

# Situational incident command in the Fire Service



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Instituut Fysieke Veiligheid  
Brandweeracademie  
PO box 7010  
6801 HA Arnhem  
The Netherlands  
www.ifv.nl  
info@ifv.nl  
+31 26 355 24 00

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Authors: J.C. Hazebroek, B. van 't Padje, J. Groenendaal, T. Geertsema,  
M.A. Hagenars  
Reflections by: I. Helsloot, E. Oomes  
With the cooperation of: A.C. Boon, P.R.J. Jetten, C.S.M. Tonnaer, M.N.M. Bertels  
Photography: T. de Kort (cover), GelreNieuws  
Project Manager: J.C. Hazebroek  
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# Preface

It is with great pride that I present the English version of the final report of the study 'Innovative Approach of Incident command'. It has become a comprehensive and unique study, to which many firefighters and experts from around the country have contributed. I use the term unique because the experiments that were conducted had never been conducted in such a way. The study is also unique because a connection was made between the command type and the human factor. Leading experts in this field have contributed to this study and have reflected upon the results. In this report the results as well as these reflections (chapters 7 and 8) are presented.

The study was started as a consequence of the fire service internal evaluation of the major chemical fire in Moerdijk (the learning arena), where it was concluded that the command structure, as it is described in the learning materials, is not followed in practice. Since many colleagues from around the country recognised this during the learning arena, it was considered to be a so-called 'second order learning point'. With this study, we have formulated a proper response to the fire service's second order learning point and we can provide education and training that is more practice oriented.

The study provides a renewed understanding of the way in which large-scale incidents are managed and how to improve this. The insights regarding the importance of the human factor were an eye opener to me. I think that these insights can be applied far wider than the fire service and I think it should lead to a paradigm shift in the organisation, assessment and evaluation of crisis management.

The study presents a proposal for 'situational incident command', based on the theory that was tested by comparative simulation research. It proposes to adjust the current type of incident command, and this will not only be an improvement, but will also fit in with actual practice. The integration of tools that create a 'forgiving infrastructure' for the 'fallibility' of the people in the system is a real innovation. Therefore, it is with good reason that we speak of an 'innovative approach of incident command'.

The study was conducted under the umbrella of the professorship of Fire Service Science (Lectoraat Brandweerkunde) and is one of the cornerstones of the current research by the Lectureship, as is the research into the tactics and techniques of the quadrant model. The study was funded by an innovation subsidy of the Ministry of Security and Justice and by contributions from a number of Fire Service Regions and the Brandweeracademie (Fire Service Academy).

The following fire brigades, safety regions and other parties have contributed financially and/or in terms of content or participated in the experiments:

- > Fire Service Amsterdam-Amstelland
- > Fire Service Gelderland-Midden
- > Safety Region Kennemerland
- > Fire Service Brabant-Noord
- > Fire Service Midden- en West-Brabant
- > Safety Region Noord-Holland Noord
- > Safety Region Haaglanden

- > Fire Service Rotterdam-Rijnmond
- > Fire Service Hollands Midden
- > Fire Service Twente
- > Fire Service Antwerpen
- > Crisislab
- > Rizoomes
- > Brandweeracademie

I am convinced that the great results from this study can be used instantly in education and training which subsequently are better geared to the practice and will lead to an improvement of incident command. The Brandweeracademie will use the outcomes of this study as a basis for the lessons on incident command in the education and training of fire service officers. At this moment we conduct a pilot study into the practical implications of 'situational command' in cooperation with 60 officers from four fire service regions. Part of that pilot is a completely new fire officers training based on the results of this study.

Nevertheless, there are still many subjects for further research. Therefore, I hope that in the years to come further research will be conducted into command types and human factors in actual practice. The assessment framework that was constructed in the context of this study can be used to collect data on the practice of incident command, and in doing so an even better understanding thereof can be gained. As of November 2015, the Brandweeracademie will create a database on large-scale firefighting and rescue and rescue operations based on this assessment framework. I hereby kindly request the cooperation of the fire brigades for this.

This document is a (partly summary) end report. A separate partial report is available (in Dutch) for phase 1 (the theoretical part) and for the comparative simulation research into the command types.

I would like to thank everyone who, in one way or another, contributed to this study. Without the financial contribution of the Ministry of Security and Justice, the fire service regions and the Brandweeracademie, but also the cooperation from the many firefighters and officers from the regions, this unique study would not have been possible on such a scale.

Ricardo Weewer  
Professor of Fire Service Science  
Brandweeracademie

# Swarming: an 'old friend'

*Discussion by the reviewer of Situational Incident command*  
M.J. van Duin, Lector Crisis Management IFV

The book *Bureaucracy* (1989) by James Q. Wilson is considered a true classic in organisational science. It starts with a story about the beginning of the Second World War. The so-called 'Blitzkrieg' played an important part in Germany's rapid success. In May 1940, the French, British, Belgian and Dutch armies were wiped out in just a few weeks. Wilson indicates that this was not the result of stealthy and unexpected attacks, as is commonly assumed, (most of the attacks were announced and the opponents were far from taken by surprise), nor did the Germans possess a technological or numerical superiority. The success could be contributed to totally different factors.

The smaller units of the ground forces, crossing the river Maas in small boats, were predominantly what determined Germany's success. There was not one operational commander commanding the entire army; there were small units *'to permit independent actions by its smallest units'* (p. 15). There was a *'...mission oriented command system. Operational commanders were to tell their subordinates precisely what was to be accomplished but not necessarily how to accomplish it.'* (p. 16).

Wilson presents a similar analysis of a successful reorganisation in the prison system, where prisoners were allocated clear responsibilities, and in education, where a new principal manages to get a difficult school back on track. In the latter case, again, responsibilities were to a large degree decentralised (with a strong leader!) and teachers and pupils were given clear (individual) roles.

As a sociologist and public administration expert, it pleases me to see that the fire service has also started to distance itself somewhat from the hierarchical command structure, for the moment only with regard to crew commanders, but this process will undoubtedly continue. This is for me the main value of the study 'Situational incident command in the Fire Service'. The opposite of the traditional hierarchical way of commanding is 'swarming', i.e. more flexibility and the individual leaders (lower in rank) mainly choose their own way. As the situation gets more complicated, swarming will be the preferred and necessary technique.

For a long time, people in charge of operational services were under the impression, and some of them still are, that they are capable of processing large amounts of data from different sources, and subsequently manage and make decisions during all kinds of large(r) incidents. I myself will never forget an exercise at Schiphol Airport in Amsterdam almost fifteen years ago. The operational commanders were leading the troops in the field, managing three or four radios simultaneously (with two ears!) while they were being addressed by others at the scene. In fact, operational leaders for multi-incidents are trained in this way as well, to be someone who processes large amounts of data in a timely fashion and subsequently takes the right steps.

The value of this study is that it supposes that the human factor has its limits, and rightly so. No human being is capable of such miracles and if we look at Klein et al. and their investigations (Naturalistic Decision-Making) we know that experience is of great importance as well. Without sufficient experience, the person in charge cannot fall back on the knowledge he or she gained earlier in practice. I hope and expect that these research efforts will be followed up, so as to find out whether aspects, such as 'freezing', and the possible options for improvement, such as 'mindfulness', can add surplus value. To me, swarming is a valuable start!

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# 1 Introduction

The fire service uses a hierarchical command model for large-scale incident management<sup>1</sup>. The model dictates that at all times the fire service organisation has single-headed leadership. Firefighters, crew commanders (*bevelvoerders*), fire officers (*officieren van dienst, OvD*) and senior fire officers (*hoofd officieren van dienst, HOvD*) are always in a fixed hierarchical relation to each other. The highest operational commander is in charge of the incident from the moment of the alarm, even if he or she has not yet arrived at the scene. There is a standardised alarm procedure that describes which units and functionaries have to be present at which type of incident. There is a rather strong emphasis on predetermined working procedures and proposed ways of attack. In training sessions, procedures and education programmes, usually the following arguments are given for the hierarchical command model.

- > The speed of decision-making is high because there is hardly anything that central management has to discuss first.
- > The organisation is efficient because all parts of the fire service organisation use the same approach ('everyone is on the same page') and follow standardised work processes as much as possible.
- > The officers build a complete and joint image (overview) based on the information provided by the crew commanders and they subsequently share this with them.
- > Because of this complete overview, the (senior) fire officers are in the best position to explicitly decide on the necessity of an attack versus the risks to be taken.
- > The fact that (senior) fire officers monitor the acts of the crew commanders is an additional guarantee for work safety.

However, in practice and from the conclusions of incident evaluations<sup>2</sup> it turns out that the fire service deviates from the hierarchical command model during large-scale incidents. Deviations that have been identified include:

- > There are more, fewer or other firefighting and rescue personnel at the scene than devised beforehand.
- > Units start an attack without instructions from the highest ranking officer at the scene.
- > The distribution of work turns out differently than expected beforehand.
- > The standard approach for handling bottlenecks is not used.
- > Safety procedures, such as disinfection procedures, are deviated from, or are not executed as laid down.
- > Superiors fulfil roles that are not laid down in the official design, such as fire officer aftercare or safety officer.
- > Communication between crews follows different paths than expected and hierarchy is not involved.
- > The regular cold (daily) management structure is used, next to the official warm command structure.

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<sup>1</sup> 'The fire service organisation has a hierarchical organisational structure in which the fire officer is the connecting executive link between the crew commander and the senior fire officer.' And: 'The fire officer directs specialists and takes on the management of the incident.' (Textbook OVD, 2012) Also see: *Bevelvoerder Oriëntatie, 2011* (Crew Commander Orientation).

<sup>2</sup> The incident at Moerdijk (NVBR, 2011), the wildfire on the Hoge Veluwe (Zijp, Slakhorst, Buiting, Hilgenberg & Beekhuis, 2014), the fire on the fishing ship Johanna Maria (Van den Ende, Frentz, Hazebroek, Tonnaer & Van Werkhoven, 2015) and the fire in the senior citizens' apartment building 'De Notenhout' in Nijmegen (to be published).

In 2013, the Fire Service Academy, with the support of the Ministry of Security and Justice and ten regional fire brigades, started an investigation into how to innovate incident command (during large-scale incidents), based on both actual practice and observations during incident evaluations.

## 1.1 Objective

The objective of this study is to create a new model that enables the fire service in the Netherlands to improve the effectiveness of its incident command during large-scale incidents. Central to his model is the fire service operational commanders' adaptability under stressful circumstances. Among other things, the organisational design of incident command during large-scale firefighting and rescue operations was looked at to research whether the unpredictability of the task environment was taken into account. Maybe the current design is too rigid, which would explain why there are so many deviations. The basic design of incident command, in relation to the required adaptability to be able to manage large-scale incidents, is key.

A command structure is always carried out and executed by people. It is always possible to develop new, more effective structures, but if the human factors are not taken into account, there is no guarantee that the new structure will work.

Therefore, often extra attention is paid to the stress that large-scale incidents generate and how it affects the decision-making by operational commanders. This stress is a decisive factor<sup>3</sup> for the accomplishments of incident command. It is expected that by involving human factors into the system of incident command, an entirely new course can be followed as far as improving decision-making is concerned, and the education, training, recruitment and selection of operational commanders.

This is why the Fire Service Academy (on behalf of the Organisation of Dutch Fire Services) participates in the European Union project *Firemind*<sup>4</sup>, aimed at the research into situational awareness and self-reflection on this competence. Obviously, there is a close connection between incident command and situational awareness.

## 1.2 Research Question

Central to this study are the following principal questions.

1. To what extent and for what reason is it problematic that the incident command of large-scale firefighting and rescue operations deviates from its organisational design?
2. What modifications of the organisational design and/or the execution of incident command can improve large-scale firefighting and rescue operations?

The research questions were selected based on the hypothesis that operational commanders have to adapt their incident command to the situation at hand during large-scale firefighting and rescue operations.

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<sup>3</sup> Christis (1997); Jansen (1996).

<sup>4</sup> The project *Firemind* researches the competence 'situational awareness' and the self-reflection on this competence. In this study, situational awareness is about how information is processed and applied in order to take safe and effective suppressive action. Participating countries include, among others, the United Kingdom, Denmark, Germany and Belgium.

It is assumed that the specific situation plays a decisive part for the way in which the fire service manages the incident. The foundation for this hypothesis was laid in the framework that was published at the end of 2014 (Van 't Padje, Groenendaal & Hazebroek, 2014).

### 1.3 Three Research Phases

The study of innovative incident command consists of three phases to find answers to the two principal questions.

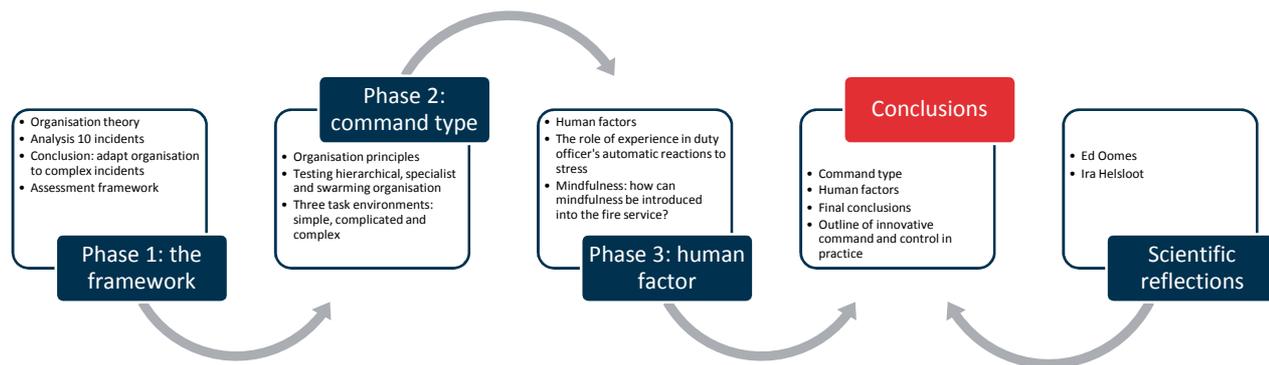
1. Phase 1 contains the creation of a theoretical model with which large-scale operations can be analysed and assessed. This is called the Analysis and Assessment Framework. In addition to the framework, several hypotheses were drawn up on how to improve incident command during large-scale firefighting and rescue operations. Phase 1 was concluded by the end of 2014 with the publication of the interim report *Innovatieve kijk op commandovoering – Het Raamwerk* (Innovative Approach of Incident command - The Framework) (Groenendaal, Hazebroek & Van 't Padje, 2014). In this interim report, hypotheses were drawn up, based on the theory found, and (subsidiary) research questions were formulated for phases 2 and 3. These hypotheses and (subsidiary) research questions for phases 2 and 3 can be found at the end of chapter 2: the theoretical basis of innovative incident command. The layout of this report follows the way in which the study was conducted.
2. In phase 2, testing the hypotheses on incident command is central. This comparative simulation research regards organisation principles and focuses on the question of how strong the hierarchy of the fire service should be (Hazebroek, Van 't Padje & Groenendaal, 2015). Phase 2 was concluded by the interim report *Deelrapport Commandotypen* (Interim Report Command Types) that was published on 1 September 2015.
3. In phase 3, testing the hypotheses is central, this time with regard to
  - > the role of experience on automatic stress responses, the powers of observation of fire officers and
  - > the helpfulness of mindfulness training for functioning under stress.In the sub-studies, the human factors were examined in order to find out how operational commanders can manage the stress that comes with large-scale incidents more effectively.

With this publication, all three research phases of the project 'Innovative Incident command' are completed.

### 1.4 Publication Layout

This publication contains the summary of the research results from phases 1, 2 and 3. The results from phases 1 and 2 will be presented in brief. For the complete studies, please see Van 't Padje et al. (2014) and Hazebroek et al. (2015). The results from phase 3 are discussed for the first time in this publication and will, therefore, be presented in more detail. Furthermore, I. Helsloot and E. Oomes, two prominent scientists in the field of firefighting and rescue, were invited to reflect upon the results and experiments in order to achieve an even more comprehensive perception of incident command in firefighting and rescue. Their reflections provide an additional basis for the final conclusions and, at the same time, offer extra points of departure for possible follow-up research.

The following figure depicts the coherence between the various phases of the research into innovative incident command, and the layout of this publication.



**Figure 1: Phasing Incident command Study**

## 1.5 Type of Research

For the main theme of the entire study, a specific type of research was used: developmental research, which is called design research. In this type of study, practical solutions are designed and tested on the basis of theoretical insights (Van Thiel, 2010). The study used three scientific domains to design the command model, and to find and formulate proposals for improvement:

- > Policy evaluation theory: in which way can (the execution and outcome of) large-scale firefighting and rescue operations be evaluated most accurately?
- > Organisational science: what organisational principles are the most appropriate for incident command during large-scale incidents?
- > Human factors: how can the operational commanders' stress, which is caused by an incident, be most effectively managed?

For the execution of the three sub-studies, various other types of research were used, which are described in the relevant chapters.

## 1.6 Research WITH and FOR the fire service

The study was conducted under the umbrella of the Lectureship Firefighting and rescue Expertise of the Fire Service Academy and was partly funded by the Ministry of Security and Justice. The fire brigades and other organisations listed below, contributed to the research, including in terms of content.

- > Fire Service Amsterdam-Amstelland
- > Fire Service Gelderland-Midden
- > Safety Region Kennemerland
- > Fire Service Brabant-Noord
- > Fire Service Twente
- > Fire Service Midden en West Brabant
- > Safety Region Haaglanden
- > Fire Service Rotterdam-Rijnmond
- > Fire Service Hollands Midden
- > Fire Service Antwerpen
- > Safety Region Noord-Holland Noord

- > Crisislab
- > Rizoomes

Apart from the participation of the organisations, a total of around 250 crew commanders and officers from the participating regions were present at the experiments, acting as a participant or observer. Everyone, without exception, was enthusiastic about the research objective. The fire service's close involvement with this study was much appreciated.

## 1.7 Definition

This study focuses on incident command during large-scale firefighting and rescue operations. A large-scale firefighting and rescue operation is defined as an attack with four or more engine companies. The focus of this study is on the following three levels of incident command: 1) crew commander, 2) fire officer (in US: battalion chief), and 3) senior fire officer (in US: district or deputy/ assistant chief), since these officials are designated to make decisions about the deployment of the fire service. The role of and relationship with traditional chain partners - medical emergency services, municipalities and the police - are not taken into consideration. Neither are the communicative, political and administrative aspects of large-scale incidents looked at in this study. The research into incident command during large-scale firefighting and rescue operations results in a new model, based on scientific knowledge that promotes the further innovation of monodisciplinary and multidisciplinary decision-making during crises.

The study aims to eliminate operational bottlenecks, i.e. limit and fight threats to physical safety, and impairment of physical safety. As far as types of incidents were concerned, the study especially looked at large-scale, serious and acute incidents, such as very large fires, accidents with hazardous materials and large-scale traffic accidents.

The study into large-scale firefighting and rescue operations did not have the objective to find out whether particular procedures were followed or not, and what the consequences were. It was aimed at the model itself. The research and the resulting model are limited to the operational aspects of incident management, i.e. how to eliminate threats to physical safety.

The study's broad scientific approach does not affect the fact that not all available scientific knowledge about incident command was taken into account. The resulting command model is not complete or all-encompassing. There are other models available as well. For instance, the Dutch Armed Forces have their own doctrine, which in some aspects differs from the command model created in this study (Ministry of Defence, 2005). Therefore, the command model resulting from this study has to be regarded as a model that provides some well-founded improvement proposals, but it is simultaneously a growth model that will have to be further developed. It is a first step in the direction of a different type of incident command, specific for the fire service.

# 2 Theoretical Basis of Innovative Incident command

## 2.1 Introduction

In this chapter, the theoretical foundation is laid for the research into innovative incident command. This theoretical foundation is based on the outcomes of Phase 1 (Van 't Padje et al., 2014) and relates to monodisciplinary operational incident command during large-scale firefighting and rescue operations. In the following chapters, this theoretical foundation is used in a comparative simulation research, an experiment and a pilot.

In this study 'incident command' is defined as:

1. making decisions on operational issues, i.e. the approach to eliminate a threat to physical safety, and
2. the subsequent execution of these decisions.

In this theoretical foundation, incident command is discussed from three lines of approach, which are all aimed at improving the fire service's adaptability.

- > Organisation principles: aimed at the management and set-up of units and functionaries (Section 2.2).
- > Human factors: aimed at the performance of the people that have to make and execute decisions in simple, complex and dangerous situations (Section 2.3).
- > Business intelligence: aimed at informing the fire service about the degree of complexity of the situation, and on the performance of the fire service itself<sup>5</sup> (Section 2.4).

On the basis of the theoretical foundation in Sections 2.2 up to and including 2.4., Section 2.5 outlines the grounds for the follow-up research that was performed in Phases 2 and 3.

In this chapter, the model aspects of the three lines of approach of the research into innovative incident command are concisely presented. A more detailed presentation, inclusive of a justification of the research methods, can be found in *Innovatieve kijk op commandovoering – Het Raamwerk* (Innovative Approach of Incident command - The Framework) (Van 't Padje et al., 2014).

## 2.2 The Organisation Principles

Central to the theoretical model of incident command is the adaptability of the fire service.

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<sup>5</sup> Business intelligence includes decision support, accessibility maps and object information.

Based on organisation and systems theory<sup>6</sup> it is assumed that the fire service will perform better when the operational commanders adjust themselves rapidly and effectively to the incident characteristics.

The current fire service's organisational designs are of the 'one size fits all' type. There is only one organisational design per incident type, whereas there can be huge differences between incidents of the same type, for instance with regard to complexity. To be able to properly manage these differences in complexity, and to optimise fire service performance, operational commanders have to be capable of adjusting the fire service organisation to the situation, i.e. to the incident characteristics (Van 't Padje et al., 2014). The basic assumption is that the fire service organisation has to be as flexible as the incident that it has to deal with. The general idea behind this is: the more complex, dynamic and unpredictable the incident, the stronger the operational commanders' adaptability has to be. This is known as situational balance.

The developed model for incident command divides adaptability into two components: situational balance and internal balance.

### 2.2.1 Situational Balance

Situational balance supposes that the command type has to be geared to the incident's degree of complexity. Van 't Padje et al. (2014) defined three incident types based on the degree of complexity: simple, complicated and complex. Subsequently, three archetypes of incident command were defined: hierarchical, specialist and swarming. These archetypes differ in degree of flexibility. A balance exists when the degree of complexity of the incident type and the degree of flexibility of the command type are in equilibrium (see Table 1 below).

Situational balance		Command type		
		Hierarchical	Specialist	Swarming
Incident type	Simple	BALANCE	IMBALANCE	IMBALANCE
	Complicated	IMBALANCE	BALANCE	IMBALANCE
	Complex	IMBALANCE	IMBALANCE	BALANCE

Table 1: Situational Balance

### 2.2.2 Internal Balance

The internal balance concerns the requirement that operational command has to be well-balanced. The internal balance supposes that the ability of command to determine the right approach (controlling power) and to properly execute this approach, or to have it properly executed (manageability) have to be equally flexible.

<sup>6</sup> Systems theory is concerned with the complexity of systems and the interdependence between the various parts of the system. In this study, systems theory is considered dominant (Hassard, 1991; Huguenin & Van Gestel, 2007).

However, to be able to determine and adjust an approach with flexibility is only useful if the organisation is capable of responding rapidly and if the chosen approach is feasible. The interplay between controlling power and manageability is called the internal balance. Refer to Section 2.2.4 for a more detailed discussion of both terms.

### 2.2.3 The Complexity of the Incident

An incident, or task environment, consists of the following three components (also see Figure 2).

- > Cause: the (potential) threat to physical safety.
- > Dynamics: the way in which the (potential) threat develops.
- > Stakeholders and objects: the individuals, objects and areas that are threatened by the cause.

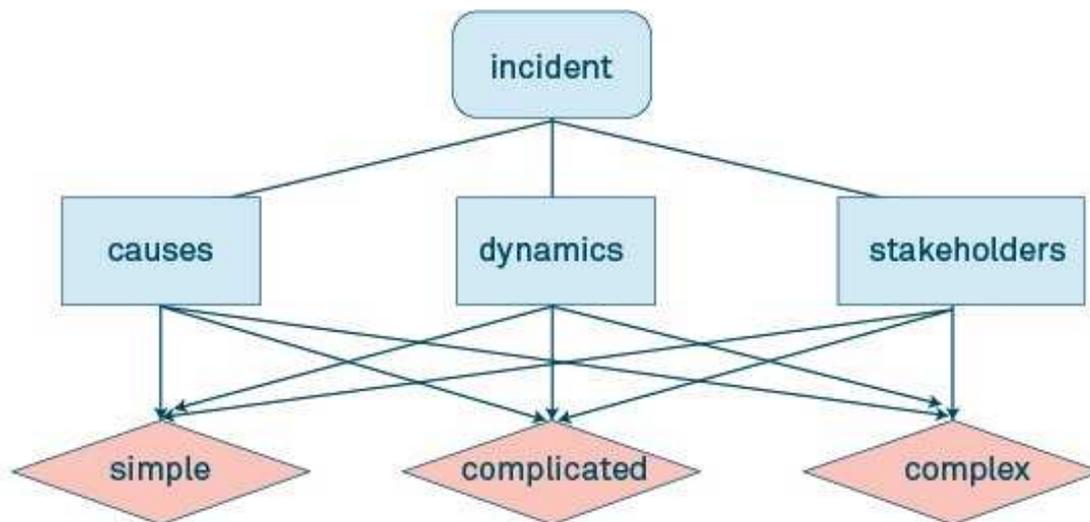


Figure 2: Complexity of an Incident

In this study, the complexity of an incident is defined as the degree of heterogeneity, dynamics and interdependence of the components of the incident (based on the definition of complexity by Lee, 1997). In this study, these concepts are defined as follows.

- > Heterogeneity: the various aspects (fire, persons being trapped, collapse, hazardous materials) that jointly make up the incident.
- > Dynamics: the degree in which the incident develops. Consider, for example, the heat of a fire, fire spread to other properties, density and toxicity of smoke, stability of the oxygen supply, force of the wind and stability of the wind direction.
- > Stakeholders: the number of persons concerned in the incident and the degree in which their interests correspond or differ. For instance, in case of a fire in an urban area: is there just one family of four involved or are there families involved with persons in need of care, and has the fire spread to the car park?
- > Interdependence: the degree in which the various aspects (fire, persons being trapped, collapse, hazardous materials), stakeholders and dynamics are connected. In the case of a plane crash, consider for instance: the type of area that has been hit (polder, urban area, industrial area), the type of plane (cargo, passenger), the amount of kerosene present, the risk the kerosene ignites, the number of passengers and their degree of self-sufficiency, the number and type of bystanders that provides aid.

The most important indicator for complexity is the predictability of a specific configuration or a condition of the incident. To what extent will the incident inevitably develop in a certain way? The more heterogeneity, dynamics and interdependence between the components of the incident, the less predictable an incident becomes. Van 't Padje et al. (2014) translated the degrees of complexity into three basic incident types: simple, complicated and complex.

### ***Simple incident***

A simple incident has one or more causes that threaten the physical safety of a few stakeholders in a relatively linear way. Examples of this type of incident are: (large) pallet fires or a fire in a freestanding and non-compartmentalised building in which the fire development is linear and predictable.

### ***Complicated incident***

The complexity of an incident grows, as the number of specific characteristics of the causes and/or stakeholders/objects grows, i.e. the degree in which their characteristics have specific, unique and/or deviant values. Consider, for example, the difference in smoke toxicity that is generally generated by a living room fire versus the smoke toxicity generated by a fire in a hazardous materials depot. With most fires, the toxicity is more or less similar, but with some types of fire it can be very different. This deviation increases the uniqueness and, with that, the complexity of the incident.



**Figure 3: A ship fire is a Complicated Incident**

### ***Complex incident***

We use the term complex incident when there are many (different) causes and the stakeholders/objects are strongly connected and influence one another. Because of this connectedness, small changes in one of the causes and/or stakeholders/objects can lead to significant changes for the incident as a whole (non-linearity). Complex incidents usually have a highly dynamic character.

During the incident, the degree of complexity changes step by step. Some incidents start out small, grow and become more and more complex. Other large-scale incidents start out complex, but subsequently rapidly become less complex. Every incident has a number of complexity phases, which are determined by the changes in incident characteristics. The fire service is faced with the challenge to adapt itself to these changing circumstances.

## 2.2.4 Command Type Flexibility

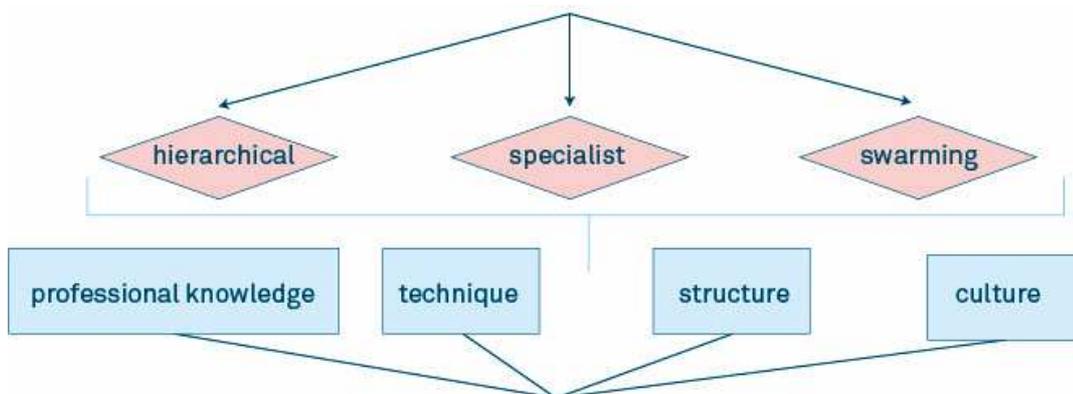
Command must have the ability to determine the right approach of an incident (controlling power) and must execute it or have it executed (manageability). Paragraph 2.2.3 shows that, in terms of flexibility, these abilities have to be adjusted to the complexity of the incident.

The *controlling power* is determined by the operational commanders' level of professional knowledge. Professional knowledge consists of two components:

- > the width and depth of expert knowledge (including the analytic ability to use this expert knowledge), and
- > the operational commanders' incident experience, i.e. how many incidents of any specific type has the operational commander experienced?

*Manageability* is determined by:

- > technique: the type and (available) number of resources to handle the incident
- > structure: the way in which tasks are allocated and the way in which the coordination between tasks is established.
- > culture: the habits, standards and values that are deemed self-evident and important by the fire service.



**Figure 4: Command Type as a Coherent Whole of Professional Knowledge, Technique, Structure and Culture**

A *command type* is an internally coherent whole between controlling power and manageability. Three basic forms of incident command have been identified.

1. Hierarchical – more or less the current model of incident command, based on the principle of single-headed leadership, a fixed and predetermined number of units per incident type, emphasis on standardised working procedures and relatively limited requirements regarding the level of professional knowledge.
2. Specialist – partly the current model<sup>7</sup>, based on the principle of specialist units and functionaries per incident type, with the important difference that the functionary with the highest level of relevant professional knowledge is in charge and that there is a greater emphasis on a participatory leadership style.
3. Swarming – for the most part different from the current model, based on the principle of self-managing teams and with great emphasis on a participatory leadership style,

<sup>7</sup> Consider 'Visie Grootschalig Brandweeroptreden 2012-2016' (Vision Large-scale Firefighting and rescue Operations 2012-2016) and 'Visie op bovenregionale brandweerspecialismen in Nederland' (Vision on Supraregional Fire Service Specialties in the Netherlands).

variable and redundant numbers of teams and functionaries, emphasis on the ability to improvise and higher demands regarding the level of professional knowledge.

Ideally, every *command type* fits a certain incident type, as is depicted in Table 5.

- > Hierarchical – Simple
- > Specialist – Complicated
- > Swarming – Complex

In the table below, all aspects of the manageability and controlling power are clustered by command type.

**Table 5: Various Aspects of the Three Command Types**

Command type		Hierarchical	Specialist	Swarming
<b>Technique</b>	Degree of specialisation of vehicles and teams	Average	Maximum	Minimum
	Degree of power of the hierarchy	Maximum	Average	Minimum
<b>Structure</b>	Degree of redundancy	Minimum	Average	Maximum
	Degree of standardisation	Maximum	Average	Minimum
<b>Culture</b>	Degree of participation in incident command	Minimum	Average	Maximum
<b>Professional knowledge</b>	Width and depth of expert knowledge	Average/superficial	Narrow/deep	Broad/average
	Width and depth of incident experience	Average/superficial	Narrow/deep	Broad/average

### 2.2.5 The Process, Objectives and Risk Profile

The command type has to be geared to the incident characteristics. It is assumed that the performance improves when the command type matches the incident type. It is important to further investigate this assumption, which was substantiated by Van 't Padje et al. (2014) in order to gain a better understanding of the relationship between command type and performance.

