# 15 Dutch Emergency Response Organization

## *Safety Region—Quantitative Approach to Operational Resilience*

*John van Trijp and M. Ulieru*

## CONTENTS

## CASE STUDY ELEMENTS

- *Fundamental essence*: This case study is about elements making up operational resilience of a Dutch emergency response organization, a safety region. As an example, an industrial blaze at an industrial plant is examined.
- *Topical relevance*: To date, a quantitative approach for operational resilience in case of an emergency response organization has not been used before. This case study presents insight on a new technique that defines the way the organization behaves.
- *Domain*: Government.
- *Country of focus*: The Netherlands.
- *Stakeholders*: Passive primary stakeholders are (inter)national administrations and emergency response organizations of all kind: fire services, crisis management services, and services like US Homeland Security and Federal Emergency Management Agency (FEMA). Active stakeholders are directly found in the Netherlands itself as they are directly confronted with the results of the research performed. One may think of primary stakeholders like the Dutch safety regions and the Dutch local, provincial, and national administrations. The Dutch citizens are secondary stakeholders as they are confronted with any actions performed, without having a direct influence on the quality of the actions.
- *Primary insights*: A very important insight is that only very resilient organizations are capable of dealing with all the risks and hazards in an efficient way. Very resilient organizations should be excellent in managing awareness, keystone vulnerabilities, adaptive capacity, and quality.

## KEYWORDS

Adaptive capacity, Awareness, Blaze, Emergency response organization, Keystone vulnerabilities, Management, The Netherlands, Threats, Operational resilience, Safety region, System of systems, Total of systems

## ABSTRACT

Currently, emergency response organizations face tough challenges caused by nature, technology, or man. Many threats are fully capable of disrupting society on a local, national, or global scale.

To cope adequately with these challenges and threats, emergency response organizations should possess the right structure, so a minimum amount of (long-term) disruption of society may be achieved. This structure may be defined by resilience or more precisely operational resilience also known as organizational resilience. This chapter defines and quantifies operational resilience in relation to a Dutch Emergency Response Service: a *Safety Region* where the safety region acts during a crisis as a system of systems (SoS).

The case study involves a major incident in the Netherlands in 2011 (an industrial and chemical blaze) to determine the operational resilience of the safety region of middle and West Brabant (MWB) battling the blaze. The case study is based on data provided by official and independent incident reports.

In this particular case study, the operational resilience of MWB as an SoS was determined; the MWB operated at 18.10% of its capacity in the midst of a crisis.

## GLOSSARY

A full glossary of abbreviations and acronyms is presented in the Appendix.

## BACKGROUND

Emergency response organizations face tough challenges caused by nature, technology, or mankind. Some well-known challenges are, for example, hurricanes, pandemics, urban riots, food and water shortages, major power failures, terrorist threats, cyber security attacks on the Internet, earthquakes, large wildfires, flooding or drought, and industrial fires. Emergency response organizations can be seen as a system of systems (SoS) as they are a collection of systems that functions to achieve a purpose not generally achievable by the individual systems when acting on their own. Some examples from crises of recent history are hurricanes, for example, Sandy that hits the east coast of the United States (October 2012) and Katrina in the US Gulf of Mexico (2005); a 2005 industrial petrochemical blaze in Buncefield, United Kingdom; wild fires in British Columbia, Canada (2009), and California, United States (2010); global-scale cyber attack *Ghostnet* (Delbert and Rohozinski, 2009); large-scale urban riots in London, United Kingdom (2011); earthquake and the related tsunami in Japan (2011); and the earthquake in Christchurch, New Zealand (2011). All such threats are fully capable of disrupting society on a local, national, or global scale.

To adequately cope with these challenges and threats, all emergency response organizations should be capable of mitigating the degree and duration of disruption to society to the extent possible. This depends strongly on the way an emergency response organization is designed and operated that is mainly dependent on its structure as an SoS. This design and operation is defined by the operational resilience (Van Trijp et al., 2011, 2012) building blocks espoused in this case study.

## PURPOSE

In this chapter, we analyze a major incident in the Netherlands in 2011 that involved a chemical and industrial blaze and how well the operational resilience of the Dutch emergency response organization called *safety region* was at the time. We will present a time line and other relevant facts of the incident for full understanding of some theoretical background and definitions on operational resilience. We also present an overview of what is understood by a safety region, how it works, its history, and the present-day challenges and role of operational resilience in relation to performance and needed capabilities. The results are of particular interest for fire services and related emergency response organizations.

The objective was to determine the operational resilience of the safety region battling the blaze in a so-called *quick scan* mode. This quick scan mode was chosen as the preferred method due to its relative simplicity in comparison to the full scan mode. The calculated results from this quick scan multiplied by two equal the results of a full scan complex method. Hence, using the quick scan method simplifies the amount of work to be done and still presents valuable results. This case study is based on the data provided through both official and independent incident reports.

## PRINCIPLE OF A DUTCH SAFETY REGION

Due to new legislation in the Netherlands that came into effect on October 1, 2010, local fire departments, municipal medical departments, medical emergency services, etc., will be working together in a new entity called a safety region or security region. This complex organization finds itself in the midst of a great variety of stakeholders varying from media (including social media) and citizens on one side to influences from the environment like risks, crises, and public opinion on the other side (see Figure 15.1).

It should be clear from Figure 15.1 that there are numerous internal and external relationships: the internal relationships (inside the oval) are mainly those that are defined by law and based on influence, either directly like the board of a safety region or indirectly like the board of national police.

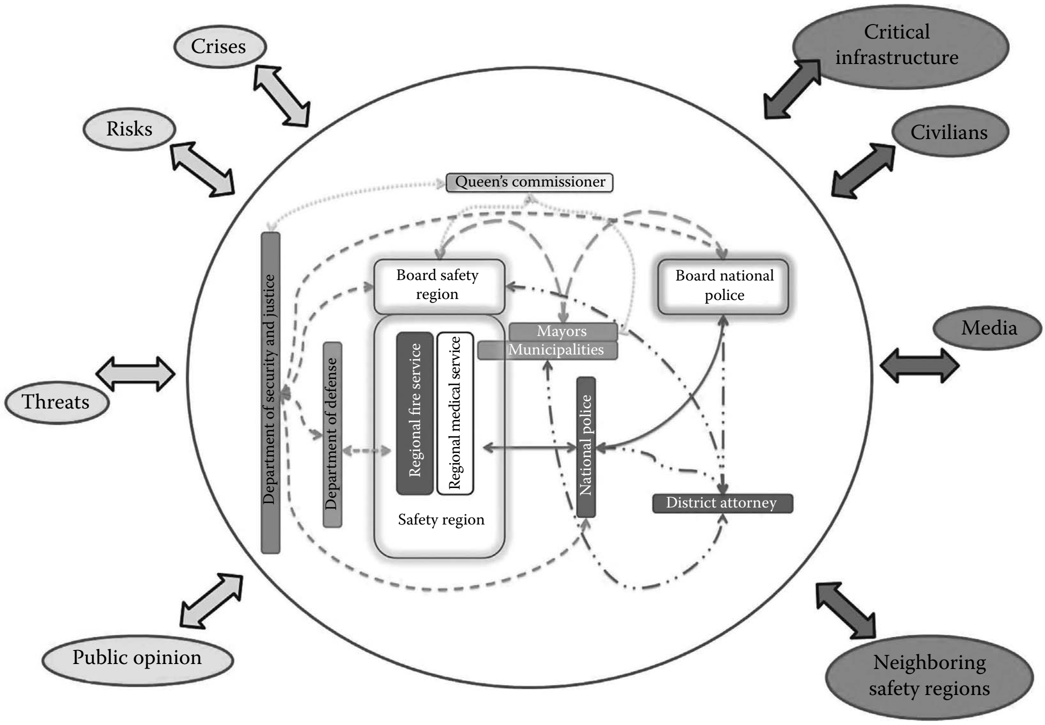


**FIGURE 15.1** Internal and external relationships of a Dutch safety region.

Inside the safety region, one finds at least the regional fire service and the regional medical service, often supplemented with specific local staff of municipalities. The members of the board of the safety region are the individual (lord) mayors of the municipalities. The chair is normally held by the mayor of the so-called *center* municipality, which is usually the largest and most influential municipality in the region. This specific role is named *coordinating mayor*. In case of a crisis or emergency, liaisons provided by the police, the department of defense, and other vital service organizations may join at different levels of the crisis emergency staff in order to optimize the response (Van Trijp et al., 2011, 2012). Outside the safety region (outside the oval), one finds any possible kind of influence categorized as *risks*, *threats*, *crises*, and, last but not least, *public opinion*. Some examples of risks are changes in the environment that enhance the danger in this environment, that is, a new chemical plant or transports of hazardous materials. Threats may be anything that is not a risk but is still of influence on the integrity of the safety region. Good examples are a lack of funds or material. The meaning of crises is rather self-explanatory: think of a large-scale incident like the one in this case study—industrial blaze over a longer period of time with great impact on all stakeholders, the safety region included. The public opinion is of great importance as members of the public use new social media with instant messaging and services creating opinion that have the potential to go viral and but are not necessarily conform the current status of the crisis hence creating an alternative reality. The safety region has to deal with all the inner and outer influences and stakeholders before, during, and after a crisis.

