

Jonas Johansson<sup>1,3)</sup>

Linn Svegrup<sup>2,3)</sup>

Björn Arvidsson<sup>2,3)</sup>

Jenny Jangefelt<sup>2)</sup>

Henrik Hassel<sup>2,3)</sup>

Alexander Cedergren<sup>2,3)</sup>

<sup>1)</sup> Division of Industrial Electrical Engineering and Automation, Lund University

<sup>2)</sup> Division of Risk Management and Societal Safety, Lund University

<sup>3)</sup> Lund University Center for Risk Assessment and Management

## Review of previous incidents with cascading effects

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## Executive Summary

The CascEff project aims to improve the emergency response in incidents that involve cascading effects, i.e. where system dependencies lead to impacts propagating from one system to other systems. An important basis for this improvement is knowledge about the nature, processes and patterns of cascading effects. One way to gain such knowledge is to study past events. In a previous delivery, Deliverable 2.1, we described a methodology for analysing cascading effects in past events. The purpose of the method was to enable systematic descriptions of key characteristics of cascading effects and it should be applicable for describing cascading effects among a broad variety of societal sectors and critical infrastructures. The effects of conditions that enable, aggravate, prevent or mitigate cascading effects are also an integral part of the method. In present Deliverable 2.2, we present a review of selected past events and the data that have been collected and systematized by using the method. The data comprise of information about past events that were gathered from existing written material in terms of scientific publications, official reports, investigations or media reports. During the use of the method some minor alterations of the method has been made, in accordance with the design science methodology underlying the method development, which is also presented in the report. In total we have so far identified 74 past events that are likely to be interesting to analyse with the method. Here we give a review of some of these past events, in total 16 cases are reviewed and data are presented. Based on the data, various analyses can be performed which can then be used as a basis to better understand the nature, processes and patterns of cascading effects. These types of analyses lies outside the scope of the present deliverable, but are considered to be an integral part of the CascEff project. Several overall conclusions are drawn regarding the method application and the systematic review of the 16 cases. Firstly, written accounts do not in general focus on the cascading effects in detail, but rather on the initiating event and the direct effects of the event. Hence the different methodological lenses that normally are used to construct e.g. incident investigations reports of past events colours what data that is available, in this case giving rise to the lack of information about the cascading effects that occurred. In some cases cascading effects are mentioned but generally lacking in detail. Secondly, it has also been difficult to find relevant information about important conditions and if they exist they are very specific to the particular case and hence difficult to generalize. Finally, it is concluded that the method enables the gathering and structuring of relevant data regarding the nature, processes and patterns of cascading effects. Such information is argued, in the CascEff project, to be very valuable input to the development of an Incident Evolution Tool and in the end for strategic emergency response of events that have the potential for cascading effects.



# 1 Introduction

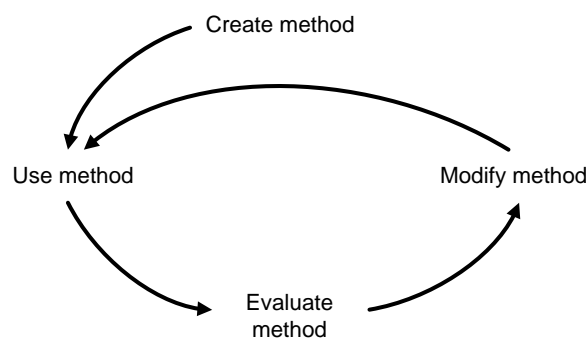
The aim of the CascEff project is to improve the emergency response in incidents involving cascading effects. This will be accomplished by developing knowledge and understanding of cascading effects in past events as well as developing an Incident Evolution Tool, which should enable improved support for strategic decision making in these types of events. The present report constitutes the deliverable for Task 2.2, which is concerned with a review of selected past events by using the method previously developed in Task 2.1 and reported in Deliverable 2.1.

An important part of the CascEff project is to study past events in order to get an understanding of the nature and processes of cascading effects. This is important for example to understand what other or additional challenges can be related to cascading effects regarding responding to such events. Information and knowledge about past cascading effects will provide an important input to the Incident Evolution Tool that will be developed in Task 4.2 of the CascEff project. In addition, it will also provide input to other Work Packages and Tasks by highlighting central aspects of cascading effects that need to be considered.

## 1.1 Aim of Task 2.2

In order to gain knowledge about cascading effects in past events, it is necessary to use a systematic and structured method for description and analysis. Such a method was the delivery of Task 2.1. The aim of Task 2.2, in accordance with the DoW of the CascEff project, is to apply the developed methodology on selected past events with cascading effects and give a review of cascading effects in these events. The aim of Task 2.3 is then to investigate additional cases and to construct a database with the data gained by applying the method.

It should be noted that the process used for developing the method is based on an iterative process (see e.g. Checkland, 1993) in accordance with Deliverable 2.1, see Figure 1.1. Hence by applying the method in more cases studies during Task 2.2, the method has been slightly modified in the light of applications and evaluations, which is further described in Section 2.3.



**Figure 1.1.** The iterative method development process (Adapted from Checkland (1993)).



## 1.2 Report outline

This report is outlined as follows:

- In Chapter 2, a short summary of the developed method in Task 2.1 is given, including key concepts and the conceptual model for cascading effects. The purpose is to describe the main outline of the method in order for the reader to easier understand the results presented in subsequent chapters. Included in the chapter is also a short description of smaller changes to the method, as applying it to real cases has necessitated some changes and additions in accordance to with the method development process.
- In Chapter 3 a list of events with cascading effects is presented, criteria for selection of these and the cases that are reviewed in Chapter 4 are highlighted.
- In Chapter 4 the selected past events are reviewed, 16 in total.
- In Chapter 5 some reflections are made based on the application of the method in several case studies and regarding the results from the case studies. We also reflect on the process of applying the method in terms of benefits, drawbacks and challenges.
- In Chapter 6, the main conclusions of the report are briefly presented.



## 2 Summary of the method

In this section a brief summary of the method developed in Task 2.1 for describing cascading effects in past events is given, with the aim to improve the understanding of the presented results in Chapter 4 (for a deeper understanding of and scientific base for the method, see Deliverable 2.1). The concepts and the conceptual model that underlies the method were developed through workshops in the early stages of the CascEff project as well as through communication of working papers between project partners. The concepts and the model provide common ground between the project partners and are therefore also first briefly recapitulated.

### 2.1 Key concepts and conceptual model

In the CascEff project cascading effects are defined as:

*The impacts of an initiating event where:*

1. *System dependencies lead to impacts propagating to other systems, and;*
2. *The combined impacts of the propagated event are of greater consequences than the root impacts, and;*
3. *Multiple stakeholders and/or responders are involved.*

A number of related concepts are here highlighted in order to facilitate the understanding of the subsequent recapitulation of the conceptual model, the proposed method and, most importantly, the review of the selected case studies:

**Initiating event (initiator)** - the first in a sequence of natural (e.g. flood), accidental (e.g. fire) or intentional (e.g. bombing) events that may affect one or several systems.

**Originating system** - a system from which a failure propagates to another system.

**Dependent system** - a system which is negatively affected by a failure in another system.

**Impacted system** - a system which is negatively affected by either an initiating event or an originating system.

**Dependency** - mechanism whereby a state change in one system can affect the state of another system.

**Interdependency** - a mutual dependency between two systems, i.e. system A is dependent on system B and vice versa.

**Incident** - a chain of events affecting multiple systems.

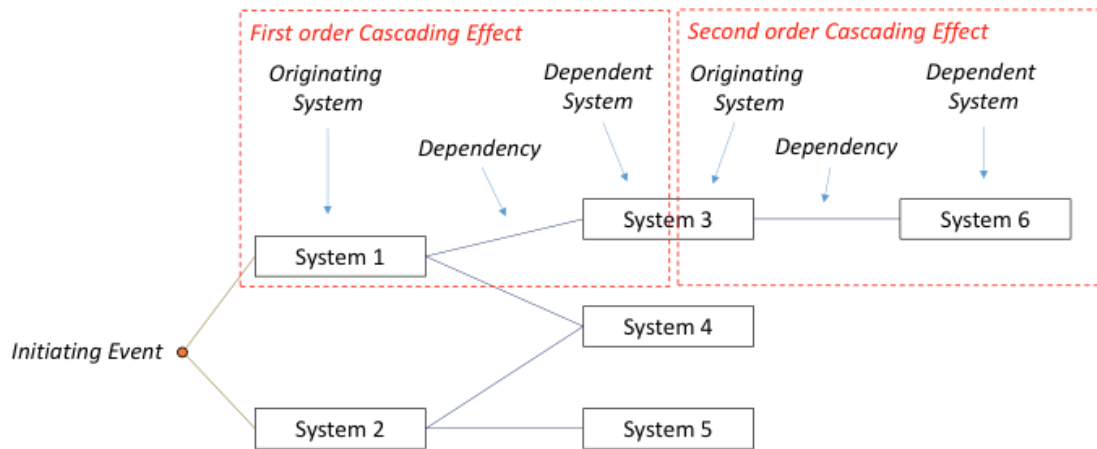
**Cascade order** - the number of stages in a propagation from a directly impacted system to a particular system that is impacted indirectly.

**Impact** - the extent to which a system is affected due to an initiating event or due to a dependency.

**Conditions** - circumstances that can enable, prevent, aggravate or mitigate dependencies and impacts.



The concepts above are synthesized into a conceptual model describing cascading effects, see Figure 2.1.



**Figure 2.1.** Conceptual model of the propagation of effects between systems in an incident that involves cascading effects.