The project innovative incident command looks at the fire service's performance during large-scale incidents from three perspectives. The first is process-oriented. The FADCM model (Dutch: FABCM-model) was used for this (Groenendaal, Helsloot & Bruggemans, 2014). This model supposes that incident command consists of five phases.

1. Fact finding: how many of the relevant incident characteristics are known to the operational commanders and the staff carrying out the work, at what stage of the incident?
2. Analysis: do the operational commanders understand the meaning of the incident characteristics in terms of realistic incident scenarios and correct incident type?

3. Decision-making: do the operational commanders translate the analysis into the right incident approach and the correct command type?
4. Communication: does the staff carrying out the work understand the orders the operational commanders formulate?
5. Monitoring: does the operational commander receive feedback on the execution of the orders?

The second way of looking at the fire service's performance during large-scale incidents regards content. Whether or not a performance is good enough, is partly subject to the objectives the fire service has set itself. As was concluded in the Framework, at the present time, the fire service has not formulated this type of objectives for large-scale firefighting and rescue operations.

Subsequently, it was proposed to use the six effect aspects below for formulating objectives. These effect aspects are derived from the 'Handreiking Regional Risicoprofiel' (Guide Regional Risk Profile).

1. Territorial safety: the surface area that is threatened and/or affected by the incident and for how long.
2. Physical safety: the number of victims the incident has caused.
3. Economic safety: the direct and indirect financial costs the incident has caused.
4. Ecological safety: the degree in which the incident has affected flora and fauna.
5. Social and political stability: the degree in which the incident has disrupted daily life and the public administration.
6. Safety of cultural heritage: the number and the quality of the monuments that were affected by the incident.

The third and last way to look at the fire service's performance is from the perspective of the risk profile of the area of coverage. From this perspective, the question is whether the fire service succeeds in controlling the effects of a specific incident type through time. The risk profiling of an area of coverage uses the same effect aspects as were used in assessing objectives. In order to arrive at a correct risk profile, the chances of a particular type of incident occurring have to be calculated. Various safety regions are experimenting with this type of risk profiling. The recently published report 'Brandveiligheid is coproductie' (2015) (Fire Safety is a Joint Production) advises to create a national model for modelling risk profiles.

### **2.2.6 Organisation Principles Incident command**

As discussed above, the organisation principles for incident command consist of the following five elements:

1. the complexity of the incident
2. the various command types
3. the command process
4. the objectives
5. the risk profile.

The diagrammatic representation in Figure 6 shows how these elements are connected.

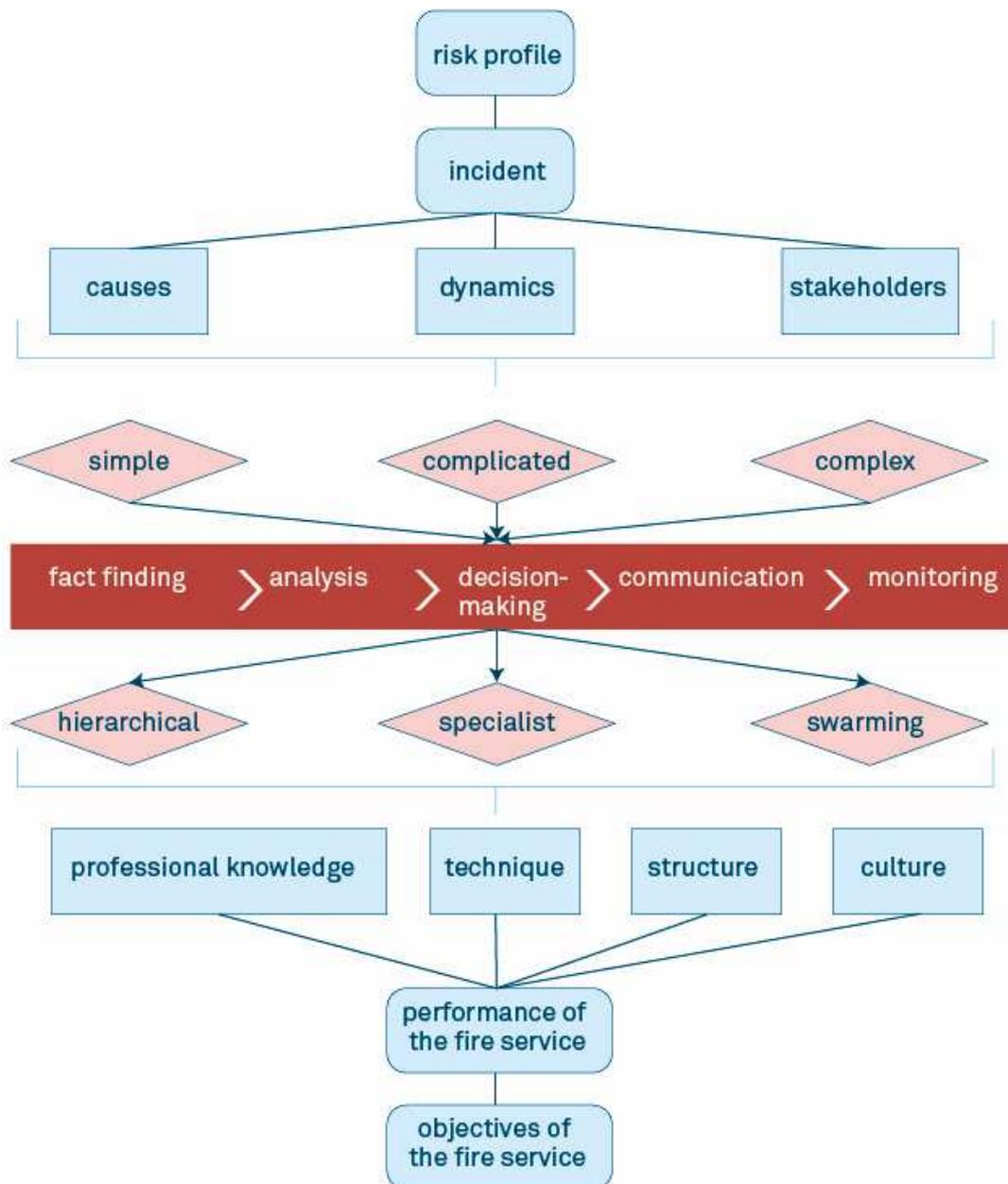


Figure 6: Organisation Principles for situational Incident command

## 2.3 Human Factors

Human factors are about the interaction between individuals and their surroundings. The environment influences how people act, positively or negatively. Human factor-scientists are trying to explain this influence and are developing strategies that professionals can use to neutralise a negative influence or even turn it into a positive influence.

There are many human factors, but within the context of large-scale fire service operations, decision-making under pressures is a dominant human factor that can positively or negatively influence performance. There are many publications on this subject, including the well-known 'Recognition Primed Decision Making' (Klein (1998), Klein (2011) and Klein,

Calderwood & Clinton-Cirocco (1986)). The strain that is discussed in these publications on RPD/ NDM<sup>8</sup> is denoted as stress<sup>9</sup> in neurobiology.

The fact that large incidents contain many stress factors is, from a neurobiological perspective, a major challenge for the fire service's adaptability. The study aimed to better understand when the influence of stress has a negative effect and to investigate whether there are ways to decrease this negative influence on decision-making under pressure.

### 2.3.1 Decision-Making Under Pressure: a Neuropsychological Perspective

An important characteristic of large incidents is that neuropsychologically they contain a large number of stress factors, i.e. 'events or situations that evoke negative emotions such as anger, fear or panic' (Christis, 1997, p. 17). Important stress factors from large incidents can be: responsibility, the threat of victims and/or damage, the pressure on own safety, the uncertainty as to how an incident will develop, a lack of experience and the severe time pressure to determine a correct approach.<sup>10</sup>

Operational commanders experience pressure because of these conditions. However, the pressure does not affect everyone in the same way. A stress factor can result in pressure, but in some individuals the pressure generates energy and alertness. However, the same stress factor can cause performances to deteriorate when under different circumstances or with another person. Negative effects that are typical for operational commanders include what operational commanders like to call 'being drawn into the incident'. The effects that are linked to this phenomenon are: insufficient overview and not looking ahead, time compression, missing key signals and information overload. Human factor theories and human factor researchers can help explain why some operational commanders are more and others are less 'drawn into the incident', and are involved in developing strategies to prevent this from happening.

The scientific literature on stress factors assumes that to be able to correctly deal with this phenomenon, it is important to have sufficient 'control options' or 'decision space' (Christis, 1991, p. 35; Jansen, 1996, pp. 205-209). Control options enable operational commanders to respond adequately. In this respect, the organisation principles described in Section 2.2 are, in fact, control options to adequately respond to pressure during incidents on an organisational level. Human factors increase the comprehension of these control options, through psychological theories on decision-making mechanisms and theories on mindfulness. Specifically, the theories provide an insight into the control capacity of professional knowledge, i.e. the way in which professional knowledge enables operational commanders to effectively deal with pressure. Based on this insight, human factors can generate specific strategies to enhance the control capacity of professional knowledge on an individual level.

### 2.3.2 Automatic Stress Response

A specific type of reaction to the stress factors from Section 2.3.1 is the automatic stress response. This type of stress was researched in the experiment that was conducted in Phase 3 of this study into innovative incident command.

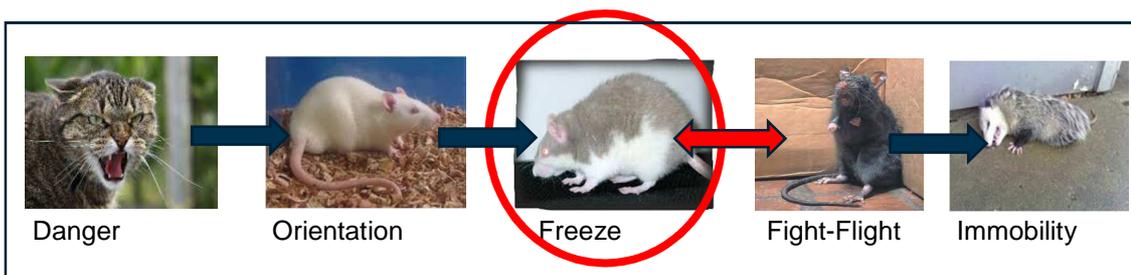
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<sup>8</sup> Naturalistic decision making.

<sup>9</sup> Every organism strives for a condition of dynamic constancy or homeostasis. This equilibrium is constantly threatened by various kinds of stimuli inside and outside the body, physical or psychological, real or imagined. The stimulus is a stress factor (usually simply referred to as stress) and the result is the stress response.

<sup>10</sup> Uri Rosenthal described a crisis situation as 'a severe threat to the basic structure of a social system's fundamental standards and values, which requires making critical decisions in a limited decision-making time frame and faced with a high level of uncertainty'.

Instinctively, all people react automatically to potentially threatening circumstances by freeze, fight or flight (Lang et al., 1997). This phenomenon also applies to firefighters and is depicted in the figure below.



**Figure 7: Automatic Stress Responses**

Perceiving a threat triggers a series of automatic stress responses - freeze, fight or flight - that are characterised by specific physiological and behavioural changes (Lang, Bradley & Cuthbert, 1997). These responses can be found in both humans and animals; they differ per person and are adaptive. They increase the chances of survival because they allow the organism to respond more quickly. The physiological characteristics of fight and flight reactions are similar, in both cases the heart rate, muscle tone and release of stress hormones increases and there is action involved (fight or flight).

Freezing is a different type of stress response: there is an increase in the release of stress hormones and muscle tone as well, but at the same time the heart rate goes down and mobility reduces (Hagenaars, Oitzl & Roelofs, 2014). During freezing, a risk assessment is made of the best possible reaction (Blanchard, Griebel, Pobbe & Blanchard, 2011). Therefore, attention and perception (Blanchard, Griebel, Pobbe & Blanchard, 2011) and the preparation for action (Butler et al., 2007) are optimal. The research into automatic stress responses in fire officers was focussed on freezing because of the characteristics of freezing.

In this study, freezing is defined as the relative decrease of the heart rate and reduced body sway under stress, since these are the central and most significant characteristics. Because of the risk assessment that takes place during freezing, freezing has an important role in selecting the correct action under pressure. However, there can also be too much freezing, which impedes the transfer to rapid decision-making and action.

Freezing in animals is associated with risk assessment. It is still scientifically unclear, however, to what extent freezing affects the situational awareness of humans and their attention and memory processes, and as a result the decision-making under pressure. The present study contributes to this scientific understanding.

### **2.3.3 Decision-Making Mechanisms and Stress**

Generally speaking, stress leads to negative effects when an operational commander has insufficient control capacity. From this follows that operational commanders with relatively limited control options will be drawn into an incident earlier, and as a result lack overview and do not look ahead as much, miss key signals and are faced with an information overload. First, this section describes how professional knowledge can provide control options or decision space.

Professional knowledge includes experience and formal expert knowledge. Both sources each play a part in the underlying decision-making mechanisms. This section explains how operational commanders use the two components of professional knowledge to make decisions and it explains the problems that are caused by stress factors.

People use two decision-making mechanisms to come to a decision: System 1 and System 2 (Stanovich & West, 2000). Both systems are presented below.

### **System 1**

System 1 works intuitively, reflexive and fast, with little or no effort and no sense of control. Experience plays the leading part. The more experience decision makers have, the more they recognise and the faster they come up with a solution for the problem. In the 1980s, the American Gary Klein started researching decision-making in the New York Fire Department. He found it fascinating that firefighters were capable of making adequate decisions under difficult circumstances, such as pressure of time, lack of information and considerable interests (Klein, Calderwood & Clinton-Cirocco, 1986; Klein, Orasanu, Calderwood & Zsombok, 1993). He described and explained his findings in the theory Recognition Primed Decision-Making, or RPD. The theory suggests that operational commanders try to recognise the situation based on visible clues presented by their surroundings (Klein, 1998). Subsequently, they choose the first option that occurs to them and which has been satisfactorily used in the past in similar situations. Therefore, operational commanders with considerable experience have more control capacity or decision space: they recognise more situations and, subsequently, are more slowly drawn in by the incident and, as a result, handle the pressure caused by the incident more effectively.

### **System 2**

System 2 operates on the basis of analysis, includes conscious awareness and control of thought processes and feels like an effort. System 2 uses logic and formal expert knowledge to solve a problem (Kahneman, 2011, p. 32). Whereas the first mechanism is always active and functions automatically, the second mechanism is usually in standby mode. System 2 is activated to provide support as soon as System 1 gets into trouble, because a situation cannot be recognised, for instance, or previously made assessments prove to be incorrect. The more formal knowledge operational commanders have, the more options they have to analyse and think of an approach. In this context Klein talks of mental simulation. According to Klein firefighters use mental simulation when the situation gives reason to do so and there is enough time. Mental simulation means mentally executing the series of actions devised, and reasoning out how these will work and affect the development of the situation (Kahneman & Klein, 2009). Formal expert knowledge increases the operational commanders' control capacity because it enables them to reflect and think about a suitable approach of an incident they do not recognise. Operational commanders who do not possess this ability will probably be drawn into the incident sooner than operational commanders who do.

So, not being able to effectively handle the stress factors of a large incident can be partly traced back to insufficient professional knowledge and/or badly applied professional knowledge. However, the scientific research into these relationships is still limited, especially where firefighting and rescue operations are concerned. There is a need for a better understanding of the relationship between stress, experience and the powers of observation. A well-functioning System 1, as well as being aware that System 1 is not functioning properly, is for a large part connected to keen observation. Stress can enhance or impede the powers of observation.

In order to learn more about this, an experiment was conducted to better understand the influence of experience on stress and the powers of observation. The results of this experiment are discussed in Chapter 4.

A second issue on which the project innovative incident command focuses is the transition from System 1 to System 2. As Klein pointed out, operational commanders find it difficult to use mental simulation. Because of time pressure, operational commanders feel that they do not have the time to think, even if they pick up signs that they misjudged the situation and/or that the approach does not work. Notably, *mindfulness* provides clues on how to reverse this feeling. This will be discussed in more detail in the next section.

### 2.3.4 Mindfulness and Stress

Contrary to the Anglo-Saxon world, in the Netherlands there has not been much attention paid to the 'receiving end' of knowledge. The 'receiving end' relates to the question of whether people are aware of what is happening in their consciousness. Sometimes a person watches without seeing anything. Sometimes a person senses that something is off, but the feeling is not acknowledged and processed. An observation, feeling or thought does not always get through to a person. The 'receiving end' of knowledge is central to the practice of mindfulness.

Mindfulness is inspired by the meditative exercises that were developed by yoga, Buddhism and other Oriental philosophies. The purpose of these exercises is to develop a concentrated, continuous awareness of one's own body, feelings, perceptions and thoughts (Weick & Putnam, 2006, p. 277). To accomplish this, both the duration and the quality of awareness have to improve (Weick, Sutcliffe & Obstfeld, 2008).

In the project, innovative incident command mindfulness is defined as 'an attentive and unbiased attitude, grounded in the here and now' (Weick & Putnam, 2006, p. 280). This attitude enhances the control options of operational commanders. Mindfulness specialists claim, for instance, that their training sessions enhance perception, as a result of which more patterns can be recognised and fewer signals are missed (Weick & Putnam, 2006). Mindfulness is, therefore, associated with an enhanced situational and option awareness. Situational awareness is being aware of what is going on around you and how this will affect you and the future (Endsley, 1995, p. 36). Option awareness is being aware of the relative desirability of available options for managing the incident, and the factors that explain this desirability (Pfaff, Klein, Drury, Moon, Liu & Entezari, 2013).

It is claimed that mindfulness training makes System 2 function better. For instance, research into the functioning of System 2 has shown that the activation of System 2 can be impeded by a feeling of time pressure, by simultaneously carrying out a great number of cognitive tasks and by an abundance of sensory signals (Kahneman, 2011). Among other things, creating mindfulness is aimed at removing these obstacles in order to facilitate the use of formal expert knowledge and analytical abilities during an incident.

As part of the research into innovative incident command, two mindfulness techniques were selected to experiment with: tactical breathing and distancing.

### ***Tactical breathing***

Basic mindfulness techniques are breathing exercises and body scan (becoming aware of all the parts of the body). There is an increasing amount of academic research (Weick and Putnam, 2006, Weick and Sutcliffe, 2007) showing the positive effects of applying these kinds of techniques on effectively dealing with stress, the ability to concentrate, recollection and the ability for reflection. When operational commanders learn how to shift their attention at the appropriate time to their breathing and their bodies, this can enhance their control options.

### ***Distancing***

A second mindfulness technique that can help the operational commanders in increasing their situational awareness is to vary their distance from the incident (Trope & Liberman, 2010). The physical relocation and the operational commander's position in the incident area, affects his or her powers of observation and reasoning skills. When close to an incident, an operational commander is able to observe other signals about the development of the incident than from far away. Both types of signals are important for forming an overview. As far as reasoning skills are concerned, it is important that at some distance from the incident there are fewer distracting triggers (e.g. the noise of the pump of a fire engine, emergency response team members walking about, etcetera): this will make it easier to concentrate and reflect.

## **2.4 Business Intelligence**

According to the Dutch Board of Fire Chiefs (*Raad van Brandweercommandanten*), business intelligence can be defined as 'to cooperate information-driven and transparently'. In the context of innovative incident command, business intelligence is concerned with the following: 1) increasing the fire service's adaptability and 2) examining, refining and improving the model that is to be developed for situational incident command.

This section starts with a discussion of how business intelligence can increase the operational commander's adaptability during large incidents. The section concludes with an explanation of why structural data collection about managing large incidents is vital for the further development of knowledge about incident command.

### **2.4.1 Information and Situational and Option Awareness**

The contemporary data revolution offers great opportunities to enhance operational commanders' situational and option awareness (see Section 2.3.4) There is already a lot of data available, particularly on incidents (data on causes, dynamics, stakeholders and objects) and to a lesser extent on incident management. Furthermore, the amount of data on both aspects is very likely to grow in the years to come because all data will be better available and accessible. However, the key question is how all this data can be converted into relevant and useful information for operational commanders. For this purpose, it must be clear what operational commanders need. The project innovative incident command provides a structure with which a first selection of relevant and irrelevant data can be made. There is also a need for understanding how operational commanders process information and what their limitations in this respect are. Rasmussen's (1983, p. 257-266) Human

Performance Model suggests that professional behaviour is based on three different types of information processing: skill-based, rule-based and knowledge-based.

### ***Skill-based behaviour***

Skill-based behaviour processes sensorimotor information, is subconscious, and even though there is a strong connection with System 1, it cannot be characterised as decision-making. Skill-based behaviour is, for instance, the way operational commanders move in the incident area, how they operate and read their communication and information resources, and whether they cast their eye over the entire incident area or not. The behaviour is a continuous integrated whole. Most behaviour is skill-based. For this type of information processing an information system might be useful, e.g. a system on a tablet that shows a map of the incident area, the risk sources and the positions of the fire engines. When an operational commander walks through the incident area, the map functions as an orientation tool.

### ***Rule-based behaviour***

Rule-based behaviour is based on an explicit lesson from the past. It strongly resembles Klein's Recognition Primed Decision-making (RPD): the recognition of a certain situation automatically calls up the solution to the problem. As opposed to skill-based behaviour, professionals can afterwards give the grounds for their rule-based behaviour. Most decisions are rule-based. During an incident an information system can present some of these rules. When driving up to an incident, the system might display the following rules: 'approach from the windward side', 'start gathering facts' or 'swarm when dealing with a complex incident'. Such an information system only provides added value if it presents the relevant rules at the right time. It should not trigger any analyses because the operational commander is working intuitively.

### ***Knowledge-based behaviour***

Knowledge-based behaviour is important in unfamiliar circumstances, where the available skills and rules do not provide a solution. During knowledge-based behaviour an explicit objective is formulated, based on the analysis of the incident. With the aid of System 2 a plan is devised to realise the objective. Rasmussen calls this improvisation. When operational commanders are in this modus, an information system that triggers and stimulates the systems of improvisation and analysis can provide added value. Operational commanders can be supported in activating System 2 by making an alarm bell ring based on data. For instance, when data becomes available about the presence of an exceptional risk, a 'stop button' might light up that signals that it is sensible to go slow. Or relevant questions might be generated to activate the operational commanders' process of analysis. For instance: 'What is the maximum objective?', 'Are you using the right command type?', 'What kind of incident are you dealing with?', 'How many realistic scenarios are there?' With this type of information processing, more time is available and more factual information about the incident and the firefighting and rescue operation can be presented.

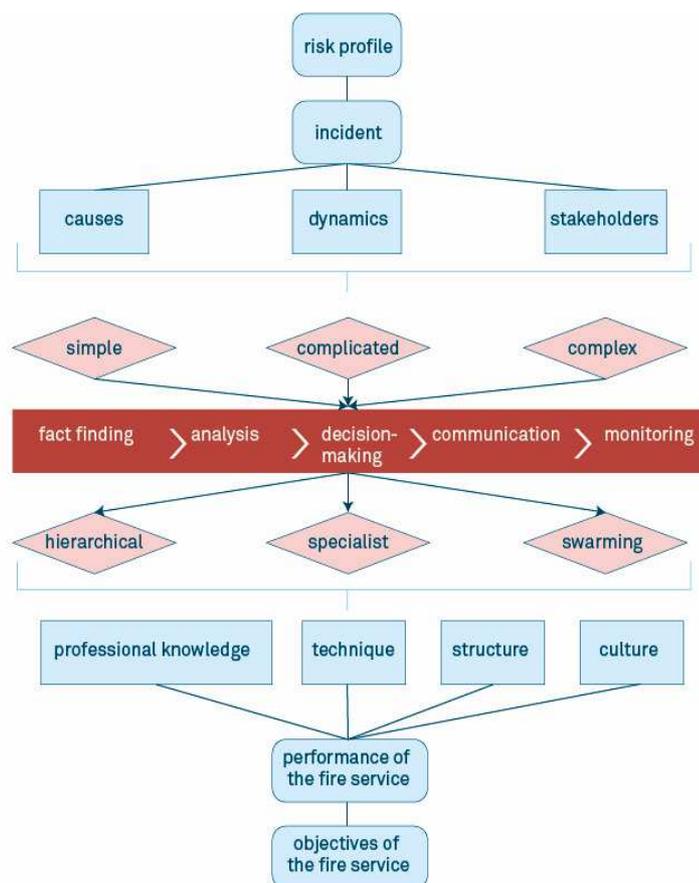
However, the problem of *information overload* - more information leads to less productivity, for instance because the information can no longer be interpreted correctly - remains a genuine risk. It makes little sense to offer the operational commanders dozens of different types of information. An experiment in the United States showed that units receiving incomplete information performed better than units receiving detailed information. The units that received detailed information lost a lot of time prioritising and examining the information. The unit with incomplete information spent more time integrating the available information into a meaningful picture and were, therefore, more effective (Klein, 2011, p. 132).

## 2.4.2 Structural Data Collection

Innovative incident command is a growth model that needs to be developed further. The study presents some founded proposals for improvement, but above all, it is the first step in the direction of a new way of incident command.

In order to further develop the model, it is crucial to gather and analyse facts about large-scale firefighting and rescue operations. This can be linked to the initiatives taken by the Information Management Network of the Safety Regions (*Netwerk Informatiemanagement of the Safety Regions*) to realise the preconditions for information-driven and transparent cooperation.

The situational incident command model is an information model of large incidents and large-scale fire service operations. The main structure of such an information model is



shown in the figure on the left, which was presented earlier.

After concluding this study, data on large incidents in the Netherlands can be structurally collected on the basis of the information model. For the first time, this would result in a factual summary of the way in which the fire service in the Netherlands manages large incidents. As a result, a better understanding of incident command can be gained and when experiments are conducted for the implementation of innovative incident command, the effects can be monitored by using the data collection. These are necessary preconditions for the learning process.

## 2.5 Choice of Sub-studies

It follows from the theory in this chapter that the incident characteristics have to be the determining factor for the way in which an incident is managed. This means that the fire service's adaptability has to be central in the research into incident command. The choice was made to focus the research into innovative incident command on command type, two of the many human factors and business intelligence.

Pursuant to the theoretical foundation found, the follow-up study into innovative incident command (Phase 2 and Phase 3) is organised as follows:

### 1. Sub-study command types (Phase 2)

It has been theoretically established that the effectiveness of firefighting and rescue operations is to a significant degree determined by the balance between the incident, on the one hand, and the type of organisation the fire service uses to manage the incident, on the other hand, i.e. the command type. However, this is only a theoretical observation that has not been proven in the actual fire service practice. It is recommended to do so before making decisions about implementation in actual practice. This results in the following central research question for the sub-study 'command types'.

*To what extent is the effectiveness of a command type connected to the task environment of large-scale firefighting and rescue operations?*

The principal question is set out in the following research questions:

- > What command type is most effective in a simple task environment during large-scale firefighting and rescue operations?
- > What command type is most effective in a complicated task environment during large-scale firefighting and rescue operations?
- > What command type is most effective in a complicated task environment during large-scale firefighting and rescue operations?
- > What is the perception of the participants and observers regarding the use of the command types?

The sub-study into command types is discussed in Chapter 3.

### 2. Sub-study into automatic stress responses in fire officers (Phase 3)

Instinctively, all people react automatically to potentially threatening circumstances by freeze, fight or flight. During freezing, a risk assessment is made of the best possible reaction (Blanchard et al., 2011). Freezing is a symptom that is scientifically associated with risk assessment, and as a result seems very useful for a study into the human factor in incident command during large-scale operations.

For this sub-study the following research questions were formulated:

- > *What is the role of experience on threat-related freezing behaviour?*
- > *Does freezing affect memory?*
- > *What is the influence of experience on memory accuracy?*

The sub-study into automatic stress responses is discussed in Chapter 4.

### 3. Sub-study mindfulness (Phase 3)

Research studies have shown that mindfulness techniques lead to better results in forming an image and decision-making under time pressure<sup>11</sup>. The powers of observation are enhanced, as a result of which more situations and risks can be recognised. It enables people to distance themselves from their feelings and thoughts and, therefore, mindfulness increases the ability to reflect upon one's own behaviour during the incident. Nevertheless, the concept of mindfulness and the accompanying techniques have not yet been introduced into the Dutch fire service.

The objective of this sub-study was to gain an understanding of how mindfulness can be introduced into the Dutch fire service and whether this will actually support fire station officers in practice. This results in the following research question:

*How can mindfulness be introduced into the Dutch fire service in order to improve the quality of incident command, and do the experimental subjects expect to benefit from this in the execution of their operational task(s)?*

For this sub-study, the following research questions were formulated:

- > Do the experimental subjects experience a change in effectiveness of their incident command?
- > Do the experimental subjects think that these instruments can be implemented in the fire service and what would be the key points to consider? and
- > Did the training provide the experimental subjects with sufficient support and how can it be improved?

The sub-study into command types is discussed in Chapter 3.

Business intelligence was incorporated in the follow-up research by developing a database for large-scale fire service operations. This database should be the foundation for further research into incident command. However, the database does not contain any information at the moment and as a consequence this report does not contain any separate research results on business intelligence.

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<sup>11</sup> Refer to part 1 'The Framework'.

# 3 Command Type

## 3.1 Introduction

In this chapter, the central research question of sub-study 1 *Situational Incident command, Sub-study 1: Command Type* is answered.

*To what extent is the effectiveness of a command type connected to the task environment of large-scale firefighting and rescue operations?*

This research question is based on the conclusion that the fire service will perform better if the operational commanders rapidly and effectively adapt to the incident characteristics (Van 't Padje et al., 2014). By conducting practical research, it was investigated to what extent the (theory-based) conclusion from this study held up in the fire service practice.

Before proceeding to answer the research question, Section 3.2 presents a summary of the set-up of the practical research. Subsequently, the answers to the sub-questions are summarised in Section 3.3. Section 3.4 contains the answer to the central research question for this sub-study. After the answer to the research question is presented, Section 3.5 presents a reflection on the limitations of the current command type.

This chapter is a summary of sub-report 1 *Command Type* (Hazebroek, Geertsema & Groenendaal, 2015). The theoretical foundation, the study design, the exact results and a more elaborate explanation can be found in this report (only available in Dutch).

## 3.2 Study Design

The effectiveness of command types in different task environments is tested by means of virtual simulation. A group of participants (operational commanders) has to handle three different kinds of incidents according to one of three command types: a simple, complicated or complex incident (or task environment). All command types are tested twice per task environment. For each task environment is then determined which command type provides the best total result. The analysis and assessment framework from Phase 1 of the study is used for this purpose (Van 't Padje et al., 2014).

Every group of operational commanders is allocated a specific command type. At the beginning of the day, the command type is explained in a briefing. After the briefing and a short rehearsal, the group completes the three scenarios by using the allocated command type to manage the incident.

The *Advanced Disaster Management Simulator* (ADMS) is used for the virtual simulation. By means of a joystick, the participants walk through a virtual world where an incident occurs. They have the opportunity to deploy virtual emergency workers by giving commands and directions. These actions are carried out by the technical director who operates the ADMS. The actions of the participants determine the course of the incident (IFV, 2014).

The three task environments are translated into a specific scenario in ADMS. Depending on the complexity of the scenario (simple, complicated or complex) the incident consists of a number of different areas of responsibility that are closely or less closely interrelated. The incident dynamics differ per scenario as well.

For each scenario, a script has been drawn up with standard times, events, responses and escalations. This way it is guaranteed that the scenarios are reproducible as much as possible, and as such are executed in a similar manner each test day.

Every group of operational commanders was based on the more or less standard composition of large scale firefighting and rescue operations in the Netherlands:

- > 8 crew commanders
- > 2 fire officers
- > 1 senior fire officer
- > 1 hazardous materials adviser (not a direct supervisor)

Responses are provided by the technical directors of ADMS and the operator of the control room. The control room exactly records in the computer system at what moment units were alerted, and how many. The control room also registers as much of the communication as possible. Two Fire Service Academy trainers and a COPI leader (leader of the multidisciplinary Command Team at the incident) take upon them the role of police and medical emergency services, and communicate with the senior fire officer.

Observers, responders and technical directors gather data based on objectified observation forms. Ultimately these are used to measure the effectiveness of the firefighting and rescue operation. At the end of the tests the participants were asked to clarify their perception of the command type used by filling out a questionnaire.



**Figure 8: Fire service convoy during large scale firefighting and rescue operation (Photo: Gelrenieuws)**

## 3.3 Answers to the Sub-questions

In this section the following research question are answered:

1. What command type is most effective in a simple task environment during large-scale firefighting and rescue operations? (subsection 3.3.1)
2. What command type is most effective in a complicated task environment during large-scale firefighting and rescue operations? (subsection 3.3.2)
3. What command type is most effective in a complicated task environment during large-scale firefighting and rescue operations? (subsection 3.3.3)
4. What is the perception of the participants and observers regarding the use of the command types? (subsection 3.3.4)

### 3.3.1 Simple Task Environment

The hypothesis was that in a simple task environment the hierarchical command type would be the most effective. This hypothesis was based on the assumption that in a simple task environment, the operational commanders would be able to rapidly and easily obtain an overview and set priorities. The incident that was designed for this task environment fulfils the principles of a simple incident: a fire in a warehousing facility with a risk of flashover to an adjacent building and a limited release of asbestos fibres. This type of incident occurs in all regions with some regularity, and theoretically speaking all participants should be able to decide on an attack rather quickly, based on overview and recognition.