By Dutch law, safety regions have to provide better protection of civilians from risks; offer better emergency management and aftercare during disasters and crises; act during emergencies as one administrative organization that coordinates and addresses the fire service, medical service, disaster and crisis control service, and the operational use of police; and enhance the administrative and operational mitigation capabilities (Anonymous, 2010). To meet these criteria and to deal with all these stakeholders and influences, the system needs operational resilience.

## (COMPLEX) SYSTEM/SYSTEM OF SYSTEMS/ENTERPRISE

To combine Figure 15.1 and operational resilience (see later on in this chapter) into an SoS, we use Figure 15.2.

Figure 15.2 represents the following:

A: Our safety region is in fact the SoS in the midst of the crisis. Inside the upper cloud are the separate systems visible (1, …, *n*) that make up the SoS. The separate systems consist of the fire fighting units, support units, command and control units, and communication. Next to these internal systems, there are also external systems, for example, research institutions, the national disaster support service, and the environmental service, which are added to the SoS on a temporary basis to act as part of the internal system. All the systems are visualized as being interconnected in the cloud. The descriptions and values of those connections are described in full in the section that covers organizational resilience.

B: The SoS is influenced by many external factors that are also valid when it is *peacetime* or in the absence of a crisis. Some of those factors are the Netherlands Act of Safety Regions,

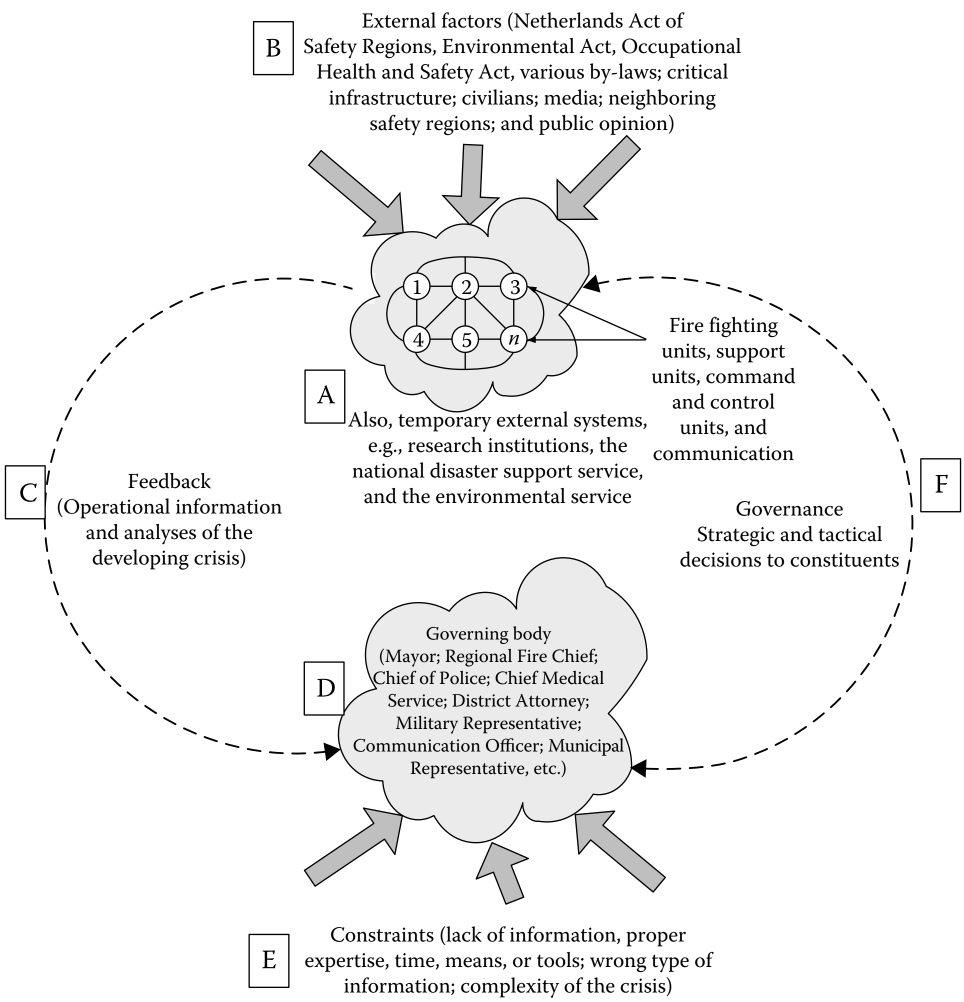


**FIGURE 15.2** (Complex) system/SoS/enterprise. (Adapted from Gandhi, S. Jimmy, Alex Gorod, Brian White, Vernon Ireland, and Brian Sauser. 2013. Personal communication.)

Environmental Act, Occupational Health and Safety Act, by-laws regarding operability of fire services, agreements with other safety regions, and the Netherlands Department of Defense concerning assistance and support. Furthermore, extra factors are depicted in Figure 15.1: the presence of critical infrastructure (like power plants) and the presence of civilians (urban centers), media (TV, newspapers), neighboring safety regions (may be influenced by what an SoS does), and public opinion. One may argue the external factors are also system adding more complexity to the current SoS.

C: In the midst of a crisis, our SoS provides feedback to the governing body. The feedback comprises of operational information and analyses of the developing crisis. In this case study, the development of the blaze and the impact of it on the first responders, the environment, urban areas, and neighboring safety regions are studied.

D: As sketched, the executive leader of the governing body is the coordinating mayor, assisted by the regional fire chief, chief of police, chief medical service, district attorney, military representative, communication officer, municipal representative, and any extra representatives from other relevant organizations when called for.

E: This governing body has to deal with constraints that may influence the proper functioning. Some constraints are the lack of information, lack of proper expertise, wrong type of information, complexity of the crisis, lack of time, and lack of means or tools. Nevertheless, along the chain of command, strategic decisions are transformed into operational commands.

F: The operational data are received by the governing body upon which strategic and tactical decisions are made that are funneled down through the chain of command to the first responders on the scene or the support units, communication and information staff, and up the chain to national institutions and departments. Again, a very complex system that may be regarded as an SoS as they need to work together from their own expertise to produce new insights needed to battle the blaze and its consequences.

In this case study, the total of systems (ToS) as shown in Figure 15.2 is governed and described by organizational resilience and its attributes. The sections in which the organizational resilience of the SoS (safety region Midden-en West Brabant [MWB]) is analyzed give detailed information about the way the ToS functioned during the crisis.

## EMERGENCY RESPONSE AND HANDLING OF AN INDUSTRIAL CHEMICAL FIRE

This case study is with permission by the respective organizations based on official reports generated by the Dutch Public Order and Safety Inspectorate of the Ministry of Security and Justice (IOOV) (2011, 2012), the Dutch Safety Board (OOV) (2012), the Netherlands Society of Fire Service and Crisis Management (2012), and the safety region MWB (2011). Some of the information of the Dutch Safety Board is also available in English at their website (www.onderzoeksraad.nl/en).

The reports were drawn up to evaluate the handling of a large blaze that occurred at an industrial chemical plant (Chemie–Pack NV) on January 5, 2011, in the industrial zone of the town of Moerdijk located in the south of the Netherlands. This location is part of the territory of the safety region MWB that is responsible for the emergency response in Moerdijk.

## INTRODUCTION

At January 5, 2011, a large industrial chemical fire broke out at the site of Chemie–Pack NV. This plant was located at the site since 1982 and specialized in handling and packaging of large amounts of hazardous chemical products (see Table 15.1).

**TABLE 15.1**
**Licensed Amount and Nature of Hazardous Substances Present at the Site of Chemie–Pack**

| Substance | Licensed Amounts |
|---|---|
| (Highly) flammable liquids | 750 tons in packaging<br>75 tons in storage tanks |
| Flammable solids | 94 tons |
| Poisonous substances | 750 tons in packaging<br>75 tons in storage tanks |
| Corrosive substances | 1100 tons in packaging<br>75 tons in bulk |
| Miscellaneous hazardous substances | 400 tons in packaging<br>75 tons in bulk |
| Hazardous waste | 35 tons in bulk |

## Overview and Location of the Incident

The town of Moerdijk, where the incident took place, is located in the safety region MWB, on the banks of a major waterway and directly bordering the safety region, Zuid-Holland Zuid (ZHZ). The fire caused a large back plume of smoke that quickly left the service area of MWB entering the service area of ZHZ subsequently threatening major urban areas. See Figure 15.3.

The local fire service that is part of MWB was alerted at 14:26 h. The fire incident scene officer of MWB raised the coordinated threat level (GRIP) to “2,” which was raised again to level “3” at 16:52 h, and to level “4” at 21:43 h, and lowered to level “3” at 02:19 h the next day. A fine explanation of the GRIP is presented by Wolff (2011). The minimum coordinated threat level “0” equals day-to-day operations while the maximum level “4” equals the situation where more than one safety regions are involved to cope with the incident. It may readily be understood level “4” has the highest complexity on all operational and strategic levels including the civil command structure supervising the fire operational command structure.

