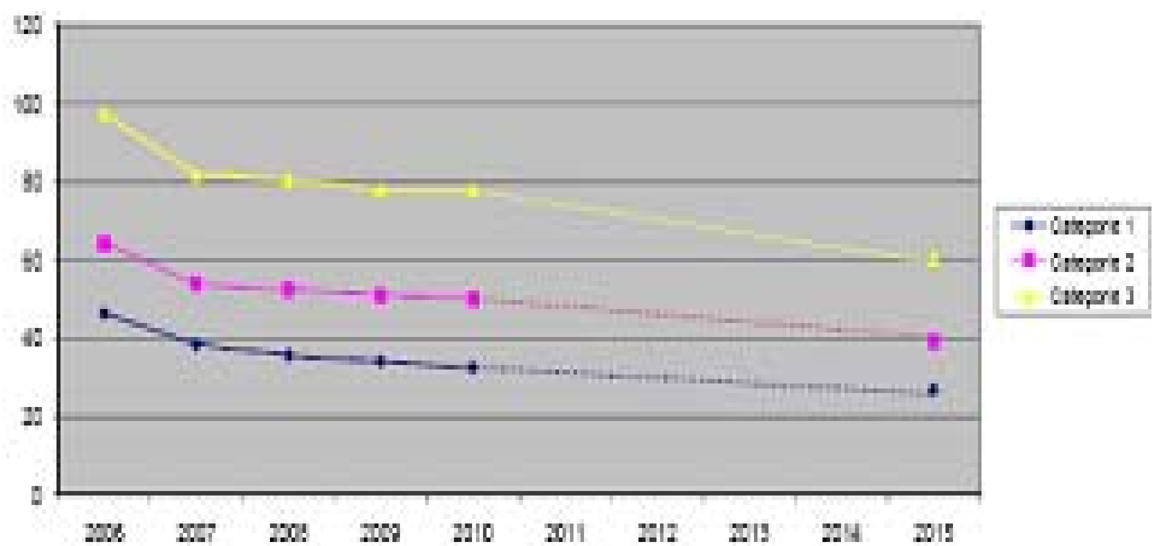

Figure 4: Increase in avarage IM process handling time in minutes (Dutch Ministry of Transportation and Water Management, 2011)

Different succesfull applied IM measures have led to a large increasement on the time duration of incidents. Since the introduction of IM in 1994, the average time of incident-related IM actions is in 2004 reduced with 25 per cent (Grontmij, 2004). Between 2004 and 2008 the incident duration has been increased with another 10 per cent. The ambition till 2015 is to reduce the process time from 2008 with another 25 per cent (Dutch Ministry of Transportation and Water Management, 2008).

2.5. Incident Management strategies and the importance of speed

In the Netherlands there have been several studies that analyze the effects of incidents and the relation with IM measures (McKinsey and Company, 1995; Wilmink and Immers, 1996; Schrijver et al., 2006; Kouwenhoven et al., 2006; van Reisen, 2006; Knoop, 2009). They all conclude that investing in IM measures is very cost-effective. IM measures may have effects in different phases of the incident handling process. These effects can be regarded as the objectives of IM measures. IM is one of the most important instruments of traffic management in the Netherlands against congestion or traffic jams and may seriously reduce the number of casualties on the roads.

Classical IM strategies are aimed at minimising the negative effects of non-recurrent congestion that is due to incidents. There is a strong relationship between the duration of an incident and the respons time required from the traffic management center and the emergency services. The basic idea is that fast clearance of the incident scene can help to reduce the incident-related congestion. An early and reliable detection and verification of incidents together with integrated traffic management strategies are important contributions, which improve the efficiency of the incident response. There are several studies that analyze the factors that determine the duration of the incident (Hall, 2002; Lee and Fazio, 2005).

Response time (speed of emergency aid) plays an important role as shown in Figure 5. The formula shows that the consequences of an incident are proportional to the square of the accident duration. This quadratic relationship illustrates the importance of IM. The value of the factor depends on the capacity and the load on the road section. Thus, the number of vehicle loss hours as the result of an incident depends on the time required to clear the road for traffic following an accident, the road capacity and the extent to which the road capacity is filled (Immers, 2007).

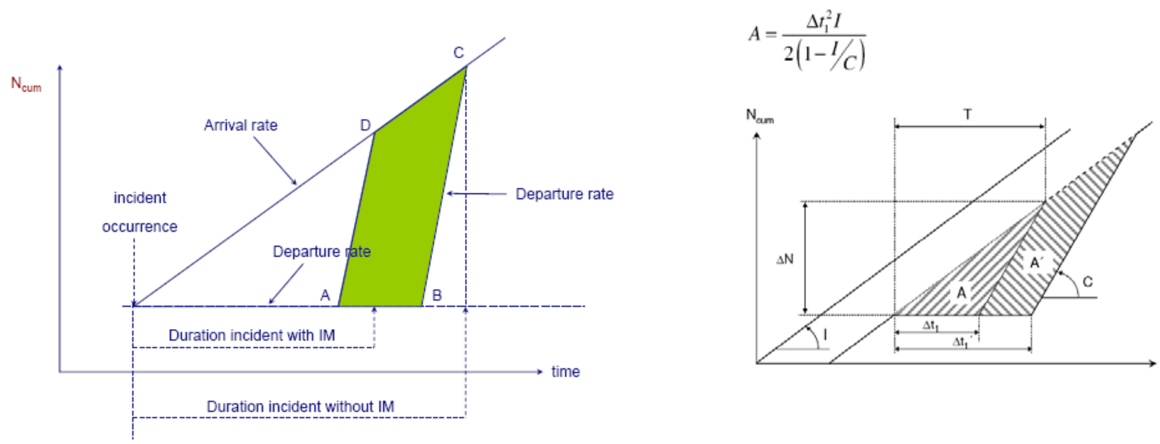

Figure 5: Relation between incident duration and respons time (Immers, 2007)

An incident means that the available capacity of a road can not be fully used, because one or more lanes are blocked. This effect is extensively studied. Thus, for a 3-lane road investigated the residual capacity (the capacity of the road is still available for the movement) as a function of the number of blocked (not negotiable) lanes. Table 3 shows the remaining capacity (Dutch Ministry of Transportation and Water Management, 2011)

Table 3: Reduction of capacity (in % of original capacity) of a 3-lane road due to an incident

Number of blocked lanes	**Hard shoulder**	**1 lane (of 3) blocked**	**2 lanes (of 3) blocked**	**0 (traffic jam caused by viewers)**
Reduction capacity	28%	64%	82%	31%

It is striking is that the loss of one or more lanes has a big influence on available capacity. A vehicle on the hard shoulder already leads to a capacity reduction of 28% (residual capacity = 72%). If a lane must be closed, the remaining capacity is only 36% (a reduction in capacity by 64%). An accident leads to the other lane (due to traffic jam caused by viewers) to a capacity reduction of 31% on the carriage way in the opposite direction. In the United States will find similar figures based on the results of a study in Washington State (WSDOT, 2011). The figures indicate that it is very interesting to remove the involved vehicles as fast as possible form the highway to the hard shoulder or even better to a parking lane located out of sight of the road users. In the Netherlands there are IM roads (driving time <15 min.) and IM+ roads (driving time <30 min.). Table 4 shows the level this criteria is accomplished. There is a slight increase in the services level.

Table 4: Services level driving times to incidents (Dutch Ministry of Transportation and Water Management, 2011)

Incident time	**2008**	**2009**	**2010**
Between rush hours	82%	81%	79%
Outside rush hours	93%	93%	91%

However, to apply succesfull IM measures, its relevant how these can improve the congested network. Hereby its relevant to realize that traffic incidents have not the same effects at different locations on de highways. There for the highways are categorized in four new groups (see figure 6). The importance of speed is strongly related to the impact its has on congestion. Next to that its also relevant if the incident occure during the rush hours (between 06:00 – 10:00 and 15:00 – 19:00).

Figure 6: Netwerk categorization in the Netherlands (Dutch Ministry of Transportation and Water Management, 2011)

3. INFORMATION SYSTEMS FOR INCIDENT MANAGEMENT

To carry out the IM process in an effective and efficient way, the need for (spatial) real-time information and supporting information systems is large. The key obstacle to effective crisis response is "*the communication needed to access relevant data or expertise and piece together an accurate understandable picture of reality*" (Hale, 1997). A well established communication, information technology and clear organisational responsibilities among emergency services are the most important issues for IM. In fact, they represent a prerequisite to effectively apply IM. Technical aspects of IM are considered to impose fewer constraints on IM. The ‘situation’ interface and the ‘control’ interface in a traffic management centre are the two main domains where information systems plays a crucial role (see Figure 7). The situational interfaces of the traffic management system for monitoring consists of induction loops, camera’s, and human observers. For the traffic measure support, the road authorities uses variable message signs, speed limitation signs, ramp metering and peak/plus lanes and special measures for IM. Peak/plus lanes are additional traffic lanes that can be opened to traffic if demand requires so. When closed, the lanes are for the exclusive use by emergency services.