To illustrate the conceptual model with a past event the following description could be useful; a) An incident always starts with an initiating event which could e.g. be a natural event such as an earthquake, an accidental event such as an explosion, or an internal system failure such as malfunctioning of a technical component; b) The initiating event gives rise to direct impacts on one or more systems; c) In order for cascading effects to arise a propagation of effects has to take place from the directly impacted systems (originating systems) to indirectly impacted systems (dependent systems); d) if the newly impacted systems give rise to additional impacts to other system, there is a continuation of the cascading effect. The first resulting effects from directly impacted systems from the initiating event to dependent systems are defined as “first-order cascading effects”. If this line of propagation continues, second, third, etc. order cascading effects arise.

## 2.2 Brief method description

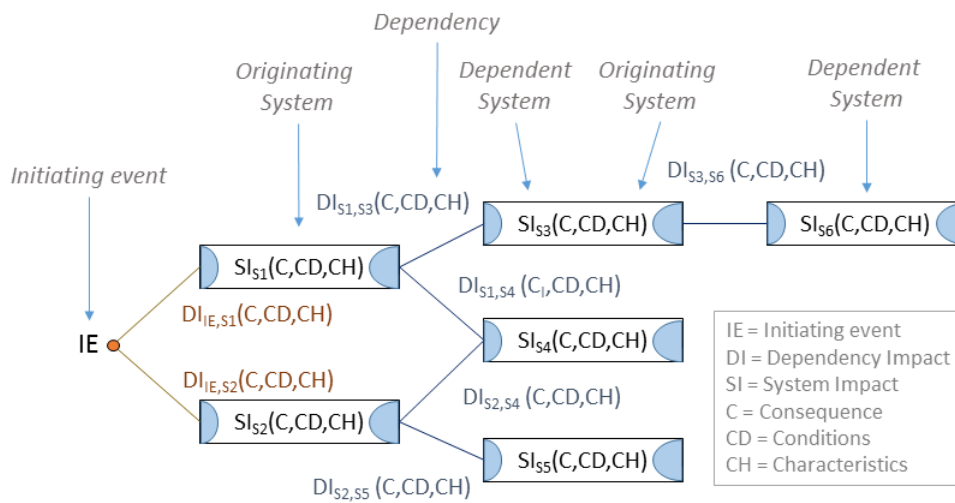
The method from Deliverable 2.1 is here shortly recapitulated, using the key concepts and the conceptual model described in the previous sections. The purpose of the method is to enable systematic descriptions of key characteristics of cascading effects in past events. These descriptive accounts can then be used to analyse cascading effects, both by analysing individual events involving cascading effects and by analysing general patterns across different events. The results from such analyses (however outside the scope of Task 2.1-2.3) can then be used and integrated for decision support in the Incident Evolution Tool (Task 4.2).

The method was developed with the aim to be useful for describing cascading effects among a broad variety of societal sectors and critical infrastructures. Hence, a more holistic approach has been taken rather than trying to capture small- scale cascading effects within a system or network, such as those occurring within electric power systems (see e.g. Zio and Sansavini, 2011) or domino effects within an industrial premise (Reniers and Cozzani, 2013). Furthermore, the aim of the method is to capture both *actual cascading effects*, where an impact on a dependent system has taken place, and *potential cascading effects*, where a dependency exists between a dependent system and an originating system but where an impact on the dependent system did not occur due to some conditions. The reason for including the latter is that valuable learning opportunities with respect to “near misses” should be included. Finally, the method should be able to capture the effects of conditions which represent circumstances that affect

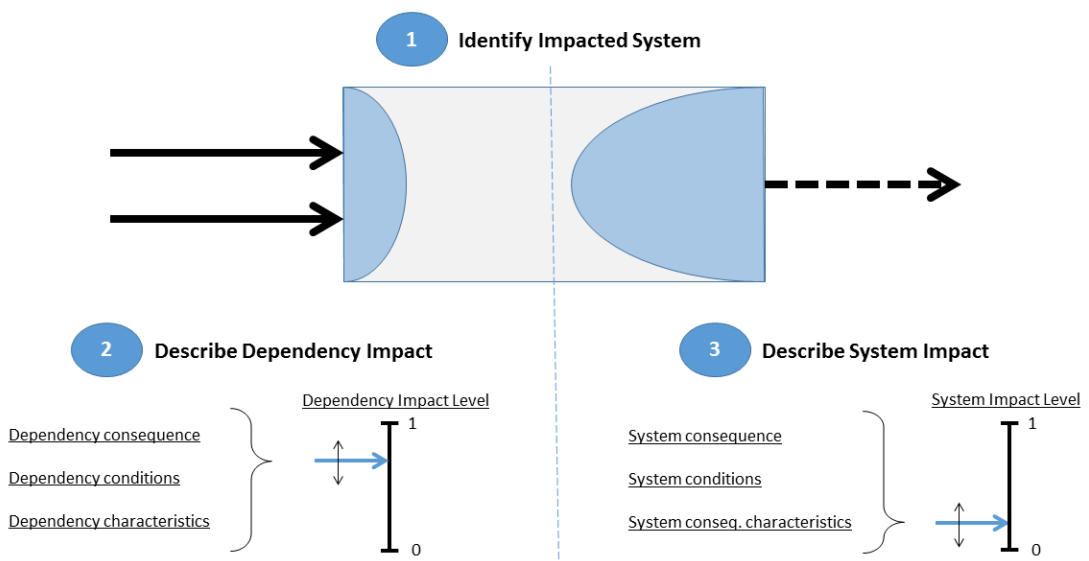


how the cascading effect develops. This can be in terms of enabling or aggravating a cascading effect, for example if a transportation incident happens to occur at rush hours instead of at night time. It can also be in terms of preventing or mitigating the cascading effect, such as if a response organisation would have more resources available than usual. These types of conditions play an important role as they enable the extrapolation and generalization of the findings from a one context to another, important in order for knowledge of past events to be useful as decision support in future events.

The method is centred around a formal model for describing cascading effects in past events, based on the conceptual model as illustrated in Figure 2.1. In Figure 2.2 an overview of the model is presented and Figure 2.3 illustrates key concepts and characteristics for a single system. The method consists of carrying out three different steps with respect to the identification of cascading effects as indicated in Figure 2.3.



**Figure 2.2.** Formal model and key concepts for the method for analysing cascading effects in past events.



**Figure 2.3.** Overview of system identification, description of dependency impact and description of system impact in accordance with the three steps of the method.





The three main steps of the method are:

- Step 1 – Identify Impacted Systems
- Step 2 – Describe Dependency Impacts
- Step 3 – Describe System Impacts.

Each step of the method is briefly recapitulated in the following sections. It should be noted, however, that the three steps are typically performed using an iterative approach, meaning that when an impacted system has been identified (Step 1) this is followed by describing Dependency (Step 2) and System Impacts (Step 3) for this system before returning to Step 1 and identifying additional impacted systems.

### 2.2.1 Step 1 – Identify impacted systems

The first step of the method constitutes identifying systems that have been impacted, either by the initiating event or through dependencies to one or several originating systems, which have been impacted in an earlier cascade order. In addition, systems that could have been impacted due to some specific and traceable conditions are also identified, i.e. potential effects.

Central to the identification of impacted systems is system boundaries and the ability to categorize different types of systems. Here we have taken a pragmatic approach and instead of defining clear-cut system boundaries, we define system categories for which it is easier to argue for inclusion or exclusion of real-life systems. Another benefit of defining system categories is that they can be employed in all case studies and therefore facilitates subsequent aggregated analyses. There exist a number of different categorisations of the systems the society is made up of and there is no single standard that can be straightforwardly adopted in the CasEff project (see the comparative study and subsequent discussions in D2.1). Drawing on existing categorisations we ended up with 22 different systems, see Table 2.1.

To identify an impacted system, an explicit statement of an effect or a potential effect within some system boundaries needs to be made in the written material, e.g. “the loss of power and communications led to missed orders and enquiries [for business and industry]” (Pitt review, 2008). Furthermore, an explicit statement about the existence of a dependency between two systems, but where this dependency did not cause an impact from an originating system to a dependent system, would be identified as a potentially impacted system. The analyst then uses the system category that most closely resembles to the actual system described in the written material, done by comparing the actual system with the descriptions and examples in Table 2.1. However, this is not always straightforward since the system definitions and categories used in investigation reports or media accounts might be vague or not consistent with the system categories used here. Hence, this is a source of uncertainty, which must be acknowledged when using the information. In case no pre-existing system categories provides a reasonable fit, additional categories are added or the scope of the existing system categories are broadened in accordance to with the iterative method development process (during the later presented review of the selected case studies in chapter 4, no such alterations have been necessary).

A single system may be influenced several times as it can be affected in several different stages of an event. For example, a certain system could be affected directly by the initiating event; but also indirectly through cascading effects due to a dependency to another system. The impacts might also be very diverse, for example a system may be struck by one type of impact on short-term but another type of impact on long-term, or having one type of impact locally and another type of impact nationally. Hence, when there are different dependencies leading to different impacts for a given system, Dependency and System impacts (Steps 2-3) will be described several times for that system.