The neighboring safety region ZHZ, as the recipient of the black plume, was raised to level “2” at 14:50 h, immediately followed by level “4” at 15:43 h, and lowered to level “2” again at 02:19 h the next day. At a national decision level, the National Coordination Center (NCC) and the interministerial committee crisis management (ICCB) were involved. In the weeks following the incident, numerous institutes and institutions all over the country were involved in interpreting the incident.

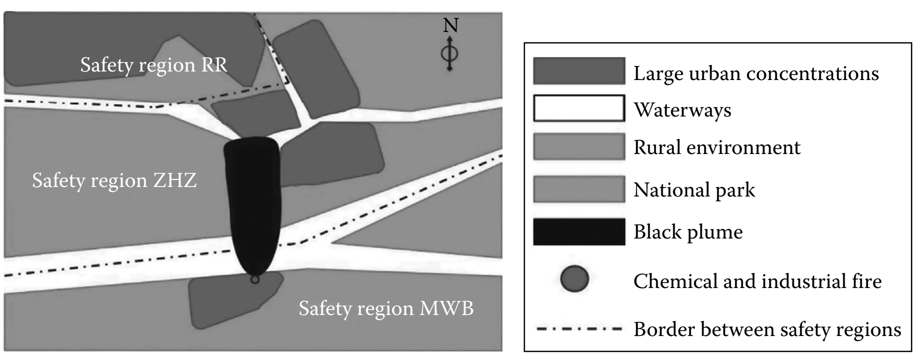


**FIGURE 15.3 (See color insert.)** Location of the incident and effect of the black plume of smoke crossing the border of the safety region MWB into the neighboring safety region ZHZ and threatening urban population.

At 00:15 h the next day, the fire was finally contained as no new outbursts of fire were expected.

The aftermath of the incident lingered on until this case study was prepared (March–May 2012). Fortunately, no personal casualties were reported.

The entire plant of Chemie–Pack, including part of a plant of a neighboring maritime service provider, was destroyed in the blaze.

According to a fact sheet of MWB, the following figures can be presented to indicate the severity of the situation (2011):

The size of the fire pool was about 6500 $m^2$. The plant consisted of five big warehouses with hazardous chemicals. Outside in the yard, several hundred intermediate bulk containers (IBCs), each with 1000 L of flammable liquids, were stored. Also placed there was a shipping container with 80 drums totaling 16,000 L of acetone and a tanker truck with an additional 33,000 L of flammable liquid. The list documenting the great variety of hazardous substances comprised a total of 52 pages.

Four hundred fire fighters with 54 fire trucks battled the blaze, and the total number of emergency service personnel in action was 700. They were assisted by three crash trucks from a neighboring military air base, one fire service vessel, and a police helicopter. They used 14,000,000 L of water complemented with 18,850 L of foam-generating liquid.

The blaze took 10 h to contain, and the total cost of the entire operation is estimated to be $100 M.

## OPERATIONAL RESILIENCE

This section introduces operational resilience and the (quantitative) status of operational resilience of the safety region MWB during the incident.

### Definitions according to Literature

In the literature, many resilience features are described. Some of those features are used to construct the survey that underlies this study. Brouns et al. (2009) present the following definition for resilience in relation to a network: "The social structure of a network determines resilience." In centralized networks, activity revolves around a small core group of people. Te Brake et al. (2008) describe as a major characteristic for resilience (for man) "to sustain normal development despite long-term stress or adversity." Wildavsky (1988) presented the following description: "The capacity to cope with unexpected dangers after they become manifest." Rutter (1985) states "Resilience is the potential (of organizations and individuals) to adapt to changing circumstances in the face of adversity, and the ability to recover after a disaster or other traumatic event."

Stolker (2008) describes operational resilience as "The capabilities of operational resilience in an organization are defined as: The ability of an organization to prevent disruptions in the operational process from occurring; When struck by a disruption, being able to quickly respond to and recover from a disruption in operational processes."

McManus et al. (2007) and Seville (2009) state "Resilience is a function of an organizations': Situation Awareness; Management of Keystone Vulnerabilities and Adaptive Capacity."

The authors finally conclude "An organization with heightened resilience is able to quickly identify and respond to those situations that present potentially negative consequences and find solutions to minimize these impacts. Furthermore, resilience enables an organization to see opportunities in even the most difficult circumstances that may allow it to move forward even in times of adversity."

Vargo and Seville (2008) combine the data from *Resilience is a function of…* into a diagram that bears a strong similarity to a bow tie model (see Figure 15.4).

The bow tie model obviously derives its name from the way it looks and is widely used in safety and risk analysis. The model was originally introduced by the hazard analysis department of Imperial Chemical Industries (ICI) in 1979 (Ale, 2009). The model shows on the left-hand side the causes (in fact a fault tree) and the consequences on the right-hand side (in fact a consequence tree) combined with lines of defense (LOD) that act as barriers and either interrupt the progression

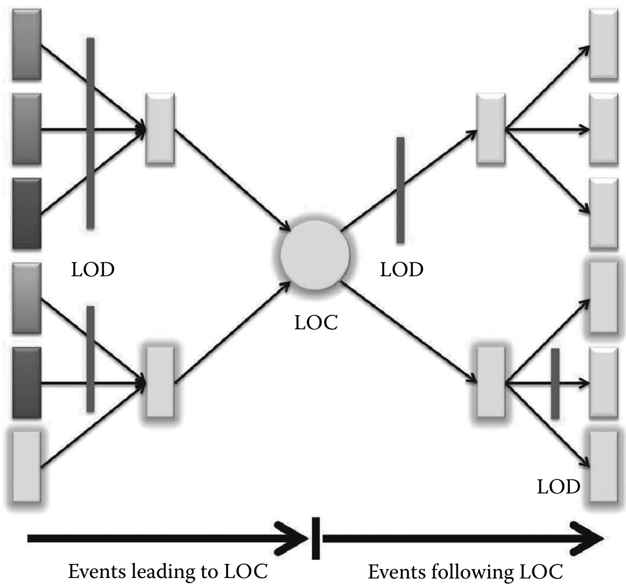


**FIGURE 15.4** **(See color insert.)** Bow tie model. LOC, LOD.

of the causes leading to the loss of containment (LOC) or interrupt the consequences after LOC. In daily life, an emergency response organization working on the left-hand side of the bow tie model is applying processes like *prevention* and *risk control*. However, on the right-hand side, some known processes are *suppression* and *search and rescue*.

On the left side of the diagram (that represents *reduction and readiness*) prior to the event (LOC), Vargo and Seville position and rank (with weight-factor values from 0.00 to 1.00) factors like *situation awareness*, *management of key vulnerabilities,* and *adaptive capacity*. After the event on the right side of the diagram (that represents *response and recovery*), they rank factors based on organization culture and leadership.

According to Hollnagel et al. (2006), resilience may be found on the left and right side of the undesirable event in the bow tie model. Van Trijp (2012) postulates resilience as part of a learning feedback loop, which starts from the right side of the bow tie diagram and connects to the left side, offering the opportunity to learn from crises or emergencies.

In general, it may be concluded from literature that the concept of *resilience* can be best described by the generic approach *operational resilience*.

The generic capabilities of operational resilience in an organization are defined by Van Trijp et al. (2011, 2012) as

- The ability of an organization to prevent disruptions in the operational process from occurring
- When struck by a disruption, being able to quickly respond to and recover from a disruption in operational processes

To obtain and sustain these capabilities, the following four items from literature are considered of prime importance and a function of an organization's operational resilience (Van Trijp et al., 2011, 2012):

- Situation awareness
- Management of keystone vulnerabilities
- Adaptive capacity
- Quality

## MODELING OPERATIONAL RESILIENCE

In 2009–2010, an extensive survey (Van Trijp, 2010) was conducted among major stakeholders of a Dutch safety region (see Table 15.2) to determine the intrinsic value *resilience* in case of an emergency response organization like a safety region.

In total, 454 (100%) requests (total subset) to fill out the survey were sent by regular mail, and 112 (24.7%) respondents (starter subset) started filling out the survey, and 84 (18.5%) made it through the entire survey (final subset).

The following preliminary objectives for the survey were formulated (see Table 15.3):

From the survey, all identified attributes (see Table 15.1 and Appendix for a full description) were ranked and sorted in a value tree where the most prevalent score receives the highest ranking or weight factor (1.00). Other attributes received lower scores and thus rankings or weight factors between 0.00 and 1.00. A method described by Goodwin and Wright (2004), based on the multiattribute utility theory (MAUT), is utilized in Figure 15.5.

In this value tree, the quick scan method uses all the attributes shown under *objectives* and the first two attributes shown under *performance measures*. The full scan method uses all the attributes instead.

According to the results of the survey, the identified attributes (these attributes make up the separate items of operational resilience as identified in literature) describing resilience $\boldsymbol{R_{ero}}$ are for the left side of the bow tie (see Table 15.4) and for the right side of the bow tie (see Table 15.5).