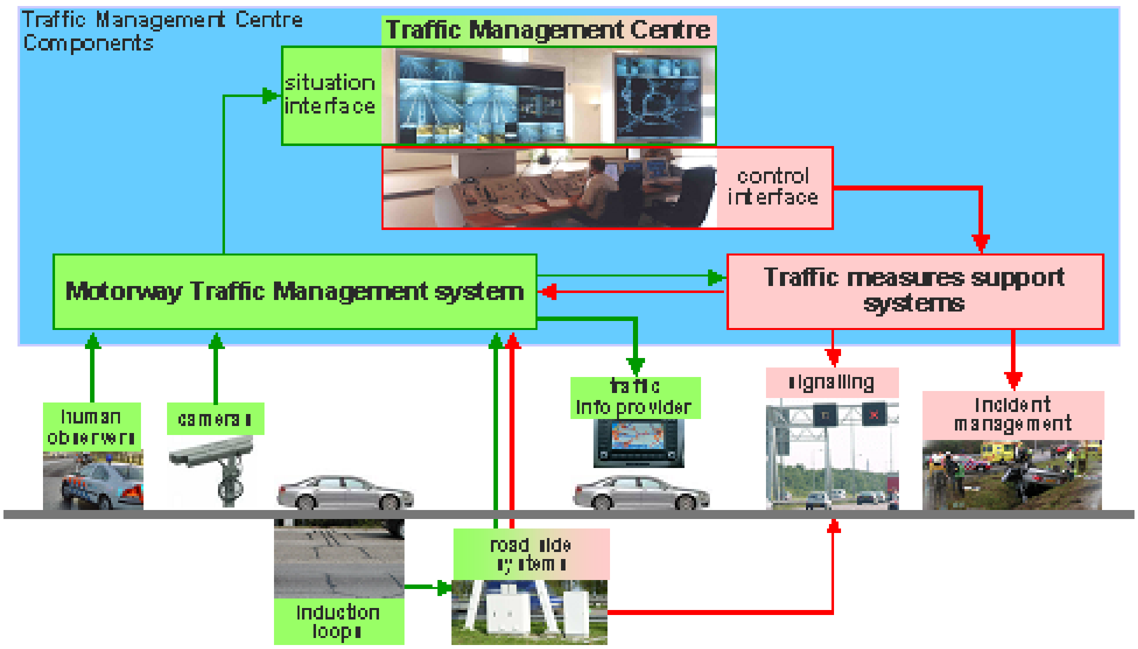

Figure 7: Traffic management building blocks

In current research, there are some general principles that are seen as the basis for successful emergency response information systems (see Turoff et al., 2000). In the latter study the authors describe 12 fundamental roles that should be supported by an emergency management system. As traffic IM can be seen as a special case of emergency response, to a certain extent these principles can also be applied to design a traffic IM system. These are clustered in Table 5 based on the situation and control interface.

Although traffic IM is a much more limited domain than general emergency management, the following design principles will also apply to this domain. First of all, in order to prevent information overload, relief workers should only receive relevant information. It is also important to understand what actually happened during the incident and to be able to review this information to improve the incident response. Because of the dynamic situation of incidents, it is important that the system can be reconfigured, for example, by changing priorities and filtering options. It should be possible to transfer roles or tasks to other persons; it should therefore, be possible to check which resources are available. Since critical decisions require the best possible up-to-date information, providing this information should be facilitated by an IM information system as much as possible.

Table 5: Fundemental roles for an emergency management system (Turoff et al., 2000)

Situation interface	**Control interface**
• Analyze situation • Edit, organize, and summarize information • Report and update situation • Oversight review, consult, advise	*Resources* • Request resources (people and equipment) • Allocate, delay or deny resources • Maintain resources (logistics) • Acquire more or new resources • Coordinate among different resource areas *Information* • Alert all with a need to know *Organization* • Assign roles and responsibilities when needed • Priority and strategy setting (e.g., command and control)

Information technology is essential to improve information sharing and decision making for emergency responders (Graves, 2004), as it has already drastically reshaped the way organizations interact with each other (Lee and Whang, 2000). Inter agency exchange of information is the key to obtain the most rapid, efficient, and appropriate response to highway incidents from all agencies. More and more, such information must be shared across system, organizational and jurisdictional boundaries. Public safety agencies and transportation organizations often have information that is valuable for each other's operations. Example are (see US NCHRP, 2004):

- Better incident detection and notification can engage appropriate public safety resources sooner, provide more rapid medical care to save lives, minimize injury consequences and reduce transportation infrastructure disruption;
- Better road situation information can speed the delivery of emergency (and support) resources to the scene;

- Better incident site status and coordination information can improve the safety of emergency responders and speed up incident stabilization, investigation, and clearance.

4. NETCENTRIC ENABLED CAPABILITIES FOR IM

Netcentric can be defined as "*participating as a part of a continuously evolving, complex community of people, devices, information and services interconnected by a communications network to achieve optimal benefit of resources and better synchronization of events and their consequences*" (see Wikipedia). The concept of 'Network Centric Warfare' (NCW) has proved to be very useful in the development of new capabilities for military operations, disaster management, homeland security and emergency management. Network centric warfare can trace its immediate origins to 1996 when Admiral William Owens introduced the concept of a 'System of Systems' (Owens, 1996). Owens described the evolution of a system of intelligence sensors, command and control systems, and precision weapons that enabled enhanced situational awareness.

As a distinct concept however, 'network-centric warfare' first appeared publicly by the US Naval Institute (Cebrowski and Gartska, 1998). It is a new military doctrine or theory of war now commonly called 'network-centric operations'. It seeks to translate an information advantage, enabled in part by information technology, into a competitive advantage through the robust networking of well informed geographically dispersed forces. This concept was introduced in the USA in the mid-1990s, together with the concept of 'Information Age Warfare'. (see Alberts et al., 2000, 2001; Alberts, 2002). The concept of Information Age Warfare is based on the emergence of information technologies and the role it can play in modern warfare. Information plays an important role in military operations and technological advantages make it possible to provide more complete, more accurate and timelier information to decision makers. Many experts believe the terms 'information-centric' or 'knowledge-centric' would capture the concepts more aptly because the objective is to find and exploit information. The network itself is only one of several enabling factors. This networking, combined with changes in technology, organization, processes, and people may allow new forms of organizational behaviour. Traditionally, military organizations provided information to forces in three ways (Alberts, 2002):

- commands (directives and guidance);
- intelligence (information about the adversary and the environment), and

- doctrine (how are you going to do it).

At the beginning of the 21st Century, several other countries began to develop their own view on NCW. In the literature different examples of definitions and concepts of Netcentric Operations can be found: Network Enabled Capabilities - NEC (UK); Ubiquitous Command and Control - UC2 (AUS)., Network Based Defence - NBD (Sweden) and Net-Centric Operations - NCO (US and NATO).

A few years later the term NEC has been also used by other government agencies in papers on disaster management and homeland security (Boyd et al., 2005). For example in the Netherlands there is an initiative between the Ministry of Defence and the Ministry of the Interior, named Netcentric Experimentation, where the NEC/NCW concepts are used for disaster management and homeland security (Brooijmans et al., 2008).

NEC offers decisive advantages through the timely provision and exploitation of information and intelligence to enable effective decision making and actions. NEC has three overlapping and dependant dimensions: networks, information and people. All three dimensions need continuous development to reach the full potential of NEC. At the heart of NEC is the network of networks to distribute information. The networked information environment provides the capability to acquire, generate, distribute, manipulate and utilize information. Information is essential for decision making. Decision makers at all levels will need to identify what information is required and how to obtain it (UK Ministry of Defence, 2005). The real value is reflected in the NEC value chain (see Figure 8).