**Table 2.1.** System categories and how they are demarcated in the CascEff project.

<b>Categories</b>	<b>No.</b>	<b>Description and exemplification</b>
Power Supply	1	Activities and assets that ensure continuous supply of electric power from suppliers to customers, e.g. production, transmission and distribution of electric power.
Telecommuni- cation	2	Activities and assets that ensure electronic communication of information over significant distances, e.g. landline and mobile phone systems, Internet, servers, etc.
Water supply	3	Activities and assets that ensure continuous supply of water from suppliers to customers, including pipes, pumps, water treatment plants, infiltration areas, etc.
Sewage	4	Activities and assets that collect and treat wastewater and day water, such as treatment plants, drain pipes, etc.
Oil and gas	5	Activities and assets that ensure continuous supply of oil and gas products, e.g. production, distribution and processing of oil and gas.
District heating	6	Activities and assets that ensure continuous supply of hot water for heating houses and premises, e.g. heating plants, pumping stations, water pipes.
Health care	7	Activities and assets that provide professional services to people in order to achieve or sustain mental and physical well-being and prevent illness and impaired health, e.g. emergency care, primary care, elderly care, child care, medicine distribution and production, disease control, etc.
Education	8	Activities and assets that contribute to a formalised transfer of knowledge, e.g. primary school, secondary school, universities, etc.
Road transportation	9	Activities and assets that enable transportation of people and goods on roads, e.g. road networks, bridges, tunnels, road maintenance activities, etc.
Rail transportation	10	Activities and assets that enable transportation of people and goods on railways, e.g. railway networks, subways, trams, signal systems, maintenance activities, etc.
Air transportation	11	Activities and assets that enable transportation of people and goods by airplane, e.g. airport operations, flight management, airspace security, etc.
Sea transportation	12	Activities and assets that enable transportation of people and goods by sea, lake and waterways, e.g. port operations, shipping industry, etc.
Agriculture	13	Activities and assets related to the cultivation of animals and plants in order to support e.g. food, biofuel and medical production, farming, livestock, etc.
Business and industry	14	Activities and assets that enable the production and exchange of goods and services to customers. Activities and assets covered in other categories are excluded here.
Media	15	Activities and assets that enable the dissemination of news and other information in society, e.g. radio, television, newspaper, social media, etc.
Financial	16	Activities and assets related to the continuous provision of economic services performed by the financial industry, e.g. insurance, cash availability, central banking system, credit cards, etc.
Governmental	17	Activities and assets that enable the provision of governmental/public services at local, regional and national levels, e.g. municipal government, county administration and national agencies. Activities and assets that are covered in other system categories are not included here.
Emergency response	18	Activities and assets that are necessary to respond to acute events where human life and health, environment or property is threatened, e.g. rescue services (land, sea, etc.), police, ambulances, emergency care, national guard, etc.
The public	19	People in a society or a community and their ability to live a normal life where they have continuous access to the services that characterise a modern society
Environment	20	Flora (i.e. all types of plants), fauna (all type of animals) and the ecosystems in which they habituate, e.g. sea, ocean, forest, etc.
Political	21	The political leadership on local, regional and national level
Food supply	22	Activities and assets that are necessary to produce and distribute food to people, e.g. food producers, wholesaler, food inspections



### 2.2.2 Step 2 – Describe Dependency Impacts

The second step of the method is to describe the Dependency Impact for each impacted system with the purpose to get an understanding of how and to what extent a system is exposed to strain when a system on which it depends on has been impacted. The description of Dependency Impacts is done by using three different categories: dependency consequences, dependency characteristics, and dependency conditions. If there are multiple dependencies that affect a system, as is the case for system 4 in Figure 2.2 (which for example would be the case when a combined failure in both rail and road transportation gives rise to a severe impact on fuel distribution), the dependency impacts are described separately.

#### Dependency consequences

This category describes the type of and the magnitude of the consequences due to the dependency (or dependencies). Five consequence categories are used: Technical (the damage and loss of e.g. technical components, and physical assets, loss of production), Organizational (relates to the organisations and institutions that manage the systems; encompassing impacts on e.g. organisational capacity, coordination, and information management), Social (encompass impacts on community such as political instability and civil unrest), Human (impact on population such as health-issues, reduced well-being, casualties and injuries), Economic (impacts in terms of direct and indirect costs), Environmental (the effects on natural resources, flora, and fauna). In order to extract as much concrete and comparable information as possible from the written material various measures are defined for each consequence category in order to standardise the way consequences are described, as free text information would be more difficult to subsequently make use of in systematic analyses of different events with cascading effects. Note though that free-text information is also extracted in order to make the results and analyses traceable.

#### Dependency characteristics

Dependency characteristics contribute to the understanding of the nature and mechanism of the dependencies. This in turn may be important for decision-making at a strategic level when considering how to respond or manage events that involve or may involve cascading effects. Four different dependency characteristic categories are used: Dependency type (Functional, Geographical, and Logical), Location and spatial extent (geographical coordinate(-s) and the size of the geographic area), System extent (the proportion of specific impacted subsystem(s) within the system), Starting and ending time (described by Date and Time).

#### Dependency conditions

Conditions that significantly either aggravate or mitigate Dependency impacts are of relevance in order to be able to generalise the information gathered and to extrapolate it to other contexts. For example, if the same event would occur during another time of the year; is it likely that it will lead to similar types of impacts or will it be more or less serious? Conditions that are explicitly mentioned as being important in the written accounts of the events are mapped. Five categories for conditions are used: Weather (cold, warm, snow, windy, etc.), Timing (summer, winter, day, night, weekday, holiday, etc.), Location (urban, rural, coastal, etc.), Initial event type (natural, accidental, intentional, etc.), Operational state (e.g. above or below normal capacity). In addition, whether it was a mitigating or aggravating condition for the impact is also noted separately.

#### Dependency Impact Level

Dependency impact level is a measure of the extent of the dependency impact and, if applicable, aggregated for several dependencies. It is, admittedly, to some extent a rough judgment made by



the analyst, but it is argued to be useful when subsequently analysing and modelling cascading effects. For example in order to get a sense of whether a relatively small system impact in one system gives rise to very large subsequent dependency impacts on other systems; or whether a rather small dependency impact may give rise to large system impacts for some systems (which e.g. could indicate a very low coping capacity). Four different levels of Dependency impact are used, ranging from no dependency impact to major dependency impact. The measure is conditioned to the spatial and system extent, e.g. only the Primary schools within the Education system and within the London area. If the reference instead would have been e.g. all parts of the Education system and the whole nation the same impact would “score” lower on the Dependency Impact level scale.

### **2.2.3 Step 3 – Describe System Impacts**

The third step of the method is to describe the System Impact for each impacted system which refers to effects on the impacted system due to one or several Dependency Impacts and taking and the impacted system’s inherent coping capacity into consideration. The difference between Dependency Impacts and System Impacts is that the Dependency Impact describes the direct exposure, e.g. two water pumps in the water distribution system were flooded due to a failure in the power system. System Impact, then, describes how the system subsequently is impacted by this exposure, e.g. the water distribution system was redundant which only lead to some minor issues with low water pressure, or on the other extreme, that it lead to complete system collapse. The characterisation is done by using three different categories, similar to what was done for the Dependency Impact: system consequences, system consequence characteristics, and system conditions. However, unlike the description of Dependency Impacts, the description of System Impacts is done considering all impacts due to dependencies (one or several).

#### **System consequences**

This category describes the type of and the magnitude of the system consequences. This is done using the same consequence categories and procedure as described for characterising dependency consequences.

#### **System consequence characteristics**

System consequence characteristics describe aspects of the consequences that contribute to a better understanding of the nature of the system impacts. Three different categories are used: Location and spatial extent (the geographical area (or areas) described by latitude and longitude coordinates and the size of the affected area in km<sup>2</sup>), System extent (proportion of impacted functions within the system, e.g. single, few, majority, all), Starting and Ending time (for what time period the consequences arose, described by date and time).

#### **System conditions**

In addition to conditions that affect the Dependency Impacts, there are also conditions that can aggravate or mitigate the System Impacts, i.e. circumstances that, if they change, would give rise to different System Impacts although the Dependency Impacts were the same. For example, looking at the water distribution example again, the system impacts due failure of two water pumps could be larger if there was a high demand on the water distribution system at the time of the failure occurrence (e.g. summertime, during hours of high industrial production, etc.). The System conditions categories are identical to the categories presented for Dependency conditions but with one additional category, namely Coping capacity (Buffers, preparedness plans, external resources, etc.).



### **System Impact Level**

The System Impact Level is a measure of the impacts on what the system aims to accomplish, i.e. related to the descriptions of the systems as presented in Table 2.1. The System Impact Level will, similar to the estimation of the Dependency Impact Level, generally be a rough judgment made by the analyst, but it is considered to be useful when subsequently analysing and modelling cascading effects. The four different levels for System impact are identical to those given for Dependency impact level and are also conditioned to the spatial and system extent.

## **2.3 Iterative alterations to method**

During the application of the method to study past events, some alterations to the method (as described in the previous section) have been made in accordance with the iterative method development process in Figure 1.1. In addition to methodological changes, slight alterations and additions to categories have also been made which are not further addressed here. In total two methodological changes have been made: the introduction of Sub-systems categories and the description of Dependency and System impact levels.

### **Sub-system categories**

During the application of the method for analysing past events it became apparent that using only 22 system categories lead to the loss of important information and also hampered the assessment of Dependency impact and System impact levels. As such the System categories were extended by sub-systems categories (about 4-8 sub-system categories for each system, giving a total of about 116 sub-systems which will be described in more detail in Deliverable 2.3). The method, as described in previous section is then applied at a sub-system level instead of at a system level. As impacts are described at a sub-system level, the consequence characteristic “System extent” is rendered unnecessary and is therefore excluded from the method. However, in order to gather enough data to do comparative studies between different events with respect to cascading effects it is also necessary to aggregate the information found at sub-system level to system level. As such the method has also been extended with a system level assessment which is based on the information at the sub-system level.