When we combine these results according to the value tree (see the right-most column of Figure 15.5) for operational resilience $\boldsymbol{R_{ero}}$, we get Equation 15.1:

$$\boldsymbol{R_{ero}} = \left(1.00\boldsymbol{c} + 0.20\boldsymbol{a} + 0.10\boldsymbol{d}\right)_{Reduction+Readiness} + \left(0.70\boldsymbol{b} + 0.30\boldsymbol{e}\right)_{Response+Recovery} \quad (15.1)$$

See also Appendix for a glossary of used symbols for Equations 15.1 through 15.10.

**TABLE 15.2**
**Major Stakeholders of a Dutch Safety Region Used as Expert Judgment Panel**

| |
|---|
| Coordinating mayor/chair safety region |
| Managing director/chief executive officer safety region |
| Regional fire chief regional fire service |
| Chief medical officer regional safety service |
| Chief of regional police |
| District fire chief regional fire service |
| (Deputy) fire chief municipal/local fire department |
| Manager |
| Other functional titles |

**TABLE 15.3**
**Preliminary Objectives to Determine the Intrinsic Value *Resilience* by Means of a Survey**

| |
|---|
| In what way is the theoretical concept from literature (see Paragraph 2.1) valid for an emergency response organization in general and a Dutch safety region in particular? |
| What are relevant key aspects determining *resilience*? |
| Is a quantitative measure of *resilience* possible/feasible? |

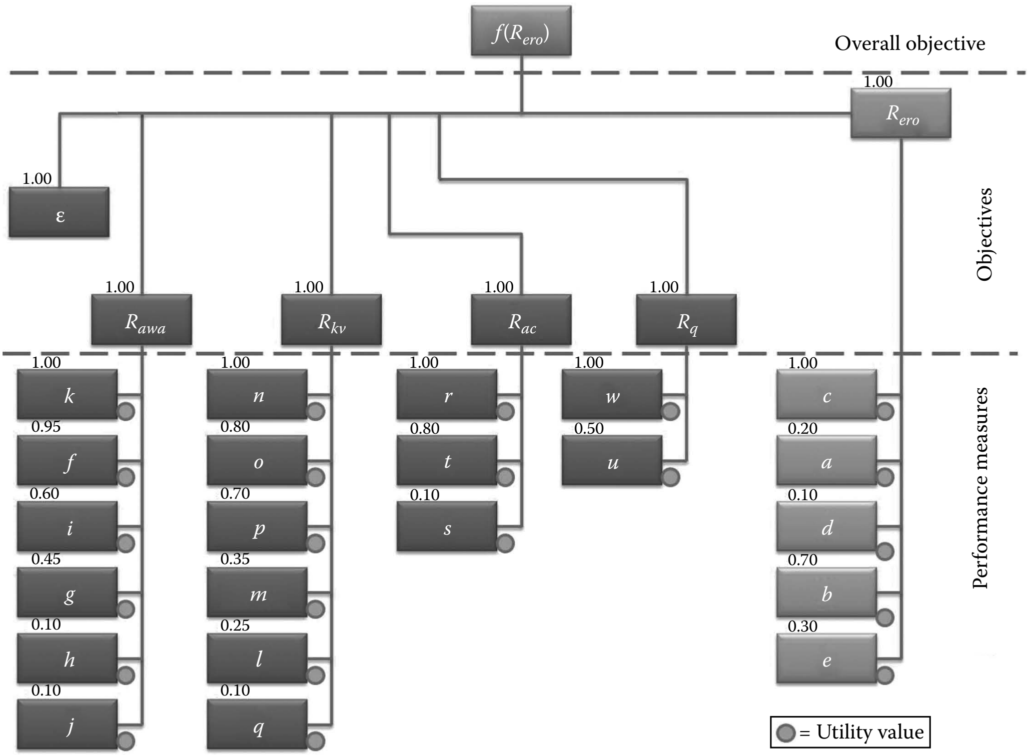


**FIGURE 15.5** Value tree describing dynamic operational resilience $f(R_{ero})$ with weight factors (figures) and undetermined UVs (spheres). (Reproduced from Van Trijp, J.M.P., Ulieru, M., and van Gelder, P.H.A.J.M. Quantitative modeling of organizational resilience in case of a Dutch emergency response safety region. *Proc. Inst. Mech. Eng. Part O J. Risk Reliab.* 266, 666, 2012. With permission.)

**TABLE 15.4**
**Reduction + Readiness (Variables in Arbitrary RU)**

| | |
|---|---|
| ***a*** | The sustenance of normal development despite long-term stress or adversity |
| ***c*** | The potential (of organizations and individuals) to adapt to changing circumstances in the face of adversity and the ability to recover after a disaster or other traumatic event |
| ***d*** | The readiness of an organization before the shock or disruptive event |

**TABLE 15.5**
**Response + Recovery (Variables in Arbitrary RU)**

| | |
|---|---|
| ***b*** | The capacity to cope with unexpected dangers after they become manifest |
| ***e*** | The response of the organization after the disruption has struck |

Equation 15.1 is an additive function as both sides of the bow tie are regarded to be of equal weight according to the concept of resilience as described by Vargo and Seville (2008). It should also be noted all attributes have as dimension arbitrary resilience units (RU). Quantification occurs by multiplication of the attributes with the weight factors and the utility values (UVs). The weight factors are shown as values on the top left-hand side of each square under the lower dotted line in the value tree (performance measures). The UVs are visible as the small spheres on the bottom

right-hand corner of each square, and they can only be determined by conducting a full assessment or audit of the emergency response organization. These UVs may range between 0 and 1 (or any other acceptable scale like 0–100). In this case study, we use a range of 0–1.

In a similar way, the identified attributes $\boldsymbol{f}$, $\boldsymbol{g}$, $\boldsymbol{h}$, $\boldsymbol{i}$, $\boldsymbol{j}$, and $\boldsymbol{k}$ describing awareness as a function of resilience ($\boldsymbol{R}_{awa}$) are presented by the second column from the left that result in Equation 15.2 (Van Trijp et al., 2011, 2012):

$$\boldsymbol{R}_{awa} = \left(1.00\boldsymbol{k} + 0.95\boldsymbol{f} + 0.60\boldsymbol{i} + 0.45\boldsymbol{g} + 0.10\boldsymbol{h}\right)_{Reduction+Readiness} + \left(0.10\boldsymbol{j}\right)_{Response+Recovery} \quad (15.2)$$

See Table 15.6.

The identified attributes $\boldsymbol{m}$, $\boldsymbol{n}$, $\boldsymbol{o}$, $\boldsymbol{p}$, and $\boldsymbol{q}$ describing keystone vulnerabilities as a function of resilience ($\boldsymbol{R}_{kv}$) are presented by the third column from the left that result in Equation 15.3 (Van Trijp et al., 2011, 2012):

$$\boldsymbol{R}_{kv} = \left(1.00\boldsymbol{n} + 0.80\boldsymbol{o} + 0.70\boldsymbol{p} + 0.35\boldsymbol{m} + 0.25\boldsymbol{l} + 0.10\boldsymbol{q}\right)_{Reduction+Readiness} \quad (15.3)$$

See Table 15.7.

The identified attributes $\boldsymbol{r}$, $\boldsymbol{s}$, and $\boldsymbol{t}$ describing adaptive capacity as a function of resilience ($\boldsymbol{R}_{ac}$) are presented by the fourth column from the left that result in Equation 15.4 (Van Trijp et al., 2011, 2012):

$$\boldsymbol{R}_{ac} = \left(1.00\boldsymbol{r} + 0.80\boldsymbol{t} + 0.10\boldsymbol{s}\right)_{Reduction+Readiness} \quad (15.4)$$

See Table 15.8.