Answering this research question was hindered due to a contamination of the results. The performances of test day 1 are incomplete and on test day 4 (hierarchical) the system crashed and had to be restarted. This obviously results in limitations on the analysis and, more importantly, renders the basis for the conclusions relatively weak.

It is established that the best results recorded occurred in the simple task environment using the swarming command type.

1. Quickest protection of the adjacent premises.
2. Quickest actual deployment in or on the adjacent premises.

It is concluded that the command type swarming was most effective in the simple task environment.

### 3.3.2 Complicated Task Environment

The hypothesis was that in a complicated task environment the specialist command type would be the most effective. This hypothesis was based on the assumption that, in a complicated task environment, the operational commanders would be able to rapidly and simply obtain an overview, but that they would lack the knowledge to understand the key issues of the incident and to solve it. The influence of specialist knowledge/skill on incident command would have to be strong. The experiment's task environment was created by having a fire occur at a petrochemical company that produces ethylene oxide. It was assumed that incident management in an ethylene oxide plant would be beyond the average knowledge level of crew commanders and officers, and that specialist knowledge would be required to successfully complete the incident.



**Figure 9: Participants during the Command Type Experiments**

On test day 5 (specialist) and 6 (swarming), the firefighting and rescue operations resulted in successfully extinguishing the fire, preventing the fire from spreading and suppressing the logically ensuing toxic cloud. It was only on test day 5 that the situation was fully understood: all the relevant objects are cooled in order of priority and with the appropriate agent. On all other test days the first attack (foam and cooling down distilling column) is executed correctly and in time, but there is clearly a lack of understanding and overview. This is demonstrated by a failure to prepare for a possible toxic cloud and/or by retreating at a time when it is dangerous to stop the cooling operations.

The conclusion is that in a complicated task environment, only the specialist structure made it possible to actually understand the incident's key issues, and translate this understanding into a correct perspective for action.

### **3.3.3 Complex Task Environment**

The hypothesis was that in a complex task environment the command type swarming would be the most effective. This hypothesis was based on the assumption that in a highly dynamic, complex task environment with a heterogeneous character a massive deployment of self-managing units will lead to maximum results.

The complex task environment consisted of a fire and an explosion in a multifunctional building that occurred during the dismantlement of an XTC laboratory by forensics. There were multiple victims involved and they all had 'priority' as far as an acute threat to their life was concerned. It was very hard for the operational commanders to get an overview and draw up a concrete plan of attack because of the great number of factors and incident types involved that were influencing each other in combination with the many victims and high time pressure.

By swarming, the firefighting and rescue operations were the most effective: all victims are rescued in good time, where necessary the fires are attacked and decisions are made most quickly. The participants using the hierarchical and specialist command types tried to obtain an overview, but they did not succeed. This is demonstrated by units that are not moving, units that are not deployed, by retreat and by not succeeding in controlling the incident. During swarming, the participants visibly proceeded faster, as a result of which some sub-problems were eliminated.

The conclusion is that in a complex task environment, swarming produced the best results. It is noteworthy that this (objective) result is diametrically opposed to the perception of the participants who rated the operational quality of both the hierarchical and specialist structure higher than swarming.

### 3.3.4 Perceptions

In this sub-section, the following research question is answered:

*What is the perception of the participants and observers regarding the use of the command types?*

In answering the research question, the following can be concluded. The respondents' opinions vary and there also is a considerable difference of opinion between the various subgroups (participants, observers, crew commanders, officers). This makes formulating one answer to the research question exceptionally hard, although significant results were measured. Still, it is possible to highlight four aspects.

1. Generally speaking, participants are more positive about the command types hierarchical and specialist, while the observers are more positive about swarming. This is to be expected since these two command types are closest to the training received and the actual practice. It should be noted that the observers' judgement about the result of the firefighting and rescue operations is more in keeping with the measured performance than the participants' judgement. This matches previous publications, where the value of the frontline operational commanders' own opinion is questioned: to what extent can they obtain an objective image of their own performance?
2. For the most part, officers are more positive about the command type swarming than crew commanders. Based on the final evaluation that was conducted each day, this can be attributed to the fact that officers notice the improved performance, but that crew commanders experience an extra and especially difficult responsibility in the performance of their duties. With that the aspect safety is often mentioned.
3. It is noteworthy that the perception of various constructs (sometimes) deviates from the actual outcome. For instance, swarming is regularly judged less effective, while in the context of the tests it does have an effective outcome.
4. Guaranteeing safety and providing sufficient information are regularly experienced as a bottle neck, regardless of the applied command type. In the perception of the participants, apparently none of the command types succeeded in sufficiently guaranteeing the issues of safety and information provision.

If it is decided to implement the command type swarming, then it can be stated, based on the research results, that extra attention will have to be paid to the trust of especially crew commanders in the functioning of this command type, particularly where safety is concerned.

## 3.4 Conclusion

Central to this section is answering the central research question:

*To what extent is the effectiveness of a command type connected to the task environment of large-scale firefighting and rescue operations?*

It must be noted that there are very many factors that have an effect on the quality and outcome of large-scale firefighting and rescue operations. Some of these factors are outside the fire service's domain, so they cannot be directly influenced.

In a way, the organisation of the fire service's incident command has to be designed as foolproof as possible. The shortcomings of both firefighters and others and the complexity of information management in a highly dynamic environment have to be reckoned with.

During the experiments, differences were noted in the performance of the fire service organisation, while working with the three tested command types in the task environments. It can be concluded that a match between task environment and command type actually leads to better results than a mismatch, albeit that in all experiments disadvantages were noted for each command type. To answer the central research question: it was demonstrated that the effectiveness of fire service operations in a specific task environment is connected to the command type used. Therefore, the fire service has to adapt to an incident in order to be effective. Adapting the type of incident command to the situation at hand is already often applied during large-scale operations. By definition, these adjustments are usually considered undesirable and have a negative connotation, but undeservedly so, as is now demonstrated.

It must be noted that there sometimes is a discrepancy between the objective results and the perception of the participants. Operational commanders can experience an incident as complex at first, even if it is actually very simple, because they lack overview and understanding of its scale, dynamics and character. It follows that the operational commanders' measure of overview and understanding seems to be a decisive factor for determining the command type. Specifically, a large-scale attack (major fires and bigger) will at first probably never be labelled as a simple incident by operational commanders. A lack of experience might play a part in such a scenario.



**Figure 10: Formation of an operational common picture of an Industrial Fire**

In the implementation phase, extra attention should be paid to the aspect of safety. On the test days, many crew commanders indicated that they experienced swarming as less safe than the traditional hierarchical model. The hierarchical model provided them with a feeling of safety, and in retrospect this might have been wrong. The next chapter includes specific proposals for improvement in the field of human factors in order to focus more attention on the safety aspect of incident command.

## 3.5 The Limitations of the Current Command Type

The fire service only has a hierarchical command model for large-scale incident management<sup>12</sup>. Usually, the following supporting arguments for the model are provided.

- > Because of the central command, there is hardly any need for consultation and the order to attack can be given rapidly, without any discussions. This would benefit a rapid attack.
- > Unambiguity (everyone is on the same page).
- > The officers create a full and joint image (overview) based on the information provided by the crew commanders and they subsequently share this with them.
- > Explicit decision-making about the need for an attack versus the risks based on the overview.
- > Because of the fact that the (senior) fire officers monitor the acts of the crew commanders, this results in an additional safeguard for work safety.
- > Unambiguous image building and decision-making by the fire service's highest in rank as a foundation for, once more, unambiguous multidisciplinary image building and decision-making at the Command Place of Incident.

This study has shown theoretically that in complex situations these assumed advantages of hierarchical incident command do not occur. This conclusion is supported by the results of the comparative simulation research.

- > There is no homogeneity in the attack.
- > It takes a long time to create a full and joint picture and by that time, it is rendered unnecessary by the dynamics of the incident.
- > Because of the incident dynamics and information overload, it is hard for central operational commanders to take stock of the whole situation and give orders for an attack. As a result, many units have to wait<sup>13</sup> before receiving any orders for attack, and the victims have to wait for help longer than necessary.
- > There is little explicit decision-making about the need and opportunities for an attack versus the risks involved, instead, operational commanders fall back on experience and rules of thumb.
- > It turns out that, in this model, the (senior) fire officers have only a limited picture of the incident, the development of the incident and the deployment of separate units. The assumption that there is adequate supervision of the operation as far as work safety is concerned, is hereby refuted.
- > As a result of the limited picture, the incident dynamics and the mental overload, there is only limited conscious decision-making, both monodisciplinary and multidisciplinary.

It should be added that during the experiments a pure form of the hierarchical command type was applied, in practice it is often applied far more flexibly.

Therefore, in practice it seems almost impossible for operational commanders to properly execute all necessary steps for a good incident command when they are in a complex situation using a hierarchical command structure.

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<sup>12</sup> 'The fire service organisation has a hierarchical organisational structure in which the fire officer is the connecting executive link between the crew commander and the senior fire officer.' And: 'The Fire officer directs specialists and takes on the management of the incident.' (Fire officer Textbook, 2012)

<sup>13</sup> In the hierarchical structure, the waiting time for the second shift to be deployed from the vehicle assembly area amounted to 20 to 30 minutes a few times. Note: in all instances there was an urgent need for extra units in the field. This contradicts the theory from the 'Leidraad Brandweercompagnie' (Guideline Fire Service Company) (1995): Apart from yielding other benefits, giving orders to one platoon commander instead of to four crew commanders saves time.

Especially the formation of a picture and forming an opinion are under pressure. For incident command, these are vital processes and hierarchically the success of the entire organisation depends on these.

This substantiates the strong indication<sup>14</sup> that the traditional choice for hierarchy as a uniform command type that fits all incidents is inadequate. Serious shortcomings were observed in all task environments: simple, complicated and complex. Moreover, there are strong indications that hierarchical incident command in acute, dynamic situations does not result in the desired outcome (better incident management).

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<sup>14</sup> A reservation has to be made because of the limited number of tests that could be executed within the (financial) boundaries of the research. However, the conclusion can be recognised in practice, during actual incidents.

# 4 Human Factors in Incident command

## 4.1 Introduction

In Section 2.2, it was stated that the adaptability of an organisation at a macro level is determined by the balance between manageability and controlling power of the organisation. The controlling power of the fire service is jointly formed by all firefighters, crew commanders, (senior) fire officers and specialists who determine goals and tactics the units apply during a large-scale incident. This implies that the organisation's controlling power is strongly determined by how capable the operational commanders are, individually and as a group, of continuously making sharp analyses of the incident and decide accordingly. Incident command of large incidents is an intensive and stressful job and scientific literature shows that the stress has an impact on the decision-making (Klein, Calderwood & Clinton-Cirocco, 1986).

Therefore, the operational commanders' human factor implicitly has a great influence on the outcome of the firefighting and rescue operation and that is why it has an important position in the research into innovative incident command. Human factors are about the interaction between humans and their environment or the situation in which they operate. The environment or the situation positively or negatively influences human behaviour, partly depending on what is the desired behaviour in that situation (Starcke & Brand, 2012). By researching the human factor an understanding is gained of the natural limits of operational commanders. Proceeding from human factors concrete improvement proposals can be formulated, as a result of which the fire service can learn to better handle the difficult circumstances they have to work in.

First, Section 4.2 provides a description of the automatic stress response to an incident on the performance of operational commanders. Subsequently, a description is given of two experiments with adjustment mechanisms that were conducted to establish whether operational commanders can deal with this influence more effectively.

The project innovative incident command contains two types of research into the human factor (see Section 4.3 and 4.4). The first type researches to what extent fire officers' acute stress responses are influenced by experiential knowledge. A large-scale experiment was conducted regarding the automatic stress response in fire officers. This experiment was conducted in cooperation with the Behavioural Science Institute of the Radboud University Nijmegen and University Utrecht. Further details can be found in Section 4.2 et seq. Subsequently, it was researched whether mindfulness could be introduced in the Dutch fire service. Mindfulness techniques can enhance the control capacity of operational commanders to cope effectively with the strain that is caused by the incident. A pilot was conducted to find out more about the effectiveness of mindfulness techniques and to find out how fire officers feel about the possibilities of mindfulness techniques. This subject is further discussed in Section 4.3.

## 4.2 Experiential Knowledge

As was stated in Section 2.3.2, all people instinctively react automatically to potentially threatening circumstances by freezing, fighting or fleeing. During freezing, a risk assessment is made of the best possible reaction (Blanchard et al., 2011). This underlines the importance of the research into the influence of freezing on decision-making under pressure during large-scale operations. Freezing was defined earlier as a relative heart rate deceleration and reduced movement under stress (see Section 2.3.2).

### 4.2.1 Research Questions

Through experimentation, it was investigated as to what influence experience has on the automatic freezing of fire officers and what effect the automatic stress responses have on the accuracy of recollection.

In this experiment, the following questions were investigated:

- > *What is the role of experience on threat-related freezing behaviour?*
- > *Does freezing affect memory?*
- > *What is the influence of experience on memory accuracy?*

### 4.2.2 General Research Design

Some years ago, an experimental design was created to objectively measure freezing in human beings (Azevedo et al., 2005; Hagenars et al., 2012). This is done by exposing the human test subjects to a stress factor, namely shocking/revolting (aversive) images.

The test subjects carried out a passive viewing task: they look at all kinds of pictures without having to perform any specific tasks. The test subjects stand on a stabilometric platform when they look at the pictures (see Section 4.2.3) so that their movements can be meticulously recorded. The test subjects' heart rates are measured as well. In the present experiment, four sets of pictures were shown, selected from the International Affective Picture System (IAPS; Center for the Study of Emotion and Attention, 1999).<sup>15</sup> The sets of pictures consist of:

- > 20 pleasant pictures (e.g. sports, fun fair)
- > 20 neutral pictures (e.g. tools)
- > 20 non-related unpleasant pictures (e.g. wild animals)
- > 20 related unpleasant pictures (e.g. fire, dead bodies).



**Figure 11: Examples of Neutral, Pleasant, Shocking and Revolting Pictures (IAPS)**

The pictures are shown per set, i.e. 20 pictures from the same category consecutively.

The pictures are shown in a presentation time of 3 seconds per picture and the entire set is shown consecutively (so 1 minute per set).

The order of the sets is counterbalanced: the sets are shown in a different order to each test subject to compensate for time effects, such as fatigue. In between sets, the screen is black

<sup>15</sup> 'The International Affective Picture System (IAPS) is being developed to provide a set of normative emotional stimuli for experimental investigations of emotion and attention' (Lang, P.J. and M.M. Bradley, 1997).

(5 seconds) followed by a fixation cross (2 seconds). The test has a total duration of 4 minutes and 28 seconds (4 x 1 minute plus 4 x 7 seconds).

As mentioned before, freezing is a *relative* measure. The reaction to shocking pictures is compared to the reaction to neutral or pleasant pictures. Freezing is established when there is a reduced heart rate and reduced body sway in reaction to the aversive pictures compared to the neutral or pleasant pictures.

In cooperation with psychologists and neurobiologists from the Radboud University Nijmegen, the University Utrecht and the University of Amsterdam, The Fire Service Academy developed an additional, innovative design for an experiment. This was specifically aimed at the role of experience in automatic stress responses of fire officers. The incident is about a spreading fire in a storage facility. A realistic incident simulation was created of a fictional incident in a virtual incident simulator. The animation (see Figure 12) lasts four minutes and is 'filmed' from the fire officer's perspective. Realistic sound recordings were added to the incident simulation: information on the radio and other sounds that can be heard around a large fire, like sirens. During the animation there are a number of events that can induce stress. In the course of the animation, the events happen more and more quickly to increase the stress.



**Figure 12: Test Subject's Screenshots during the Drive Up and At the Scene**

The test subjects watch the incident simulation while standing on a stabilometric platform and wearing a heart-rate monitor. Fifteen minutes after the film ends, they fill out a questionnaire containing questions about the film to test which events they remember.

The question was whether the fire officer's heart rate and body sway changed during the incident simulation, and whether this already happened during the first part of the simulation. The film was divided into 5 blocks of 51 seconds. Initially, the heart rate during these 5 time frames was looked at, to test whether the film was effective in inducing stress throughout all the groups. The film contained no isolated instances of stress, but there was an accumulation of stressful moments in the second part of the film. Consequently, the groups were compared for changes in heart rate during the first half of the film (contrast score: heart rate during the third time frame [104-155 sec] minus heart rate at the beginning [first 51 seconds]) and heart rate changes during the entire film (contrast score: heart rate at the end [final 51 seconds] minus heart rate at the beginning [first 51 seconds]).

### 4.2.3 Measuring Methods

*Objective* freezing is defined as a decrease of body sway and a deceleration of the heart rate during non-related and related unpleasant pictures compared to neutral and pleasant IAPS pictures. In addition to this, the response time is used as an indicator for freezing. A longer response time indicates more freezing. The stabilometric platform (Figure 13) measures the movements of the body, or body sway (Figure 14) in reaction to the pictures shown (Figure 12). Subsequently, this is referred to as freezing in combination with heart rate.

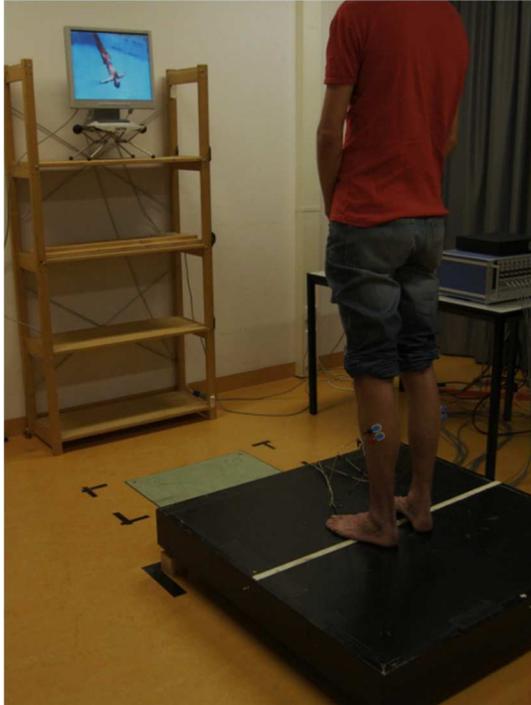


Figure 13: Stabilometric platform

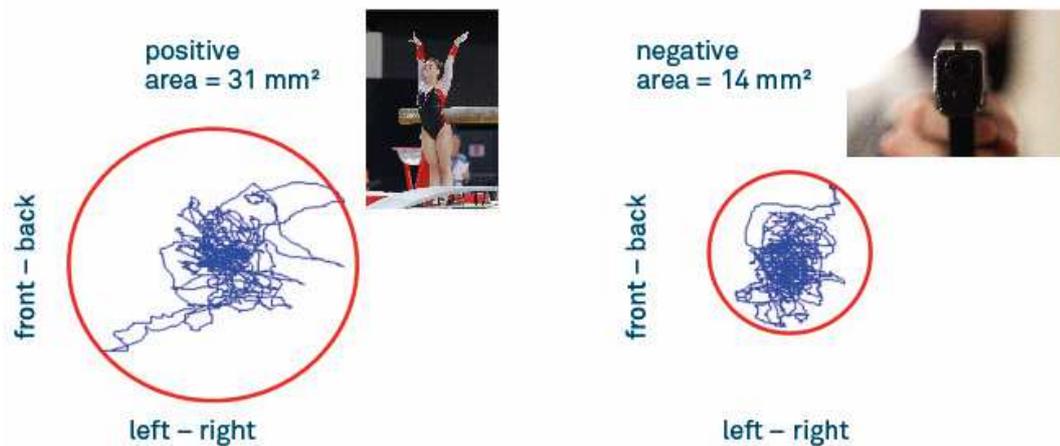


Figure 14: Interpretation of Body Sway

*Subjective* freezing (the extent to which the test subjects themselves experience freezing) is measured by having the test subject rate pictures as follows:

- > Pleasantness ('To what extent did you consider this picture to be pleasant/unpleasant?')
- > Arousal (severity/intensity: 'To what extent did you consider this picture to be severe/intense?')
- > Freezing ('To what extent did you have the feeling that you could not move when you looked at this picture?')

Fifteen minutes after the incident simulation ended, the test subjects received a questionnaire containing 40 statements about the events in the incident simulation to test the accuracy of their recollection. The statements are either true or false. 15 statements are about instances of stress during the incident simulation, 25 statements are about non-stressful instances. The test subject has to indicate whether the statements are true or false. A more accurate recollection is defined as a higher number of correct positive answers (true when a statement is actually correct) and correct negative answers (false when a statement is actually incorrect).

#### 4.2.4 Population

Two groups of fire service officers were recruited:

- > experienced fire officers (25)
- > inexperienced fire officers (16)<sup>16</sup>

A fire officer was considered experienced when he or she had been involved in more than 3 large fires as a fire officer. An inexperienced fire officer had been involved in fewer than 3 large fires. A large fire was defined as a fire where at least 3 engine companies were deployed in accordance with fire service jargon.

All recruited fire officers were male because it was impracticable to recruit sufficient female fire officers to be able to make a reliable analysis. All test subjects have to meet the following criteria:

- > age: 18-60 years old
- > bodily weight: < 120 kg.

To ensure that the groups did not differ before the experiment started, they were compared on a number of points beforehand.

The groups did not differ in fear during their most stressful incidents, nor did they differ in positivism. The baseline heart rate (resting heart rate) was measured during a neutral (non-inciting) film. The groups did not differ in baseline heart rate. There are some differences in age and level of education: the experienced fire officers are older and have a higher level of education (in terms of 'civil' education) than the inexperienced fire officers.

#### 4.2.5 Results

The most important findings are described below. For the complete (statistical) findings, refer to the Annex Automatic Stress Responses in Fire officers.

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<sup>16</sup> The number of inexperienced fire officers is lower than the number of experienced fire officers. The difference is acceptable for a statistical analysis. The difference can be explained by that fact that in the years leading up to the study, a relatively small number of fire officers were trained. As a result there are a relatively small number of inexperienced fire officers available (in accordance with the definition).

### ***Passive viewing IAPS pictures***

- > The inexperienced fire officer, subjectively, experience more freezing in reaction to the related unpleasant pictures, despite the fact that the groups do not differ in how unpleasant or intense they consider the pictures to be.
- > There is an objective delay of response time (indicative of freezing) in all fire officers in their reaction to the non-related and related unpleasant pictures.
- > Inexperienced fire officers show more delay in the response time than the experienced fire officers to the non-related unpleasant pictures.
- > All fire officers showed a heart rate deceleration in reaction to the non-related and related negative pictures compared to the neutral and positive pictures. Inexperienced fire officers showed a stronger heart rate deceleration than experienced fire officer when looking at non-related and related pictures.
- > All fire officers showed reduced body sway in reaction to the negative pictures, compared to the neutral and positive pictures. The inexperienced fire officers showed a stronger reduction in body sway when looking at non-related pictures than experienced fire officers. There was no difference in body sway in reaction to related negative pictures.

Subjective freezing is higher with inexperienced fire officers in reaction to related unpleasant pictures (severe stress), while both groups rate the pictures equally unpleasant. I.e. the experienced fire officers rate the related unpleasant pictures just as negative, but apparently they freeze to a lesser extent. Perhaps they recognise these situations because of their experience and know how to act and, therefore, freeze less.

Objectively, the inexperienced fire officers show a delay in response to the non-related unpleasant pictures (moderate stress). To the related unpleasant pictures all the test subjects show a strongly delayed response. This fits in with the idea that it is an adequate response, to focus one's attention on a substantial or severe threat when faced with such a threat. The pictures 'draw' so much attention that responses slows down. Speculatively, this could mean that experienced fire officers regard the related unpleasant pictures as a substantial threat, but not the non-related ones, while the inexperienced fire officers experience all unpleasant pictures as a significant threat. This fits in with the idea that there are many more kinds of negative triggers to 'draw them into the incident'.

Inexperienced fire officers show freezing in reaction to all kinds of threats (also to non-related threats), experienced fire officers only to relevant or severe threats. Experienced fire officers only respond when the threat is substantial or severe, while the inexperienced fire officers already respond to a moderate threat.

### ***Passive viewing incident simulation***

- > The negative film causes stress (increased heart rate and reduced body sway).
- > The stress response predominantly occurs from block 3 to block 4, when the instances of stress become more frequent and the fire is actually visible in the film.
- > During the film, inexperienced fire officers show stronger heart rate acceleration than experienced fire officers.
- > The heart rate was affected by age as well. Throughout the groups a higher age corresponded with a heart rate that accelerated less strongly from the beginning of the film until the end.

Closer inspection revealed that this was only strongly the case for the inexperienced fire officers. There was no connection between age and heart rate acceleration for experienced fire officers.

During the film, the entire group showed heart rate acceleration. The heart rates of experienced fire officers accelerated less from the beginning of the film until the end than those of inexperienced fire officers.

Throughout both groups, the fire service film results in a slight trend to move less. Similar to the heart rate, the decrease in body sway predominantly occurs from block 3 to block 4, when the instances of stress become more frequent and the fire is actually visible in the film. As far as the decrease in body sway is concerned, there was no difference between the experienced and inexperienced fire officers. (When age is included as covariate there was still no effect.)

### **Visual inspection of the heart rate and body sway data**

Since inducing stress by way of a specific incident simulation was a new test design, the data were visually inspected for distinctive patterns. Figures 15 and 16 depict the development of the heart rate and body sway during the film. Obviously, since this was only a visual inspection, and no testing was involved, no conclusions can be drawn from this.

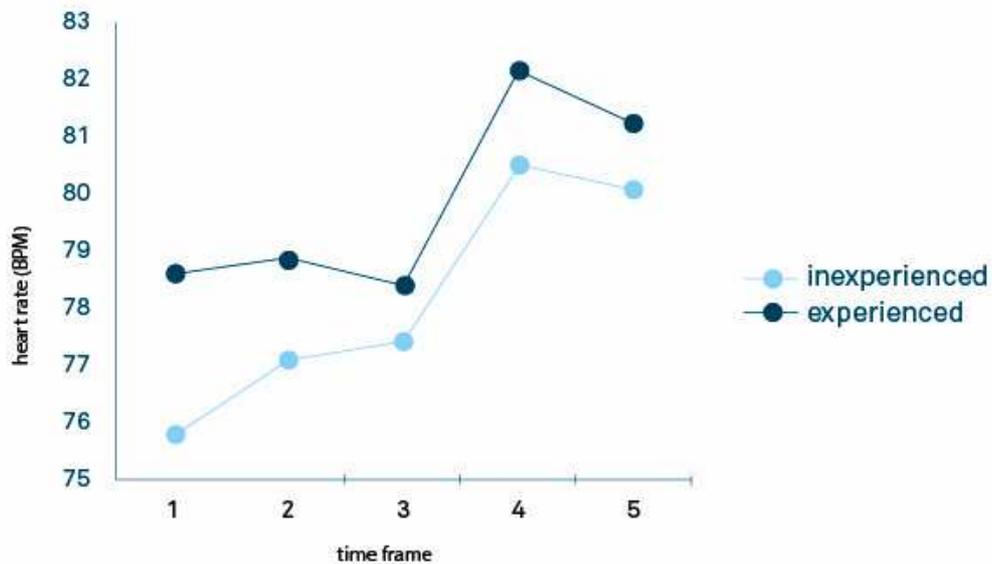


Figure 15: Heart Rate

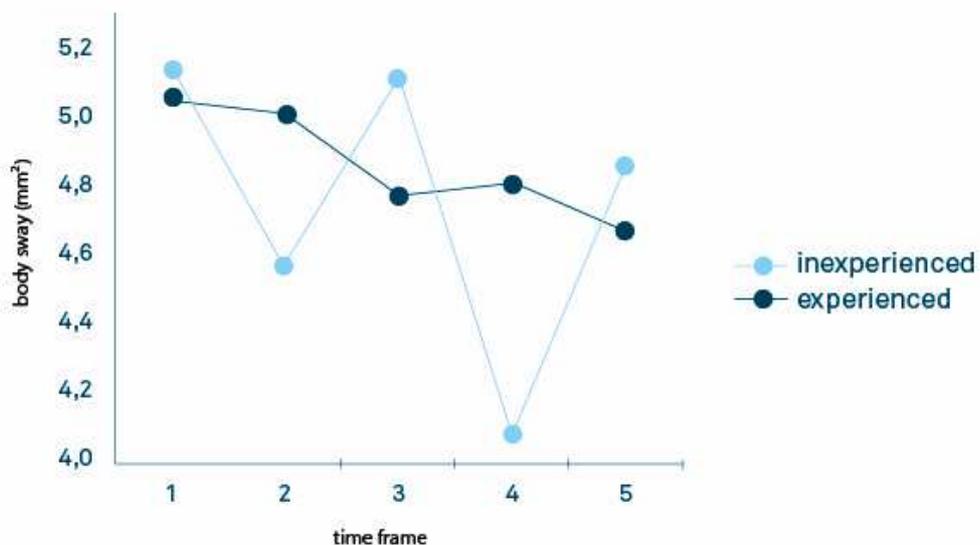


Figure 16: Body Sway

The following patterns can be observed:

- > As from block 4, the patterns of heart rate and body sway point at stress, when the fire becomes visible and the instances of stress occur in quick succession.
- > Speculative and to be confirmed by further research: The reduced body sway during block 4, combined with strong heart rate acceleration can point at a stronger stress response by the inexperienced fire officers.
- > The inexperienced fire officers demonstrate a much more variable pattern in their body sway, and the experienced fire officers are 'more stable'. This could be due to the small sample of inexperienced fire officers. However, it is a notable difference and should be further investigated.

#### **Fire Service Film Recognition**

- > The groups did not differ much in the percentage of correct answers and there also was no difference between the groups regarding correct answers to stress items or non-stress items.
- > Throughout the group (experienced and inexperienced fire officers combined), the changes in heart rate and body sway during the film were unrelated to the percentage of correct answers.
- > However, inexperienced fire officers who had strong heart rate acceleration during the first half of the film, could not remember the instances of stress as well. Experienced fire officers with a stronger increase of body sway during the first half of the film, could not remember the non-stress instances as well.

An experienced fire officer who is under stress might regard the non-stress related information as less relevant and instead focuses more on relevant/stress-related information.

While this corresponds with the rest of the results and the research into Recognition Primed Decision Making and the Einstellung effect<sup>17</sup>, it is a speculative interpretation that has to be further substantiated.

#### **4.2.6 Conclusion and Interpretation**

In this section, the research questions are answered that were formulated for this sub-study:

- > *What is the role of experience on threat-related freezing behaviour?*
- > *Does freezing affect memory?*
- > *What is the influence of experience on memory accuracy?*

In conclusion, a number of observations are made regarding the research design.

#### ***What is the role of experience on threat-related freezing behaviour?***

Based on the two experiments (the pictures and the incident simulation) it can be stated that experienced fire officers respond differently to a threat than inexperienced fire officers. With respect to the pictures, inexperienced fire officers demonstrate freezing in reaction to all kinds of threats (including moderate and non-related threats), experienced fire officers demonstrate freezing only in reaction to substantial or severe threats. In other words, all fire

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<sup>17</sup> The Einstellung effect occurs when a person is presented with a problem or situation that is similar to problems they have worked through in the past. If the solution (or appropriate behaviour) to the problem/situation has been the same in each past experience, the person will likely provide that same response, without giving the problem too much thought, even though a more appropriate response might be available. Essentially, the Einstellung effect is one of the human brain's ways of finding an appropriate solution/behaviour as efficiently as possible. Note, however, that although finding the solution is efficient, the solution found might not necessarily be the most appropriate solution. Experiments show that stressful situations increase the prevalence of the Einstellung effect (from: Duncker, K. (1945). On problem solving. Psychological Monographs, 58:5 (Whole No. 270).

officers show freezing when faced with severe, related threats and only inexperienced fire officers show freezing when faced with moderate/non-related threats.

Experienced fire officers seem to freeze at the right moment when passively experiencing a threat, i.e. when there is a considerable threat. Since freezing is associated with risk assessment, this could be functional in that they find out as much about the actual situation as possible. Inexperienced fire officers do not differentiate, perhaps unguided by experience; they approach each situation as potentially relevant. This is obviously speculative, but it is an indication that further research is very important.

As far as the film is concerned, the inexperienced fire officers seem to show a fight-flight reaction earlier when they are faced with a situation where they may have to act.

Speculatively, this could mean that they:

- > experience a more urgent tendency to act;
- > experience more stress because they are not familiar with the situation and, therefore, are more cautious and cannot rely on familiar scenario's from the past.