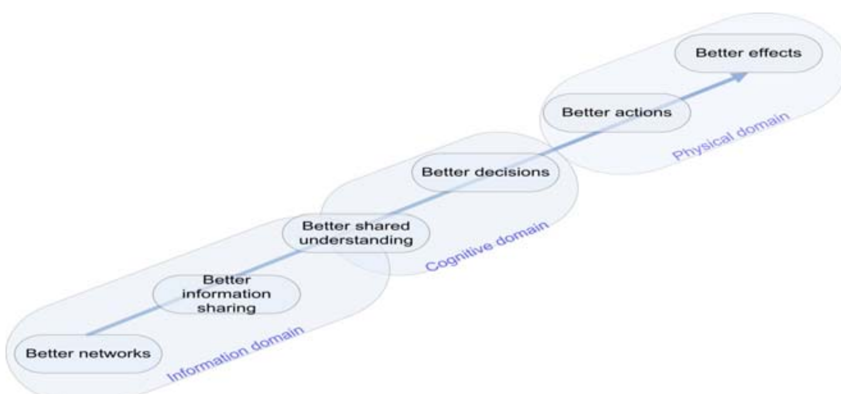

Figure 8: NEC value chain (UK Ministry of Defence, 2005)

As traffic IM can be seen as a special case of disaster management and homeland security, the NEC concept and the value chain can also be applied to design a traffic IM system.

5. COMMON OPERATIONAL PICTURE

A Common Operational Picture (COP) is a term widely used within the military domain to support situational awareness for command and control in netcentric operations (Wark et al., 2009). It has been defined in many ways. Some definitions address the joint, multi-service and interoperabiliy aspects of the COP. The US Department of Defense (2005) for example, defines a COP as "*a single identical display of relevant information shared by more than one command. A COP facilitates collaborative planning and assists all echelons to achieve situational awareness*" (FM 3-0)[1]. In Wikipedia[2], a COP is defined as: "*Military commanders need to know where all their own troops are, where their enemies are, and various other information about the battlefield (or battlespace)*". This knowledge is described in terms of situation awareness. The concepts of (shared) situational awareness and a COP have been adopted by the military as a guiding principle for combat operations (Pentagon, 2006). Other definitions address the way in which the information can be contained in a COP. A military view on this definition of a COP[3] is "*a distributed data processing and exchange environment for developing a dynamic database of objects, allowing each user to filter and contribute to this database, according to the user's area of responsibility and command role*". The COP provides the integrated capability to receive, correlate, and display a common tactical picture. The concept of a COP has after also been adopted as a goal for law enforcement, emergency management, firefighters and other first responders (Harrald and Jefferson, 2007). During the last few years, there has been a significant interest from various actors in designing information systems for the use of a COP for crisis response[4]. It is widely used to support situational awareness for command and control in netcentric operations (Wark et al., 2009). In line with different military views also for emergency services, there are several approaches, for example in Homeland (2008), which focus on information: "*a COP is established and maintained by gathering, collating, synthesizing, and disseminating incident information to all appropriate parties*". Focussing on collaboration and multi services: "*Achieving a COP allows on-scene and off-scene personnel to have the same information about the incident, including the availability and location of resources and the status of assistance requests*". Additionally, a COP offers an incident overview that enables to make

[1] http://www.huntinginfo.net/infantryglossary/C.htm
[2] http://en.wikipedia.org/wiki/Common_Operational_Picture
[3] www.dtic.mil/cjcs_directives/cdata/unlimit/3151_01.pdf
[4] http://jonaslandgren.blogspot.com/2007/03/common-operating-picture.html

effective, consistent, and timely decisions. In order to maintain situational awareness, communications and incident information must be updated continually. Having a COP during an incident helps to ensure consistency for all emergency management/response personnel engaged in the incident.

FEMA (2009), for example, applies the definition of a COP in reference to a single disaster or incident which is representative of many others: "*A COP offers a standard overview of an incident, thereby providing incident information that enables the Incident Commander/Unified Command and any supporting agencies and organizations to make effective, consistent, and timely decisions. Compiling data from multiple sources and disseminating the collaborative information COP ensures that all responding entities have the same understanding and awareness of incident status and information when conducting operations*". This definition supports that a COP is a product of a successful situational awareness environment. If SA is the culmination of comprehensive information sharing for the operating environment, then a COP is a compilation of that body of knowledge, captured and distributed.

As traffic IM can be seen as a special case of emergency response, a COP can also be applied to design a traffic IM system. IM involves the coordinated interactions of multiple public agencies and private-sector partners. In the literature, some reports analyze information sharing between different IM organisations. Different methods have been described on how organisations share information (US NCHRP, 2004). However, they are still far from sharing detailed and situational information and do not use a COP or netcentric operations. They mainly focus on interoperability issues. In a more recent report (US Department of Transportation, 2009) which focuses also on information needs, issues and barriers for information sharing between public and private IM organisations, they also do not use the concepts of a COP, shared SA or netcentric operations.

6. CONTEXT IN A COMMON OPERATIONAL PICTURE

The main objective of context-aware computing is to make interaction with computers easier and more supportive for human activity. This can be done in several ways, one of the most important being the filtering of the information flow from application to user to prevent the problem of information overload (Schmidt et al., 1999). In other words, getting the right information / services at the right moment in the right context. The other way around the flow of information from user to application can automatically be enriched with relevant context information, of which time location and identity are usually the most important context elements. The impact that the different context variables have on information systems largely depends on de specific characteristics of the process and information needs which they support.

The context is defined by van Eijk et al. (2004) (see also Dey, 2001) as "*any information that can be used to characterize the environment of a person that is considered relevant to the user, the device or the service*". From a computer point of view, context is defined more concisely by Moran and Dourish (2001) who define context as being "*the physical and social situation in which computational devices are embedded*". Dey and Abowd (1999, 2000) distinguish between primary and secondary context types. Primary context types describe the situation of an entity and are used as indices for retrieving second level types of contextual information. Küpper (2005) termed the context 'data' as primary context (main categories: Time, Location, Identity and Activity) and the context 'information' as secondary context, categorized into personal, technical, spatial, social and physical contexts. Both Pascoe (1998) and Schilit et al. (1994) have attempted to categorize the features of context-aware services using two orthogonal dimensions that on one axis describe whether a task is to get information or to execute a command and on the other axis, whether the task is executed manually or automatically. Dey and Abowd (2000) discuss these taxonomies in detail and finally come up with a general list of three context-aware features that context-aware services may support:

- presentation of information and services to a user (getting information);
- automatic execution of a service (execute command);
- tagging of context (by the user) to information for later retrieval (storing information).

Cassen and Kofod-Petersen (2006) suggest a context model based on activity theory. This context taxonomy incorporates the tradition in context-aware systems, and the general concepts found in activity theory. Other definitions have simply provided synonyms for context; for example, referring to context as the environment or situation. Some consider context to be the user's environment, while others consider it to be the application's environment. Brown (1996) defined context to be "*the elements of the user's environment that the user's computer knows about*". Franklin and Flaschbart (1998) see it as the situation of the user. Ward et al. (1997) view context as the state of the application's surroundings, while Rodden et al. (1998) define it to be the application's setting. Hull et al. (1997) included even the entire environment by defining context to be aspects of the current situation.

Table 6: Types of context information to improve a Situational interface (COP)

<u>IM Phase</u> <u>Context information</u>	**Phase 1 and 2** **Detection, Warning (notification) and Verification**	**Phase 3** **Respond, Driving and Arrival**	**Phase 4** **Site Management Operation (action)**	**Phase 5 and 6** **Normalization, Flow Recovery**
Location	- incident location	- location emergency vehicles - location emergency services	- safety zone incident location	- location traffic jam information caused by incident
Time	- date and time incident - warning time emergency services	- prognosis driving time vehicles - prognosis total incident time - departing time to incident - arrival time by incident	- realisation save incident location - waiting time towing service - clearence time towing service	- normalization time - flow recovery time
Activity	- detection incident by road users (drivers), camera's, police, road inspector, towing services and e-call - warning other emergency services - verification information - allocate resources - incident registration	- availability and capacity emergency services (resources) - inform emergency services - driving to incident location - Incident registration	- safety on location establised - stabilization rescue operation - cleaning or recovering and clearence road - coordination between emergency services - incident registration	- stable incident situation - clearance time peak lanes
Identity	- Incident number, type and magnitude (number involved vehicles and injuries).	- identity emergency material (vehicles) - indentity emergency workers	- aid question for traffic management measures, injured, fire, towing vehicles, road reparation - coordination emergency - police investigation (question of guilt)	
Environmental context	- sensors which provide a direct (near) realtime status of the incident location and the surrounding environment in terms of saftey and mobility consequences (video, camera, temperature sensors, photodiodes, omni-directional microphones, telecom data, RF beacons, fire detection, airpolution detectors etc.	- location critical infrastructure - information about events	- weather conditions - historical information - information of other incidents in surrounding area - information about damaged infrastructure	- road conditions in surrounding area (blocked roads, traffic jams)

The variety of attempts to define a context signal the difficulty to define context in a general yet useful way to create an intelligent COP. In spite of the lack of a consistent, unified and operationally useful definition of context, there are certain types of information dimensions that systematically appear in the literature and applications on context-aware computing. In practice, it is not essential to achieve a comprehensive and universal classification of context variables. The relevance of some variables, or groupings, changes with the uses of the services that rely on context information. What is essential is that any context-aware service within a COP provides a clear definition of the context variables that influence the service itself. This is important to justify the use of these variables in terms of added value or usefulness to the service, but also to identify the technical features of the service that rely on context information. In Table 3 we give some examples which context variables are contained in a COP and need to be shared between different IM chain members. We combine these with the different IM process phases as defined in Zwanenveld et al. (2000).