**TABLE 15.6**
**Reduction + Readiness and Response + Recovery Variables (in Arbitrary RU)**

| | |
|---|---|
| $\boldsymbol{f}$ | The ability to look forward for opportunities as well as potential crises |
| $\boldsymbol{g}$ | The ability to identify crises and their consequences accurately |
| $\boldsymbol{h}$ | The level of enhanced understanding of the trigger factors for crises |
| $\boldsymbol{i}$ | The level of increased awareness of the resources available both internally and externally |
| $\boldsymbol{j}$ | The level of better understanding of minimum operating requirements from a recovery perspective |
| $\boldsymbol{k}$ | The level of enhanced awareness of expectations, obligations, and limitations in relation to the community of stakeholders, both internally (staff) and externally (customers, suppliers, consultants, etc.) |

**TABLE 15.7**
**Reduction + Readiness Variables (in Arbitrary RU)**

| | |
|---|---|
| $\boldsymbol{l}$ | The level of importance of buildings, structures, and critical supplies |
| $\boldsymbol{m}$ | The level of importance of computers, services, and specialized equipment |
| $\boldsymbol{n}$ | The level of importance of individual managers, decision makers, and subject matter experts |
| $\boldsymbol{o}$ | The level of relationships between key groups internally and externally |
| $\boldsymbol{p}$ | The level of importance of communication structures |
| $\boldsymbol{q}$ | The level of perception of the organizational strategic vision |

**TABLE 15.8**
**Reduction + Readiness Variables (in Arbitrary RU)**

| | |
|---|---|
| ***r*** | The level of importance of leadership and decision-making structures |
| ***s*** | The level of importance of the acquisition, dissemination, and retention of information and knowledge |
| ***t*** | The degree of creativity and flexibility that the organization promotes or tolerates |

**TABLE 15.9**
**Reduction + Readiness Variables (in Arbitrary RU)**

| | |
|---|---|
| ***u*** | The level of greater awareness of itself, its key holders, and the environment with which it conducts business |
| ***w*** | The level of ability to adapt to changed situations with new and innovative solutions and/or the ability to adapt the tools that it already has to cope with new and unforeseen situations |

**TABLE 15.10**
**Overall Object Function [$f(R_{ero})$] Variables (in Arbitrary RU)**

| | |
|---|---|
| $f(R_{ero})$ | Dynamic operational resilience of an emergency response organization (i.e., a Dutch safety region) |
| $R_{ac}$ | The level of adaptive capacity of an emergency response organization |
| $R_{awa}$ | The level of awareness of an emergency response organization |
| $R_{ero}$ | The level of resilience of an emergency response organization |
| $R_{kv}$ | The level of importance of keystone vulnerabilities of an emergency response organization |
| $R_q$ | The level of quality of an emergency response organization |
| ε | The level of unspecified data and items that are also a function of resilience |

The identified attributes ***u*** and ***w***, reduction and readiness variables, describing quality as a function of resilience ($R_q$) are presented by the fifth column from the left that result in Equation 15.5 (Van Trijp et al., 2011, 2012):

$$R_q = (1.00w + 0.50u) \tag{15.5}$$

See Table 15.9.

By another look at the value tree, we notice a set of variables between the dotted lines called *objectives*. These variables are each the sum of the five individual equations we have just calculated (15.1)–(15.5) plus the variable ε that stands for the level of unspecified data and items that are also a function of resilience.

We already know

- Situation awareness
- Management of keystone vulnerabilities
- Adaptive capacity
- Quality

are a function of an organization's operational resilience (see that section). In the value tree, this is expressed by multiplying the right-most column ($R_{ero}$) with the remaining columns on the left-hand side as is described by Equation 15.6 (Van Trijp et al., 2011, 2012):

$$f(R_{ero}) = R_{ero}(R_{awa} + R_{kv} + R_{ac} + R_q + \varepsilon) \tag{15.6}$$

See Table 15.10.

Maximum resilience $f(R_{ero})_{max}$ is achieved when $R_{awa}$, $R_{kv}$, $R_{ac}$, $R_q$, $\varepsilon$, and $R_{ero}$ are all as large as possible. A high score for $R_{ero}$ alone is no guarantee that the resilience of an emergency response organization like a Dutch safety region is good as well. Equation 15.6 shows us this is also dependent on good scores for awareness, keystone vulnerabilities, adaptive capacity, and quality that are all part of reduction and readiness before the event (LOC) takes place (Vargo and Seville, 2008).

Hence, $f(R_{ero})$ is defined as dynamic operational resilience of a Dutch safety region as it dynamically describes the organizations' actual state of resilience.

We also have to take into account the UVs (remember the little green spheres in the value tree) and include those into Equation 15.6 giving a *unique dynamic operational resilience* $f(R_{ero})_{UV}$ factor that is made up of all relevant key aspects (15.7) (Van Trijp et al., 2011, 2012):

$$f(R_{ero})_{UV} = (R_{ero})_{UV}\left(R_{awa} + R_{kv} + R_{ac} + R_q + \varepsilon\right)_{UV} \tag{15.7}$$

It is assumed $R_{ero}$, $R_{awa}$, $R_{kv}$, $R_{ac}$, $R_q$, and $\varepsilon$ are all of the same importance and as a result have a weight factor equal to 1.00. Hence, $f(R_{ero})_{UV}$ has a maximum value of 22.54 **RU** (= $f(R_{ero})_{max}$) and a minimum of 0.00 **RU** when calculated using the value tree based on the MAUT developed by Goodwin and Wright (2004) as cited in Stolker (2008). To calculate the maximum value, all ***UVs*** have to equal to 1. For practical purposes, $\varepsilon$ will not be taken into account (= nullified) as we like to concentrate on the key aspects we can measure.

The undetermined ***UVs*** can be assessed for each safety region by auditing this organization. In general when an attribute is fully implemented, an operational score of 100% is assessed, and the related UV equals 1.00. A score of 80% results in a UV of 0.80, like a score of 35% results in a UV of 0.35.

It is also possible to use a simplified approach for $f(R_{ero})_{UV}$ by using a quick scan method, $f(R_{ero})_{QS}$. This quick scan contains only the two most important attributes from each column of the value tree, which are part of $f(R_{ero})_{UV}$. In this case, the two attributes with the highest scores result in Equation 15.8:

$$f(R_{ero})_{QS} = \left(1.00\boldsymbol{c} + 0.70\boldsymbol{b}\right)_{UV} \cdot \left(\left(1.00\boldsymbol{k} + 0.95\boldsymbol{f}\right) + \left(1.00\boldsymbol{n} + 0.80\boldsymbol{o}\right) + \left(1.00\boldsymbol{r} + 0.80\boldsymbol{t}\right) + \left(1.00\boldsymbol{w} + 0.50\boldsymbol{u}\right) + \varepsilon)_{UV}\right) \tag{15.8}$$

Thus, reducing the amount of work to be done by almost 50%! (10 vs. 22 attributes!).

Again in a similar fashion as we described for Equation 15.8, we nullify ε and set UV = 1.00. We do this as we like to calculate the highest value possible. As a result, the maximum achievable dynamic operational resilience $f(R_{ero})_{QSmax}$ using a quick scan totals

$$f(R_{ero})_{QSmax} = 11.99\,\mathbf{RU} \tag{15.9}$$

which is 53.19% of $f(R_{ero})_{max}$.

When taken all uncertainties into account, it is postulated that the result from the quick scan method is about half the score possible. So we conclude (15.10)

$$f(R_{ero})_{max} = 2.0\,f(R_{ero})_{QSmax} \tag{15.10}$$

Based on the results presented, it is concluded it is possible to quantify resilience of an emergency response organization like a Dutch safety region by using the quick scan method and by assessing the unique ***UVs*** of the attributes of this emergency response organization.

## ANALYSIS

### Operational Resilience of the Safety Region MWB during the Incident

In this section, we look at the operational resilience of the safety region MWB around and during the incident at Chemie–Pack. For convenience, we use the quick scan method $\boldsymbol{f}(\boldsymbol{R}_{ero})_{QS}$ (15.8). The range of the UVs is 0–1. The reader may notice the absence of any values between 0 and 1. We use 0 and 1 only as this case study is not based on an extensive audit that should provide intermediate values but solely on the interpretation of external reports regarding the incident that leaves no other room than to use 0 or 1. This remark applies for the rest of this section.

### UV of *c*

According to Table 15.4, ***c*** equals "the potential (of organizations and individuals) to adapt to changing circumstances in the face of adversity and the ability to recover after a disaster or other traumatic event." In this case, it may be translated into the potential of MWB to adapt to changing circumstances and recover. According to the reports, MWB was slow in determining the correct coordinating threat level; instead of level 3, which was needed, MWB remained too long at level 2, hence lacking the possibility of proper coordination at the public order level (mayor is involved as coordinating authority from level 3). Adaptation to changing circumstances like suppression of the blaze lacked proper coordination and control. When we look at these important findings, we should conclude on a scale of 0–1, the UV for ***c*** equals 0. In reality, it is not 0 but close to 0 as the blaze was of such a complex nature that any possibility of saving the plant was negligible. For this case study, $\boldsymbol{c} = 0$.

### Utility Value (UV) of *b*

According to Table 15.5, ***b*** equals "the capacity to cope with unexpected dangers after they become manifest." In this case, it may be translated into the capacity of MWB to cope with unexpected dangers after they become manifest. The reports state MWB failed to react adequately to the large amounts of polluted water that were generated in the process of firefighting: subsequent decontamination of personnel and vehicles was not carried out. This danger was underestimated in the command and control chain, and as such, we should conclude, on a scale of 0–1, the UV for ***b*** should equal 0. As other more immediate dangers were met when needed (like removing fire fighting crew when walls became unstable or the quick suppression of a large pool fire that moved toward a crash truck), it is decided for this case study not to use the value "0," but $\boldsymbol{b} = 1$.

### Utility Value (UV) of *k*

According to Table 15.6, ***k*** equals "the level of enhanced awareness of expectations, obligations, and limitations in relation to the community of stakeholders, both internally (staff) and externally (customers, suppliers, consultants, etc.)." In this case, it may be translated into "the level of enhanced awareness of expectations, obligations, and limitations in relation to the municipality of Moerdijk and its administration." The reports state at the time of the blaze the establishment of a special dedicated plant fire service as was advised by MWB was not yet enforced by the responsible authorities of the town of Moerdijk, which was then responsible for enforcing this dedicated fire service. According to the reports, this was still in the process of communication. In October 2010, the law in the Netherlands was changed, and after this change, MWB became responsible for enforcement of the dedicated plant fire service instead of the administration of Moerdijk. MWB failed to do so. MWB is not alone in this as still two-third of 539 similar plants in the Netherlands have to be evaluated by the respective safety regions whether a dedicated plant fire service is needed (2012).