This system level assessment is done by the analyst by considering one or several sub-system impacts and dependencies. Here the Impacted system, Originating system, Cascade Order, Geographical area, Impact duration, Dependency impact level and System impact level are interpreted and judged by the analyst given the sub-system impacts found in the written accounts of the event. As such these assessments holds some uncertainty as they are not directly related to written accounts of the events, but necessary in the end to compare and contrast cascading effects across different type of events.

### **Dependency and System Impact levels**

Dependency and System Impact levels were originally only done by using four different levels, ranging from (1) no dependency impact to (4) major dependency impact. As these levels were of both low granularity and did not account for uncertainties of in the assessment (as done by the analyst) changes were deemed necessary. Instead a quantitative percentage scale is used (ranging from 0% impact to 100% impact) to give a higher degree of freedom in the assessments. Further, in order to address uncertainties regarding the assessments, three different numerical values are given by the analyst; minimum value, most likely value and maximum value. These changes enable the inclusion of uncertainties in subsequent analyses of cascading effects across different type of events, which in the end is likely to give more effective decision support possibilities.



### 3 List of potential case studies

The data that have been (current Deliverable 2.2) and will be collected (Deliverable 2.3) and systematized comprise of existing empirical data, i.e. information about past events, that are gathered from written material in terms of official reports, investigations or media reports written in English or Swedish. This chapter presents criteria for the selection of which cases (past events) to study, as well as a list of selected case studies, which includes the cases selected and reviewed in the present deliverable.

#### 3.1 Selection of cases

When selecting potential past events (cases) to study the aim are is to obtain a great variety of cascading effects. The underlying motivation is to ensure that the data gathered and presented in the current deliverable as well as in Deliverable 2.3, includes a variety of types of events so that the data set will cover many different types of dependencies, systems and cascading effects. In the selection process, several reports that give an overview of past events in Europe were used as part of point of departure, e.g. EEA (2010) and EPC (2013). In addition, the CascEff project partners were also asked to specify events that may be of interest. When choosing potential cases to analyse, the focus was to cover diverse aspects across the following characteristics:

- Types of initiating events
- Spatial extent of Initiating Event
- Spatial extent of cascading effects
- Geographical location
- Duration
- Impacted systems
- Dependency types involved

The selection of potential events resulted in a long list of potential case studies. All these cases where then evaluated against three selection criteria:

1. The event has to be well documented and the documented empirical data should be written in English or Swedish
2. The existing material has to describe cascading effects
3. The societal consequences has to be substantial

#### 3.2 List of case studies

In Table 3.1 an overview of potential cases is presented. The cases were selected in accordance with the approach outlined in Section 3.1. The list consists of 74 potential cases and they cover a rather large variety of different types of events. The 16 cases that are highlighted in bold are those that have been selected for the review in Chapter 4. These were chosen as they were considered to provide good learning opportunities as well as they cover diverse aspects of the selection criteria described in previous section.



**Table 3.1.** List of potential case studies. The 16 cases included and reviewed in the present deliverable are highlighted in bold.

No.	Short name	Continent	Country	Year	Initiating event
<b>1</b>	<b>Auckland</b>	<b>Oceania</b>	<b>New Zealand</b>	<b>1998</b>	<b>Power outage</b>
<b>2</b>	<b>Tieto</b>	<b>Europa</b>	<b>Sweden</b>	<b>2011</b>	<b>IT-event</b>
<b>3</b>	<b>UK floods</b>	<b>Europa</b>	<b>UK</b>	<b>2007</b>	<b>Flooding</b>
<b>4</b>	<b>Enschede</b>	<b>Europa</b>	<b>Netherlands</b>	<b>2000</b>	<b>Explosion</b>
<b>5</b>	<b>London bombing</b>	<b>Europa</b>	<b>UK</b>	<b>2005</b>	<b>Terrorism</b>
<b>6</b>	<b>Mont Blanc</b>	<b>Europa</b>	<b>Switzerland; France</b>	<b>1999</b>	<b>Fire</b>
7	Katrina	North America	USA	2005	Hurricane
<b>8</b>	<b>Sandy</b>	<b>North America</b>	<b>US; Canada; Jamaica; Haiti; Dominican Republic; Bahamas; Cuba; Puerto Rico; Bermuda</b>	<b>2012</b>	<b>Hurricane</b>
<b>9</b>	<b>Eyjafjallagökull</b>	<b>Europa</b>	<b>Island</b>	<b>2010</b>	<b>Volcano eruption</b>
<b>10</b>	<b>Malmö floods</b>	<b>Europa</b>	<b>Sweden</b>	<b>2014</b>	<b>Flooding</b>
11	Colorado floods	North America	USA	2013	Flooding
<b>12</b>	<b>Kista blackout</b>	<b>Europa</b>	<b>Sweden</b>	<b>2001</b>	<b>Power outage</b>
<b>13</b>	<b>Myyrmanni bombing</b>	<b>Europa</b>	<b>Finland</b>	<b>2002</b>	<b>Terrorism</b>
14	Buenos Aires blackout	South America	Argentina	1999	Power outage
15	Boliden dam rupture	Europa	Spain	1998	Dam rupture
<b>16</b>	<b>European blackout 2003</b>	<b>Europa</b>	<b>Germany; France; Belgium; Netherlands; Italy; Spain</b>	<b>2006</b>	<b>Power outage</b>
18	Earthquake Umbria and Marche	Europa	Italy	1997	Earthquake
19	Oslo Outage	Europa	Norway	2005	Power outage
<b>20</b>	<b>Ice storm North America</b>	<b>North America</b>	<b>Canada; USA</b>	<b>1998</b>	<b>Ice storm</b>
21	Land slide	Asia	Japan	2012	Landslide
<b>22</b>	<b>Östersund</b>	<b>Europa</b>	<b>Sweden</b>	<b>2010-2011</b>	<b>Contaminated water supply</b>
<b>23</b>	<b>Baltimore</b>	<b>North America</b>	<b>USA</b>	<b>2001</b>	<b>Tunnel Fire</b>
<b>24</b>	<b>L'Aquila</b>	<b>Europa</b>	<b>Italy</b>	<b>2009</b>	<b>Earthquake</b>
25	Zambia blackout	Africa	Zambia	2008	Blackout
26	North India blackout	Asia	India	2012	Blackout
27	Malaga tornado	Europa	Spain	2012	Tornado
28	Zanzibar blackout	Africa	Zanzibar	2009-2010	Blackout
29	Darwin blackout	Oceania	Australia	2014	Blackout
30	Great East Japan Earthquake	Asia	Japan	2011	Earthquake
31	Quebec solar storm	North America	Canada	1989	Solar storm



32	Philadelphia strike	North America	USA	2009	Strike
33	Krymsk flash flood	Asia	Russia	2012	Flooding
34	Russian heat wave	Asia	Russia	2010	Heat wave
35	Pinatubo eruption	Asia	Philippines	1991	Volcano eruption
36	Manchester telecom failure	Europa	UK	2004	Fire
37	UK fuel crisis	Europa	UK	2000	Fuel shortage
38	Yosemite wildfire	North America	USA	2013	Wildfire
39	New Mexico cold snap	North America	USA	2011	Cold snap
40	Kyrgyzstan energy emergency	Asia	Kyrgyzstan	2007	Water shortage
41	North Gila-Hassayampa	North America	USA/Mexico	2011	Blackout
42	Warrnambool exchange fire	Oceania	Australia	2012	Fire
43	Maui pipeline outage	Oceania	New Zealand	2011	Landslide
44	Hawaii cable outage	Oceania	USA	2014	Cable rupture
45	Lanzhao pipeline	Asia	China	2014	Pipeline rupture
46	UK France storms	Europa	UK	2013-2014	Storm
47	Puyehue-Cordón Caulle	South America	Argentina	2011	Volcano eruption
48	Seacom cable outage	Africa	Egypt	2013	Cable rupture
49	Eurasia cable outage	Europa	Italy	2008	Cable rupture
50	DNS Spamhouse	Europa	Netherlands	2013	Cyber attack
51	Virginia server crash	North America	USA	2010	IT-event
52	Taiwan cable outage	Asia	Taiwan	2006	Earthquake
53	California cable outage	North America	USA	2009	Sabotage
54	Canada satellite failure	North America	Canada	2011	IT-event
55	Philadelphia pipe rupture	North America	USA	2013	Water pipe rupture
56	Boston pipe rupture	North America	USA	2010	Water pipe rupture
57	Florida blackout	North America	USA	2008	Blackout
58	Gas shortage EU	Europa	Ukraine and more	2009	Fuel shortage
59	Varanus Island explosion	Oceania	Australia	2008	Explosion
60	Bushfires Sydney area	Oceania	Australia	2013	Fire
61	Central Europe flooding	Europa	Central EU	2010	Flooding
62	Serbia flooding	Europa	Serbia	2014	Flooding
63	Kolontar dam break	Europa	Hungary	2010	Dam rupture
64	Charles Village landslide	North America	USA	2014	Flooding
65	Mid-Atlantic and Midwest derecho	North America	USA	2012	Storm
66	Greece Wild Fire	Europe	Greece	2006	Wildfire
67	Arcwood Recycling Fire	Europe	UK	2012	Fire





68	Kyrill	Europe	German; Poland; Austria; Czech Republic	2007	Storm
69	Summer of 2003	Europe	Germany; Switzerland; France; Spain	2003	Heat wave
70	WSD in Barcelona	Europe	Spain	2008	Water drought
71	Avalanche Marchkar	Europe	Austria	2009	Avalanche
72	Friuli Venezia Giulia landslide	Europe	Italy	2003	Landslide
73	Styria landslide	Europe	Austria	2005	Landslide
74	Buncefield fire	Europe	UK	2005	Fire

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## 4 Review of selected cases

In the present chapter the selected cases are reviewed and key characteristics about the cases are described. The information has been automatically generated from data about the events, stored in a database, which is structured in accordance with the methodology. As such each case description, impacts at sub-system level, cascading effects, and conditions follows the same repetitive structure (except the abstract about the event which is a free-text input by the analyst). This way of presenting the data hence gives an idea of the structure used and the availability of data, which is important for subsequent analyses of the data. Depending on the availability of requested data in the written accounts of the event, the descriptions can be of different lengths. For each event an automatically generated figure of the overall cascading effects and cascade order for the impacted systems is also given (i.e. based on the system level assessment in accordance with Section 2.3). It should be noted that only some selected parts of the available data is presented for each case in order to limit the length of the review, e.g. all information about dependency impacts has been deliberately omitted. In the end of each case description an account of references behind the data are also given.