Feng et al. (2009) claimed to be the first one who incorporated the notion of context awareness for providing customized situation awareness. They stated that "*Whereas Context awareness is about exploiting the context of a user and helping the user to have a more effective interaction with the system by actively changing the system's behavior according to the user's current context or situation, Situation awareness focuses more on the modelling of a user's environment to help the user to be "aware of his current situation*". As far as we know, in literature there is not yet a clear understanding which context variables should support Situational Awareness for traffic IM.

7. SITUATIONAL AWARENESS

Most simply Situational Awareness (SA) has been general defined as "*knowing what is going on around you*" (Adam, 1993; Adams et al., 1995; Endsley and Garland, 2000). Although the term Situational Awareness (SA) itself is fairly recent, the evolution and adoption of the concept has a long history (Harrald and Jefferson, 2007). The concept finds its roots in the history of military theory[5] in combination with NCW (Alberts et al., 2000; Alberts et al., 2001; Alberts, 2002). Most of the related research has originally been conducted in military aviation safety in the mid 1980's to design computer interfaces for human operators.

[5] http://en.wikipedia.org/wiki/The_Art_of_War

(Endsley 1988, Dominques, 1994; Endsley, 1995, Naval Aviation Schools, 2006; NASA, 2006). The concepts of SA and COP have been adopted by the military as a whole as a guiding principle to define and/or oversee combat operations.

SA has been identified as one of the primary factors in accidents attributed to human error (see Hartel et al., 1991; Redding, 1992; Merket et al., 1997; Nullmeyer et al., 2005). The SA literature gives many examples of incidents and accidents, which could have been avoided if operators had recognized the situation in time. SA is especially important in work domains where the information flow can be quite high and poor decisions may have serious consequences. It is also a field of study concerned with perception of the environment critical to decision makers in complex, dynamic areas such as aviation, air traffic control, power plant operations, military command and control, and emergency services. Klein (2000) present four reasons why SA is important: 1) SA appears to be linked to performance; 2) Limitations in SA may results in errors; 3) SA may be related to expertise; and 4) SA is the basis for decision making. A distinction can be made between individual and shared or team SA which will be explained in the next sections.

7.1. Definitions and models for individual Situational Awareness

Models that currently dominate the literature focus on the SA of individual operators (see Stanton et al., 2001). These are individually oriented theories, including Endsley's three-level model (Endsley, 1995), Smith and Hancock's perceptual cycle model (Smith and Hancock, 1995) and Bedny and Meister's activity theory model (Bedny and Meister, 1999). These models differ in process versus product and in terms of the psychological approach. For example, Endley's three level model takes an information processing approach and is purely cognitive and does not include technological aspects, Smith and Hancock use a perceptual cycle model approach, and Bedny and Meister use an activity theory model to describe SA.

Of the individual oriented SA theories, Endsley's information processing based on a three-level model is the most popular (see Salmon *et al.*, 2007). Endsley (1988) defines SA as a product comprising "*the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future*". Wickens (2008) gives an extensive review of Endsley's articles on SA theory and measurement. Endsley (2000) argues that achieving (human) SA involves combining, interpreting, storing, and retaining information. Endsley's SA model is the result of processing at three distinct levels (Endsley, 1995):

- perception: attributes and dynamics of the elements in the environment are perceived;

- comprehension: multiple pieces of information are integrated and their relevance to the decision maker's goals is determined;
- projection: future events are predicted.

Several definitions of SA have been suggested, but these generally restate the same themes (e.a. Sarter and Woods, 1991; Fracker, 1991; Dominguez et al., 1994; Smith and Hancock, 1995; Adam, 1993; Jeannot et al., 2003). Endley's theories of individual SA do not use the concepts of a 'COP' and 'network-centric operations', but are more defined as a set of goals and decision taks for a certain job or activity of individuals within an organization. So its context depends on what is the right information to support a SA environment. However there is a strong relation between the quality of shared SA in terms of interaction, when the individual also works within a team to perform the required task in network-centric operations based on individual SA. Next to the different levels of SA of the environment, it is also relevant what is the SA of the own organisation. This is also called organisation awareness (see Oomes, 2004).

7.2. Definitions and models for shared Situational Awareness

A general accepted definition of shared SA is lacking. Endsley (1995), for example, defines team SA as "*the degree to which all of the team members develop sufficient individual SA to perform their required tasks*". However, this does not necessarily imply a sharing of SA (Salas et al., 1995). According to Klein (2000) shared Situation Awareness refers to "*the degree to which the team members have the same interpretation of ongoing events*". Nofi (2000) examines the definitions of 'common operating picture' and 'situational awareness' and finds through his extensive literature review that considerable ambiguity exists. SA is defined as: "*The result of a dynamic process of perceiving and comprehending events in one's environment, leading to reasonable projections as to possible ways that environment may change, and permitting predictions as to what the outcomes will be in terms of performing one's mission. In effect, it is the development of a dynamic mental model of one's environment*".

Nofi (2000) defines the difference between Situational Awareness and shared Situational Awareness: "*Shared SA implies that we all understand a given situation in the same way*". In the multi-jurisdictional or multi-agency environment, the "we" in his definition is the group of agencies and leaders having a vested interest in understanding their shared operating environment in the same manner. From this we can conclude that SA is maintained by the organization and shared situational awareness is sought between organizations and others.

Awareness information environments help to support the coordination of working groups. Typically, they provide application-independent information to geographically dispersed members of a working group about the members at the other sites such as their presence, availability, past and present activities. Often they consist of sensors capturing information, a server that processes the information, and indicators to present the information to the users (Gross and Specht, 2001). Awareness information environments capture various types of information and events from the physical world and from the electronic world and present the information to the members of workgroups. As these environments can potentially have a big number of sensors that constantly capture a vast amount of information, some structuring of the information is required. Furthermore, the members of the working group need a common reference on the shared world as a basis for communication and cooperation. Context information can be used to structure awareness information and to provide users with this common reference (Clark and Brennan, 1991). The SA of the team as a whole is dependent upon both (1) a high level of SA among individual team members for the aspects of the situation necessary for their job; and (2) a high level of shared SA between team members, providing an accurate common operating picture of those aspects of the situation common to the needs of each member (Endsley and Jones, 2001).

8. A COMMON OPERATIONAL PICTURE FOR IM

8.1. Introduction within traffic IM

In Harrald and Jefferson (2007), is stated that "*the transfer of these concepts from its safety and combat origins to the complex, heterogeneous emergency management structure will be exceedingly difficult, and that short term strategies based on the assumption that shared situational awareness will be easily achieved are doomed to failure*". The collaboration between the different IM actors takes place at 3 different levels: (1) policy; (2) management; and (3) operations.

The collaboration is formalized by policy rules and contracts between the different road authorities, towing services and insurance organisations. On an operational level, a COP can support the daily activities in terms of information sharing between the IM field workers (e.g. road inspectors, fire brigade, medical ambulance services and police). This means that a COP provid a SA for each field worker based on their specific tasks to support IM. In Harrald and Jefferson (2007) is stated that “*those controlling and coordinating the response and recovery will attain and maintain an accurate, shared COP and SA*”. This means that for IM this task will be done by the traffic management centres and the dispatch centres of the other emergency services (e.g. police, firebrigade, medical services and towing services).