When we look at these findings, we should conclude, on a scale of 0–1, the UV $\boldsymbol{k} = 0$.

## Utility Value (UV) of *f*

According to Table 15.6, ***f*** equals "the ability to look forward for opportunities as well as potential crises." In this case, it may be translated in the ability of MWB to look forward for opportunities as well as potential crises. The reports state MWB did not possess the compulsory coordinating multidisciplinary and monodisciplinary exercise and training plan following the year 2009. This plan should have comprised data how and when MWB would practice and drill emergency response in case of major crisis at plants like Chemie–Pack. Practice training for senior fire officers that did occur did not include major incidents involving hazardous chemicals although such type of incidents could be expected due to the nature of the risks involved. Hence, it is concluded the UV ***f*** = 0.

## Utility Value (UV) of *n*

According to Table 15.7, ***n*** equals "the level of importance of individual managers, decision makers, and subject matter experts." In this case, it is interpreted as "the level of importance of the senior officers involved in handling the incident." The reports state severe shortcomings were noted in leadership, command structure, and coordination during the incident. The result was the emergence of an informal command structure next to the official command structure that clouds the effort of the organization of controlling the blaze. It is also noted leadership and coordination at the administrative level of Moerdijk was flawed contrary to leadership and coordination at the regional administrative level, which did function properly. Hence, it is concluded the UV of ***n*** = 0.

## Utility Value (UV) of *o*

According to Table 15.7, ***o*** equals "the level of relationships between key groups internally and externally." This is interpreted in this case as "the level of relationships between MWB key groups internally and between key groups externally like other safety regions and administrative bodies." The reports concluded the relationships between MWB and the neighboring safety region ZHZ (see also Figure 15.2) were adequate in contrast to the relationships with other safety regions and national partners that were mainly carried out at informal levels creating a lot of noise. This was not due to MWB but to the system in general and a troubled perspective on the role each partner has. Recommendations were made by the investigating parties to all partners involved to improve the relationships in case of a crisis. Hence, it is concluded the UV of ***o*** = 1.

## Utility Value (UV) of *r*

According to Table 15.8, ***r*** equals "the level of importance of leadership and decision-making structures." For MWB, these are very important factors to deal with as they make up a substantial part of the operational structure and striking capability. The reports state shortcomings in the leadership function and decision-making structures concerning getting an overall picture of the incident at hand. In this particular incident, no negative effects could be noted as the blaze was too large to be influenced by the shortcomings. Nevertheless recommendations were made to improve leadership and decision-making structures to cope with future major crises. Hence, it is concluded the UV of ***r*** = 0.

## Utility Value (UV) of *t*

According to Table 15.8, ***t*** equals "the degree of creativity and flexibility that the organization promotes or tolerates." This is interpreted as the degree of creativity and flexibility MWB promotes or tolerates while battling the blaze. MWB showed great skill in creativity and flexibility in fighting the blaze using nonconventional techniques like deploying crash trucks from a nearby military air base, a police helicopter, and unprecedented large amounts of foam. The incident was of such a magnitude that out-of-the-box thinking was needed to contain the blaze and its effects.

Although the reports have noted shortcomings that influence the other described attributes, enough flexibility and creativity was shown to be effective. Hence, it is concluded $\boldsymbol{t} = 1$.

### Utility Value (UV) of *w*

According to Table 15.9, ***w*** equals "the level of ability to adapt to changed situations with new and innovative solutions and/or the ability to adapt the tools that it already has to cope with new and unforeseen situations." This attribute is closely related to attribute ***t***, and it is assumed in this case (i.e., battling the blaze) $\boldsymbol{w} = \boldsymbol{t}$. Hence, it is concluded $\boldsymbol{w} = 1$.

### Utility Value (V) of *u*

According to Table 15.9, ***u*** equals "the level of greater awareness of itself, its key holders, and the environment with which it conducts business." It is interpreted as the level of greater awareness of MWB, its key holders, and the environment with which it conducts business prior and during the incident. According to the reports, MWB failed to communicate properly with its prime key holders the media (including social media) and citizens. MWB also failed to carry out surprise inspections at the site of Chemie–Pack during operational hours. The dates of the inspections that MWB did perform were shared in advance with Chemie–Pack hence facilitating masking any shortcomings prior to the actual moment of inspection. MWB was closely involved in the process of the needed permits but was not able yet to enforce the establishment of a dedicated plant fire service at the time of the incident. It is also noted communication between MWB and key holders was flawed and in time unidirectional. The relationship with prime key holder the administration of Moerdijk was such that in the years 2009 and 2010, no multidisciplinary exercises at the proper level including the administration of Moerdijk were conducted involving large amounts of hazardous chemicals like the incident at Chemie–Pack. In addition, MWB did not have a training and exercise plan for the years following 2009 by which it was in violation of the gentlemen's agreement MWB had with the minister of the Dutch Ministry of the Interior and Kingdom Relations. Based on these data, it is concluded the UV of $\boldsymbol{u} = 0$.

### Calculating Operational Resilience

When all UVs are entered in Equation 15.8 and again nullifying ε, the result is (15.11)

$$\boldsymbol{f}(\boldsymbol{R}_{ero})_{QS} = 2.17\mathbf{RU} \tag{15.11}$$

To equate the percentage, we divide 2.17 by 11.99 (from Equation 15.9) and multiply by 100%: $\boldsymbol{f}(\boldsymbol{R}_{ero})_{QS}$ is 18.10% of $\boldsymbol{f}(\boldsymbol{R}_{ero})_{QSmax}$ at the time of the incident and just under one-fifth of the possible operational resilience! Hence, we can conclude the SoS operated in the midst of a crises at less than one-fifth of its potential.

### Lessons Learned

When we combine the findings of the time line of the incident and the characteristics of operational resilience as shown in the paragraphs dealing with the UVs, we can conclude the challenges were met by means of improvisation during the unfolding events. This was necessary as proper preincident planning was not adequate enough, and the improvisation led to confusion between operational units in and between the fire service, neighboring safety regions, communication staff, and regional and national administrations. When we take a look at Figure 15.1 again, we notice a high complexity of relationships the safety region has to deal with. These relationships exist in a preincident situation but are also active during and after an incident. It was recommended afterward by the investigating authorities the way these relationships work during an incident or crises should be reevaluated as the law involved (act concerning the safety regions). With specific attention to the competences, authority figures like the coordinating mayor should need to work with issues on transboundary incidents between safety regions, the competences of all departments involved (in fact who is in command and when) and who is in operational command and in control of related and relevant national services concerning the environment, and a large array of diverse advisory boards.

Furthermore, it was recommended to provide a national communication center to assist safety regions and municipalities during a major incident or crisis.

The type of communication and its contents should directly link up with the needs of the general public—especially today where social media provide instant news beyond control of the authorities.

Basically, it all boils down to the right type of communication between people, parties, and the subsequent follow-up whether before, during, or after the incident. Failing to do so and trusting paper structures beyond reasonable belief creates a nonexisting world for which no safety region can prepare itself. The calculated operational resilience attributes in this case study show the safety region MWB was not prepared and resilient enough to deal with this particular type of incident.

This raises the question when MWB would have been prepared enough. In the current stage of our research, this can only be answered by looking at the outcome the way this major incident was handled. In an ideal world, the incident either never occurred or when it does occur is quickly brought under control. For this to happen, MWB needs to be resilient in relation to the prospective incident(s) to happen. In other words, MWB should be aware of the risk profile (i.e., type of industries, critical infrastructures, urban and rural population, presence of nature, possible types of weather, possibility of flooding) present in the safety region and adjust the organization accordingly to deal with all possible risks based on an elaborate risk analysis of each hazard. For those hazards that may be beyond the capability of MWB to control or contain, MWB has the possibility to join forces with neighboring safety regions and the department of defense for assistance. For this to happen, MWB needs to make solid agreements and in case of a crisis needs to live up to them or *to be resilient*.

A scale defining when a safety region is or is not resilient cannot be presented as throughout the Netherlands, the risk profile of each safety region varies greatly. We can only state resilience should meet the respective risk profile. Further research is planned to define and explore the limits of this statement.

### Best Practices

Other safety regions and safety-related structures in the Netherlands are intensely studying the outcome of the different types of investigations of these incidents. The results are used to enhance the command, communication, and control structures. Also extra courses are provided for fire fighters on junior and senior levels with regard to this type of incident. These courses are in the field of suppression techniques, how to inspect similar type of plants, risk management and preparedness. One of the immediate results in the Netherlands was safety regions gave a closer look to the need of assigning private dedicated plant fire services. These plant fire services are based on location and paid for by the plant owners itself but are under direct command of the safety region. The use of this type of fire service has the possible advantage of immediately responding to the first sign of a possible incident. This improves the potential for containment before the fire service of the safety region arrives on the scene.