This can have both a negative and positive outcome. Possibly this automatic reaction contributes to the learning process of inexperienced fire officers in that they gain experience. In any case, it indicates that there are differences between experienced and inexperienced fire officers in the way they approach an incident. The findings are consistent with the idea that inexperienced fire officers show fight-flight behaviour earlier in threatening, complex situations, while experienced fire officers take more time to size up the situation. Further research will have to confirm this.

### ***Does freezing affect memory? What is the influence of experience on memory accuracy?***

The heart rate acceleration of inexperienced fire officer was related to a poorer recollection of instances of stress. On the other hand, experienced fire officers recollected non-stressful instances less well when they experienced more stress. This corresponds with the idea that in threatening situations experienced fire officers focus more on specific aspects, while inexperienced fire officers still focus more widely.

### ***Study Design***

The research design was very innovative. Despite the fact that the human factor has a great influence on performance during incidents, and that automatic stress responses are important decisive factors in the human factor, no previous research has been conducted into these responses in fire officers. By conducting this research, the first step has been made towards the optimisation of human behaviour during large-scale incidents.

Another important conclusion regarding the research design is that the incident simulation demonstrably induces stress in the participants. They identify themselves with the fire officer in the film, which emphasises the value of virtual incident simulations for teaching, training and exercising.

## **4.3 Mindfulness: a Useful Stress Coping Mechanism?**

### **4.3.1 Introduction**

In the project, innovative incident command mindfulness is defined as: an attentive and unbiased attitude, grounded in the here and now. As was discussed in Chapter 2, operational commanders can increase their effectiveness when they succeed in limiting the negative aspects of decision-making under pressure, and transform these into positive

effects. This requires an increase of control capacity for operational commanders. Research studies have shown that mindfulness techniques can enhance control capacity. It was found that mindfulness improves the forming an image and decision-making under time pressure<sup>18</sup>. The powers of observation are enhanced as a result of which more situations/risks can be recognised. It enables people to distance themselves from their feelings and thoughts and, therefore, mindfulness increases the ability to reflect upon one's own behaviour during the incident.

Nevertheless, the concept of mindfulness and the accompanying techniques have not yet been introduced into the fire service in the Netherlands. The objective of the pilot study was to gain an understanding of how mindfulness can be introduced into the Dutch fire service. This results in the following research question:

*How can mindfulness be introduced into the fire service in order to improve the quality of incident command, and do the test subjects expect to benefit from this in the execution of their suppressive task?*

More specific, the question was whether the participants:

- > experience a change in effectiveness of their incident command?
- > think that these instruments can be implemented in the fire service and what would be the key points to consider? and
- > think that the training provided enough support and do they think that it can be improved in any way?

### 4.3.2 Short Description of the Pilot

In a period of 8 weeks, two groups of 5 fire officers<sup>19</sup> were introduced to mindfulness. The period started with registering for the training and receiving the programme and background material on mindfulness. The background material consisted of a video on how Navy Seals in the United States use mindfulness.

In the first training, the techniques tactical breathing and body scan were learned. The participants were asked to keep practising the techniques after the training and to use the techniques during incidents or training sessions. In the second training, the technique distancing was learned. Again, the participants were asked to keep practising the technique after the training and to use the techniques during incidents or training sessions. The period was concluded with a group discussion about the participants' experiences. In between, a number of participants filled out a questionnaire.

### 4.3.3 Results

The participants consider the mindfulness techniques to be both useful and practicable. This is particularly the case with regard to tactical breathing and body scan, since these are not yet part of the curriculum of crew commander, fire officer and senior fire officer. Enhancing situational awareness by creating a distance is in a way already part of the curriculum. However, in the mindfulness training this concept was interpreted differently.

Almost all participants are of the opinion that mindfulness helps them perform better as a fire officer. The usefulness of mindfulness is described as follows:

- > 'After focusing for a moment on your breathing and your body, you see the incident in a new light.'
- > 'It can help you step out of your stress.'

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<sup>18</sup> Refer to part 1 'The Framework'

<sup>19</sup> From Fire Service Amsterdam-Amstelland, Fire Service Kennemerland and Fire Service Hollands-Midden. A combination of officers who work in a professional fire brigade and participants who work in a mixed professional/volunteer fire brigade.

- > 'It prevents you from 'going in' and focussing on the one thing.'
- > 'To me it is staying in the here and now, not getting carried away by sensations, and not judging the things happening to you. Making your own choices and deciding how to respond to things.'
- > 'Because of the stress, your controlling mechanism can sometimes become unstable. If you can recognise that and can make it stable again, it is of great benefit.'
- > 'You have to compose your thoughts during an incident. Mindfulness is a functional step in your actions. It results in order, and order results in speed.'

However, most participants did not experience an immediate difference during incidents. According to the participants, merely learning the techniques in two sessions is not enough. Some participants emphasised that it is particularly important to practise the techniques twice a day: for the techniques to be effective in practice, they have to become automatisms. 'But the most important is the morning you have your sessions. The improvement is obvious.' One of the participants of the pilot described his experiences during an incident: 'I walked three storeys down and I thought: check my breathing. And I did. But when I discovered that it (the incident - ed.) concerned a colleague, it was gone immediately. And it did not come back.'

According to the participants, merely acquiring the technique is not enough. Firstly, they gave the advice to teach mindfulness techniques under stressful circumstances and, secondly, to provide immediate feedback when the technique is not applied correctly during these stressful circumstances.

Some quotes from the participants:

- > 'It is about the moments you do not notice yourself, that your knuckles should be rapped. I think it should be connected to incidents. During an exercise or an actual incident. We do not train during incidents, for instance with shadow fire officers following you around and providing immediate feedback.'
- > 'Last week, I went to England for a realistic training. I intended to apply tactical breathing. When you are at rest, then you remember to pay attention to it. But nobody paid any attention to my breathing during the training. You only notice it yourself when things around you settle down again.'
- > Another participant in the training described how you can help each other to stay calm, alert and sharp during an incident. 'How do you recognise it [that you are not mindful]? How do you see it yourself? Usually someone will put a hand on your shoulder or something like that. Someone looked at me during an incident and in hindsight I recognised that look as the observation: 'What a madhouse'. Then I should have gotten out.'
- > According to some participants, it is advisable to learn the mindfulness techniques consciously and apply them under extremely stressful circumstances, such as the so-called 'respiratory crisis'.

#### 4.3.4 Conclusions

In this section, the research question is answered that was formulated for this sub-study: *How can mindfulness be introduced into the fire service in order to improve the quality of incident command, and do the test subjects expect to benefit from this in the execution of their suppressive task?*

Most participants in the pilot find mindfulness techniques useful for the suppressive practice, and consider it a welcome addition to the operational commanders' curriculum. Mindfulness could be part of the training programmes (for crew commander, fire officer, senior fire officer and hazardous materials adviser - ed.) Some participants stress the importance of an

accurate description of what mindfulness techniques are. The concept could be perceived as a bit alternative or hippie-like and, therefore, hard to fit in with the 'tough' culture of firefighting and rescue.

According to the participating officers, it is definitely possible to introduce mindfulness into the world of firefighting and rescue. In doing so, it is important to emphasise the improvement of incident command instead of the mental concept. However, it should be realised that operational commanders will not become mindful 'just like that'. There is more to it than learning the techniques. It will also have to be learned under very stressful circumstances. But perhaps most importantly, it has to become a habit and an integral part of firefighting and rescue practice.

# 5 Conclusions

## 5.1 Introduction: Definition of the Problem

The Dutch fire service handles an estimated two to three incidents per week with four or more appliances/ pumps<sup>20</sup>. This is called 'grootschalig brandweeroptreden' (large-scale firefighting and rescue operations) and, for this type of operation, specific procedures have been laid down.<sup>21</sup>

It turns out that during actual large-scale incidents, the procedures and incident command structure are not followed as they are taught and they are applicable at that moment. As evidenced by the conclusions of Learning Arena Moerdijk this is broadly recognised within the fire service, and it reoccurs in recent evaluations of other large-scale incidents, such as the fire on the fishing ship Johanna Maria, the wildfire in National Park Hoge Veluwe and the fire in the senior citizens' apartment building 'De Notenhout' in Nijmegen. This raises the question of why this happens, whether it is a good or a bad thing, and whether an alternative command structure or method could be developed that better meets existing needs.

The project 'Innovative Approach of Incident command' researched the way in which operational commanders lead large-scale firefighting and rescue operations on the basis of the following two research questions:

1. *To what extent and for what reason is it problematic that the incident command of large-scale firefighting and rescue operations deviates from its organisational design?*
2. *What modifications of the organisational design and/or the execution of incident command can improve large-scale firefighting and rescue operations?*

In answering these principal questions both the organisational components and the human factor are considered. The organisational principles are discussed in Section 5.2. The human factor will be discussed in Section 5.3. In Section 5.4, the final conclusions are drawn regarding the research questions.

## 5.2 The Command Type

Actual (fire service) practice and organisational science both state that an organisation has to respond flexibly to its (task) environment. The fire service's adaptability was, therefore, central to this study. The organisational design of incident command of large-scale firefighting and rescue operations was looked at to research whether the unpredictability of the task environment was taken into account. The objective of the study is not to determine whether a particular procedure was followed or what the consequences were. It is about the basic design of incident command in relation to the required adaptability in order to be able to manage large-scale incidents.

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<sup>20</sup> In total there are about 625 fire officers and 150 senior fire officers in the Netherlands. This indicates that on an individual level actual experience with large-scale operations is relatively low.

<sup>21</sup> The Guideline 'Visie GBO, leidraad Brandweercompagnie' (Vision Large-scale Firefighting and rescue Operations, Guideline Fire Service Company (still used by several regions), training programmes for fire officer and senior fire officer

### 5.2.1 Is Deviation a Problem?

The initial principal question was: *To what extent and for what reason is it problematic that the incident command of large-scale firefighting and rescue operations deviates from its organisational design?*

Three answers to this question were found.

#### ***Answer 1: it is not a problem.***

It is not a problem that there is a difference between the designs and practice because the designs have significant shortcomings regarding the adaptability of the fire service. To consequently follow the organisational design would, therefore, more likely cause a deterioration of the performance. Indeed, by not following the organisational design, the fire service regularly demonstrates that it wants to adapt to incidents, but at this moment it is limited by the rigid structure that hardly ever fits the incident (in the acute stage).

#### ***Answer 2: it is a problem.***

It is a problem that there is a difference between the designs and actual practice because in the supporting processes 'training and exercising' and 'evaluations & research', the designs are used as benchmarks. As a result, there is no concordance between the supporting processes and the primary processes as to the most suitable type of incident command. This will probably negatively affect performances, since operational commanders sometimes receive conflicting feedback on their performance as a result. This explains why during many exercises operational commanders state that 'I chose this approach because it is an exercise, but in real life I would handle this type of incident very differently'. Furthermore, it is certain that in the perception of the media and of the public 'a deviation from the planning process' is almost always labelled as negative.

#### ***Answer 3: it might be a problem.***

Even though there is no evidence to support this, it is possible that in practice the fire service deviates from the designs unproductively. After all, not every deviation from the organisational designs results by definition in a better performance. As stated before, finding the right balance between the task environment and the fire service organisation is key. Wrong choices automatically lead to imbalance and as a consequence to ineffective and inefficient performances. Further research will have to be conducted into the practice of large-scale firefighting and rescue operations related to the new concept of situational incident command.

### 5.2.2 The Limitations of Hierarchical Incident command

At the time of publication of this study the fire service has a hierarchical command model<sup>22</sup> for large-scale incident management. In procedures, education programmes and training, the following supporting arguments for the hierarchical model are usually provided:

- > Because of the central command there is hardly any need for consultation and deployment orders can be given rapidly, without any discussions. This would benefit a rapid deployment of units.
- > Unambiguity (everyone is on the same page).
- > The officers create a full and joint image (overview) based on the information provided by the crew commanders and they subsequently share this with them.
- > Explicit decision-making about the need for an attack versus the risks based on the overview.

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<sup>22</sup> 'The fire service organisation has a hierarchical organisational structure in which the fire officer is the connecting executive link between the crew commander and the senior fire officer.' And: 'The fire officer directs specialists and takes on the management of the incident.' (Textbook fire officer, 2012)

- > Because of the fact that the (senior) fire officers monitor the acts of the crew commanders, this results in an additional safeguard for work safety.
- > Unambiguous image building and decision-making by the fire service's highest in rank as a foundation for, once more, unambiguous multidisciplinary image building and decision-making at the Command Place of Incident.

This study has shown theoretically that these assumed advantages of hierarchical incident command do not occur in complex situations, and this conclusion is supported by the results of comparative simulation research:

- > There is no homogeneity in the attack.
- > It takes a long time to obtain a full and joint picture and it is rendered unnecessary by the dynamics of the incident.
- > Because of the incident dynamics and information overload, it is hard for central operational commanders to take stock of the whole situation and give orders for an attack. As a result, units have to wait<sup>23</sup> before receiving any order for the attack and the victims have to wait for help longer than necessary.
- > There is little explicit decision-making about the need and opportunities for an attack versus the risks involved, instead, operational commanders fall back on experience and rules of thumb.
- > In this model the (senior) fire officers have only a limited picture of the incident, the development of the incident and the deployment of separate units. The assumption that there is adequate supervision of the operation as far as work safety is concerned, is hereby refuted.
- > As a result of the limited picture, the incident dynamics and a mental overload, there is only limited conscious decision-making, both monodisciplinary and multidisciplinary.

In practice, it seems almost impossible for operational commanders to properly execute all the necessary steps for a good incident command when they are in a complex situation using a hierarchical command structure. The structure of incident command does not take the human factor into account. Especially, the formation of an operational picture and making an analysis are under pressure. However, these are vital processes for incident command and in the hierarchical system the success of the entire organisation depends on them.

This substantiates the strong indication<sup>24</sup> that the traditional choice for hierarchy as a uniform command type that fits all incidents is inadequate. In all task environments shortcomings were observed: simple, complicated and complex. Moreover, there are strong indications that hierarchical incident command in acute, dynamic situations does not result in the desired outcome (better incident management).

It is concluded that a hierarchical command model is not effective in complex situations. It is demonstrated that there are different types of incident command that each fit a certain level of complexity of the situation.

The fire service works in situations that consist of different levels of complexity. Therefore, to be effective, incident command has to adapt to the level of complexity of the situation.

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<sup>23</sup> In the hierarchical structure, the waiting time for the second shift to be deployed from the vehicle assembly area amounted to 20 to 30 minutes a few times. Note: in all instances there was an urgent need for extra units in the field. This contradicts the theory from the 'Leidraad Brandweercompagnie' (Guideline Fire Service Company) (1995): Giving orders to one squad commander instead of four crew commanders saves time, in addition to other benefits.

<sup>24</sup> A reservation has to be made because of the limited number of tests that could be executed within the (financial) boundaries of the research. However, the conclusion can be observed in actual practice, during actual incidents.

### 5.2.3 Differences in Organisation

The second research question was: *What modifications of the organisational design and/or the execution of incident command can improve large-scale firefighting and rescue operations?*

The current fire service's organisational designs are of the type 'one size fits all'. There is just the one organisational design, while in reality there are significant differences between incidents regarding type and complexity. This study demonstrated, first theoretically and subsequently via experiments, that the current organisational design does not handle these differences in complexity well. The reason for this is that the design is geared to one, relatively low, level of complexity. Currently there are not enough design principles available for the fire service for incidents with a high level of complexity, and in large-scale operations there usually is a high level of complexity. In this respect, it has to be mentioned that the level of complexity is not only connected to the type of incident, but also to the extent in which there exists a clear picture of the size and seriousness of the incident. It turns out that 'the incident' changes in character from start to finish and, therefore, calls for another type of fire service organisation. It is up to the operational commanders and the organisation to keep adjusting to the (complexity of) the incident.

The comparative simulation research into organisational principles was focused on the measure of hierarchy and specialisation of operational commanders within the organisation. It showed that:

- > In most cases limited hierarchy in large-scale incidents results in more decisiveness.
- > It is confirmed that the fire service does not perform optimally with a high level of hierarchy in complex situations.
- > Participants in the experiments were most positive about the specialist control during the complicated incident. However, the division of roles with the formal operational commanders (fire officers and senior fire officers) has to be described in more detail.
- > A weak hierarchy leads to a stronger self-regulatory capacity.

For operational commanders, the factor overview/ understanding of an incident is decisive regarding the extent to which they judge an incident as complex. I.e. regardless of how simple a large-scale incident may be from an objective point of view, operational commanders will judge it to be complex because of a lack of overview and understanding as to its size, dynamics and character. This suggests that initially, large-scale operations will almost never be considered simple. It follows that the operational commanders' measure of overview/understanding seems to be a decisive factor for determining the command type. This is partly determined by the human factor (see 5.3).

In answer to the second research question, it is concluded that the performances of the fire service improve when they adjust the command type to the incident characteristics. This is called situational incident command in the new vision (see Section 5.2.4). Whether in practice performances will improve as a result of situational incident command, has to be one of the subjects for follow-up research. For this follow-up research the database for large-scale operations will have to be populated structurally.

### 5.2.4 Outline Description of Situational Incident command

Situational incident command is a practical and innovative model to enhance the adaptability of the fire service. Furthermore, situational incident command is geared to important aspects of actual practice.

Situational incident command signifies that the command type, i.e. the way in which decisions are made about managing an incident and the way in which operational commanders have these decisions carried out, has to be geared to the incident characteristics or task environment.

Situational incident command looks at large-scale firefighting and rescue operations from three angles:

- > The command type: aimed at the interaction between units and functionalities in relation to the incident. There are three command types formulated:
  - > Hierarchical incident command;
  - > Specialist incident command;
  - > Swarming incident command.
- > The human factors: aimed at the performance of the people that have to make and execute decisions in simple, complex and dangerous situations.
- > Business intelligence: aimed at informing the fire service about the degree of complexity of the situation and its own performance<sup>25</sup>.

The three angles are discussed separately, but situational incident command will only lead to optimum results when they are applied together. During an incident the organisational principles have to be closely geared to the human factors of the operational commanders. The controlling power of the organisation is strongly determined by how capable the operational commanders are, individually and as a group, of continuously making sharp analyses of the incident and deciding accordingly. At the same time, size up and decision-making cannot be left solely to the fallible operational commanders, but have to be supported specifically. The system of large-scale operations should be executed so redundantly, that it is not just based on the vulnerability of a single-headed leader, i.e. a forgiving infrastructure.

The model below represents the link between an incident and its measure of complexity, on the one hand, and the command structure and performance, on the other hand. The different components of the model are worked out in more detail in a previous report.<sup>26</sup>

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<sup>25</sup> For instance: decision support, accessibility maps, object information.

<sup>26</sup> B. van 't Padje, J. Groenendaal, J.C. Hazebroek, 'Innovatieve kijk op commandovoering – Het Raamwerk', IFV, Arnhem, 2014 (Innovative Approach of Incident command - The Framework)

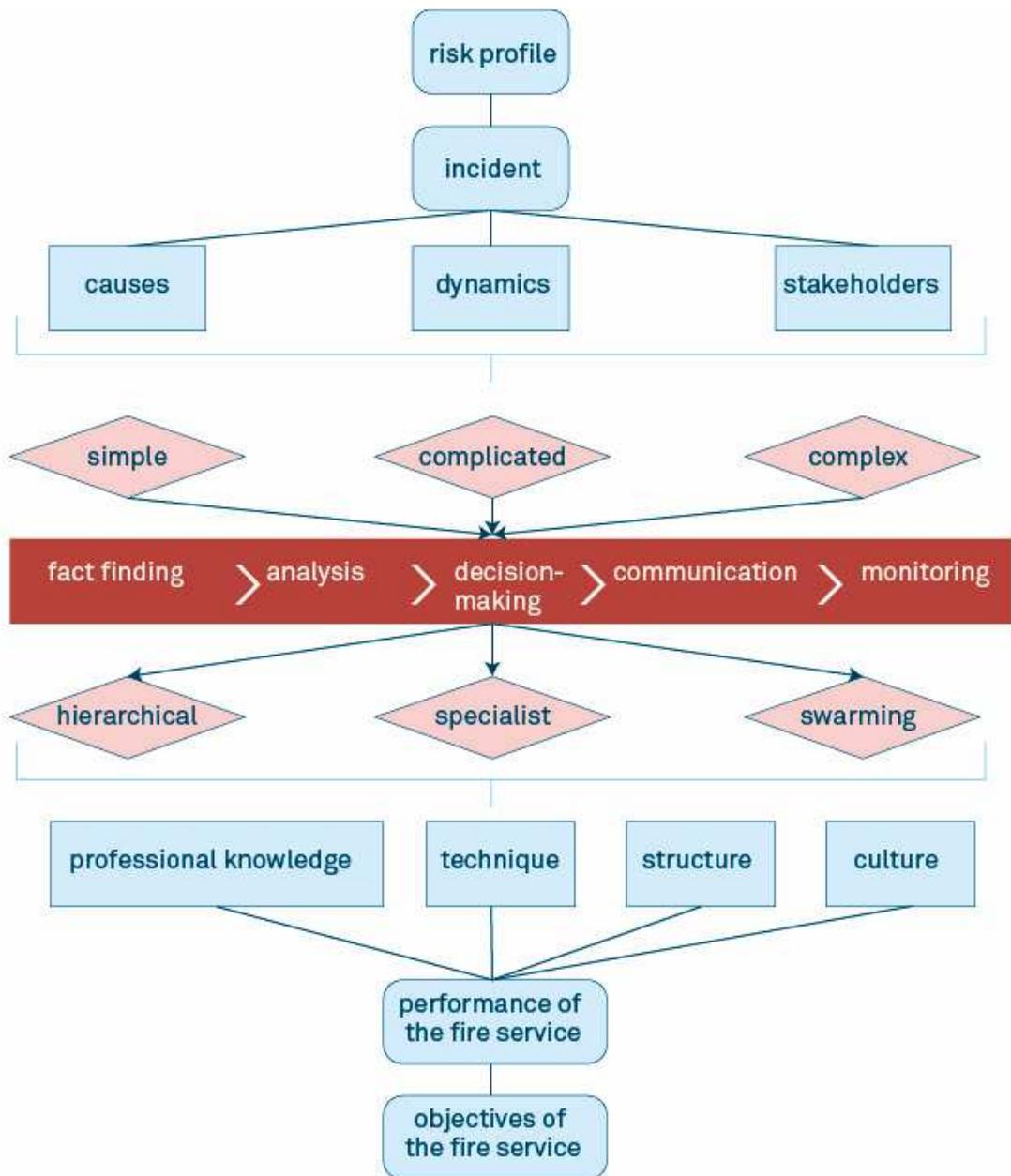


Figure 17: Model Situational Incident command

## 5.3 Human Factors

There are three human factors involved in this study:

- > Experience level
- > Mindfulness
- > Formal knowledge.

These three aspects are worked out in the following three sub-sections.

### 5.3.1 Experience Level

People can use two decision-making mechanisms to come to a decision. In the vast majority of cases, people use recognition or intuition. People have the ability to recognise a new situation and subsequently choose an approach that worked satisfactory in the past in a similar situation. Experience plays the leading part. The more experience decision makers

have, the more situations they recognise and the faster they have a solution for the problem. The more experience, the higher the fire service's adaptability.

In order to find out how experience influences automatic stress responses (see Chapter 4), in the second part of the study experiments were conducted based on the following research questions:

- > *What is the role of experience on threat-related freezing behaviour?*
- > *Does freezing affect perception?*
- > *What is the influence of experience on memory accuracy?*

*What is the role of experience on threat-related freezing behaviour?*

Based on the two experiments (pictures and incident simulation) it can be stated that experienced fire officers respond differently to threat than inexperienced fire officers.

The principal interpretations of this research are:

- > Experienced fire officers seem to freeze at the right moment, i.e. when faced with a threat, as a result of which they have more time to obtain the full picture and make an assessment.
- > During the incident simulation, inexperienced fire officers seem more likely to show a fight-flight reaction when faced with a threat. The result may be both positive and negative: the automatic reaction may contribute to the learning process of inexperienced fire officers (gaining experience).
- > The (probable) fight-or-flight response in inexperienced fire officers correlates with remembering the main issues of the incident less well, while experienced fire officers have a poorer recollection of the side issues of the incident. This indicates that in threatening situations experienced fire officers remember the main issues of the incident better than inexperienced fire officers.
- > The above suggests that inexperienced fire officers show fight-flight behaviour faster in threatening, complex situations, while experienced fire officers take more time to clarify their situational awareness.

The experiments confirm the assumption that experience has an effect on the (individual) assessment of the situation (situational awareness), but also on the fire service's adaptability, because main issues and side-issues are separated better and more time is taken to arrive at a judgement. This is especially of importance in complex situations.

### **5.3.2 Mindfulness**

There is ample scientific evidence that mindfulness leads to better results in the formation of an image and decision-making under time pressure. The powers of observation are enhanced as a result of which more situations/risks can be recognised. It enables people to distance themselves from their feelings and thoughts and, therefore, mindfulness increases the ability to reflect upon one's own behaviour during the incident. These are important skills for situational incident command, because the organisation has to follow the incident development continuously. Therefore, the question is not whether mindfulness is of added value to the fire service, but rather how mindfulness can be implemented.

In this section, the research question is answered that was formulated for this sub-study: *How can mindfulness be introduced into the fire service in order to improve the quality of incident command, and do the test subjects expect to benefit from this in the execution of their suppressive task?*

Most participants in the pilot find mindfulness techniques useful for the suppressive practice, and consider it a welcome addition to the operational commanders' curriculum. Mindfulness could be part of the training programmes (for crew commander, fire officer, senior fire officer and hazardous materials adviser - ed.). Some participants stress the importance of an accurate description of what mindfulness techniques are. The concept could be perceived as a bit alternative or hippie-like and, therefore, hard to fit in with the 'tough' culture of firefighting and rescue.

According to the participating officers, it is definitely possible to introduce mindfulness into the world of firefighting and rescue. In doing so, it is important to emphasise the improvement of incident command instead of the mental concept. However, it should be realised that operational commanders will not become mindful 'just like that'. There is more to it than learning the techniques. It will also have to be learned under very stressful circumstances. However, perhaps most importantly, it has to become a habit and an integral part of firefighting and rescue practice.

The circumstances during incidents strain the operational commanders to the utmost. They need to be calm, sharp and alert to perform well under these circumstances. It must be concluded that mindfulness is an important component of situational incident command, especially in relation to the observations in Section 5.3.1 on the (neuropsychological) influence of stress.

### 5.3.3 Formal Knowledge

This study did not focus on the formal knowledge, i.e. education programme and level of knowledge, of the operational commanders and there are, therefore, no research questions regarding this subject. Still, we take the liberty to present a number of observations regarding this human factor.

Formal knowledge plays an important part in incident command: the actual way in which the incident is handled and the appropriate incident command are at least partly based on formal knowledge. It requires considerable expertise to act as an operational commander in applying situational incident command and carry out the following tasks:

- > make an assessment of the current situation of the incident;
- > make an assessment of the development of the incident in  $t + 5$  minutes (crew commander),  $t + 15$  minutes (fire officer) and  $t + 30$  minutes (senior fire officer), taking into account the effect of ongoing operations to handle the incident. The operational commanders do this themselves to acquire a personal picture of the operational area and its opportunities and limitations;
- > draw up an approach for  $t + 5/15/30$  including the command type;
- > state specifically which goals, technique, tactic and formation are required to manage the incident<sup>27</sup>.

During the experiments, considerable differences in formal knowledge were observed, especially between the participating (senior) fire officers. For situational incident command, it seems important to both broaden and deepen the formal knowledge, since for all types of situations an adequate response has to be provided, based on predictive power. This applies specifically to the fire officer and senior fire officer.

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<sup>27</sup> Inclusive of very practical but vital factors, such as operation depth water cannons and rescue vehicles, the amount of water used for firefighting and rescue, specialist rescue tools and teams, etc.

## 5.4 Final Conclusions

### ***The current designs are sub-optimal***

The current organisational designs for large-scale firefighting and rescue operations are typically hierarchical in nature. Theoretical and experimental research has shown that these designs - both from an organisational perspective and from the perspective of the individual within an organisation - are predominantly appropriate for relatively simple incidents in a stable phase and not for complex incidents in an acute phase. When they are in the acute phase, most large-scale incidents have the characteristics of a complex or complicated incident. It is, therefore, explainable that the standard organisational design discords with the actual practice and that in practice crew commanders and officers deviate from the design.

### ***Situational incident command is the solution***

The fire service can perform better when there is a balance between the organisation and the actual complexity of the incident. The fire service organisation has to learn to adjust more quickly and more effectively to an incident: situational incident command. In practice, this already occurs regularly during large-scale operations, but the supporting processes such as the planning process and education programmes are still focussed too much on the model 'one size fits all'. Situational incident command will enhance the fire service's performance during large-scale operations. To a certain extent it will have to be accepted that real large-scale operations can never meet the same quality standards as small or medium-sized incidents, with regard to effectiveness, efficiency and safety. There simply are too many factors simultaneously active in a highly dynamic environment.

### ***Enhancing controlling power***

Situational incident command demands a great deal from our operational commanders. They have to interpret the complexity of the incident and continuously translate this into an appropriate organisational design. Formal knowledge, business intelligence, mindfulness and a forgiving infrastructure can support them in this (see Chapter 8).

# 6 Methodological Retrospective

There are no previous studies that test three theory-based organisational archetypes within three virtual incident environments that the fire service is familiar with.

There were 12 participants and 15 observers involved in the execution of the experiments every day, ranging from crew commanders to senior officers. During 6 test days and 1 pre-test day, 168 colleagues from 10 regions were directly involved in the execution of the sub-study command type. As far as is known, this type of intensive and specific research into the effectiveness of the different types of incident command in the fire service hasn't been conducted before, nationally or internationally. This also applies to automatic stress responses in fire officers. This is a new study of automatic stress responses in a target group that has not been researched before regarding this subject. The research into incident command in the fire service is, in itself, already innovative, which gives cause to look back with some pride. The conclusion that a virtual incident simulator such as ADMS offers an effective method to become and stay skilled in large-scale operations, is very valuable for fire service regions when determining how to train for this fire service task.

Innovation goes hand in hand with making mistakes, as is shown during the execution of the research. The investigation techniques did not always run smoothly, which forced us to base the conclusions on relatively little hard data. Simultaneously, the results provide strong indications that the theory is confirmed.

The various methodological limitations are discussed in more detail below. To a degree these limitations should be considered as a methodological reservation regarding the conclusions found, but even more as lessons learned for follow-up research in the future.

## 6.1 The Scientific Foundation

At the start of the comparative simulation research into command types it was known that, due to practical and financial limitations, the resulting number of 18 simulations was low from a scientific point of view. The consequences of a limited number of simulations were that special care has to be taken regarding the generalisation of results: the command types are only tested twice for just three kinds of scenarios. This small number (two) means that it cannot be ruled out that two other experiments would lead to completely different results. Furthermore, the results only pertain to the three scenarios and not automatically to three complete different scenarios. The design was such that after the simulations, conclusions were limited to either confirmation or denial of the hypotheses.

In addition, there was a technical malfunction during the execution of some of the tests, as a result of which the data obtained during these tests cannot be considered completely representative. Consequently, the foundation for the analysis is weaker than intended, despite the careful planning and the dedication of the participants. This does not impair the value of this study, but sometimes the conclusions that can be drawn are a little less firm than desired. The foundation could have been strengthened by:

- > Planning more tests to strengthen the foundation and increase the margin if the results of one of the tests should be unusable.
- > Planning more time between the pre-test and the actual test days in order to have more time to solve any (technical) issues.

## 6.2 The Added Value and Limitations of the Virtual Environment

Because of the use of a virtual environment in the study, the external validity of the experiment is relatively high compared to other exercise and research environments. Perception measurements and conversations with the participants show that they experienced the exercise environment, scenarios and responses as realistic for the most part, and this is confirmed by the observations of the observers who recorded real stress in the participants. This is quite an achievement, since creating an externally correct environment for so many participants is on the one hand a strict condition for a correct analysis, and on the other hand is very challenging for the research or exercise staff.

On the basis of this conclusion, the use of a virtual test environment can be recommended to other researchers who want to find out more about decision-making under pressure by (large) groups of participants. However, ALL aspects that play a part, in terms of the passage of time and execution, have to be realistically worked out.

In spite of this, it still is a virtual environment that significantly deviates from actual practice. There are fewer environmental stimuli (smell, temperature, taste) and it is physically less taxing. Therefore, caution should be exercised in the translating the results of the test environment into the actual practice of large-scale operations.

## 6.3 The Value of Observation

The design of the comparative simulation research was such that the observers would record the actual results of the fire service operation. I.e. they had to record the point in time the victims were rescued, the moment the water cannons were deployed, etc. Since the simulations were predominantly geared to the effectiveness of the various command types, these results, per engine company and per officer, were of the utmost importance. The test design provided for this by appointing an observer for each participant who had to continuously follow him/her during the simulations. The observers received instructions on their task and received an example of a filled out observation form. Apart from the individual observers, there were three observers of the MCE level (MasterClass Evaluators) who observed the group process daily.