In the literature it is generally accepted that decision making in a Command and Control environment is composed of a number of dynamic and cyclic perceptual, procedural and cognitive activities, achieved either by humans, computer systems or both (Roy, 2007). The support of a COP for Command and Control reflects to the process that delivers strategic and operational intelligence products which is generally depicted in cyclic form. Intelligence refers to a special kind of knowledge necessary to accomplish succesfully a mission (Waltz, 2003). In a military organization Command and control can be defined as ‘the exercise of authority and direction by a properly designated commanding officer over assigned and attached forces in the accomplishment of the mission’. Command and control functions are performed through an arrangement of personnel, equipment, communications, facilities, and procedures employed by a commander in planning, directing, coordinating, and controlling forces and operations in the accomplishment of the mission. However, colloboration and information sharing in the domain of traffic IM involves different public organizations with their own specific responsibilities. Command and control plays here a different role and the introduction of the militairy concepts needs to be carefully managed and applied to these specific situation.

Incident data need automatically to be logged by the field workers and the traffic management centrales to obtain real-time SA on a operational level. This provides a monitoring instrument at management level. Thus, a COP also serves the management need to measure the overal IM performance in terms of response time, clearence time, the impact on traffic jams and vehicle lost hours. This can also provide relevant information for policy makers. This provides a basis for monitoring IM policy goals, gives a instrument to justify investments in IM measures and gives a tool for comparing different traffic management investments in general. Finally, the introduction of a COP can also provide relevant information for road users in terms of road traffic conditions, expected traffel times and inside what the impact is of an incident on the entire network.

As stated above, to introduce the concept of a COP is extremely difficult and short term strategies are doomed to fail (Harrald and Jefferson, 2007). This means that for a succesful adoption these concepts need to be carefully introduced. A logical step is to introduce a COP in different stages. The first choice is the user perspective. It make sense to start with those who are controlling and coordinating the response and recovery processes. It is them who will attain and maintain an accurate, shared COP and SA as stated by Harrald and Jefferson (2007). The second choice is which IM actors will be involved. It makes sense that those who are the most involved in the IM process in terms of responsibility and involved incident numbers will take the lead. For IM, these are the road authorities, the police and the towing services. In next stages other IM actors can be involved. The third choice is the data which contains a COP. Table 2 defines which data are relevant in the different IM proces phases as argued before. One of the main problems is information overload (Endsley and Kiris, 1995). Thus it make sense to not integrate all information as mentioned in Table 2 for a first introduction of a COP. The information to support IM can be clustered in different groups: (1) incident text message; (2) geo-information; and (3) sensor information (e.g. camera, detection loop, telecom data). Next to that information need to be filtered and personalized for end users.

The fourth choice is the ambition level for achieving shared SA using a COP. To build up shared awareness all teams need to share information and share understanding of the situation (Albert et al., 2002). Alberts suggest a maturity model to go from the traditional command and control process to self synchronization (see Figure 9):

- Level 0: baseline, traditional command and control;
- Level 1: significant amount of information sharing;
- Level 2: collaboration across location, function and organization among participants;
- Level 3: Improved level 2, by not focusing on sharing information but on what it means;
- Level 4: permits self-synchronization

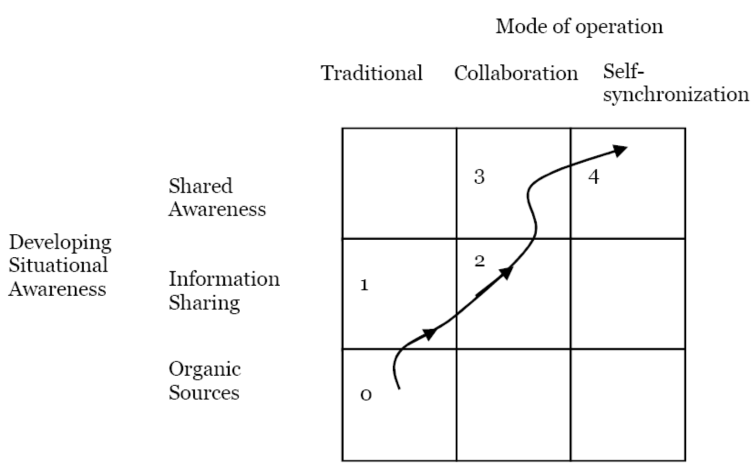

Figure 9: Network-Centric Maturity Model (based on Alberts et al., 2002)

The current IM work processes in the Netherlands could be characterized somewhere between level 1 and 2. However, even on level 1, there are still many problems identified in the daily operations on information sharing and communication.

8.1. Measuring value added service

Netcentric working is a basic constraint to achieve shared SA based on a COP between the different IM organizations. In Table 7 the components of the NEC value chain are combined with the different IM process phases as defined by Zwaneveld et al. (2000). The logic behind this table is the following. Improved situational interface is created by detection, warning and verification based on better information. Better information leads to better responding of the emergency services. By better responding, resources are used more effectively so that better action can take place. This leads to a better outcome, faster clearence of an incident site and therefore to a reduction of traffic jams and vehicle lost hours.

Table 7: Relation between NEC value chain and the IM process phases

NEC Value chain	Incident Management phase	Benefitts
Better networks	Technical infrastructure	field workers and traffic management central
Better information sharing	Detection, warning	Improved Situation interface
Better understanding	Verification	based on improved Situation interface
Better decisions	Respond, driving and arrival	better use of resources
Better actions	Site management, operation, action	more effective field operations
Better effects	Normalization, flow recovery	reduction on traffic jams and vehicle lost hours

The term “picture” in a COP refers not so much to a graphical representation, but rather to the data used to define the operational situation. As such, “the creation and dissemination of the COP is as much an information management challenge as it is a visualization challenge“ (Mulgund and Landsman, 2007). To measure the value added services of SA for IM we introduce a 3D model (see Figure 10). This is based on:

- Level of SA, Reformulation of Endsley’s definition on SA (see Hone, 2006);
- SA components of IM (incident, environment and organizations);
- IM Process phases (see Zwaneveld et al., 2000).

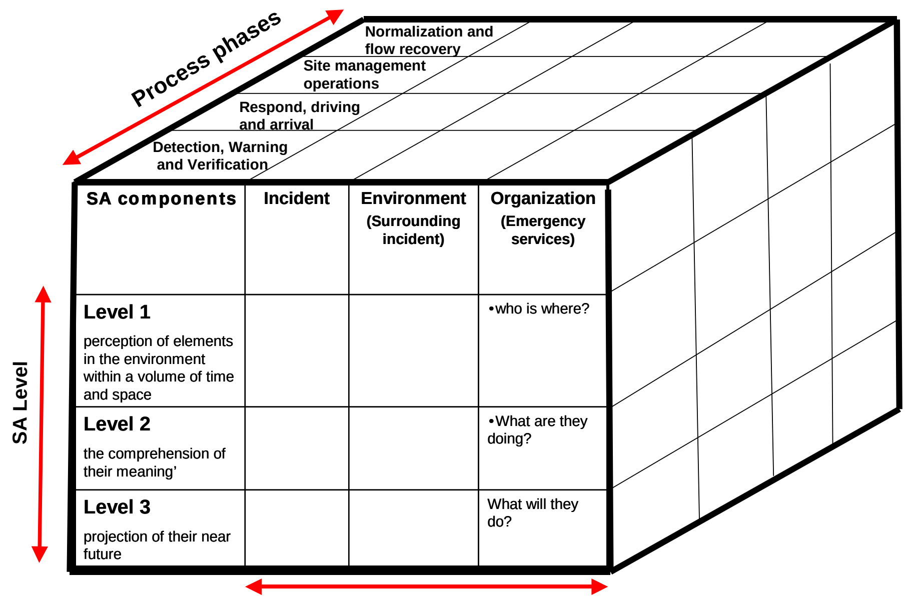

Figure 10: 3D model of measuring SA for traffic IM

This 3D model will be used to measure the qualitative and quantitative value added services in daily traffic IM workprocces between involved organizations. Qualitative aspects will focus on economics effects (Koster and Rietveld, 2011) in terms of reduction of speed and vehicles lost hours. Quantitative aspects will focus more on the quality of collaboration and system- and information quality (Strong et al. 1997; Perry et al. 2004; Singh et al., 2007; Bharosa et al., 2009) . Here for we will use the Technology Acceptance Model (TAM) which is extensively described in literature (Davis, 1989; Venkatesh et al., 2003; Wixom and Todd, 2005). This will be future work and not further described in this paper.

9. PROBLEMS ACHIEVING A COMMON OPERATIONAL PICTURE

There are several private and public actors involved with different responsibilities and tasks to support the IM process which use their own information systems. (Hale, 1997) mentioned that "*The key obstacle to effective crisis response is the communication needed to access relevant data or expertise and piece together an accurate understandable picture of reality*". The problem with today's information systems is not the lack of having information, but to find or display the right information when it is needed. (Endsley and Kiris, 1995) defined this as the 'information gap'. Furthermore, a distinction can be made between have and share information for an effective colloboration between the different chain members. It is widely agreed that more data does not mean better information in terms of information overload.