## EPILOGUE

In October 2012, the eastern seaboard of the United States was hit by Hurricane Sandy. This giant made landfall on October 29 and created coastal havoc in the states of New Jersey, Connecticut, Rhode Island, and New York, including Staten Island and the south tip of Manhattan of New York City. Many houses alongside the coastline were swept away, major power outages occurred, and

the financial heart of the United States and the world, Wall Street, was unable to function for a period of time. Subways were submerged with water and local activities came to a full stop.
By March 27, 2013, the FEMA reported (FEMA, 2013)

- FEMA personnel deployed: 2884
- Assistance registrations: 527,089
- Approved in assistance: $1.31 billion

while damage is estimated to range in the billions of dollars.

Although help and assistance was provided and a state of emergency was declared by the federal administration, the general question was how this may have happened.

One of the key aspects in this was the absence of any flood and/or tidal barriers that may have protected the mainland from flooding. Over time, many residents built their houses close to the shoreline without any protection from tidal surges. The same can be said about lower Manhattan where street level is just a few feet above the water table. Entrances of the subway could not be closed as flood doors were not present causing major flooding of the transport system. It seems residents and the administration were not prepared for what was to come. It can readily be recognized that operational resilience (look again at the attributes defined!) was substandard as especially attributes at the left side of the bow tie model were not adequately dealt with by the authorities.

Hurricane Sandy will undoubtedly induce a steep learning curve for everyone involved. One aspect of this learning curve will surely be increased operational resilience of emergency response organizations.

Increased operational resilience of the emergency response organizations will demand a different type of strategy in the future: not wait and see if an incident happens and subsequently response but be actively involved in urban planning and zoning and use risk analysis as a standard tool to provide answers to questions like "what are the hazards involved, what is the possibility an incident happens, and what will occur when an incident happens?" Where do we want the population to live? Near a hazard like a plant or an unprotected seaboard—or is it a good idea to relocate the population and/or install special safeguards like flood protection? How do we inform the public? What can we do to make the population more self-sustainable? A sound risk analysis followed by the policy decision-making process creates more resilient emergency response services (and societies!). To do so, emergency response organizations should be actively involved in these types of processes. If this was the case in NY, one can imagine flood defense systems would have been in place at the time Sandy struck presenting a whole different outcome with less economic damage and less casualties.

When we look at Figure 15.2, where the (complex) system/(SoS)/enterprise of the Dutch situation is described, we see a lot of similarities with this case. The separate systems involved in the governing body (D) and the external factors (B) in the United States have different names, but the problem is exactly the same: how to respond to an ongoing crisis that transgresses state borders like in the Dutch situation, a crises that transgresses safety region borders complicating the response by the governing body. Of course, the scale of the US Hurricane Sandy-induced crisis is much larger than the scale of the Dutch industrial blaze, but the (complex) system/SoS/enterprise relationships are similar.

## SUMMARY AND CONCLUSIONS

Based on the findings of the cited reports, the Netherlands Branch Organization of Fire Services (NVBR) has started a program titled *Learning Arena Moerdijk* (2011) to improve the learning capabilities of all the Netherlands regional fire services, which are part of the respective safety regions. It is expected that this program will enhance operational resilience at future incidents. In addition at the national level, all procedures are carefully reexamined to be either enhanced or abolished. The Public Order and Safety Inspectorate of the Dutch Ministry of Security and Justice has released a report in February 2012 with the results of a survey among the Dutch safety regions concerning the allocation of dedicated plant fire services at high-risk locations. The results show a substantial backlog in evaluations and allocations. Recommendations are made by Dutch authorities to improve the situation.

Resilience can only be achieved when a number of criteria are met: be aware of the risk profile; make sound policy decisions on the basis of this risk profile; get the communication structures in order; be aware of the (im-)possibilities of the emergency response organization and report those to the responsible authorities; invest actively in the relationship with key stakeholders (internally and externally); be proactive instead of reactive and be ahead of any possible incident; invest actively in leadership; and finally make sure the emergency response organization has eyes and a voice in society before, during, and after an incident or crisis.

Failing to do so and trusting paper structures beyond reasonable belief create a nonexisting world for which no safety region (or any other emergency response organization—SoS) can prepare itself.

## SUGGESTED FUTURE WORK

### Questions for Discussion

Consider the following questions:

- Based on the presented data, what may be needed to reach maximum operational resilience for an emergency response organization or SoS? To what extend do you believe this may be possible?
- This case study presents a model to calculate operational resilience. Should in your opinion all emergency response organizations strive for the highest score (22.54 RU), or do you see other possible solution(s) that work? If so, present the solution(s) with a sound argumentation. Take into account the different high-/low-risk environment emergency response organizations have to work in.
- Study the case of Hurricane Sandy (see Epilogue) and construct a (complex) system/SoS/enterprise diagram during the crises similar to Figure 15.2. What part of the (complex) system/SoS/enterprise would you change so emergency response organizations can cope better with a similar kind of crisis in the future and why? Can you think of any aspect or aspects how operational resilience of the emergency response organizations can be enhanced regarding super storms like Sandy?
- Can you think of other applications of operational resilience other than optimizing the performance of an emergency response organization? You may consider in your answer the stakeholders to whom the organization is accountable.

### Future Work

Future research may focus on establishing correct UVs (validating the model) by auditing a representative set of emergency response organizations and checking the findings from this case study to the situation in North America (United States, Canada) and compare those to the Dutch results.

Research is planned to define and explore the limits of resilience in combination with the respective risk profile, and research is planned to study the resilience relationships of a self-organizing security network (SOSN) (Ulieru, 2007, 2008, 2009). An SOSN is a network of security or safety stakeholders (internal and external) related to each other by meta-organizational decision-making structures, practices, and processes.

## APPENDIX

Glossary of Used Symbols

| | |
|---|---|
| $a$ | The sustenance of normal development despite long-term stress or adversity |
| $b$ | The capacity to cope with unexpected dangers after they become manifest |
| $c$ | The potential (of organizations and individuals) to adapt to changing circumstances in the face of adversity and the ability to recover after a disaster or other traumatic event |
| $d$ | The readiness of an organization before the shock or disruptive event |
| $e$ | The response of the organization after the disruption has struck |
| $\varepsilon$ | The level of unspecified data and items that are also a function of resilience |
| $f$ | The ability to look forward for opportunities as well as potential crises |
| $f(R_{ero})$ | Dynamic operational resilience of an emergency response organization (i.e., a Dutch safety region) |
| $f(R_{ero})_{max}$ | Maximum achievable dynamic operational resilience of an emergency response organization (i.e., a Dutch safety region) |
| $f(R_{ero})_{QS}$ | Dynamic operational resilience of an emergency response organization (i.e., a Dutch safety region) using the quick scan method |
| $f(R_{ero})_{QSmax}$ | Maximum achievable dynamic operational resilience of an emergency response organization (i.e., a Dutch safety region) using the quick scan method |
| $f(R_{ero})_{UV}$ | Unique dynamic operational resilience of an emergency response organization (i.e., a Dutch safety region) dependent on UVs |
| $g$ | The ability to identify crises and their consequences accurately |
| **GRIP** | Coordinated threat level |
| $h$ | The level of enhanced understanding of the trigger factors for crises |
| $i$ | The level of increased awareness of the resources available both internally and externally |
| **IBC** | Intermediate bulk container |
| **ICCB** | Interministerial committee crisis management |
| **ICI** | Imperial Chemical Industries |
| **IOOV** | Inspectorate of the ministry of security and justice |
| $j$ | The level of better understanding of minimum operating requirements from a recovery perspective |
| $k$ | The level of enhanced awareness of expectations, obligations, and limitations in relation to the community of stakeholders, both internally (staff) and externally (customers, suppliers, consultants, etc.) |
| $l$ | The level of importance of buildings, structures, and critical supplies |
| **LOC** | Loss of containment |
| **LOD** | Line of defense |
| $m$ | The level of importance of computers, services, and specialized equipment |
| **MAUT** | Multiattribute utility theory |
| **MWB** | Safety region Midden-en West Brabant |
| $n$ | The level of importance of individual managers, decision makers, and subject matter experts |
| **NCC** | National Coordination Center |
| $o$ | The level of relationships between key groups internally and externally |
| **OOV** | Dutch Safety Board |
| $p$ | The level of importance of communication structures |
| $q$ | The level of perception of the organizational strategic vision |
| $r$ | The level of importance of leadership and decision-making structures |
| $R_{ac}$ | The level of adaptive capacity of an emergency response organization |

| | |
|---|---|
| $R_{awa}$ | The level of awareness of an emergency response organization |
| $R_{ero}$ | The level of resilience of an emergency response organization |
| $R_{kv}$ | The level of importance of keystone vulnerabilities of an emergency response organization |
| $R_q$ | The level of quality of an emergency response organization |
| **RU** | Resilience units |
| $s$ | The level of importance of the acquisition, dissemination, and retention of information and knowledge |
| **SoS** | System of systems: a collection of systems to achieve a purpose not generally achievable by the individual acting independently |
| **SOSN** | Self-organizing security network |
| $t$ | The degree of creativity and flexibility that the organization promotes or tolerates |
| **ToS** | Total of systems: a system of systems plus the governing body relationship including external factors, feedback, governance, and constraints |
| $u$ | The level of greater awareness of itself, its key holders, and the environment with which it conducts business |
| **UV** | The utility value of an attribute in a value tree |
| $v$ | The level of increased knowledge of its keystone vulnerabilities and the impacts that those vulnerabilities could have on the organization: both negative and positive |
| $w$ | The level of ability to adapt to changed situations with new and innovative solutions and/or the ability to adapt the tools that it already has to cope with new and unforeseen situations |
| $x$ | The level of importance of individual aspects of resilience |
| $y$ | The level of importance of keystone vulnerabilities and adaptive capacity for resilience |
| **ZHZ** | Safety region ZHZ |