During the test days, all individual observers tried to carry out their role as best as they could and with great enthusiasm. However, it turned out that they had had still many questions. In retrospect, it has to be concluded that specifically the results were not fully recorded. This limitation has been resolved as best as possible by watching the fire service operation in the virtual system again. However, this is a very time-intensive 'emergency measure' and ideally should not be the basis for an analysis.

Therefore, these are the important lessons for conducting follow-up research:

1. Specify the crucial results and specify which (fire service) approach should be used to obtain these results. For instance: provide a detailed description on how many hose lines have to be deployed to prevent fire spread to another building. This prevents discussion and enables yes/no rating.
2. Rating the results with yes/no enables the automated processing of the binary ratings in the virtual system. Use automated observations where possible.
3. When a yes/no rating, or binary rating, is impossible, observers will have to be used. It is recommended to select the observers more specifically. In the experiments at hand, a participant was simply observed by a colleague with the same suppressive function. Reliable data are vital for a good analysis, and certain requirements will have to be set for the persons collecting the data.

Another methodological limitation regarding the observation during the simulation is the inter-rater agreement. Different observers were used on the different test days. However, it is not known to what extent the observers used the analysis and assessment framework similarly. For example: one observer might be of the opinion that the given order is brief, while another observer judges the same order as comprehensive. In some cases it seems certain that observers saw the same incident in a different light. E.g.: most operational commanders contacted the fire officer only a few times, but one of them contacted the fire officer more than 30 times. This could be explained by the fact that, in the latter case, the communications by radio were recorded; they were not recorded in the other cases. In order for the inter-rater agreement not to be a factor, the same observers will have to be used every day or a more strictly formulated and uniform assessment framework will have to be developed.

## 6.4 The Participant

The 'training' that the participants received for operating according to a specific command type was limited. Each test day, the training consisted of an introduction of 45 minutes in which the basic principles of the command type are explained. The people leading the exercise sometimes had to intervene to instruct the participants on the proper execution of the command type. This may have affected the results of the simulations: under pressure, the participants quickly fell back on their own experience and the procedures they learned during exercises or have applied themselves during large fires. It is entirely possible that when the participants have had more experience with the different command types, they are better able to execute them, and as a consequence, improve the effectiveness of that particular command type. This could be realised by practising one of the exercise scenarios the day after the introduction. This way, the participants have an opportunity to get used to the new procedure before the actual test and the recordings start.

The participants changed operational roles on every test day. This means that a participant may have been deployed on test day 1 as the 5th crew commander, on test day 2 as the 2nd crew commander and on test day 3 as the 7th crew commander. A problem here is that a difference in the effectiveness of the command type per scenario could be explained by the fact that other operational commanders were appointed. The influence of the personal competencies of the participants is inadvertently magnified, since it has been demonstrated that the first actions of the participants have a considerable impact on the subsequent course of the incident management.

However, it should be noted that there are also disadvantages when the participants do not rotate: a learning effect might develop, i.e. if all the participants keep the same roles, they will subconsciously adapt to their colleagues and the environment, resulting in the value of the outcomes decreasing as well.

# 7 On the Verge of Ability - a Plea for a Forgiving Infrastructure

By E. Oomes

*It's not the strongest firefighter who survives, nor the most intelligent, but rather the one who is the most responsive to change.*

Adapted from Charles Darwin

## 7.1 On the Verge of Ability

On 5 January 2011, there was a very large fire at Chemie Pack in Moerdijk. The impact of the incident was huge. The safety regions that were involved, Midden- en West Brabant and Zuid Holland Zuid, decided that they wanted an operational analysis from the fire service, in addition to the official investigations. This was organised in what is now known as the learning arena. In cooperation with the Organisation of Dutch Fire Services, then called NVBR, an evaluation design was developed that is based on second order learning: what elements of the fire service system did not work during the firefighting and rescue operation, formed an obstacle or were absent? Additionally, it is important to answer the question what the similarities are between the Moerdijk fire and other fires, rather than looking at the differences. Assuming that every fire has its unique characteristics, looking for differences might be interesting, but it is not always relevant for changing the system. However, when there are elements that keep recurring, you are confronted with a design fault and the system will have to be adjusted.

The learning arena generated a few second-order learning assignments and some of these are exceptionally relevant for the research into large-scale incident command. I will mention three, for the complete list, please refer to the text of 'Leerarena Moerdijk' (Learning Arena Moerdijk).

- > Make room for craftsmanship and improvisation based on the professionalism of firefighters. The emergency response plan is not a manual for operations where no deviations are possible.
- > Develop situational awareness. In order to be able to choose the appropriate tactic and technique for the incident, it is important to have a clear picture of the incident.
- > Conduct research into handling effects. What options does the fire service have for fighting large-scale fires? The term option awareness is used to describe this, in line with situational awareness.

The similarity between these three learning assignments is that they are all about the human factors of incident command during large-scale operations. The fire at Chemie Pack was so big and overwhelming and so unpredictable for the first responders that there was not a lot they could do with the resources available to them.

In the current system for large-scale operations, it is impossible for the operational commanders to simultaneously take care of the size up, assessment and decision-making within the time frame the fire dictates. If Moerdijk taught us anything, it is that there is a limit to the infallibility of humans. And once you are aware of this, you have to redesign the system with the fallibility of humans, the human factor, as the starting point. You try to prevent human errors by using, for instance, technical and organisational measures. Therefore, the professional skills of firefighters have to be improved to better prepare them for large-scale incidents. Moreover, safety nets have to be designed to cushion the consequences of mistakes. In addition, resources have to be integrated into the organisation of large-scale operations, which automatically create protection as an extra line of defence.

Eventually, this should result in the fire service performing at the verge of its ability, and not beyond it. In this reflection I call this a forgiving infrastructure: measures that help prevent errors and mitigate their consequences. In Section 7.3 I will discuss this in further detail.

For the development of these measures, research is required. It is, therefore, satisfying that the Lectureship Firefighting and rescue Expertise of the Dutch Fire Service Academy has conducted an impressive study of incident command during large-scale operations. Never before have firefighters been studied during their operational task in such a scientific way. The results found are not mere opinions, but are based on facts. According to Eliyah M. Goldratt, writer of *The Goal* (1984) science is: '*simply the method we use to try and postulate a minimum set of assumptions that can explain, through a straightforward logical derivation, the existence of many phenomena of nature*'. Goldratt states that this requires: '*the courage to face inconsistencies and to avoid running away from them just because "that's the way it was always done"*'. Based on these definitions, I can state with certainty that the Lectureship's study is scientific. Especially the last part of Goldratt's statement, to avoid running away, speaks clearly from the report and the recommendations. I would like to quote the second conclusion from the chapter All Things Considered:

*Secondly, we more than sufficiently demonstrated in this study that human factors are at least as significant as structures and knowledge, and maybe even more so. However, this is contrary to current paradigms, both inside and outside the fire service. Because society, but also our administrators and inspections, and last but not least our leaders themselves, are under the impression that a single-headed leader has to be capable of everything. This has to be reversed. People are fallible and therefore, they make mistakes, especially when they have to operate under unpredictable circumstances and are under pressure of time and/or threat. This is not the fault of the individual, but this happens because they are human. The fallible human factor can be counterbalanced by resources, but never completely.*

This is a very significant conclusion on which I will reflect further because it is true that you can never completely counterbalance the human factor by resources. You can get a long way if you start looking at the subject matter from a different perspective, however. That is why Section 7.2 is about an investigation into plane pilots who failed, 'The Limit of Expertise'. There it will be demonstrated that crashes are not caused by human errors, but that, at the most, human errors can increase or decrease the chances for a system failure, depending on four factors. Situational circumstances are included in this, and these findings correspond with the Lectureship's study of incident command.

In Section 7.3, I will introduce the term forgiving infrastructure for the fire service, where before this has been applied to traffic safety. Mindful of the conclusions of the Lectureship Firefighting and rescue Expertise that a new paradigm has to be formulated, I plead in favour

of forgiving infrastructure to be the new paradigm. In my opinion, the new paradigm is inevitably flexible, since the concept of situational incident command can never be executed within strict rules and regulations. An organisation based on principles and starting points can replace those. How the forgiving infrastructure can be further developed, is discussed in the following sections. By means of a few symbols, I will illustrate the principles behind the paradigm of a forgiving infrastructure. You will get acquainted with the stop sign (Section 7.4), sign post (Section 7.5), paving stone (Section 7.6), egg timer (Section 7.7) and check light (Section 7.8). These five functionalities constitute the foundation for the new paradigm for (large-scale) firefighting and rescue operations. How these functionalities are to be put into practice depends on the situation in a specific region or fire brigade.

Then, there is the period after the fire: the media, investigations and evaluations. A forgiving infrastructure is needed here as well. Therefore, Section 7.9 contains the closing argument for a forgiving infrastructure. To end this Section, and in keeping with the reflection, I ask for forgiveness for the length of the text. I tried to keep it short, but I did not succeed. On the other hand, you can skip the parts you are already familiar with. That depends on your individual situation as well.

## 7.2 The Limit of Expertise

The novel *The Limits of Expertise, Rethinking Pilot Error and the Cause of Aircraft Accidents* was published in 2007, edited by R. Key Dismukes. Key Dismukes was the Chief Scientist for Aerospace Human Factors at NASA. Their research was aimed at the behaviour of pilots under difficult circumstances and at the question when the chances for errors by pilots increase. The connection with crew commanders and officers, who have to make critical decisions under difficult circumstances, is obvious. In *The Limits of Expertise* 19 fatal aircraft crashes are re-analysed. The National Transport Safety Board (NTSB) investigated all 19 crashes and these data are reused for the new analysis. The reanalysis is not a reinvestigation, and it does not check whether the NTSB did a good job or not.

The central question of the researchers is whether other well-educated pilots would make the same mistakes in the same crash situation. An important basic principle regarding the question is that there hardly ever is only one single cause for an accident. Therefore, in their opinion human errors cannot be the reason for a crash. At most, human behaviour leads to an increased or decreased chance of an accident.

*Accidents are rarely, if ever, caused by a single factor but rather by a complex interplay of multiple factors, combining in ways driven in large degree by chance, each factor influencing the effects of the others. (Reason, 1990)*

Key Dismukes identifies four general factors that influence making errors by experts.

- > The characteristics of the task.
- > Specific circumstances in the environment during the execution of the task.
- > The demands made on human cognition by both the task, and the specific circumstances under which the task has to be executed.
- > The social and organisational factors that control the way in which a representative group of experts behaves under certain circumstances. This could be regarded as the social cultural logic of the profession: 'This is how we do it, people'.

The last sentence will have raised some eyebrows in recognition. Indeed, it could just as well be about the fire service. That is why in my opinion Key Dismukes' research is very relevant for the fire service, especially for incident command during large-scale operations. His findings are in keeping with the conclusions from the study by the Lectureship Firefighting and rescue Expertise into incident command.

*To a certain extent it has to be accepted that real large-scale operations can never meet the same quality standards regarding effectiveness, efficiency and safety as small or medium-sized fires. There simply are too many factors simultaneously active in a highly dynamic environment. Central operational leaders can never continuously monitor all factors that play a part, no matter how well the organisation and information management work. Central operational command should be more of an adjusting/complementary/reinforcing factor than an ultimately controlling factor. There simply are too many factors and actors involved to centrally control all factors involved. (Hazebroek et al., 2015, p. 80)*

I would like to name some additional relevant findings by Key Dismukes (2007) that are in line with the research into incident command.

- > In the last phase before the crash, the workload is very high and there is no appropriate workload management in place. The pilots miss subtle but significant signals, as a result of which they lack situational awareness. *'They may also revert to a reactive mode; rather than strategically managing the situation, they may respond to each demand as it arises, without prioritization, because they lack sufficient free mental resources to take a strategic approach. Monitoring and cross-checking may also suffer'* (p. 296). They have been overtaken by events and they do not succeed in 'getting ahead of the incident', as it is known in the fire service. This was also observed several times in the comparative simulation research into command types: operational commanders who 'are busy switching off lights' instead of reflecting on the core of the incident.
- > Sometimes circumstances require a very quick response, but the response fails or fails to occur. This could be called a tipping point, as a result of which the situation suddenly gets out of hand. Initially, the researchers were surprised that this factor was relevant in 65% of the cases. Further analysis shows that it is not that surprising, Key Dismukes states: *'In unfamiliar situations requiring very rapid response, no automatic response set is available, and the pilot does not have time to assess the situation adequately and to fashion the most appropriate response using controlled processing; thus error is likely'* (p. 297). These findings closely fit in with the theory of Recognition Primed Decision Making (RPD) and they also explain why so much goes wrong during non-standard fires. In this context the lector Crisis Management Menno van Duin stated: 'What you rarely do, you rarely do well.'
- > Plan continuation bias is an important human property that in some cases causes mistakes, specifically when a standard plan is concerned that is hit close to the target. Experts no longer see the signals that actually falsify the plan and no longer listen to critical voices, or do not listen properly. They stick to the plan and continue with the interior attack, procedure or attack plan they have already started.
- > In 30 per cent of the cases, inadequate education and training play a part. The researchers state justifiably that you cannot train everyone for all exceptions and for all specific circumstances. So with the current training methods, you can never be fully prepared for exceptional situations. *'Which raises the question of how best to provide generic training and procedures that will work in a broad range of situations, including those that are not likely to be anticipated'* (p. 298).

An answer might be to train more on the use of principles when improvising, and less on following procedures. With rules, the focus is on avoiding mistakes, whereas principles focus on finding the best possible solution.

Ultimately, Key Dismukes et al. conclude that the design of the operational flight system has to be looked at from a different perspective. Again, the link with the findings of the Lectureship is obvious. *'When equipment, procedures, and training are designed to reflect the characteristics and limitations of human cognitive and perceptual processes, it becomes possible to limit the frequency of errors, improve early detection of errors, and limit the propagation of errors into accidents. The object is to design the operational system to be resilient to the equipment failures, unexpected events, and human errors that inevitably occur'* (p. 302).

This resembles what the Dutch SWOV Institute for Road Safety Research called forgiving infrastructure. *'In almost every accident human errors play a part. Therefore, we need to make sure that an error does not automatically lead to a fatal accident, by a forgiving infrastructure. For instance by removing obstacles from shoulders'*.<sup>28</sup>

The issues with large-scale firefighting and rescue operations are more complex than removing obstacles from shoulders, but it is the concept that is important: structuring an organisation in such a way that a wrong decision does not automatically result in fatal consequences. It would be even better to design an organisation in such a way that the chances of making a wrong decision are minimised, and at the same time the consequences are not fatal: neither directly, in the sense of victims or injuries, nor indirectly, in the sense of criminal-law consequences for making the wrong decisions in retrospect. This reflection is a plea for a forgiving infrastructure in the fire service. Because we know that our officers in charge of fire suppression are bound to make mistakes, since they operate on the boundaries of possibility, we have to take measures to prevent and limit those mistakes. We need to take measures that support our officers in charge of fire suppression and help them because we know that the tasks they might be confronted with can be too big to manage single-handedly. Single-headed leadership is well and good, but it should not kill you.

### 7.3 Functions in a Forgiving Infrastructure

A forgiving infrastructure consists of systematically carrying out measures that reduce the chances of failure and soften the effects thereof in such a way, that there are no direct fatal consequences. As everyone knows, accidents and mistakes only rarely have one single cause, but usually are the result of a multitude of sub-standard situations. Therefore, a multitude of measures has to be taken to prevent those mistakes and soften their consequences. A quantitative multitude and a qualitative multitude are concerned here: measures can be aimed at behaviour, technique and organisation and can vary from an adjustment of the signal to retreat to a more flexible way of scaling up.

The concrete measures that a fire brigade has to take depend on their situation, which includes risk profile and area of coverage. Mindful of the conclusions of the research into incident command that structures have to adapt to the circumstances, no rigid safety management system with accompanying obligations is suggested.

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<sup>28</sup> For more information, refer to the website (in Dutch): <http://www.rizoomes.nl/snelle-interventie-niet-snel-de-zoektocht-naar-vergevingsgezinde-infrastructuur/>

When it is shown that the rigidity of a system leads to problems, you should not provide a solution by imposing another obligation. That would be exchanging one inflexibility for another. That is why I use the term infrastructure in this review, i.e. all measures that aim to reduce the chance of errors and soften the consequences of errors. A forgiving infrastructure is exactly that.

A forgiving infrastructure covers several categories of errors, which all have the common denominator that it concerns inadvertent, subconscious and/or unintended mistakes. Humans are fallible, especially when under pressure of time and in unfamiliar situations. At the same time, so much can go wrong that a comprehensive topology of errors is an illusion: that assumption is an error in itself. In the twenty years that I have occupied myself with human behaviour during incident management, I have described a few threads that I consider to be a vulnerability for the fire service. Each vulnerability corresponds with a functionality of the forgiving infrastructure, which can be represented by a symbol. Complicated processes can be illustrated rather easily with symbols. The symbols represent descriptions of concrete measures. Examples can be found in Section 7.4 and further. I identify the following five vulnerabilities in the suppressive system, with accompanying symbols.

> *Irrational and automatic behaviour*

This occurs especially in situations under pressure of time, when people make decisions based on recognition. However, irrational behaviour also occurs as a result of information overload, which disturbs all kinds of cognitive processes, often without the individual involved noticing it. Irrational behaviour can also be caused by the biological system, the nervous system, and includes the fight or flight response. This effect was also demonstrated during the freezing experiments of the research into incident command. The stop sign aims to interrupt this automatic way of acting, in order to create a better situational awareness.

> *Insufficient knowledge about the situation and possible solutions.*

'Experience is that what you miss, when you need it for the first time', Johan Cruyf already stated. This usually happens during unexpected or new incidents, about which the units at the scene have (yet) insufficient experience and knowledge. In this regard, the firefighting and rescue triangle mentions standard deviations and deviations. In this type of situation, there usually is adequate situational awareness, i.e. the problem is clear, but there is a lack of option awareness: what is the solution? The sign post symbolises back-up of option awareness and decision-making during such deviations.

> *Commanders who do not set clear objectives*

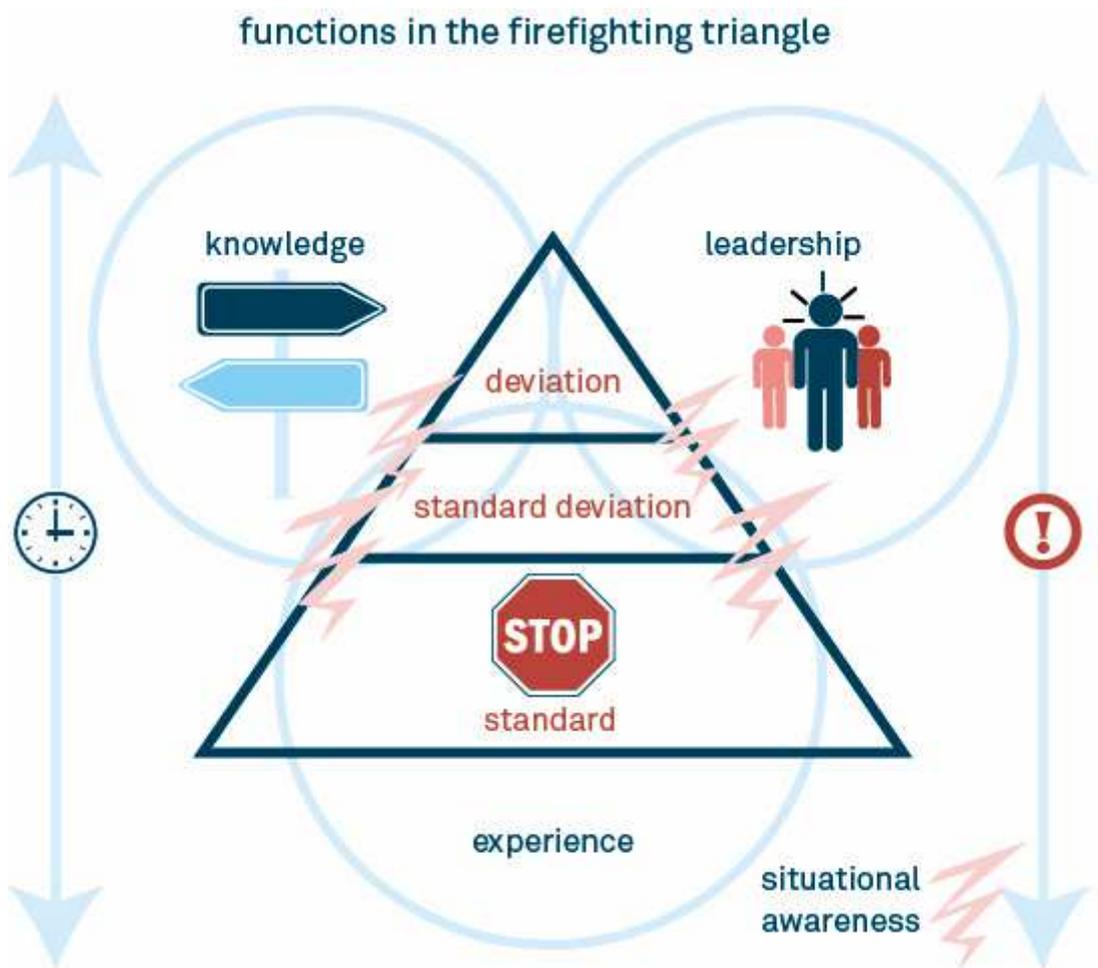
In a great article, *The Collapse of Sensemaking* (1993), Karl Weick describes how a lack of 'sensemaking' leads to a fatal accident. At a certain point, the incident's firefighters have no idea why they are doing what, and they flee from a wildfire that rushes towards them. Therefore, commanders have an important job in setting clear objectives and providing sense for an attack (sense making). Unfortunately, operational commanders get drawn in by incidents and many are absorbed by the high-frequency stream of small events. The paving stone symbolises commanders who see the big picture from an adequate distance, can adjust the essentials and do not lose themselves in stress of the moment.

> *Errors and violations in the execution of activities*

A proper attack can fail at a later stage when in the execution of the supporting and facilitating processes, errors and violations are committed, resulting in more damage than necessary. The damage can present itself during the incident, e.g. unhygienic situations, or afterwards, e.g. environmental damage. The check light symbolises monitoring the processes, to be able to intervene in time.

- > *Asynchronous experience of time and having been overtaken by events*  
There is a great discrepancy between the experience of time and actual time. During a large incident, multiple experiences of time can cut across the actual time. An incorrect experience of time can be a great source of unsafety, for instance because the assessment of the 'incident speed' can be incorrect as well. This can lead to dangerous situations, such as the collapse of building materials and building structures. The egg timer aims to synchronise the experience of time. In doing so, a plan can be made, expectations can be matched and firefighters can be relieved in time.

The five vulnerabilities and their symbols can be placed in the firefighting and rescue triangle<sup>29</sup>. In doing so, the functions become interrelated and can be seen as a forgiving infrastructure for suppressive operations, but only on a strategic level because the separate measures are anchored in the behaviour, the technique or the organisation.



**Figure 18: Functions in the Firefighting and rescue Triangle**

The stop sign is primarily seen in skill-based situations, during standard situations. All kinds of vulnerabilities that are connected to experience lie in wait there, such as blindsight, time compression and tunnel vision.

<sup>29</sup> For a further explanation of the firefighting and rescue triangle please refer to my article 'De vanzelfsprekendheid van alledag. Een beschouwing in drie delen over de gewoonten in het brandweervak' (2006) (Everyday Casualness. An View in Three Parts on Habits in Firefighting and rescue) and the website <http://www.rizoomes.nl/het-begin-van-de-sturingsdriehoek/> (in Dutch)

The sign post offers support in situations that are out of the ordinary, i.e. rule-based and knowledge-based scenarios. It includes providing option awareness, knowledge, for instance through scenario cards, procedures or accessibility cards that support the right decision-making. Consulting experts and specialist is a form of direction as well, as is the deployment of the Fire Service Support Team (Dutch: Ondersteuningsteam Brandweer, OTB).

The paving stone is about leadership. In standard situations, leadership has a mainly coaching character. However, during deviations (rule-based/knowledge-based), leadership is directive and of the utmost importance for a successful operation. The check light and egg timer are functions that appear in all areas of the firefighting and rescue triangle. Every situation requires specific measures that go with the functions of the check light and the egg timer.

The strategic component of the forgiving infrastructure makes it so that the system is not directly applicable in your own fire brigade. The various functions have to be translated into operational and concrete measures. Basically, there are two types of measures: measures that prevent people from making errors and measures that limit the consequences of an error. The measures have in common that they are all part of a forgiving infrastructure. They are the safety nets to prevent worse from happening.

All measures have to be laid down in an operational safety system, and have to be guaranteed by means of a standard PDCA system (Plan Do Check Act). Thus, a basis is created to control foreseeable risks in optimal fashion, and on a safety level that has been strategically agreed upon. This way, the measures become part of the professional skills of firefighters.

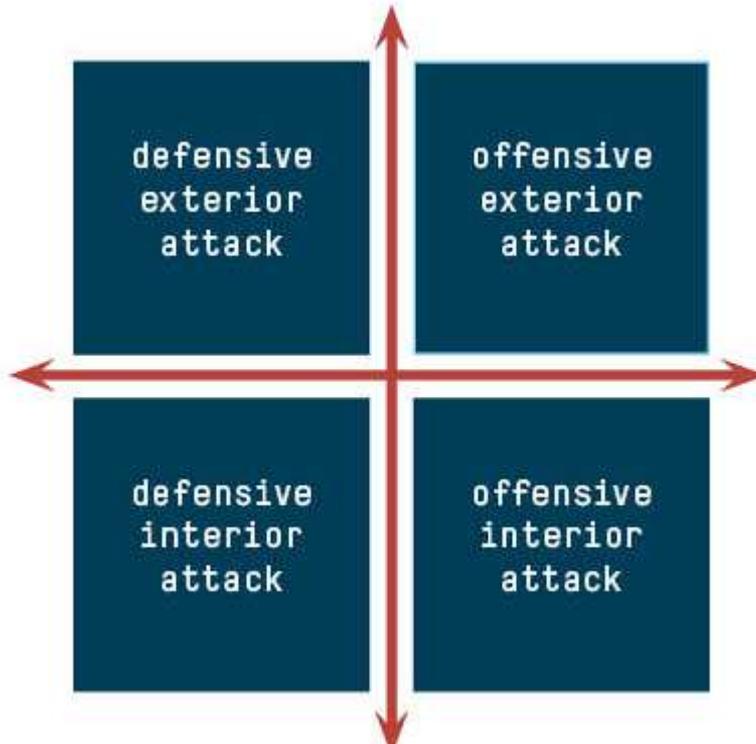
The non-foreseeable risks, the deviations and the black swans will have to be assessed and judged as they occur. The five functions of the forgiving infrastructure are formulated in such a way, that they also work with deviations. They can help structure the improvisation at the scene and create cognitive space (metacognition), which increases situational awareness. Every operation demands that measures are taken to overcome irrational behaviour, support decision-making, and that set up leadership well. Apart from that, controls have to be built in that monitor and, if necessary, adjust time management and command support. Improvisation in the fire service is never a really free improvisation. You have to decide in advance what functionalities to organise, depending on the situation at the scene. Ultimately, this is the main conclusion of the study into incident command.

## 7.4 Preventing Irrational Automatic Behaviour: the Stop Sign

The stop sign has to curb the risk of undesirable behaviour by pausing the launched flow, letting you check where you are (come to your senses) and then, decide how to proceed. Proceed with the same action, if it was appropriate, or maybe choose one that is better. Another aim of the stop sign is to regulate the safety culture in the group. By externally determining limit values, the chances for negotiations during fire attacks are smaller, and there is less informal pressure on the operational commanders to continue under dangerous circumstances. Here is a list of the possible stop signs:

### **The Quadrant Model**

The quadrant model was the first spin off from the De Punt research. The realisation that, historically, we train and instruct firefighters for an interior attack, led to the thought that we had to interrupt that automatism by making a deliberate choice for an operational tactic. This resulted in the quadrant model, where two variables (offensive - defensive and interior - exterior) lead to four scenarios.



**Figure 19: Quadrant Model**

In a way, the quadrant model outlines situational incident command. Thus, it functions primarily as a sign post. See Section 7.5 for a follow-up discussion. For the stop sign, however, interrupting automatism is a key function. The IFV published a document that further discusses the quadrant model (Hagen, Hendriks & Molenaar, 2014).

### **The rule of three**

I first heard of the rule of three from Patrick Hudson<sup>30</sup>, who is also known from the Hudson Ladder. Hudson investigated the psychology of decision-making in the cockpit. He noticed that pilots respond well to clear signs. He also noticed that there are things happening that are less clear. If the pilots subsequently decided to continue, the suboptimal condition disappeared from their awareness. This was repeated with every 'orange' signal, until there were so many orange lights that it actually was a red light; a red light consisting of many orange lights combined, all fallen lines of defence. This inspired the rule of three: *three times orange is red*. When there are multiple signs of things not being quite right, or not being entirely clear, STOP the operation. The following signs might be unclear:

- > Incident: smoke colour, sound, heat, scent, flames keep coming back, unclear seat of the fire, etc.
- > Materials: indistinct damages and disruptions, not having the right tools, lots of improvisation.

<sup>30</sup> See the website: <http://www.skybrary.aero/bookshelf/books/2417.pdf>

- > Equipment: scaling up takes a long time, there is another incident somewhere else, specialist vehicles are not or only partly available.
- > People: fatigue, inexperience, unusual team composition (many watch changes, combined teams), weather conditions (cold, warm, storm, rain), atmosphere, special occasions (departure of a colleague, memorial day, holiday).

I think it is a great tool to compensate for psychological pitfalls and it really belongs to the symbol of the stop sign.

### ***The control line***

The control line is a great example of a procedural stop sign. Since the (fire) control line is inextricably bound up with the tactics in the training programme, the automatic flow is regulated into a moment of reflection: what is the situation and what will we do?

However, the other side of the coin is that for some incidents involving hazardous materials, the control line is used very rigidly.

### ***(SCBA) Whistle***

Or the whistle. The whistle is of the utmost importance for overcoming time compression that lies in wait during an interior attack. It has to be assumed that firefighters do not constantly look at the clock to check whether they have to get back yet, because they experience time not like actual time. Therefore, there has to be an automatic signal that it is time to go back. The idea that you have to be outside before the whistle sounds is noble, but it ignores time compression and is a starting point for accidents. A technical solution would be to use two whistle signals: one to go back and the next to start emergency procedures when you are not yet outside.

### ***The emergency procedure***

The emergency procedure is a stop sign as well: reality is redefined; there is a colleague in distress who needs to be rescued. Whatever procedure is used, it has to be practised and it has to be right; the procedure has to actually work.

### ***Retreat procedure***

I am not sure whether there are fire brigades that have described retreat procedures, or whether the procedure is improvised when needed. However, a coordinated retreat because the situation gets too dangerous is an important stop sign. Reality is redefined here as well: the 'sensemaking' has changed. Where the risks were once acceptable, they are not any longer. This calls for a readjustment and some people will not see the risk, or assess it differently. All kinds of psychological pitfalls open up, such as plan continuation bias and information bias. That is more than enough reason to firmly anchor this stop sign in standard procedures.

These are a number of measures that belong to the stop sign. Obviously, the list is not exhaustive, but it gives an impression of what the stop sign implies. The stop sign is important for large-scale operations as well. Especially in the swarming phase of a large-scale incident the stop sign can help prevent automatism errors.

## 7.5 Supporting the Problem-solving Approach and Improvisation: the Sign Post

Where the stop sign mainly intervenes in routine and irrational processes, the sign post functions primarily at a rule-based level. The stop sign regulates the internal memory and psyche, the sign post points towards external sources of memory. A problem is vaguely recognised (situational awareness), but it has not been explicitly experienced before, and a helping hand is very useful. Moreover, the sign post supports option awareness.

Pfaff et al. (2012) describe in the article 'Supporting Complex Decision Making Through Option Awareness' option awareness as: *'the perception and comprehension of the relative desirability of available options, as well the underlying factors and trade-offs that explain that desirability'*. By analogy with the three levels of situational awareness of Endsley (perception, comprehension and projection) they define three levels of option awareness: perception, comprehension and projection. Perception is level 1 and literally means to see: you are aware of the facts, and you see them happen and recognise them as standard, a standard deviation or as a deviation. Level 2 is comprehension: you know what options you could use in that particular situation, and you understand the effects of those options.

You understand the underlying pattern. On level 3, you can generate new options. You could also call it improvisation, but in the sense that the option is very likely to succeed, and it is not a case of trial and error. Trial and error is level 1 of option awareness.