The terms “common operating picture” and “shared situational awareness” imply that (1) technology can provide adequate information to enable decision makers in a geographically distributed environment to act as though they were receiving and perceiving the same information; (2) common methods are available to integrate, structure, and understand the information; and (3) critical decision nodes share institutional, cultural, and experiential bases for imputing meaning to this knowledge. The first two steps are necessary for the common operating picture, all three are required for a shared situational awareness (Harrald and Jefferson, 2007).

In the literature, many problems are identified to introduce these concepts. Lambert (2001, 2003) and Lambert and Scholz (2005) discuss problems with the different meanings of ‘Common’ in a COP and the nature of information and its presentation. Mulgund and Landsman (2007) describe the different meanings of ‘picture’ in a COP. Problems with individual Situational Awareness can be found in Endsley et al. (2003).

One tenet of the NCW is that information sharing and collaboration enhance the quality of information and shared SA (Alberts, 2002). The value of communication networks depends upon how they are used. Shared SA will result by using the communication networks to disseminate a COP. However, as we move from an individual or narrowly focused operating picture to that of a common operating picture with shared situational awareness the problems increase (Harrald and Jefferson, 2007; Lambert and Scholz, 2005). Primary goal is that effective decisions and actions are related to the right context. Obstacles in sharing and coordinating information are discussed by Bharosa et al. (2010). In an information-rich environment users can be easily overloaded (Endsley and Kiris, 1995). To achieve a ‘shared’ SA for users in diverse roles and operating domains (i.e. contexts). the interpretation of a common ‘picture’ will also be influenced by their individual circumstances (Endsley, 1995).

10. RETROSPECT AND PROSPECT

IM involves the coordinated interactions of multiple public agencies and private-sector partners. Transportation operations and public safety operations are intertwined in many respects. Public safety providers (law enforcement), fire and rescue, and emergency medical services ensure safe and reliable transportation operations by helping to prevent crashes and rescueing accident victims. Conversely, the transportation network enables access to emergency incidents and, increasingly, provides real-time information about roadway and traffic conditions.

Information systems become increasingly important to help daily activities for supporting IM. However, information sharing between different IM organization is still in his early stages of development. Various papers have concluded that information quality and system quality are still major hurdles for efficient and effective multiagency emergency services and are crucial for information systems success (Lee et al., 2011). A COP to create situational awareness becomes more and more accepted as an instrument to add value to share information in an effective way. The introduction of these concepts is extremely difficult and short-term strategies are doomed to fail. In the literature, these concepts are mainly discussed for large-scale disasters and emergency services. Traffic incidents happen on a daily basis and are carried out by trained and experienced emergency services. This should make it relatively easy to adopt and apply these concepts to IM. This paper has demonstrated – through a broad literature overview from different domains – that the use of a COP holds a promise for applying smart IM. Clearly, more work needs to be done to explain the benefits of such systems and to overcome the many problems as identified in the literature.

The following general conclusions can be drawn:

- IM is very relevant for mobility issues and its direct impacts in terms of property damage, injuries and fatalities and road saftety for the road users;
- Road traffic deaths and injuries in the EU are a major public health issue;
- Effective IM activities rely on flexible communications and information systems
- The concepts of COP, situational awareness, and netcentric working have their roots in the military domain and are slowly adopted in emergency and disaster management environments;
- In the literature, there is not yet an accepted model which defines the context variables used in a COP to provide Situational Awareness for IM;
- There are still many unresolved problems identified which are mainly related to the cognitive domain;
- Succesful adoption of these concepts need to be carefully introduced in different stages.

REFERENCES

Adam, E.C. (1993). Fighter cockpits of the future. *Proceedings of 12th IEEE/AIAA Digital Avionics Systems Conference* (DASC), pp. 318–323.

Adams, M., Tenney, Y., and Pew, R. (1995). Situation awareness and the cognitive management of complex systems. *Human Factors* 37(1), pp. 85–104.

Alberts, D.S., Garstka, J.J.and Stein, F.P. (2000). Network Centric Warfare. Developing and Leveraging Information Superiority. CCRP Publication Services, Washington, pp 287.

Alberts, D.S., Garstka, J.J., Hayes, R.E. and Signori, D.A. (2001). *Understanding Information Age Warfare*. CCRP Publication Services, Washington, pp. 319.

Alberts, D.S. (2002). *Information Age Transformation. Getting to a 21st Century military*. CCRP Publication Services, Washington, pp. 155, First published 1996.

Alberts, D.S., Garstka, J.J.and Stein, F.P. (2002). *Network-Centric Warfare: Developing and Leveraging Information Superiority* (2nd ed. Vol. 2): CCRP Publication series.

Bedny, G. and Meister, D. (1999). Theory of activity and situation awareness, *International Journal of Cognitive Ergonomics* 3, pp. 63-72.

Berenschot, (2009), *Eindrapport Kwalitatieve jaarmeting IM 2008*, Leopold, J-H and Doornbos, H.

Bharosa, N., Van Zanten, B., Zuurmond, A. & Appelman, J. (2009). Identifying and confirming information and system quality requirements for multi-agency disaster management. In*Proceedings of the 6th International Conference on Information Systems for Crisis Response and Management (ISCRAM)* (Landgren, J. and Nulden, U. and Van De Walle, B., Eds).

Bharosa N., Lee, J. and Janssen, M. (2010). Challenges and obstacles in sharing and coordinating information during multi-agency disaster response: Propositions from field exercises, *Inf Syst Front* (2010) 12 pp. 49–65.

Boyd, C., Williams, W., Skinner, D. and Wilson, S. (2005). A comparison of approaches to assessing Network-Centric Warfare (NCW) concept implementation, Systems Engineering / Test & Evaluation (SETE 2005) conference, http://www.concepts.aero/documents/SETE-2005-NPI.pdf (last accessed 12-01-2011).

Brown, M. (1996). Supporting User Mobility. International Federation for Information Processing. Graphics, Visualization and Usability Center and College of Computing,Georgia Institute of Technology, Atlanta, GA, USA 30332-0280

Brooijmans, P., Riedijk, A., Jacobs, C., Lassche, R. and Scholten, H.J. (2008). Measurement of the added value of geographic information in disaster management, VU University Amsterdam, Spatial Information Laboratory, The Netherlands, *Proceedings of the 11th GDSI conference*, Rotterdam, the Netherlands, 2009.

Cassens, J., and Kofod-Petersen, A. (2006). Using Activity Theory to Model Context Awareness: A Qualitative Case Study. FLAIRS Conference, Melbourne Beach, Florida, USA 2006 pp. 619-624.

Cebrowski, A. K. and Garstka, J. (1998). Network Centric Warfare: Its Origins and Future, *Proceedings of the US Naval Institute* 124(1) (January, 1998), pp. 28–35

Clark, H.H. and Brennan, S.E. (1991). Grounding in Communication. In Resnick, L.B., Levine, J.M. and Teasley, S.D., eds. *Perspectives on Socially Shared Cognition*. American Psychological Association, Washington, DC, 1991. pp. 127-149.