## ACKNOWLEDGMENTS

The authors wish to thank Mrs. Arlette van de Kolk, Mrs. Annabelle van Roosmalen, Mrs. Annemarie van Daalen, and Mr. Noud Bruinincx for reading the manuscript. We like to thank the editors Dr. Jimmy Gandhi, Dr. Alex Gorod, Dr. Vernon Ireland, Dr. Brian Sauser, and Dr. Brian White for their continuous support and patience.

## REFERENCES

Ale, B.J.M. 2009. *Risk: An Introduction—The Concepts of Risk, Danger and Chance*, 1st ed., pp. 48. New York: Routledge.

Anonymous. 2010. Dutch Security Regions Act Official Consolidated Version. The Hague, the Netherlands: Ministry of the Interior and Kingdom Relations. Retrieved March 7, 2012, from: http://www.government.nl/documents-and-publications/decrees/2011/09/29/dutch-security-regions-act-official-consolidated-version.html.

Brouns, F., Berlanga, A.J., Van Rosmalen, P., Bitter-Rijpkema, M.E., Sloep, P.B., Kester, L., Fetter, S., and Nadeem, D. 2009. ID8.16—Policies to stimulate self-organisation and the feeling of autonomy in a network. Heerlen, the Netherlands: Open University of the Netherlands, TENCompetence. Retrieved March 7, 2012, from: http://hdl.handle.net/1820/1944.

Delbert, R. and Rohozinski, R. 2009. Tracking Ghostnet: Investigating a Cyber Espionage Network. Toronto, Ontario, Canada: Information Warfare Monitor. Retrieved April 28, 2012, from: http://www.scribd.com/doc/13731776/Tracking-GhostNet-Investigating-a-Cyber-Espionage-Network.

Dutch Safety Board. 2012. Brand bij Chemie–Pack te Moerdijk (Fire at Chemie–Pack in Moerdijk). The Hague, the Netherlands, Report in Dutch. Retrieved March 23, 2012, from: http://www.onderzoeksraad.nl/index.php/onderzoeken/onderzoeksraad-start-onderzoek-naar-brand-in-moerdijk/.

Goodwin, P. and Wright, G. 2004. *Decision Analysis for Management Judgment*. Chichester, U.K.: John Wiley & Sons.

FEMA. 2013. Hurricane Sandy. Retrieved March 30, 2013, from: http://www.fema.gov/hurricane-sandy.

Fire Safety Region Midden-en West Brabant (MWB). 2011. Fact Sheet. Breda, the Netherlands, Fact Sheet in Dutch. Retrieved March 23, 2012, from: http://www.veiligheidsregiomwb.nl/Organisatie/Onderzoeksrapporten-Brand-Moerdijk.aspx.

Hollnagel, E., Woods, D.D., and Leveson, N. 2006. *Resilience Engineering, Concepts and Precepts*. Farnham, U.K.: Ashgate Publishing Limited.

McManus, S., Seville, E., Brunsdon, D., and Vargo, J. 2007. Resilience management, Resilient Organizations Research Report 2007/01. Retrieved September 25, 2012, from: http://www.resorgs.org.nz/pubs/Resilience%20Management%20Research%20Report%20ResOrgs%2007-01.pdf.

Netherlands Branch Organization of Fire Services NVBR. 2011. Leerarena Moerdijk (Learning Arena Moerdijk), Arnhem, the Netherlands, Report in Dutch. Retrieved March 31, 2012, from: http://www.nvbr.nl/publish/pages/18638/leerarena.pdf.

Public Order and Safety Inspectorate, Dutch Ministry of Security and Justice. 2011. Brand Chemie–Pack Moerdijk (Fire at Chemie–Pack Moerdijk), The Hague, the Netherlands, Report in Dutch. Retrieved March 28, 2012, from: http://www.ioov.nl/aspx/download.aspx?file =/contents/pages/106258/rapportagechemie-packmoerdijk.pdf; Summary, conclusions and recommendations in English retrieved March 28, 2012, from: http://www.ioov.nl/aspx/download.aspx?file =/contents/pages/106291/chemi-packmoerdijk.pdf.

Public Order and Safety Inspectorate, Dutch Ministry of Security and Justice. 2012. Aanwijzing bedrijfsbrandweer risicobedrijven (Allocation of dedicated plant fire service for high-risk plants). The Hague, the Netherlands, Report in Dutch. Retrieved April 28, 2012, from: http://www.rijksoverheid.nl/bestanden/documenten-en-publicaties/rapporten/2012/02/10/rapport-aanwijzing-bedrijfsbrandweer-risicobedrijven/aanwijzing-bedrijfsbrandweer-risicobedrijven.pdf.

Rutter, M. 1985. Resilience in the face of adversity: Protective factors and resistance to psychiatric disorder. *British Journal of Psychiatry* 147: 598–611.

Seville, E. 2009. The Goal of Resilient Organizations. Keynote presentation—Business Continuity Institute Summit, Brisbane, Queensland, Australia. Retrieved September 25, 2012, from: http://www.resorgs.org.nz.

Stolker, R.J.M. 2008. A generic approach to assess operational resilience. Technische Universiteit Eindhoven (TUE). Capaciteitsgroep Quality and Reliability Engineering (QRE), Eindhoven, the Netherlands. Retrieved March 7, 2012, from: http://library.tue.nl/catalog/LinkToVubis.csp?DataBib=6:639658.

Te Brake, H., van de Post, M., and de Ruijter, A. 2008. Resilience from concept to practice—The balance between awareness and fear; citizens and resilience; impact, Dutch knowledge and Advice Centre for Post-Disaster Psychosocial Care, Amsterdam, the Netherlands.

Ulieru, M. 2007. A complex systems approach to the design and evaluation of holistic security ecosystems. In: *International Conference of Holistic Security Ecosystems*, Boston, MA. Retrieved September 25, 2012, from: http://www.theimpactinstitute.org/Publications/Boston-submitted.

Ulieru, M. 2008. Enabling the SOS network. In: *Proceedings of the IEEE SMC 2008 Conference*, Singapore, Singapore. Retrieved September 25, 2012, from: http://www.theimpactinstitute.org/Publications/Ulieru-Formatted-Final-sos.pdf.

Ulieru, M. 2009. Towards holistic security ecosystems, opening keynote address and invited tutorial lecture. In: *3rd IEEE International Conference on Digital Ecosystems and Technologies,* Istanbul, Turkey. Retrieved September 25, 2012, from: http://www.theimpactinstitute.org/Publications/Keynote-Reformatted.pdf.

Van Trijp, J.M.P. 2010. An attempt to quantify resilience of emergency response organizations—Results from a large scale survey among safety stakeholders in the Netherlands, Master of Public Safety thesis Delft TopTech/Delft University of Technology, Delft, the Netherlands.

Van Trijp, J.M.P. 2012. Propelling beyond the Bow Tie: An emergent dynamic risk—Resilience model. In: *Proceedings of the PSAM11/ESREL2012 11th International Probabilistic Safety Assessment and Management Conference and The Annual European Safety and Reliability Conference*, Helsinki, Finland.

Van Trijp, J.M.P., Ulieru, M., and van Gelder, P.H.A.J.M. 2011. Quantitative approach of organizational resilience for a Dutch emergency response safety region. In: *Advances in Safety, Reliability and Risk Management*, eds. Bérenguer, C., Grall, A., and Guedes Soares, C., pp. 173–180. Taylor & Francis Group, London, U.K.

Van Trijp, J.M.P., Ulieru, M., and van Gelder, P.H.A.J.M. 2012. Quantitative modeling of organizational resilience in case of a Dutch emergency response safety region. *Proceedings of the Institution of Mechanical Engineers, Part O, Journal of Risk and Reliability* 266(6): 666–676.

Wildavsky, A. 1988. Playing it safe is dangerous. *Regulatory Toxicology and Pharmacology* 8(3): 283–287.

Wolff, C. 2011. Procedures regarding major waterway blockades. The Hague, the Netherlands. Retrieved March 23, 2012, from: http://www.ivr.nl/fileupload/publications/congres2011/ivrcongres2011/WS-7-WOLFF-ENGELS.pdf.