More than the stop sign, the sign post creates an active link with the risks in the area of coverage. Therefore, the sign post cannot be applied as generally as the stop sign. Moreover, it also requires a proactive approach: you want to determine in advance what knowledge is hardly used, but might be crucial the moment you face an incident.

One of the biggest risks in creating sign posts is thinking that there should be as few sign posts as possible, and they should preferably be brief and to the point. Before you know it, you are dealing with the army's two clothing sizes: too large or too small, or too little and too short. Ensure to strive for accuracy: the right number of cards with the right information. To determine what is right, you have to test the cards in a (virtual) exercise with end users. Let the content be determined by the end users, but let operational preparation and risk managers draw up the sign post.

Apart from that, it is important to determine the objective of the sign post. Is it the objective to find information quickly, or is there plenty of time and is scrupulousness of the utmost importance? Are the firefighters operating under pressure of time, and are they already strained and in need of rules of thumb, or are they working in long-lasting operations where additional knowledge might help to limit the (consequential) damages as much as possible? These types of questions determine the way in which the sign post is set up. Knowledge can also be offered in the shape of specialists and experts, people who possess the knowledge to help you during an attack, and who might provide answers to questions you have not posed yet.

The way in which information is presented, is also of importance, e.g. analogue or digital, pocket-size or a manual. Finally, maybe you do not need to actually provide knowledge, but rather make available the right questions, or information from databases. Sometimes comprehension without an answer can be more helpful than an answer without comprehension. By way of illustration, I describe some sign post below.

### ***The quadrant model***

The quadrant model (see figure 19) has a double function: it interrupts the automatic flow of 'one choice is no choice' by offering four operational models. The interior attack is no longer the standard choice: first a quick assessment is made of the objective and risk of an attack.

### ***Accessibility maps and incident response plans***

There is a gradual difference between accessibility maps and an incident response plan, which is connected with the objective of the knowledge source. Do you need a quick prompt (accessibility map) or do you need the details of a company, such as the shut-off valves for fire water retention? There is a tendency to make meticulous information subservient to quickly accessible information. In my opinion, both are needed and you need to think carefully about the form in which to make knowledge accessible. I think that quickly accessible information requires paper, since the average individual still shows analogue search behaviour. Meticulous information is better supported by way of Mobile Data Terminals (MDT). In any case, MDT is suitable for providing information that was not looked for, but could be useful all the same. In fact, this stimulates the serendipity of operational commanders.

### ***Memory cards***

Memory cards are intended for very quick reference on rule-based situations. For instance, you heard about it, but are no longer sure. Can you extinguish high voltage from five or from seven meters? And do you use a water jet or a water spray? Such questions require a good answer and the memory cards provide these. At this point, many fire brigades use memory cards, and the cards are made fire brigade specific. They have to be applicable for the area of coverage concerned. There are also regions that turned the memory cards into an app. This might be a first step towards decision support systems.

### ***Decision support systems***

The aforementioned article by Pfaff and Klein uses decision support systems (DSS) to support option awareness. As far as I know, there are no real DSS set up in the fire service. This would be an interesting option to research, possibly as an extension of the National Crisis Management System (Dutch: LCMS). I do not expect future DSS to contribute to the first phase of large-scale operations in the short term. However, I do think that, later on, when there has been a significant scale up, DSS might be supportive in deciding upon resources, incident development and providing perspectives for action.

### ***Specialists and experts***

Knowledge can also be provided by people: specialists and experts. It is, in fact, a type of support, not in the form of pumps, aerials or rescue units, but in the form of brains. There are various centres of expertise available for specialist expertise, but it is also available within the fire service itself. The Fire Service Support Team (OTB) was created specifically to support the regions during large-scale operations. Use that knowledge. It is impossible to do everything yourself and it relieves the people in charge. Comparative simulation research shows that specialist incident command best understood the full incident during the complicated scenario on test day 5. That corresponds with level 2 of situation awareness.

The essence of the sign post is the understanding that it should support the call-outs in delivering a better product. So it is a means, not an end in itself. As far as sign posts are concerned: you can ignore them if you know better, as long as you communicate clearly. That is why it is important to practice using the sign posts: how to use them, when to use them, and how to handle deviations from the standard and deviations from the sign post. Think of an exercise where the standard sources of information are not very helpful and the

participants have to find their own solutions: operational commanders have to deal with this as well.

## 7.6 Organisation of Adequate Leadership and Incident command: the Paving Stone

During the basic training programme for the (junior) fire officer, the paving stone fire officer was the terror of every self-respecting officer to be. To stay in one place and lead from there was unthinkable. You had to get out there yourself, go in, make a reconnaissance, go out and go everywhere. It didn't really matter, as long as you didn't stay in one place, on that paving stone. Never ever.

Due to various experiences, my opinion about this has changed. For instance, I discovered early on that the most dangerous fire officers are the ones that step into the shoes of the first crew commander. This is often a manifestation of tunnel vision and it means that the overview over the whole of the incident is gone. It is a phenomenon that occurs throughout all ranks.

During complex incidents, there is a need for a beacon that is grounded in actual reality, and that has an overview of the incident and can easily be found and be a connection between incident management and the other necessary activities. In fact, a paving stone.

### **Systems theory**

There are also systems theoretic reasons to rehabilitate the paving stone. From a systems theoretic perspective, the paving stone is about leadership during fire and rescue operations. It is not about inspirational leadership or empathic management, but about carrying out the tasks and actions that are necessary to jointly extinguish the fire and are of an acceptable standard of quality. An important part of the system's perspective is the concept of the control circle. A fire and rescue operation could be regarded as a series of control circles that have to be geared to one another in order to achieve the intended results. Usually, a control circle consists of some standard components: a production unit (activities), input and output measurements, a regulator for adjustment and, finally, the control unit.

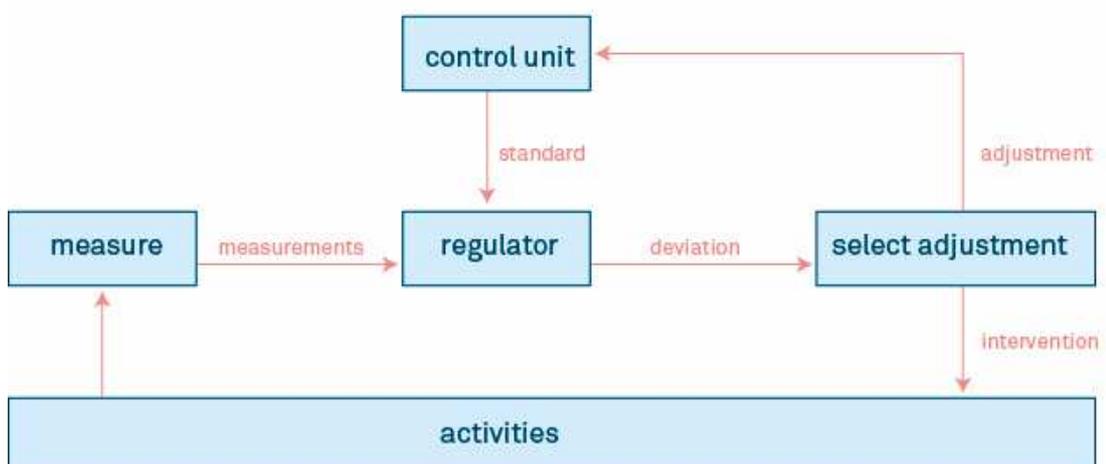


Figure 20: Systems Theory

Translated roughly into a fire and rescue operation, the deployed units are the input, the output moments are the activities to enable the fire extinguishment and the stages of firefighting and rescue, and, finally, the extinguished fire is the end result. Incident command is performed by the control unit. No additional control circle is needed as long as incident management falls within the definition of output. However, when output exceeds the standards, a scale-up to a higher control circle is required, since a control circle cannot adjust its own quality standards. As the fire service would say: 'We scale up'. Scale up until the level is reached at which the highest control circle present, has redefined the output in such a way, that the suppressive system functions as it should.

This contains a strong strategic component as well. As a region, what performance do you want to be able to deliver in standard situations and how do you deal with deviations from the standards, while you simultaneously monitor and promote the organisation's strategic targets. This means that the ranking paving stone is always the chief officer, or a functionary who 'stretches out' the strategic targets on behalf of the chief officer. We have now arrived at the knowledge-based scenarios, i.e. the deviations in terms of the firefighting and rescue triangle.

### ***Workload management***

Back to the control circle. The control unit is a vulnerable component: when the control unit does not scale up, the system comes apart at the seams and safety risks occur.

Therefore, workload management is important, to prevent the vital system elements from becoming overloaded. At the beginning of an incident, there is always the risk that everyone gets absorbed. Subsequently, the control units start producing and ignore their management tasks. This is a crucial point in the safety management of suppressive organisations, and in my opinion this is not acknowledged sufficiently. Therefore, I plead for a remote automatic scale-up when certain quality standards are not met, such as receiving an on-scene situation report within 15 minutes. A control unit that does not control in time is, in fact, a constraint impeding the flow (Goldratt, 1986). The organisation has to recognise these constraints and take action. Just to clarify: it is not about individuals (culpability), but about functions (avoidability).

In aviation we are familiar with the phenomenon of task saturation, as described in Section 2, i.e. the limit of expertise and experience. During task saturation people are not aware that they are 'full' and they do not respond adequately to new input. Here lies the importance of the paving stone: to guard against a system overload. Therefore, it is important that the paving stone is not too busy to avoid task saturation. Another risky phenomenon is the plan continuation bias. Under pressure of time, people tend to stick to the original plan, whatever the circumstances. Sometimes the circumstances are so anomalous, that the original plan has to be abandoned. The paving stone has an important task in making adjustments regarding this phenomenon.

### ***Impact area***

A final important task for the paving stone is to monitor the impact area, or to have it monitored. The paving stone is the interface between the firefighting and rescue and other (public) actors he/she has to monitor. This is known as integrated incident management. For instance, the speed of social media leaves room for story-building on Twitter (Kiel & Oomes, 2014). As such, the significance of an incident can suddenly assume rather large proportions. If the fire service is too late in noticing this, or misses it completely, it can have rather unpleasant consequences. On the other hand, a change in significance also provides

opportunities, and it would be a waste not to use them. Therefore, it is important to scale-up in time until the commander is eventually there to manage the strategic elements.

Of course, even the highest possible ranking paving stone can be overwhelmed by too big a workload. At that moment, it is not possible to scale up any further. However, it is of course possible to get support by increasing the number of control circles. Support should be seen in a broad perspective, it can consist of people, vehicles, knowledge and advice. In that sense, the Fire Service Support Team (OTB) plays an important role.

The paving stone is the third symbol of the forgiving infrastructure. Where the stop sign regulates automatic and irrational behaviour, and the sign post supports decision-making, the paving stone controls adequate leadership. It is crucial for the firefighting and rescue system that the control units keep controlling in order to determine whether the required quality standards are met. The organisation has to take action to safeguard the control task, by scaling up quickly, scaling up automatically, providing appropriate support and drawing up good quality standards that are linked to the strategic objectives of the organisation. These are all preparative activities, and all of these should be completed when the time comes. Otherwise, there is nothing to control and leadership suddenly becomes an individual matter of the persons that happen to be on duty. That is not a forgiving infrastructure.

## 7.7 Monitoring Time and the Experience of Time: the Egg Timer

Some things are so obvious that you only start to think about them when something extraordinary happens. Time is a good example of that. Clocks depict the time, so you know what time it is, what time of the day it is, and what you are going to do. It is convenient when everybody has the same time, because it enables planning and making appointments in the future. We do not normally realise that the time in Amsterdam is the same as in Maastricht. In fact, this has only been the case since 1 May 1909. Dutch Time was introduced then, a necessary condition to enable travelling by train.

Another obvious thing for Westerners is that time is linear. There is a past, a present and a future. Everything follows something else. In other parts of the world, however, this is not quite so obvious. Southern-Europe has a multi-active time perspective: time is subjective and the interest of the moment is more important than the interest of the planning, as is the case with the linear time perspective. Richard Lewis (2014) described it in his blog, which is definitely worth reading. *'In countries inhabited by linear-active people, time is clock- and calendar-related, segmented in an abstract manner for our convenience, measurement, and disposal. In multi-active cultures like the Arab and Latin spheres, time is event- or personality-related, a subjective commodity which can be manipulated, molded, stretched, or dispensed with, irrespective of what the clock says'.*

Lewis also describes how two perceptions of time can lead to irritation. *'For an Italian, time considerations will usually be subjected to human feelings. 'Why are you so angry because I came at 9:30?' he asks his German colleague. 'Because it says 9:00 in my diary,' says the German. 'Then why don't you write 9:30 and then we'll both be happy?' is a logical Italian response. The business we have to do and our close relations are so important that it is irrelevant at what time we meet. The meeting is what counts. Germans and Swiss cannot swallow this, as it offends their sense of order, of tidiness, of planning'.*

### ***Time emotion paradox***

Another relevant question is whether there is experience of time without a clock. Is there such a thing as an internal clock? Is there a difference between clock time and experience of time? The answer is yes, but it gets rather vague after that. So far, no organ has been found that can be designated as the internal clock. It has been proven that experience of time depends on context. Time moves faster in a pleasant environment than in an unpleasant one. An interesting article by two French psychologists (Droit-Volet & Gil, 2009), indicates that the experience of time is completely dependent on what happens in the environment. *'The entire series of studies that we have reported nevertheless show that the representation of a particular duration is highly context dependent. It depends on both intrinsic context, such as the emotional state at the onset of time processing, and extrinsic context, such as others' activity rhythm. Our studies also suggest that these contextual variations of subjective time do not result from the incorrect functioning of the internal clock but, on the contrary, from the excellent ability of the internal clock to adapt to events in the environment.'*

And this is where it gets interesting for the fire service. For if an internal clock adjusts to the rhythm of the context, the chaotic stage of the fire may result in a chaotic perception of time. Indeed, it could be that during a large incident with many different environments, different perceptions of time exist. You can observe on a small scale where this could lead to when you try to do something at the exact same time with several people.

If you have not synchronised your watches, you don't stand a chance. Let alone that you would have to deal with chaos and pressure of time as well. Incorrect perception of time can cause accidents. During the fire in the Koningkerk in Haarlem the perception of time was disturbed. The inspection report contains the following conclusion: *'The stress that operating in crisis situations generates, results in a perception of time compression and, as a consequence, in a limitation of the human ability to come to a renewed assessment of the situation. A chosen operational tactic is extremely hard to abandon.'* (Scholtens & Drent, 2004, p. 183).

During time compression many minutes feel like a few, i.e. you do not realise you have been working for 20 minutes already. This can result in a dangerous situation for a BA firefighter: if the whistle blows unexpectedly, the way back may be too long for the amount of air that is still in the tank. The idea that you need to keep checking your watch and have to be outside before the whistle blows is a dangerous overestimate of the human ratio. From a safety net point of view, the whistle has to be set in such a way that there is more oxygen for the retreat than for the way in. And when the whistle blows, the firefighters must immediately go back. This is a much safer option than looking at your watch because you will forget to do this once the context is chaotic and busy.

Another risk of time compression is that the environment suddenly becomes more dangerous because the resistance to fire penetration and fire spread has expired. This can result in extreme fire behaviour, for instance the fire might penetrate the insulating materials, or in a collapse. In any case, for the sake of one's own safety, there is good reason to assume that materials perform not as well during an actual fire than in the context of a laboratory. For instance, if a material has a resistance to fire penetration and fire spread of 20 minutes, I can imagine that you start taking extra care after 15 to 16 minutes.

### ***Bad decision-making under pressure of time***

Much research has been conducted into the quality of decision-making under pressure of time. Obviously, the Dutch fire service is familiar with Recognition Primed Decision-Making (RPD). The quality of decision-making under pressure of time has been studied as well.

In 'A Timely Account on the Role of Duration in Decision Making' Ariely and Zakay (2001) describe what goes wrong when decisions are made under pressure of time.

1. *'A reduction in information search and processing.*
2. *A reduction in the range of alternatives and dimensions that are considered.*
3. *An increased importance of negative information.*
4. *Defensive reactions, such as neglect or denial of important information.*
5. *Bolstering of the chosen alternative.*
6. *A tendency to use a strategy of information filtration; that is, information that is perceived as most important is processed first, and then processing is continued until time is up.*
7. *Increased probability of using non-compensatory choice strategies instead of compensatory ones.*
8. *Forgetting important data.*
9. *Wrong judgment and evaluation.'*

An important question concerning pressure of time is whether it is a matter of objective or subjective time pressure. Ariely and Zakay indicated that there is no proper definition of pressure of time, which is why it is not possible to compare many of the experiments. *'People can react differently to time pressure. Some can be stimulated to engage in more thought and even do better when deadlines are imposed, while others are doing much worse than they would under normal conditions. Findings like these indicate that the relationship between objective shortage of time and time-stress might be a complex one and not limited to direct effects of time-stress on decision outcomes'*. Because of the difficult distinction between objective and subjective time pressure, it is important to use a fixed time clock, i.e. the egg timer, in addition to the paving stone.

The paving stone has to monitor whether the way the incident is managed, is still in balance with the costs and the profits, and has to promote using the egg timer and keep doing so. The egg timer has to make sure that a Standard Incident Time is used to prevent chaos. Egg timers are especially important during the swarming stage of an incident. Due to the lack of hierarchical control, the time agreement is the connecting element. The following measures could be considered:

- > The control room automatically scales up when an on-scene report is not received within 15 minutes and it is not possible to make contact with the units.
- > Contact is made on predetermined times to 'synchronise the watches and find the same page'. The clock determines, not experience.
- > Every 10 minutes the units receive the message that 10 minutes have passed and are informed about how long the operation will continue.
- > A person is designated to keep track of the time the teams are operational, in England known as the Tallyman (PASS device).
- > The units are relieved in time, not based on experience, but based on the clock. The time of the relief is based on the situation, but has to be agreed upon beforehand.

The above list is not exhaustive; there are probably many more measures one can think of. The essence is that people become aware of how unexpectedly dangerous time can be, and that you need an egg timer to safely manage time and safety.

## 7.8 Monitoring Supportive and Facilitating Processes: the Check Light

The popular series Big Bang Theory has a running gag on the check engine light of Penny's car. It features in multiple episodes and every time goes something like this:

**Sheldon:** Your check-engine light is on.

**Penny:** Uh huh.

**Sheldon:** Typically, that's an indicator to, you know, check your engine.

**Penny:** It's fine. It's been on for like a month.

**Sheldon:** Well, actually that would be all the more reason to, you know, check your engine.

**Penny:** Sheldon, it's fine.

**Sheldon:** If it were fine, the light wouldn't be on. That's why the manufacturer installed that light, to let you know it's not fine.

**Penny:** Maybe the light's broken.

**Sheldon:** Is there a check the check-engine-light light?

Check lights come in all shapes and sizes. Some provide information on fluid levels that you have to fill up regularly, others signal you to immediately stop and pull over. This section concentrates on the principle behind the check light: while you are driving in your car, information is gathered and monitored behind the scenes. This information can result in a warning that action needs to be taken to prevent problems. While you are trying to reach your objective (arrive at your destination), the vital processes to get you there are automatically checked.

The analogy with operational firefighting and rescue operations is not hard to make: while you are fighting the fire (your target) the fully automatic vital processes are monitored and you are informed when critical limits are passed, or an intervention occurs. I would like to discuss three types of processes: health and safety at work & the environment, logistics & support, and finally media & the surroundings

### ***Health and safety at work & the environment***

When an incident lasts a long time and no lives can be saved (any more), all kinds of exceptions under the Dutch Working Conditions Act/ Health and Safety act expire. This means that all kinds of conditions have to be met, such as safely work at heights, hygienically handle contaminated fire extinguishing water, working hours and relief, decontamination and cleaning of contaminated turnout gear, and so on. These conditions still are not met during prolonged operations: firefighters work for hours on end and are not relieved, contaminated clothing is taken home, and the next day volunteer firefighters go back to work without a night's sleep. It would be a good idea to designate an officer to monitor these types of issues, who subsequently, can report unsafe or unhealthy conditions and intervene.

### ***Logistics & support***

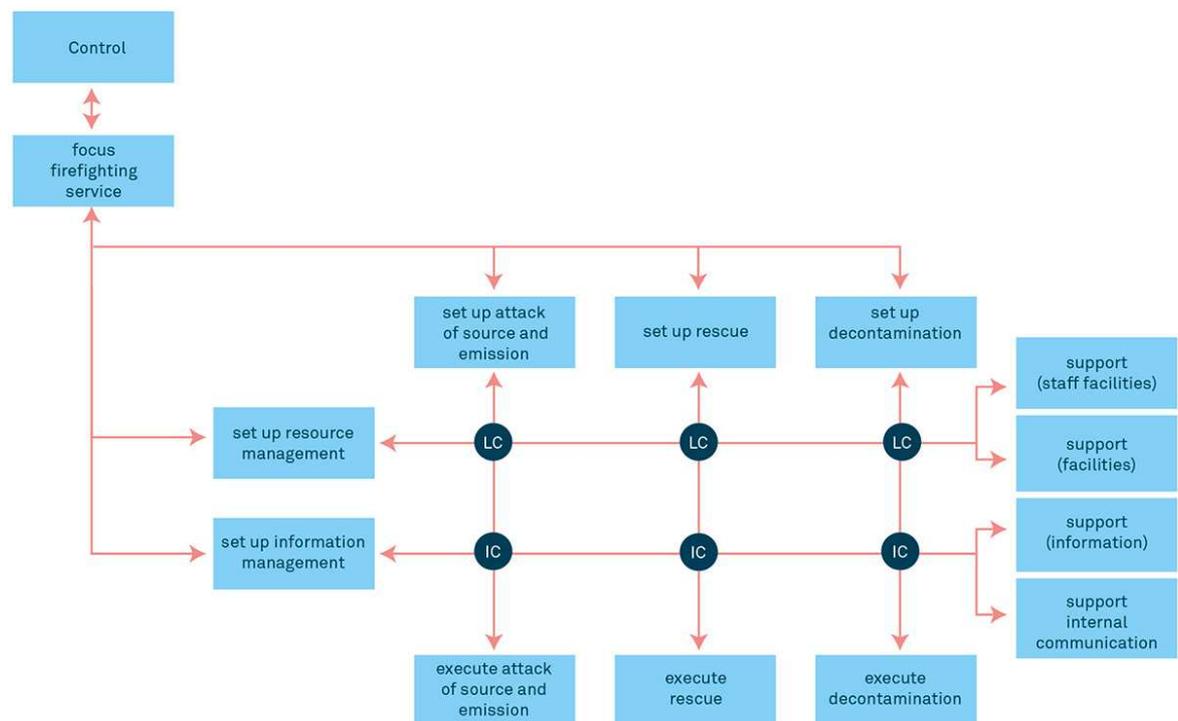
Of course, fires happen at the most inconvenient times, like at night or on holidays, when the shops are closed. And of course, it is hard to find provisions then. However, even then diesel oil is needed, and the inner man/woman needs to be fortified. Especially when firefighters have been working for hours, they need food and drink to not get into difficulties. And please order in time. The strategy of a predictable outcome also shows how long an incident is going to last, so with a little planning it is not hard to set up decent catering facilities. Do not organise the catering in such a way that the firefighters have to make a run for it to get there

first, or otherwise have to go without food and drink. Here too it is important to monitor processes and adjust with a check light function, because all too often these things go wrong.

### Media & the surroundings

Everybody has their backs to their surroundings when fighting a fire. Which is logical, but it is increasingly important to pay attention to what is happening in that environment. Not because of a rescue or for safety reasons, but because of story-building and opinion. How do people see the incident and how do they communicate about it, especially in the social media? Is a story developing, is there a lot of criticism or is there support, what is the impact of the incident in the social media and in the public opinion? Organise a check light to warn you when the image is swinging the other way and the fire service is seen as the offender instead of as rescuer. That would be the time to intervene.

### Process Model



The above processes were all described in the 'Referentiekader Regionaal Crisisplan 2009' (Reference Framework Regional Crisis Plan 2009). All processes are included in a model (Dutch: knoppenmodel) as depicted above in the process model Firefighting and rescue services. However, the function of the check light is not the model itself nor the processes that are illustrated in it. The check light monitors the execution of the quality of those processes and it is an indicator to intervene and make adjustments when things do not go as they should, to prevent problems. It is a safety net to help the organisation to realise its objectives under hectic circumstances and to prevent avoidable accidents.

## 7.9 Closing Argument: the Forgiving Infrastructure after the Fire

In the sections hereinabove, I provided a description of what a forgiving infrastructure should look like before and during large-scale operations, as was the Lectureship's question. I would like to add an unsolicited closing argument for a forgiving infrastructure after the fire because, after a fire, forgiveness is needed as well. Again, in this respect, forgiveness should be interpreted broadly: all measures taken to prevent and soften the consequences of mistakes and to not place the responsibility on an individual.

All too often the teams and individuals that were deployed are criticised, sometimes without having all of the facts. The criticism comes from everywhere: social media, newspapers, television, from pseudo-experts who are given a free rein to vent their spleen, from 'colleagues' who give advice too easily with hindsight via fora and from all kinds of people who were indirectly or directly involved and who try to gain an advantage for themselves at someone else's expense.

In this phase, measures to protect operational commanders are called for as well. By providing support within the organisation and helping them to come to grips with the incident, but also by being visible to the outside world. There is a great need among firefighters to see fire service functionaries refute the criticism, whether unfounded or not. Functionaries from their own fire station, their own region or other regions, or from the Organisation of Dutch Fire Services, to shed light upon the other side of the story, and express the fire service's pride by communicating proactively. This does not take away all criticism, but it does show resilience and identity.

Another instance for proactive communication is during the investigations by official authorities. Whereas the investigations should be focussed on the avoidability of accidents, they have the tendency to focus on the culpability for an accident. As shown in previous sections, there can be no question of culpability, unless it was intentional. This should be the starting point in managing accident inquiries and the proactive communication that goes with it. That message is the foundation for the identity you project and the resilience you show. That is a forgiving infrastructure as well.

# 8 Towards an Understanding of Effective Incident command

By I. Helsloot

## 8.1 Introduction

Incident command is a neglected subject in science (Hannah et al., 2009; Campbell, 2012). This makes all research worthwhile and the same goes, in advance, for the study of incident command during large-scale firefighting and rescue operations (hereinafter: the LFO study<sup>31</sup>) where this reflection is about.

The concept of incident command originates from the armed forces. We define it as operational leaders making decisions and having these carried out by subordinates in situations that are characterised by pressure of time, uncertainty and major interests. This management form is typical for organisations such as the army, the fire service and the police, but is also present in managing vital infrastructures where disruptions of the primary process can have a great social and economic impact, for instance power stations, nuclear power plants, oil rigs, petrochemical industries (Flin, Slaven & Stewart, 1996; Crichton, Lauche & Flin, 2005; Flin & Arbutnot, 2005).

In the LFO study and this reflection on the study, incident command by fire service officers is central. During larger or more complex incidents fire service officers have to command several crew commanders - the commanders of basic fire engines. Recent national incident evaluations (for instance, Helsloot, Oomes & Weewer, 2010; Nederlands Instituut Fysieke Veiligheid, 2011; Inspectie Openbare Orde en Veiligheid, 2011) and international incident evaluations (for instance, Moynihan, 2009) show that incident command by fire service officers was often inadequate. The Dutch Institute for Safety (IFV) concluded, for instance, that during the fire in the underground car park De Appelaar in Haarlem (2010) the crew commanders made decisions without coordinating with the fire officer and did not carry out the fire officer's orders (Nederlands Instituut Fysieke Veiligheid, 2011). Furthermore, these incident evaluations made clear that there is very limited understanding within the fire service practice of how fire service officers' incident command can be improved.

The committee that investigated the fatal fire in De Punt (2008) where three firefighters lost their lives, stated for instance that the fire service officers were not selected, educated and trained to make a difference as 'fire technical manager' (Helsloot et al., 2010). The committee could not make concrete what it meant exactly and how things should be, due to a lack of scientific knowledge on the subject.

<sup>31</sup> The formal title of the study is of course 'Innovative Approach of Incident command'. Contrarily but consciously, I adhere in this reflection to the title 'Study of Incident command during Large-scale Firefighting and rescue Operations' because (a) this is the core of the study because the study is not about incident command of regular incidents, and (b) it is nice that the study is innovative, but that can never be the objective of a study.

The LFO study attempts to take the first steps to fill this gap. 'Originally', the objective of the study was focussed solely on the process of effective incident command by fire service officers during large-scale firefighting and rescue operations. 'Process' we understand to be all procedural steps that fire service officers have to take to make meaningful decisions during an incident and to have these executed. 'Effective' means the incident command that actually lets fire service officers be of added value during the incident management.

With this, the ultimate research question has a double character: why do fire service officers never follow the recorded procedures for commanders during large-scale firefighting and rescue operations; is that a bad thing? Quick answer: Of course this is a bad thing because it means that the procedures fail to support operational commanders in critical situations and how can this be done better if we take into account the human limitations of operational commanders.

## 8.2 The LFO Study Further Characterised and Placed into Context

This LFO study can be characterised as design-related action research. This means it is a type of research that has a design objective to arrive at the solution to a practical problem, or recommendation for improvement of a situation. Design knowledge is prescriptive knowledge, i.e. instead of descriptive or explanatory knowledge, concrete recommendations for the improvement of the situation that was researched are pursued (Van Thiel, 2009).

The LFO study is about knowledge represented by a model that describes how operational commanders have set up the incident command process during large-scale firefighting and rescue operations, to enable them to make meaningful decisions and to have them executed.

In comparison: Crisislab researched the modelling of current firefighting and rescue operations. We named this model the FADCM model (Dutch: FABCM). FADCM stands for Fact finding and checking, Analysis, Decision-making, Communication and Monitoring. The model came into being by studying scientific literature and subsequently analysing the recordings of actual operations and exercises (Groenendaal, 2015).

Traditionally, management sciences were always aimed at investigating management practices in an office setting. A classic example is the study by Mintzberg into the performance of managers in different sectors (Mintzberg, 2009) in which he looked at what managers do exactly and how this could be improved. The findings of this study cannot be automatically transferred to incident command in an operational context and to the fire service, since the research does not take into account the special conditions during firefighting and rescue operations, such as time pressure, uncertainty, major risks and divergent and sometimes conflicting interests (Zsombok & Klein, 1997).

It was only during the last decades that the organisational sciences have conducted research from different angles into managing organisations in unpredictable, dynamic and risky circumstances.

Well-known is the research work by Weick and Sutcliffe (2011) into organisations that are very competent in preventing and controlling emergencies, the so-called high reliability organisation (HRO). According to Weick and Sutcliffe (2011) these organisations have a culture of mindfulness that consists of five elements: preoccupation with failure, reluctance to

simplify, sensitivity to operations, commitment to resilience and, finally, deference to expertise, i.e. decentralisation of power to the individuals that are best equipped to solve the problem. However, Weick and Sutcliffe (2011) did not combine these rather abstract principles and give a concrete form to them in a model that could show operational commanders what effective incident command is in practice. It can even be argued that the prototypical HRO organisations that Weick and Sutcliffe studied (such as nuclear plants and aircraft carriers) are exceptions, since these organisations have sufficient funds and the effects of an accident are so immense that there is an almost unlimited safety budget, which is evidently not the case for the fire service.

By contrast, military science did give due attention to models to describe the process of incident command. Most of these models are based on cybernetics (Ashby, 1956; Morgan, 1982; Brehmer, 2005; 2007). Central to cybernetics are information and feedback loops, i.e. the system receives feedback on the effects of a system intervention, as a result of which the system can adjust itself and stabilise. Cybernetic models are goal-oriented and include sensors and control mechanisms to observe and counter deviations from the desired goal. Well-known cybernetic models are Boyd's OODA loop (Boyd, 1987) and Brehmer's DOODA loop (Brehmer, 2005). These models have in common that they identify approximately the same five phases: gathering information, analysing information, making decisions and having these decisions executed and checking to see whether the desired result is achieved. These phases were the foundation for the FADCM model of Crisislab.

A limitation of cybernetics is that the models pay little attention to the way in which professionals make decision in standard and sometimes stubborn practice. The research that does take this into account is called *Naturalistic Decision Making* (NDM) (Zsombok & Klein, 1997). NDM researchers try to understand how professionals such as firefighters, pilots and physicians make decisions in their natural working environment, and which cognitive and situational factors play a part in this (Lipshitz, Klein & Carroll, 2006). These natural environments are usually characterised by badly structured problems, uncertainty, changing goals, pressure of time, major interests, several players with different interests and values (Zsombok & Klein, 1997). The difference in natural working environment and goals means that what is natural for a crew commander, is not the same for a fire officer, and also, that optimal in a 'normal' working environment does not have to be the same in the special circumstances of a large-scale firefighting and rescue operation. The table below summarises the relevant insights for the 'regular' fire service incident command by fire officers per FADCM phase. The table also contains the corresponding recommendations from the NDM study.