Corbin, J. and Noyes, P.B. (2003). Traffic Incident Management Planning: The Case for Mainstreaming. ITE Journal, February 2003. Available online: http://www.findarticles.com/p/articles/mi_qa3734/is_200302/ai_n9211940
Davis, F. D. (1989), "Perceived usefulness, perceived ease of use, and user acceptance of information technology", *MIS Quarterly* 13(3): 319–34
Dey, A.K. and Abowd, G.D. (1999). Towards a Better Understanding of Context and Context-Awareness. GITGVU-99-22, College of Computing, Georgia Institute of Technology, ftp://ftp.cc.gatech.edu/pub/gvu/tr/1999/99-22.pdf, 1999. (Accessed 12/01/2011).
Dey, A.K. and Abowd, G.D. (2000). *Towards a Better Understanding of Context and Context Awareness*. Conference paper presented at the CHI 2000 Workshop on the What, Who, Where, When, Why and How of Context-Awareness, April 1-6, 2000.
Dey, A.K. (2001) Understanding and Using Context. *Personal and Ubiquitous Computing Journal* 5(1), 2001, pp. 4-7.
Dominguez, C., Vidulich, M., Vogel, E. & McMillan, G. (1994). Situation awareness: Papers and annotated bibliography. Armstrong Laboratory, Human System Center, ref. AL/CF-TR-1994-0085
Dutch Ministry of Transportation and Water Management in the Netherlands (1999). Policy rules Incident Management Rijkswaterstaat, 1999.
Dutch Ministry of Transportation and Water Management (2003) 'Prestaties Nederlands Wegennet: De ontwikkeling van het wegverkeer, de wegcapaciteit en congestie in verleden en toekomst.' RWS AVV, Rotterdam, mei 2003
Dutch Ministry of Transportation and Water Management (2004), Memorandum on Mobility - Towards a reliable and predictable access, Ministry of Transport, Public works and Water Management, 30 September 2004
Dutch Ministry of Transportation and Water Management (2005). Red blue booklet, the roles of Emergency services in Incident Management in the Netherlands, ISBN 90-369-0097-2 April 2005.
Dutch Ministry of Transportation and Water Management (2007), Verkeersmanagement 2020. De verkeersmanagement ambitie van Rijkswaterstaat voor hoofdwegen. Rijkswaterstaat, februari 2007.
Dutch Ministry of Transportation and Water Management (2008). Policy Framework 'Better Utilization of existing infrastructure'. Ministerie van Verkeer en Waterstaat, Januari 2008.
Dutch Ministry of Transportation and Water Management (2011). Positioning Paper Incident Management. Ministerie van Verkeer en Waterstaat, 2011.
European Conference of Ministers of Transport – ECMT (2007). Managing Urban Traffic Congestion, ISBN 978-92-821-0128-5 - ECMT, 2007
Eijk, R. van, Mulder, I., Hofte, H. ter and Steen., M. (2004). *We-centric, context-aware, adaptive mobile service bundles*. Defining concepts, functionalities and research questions. Telematica Instituut.
Endsley, M. R. (1988). Design and evaluation for situation awareness enhancement. In *Proceedings of the Human Factors Society 32nd Annual Meeting* (pp. 97–101). Santa Monica, CA: Human Factors Society.
Endsley, M. R. (1995). Toward a Theory of Situation Awareness in Dynamic Systems. *Human Factors* **37**(1) pp. 32-64.

Endsley, M. R. and Kiris, E. O. (1995). The out-of-the-loop performance problem and level of control in automation. *Human Factors, 37, pp.* 381–394.

Endsley, M. R. (2000). Theoretical Underpinning of Situation Awareness: Critical Review. In: Endsley MR, Garland DJ, editors. Situation Awareness Analysis and Measurement. Mahwah, New Jersey: Lawrence ErlbaumAssociates, 2000. pp. 3-32

Endsley, M. R. and Garland, D. G. (2000). *Situation Awareness,Analysis and Measurement,* Lawrence Erlbaum Associates, Publishers, Mahway, New Jersey, 2000.

Endsley, M.R. and Jones, W.M. (2001). A model of inter- and intrateam situation awareness: Implications for design, training and measurement. In M. McNeese, E. Salas & M. Endsley (Eds.), New trends in cooperative activities: Understanding system dynamics in complex environments. Santa Monica, CA: Human Factors and Ergonomics Society.

Endsley, M. R., Bolte, B., and Jones D. G. (2003). *Designing for Situational Awareness: An Approach to User-CenteredDesign*, Taylor and Francis, New York, 2003.

Federal Emergency Management Agency. (2009). NIMS FAQ: What is a common operating picture? Retrieved January 12, 2011 from: http://www.fema.gov/emergency/nims/CommunicationsInfoMngmnt.shtm

Feng, Y.H., Teng, T.H. and Tan, A.H. (2009).Modelling situation awareness for Context-aware Decision Support, Expert Systems with Applications 36, 455–463

Fracker, M., (1991). Measures of Situation Awareness: Review and Future Directions, (Rep. No.AL-TR-1991-0128). Wright Patterson Air Force Base, Ohio: Armstrong Laboratories, Crew Systems Directorate

Franklin, D. and Flaschbart, J. All Gadget and No Representation Makes Jack a Dull Environment. AAAI 1998 Spring Symposium on Intelligent Environments, Technical Report SS-98-02 (1998) pp. 155-160

Graves, R. (2004). Key technologies for emergency response. Paper presented at the First International Workshop on Information Systems for Crisis Response and Management ISCRAM2004, Brussels.

Grontmij (2004). *Richtlijn voor incident evaluaties.* De Bilt: Grontmij Advies & Techniek B.V.

Gross, T. and Specht, M., (2001). Awareness in Context-Aware Information Systems, GMD-FIT, St. Augustin, Mensch & Computer 2001: Fachübergreifende Konferenz. Stuttgart: B.G. Teubner, 2001, pp. 173-181

Hale, J. (1997). A layered communication architecture for the support of crisis response, *Journal of Management Information Systems*, summer 1997, 14(1) pp. 235-255.

Hall, R. W. (2002): 'Incident Dispatching, Clearance and Delay', Transportation Research, 36A, 1–16.

Harrald, J. and Jefferson, T. (2007). Shared Situational Awareness in Emergency Management Mitigation and Response, Proceedings of the 40th Hawaii International Conference on System Sciences, 1530-1605/07, 2007 IEEE.

Hartel, C.E.J., Smith, K. and Prince, C. (1991). Defining aircrew coordination: Searching mishaps for meaning. Paper presented at the 6th International Symposium on Aviation Psychology, Columbus, OH.

Homeland Security (2008). *National Incident Management System, december 2008.*

Hone, G., Martin, L., and Ayres, R., (2006) Awareness – does the acronym "SA" still have any value? Proceedings of the 11th International Command and Control Research and

Technology Symposium: Coalition Command and Control in the Networked Era. held at Cambridge UK. Washington

Hull, R., Neaves, P. and Bedford-Roberts, J. (1997). *Towards Situated Computing*. 1st International Symposium on Wearable Computers 1997 pp. 146-153.

Immers, L.H. (2007), Guide to professional Incident Management, TNO-rapport 2007-D-R1242/B Wegwijzer naar professioneel Incident Management, November 2007

Jeannot, E., Kelly, C. and Thompson, D. (2003). The development of situation awareness measures in ATM systems. Brussels: Eurocontrol.

Klein, G. (2000). Cognitive Task Analysis of Teams. In J. M. Schraagen, S. F. Chipman, V. L. Shalin (Eds). *Cognitive Task Analysis*, pp. 417-431. Lawrence Erlbaum associates.

Knoop, V. L. (2009), Road Incidents and Network Dynamics Effects on driving behaviour and traffic congestion. Dissertation 2 december 2009, Technische Universiteit Delft

Koster, P. and Rietveld, P. (2011), Optimising Incident Management on the Road, *Journal of Transport Economics and Policy*, (45) 1 , pp. 63-81, January 2011

Kouwenhoven M., H. Siemonsma, and R. van Grol (2006): 'Voertuigverliesuren door incidenten', Report PM-2066-AVV (in Dutch).

Küpper, A. (2005). Location-based Services - Fundamentals and Operation, Wiley 2005

Lambert, D. A. (2001). Situations for Situation Awareness. *Proceedings of the 4th International Conference on Information Fusion* Montreal, Canada.

Lambert, D. A. (2003). Grand Challenges of Information Fusion. *Proceedings of the 6th International Conference on Information Fusion* Cairns, Australia.

Lambert, D. and Scholz, J., A (2005). *Dialectic for Network Centric Warfare* Proceedings of the 10th International Command and Control Research and Technology Symposium (ICCRTS), MacLean, VA, June 13–16, 2005.

Lee, H. L. and Whang, S. (2000). Information sharing in a supply chain. International Journal of Technology Management, 20(3) pp. 373–387. doi:10.1504/IJTM.2000.002867.

Lee, J. T. and J. Fazio (2005): 'Influential Factors in Freeway Crash Response and Clearance Times by Emergency Management Services in Peak Periods', Traffic Injury Prevention, 6(4), 331–9.

Lee, Y, Bharosa, N, Yang, J, Janssen, M & Rao, H. (2011). Group value and intention to use - A study of multi-agency disaster management information systems for public safety. Decision Support Systems, 50 (1), pp. 404-414.

McKinsey and Company (1995) Filearm wegbeheer (Eng: Tailback free traffic management), Ministerie van Verkeer en Vervoer, The Hague, in Dutch

Merket, D.C., Bergondy, M. and Cuevas-Mesa, H. (1997). Making sense out of teamwork errors in complex environments. Paper presented at the 18th Annual Industrial/Organizational-Organizational Behavior Graduate Student Conference, Roanoke, VA.

Moran, T. and.Dourish, P. (2001). *Special issue on context-aware computing*. Human-Computer Interaction, 16, 2001.