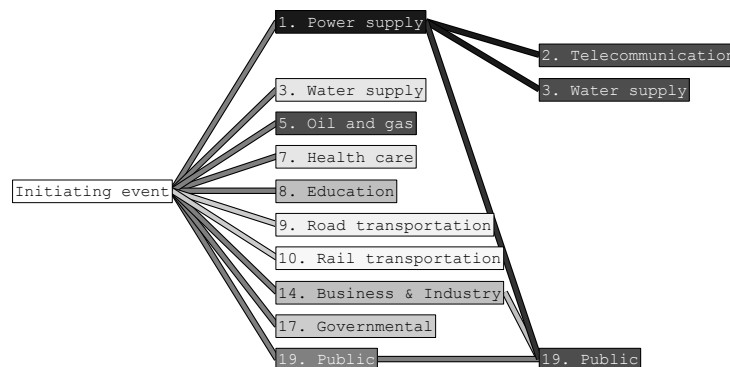
### 4.1 L'Aquila Earthquake, 1998

#### Case description:

L'Aquila occurred in the year 2009 in Europa (Italy). The initiating event was Earthquake starting 06-Apr-2009 03:32:00 and lasted for 5 minute(s), affecting an area of 0.78 square km (epicentre of the earthquake, end time estimated).

#### Abstract:

On Monday morning, 6th of April 2009, an earthquake of a magnitude  $M_W=6.3$ , shook the city and province of L'Aquila, a mountainous area in the middle of Italy. An estimate of 100 000 buildings were collapsed or deemed unusable for use, resulting in the death of 308 persons, 1 500 injured and 60 000-70 000 homeless. The water, power and telecommunication systems suffered minor damage, while the gas distribution system was affected more severely. The historical buildings of L'Aquila, of which there were many, also suffered heavy damages. One of the major cascade effects was that several business and industries had to move their operation elsewhere, because of the loss of workforce and customers. This in turn resulted in sky-high unemployment rates when the relocated people returned to their homes. The damages were calculated to be in the vicinity of 4-16 billion EUR.



**Figure 4.1** Impacted systems, cascade order and dependency impact from originating to impacted system. Grey scale (white 0% and black 100%) is used to illustrate system impact level (system boxes) and dependency impact level (dependency line).



**Impacted system Public (Sub-system Not specified)**

From Initiating event. Consequences that arose were Human Fatalities 308 People. The area affected was 164 square km. Conditions affecting the consequences were Weekday Timing with a mitigating effect (Many weekend houses situated in the area) and Night Timing with a mitigating effect (No gatherings in church or schools, which were vulnerable).

**Impacted system Public (Sub-system Not specified)**

From Initiating event. Consequences that arose were Human Homeless 67 500 People. The area affected was 391 square km during 1 year(s) and 6 month(s).

**Impacted system Public (Sub-system Not specified)**

From Initiating event. Consequences that arose were Human Injuries 1 500 People. The area affected was 164 square km. Conditions affecting the consequences were Weekday Timing with a mitigating effect (Many weekend houses situated in the area) and Night Timing with a mitigating effect (No gatherings in church or schools, which were vulnerable).

**Impacted system Public (Sub-system Not specified)**

From Initiating event. Consequences that arose were Technical Damaged property 25 % Buildings. The area affected was 391 square km.

**Impacted system Governmental (Sub-system Not specified)**

From Initiating event. Consequences that arose were Technical Damaged property 20 % Buildings. The area affected was 391 square km.

**Impacted system Health care (Sub-system Primary care)**

From Initiating event. Consequences that arose were Technical Damaged property 10 % Buildings. The area affected was 391 square km. Conditions affecting the consequences were External resources Coping capacity with a mitigating effect (Within 24 hours it was completely replaced by the first of two field hospitals that arrived in the area).

**Impacted system Education (Sub-system Not specified)**

From Initiating event. Consequences that arose were Technical Damaged property 13 % Buildings. The area affected was 391 square km during 3 month(s) and 4 week(s).

**Impacted system Business and industry (Sub-system Not specified)**

From Initiating event. Consequences that arose were Technical Damaged property 15 % Buildings. The area affected was 391 square km.

**Impacted system Power supply (Sub-system Local Distribution)**

From Initiating event. Consequences that arose were Technical Loss of network and Economic Direct economic costs 15 000 000 EUR. The area affected was 391 square km during 1 day(s).

**Impacted system Telecommunication (Sub-system Not specified)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of supply. The area affected was 391 square km during 1 day(s). Conditions affecting the consequences were External resources Coping capacity with a mitigating effect ("Problems were solved by putting emergency generators into service.").

**Impacted system Water supply (Sub-system Distribution)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of supply. The area affected was 391 square km during 1 day(s).



**Impacted system Water supply (Sub-system Distribution)**

From Initiating event. Consequences that arose were Technical Loss of network. The area affected was 0.60 square km.

**Impacted system Oil and gas (Sub-system Distribution)**

From Initiating event. Consequences that arose were Technical Loss of network and Economic Direct economic costs 20 000 000 EUR. The area affected was 73 square km during 3 month(s) and 6 day(s).

**Impacted system Road transportation (Sub-system National Network)**

From Initiating event. Consequences that arose were Technical Loss of network. During 3 day(s).

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Business and industry (Sub-system Not specified). Consequences that arose were Economic Loss of jobs 26 000 Number. The area affected was 391 square km. Conditions affecting the consequences were Below normal capacity Operational state with an aggravating effect (Already 12.2% unemployed before EQ).

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Public (Sub-system Not specified). Consequences that arose were Human Mental health injuries. The area affected was 391 square km. Conditions affecting the consequences were Buffers Coping capacity with an aggravating effect (The hardships of relocation were exacerbated by financial burdens. Many people were forced to continue paying local taxes and mortgages on properties that had been destroyed).

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of supply 15 000 People. The area affected was 391 square km during 1 day(s).

**Impacted system Rail transportation (Sub-system Railway network)**

From Initiating event. Consequences that arose were Technical Loss of network. The area affected was 22 square km during 4 hour(s) and 28 minute(s).

**Impacted system Business and industry (Sub-system Tourism)**

From Initiating event. Consequences that arose were Technical Damaged property. The area affected was 1 square km during 5 year(s).

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Business and industry (Sub-system Tourism). Consequences that arose were Economic Loss of jobs. The area affected was 391 square km during 5 year(s).

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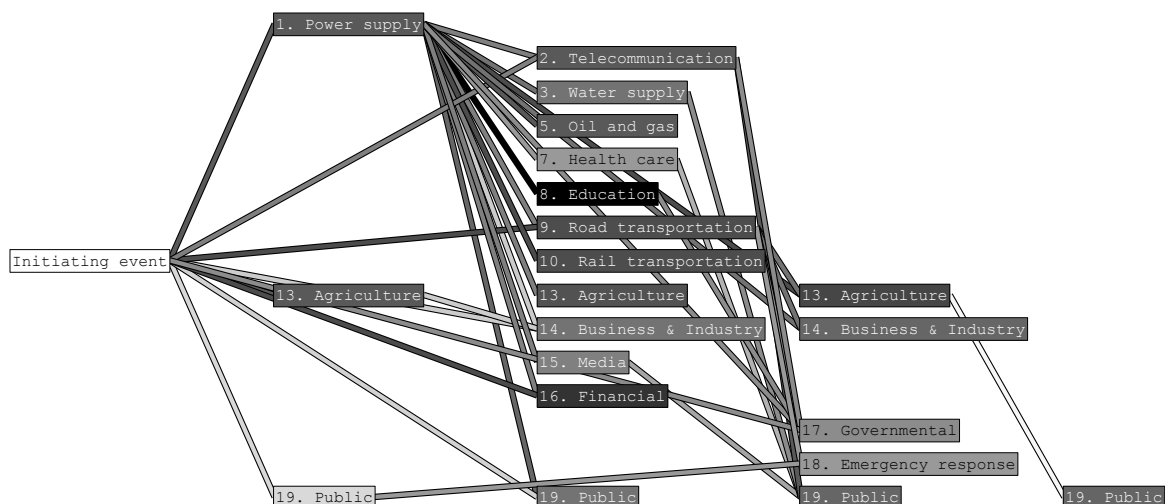
## 4.2 Ice storm North America, 1998

### Case description:

Ice storm North America occurred in the year 1998 in North America (Canada; USA). The initiating event was Snow starting 04-Jan-1998 15:00:00 and lasted for 6 day(s) and 8 hour(s), affecting an area of 407 854 square km.

### Abstract:

In the afternoon of 4 January 1998 an ice storm hit the north-eastern parts of Canada and United States. In the United States parts in Maine, Vermont, New York and New Hampshire were affected, and in Canada parts of New Brunswick, Nova Scotia, Ontario and Quebec were affected. The ice storm caused massive power outages, which affected a number of other systems including education, water supply and agriculture. Total around two million households were without electricity for up to a month. Also million acres of forest were damaged during the storm. This had effects both in tourism and in industry linked to forest. Fallen trees also made roads impassable and cut off the landline telephone. The insurance costs after the storm were at least 990 million USD.