	Insights from NDM literature	Recommendations for operational (fire service) commanders
<b>Fact finding and checking</b>	Decision makers make decisions based on their perception of reality	Actively compare the picture formed with actual reality
	Powers of observation and memory for information processing are limited	Limit the number of tasks to carry out simultaneously
	The distance from an object determines perception	Observe the situation up close as well as from a distance
<b>Analysis</b>	People tend to decide immediately based on recognition of a situation when they are under pressure of time	Be critical about the first impulsive decision that comes up and think about the consequences
	Pressure of time and work overload limit mental abilities	Take time in making a decision and limit the workload
<b>Decision-making</b>	Making too many decisions reduces the chance that they are actually executed	Limit the number of critical orders for subordinates
<b>Communication</b>	Orders are interpreted within own frame of reference	Verify that orders are understood by subordinates
	In a turbulent environment communication is usually inefficient and limited	Communicate the goal of the order and the preconditions
<b>Monitoring</b>	Giving an order does not mean it will be executed as intended	Actively monitor the execution of orders

In this reflection a key insight of the NDM study will be addressed a number of times: you cannot teach an old dog new tricks, i.e. professionals can barely be prepared for using deviating procedures in emergency circumstances (pressure of time, great uncertainty, major interests), if at all. They will automatically revert to their standard procedures during emergency circumstances.

In view of the above, we consider the LFO study to be an NDM study into the way in which fire service commanders can decide optimally during large-scale firefighting and rescue operations. Commanders come in different types: crew commanders, fire officers and senior fire officers. Therefore the 'solution' will automatically consist of more than one 'much of a muchness' and a little fatalism, i.e. on the one hand optimal procedures will take into account the essential differences between the ways in which levels of commanders (can) make decisions in practice, and, on the other hand, it has to be accepted that under pressure of time no rational decisions can be made, especially by crew commanders.

## 8.3 The Outcomes of the LFO Study for the Present

The results of the LFO study can be divided as follows:

- > What does the study conclude about the original question concerning incident command during large-scale firefighting and rescue operations?
- > What does the study conclude about human factors?

### 8.3.1 Incident command during Large-scale Firefighting and rescue Operations

The LFO-study starts off with a claim that seems indisputable: the present incident command procedures for large-scale firefighting and rescue operations do not work in practice. The well-known dogma that single-headed leadership is necessary for decision-making under emergency circumstances is not true for the fire service. Organisations that have to work under emergency circumstances on a regular basis all arrive at this conclusion at some point in time. Only organisations that are only rarely confronted with large-scale operations, as is in fact the fire service, can afford the illusion that incident command is an appropriate controlling mechanism. In the occasional instance when practice shows that incident command does not work, such organisations state, after an evaluation that next time things will go well because of more elaborate procedures, improved training programmes and exercises. The reader will recognise the pattern of the Dutch three levelled crisis organisation, that also never works, but every time after yet another disaster, is laid down more firmly by law, as if that helps.

In view of the NDM insights that were described hereinabove, this is not surprising: firefighting and rescue operations are usually based on self-reliant units, so it just is not realistic to expect them to wait for orders under emergency circumstances. The same applies for the 'top' of the commanders: fire service officers use directive leadership, but manage (if they succeed in doing so) by using a reactive, correcting leadership style. They too will not be able to demonstrate the procedurally desired rational top-down decision-making under the emergency circumstances of large-scale firefighting and rescue operations.

So things will have to change. The incident command concept that the LFO study presents, fits in with the standard practice: swarming actually means confidence in self-managing units. Just like that other concept of specialist incident command fits in with one specific circumstance: when a unit is confronted with a danger that deviates from standard practice, it will come to a standstill due to a lack of automatisms, and look about for leadership, or advice.

Therefore, theoretically it is not surprising that the control experiments (Section 3.3 of the report) show that swarming works best in a more-of-the-same-task environment, which the researchers call complex. In addition, it is theoretically not surprising that during an incident with hazardous materials, the specialist incident command model emerges.

Of course, 'theoretically not surprising' is easy armchair wisdom in hindsight. Obviously, the experiments have to be conducted first. The researchers deserve appreciation and compliments for having demonstrated this experimentally.

A nice by-product is that the experiments suggest that relatively inexpensive simulations are a decent replacement for the expensive realistic exercises with large-scale firefighting and rescue operations. I will get back to this later on.

As was said before, ordinary firefighters do not benefit from participating in this type of large-scale exercises and it is, therefore, an expensive method for operational commanders to practise.

Another outcome is not surprising: the guinea pigs' appreciation for the new, different incident command models is not as high as for the existing hierarchical model. The results of the experiments underline once more that perception research is of very limited value. Of course, the well-known feels better than the unknown. Of course, people fall back on their experience...but who is really experienced in large-scale firefighting and rescue operations? Leading a large-scale operation 5 times in 10 years does not say anything about actual experience. We would as a patient not put our trust in a surgeon who operates with this frequency. Actual experience consists of two components: very regular execution and having the opportunity to see the effect of your actions and learn from that. The latter aspect is hardly ever possible during large-scale firefighting and rescue operations. The different perceptions of officers and crew commanders are probably even more complex than the researchers think. Crew commanders might suffer from the extra pressure that rests on their shoulders as a result of the swarming model, but earlier research already showed that crew commanders especially appreciate prototypical leadership, i.e. officers who decide what the crew commanders want (Groenendaal et al., 2015). Therefore, they are not really a fan of hierarchical control, even if they say so.

Looking ahead from the same armchair, there are some tips for an effective implementation of swarming. In her lectureship speech Astrid Scholtens already pointed at an analogy with ants: these little animals swarm as well and are controlled by probably five simple rules (Scholtens, 2007 and Hölldöbler & Wilson, 2008). One of these effective rules for large-scale firefighting and rescue operations would be the implementation of a variant of 'blowing the whistle': blowing the whistle means that all operations are stopped because of a safety risk. An inexorable action like that will not be executed often, but it could have been an appropriate tool during the salvage operation at De Punt, when the different firefighting and rescue operations were a danger to one another.

### 8.3.2 Human Factors

Two concepts are central to the part of the LFO study concerned with human factors: automatic stress responses and mindfulness.

*Automatic Stress Responses* Once again: this is truly new research. There are no experiments to be found anywhere in the scientific literature that attempted to register the inevitable stress responses of the fire service and its effects, and more specifically the difference between experienced and inexperienced firefighters. A key element of the study is that, by definition, the outcome is uncertain. Therefore, negative results are good results as well.

The LFO study used freezing as a measurable indicator for the occurrence of automatic stress responses. We know from the quoted NDM study that other stress responses might occur, such as tunnel vision, for which the relationship with freezing is still unknown. The tendency to search for tentative relations between freezing and, for instance, 'taking/having more time to make a decision' is high, but modesty is in order: there is no scientific research study into this yet.

The LFO study shows that freezing occurs in both inexperienced and experienced fire service officers. In essence, the differences between the various types of freezing that occur in inexperienced and experienced firefighters seem not significant: all partial results are 'just about' significant, but do not point in the same direction when looking at it overall. Especially in view of the small test groups, a significant relation between experience and quality of decision-making during large-scale firefighting and rescue operations cannot be concluded. Looking at it from the armchair with hindsight, once again, this is not surprising because as was argued above, there are no truly experienced fire service officers in the field of large-scale operations. Subsequently, it is important to realise that newcomers often do better than experienced experts when decision-making in a new environment is concerned. Experienced experts can always rely on their intuition (experience), which is why they are no longer used to thinking, while newcomers have to wrestle with the question of what decision to make. In other words, newcomers are trained thinkers and that gives them an advantage compared to the experienced commanders in *new* situations.

The most significant outcome might be that this part of the study suggests again that simulations present a true view of reality, also regarding triggered stress responses in fire service officers.

*Mindfulness* The first remark I would like to make is that the research question '*How can mindfulness be implemented?*', does not leave room for the question '*whether mindfulness should be implemented*'.

Obviously, nobody can object to mindfulness in the sense of Weick, but the question is whether it is possible to train mindfulness with a reasonable effort in such a way that it really takes root.

The tips and tricks that Ed Oomes describes in his reflection, fit seamlessly in with the NDM study: almost all of them enable the operational commanders to take their time and in doing so, escape from the pressure of the emergency circumstances. This should enable them to consciously deviate from what they normally do, and, therefore, do under the pressure of emergency circumstances. These tricks might be less expensive to implement than mindfulness training courses. There is only one downside: the tips do not guarantee that the operational commanders can escape from the pressure. An example from the report is a crew commander forgetting everything he learned during the mindfulness training the moment he thought one of his crew members was in danger. The environment where the firefighting and rescue operations take place is not always forgiving.

The FLO study cannot convince in this respect because it did not answer the first question. More research is needed to find out which tricks are useful for the operational commanders. This will depend upon their operational role: crew commanders will not benefit from mindfulness training because, by definition, they have to decide in a split second. The costs of implementation will have to be researched as well. A classic pitfall presents itself here: if it does not work in practice, 'we' need to provide better training programmes and exercises.

## 8.4 Into the Future; How Can the Results of this Study be used for LFO?

There still is scope for debate as to what extent the results of the study are actually 'proved'. As was done before. At least, it has to be considered that the present (LFO) incident

command structures are not based on any scientific research studies and, even worse, almost all evaluations show that they do not work as they were intended. Contrary to the current hierarchical procedures, the research results fit in with what we know scientifically.

Specifically as far as large-scale firefighting and rescue operations are concerned, there is no good reason not to immediately adapt the present guidelines to the key results of the LFO study: by default start with the swarming incident command type for LFO. At any moment in time, a transfer to a more structured operation can be made, depending on the individual officer. An obvious specific danger, such as hazardous materials, is a trigger to interrupt 'normal' procedures. All units present stop their normal procedures to wait for specialist advice.

# 9 Outline of Situational incident command in Operational Practice

Section 5.4 concluded that situational incident command is highly preferable to the one-size-fits-all model that is now used as a doctrine for large-scale operations. However, situational incident command will still be an abstract model for many, despite the explanation provided. Therefore, this chapter includes a first draft of the way situational incident command works in the operational firefighting and rescue practice for crew commanders and (senior) fire officers<sup>32</sup>, based on a logical translation of the theoretical principles. This chapter does not contain 'the new procedure', but a draft for the purposes of clarification and discussion.

## 9.1 Objective of Large-scale Operations

The fire service organisation's objective during large incidents is to create a maximum ability to take action within the prior conditions for safety. By definition, this consideration is situational: more risk is taken in an incident where more victims are involved. As an organisation and as operational commander, you only want to take very limited risks when there are a few or no victims involved.

It has been demonstrated that quick and decisive action during large-scale incidents is usually realised by quickly and autonomously deploying units such as pumps, rescue units, turntable ladders/ aerials, but also water supply, without or with a minimum of interference from central command. That is why swarming is used *at the start* of large incidents. For swarming leads to the best results in simple *and* complex task environments.

The suggested approach implies that the ability to take action during large-scale operations is realised by having many units form a swarm, in which the separate units autonomously solve small sub-problems of the incident. This is a choice for an organisation where effectiveness is more important than efficiency: we will handle large-scale operations with more fire appliances and supporting units more often.

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<sup>32</sup> Even though there are more parties that play an express part in situational operations, e.g. the control room and the hazardous materials adviser, we chose to limit this first draft to the crew commander and (senior) fire officer.



**Figure 21: Process Support during a Large Incident**

## 9.2 The Role of the Crew Commander during Large-scale Operations

In large-scale operations, the basic fire appliance/ pump is first and foremost seen as a self-managing unit that acts autonomously under the leadership of the crew commander. The crew commanders' objective while operation situationally is to independently handle a sub-problem of the incident.

Crew commanders deploy their unit to the best of their ability and understanding, and coordinate their approach with crew commanders in the immediate vicinity. Every crew commander stays in charge of their own unit, so there is no coordinating crew commander who has the explicit task to coordinate the actions and decisions of the crew commanders. A coordinating crew commander would fall into the same pitfall as fire officers currently do: any attempt at coordination will be frustrated by the dynamics and complexity of the incident.

Therefore, crew commanders coordinate their attack with other crew commanders and share information, but they do not give each other orders. In doing so, safety is obviously a continuous focus point: crew commanders watch each other and ask critical questions about risk assessments to keep each other alert. Less experienced crew commanders ask more experienced crew commanders for advice.

As long as swarming is applied, staging areas/ assembly points remain unused, since this would slow down the rapid deployment of the self-managing units. Crew commanders make their own choices as to where they deploy their unit, such as pumps, fire rescue units, water supply, etc.

It is only when the (senior) fire officer decides to change the command type that the crew commander's role changes. In both the hierarchical and specialist command type, crew commanders will let themselves be guided by the fire officer and/or specialist at the scene, in deciding how to deploy their unit. This does not affect the fact that the crew commander keeps having maximum freedom to act in order to operate as flexible as possible.

## 9.3 The Role of the (Senior) Fire officer during Large-scale Operations

When the (senior) fire officer arrives at the scene, he or she makes an assessment whether the mobilised potential is sufficient to gain control over the incident, based on his or her first impressions. If this is not the case, the (senior) fire officer will scale up. Scaling up in this phase, when there is still no concrete overview or deployment plan, happens according to the principle of 'better too many than too few'. Furthermore, the (senior) fire officer checks whether the essential preconditions are taken care of, so the crew commanders can continue to operate autonomously: logistics support, breathing apparatus (cilinders), water supply.

Then, it is up to the (senior) fire officer to decide which course of action should be carried out and to what extent the command type swarming is still appropriate for the ongoing incident. Due to the fact that the crew commanders execute the first deployment largely autonomously, the fire officers have the mental and practical space to form a good picture, to share this picture and to scale up. It should be noted that the normative type of deployment for this study (at least 4-8 fire engines) requires at least two fire officers and a senior fire officer, almost always assisted by a hazardous materials adviser.

The (senior) fire officers are aware of the human fallibility and use the situational support of the following tools in forming a picture and decision-making:

- > Stop sign
- > Sign post
- > Egg timer
- > Paving stone
- > Check light.

In addition to using the tools mentioned hereinabove, the (senior) fire officers apply mindfulness techniques during the incident. Examples are tactical breathing, body scan, continuously changing the physical distance to the incident. This means that they do the size-up themselves (on all sides) to find out how the incident is developing. Subsequently, they analyse the data in a relatively quiet place. This way they can pick up all the signs about the incident and its development, and thereupon make decision in relative peace and quiet.

It also emphasises that the (senior) fire officers are not alone in this: there are more fire officers at the scene and their thinking power has to be exploited optimally in order to fully understand the incident, and subsequently translate this into a concrete deployment plan at t+15 minutes (fire officer) and t+30 minutes (senior fire officer).

## 9.4 Changing to a Different Command Type?

Since an incident and, as a consequence, a task environment is dynamic, it is only logical within situational incident command to change command types during an incident. Proceeding from the baseline situation, the (senior) fire officer can decide to switch to another command type than swarming, based on the following arguments.

- > After the (senior) fire officers have jointly compiled a complete picture and made an assessment of the incident development to be expected in t+15/30 minutes, the transfer from the chaotic to the structured phase occurs, and they deploy units in accordance with the situation they expect. At that moment, the switch is made to a hierarchical or specialist command type.
- > The crew commanders and officers possess insufficient knowledge with regard to content to start or continue the fire or rescue efforts. This could be the case when confronted with –for instance- collapse, petrochemical fires or ship fires. At that moment, specialist knowledge is required to be able to control the core of the attack. Applying a specialist command approach seems obvious.
- > Crew commanders sometimes insufficiently clarify acute safety risks. If according to the (senior) fire officer, a majority of the crew commanders do not observe risks in the incident, he/she can decide to provide instructions for the execution and/or pause the incident attack until the attack is redirected. If the (senior) fire officer decides to pause the firefighting or rescue efforts, and to retreat, changing to a hierarchical operation seems obvious. It should be noted that, especially during swarming, all operational commanders should have the possibility to bring an operation to a halt when they observe an escalation of the incident or some other danger.
- > An incident can call for a similar approach by all units at the same the same time, as for instance would be the case at the start of a large-scale extinguishing operation using foam. In those cases a hierarchical style should be used.
- > If for whatever reasons, crew commanders themselves are not in a position to act. In such cases, it will have to be looked at as to why the crew commanders are not in a position to act. Is there a lack of knowledge? Is it impossible to make an adequate risk assessment? Is there a difference of opinion?

Within the model of situational incident command, the specialist command type is in fact a differentiation of the hierarchical command type. With the specialist command type, the highest commander stays in charge, but he or she explicitly calls in the advice of an expert in the field. The study showed that when an (external) specialist is formally in charge, this leads to confusion and, therefore, not to better results. Essentially, the highest commander stays in charge, but he or she is advised by someone with knowledge/understanding<sup>33</sup>, as would happen during incident management of hazardous materials. Participants to the experiment indicated that they prefer to be advised by a specialised fire service functionary, because of potential 'two-hat-discussions', and the fact that mutual confidence between colleagues is easier than confidence in a civilian who has no fire service background. With regard to this opinion, it should be noted that the knowledge of the person involved should be leading and not his or her background.

## 9.5 After the Operation

Immediately following an incident, the (senior) fire officers fill out the assessment framework themselves, to gather information on incident command for follow-up research. The Fire Service Academy provides support and periodically gathers and analyses the data.

<sup>33</sup> Examples are: boat fires, collapses, complex emergency responses, wildfires.

# 10 All Things Considered

After 2.5 years of research into the incident command of the fire service, we can now take stock. What do the results mean for the actual practice? What have we learned and are there truly new insights? Should we change course?

In simple, non-scientific terms, this chapter includes:

- > a summary of what we as authors of the report think we can deduce from the results;
- > a potential speck on the horizon, and;
- > the first steps we can take to innovate incident command on the basis of this study.

## 10.1 The Objective

It is worthwhile to start out with stating once more, in simple terms, what the objective of the study was. The objective consisted of several elements. First, we wanted to find out why the present command structure is so often deviated from in practice, whether the present command structure might be faulty, and whether the deviations are undesirable. We also wanted to find out what caused the deviations. A second element was the idea that incident command does not take human factors sufficiently into account. Therefore, it was our express intention to connect the human factors and the command structure in order to find an adjustment of the structure that does justice to both the practice and the human factor. This is innovative. As far as we know, this has not been researched before, and there are no publications about a structure for the fire service that incorporates human (in)capacities.

## 10.2 Theoretical Foundation

We can safely state that the first part of the study, the literature research and case histories, has become a great summary of the available materials on decision-making under pressure and the human factors that play a part herein. The principles have been known and recorded in the literature for some time now. Until now, the principles on decision-making were primarily known to the experts and were discussed and written about in fragmentary form. This has now been gathered into one document (**Result 1**). Much has been written about it, but it has hardly ever been used in practice. This can change because we can now give it tangible substance. Subsequently, it was researched how an organisation should behave in a particular environment to achieve good results (**Result 2**). It then turns out that a structure has to be able to adapt itself to the situation. We identified the factors that play a role in this. All this resulted in a framework with measurable variables, the so-called assessment framework incident command. In years to come we can use the assessment framework to gather more information on the actual practice and if necessary, make evidence based improvements to incident command (**Result 3**). Finally, the first part of the study resulted in hypotheses, which we further investigated through practical research. Based on the theory, we distinguished separate types of incidents, which are actually different in characteristics. You can call this a result as well, because we can use it to build scenarios for exercises in the future (**Result 4**). Furthermore, we deduced a number of hypothetical command types from the literature that possibly can be applied. However, command types alone are not

enough, as is confirmed by the literature. It is all about the interaction between humans and structure, and that is why we specifically looked at those humans. One of the conclusions that can be found in the literature concerns the way in which decisions are made. Recognition Primed Decision Making states that experience is of the utmost importance for rapid decision-making. That is why we looked at whether and how experience influences how people will react to unexpected events, which is not unimportant for operational commanders in the fire service. There is more, however. It is common knowledge that people have certain characteristics that might lead them to misjudge a situation. Much has already been written about this subject and we have included these characteristics as well. People can suffer from an information overload and only observe and process a limited number of things. Apart from that, situational awareness might be affected, operational commanders might have limited experience, and biases and tunnel vision might occur (**Result 5**). Can this be observed during practical research as well, and can it be corrected?

### 10.3 Command Types

Subsequently, we applied the various command type to the various incident types. The experiments were set up large in size, but not so big that the results can be fully generalised. Each combination of incident type and command structure was tested only twice. The results reflect both objective and subjective quantities. Scientifically, this is a unique but difficult study. In studies that involve humans, subjective elements are always a factor. For instance, people were asked to behave differently than they usually would by using other command types. Despite the scientific limitations of this research, there are some very strong clues for possible improvements of the command structure to be obtained, when we look at it through our eyelids.

We observed that the purely hierarchical structure quickly leads to paralysis. It simply doesn't work to focus on a single-headed leader who sees, knows, supervises, predicts, monitors everything and gives commands. The theory of human factors provides a very good explanation for this. It is not because the leaders are selected or trained badly, but they are people and people have limitations. Contrary to expectation, this type of command structure does not only work poorly during complex incidents, but also in the early stages of 'simple' incidents according to its characteristics. This explains why in actual practice this structure is deviated from. In fact, it only exists on paper.

In the early stages of an incident, several units arrive at the scene that are all used to deploying themselves. We named this the swarming structure. The crew commanders communicate with each other about the tasks they are going to execute and they themselves decide what to prioritise. In practice, this is usually how it goes until the fire officer arrives at the scene. What we have seen, is that in the hierarchical structure the fire officer immediately takes charge, i.e. obtains the available information from the crew commanders, and as a result becomes swamped. In a swarming structure the fire officer only takes charge after having obtained a complete size-up and picture of the scene. In this case, the command structure supports the human factor. Information overload is prevented by continuing the swarming structure for a longer period of time, until the fire officer has acquired an overview. In addition to this, the fire officer has the time and space to observe what is actually going on (situational awareness).

The effect of a specialist as leader was also looked at. The results of that command structure were not as good, but from the experiments we can conclude that room must be found for the specialist as a key adviser.

All things considered, we find sufficient cause to state that the hierarchical command structure only exists on paper and is superseded by theory and comparative simulation research, and should be adjusted. This doesn't mean that one of the other command types has to replace it. The structure has to be more flexible. We named it situational incident command.

## 10.4 Human Factors

As mentioned before, the objective of the research was to place the people central in the structure, apart from the structure itself. Furthermore, in selecting structures, the objective was to take into account the theory on human factors during decision-making. However, there is an abundance of human factors and the scope of this study did not allow us to exhaustively research all of them in practice. We had to make a choice. This does not alter the fact that the human factors that are described in the literature already have been researched, and we can assume that these apply to incident command during large-scale firefighting and rescue operations.

We chose to look at the influence of experience on decision-making. We did this by looking scientifically at the phenomenon of 'freezing'. The philosophy behind this is that leading a dynamic incident, where surprises occur all the time, is stressful. Freezing is one of the stress responses that might occur. We wanted to know whether freezing actually occurs and to what extent experience influences those stress responses. Freezing can have a positive effect (open mind) or a negative effect (clam up). We made a first attempt to research the latter by finding out to what extent certain events that happened during the incident were remembered. Even though this research generated significant results, representativeness was not very high. That is why this research should be considered a first step. However, taking this into account, we can distil a few interesting clues.

We observed that freezing actually occurs. Therefore, that expectation proved right. We also see that experience results in less freezing. This corresponds with the literature which states that experience plays a part in decision-making. However, we also saw that older participants freeze less, as well. And that is new. Furthermore, we saw that stress has an effect on the extent to which stressful moments can be recollected and that experienced people remember more than inexperienced people.

We would like to perform follow-up research into the extent freezing influences decision-making positively or negatively and how that connects with experience. It could be that the freezing that was observed was functionally right in both cases, experienced and inexperienced. It is not possible to make a value judgement on this yet.

Regarding the command structure, we can carefully point to a relationship with the extent to which (senior) fire officers are capable of operating as a single-headed leader. There is at least an indication that a single-headed leader is vulnerable, since all leaders suffer from freezing. It is a neuropsychological principle. Therefore, we should practise risk control both in the structure and in using resources, to protect the single-headed leader from this

phenomenon, and to prevent the incident from getting out of control because of the leader's vulnerability.

Finally, we found strong indications in the literature that leaders should be 'mindful'. This results in better 'sensemaking' and situational awareness. This is why we took a first step to find out if a mindfulness training can help operational commanders to distance themselves both physical and mentally, and in doing so reduce the well-known phenomenon of information overload and increase situational awareness. The question we researched was whether the operational commanders are of the opinion that such a training is useful for the fire service. The tentative conclusion is that officers experience this training as positive. Obviously, the effectiveness of the training has to be further researched, but for now the theory seems to be supported.

## 10.5 Added Bonus

Apart from the direct test results, we made some observations that we might take advantage of for the future.

- > Observation (at exercises and incidents) has to be more objective. Different firefighters looking at the same performance, observe different things. They also differ in their judgement of what they see.
- > A virtual environment such as ADMS is very suitable for creating realistic large-scale dynamic training scenarios.
- > Perceptions differ greatly. We observe that there are different types of participants: flexible, progressive and conservative. There is a great need for a united doctrine. There are no strict assessment frameworks.
- > There are considerable differences in knowledge with regard to content and this knowledge is not always sufficient.
- > In general, there is little attention in incident command for estimating the development of the incident, which might be partly caused by the information overload. However, there also seems to be a lack of knowledge or experience for officers to be able to estimate what is going to happen. As a result, there is a great chance to be overtaken by events.

## 10.6 Concrete Adjustments

What concrete adjustments do we suggest based on this study?

Before we discuss potential adjustments, there are two points to make that are of the utmost importance.

1. We could place a faraway speck on the horizon. This would go far beyond what we suggest here, and we could consider other studies in doing so. We will not do this. We choose consciously for a first feasible step from the current situation; we do not choose a step further into a brighter future that is not feasible.
2. Secondly, we more than sufficiently demonstrated in this study that human factors are at least as significant as structures and knowledge, and maybe even more so. This is contrary to current paradigms, however, both inside and outside the fire service. Because society, but also our legislators, administrators and inspectorates, and last but not least our leaders themselves are under the impression that a single-headed leader has to be capable of everything. This has to be reversed. People are fallible and therefore, they make mistakes, especially when they have to operate under

unpredictable circumstances and are under pressure of time and/or threat.

This is not the fault of the individual, this happens because they are human. The fallible human factor can be counterbalanced by resources, but never completely.

This paradigm is founded on, or is the cause of a number of cultural characteristics that can impede both the ability to improvise and to learn. This results in people thinking that they 'have to be able to do it by themselves'. As a consequence, they do not call for assistance, try to cover up mistakes and do not learn or dare to experiment.

Specifically, we arrive at the following adjustments:

1. Internal (in the Fire Service): awareness of the limitations of the human factors for the performance as operational commanders and as a result of that also for the operational structure. A programme that was created with, among others, England might assist in this: the project Firemind.
2. Flexibilisation of the operational structure: 'situational incident command'  
Situational incident command has the following characteristics:
  - > begins like a swarming structure, in which the mobilised units deploy themselves;
  - > depending on the incident, stays swarming until the (senior) fire officer has sufficient understanding and insight to take charge (this involves an important human factor);
  - > as operational commander (crew commander, fire officer and senior fire officer) in complicated and complex incidents you can never act alone because of the limitations of human factors. That is why the crew commander and the (senior) fire officer call in extra support, these functionaries have a position in the command structure;
  - > these functionaries are, for instance, a specialist (in whatever form), a 'predictor', a 'co-thinker', a 'helper', a 'messenger', a 'environment observer' or a 'safety observer'; This model of situational incident command fits in with current practise during large incidents and, therefore, can be used immediately by operational commanders. To achieve optimum results, the model has to be further developed and translated for the various functions of operator, crew commander, (senior) fire officer and specialist.
3. Implementation of some of the tools to support the operational commanders and in doing so, compensate as much as possible for the human fallibility.
  - > stop sign
  - > egg timer
  - > sign post
  - > paving stone
  - > check light.
4. Implementation of mindfulness (especially for young and inexperienced officers) in the education programme, exercises and training.
5. Continuously updating the assessment framework by officers themselves in order to gather information for further research. The Fire Service Academy can support this and periodically gather and analyse the data.
6. Professional knowledge seems to require more attention during the education programme, specifically at the level of (senior) fire officers.

This means providing better points of reference to assess the development of an incident and provide training that focuses on this aspect. It will be easier for an operational commander when he/or she possesses strong analytical skills.

7. As far as gaining more experience is concerned, there are various options that, when combined, lead to more experience.
  - > Firstly, officers can gain more practical experience by reducing the number of (senior) fire officers (or enlarging duty areas). By implementing situational incident command an increase in response time has less effect on the operational practice since the units are self-managing. Lector crisis management Menno van Duin pleaded for this in his lectureship speech 'Veerkrachtige crisisbeheersing: nuchter over het bijzondere' (Resilient Crisis Management: Commonsensical about the Extraordinary).
  - > Secondly, enabling officers to gain more experience with complicated and complex incidents by realistic virtual exercises, as were used in the comparative simulation research. Complex, complicated and dynamic large-scale incidents can only be practised in a virtual environment. By using scenario's based on actual incidents, the experience of the actual incidents is exchanged as well.
  
8. **SPECK ON THE HORIZON:** quality frameworks (test team of field officers) that may and can judge both operational tactics and operational strategy. Thus, we are working on a united doctrine that is needed to objectify observations and evaluations.

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# Annex: Automatic Stress Responses in Fire officers

## Population

- > Experienced fire officers: N = 25
- > Inexperienced fire officers: N = 16
- > Exactly 3 large fires: N = 1 (excluded)

Experience is defined as having been involved in more than 3 large fires (inexperienced fire officers = fewer than 3 large fires, experienced fire officers = more than 3 large fires).

### *Descriptive statistics*

Group differences in age, level of education, TIS, positivism and baseline heart rate.

- > Age: The experienced fire officers were older than the inexperienced fire officers ( $t(39) = -2.22$ ,  $p = .03$ )
- > Level of education (4 missing values): the experienced fire officers had a higher level of education than the inexperienced fire officers ( $\chi^2 (N = 38, 2) = 6.43$ ,  $p = .04$ ).
- > Fear during the most stressful incident (TIS-fear): There is no difference between the groups ( $t(39) = -.26$ ,  $p = .80$ ).
- > Freezing during the most stressful incident (TIS-TI): There is no difference between the groups ( $t(39) = -.20$ ,  $p = .84$ ).
- > Positivism: There is no difference between the groups ( $t(39) = -.02$ ,  $p = .98$ ).
- > Baseline heart rate (the heart rate when watching a neutral film; 1 missing value): There is no difference between the groups in the development of the heart rate over time (Time x Group interaction effect:  $F(2, 76) = .16$ ,  $p = .85$ ) and no difference between the groups in the speed of the heart rate ( $p = .71$ ).

The effects remained the same with age as covariate in the model (Time x Group interaction effect:  $p = .89$ , main effect Group:  $p = .34$ ).

Averages (SD) between groups

	Inexperienced fire officers (N = 16)	Experienced fire officers (N = 25)
Age*	39.8 (5.9)	45.0 (8.3)
Level of education*		
Intermediate Vocational Education	63%	23%
Higher Professional Education	38%	73%
Higher Education	0%	5%
TIS-fear	10.3 (3.3)	10.6 (2.8)
TIS-TI	9.9 (6.0)	10.3 (6.4)
Positivism	35.1 (2.9)	35.0 (3.6)
Baseline heart rate (during the neutral film)	71.9 (2.8)	70.2 (3.4)

\*p < .05

### Subjective Rating of the IAPS Pictures

Experienced fire officers: N = 24 (1 fire officer was excluded because last week he experienced 2 stressful incidents, as a result of which the pictures triggered memories)  
Inexperienced fire officers: N = 16

The 2 groups (experienced, inexperienced) rated 4 types of pictures (neutral, pleasant, non-related unpleasant and related unpleasant) on pleasantness, arousal (severity/intensity) and freezing on a scale of 0-10.

#### **Main effect of the pictures (manipulation check)**

There is a main effect of 'type of picture' on pleasantness ( $p < .001$ ), arousal ( $p < .001$ ), and freezing ( $p < .001$ ):

- > Pleasantness: all categories of pictures differed from each other, the positive pictures were rated the most pleasant and the related negative pictures as the most unpleasant (neutral pictures:  $M = 5.4$ ; positive pictures:  $M = 6.8$ ; non-related negative pictures:  $M = 3.1$ ; related negative pictures:  $M = 2.5$ ).
- > Arousal: The neutral pictures ( $M = 2.7$ ) were rated as less arousing/severe/intense than the other pictures (positive pictures:  $M = 5.2$ ; non-related negative pictures:  $M = 4.9$ ; related negative pictures:  $M = 5.9$ ; all  $ps < .001$ ). The positive pictures were as arousing as the unrelated negative pictures ( $p = .28$ ) and there was only a trend difference with the related unpleasant pictures ( $p = .06$ ). The related negative pictures were more arousing than the non-related negative pictures ( $p < .001$ ).
- > The test subjects indicated that they experienced hardly any freezing with the neutral ( $M = .2$ ) and positive ( $M = .6$ ) pictures. They indicated that they did experience freezing with the non-related ( $M = 1.5$ ) and related ( $M = 1.8$ ) negative pictures. All picture categories differed from each other in the extent to which they triggered freezing (all  $ps < .03$ ).