Mulgund, S. and Landsman, S. (2007). User defined operational pictures for tailored situation awareness. Proceedings of the 12th international command and control research and technology symposium – Adapting C2 to the 21st century, Newport, RI, 19–21 June 2007.

NASA: Human-Centered Systems Lab (2006). NASA Ames Research Center, CA [Online]. Available: http://human-factors.arc.nasa.gov/ihi/hcsl/sadisplays.html.

Naval Aviation Schools Command, Pensacola, FL: CRM: Seven Skills (2006). Naval Aviation Schools Command, FL [Online]. Available: https://wwwnt.cnet.navy.mil/crm/crm/stand_mat/seven_skills/sev_skills.asp.

Nofi, A.A. (2000). Defining and measuring shared situational awareness. Center for Naval Analysis, Report CRM D0002895.A1/Final, pp. 76.

Nullmeyer, R.T., Stella, D., Montijo, G.A. and Harden, S.W. (2005). Human factors in Air Force flight mishaps: Implications for change. Proceedings of the 27th Annual Interservice/Industry Training, Simulation, and Education Conference (paper no. 2260). Arlington, VA: National Training Systems Association.

Oomes, A.H.J. (2004). Organization Awareness in crisis management; Dynamic organigrams for more effective disaster management. In B. Carle en B. van de Walle (Eds.), Proceedings of ISCRAM2004, pp. 63-68.

Owens, W. (1996). System of Systems: US Emerging Dominant Battlefield Awareness Promises to Dissipate ‘Fog of War’, *Armed Forces Journal International* (January 1996), p. 47.

Özbay, K. and Kachroo, P. (1999). *Incident Management for Intelligent Transportation Systems* (ITS), Artech House, Massachusetts.

Pascoe, J. (1998). Adding Generic Contextual Capabilities to Wearable Computers. 2nd International Symposium on Wearable Computers (1998) pp. 92-99

Pentagon (2006). Reports Situational Awareness (2006, May). Storming Media, LLC, Washington DC [Online].Available: http://www.stormingmedia.us/keywords/situational_awareness.htm.

Perry, W., Signori, D., & Boon, J. (2004). “Exploring Information Superiority: A Methodology for Measuring the Quality of Information and its Impact on Shared Awareness.” Santa Monica, CA: The RAND Corporation. ISBN 0-8330-3489-8.

Redding, R.E. (1992). Analyses of operational errors and workload in air trafic control. Proceedings of the Human Factors Society 36th Annual meeting pp. 1321-1325, Sante Monica, CA: Human Factors Society.

Reisen, R. van (2006): ‘Incidentele files, de kenmerken, de kosten en het beleid’, SEO Discussion Paper No. 50 (in Dutch).

Rodden, T., Cheverst, K., Davies, K. and Dix, A.(1998). Exploiting Context in HCI Design for Mobile Systems, Workshop on Human Computer Interaction with Mobile Devices.

Roy, J. (2007), A Knowledge-Centric View of Situation Analysis Support Systems, (TR 2005-419) DRDC Valcartier. Technical Report, January 2007.

Salas, E., Prince, C., Baker, P.D. and Shrestha, L. (1995). Situation awareness in team performance, *Human Factors*, 37, pp 123-126.

Salmon P., Neville, M., Stanton, A., Ladva, D., Jenkins, D.P., Walker, G.H. and Rafferty, L. (2007). Measuring Situation Awareness during Command and Control Activity: A Comparison of Brunel University Measures Study Human Factors Integration Defence Technology Centre 2007, HFIDTC/2/1.2.5/3, Version 2/ 25 September 2007.

Sarter, N. B. and Woods, D. D. (1991). Situation Awareness - A Critical But Ill-Defined Phenomenon. *International Journal of Aviation Psychology*, 1 pp 45-57.

Schilit, B., Adams, N. and Want, R. (1994). *Context-Aware Computing Applications*. 1st International Workshop on Mobile Computing Systems and Applications pp. 85-90.

Schmidt, A., Beigl, M. and Gellersen, H.W. (1999). *There is more to Context than Location.* Computer and Graphics 23(6) pp. 893-901.

Schrijver J., B. Immers, M. Snelder, and R. de Jong (2006): ‘Effecten van de landelijke invoering van incidentmanagementmaatregelen op de voertuigverliestijd in het netwerk’, TNO Mobility and Logistics (in Dutch).

Singh, P., Singh, P., Park, I., Lee, J., and Rao H.R., (2007), Information Sharing: A study of information attributes and their relative significance during catastrophic events

Smith, K. and Hancock, P.A., (1995). Situation awareness is adaptive, externally directed consciousness, *Human Factors* 37, pp. 137-148.

Stanton, N. A., Chambers, P. R. G. and Piggott, J. (2001). Situational awareness and safety. *Safety Science*, 39, pp.189-204.

Strong, D.M., Lee, Y.W., and Wang, R.Y. “Data quality on context.” *Communication of the ACM*, 40(5). 1997. pp.103-110.

Turoff, M. Chumer, Walle, B. van de, and Yao, X. (2004). The Design of a Dynamic Emergency Response Management Information System (DERMIS), *The Journal of Information Technology Theory and Application (JITTA)*, 5(4), pp. 1-35.

UK Ministry of Defence (2005). Networked Enabled Capability JSP 777 Edition 1, UK Ministry of Defence, http://www.mod.uk/DefenceInternet/AboutDefence/CorporatePublications/ScienceandTechnologyPublications/NEC/Jsp777NetworkEnabledCapability.htm (last accessed 12-01-2011).

US Department of Defense (2005), *Dictionary of Military Terms*, available from http://www.dtic.mil/doctrine/jel/doddict/; Internet; accessed 12 January 2011.

US Federal Highway Administration (2000). *Traffic Incident Management Handbook*, Office of Travel Management.

US Federal Highway Administration (2004), Traffic Congestion and Reliability: Linking Solutions to Problems prepared by Cambridge Systematics with Texas Transportation Institute, July 19, 2004

US National Cooperative Highway Research Program (2004). Sharing Information between Public Safety and Transportation Agencies for Traffic Incident Management, NCHRP Report 520, K. Brooke, K. Dopart, T. Smith and A. Flannery, Mitretek Systems, Inc. Washington, DC, Transportation Research Board, ISBN 0-309-08792-9.

U.S. Department of Transportation (2009). Information Sharing for Traffic Incident Management, Federal Highway Administration, Ingrid Birenbaum, Report No. FHWA-HOP-08-059.

Venkatesh, V., Morris, M.G., Davis, G.B., and Davis, F.D. (2003). User acceptance of information technology: Toward a unified view. MIS Quarterly, 27(3):425-478, 2003.

Waltz, E. (2003). Knowledge Management in the Intelligence Enterprise, Artech House, Norwood, MA, 2003.

Ward, A., Jones, A. and Hopper, A. (1997) A New Location Technique for the Active Office. IEEE Personal Communications 4(5) pp. 42-47.

Wark, S., Lambert, D., Nowina-Krowicki, M., Zschorn, A. and Pang, D. (2009). *Situational Awareness: Beyond Dots On Maps To Virtually Anywhere* (2009).

Wickens, C. D. (2008). Situation Awareness: Review of Mica Endsley’s 1995 Articles on Situation Awareness Theory and Measurement, HUMAN FACTORS**,** Vol. 50, No. 3, June 2008, pp. 397–403. DOI 10.1518/001872008X288420.

Wixom, B. H. and Todd, P. A. (2005). A Theoretical Integration of User Satisfaction and Technology Acceptance. *Information Systems Research*, *16*(1), 85-102.

Wilmink, I. R. and L. H. Immers (1996): ‘Deriving Incident Management Measures Using Incident Probability Models and Simulation’, Transportation Research Record, 1554.

World Health Organization (2004). *Preventing road traffic injury: A public health perspective for Europe*, (Report from Francesca Racioppi, Lars Eriksson, Claes Tingvall and Andres Villaveces) ISBN 92 890 1093 2.

World Health Organization (2009). *Global status report on road safety, time for action* ISBN978 92 4 156384 0.

Washington State Department of Transportation (2011). Incident Response Evaluation, WSDOT Research Report, February 2011.

Zwaneveld P., Wilmink, I., Immers, B. Malipaard, E. and Heyse, D. (2000). An overview of Incident Management projects in the Netherlands. Peter Zwaneveld, Isabel Wilmink TNO Inro Ben Immers, TNO Inro and K.U. Leuven, Department of Civil Engineering Emst Malipaard, Grontmij, Dick Heyse Rijkswaterstaat, Projectbureau Incident Management.

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