**Figure 4.2** Impacted systems, cascade order and dependency impact from originating to impacted system. Grey scale (white 0% and black 100%) is used to illustrate system impact level (system boxes) and dependency impact level (dependency line).



**Impacted system Power supply (Sub-system Local Distribution)**

From Initiating event. Consequences that arose were Technical Loss of components 54 420 Number and Economic Direct economic costs 976 000 000 USD. The area affected was 474 350 square km during 1 month(s) and 1 day(s).

**Impacted system Power supply (Sub-system Transmission)**

From Initiating event. Consequences that arose were Technical Loss of components 5 059 Number. The area affected was 474 350 square km during 1 month(s) and 1 day(s).

**Impacted system Power supply (Sub-system Local Distribution)**

From Originating system(s) Power supply (Sub-system Local Distribution) and Power supply (Sub-system Transmission). Consequences that arose were Technical Loss of supply and Technical Loss of network. The area affected was 474 350 square km during 1 month(s) and 1 day(s).

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Human Loss of services 2 219 000 Households. The area affected was 474 350 square km during 1 month(s) and 1 day(s). Conditions affecting the consequences were Winter Timing with an aggravating effect (Cold in this parts of Canada and the US during winter).

**Impacted system Education (Sub-system Primary school)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of services 5 Pupil days. The area affected was 1 301 square km during 1 week(s).

**Impacted system Education (Sub-system Secondary school)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of services 5 Pupil days. The area affected was 1 301 square km during 1 week(s) and 5 day(s).

**Impacted system Education (Sub-system University)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of services 5 Pupil days. The area affected was 1 301 square km during 1 week(s) and 5 day(s).

**Impacted system Business and industry (Sub-system Retail)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of services. The area affected was 1 301 square km during 1 week(s) and 6 day(s). Conditions affecting the consequences were Snow Weather with an aggravating effect (Voluntary restrictions on business hours for downtown Montreal until 1998 01 20. [4:11]).

**Impacted system Water supply (Sub-system Distribution)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of components. The area affected was 474 350 square km.

**Impacted system Water supply (Sub-system Distribution)**

From Originating system(s) Water supply (Sub-system Distribution). Consequences that arose were Technical Loss of supply. The area affected was 474 350 square km during 6 day(s).



**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Water supply (Sub-system Distribution). Consequences that arose were Human Loss of services. The area affected was 474 350 square km during 6 day(s). Conditions affecting the consequences were Preparedness plans Coping capacity with a mitigating effect (Possible to obtain water from the local fire halls).

**Impacted system Agriculture (Sub-system Dairy)**

From Originating system(s) Power supply (Sub-system Local Distribution) and Road transportation (Sub-system Local Network). Consequences that arose were Economic Indirect economic costs 13 320 000 USD and Technical Loss of production. The area affected was 474 350 square km during 6 day(s) and 8 hour(s). Conditions affecting the consequences were Preparedness plans Coping capacity with a mitigating effect (Backup installed in some farms) and External resources Coping capacity with a mitigating effect (Generators) and Above normal capacity Operational state with a mitigating effect (Excellent growing season spring and summer).

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Agriculture (Sub-system Dairy). Consequences that arose were Human Loss of services. The area affected was 474 350 square km during 6 day(s) and 8 hour(s).

**Impacted system Agriculture (Sub-system Cattle)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of production 148 000 Number. The area affected was 474 350 square km during 6 day(s) and 8 hour(s). Conditions affecting the consequences were Preparedness plans Coping capacity with a mitigating effect (Many large hog and chicken farms had backup sources of power for heating, lighting, and ventilation. [3:10]).

**Impacted system Agriculture (Sub-system Not specified)**

From Initiating event. Consequences that arose were Economic Indirect economic costs and Technical Damaged property. The area affected was 407 854 square km.

**Impacted system Agriculture (Sub-system Plantations)**

From Initiating event. Consequences that arose were Economic Indirect economic costs and Technical Loss of production. The area affected was 407 854 square km.

**Impacted system Business and industry (Sub-system Not specified)**

From Originating system(s) Power supply (Sub-system Local Distribution) and Road transportation (Sub-system Local Network). Consequences that arose were Organisational Reduced staffing 2 600 000 People. The area affected was 329 843 square km.

**Impacted system Agriculture (Sub-system Forest)**

From Initiating event. Consequences that arose were Economic Indirect economic costs 35 000 0000 USD and Technical Damaged property. The area affected was 407 854 square km. Conditions affecting the consequences were Warm Weather with an aggravating effect (To make matters worse, the clean-up had to be done quickly, as warm temperatures caused the sap to run early. [1:1]).

**Impacted system Agriculture (Sub-system Forest)**

From Originating system(s) Agriculture (Sub-system Forest). Consequences that arose were Technical Loss of production 50 %. The area affected was 140 325 square km during 10 year(s).



**Impacted system Business and industry (Sub-system Tourism)**

From Originating system(s) Agriculture (Sub-system Forest) and Initiating event. Consequences that arose were Technical Loss of supply and Economic Indirect economic costs. The area affected was 407 854 square km.

**Impacted system Business and industry (Sub-system Retail)**

From Originating system(s) Power supply (Sub-system Local Distribution) and Initiating event. Consequences that arose were Economic Indirect economic costs 198 000 000 USD. The area affected was 447 square km.

**Impacted system Business and industry (Sub-system Retail)**

From Initiating event and Power supply (Sub-system Local Distribution). Consequences that arose were Economic Indirect economic costs. The area affected was 11 857 833 square km during 1 month(s).

**Impacted system Agriculture (Sub-system Forest)**

From Initiating event. Consequences that arose were Technical Damaged property 171 000 Square km. The area affected was 407854 square km.

**Impacted system Public (Sub-system Not specified)**

From Initiating event and Power supply (Sub-system Local Distribution). Consequences that arose were Human Fatalities 45 People. The area affected was 407 854 square km.

**Impacted system Financial (Sub-system Insurance)**

From Initiating event and Power supply (Sub-system Local Distribution). Consequences that arose were Economic Direct economic costs 990 000 000 USD. The area affected was 407 854 square km.

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Human Injuries 100 People. The area affected was 329 843 square km.

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Human Evacuated 600 000 People. The area affected was 329 843 square km during 1 month(s) and 1 day(s). Conditions affecting the consequences were Preparedness plans Coping capacity with a mitigating effect (temporary shelters) and Buffers Coping capacity with a mitigating effect (Homes with electricity became hostels; hospitals and other buildings were turned into shelters).

**Impacted system Public (Sub-system Not specified)**

From Initiating event. Consequences that arose were Human Mental health injuries. The area affected was 329 843 square km.

**Impacted system Road transportation (Sub-system Local Network)**

From Initiating event and Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of components. The area affected was 407 854 square km.

**Impacted system Road transportation (Sub-system Local Network)**

From Originating system(s) Road transportation (Sub-system Local Network). Consequences that arose were Technical Loss of network. The area affected was 407 854 square km.





**Impacted system Rail transportation (Sub-system Railway network)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of components. The area affected was 329 843 square km.

**Impacted system Rail transportation (Sub-system Railway network)**

From Originating system(s) Rail transportation (Sub-system Railway network). Consequences that arose were Technical Loss of supply and Technical Loss of network. The area affected was 329 843 square km.

**Impacted system Telecommunication (Sub-system Telephone landline)**

From Initiating event and Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of components. The area affected was 329 843 square km.

**Impacted system Telecommunication (Sub-system Telephone landline)**

From Originating system(s) Telecommunication (Sub-system Telephone landline). Consequences that arose were Technical Loss of supply and Technical Loss of network. The area affected was 329 843 square km.

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Telecommunication (Sub-system Telephone landline). Consequences that arose were Human Loss of services. The area affected was 329 843 square km. Conditions affecting the consequences were Below normal capacity Operational state with an aggravating effect (cellular phone and radio towers without back-up power could not transmit signals. [5:8]).

**Impacted system Oil and gas (Sub-system Distribution)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of components. The area affected was 329 843 square km.

**Impacted system Oil and gas (Sub-system Distribution)**

From Originating system(s) Oil and gas (Sub-system Distribution). Consequences that arose were Technical Loss of supply. The area affected was 329 843 square km.

**Impacted system Media (Sub-system Newspapers)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of production. The area affected was 329 843 square km.

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Media (Sub-system Newspapers). Consequences that arose were Human Loss of services. The area affected was 329 843 square km. Conditions affecting the consequences were Below normal capacity Operational state with an aggravating effect (Since there was a power outage people could not watch TV or listen to the radio).

**Impacted system Telecommunication (Sub-system Telephone mobile)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of components. The area affected was 474 350 square km. Conditions affecting the consequences were Below normal capacity Operational state with an aggravating effect (Difficulties getting fuel to the generators, since trees were blocking the roads).

**Impacted system Telecommunication (Sub-system Telephone mobile)**

From Originating system(s) Telecommunication (Sub-system Telephone mobile). Consequences that arose were Technical Loss of supply and Technical Loss of network. The



area affected was 474 350 square km. Conditions affecting the consequences were Buffers Coping capacity with a mitigating effect (Auxiliary power sources, including batteries and generators Backup antenna sites System redundancy (alternate ways of bypassing off-line towers) [2:27]) and External resources Coping capacity with a mitigating effect (Excellent cooperation within the industry Providers having an adequate parts inventory or the means to buy or borrow on short notice. [2:27]).