### Difference between groups

There is no interaction effect (Type of Picture x Group) on pleasantness ( $F(3, 114) = .59, p = .62$ ) and arousal ( $F(3, 114) = .123, p = .30$ ). There is an interaction effect on freezing ( $F(3, 114) = .59, p = .05$ ). Inexperienced fire officers experience more freezing than experienced fire officers when looking at the related unpleasant pictures (inexperienced = 2.5; experienced = 1.2;  $t(38) = 2.21, p = .03$ ), but not when looking at neutral, positive and non-related unpleasant pictures ( $p = .55, p = .12$  and  $p = .18$ , respectively).

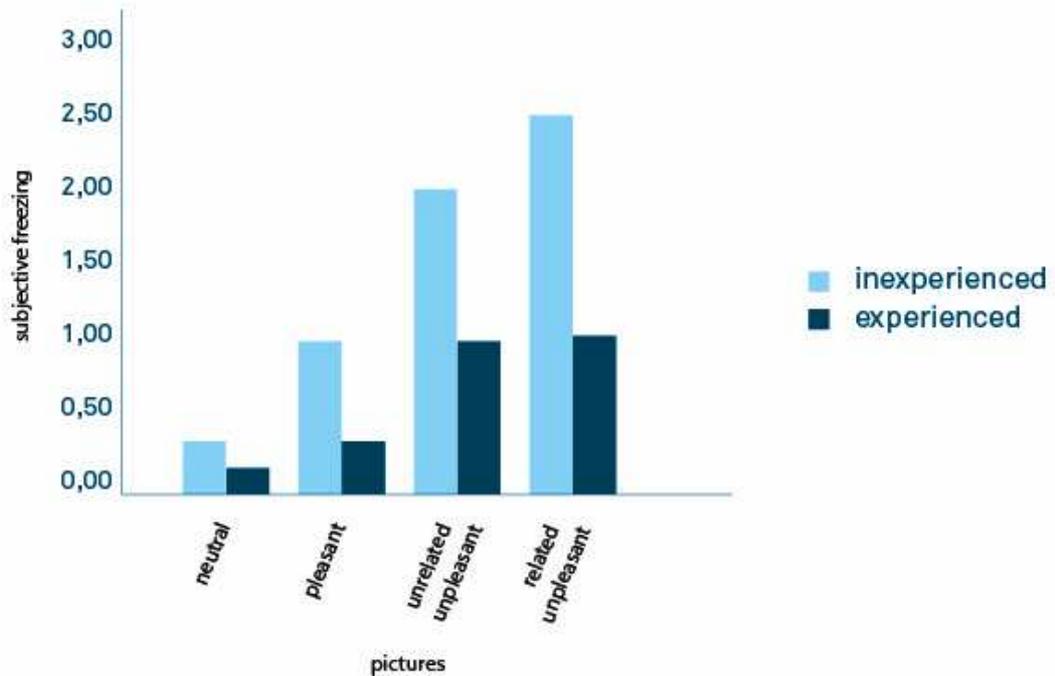


Figure 22: Average Subjective Freezing per Picture Category

### Effects on response times

For the response time analysis composite scores were made of the increase in response time for (non-)related pictures minus response times for positive pictures, to check for arousal effects (RT on non-related negative pictures minus RT on positive pictures, and RT on related negative pictures minus RT on positive pictures). This was done for all 3 scales, so from picture onset until the first action (rating the picture on the 1st scale, arousal), the second action (rating the picture on the 2nd scale, valence) and the third action (rating the picture on the 3rd scale, freezing).

The groups did not differ in their reaction to the related negative pictures (all  $p$ s > .18), but they did differ in their reaction to the non-related pictures. The inexperienced fire officers slow down more than the experienced fire officers in reaction to the non-related negative pictures (valence scale:  $F(38) = 6.17, p = .02$ ; freezing scale:  $F(38) = 4.02, p = .05$ ), which may be indicative of freezing. The inexperienced fire officers do not slow down more than the experienced fire officers in their reaction to the non-related pictures in rating the first scale (arousal;  $F(38) = 2.34, p = .13$ ).

### Conclusions

- 1) The manipulation during passive viewing succeeded: the negative pictures are seen as negative, the positive ones as positive and the neutral ones as neutral. The positive

pictures are an appropriate control condition because they are as intense as the negative (non-related) pictures. And the pictures invoke freezing.

- 2) The inexperienced fire officers experience more freezing in reaction to the related unpleasant pictures, despite the fact that the groups do not differ in how unpleasant or intense they consider the pictures to be.
- 3) There is an objective delay of response time (freezing?) in all fire officers in their reaction to the non-related and related unpleasant pictures.
- 4) Inexperienced fire officers show more delay in response time than the experienced fire officers to the non-related unpleasant pictures.
  - ➔ Subjective freezing is higher with inexperienced fire officers in reaction to related unpleasant pictures (severe stress). Objective freezing starts earlier: it is higher with inexperienced fire officers in reaction to non-related unpleasant pictures (moderate stress). Everyone shows a lot of objective freezing with the related unpleasant pictures (ceiling effect?).

### IAPS Passive Viewing

Freezing is characterised by a decrease of the heart rate and of movement (body sway) in reaction to negative versus positive or neutral stimuli. Since the contrast with positive stimuli checks for arousal, we decided to analyse this contrast.

An outlier was removed because it was more than 3 SDs above average of the heart rate contrast score. For 3 test subjects the data were not unusable because of technical reasons (problems in recording the data), which left 16 inexperienced and 20 experienced fire officers. Age was included as a covariate to ensure that the outcome was not the result of age difference (age has an influence on the heart rate and freezing).

#### Heart Rate

The heart rate strongly reduced in reaction to non-related and related pictures versus neutral and positive pictures ( $F(3, 105) = 11.28, p < .001$ ).

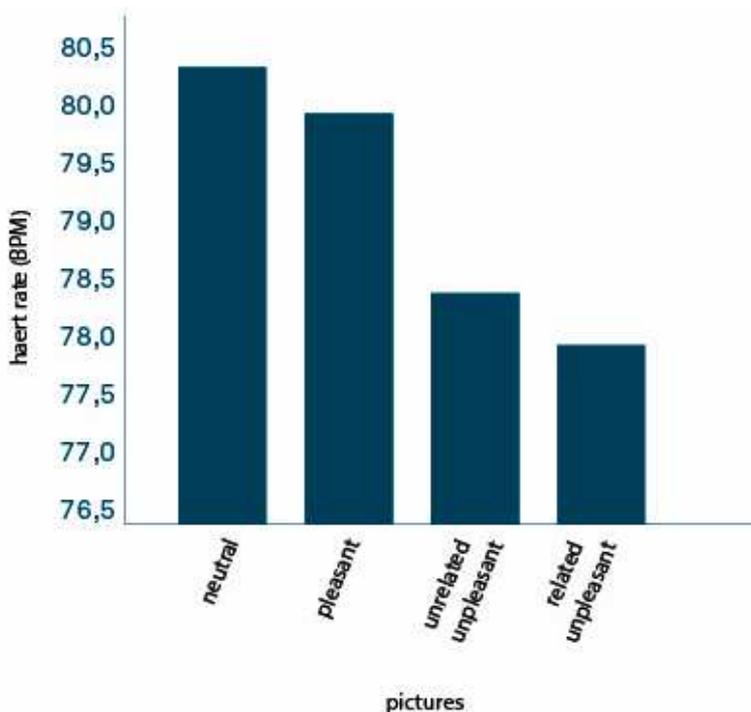


Figure 23: Average Heart Rate per Picture Category

The TypePicture x Group interaction was almost significant ( $F(3, 99) = 2.59, p = .057$ ). Post hoc analyses showed a significant difference between the groups on the contrast Positive - Related Negative ( $F(1, 33) = 4.83, p = .04$ ) and an almost significant difference on the contrast Positive - Non-related Negative ( $F(1, 33) = 4.10, p = .05$ ). The inexperienced fire officers showed a stronger reduction in heart rate than experienced fire officers.

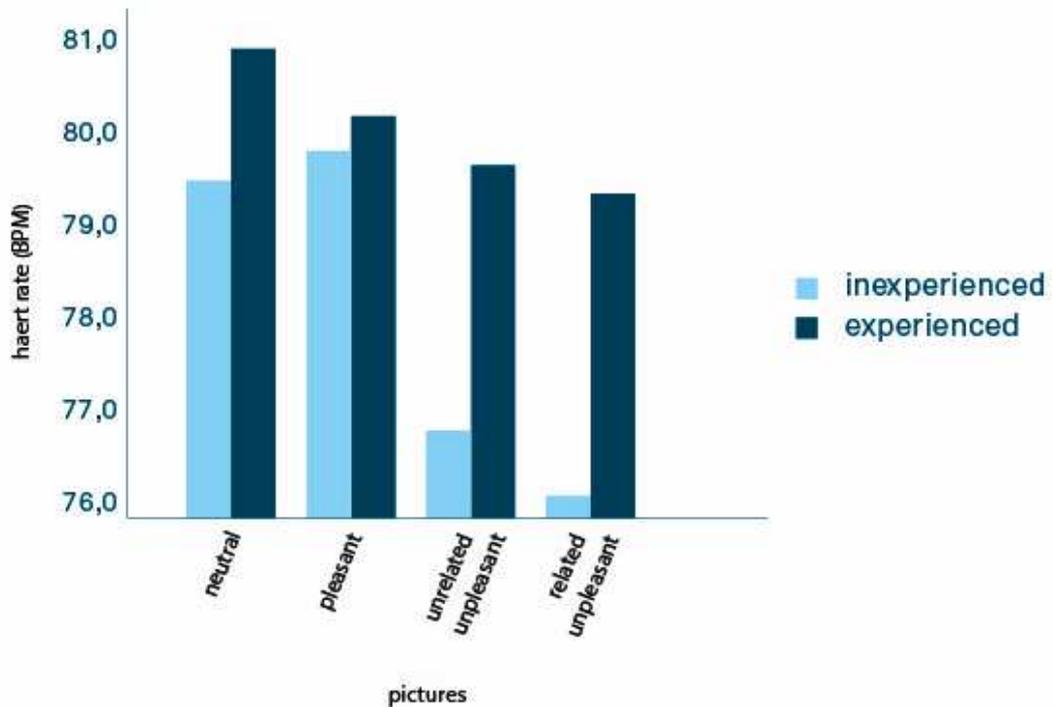


Figure 24: Average Heart Rate per Picture Category

### **Body sway**

Body sway decreased ( $F(3, 34) = 3.58, p = .02$ ) in reaction to the related pictures versus the neutral pictures ( $p = .01$ ) and a trend towards positive pictures ( $p = 0.057$ ). There was also a trend reduction in body sway in reaction to unrelated pictures versus neutral pictures ( $p = .06$ ), but not versus positive pictures ( $p = .21$ )

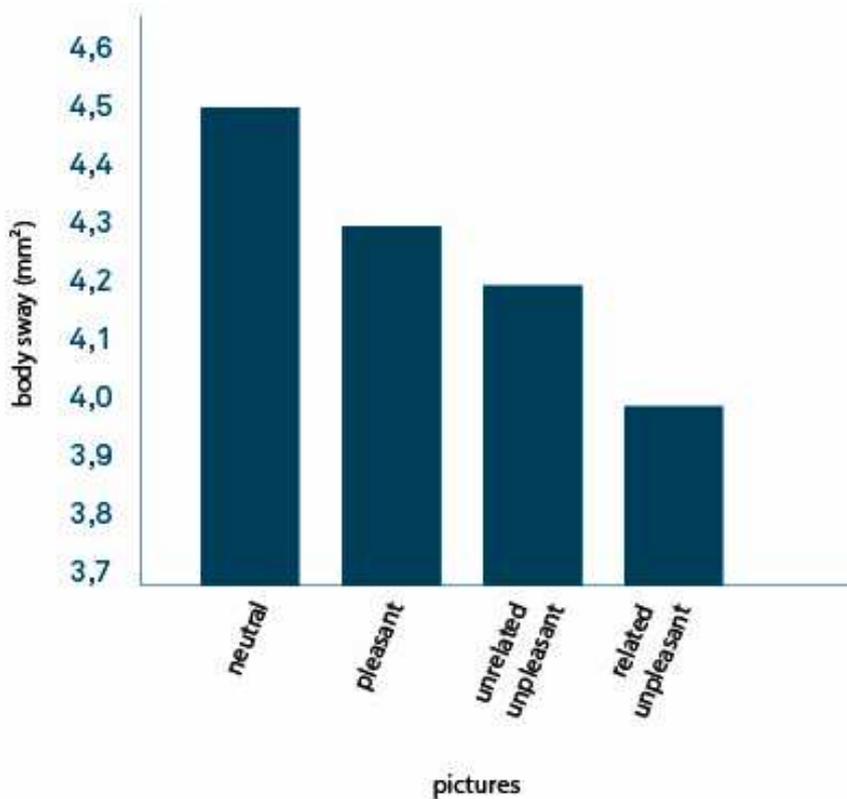


Figure 25: Average Body Sway per Picture Category

The TypePicture x Group interaction was significant ( $F(3, 99) = 3.22, p = .03$ ). Post hoc analyses showed no difference between the groups on the contrast Positive - Related Negative ( $F(1, 33) = 37, p = .55$ ), but a strong and significant difference on the contrast Positive - Non-related Negative ( $F(1, 33) = 14.39, p = .001$ ). The inexperienced fire officers showed a stronger reduction in body sway than experienced fire officers.

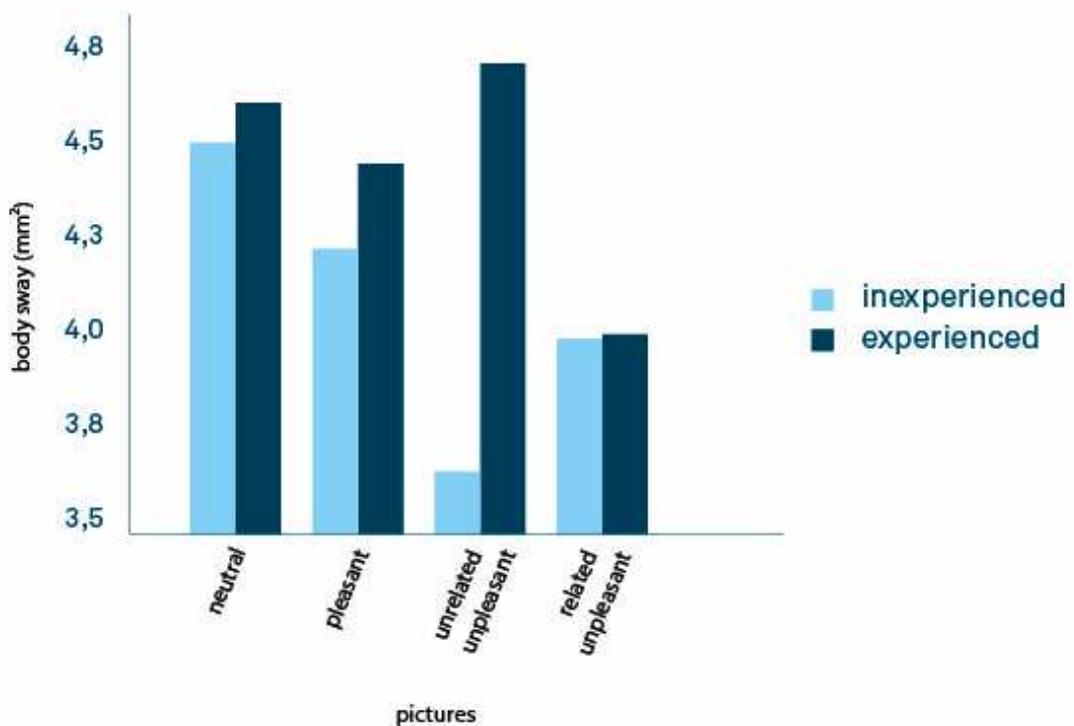


Figure 26: Average Body Sway per Picture Category

## Conclusions

- > The negative pictures cause freezing (a reduced heart rate and body sway).
- > The inexperienced fire officer show freezing in reaction to all negative pictures, the experienced fire officer only in reaction to the related negative pictures.
- > Inexperienced fire officers show freezing in reaction to all kinds of stress (also moderate, non-related stress), experienced fire officers only to relevant or severe stress. In other words: all fire officers show freezing under severe, related stress, when faced with moderate/non-related stress only inexperienced fire officers show freezing.

## Incident Simulation Passive Viewing

### Heart Rate

An outlier was removed because this went from an extremely high heart rate at the start (124 BPM) to an extremely low heart rate during the film (43 BPM, 3rd block). For 3 test subjects the data were not unusable because of technical reasons (problems in recording the data), which left 15 inexperienced and 22 experienced fire officers. The question was whether the fire officer would show a change in heart rate and body sway during the film, and whether this was already the case in the first part of the film. The film was divided into 5 blocks of 51 seconds. At first, the increase in heart rate during these 5 blocks of time was looked at, to test whether the film was effective in inducing stress throughout all the groups. Since there were no isolated instances of stress, but there was an accumulation of stressful moments in the second part of the film, the groups were compared for increases in heart rate during the first half of the film. Contrast score: heart rate during the third time frame [104-155 sec] minus heart rate at the beginning [first 51 seconds]) and increases in heart rate during the entire film (contrast score: heart rate at the end [final 51 seconds] minus heart rate at the beginning [first 51 seconds]).

A repeated measures ANOVA showed that the heart rate increased during the film ( $F(4, 144) = 6.54, p < .001$ ). Post hoc analysis showed that the increase occurred predominantly as from the third block: the first three blocks did not differ from each other (all  $ps > .27$ ), but in the fourth and fifth block (where the stressful moments became more frequent) the heart rates were higher than in the first three blocks (all  $ps < .02$ ).

A MANOVA was performed with the Group (experienced/inexperienced) as a between-subjects variable, and the contrast scores as the dependent variable. Age was included as covariate. From the beginning of the film until the end, the heart rates of experienced fire officer increased less strongly ( $M = 2.35, SD = .65$ ) than the heart rates of inexperienced fire officers ( $M = 4.44, SD = .79$ ) ( $F(1, 37) = 5.2, p = .03$ ).

The main effect of Age was also significant ( $F(1, 37) = 4.80, p = .04$ ), as was the Group x Age interaction ( $F(1, 37) = 4.18, p = .049$ ). Throughout the population a higher age was connected with a heart rate that accelerated less from the beginning of the film until the end ( $r = -.30, p = .07$ ). However, this was only strongly the case for the inexperienced fire officers ( $r = -.53, p = .04$ ). There was no connection between age and heart rate acceleration for experienced fire officers ( $r = -.04, p = .88$ ).

The heart rate acceleration during the first half of the film did not differ (experienced fire officers:  $M = -.16, SD = .68$ ; inexperienced fire officers:

$M = 1.52, SD = .82$ ) ( $F(1, 37) = .69, p = .41$ ), and also the Age of the Group x Age interaction was not significant for the first half of the film.

### Body sway

An outlier was removed because it contained an extremely high SD-AP increase in block 3 (from 3 to 10 mm, more than 3 SDs above the average increase), probably due to

repositioning. The analyses were performed on 14 inexperienced and 23 experienced fire officers.

A paired samples t-test showed a trend for increase in body sway from the beginning until the end of the film throughout the entire group ( $t(37) = 1.68, p = .10$ ). There was no change in body sway during the first half of the film ( $t(37) = .83, p = .41$ ).

A MANOVA was performed with the Group (experienced/inexperienced) as between-subjects variable and contrast scores (SD-AP block 5 minus block 1 = increase of body sway from the beginning until the end of the film and body sway/SD-AP block 3 minus block 1 = increase in body sway during the first half of the film). There was no difference in change of body sway between during the entire film or during the first half of the film (both  $F_s < .05$ , both  $p_s > .94$ ).

When Age is included as a covariate there was also no effect (both  $F < 3.10$ , both  $p_s > .58$ ).

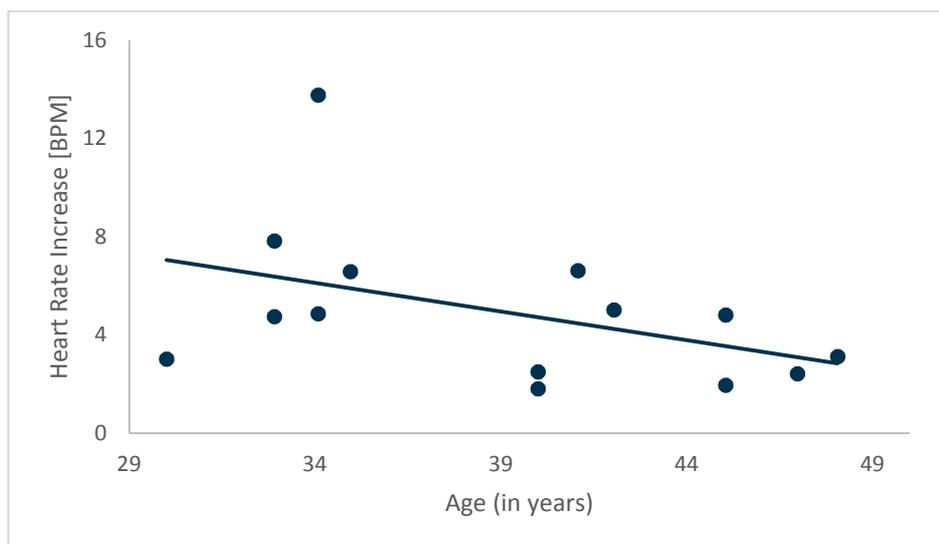


Figure 27: Relation Age-Heart Rate Increase during the Entire Film in Inexperienced Fire officers

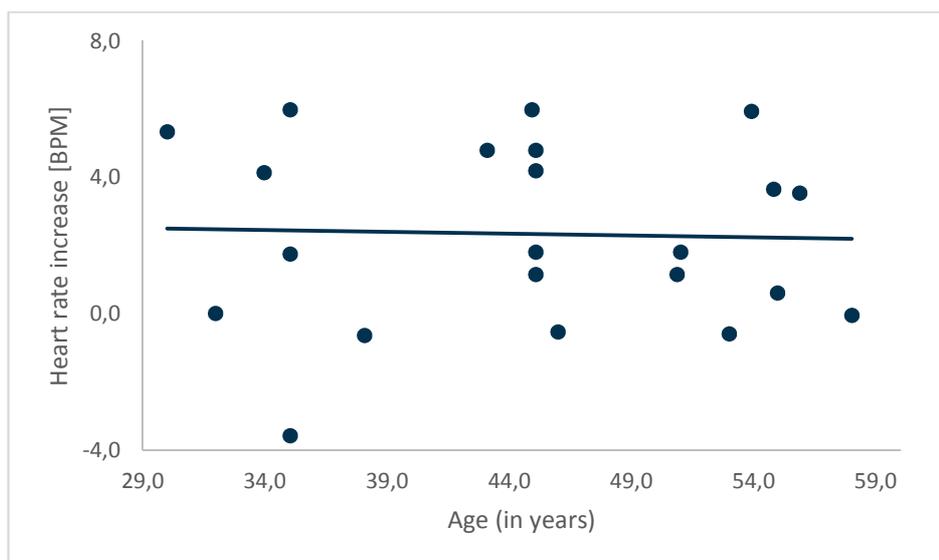


Figure 28: Relation Age-Heart Rate Increase during the Entire Film in Experienced Fire officers

### **Conclusion heart rate**

- > The negative film causes stress (increased heart rate and reduced body sway).
- > The stress response predominantly occurs from block 3 to block 4, when the instances of stress become more frequent and the fire is actually visible in the film.
- > During the film, inexperienced fire officers show stronger heart rate acceleration than experienced fire officers.
- > Older fire officers show stronger heart rate acceleration than younger fire officers, but this age effect is counterbalanced by experience: only in inexperienced fire officers age is related to heart rate acceleration.

### **Body sway**

An outlier was removed because it contained an extremely high SD-AP increase from block 2 to block 3 (from 3 to 10 mm, more than 3 SDs above the average increase), probably due to repositioning. The analyses were performed on 14 inexperienced and 23 experienced fire officers.

A repeated measures ANOVA showed that the body sway increased during the film ( $F(4, 144) = 2.00, p = .10$ ). Post hoc analyses show that only 1 block differed from the rest: there was a decrease in body sway in block 4 compared to block 1 ( $p = .03$ ), block 2 ( $p = .07$ ) and block 3 ( $p = .07$ ). There was no difference in body sway between the block 4 and 5 (where the stressful moments became more frequent;  $p = .33$ ).

A MANOVA was performed with the Group (experienced/inexperienced) as a between-subjects variable, and the contrast scores as the dependent variables (see heart rate analyses). Age was included as covariate. There were no effects for Group, Age or Group x Age for changes from the beginning until the end of the film (all  $F_s < .13$ , all  $p_s > .73$ ). As to the changes in body sway during the first half of the film, there was a trend effect of Age ( $F(1, 37) = 3.76, p = .06$ ): older fire officers showed a smaller decrease in body sway ( $r = .29, p = .08$ ). The effects of Group or Group x Age were not significant during the first half of the film ( $F_s < .52, p > .48$ ).

### **Conclusion body sway**

- > The negative film causes changes in body sway.
- > Similar to the heart rate changes, the decrease in body sway predominantly occurs from block 3 to block 4, when the instances of stress become more frequent and the fire is actually visible in the film.
- > Younger fire officers show a stronger decrease in body sway during the first half of the film than older fire officers.

### **Visual inspection of the heart rate and body sway data**

Since this was new test design, the data were visually inspected for distinctive patterns.

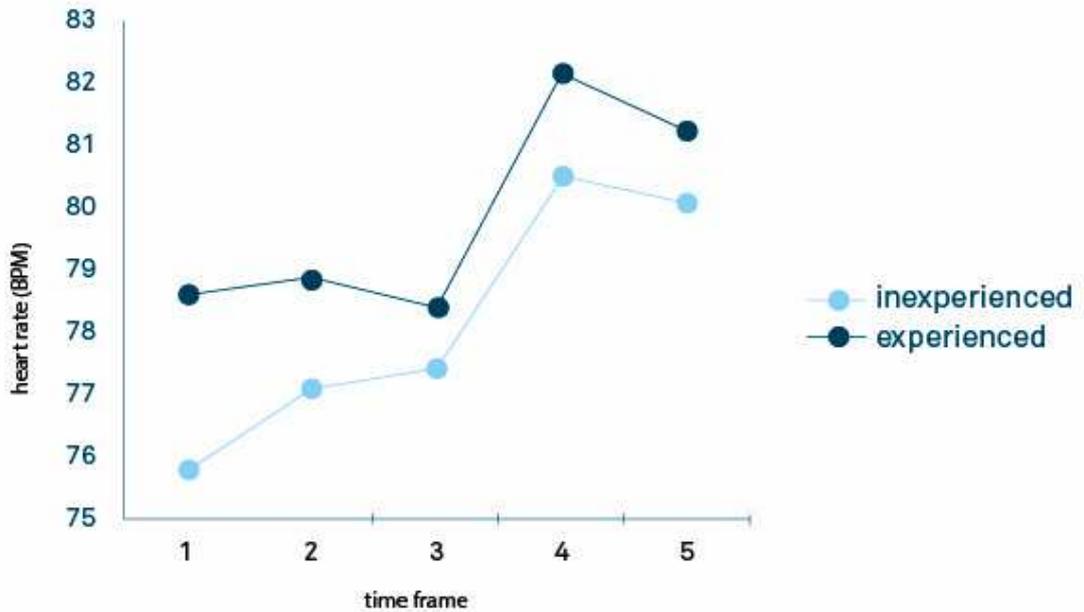


Figure 29: Heart Rate (Age as Covariate)

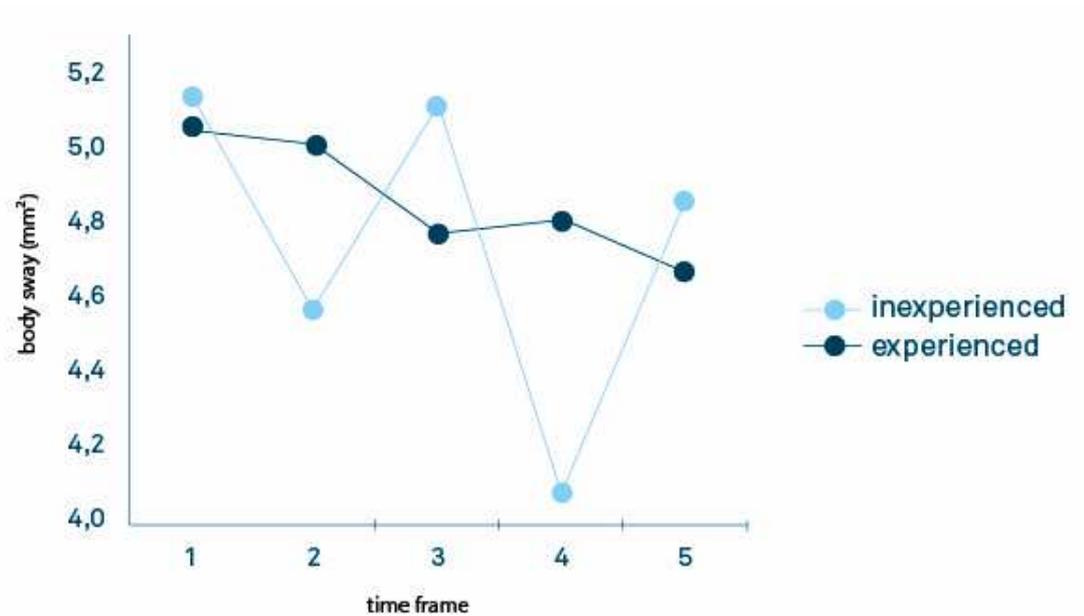


Figure 30: Body Sway (Age as Covariate)

### Conclusions

- > Since it is a mere visual inspection, strong conclusions are not possible.
- > As from block 4, the patterns of heart rate and body sway point at stress, when the fire becomes visible and the instances of stress happen in quick succession.
- > Speculative and to be confirmed by further research: The reduced body sway during block 4, combined with strong heart rate acceleration can point at a stronger freezing reaction in the inexperienced fire officers.
- > The inexperienced fire officers demonstrate a much more variable pattern in their body sway, and the experienced fire officers are 'more stable'. This can be caused by the small sample of inexperienced fire officers. However, it is a notable difference and should be further investigated.

## Fire Service Film Recognition

Because age can affect memory, age is included as a covariate in the MANOVA. There was no difference between the groups in the percentage of correct answers to the recognition questionnaire, consisting of 41 questions about the fire service film ( $F(1, 40) = .12, p = .74$ ). The inexperienced fire officers answered an average of 72.3% correctly, the experienced fire officer 71.3%. The groups also did not differ in the percentage of correct answers to stress related and non-stress related questions (both  $F_s < .08$ , both  $p_s > .78$ ).

Partial correlations checking for age showed that there is no relation between the changes in heart rate or body sway-SD-AP and the percentage of correct answers (total, stress items and non-stress items; all  $r_s < -.25$ , all  $p_s > .14$ ).

The inexperienced fire officer showed a significant correlation trend between change in heart rate during the first half of the film and the percentage of correct answers to the stress-items: **a higher increase in heart rate was related to fewer correct answers to the stress items ( $r = -.45, p = .10$ )**

The relation between the percentage of answers to non-stress items was not significant ( $r = .28, p = .34$ ). There was no relation between heart rate changes from the beginning of the film until the end and the percentage of correct answers (stress or non-stress, both  $r_s < .26$ , both  $p_s > .36$ ).

There was no relation between recognition and body sway (SD-AP) in the inexperienced fire officers.

The experienced fire officers showed no significant relations between heart rate increase (in the first half or during the entire film) and recognition of stress or non-stress items (all  $r_s < -.26$ , all  $p_s > .24$ ). There was, however, a negative relation between change in body sway/SD-AP in the first half of the film and the percentage of correct answers for non-stress items: **a higher increase in body sway was related to fewer correct answers to the non-stress items ( $r = -.39, p = .07$ )** There was no relation between body sway changes from the beginning of the film until the end and the percentage of correct answers (both  $r_s < -.21$ , all  $p_s > .35$ ).

## Conclusion

- 1) Inexperienced fire officers: more stress (heart rate acceleration) = recollection of stress-related information is worse.
- 2) Experienced fire officers: more stress/unrest (movement) = recollection of non-stress information is worse.