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Telecommunication (Sub-system Telephone mobile). Consequences that arose were Human Loss of services. The area affected was 474 350 square km. Conditions affecting the consequences were Below normal capacity Operational state with an aggravating effect (Also telephone landline was down).

**Impacted system Financial (Sub-system Cash availability)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of supply. The area affected was 329 843 square km.

**Impacted system Health care (Sub-system Medicine and material supply)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of services. The area affected was 329 843 square km.

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Health care (Sub-system Medicine and material supply). Consequences that arose were Human Loss of services. The area affected was 329 843 square km.

**Impacted system Governmental (Sub-system Local)**

From Originating system(s) Power supply (Sub-system Local Distribution) and Telecommunication (Sub-system Telephone landline) and Telecommunication (Sub-system Telephone mobile). Consequences that arose were Organisational Affected organisational units. The area affected was 329 843 square km.

**Impacted system Governmental (Sub-system Local)**

From Originating system(s) Road transportation (Sub-system Local Network) and Initiating event and Power supply (Sub-system Local Distribution) and Education (Sub-system Primary school). Consequences that arose were Organisational Reduced staffing. The area affected was 329 843 square km.

**Impacted system Emergency response (Sub-system Rescue services)**

From Originating system(s) Road transportation (Sub-system Local Network) and Public (Sub-system Not specified). Consequences that arose were Organisational Affected organisational units. The area affected was 329 843 square km.

**Impacted system Emergency response (Sub-system Police)**

From Originating system(s) Public (Sub-system Not specified). Consequences that arose were Organisational Affected organisational units. The area affected was 329 843 square km.

**Impacted system Health care (Sub-system Hospitals)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Increased load. The area affected was 329 843 square km.



**Impacted system Public (Sub-system Not specified)**

From Initiating event and Power supply (Sub-system Local Distribution). Consequences that arose were Human Loss of services. The area affected was 329 843 square km.

**Impacted system Public (Sub-system Not specified)**

From Initiating event. Consequences that arose were Social Social unrest. The area affected was 329 843 square km.

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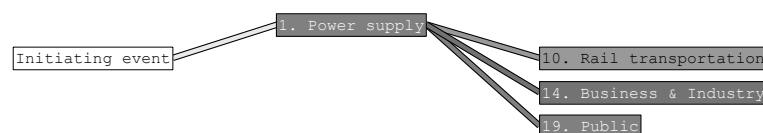
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**4.3 European Blackout, 2006****Case description:**

European Blackout 2006 occurred in the year 2006 in Europe (Germany; France; Belgium; Netherlands; Italy; Spain). The initiating event was Internal failure starting 04-Nov-2006 22:10:11 and lasted for 1 second(s), affecting an area of 315 670 square km (A routine disconnection to allow a ship pass. Insufficient communication caused overloading of lines).

**Abstract:**

In the evening of 4 November 2006 a high voltage line was switched off in Germany, allowing a ship to pass underneath. At the same time some other lines already were disconnected. Insufficient communication caused overloading of lines and resulted in a cascade of lines tripping throughout Europe. Totally 33 lines tripped, starting in Germany and then to Hungary, Austria, Ukraine, Serbia, Croatia, Romania, Spain and also Morocco. 15 million households were cut off, mainly in France but also Germany, Belgium, Netherlands, Spain and Italy. The blackout also caused long delays in rail transport, subways had to be evacuated and restaurants lost incomes.



**Figure 4.3** Impacted systems, cascade order and dependency impact from originating to impacted system. Grey scale (white 0% and black 100%) is used to illustrate system impact level (system boxes) and dependency impact level (dependency line).



**Impacted system Power supply (Sub-system Transmission)**

From Initiating event. Consequences that arose were Technical Loss of components 1 Number. The area affected was 315 670 square km during 1 hour(s) and 36 minute(s). Conditions affecting the consequences were Windy Weather with an aggravating effect (Extraordinarily high wind feed-in on that evening can be ruled out as the cause of the overloading of the Landesbergen-Wehrendorf line. [26:3]).

**Impacted system Power supply (Sub-system Transmission)**

From Originating system(s) Power supply (Sub-system Transmission). Consequences that arose were Technical Loss of components 33 Number. The area affected was 3 281 928 square km during 1 hour(s) and 36 minute(s).

**Impacted system Power supply (Sub-system Local Distribution)**

From Originating system(s) Power supply (Sub-system Transmission). Consequences that arose were Technical Loss of supply and Technical Loss of network. The area affected was 3 281 928 square km during 1 hour(s) and 36 minute(s).

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Human Loss of services 15 000 000 Households. The area affected was 3 281 928 square km during 1 hour(s) and 36 minute(s).

**Impacted system Rail transportation (Sub-system Trains)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of supply. The area affected was 315 670 square km.

**Impacted system Rail transportation (Sub-system Subway)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of supply. The area affected was 3 281 928 square km.

**Impacted system Business and industry (Sub-system Hotel & Restaurant)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Economic Indirect economic costs 139 000 000 USD. The area affected was 3 281 928 square km.

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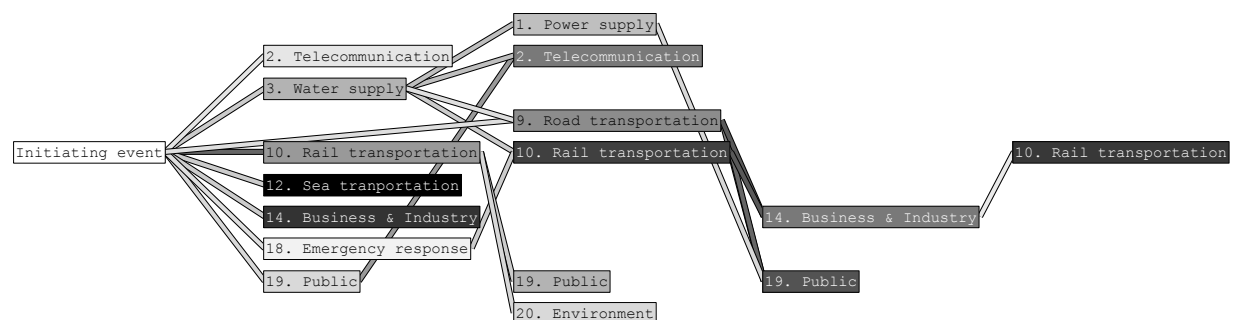
## 4.4 Baltimore tunnel fire, 1998

### Case description:

Baltimore occurred in the year 2001 in North America (USA). The initiating event was Fire starting 18-Jul-2001 15:15:00 and lasted for 4 day(s) and 15 hour(s), affecting an area of 0.31 square km (Freight train in tunnel derailed and caught fire. The load carried hazardous materials. [1:7]).

### Abstract:

In the afternoon of 18 July 2001 a freight train derailed and caught fire in Howard Street Tunnel, Baltimore. Baltimore is located in Maryland, US. As a consequence of the fire, a water main broke and flooded both the tunnel and the streets above the tunnel. Due to the flooding and the fire several roads were closed and trams, commuter trains and freight trains were disrupted and cancelled. The broken water main also knocked out electricity to 1 200 households in Baltimore and disrupted the landline telephone. The fire destroyed an Internet pipe serving some of the biggest Internet Information Service Providers in US. This caused slowdowns in parts of US, especially the east coast, and also in the US embassy in Lusaka, Zambia. Around 227 000 cubic meters of water were lost due to the water main breakage. Part of this was a human decide, since the water flooded into the tunnel and helped control the fire.



**Figure 4.4** Impacted systems, cascade order and dependency impact from originating to impacted system. Grey scale (white 0% and black 100%) is used to illustrate system impact level (system boxes) and dependency impact level (dependency line).

### Impacted system Water supply (Sub-system Not specified)

From Initiating event. Consequences that arose were Technical Loss of components 1 Number. The area affected was 0.31 square km during 1 week(s) and 3 day(s).

### Impacted system Road transportation (Sub-system Local Network)

From Originating system(s) Water supply (Sub-system Not specified). Consequences that arose were Technical Loss of components. The area affected was 0.31 square km during 1 month(s) and 2 week(s).

### Impacted system Road transportation (Sub-system Local Network)

From Originating system(s) Road transportation (Sub-system Local Network). Consequences that arose were Technical Loss of network. The area affected was 2 square km during 4 day(s) and 19 hour(s).

### Impacted system Public (Sub-system Not specified)

From Originating system(s) Road transportation (Sub-system Local Network). Consequences that arose were Human Loss of critical services. The area affected was 2 square km during 4



day(s) and 19 hour(s). Conditions affecting the consequences were Evening Timing with an aggravating effect (Rush hour) and Evening Timing with an aggravating effect (Baseball game).

**Impacted system Road transportation (Sub-system Regional Network)**

From Originating system(s) Road transportation (Sub-system Local Network). Consequences that arose were Technical Loss of network. The area affected was 212 square km during 15 hour(s) and 30 minute(s).

**Impacted system Road transportation (Sub-system Road traffic)**

From Originating system(s) Road transportation (Sub-system Local Network). Consequences that arose were Technical Loss of critical services. The area affected was 212 square km.

**Impacted system Rail transportation (Sub-system Subway)**

From Initiating event. Consequences that arose were Technical Loss of components 1 Number. The area affected was 0.01 square km during 2 day(s) and 7 hour(s).

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Rail transportation (Sub-system Subway). Consequences that arose were Human Loss of critical services. The area affected was 212 square km during 2 day(s) and 7 hour(s).

**Impacted system Rail transportation (Sub-system Trams)**

From Originating system(s) Water supply (Sub-system Not specified). Consequences that arose were Technical Loss of components. The area affected was 0.31 square km during 2 week(s) and 2 day(s).

**Impacted system Rail transportation (Sub-system Trams)**

From Originating system(s) Rail transportation (Sub-system Trams). Consequences that arose were Technical Loss of critical services 100 % and Technical Loss of network. The area affected was 13 square km during 2 week(s) and 2 day(s).

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Rail transportation (Sub-system Trams). Consequences that arose were Human Loss of critical services. The area affected was 212 square km during 2 week(s) and 2 day(s). Conditions affecting the consequences were External resources Coping capacity with a mitigating effect (Buses).

**Impacted system Rail transportation (Sub-system Trains)**

From Initiating event. Consequences that arose were Technical Loss of critical services 100 %. The area affected was 48 square km during 5 day(s) and 7 hour(s).

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Rail transportation (Sub-system Trains). Consequences that arose were Human Loss of critical services. The area affected was 212 square km during 5 day(s) and 7 hour(s). Conditions affecting the consequences were External resources Coping capacity with a mitigating effect (Buses).

**Impacted system Sea transportation (Sub-system Ports)**

From Initiating event. Consequences that arose were Technical Loss of components 1 Number. The area affected was 0.43 square km during 12 hour(s).



**Impacted system Rail transportation (Sub-system Railway network)**

From Initiating event. Consequences that arose were Technical Loss of components 1 Number. The area affected was 0.31 square km during 5 day(s) and 8 hour(s).

**Impacted system Rail transportation (Sub-system Railway network)**

From Originating system(s) Rail transportation (Sub-system Railway network). Consequences that arose were Technical Loss of critical services and Technical Loss of network. The area affected was 2499428 square km during 5 day(s) and 8 hour(s). Conditions affecting the consequences were Buffers Coping capacity with a mitigating effect (Also another freight line) and External resources Coping capacity with a mitigating effect (Help from another train company).

**Impacted system Telecommunication (Sub-system Internet)**

From Initiating event. Consequences that arose were Technical Loss of components. The area affected was 0.31 square km.

**Impacted system Telecommunication (Sub-system Internet)**

From Originating system(s) Telecommunication (Sub-system Internet). Consequences that arose were Technical Loss of critical services. The area affected was 4 689 642 square km and 0.05 square km. Conditions affecting the consequences were Buffers Coping capacity with a mitigating effect (Backup).

**Impacted system Telecommunication (Sub-system Telephone landline)**

From Originating system(s) Water supply (Sub-system Not specified). Consequences that arose were Technical Loss of components. The area affected was 0.31 square km.

**Impacted system Telecommunication (Sub-system Telephone landline)**

From Originating system(s) Telecommunication (Sub-system Telephone landline). Consequences that arose were Technical Loss of critical services. The area affected was 2 square km.

**Impacted system Business and industry (Sub-system Not specified)**

From Originating system(s) Rail transportation (Sub-system Trams) and Road transportation (Sub-system Local Network). Consequences that arose were Economic Indirect economic costs. The area affected was 2 square km during 4 day(s) and 19 hour(s). Conditions affecting the consequences were External resources Coping capacity with a mitigating effect (The train company covered some of the costs).

**Impacted system Business and industry (Sub-system Not specified)**

From Initiating event. Consequences that arose were Economic Indirect economic costs 4 500 000 USD. The area affected was 0.16 square km during 2 day(s) and 8 hour(s).

**Impacted system Public (Sub-system Not specified)**

From Initiating event. Consequences that arose were Social Social unrest. The area affected was 2 square km.

**Impacted system Telecommunication (Sub-system Telephone mobile)**

From Originating system(s) Public (Sub-system Not specified). Consequences that arose were Technical Loss of critical services. The area affected was 2 square km during 8 hour(s) and 45 minute(s).



**Impacted system Environment (Sub-system Not specified)**

Potential Effects - From Initiating event. Consequences that arose were Environmental Affected land. The area affected was 2 square km.

**Impacted system Public (Sub-system Not specified)**

Potential Effects - From Initiating event. Consequences that arose were Human Fatalities 115 People. The area affected was 2 square km.

**Impacted system Environment (Sub-system Not specified)**

Potential Effects - From Initiating event. Consequences that arose were Economic Direct economic costs 3 000 000 000 USD. The area affected was 2 square km.

**Impacted system Power supply (Sub-system Local Distribution)**

From Originating system(s) Water supply (Sub-system Not specified). Consequences that arose were Technical Loss of supply. The area affected was 212 square km.

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Human Loss of critical services 1 200 Households. The area affected was 212 square km.

**Impacted system Emergency response (Sub-system Police)**

From Initiating event. Consequences that arose were Organisational Affected organisational units. The area affected was 212 square km during 4 day(s) and 14 hour(s). Conditions affecting the consequences were External resources Coping capacity with a mitigating effect (The train company covered the costs of overtime).

**Impacted system Emergency response (Sub-system Rescue services)**

From Initiating event. Consequences that arose were Organisational Affected organisational units. The area affected was 212 square km during 4 day(s) and 15 hour(s). Conditions affecting the consequences were External resources Coping capacity with a mitigating effect (The train company covered the costs of overtime).

**Impacted system Rail transportation (Sub-system Trains)**

From Originating system(s) Emergency response (Sub-system Rescue services) and Emergency response (Sub-system Police). Consequences that arose were Economic Direct economic costs 1 300 000 USD. The area affected was 212 square km.

**Impacted system Rail transportation (Sub-system Trains)**

From Originating system(s) Business and industry (Sub-system Not specified). Consequences that arose were Economic Direct economic costs 20 000 USD. The area affected was 212 square km.

**Impacted system Water supply (Sub-system Distribution)**

From Originating system(s) Water supply (Sub-system Not specified). Consequences that arose were Technical Loss of components 227 000 Cubic meters (1 000 litres). The area affected was 0.31 square km during 4 hour(s) and 45 minute(s).

**Impacted system Rail transportation (Sub-system Trains)**

From Initiating event. Consequences that arose were Technical Release of hazardous material 19 Cubic meters (1 000 litres). The area affected was 0.31 square km.





### Impacted system Environment (Sub-system Ocean)

From Originating system(s) Rail transportation (Sub-system Trains). Consequences that arose were Environmental Affected sea. The area affected was 2 square km.

### Impacted system Public (Sub-system Not specified)

From Initiating event. Consequences that arose were Human Injuries 2 People. The area affected was 0.31 square km.

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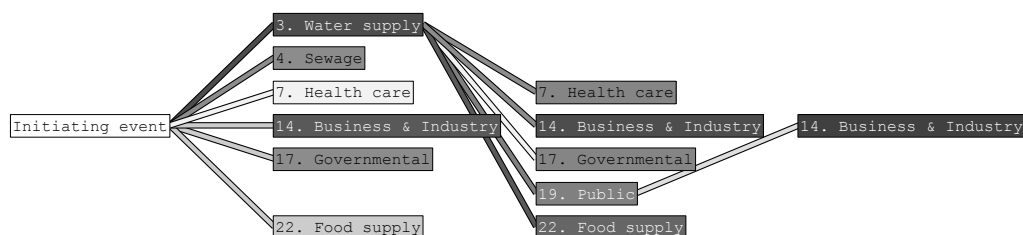
## 4.5 Östersund contamination, 2010-2011

### Case description:

Östersund occurred in the year 2010-2011 in Europe (Sweden). The initiating event was Internal failure starting 01-Nov-2010 and lasted for 1 month(s) and 2 week(s), affecting an area of 26 square km.

### Abstract:

In November 2010 the drinking water in Östersund, Sweden, was contaminated with *Cryptosporidium*. About 27 000 people became ill, which is nearly 45 % of the inhabitants of Östersund. If the water was boiled, you could drink and use it as normal and therefore the municipality early urged the inhabitants to boil their water. Many organisations were affected due to extra work with boiling water. Also some companies were affected, especially food producing companies. The tourism in Östersund decreased, affecting hotels, restaurants and trade commercial. 18 February 2011 the quality of water again was acceptable and the boiling instruction was withdrawn. The reason why the drinking water was contaminated is still unclear, but some leakages from sewage were found and repaired.



**Figure 4.5** Impacted systems, cascade order and dependency impact from originating to impacted system. Grey scale (white 0% and black 100%) is used to illustrate system impact level (system boxes) and dependency impact level (dependency line).

### Impacted system Water supply (Sub-system Distribution)

From Initiating event. Consequences that arose were Technical Loss of supply. The area affected was 2 462 square km during 3 month(s) and 1 week(s). Conditions affecting the consequences were External resources Coping capacity with a mitigating effect (UV-system from Katrineholm could be used).



**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Water supply (Sub-system Distribution). Consequences that arose were Human Injuries 27 000 People. The area affected was 2462 square km during 3 week(s) and 5 day(s). Conditions affecting the consequences were Preparedness plans Coping capacity with a mitigating effect (Recommendation to boil the water).

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Water supply (Sub-system Distribution). Consequences that arose were Human Injuries. The area affected was 7 658 square km during 3 week(s) and 5 day(s). Conditions affecting the consequences were Preparedness plans Coping capacity with a mitigating effect (Boiling recommendations in the region).

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Water supply (Sub-system Distribution). Consequences that arose were Human Injuries 20 000 People. The area affected was 52 square km. Conditions affecting the consequences were External resources Coping capacity with a mitigating effect (UV-system was installed).

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Public (Sub-system Not specified). Consequences that arose were Human Injuries 3 People. The area affected was 2 462 square km during 3 week(s) and 5 day(s).

**Impacted system Governmental (Sub-system Local)**

From Initiating event. Consequences that arose were Organisational Affected organisational units. The area affected was 26 960 square km.

**Impacted system Business and industry (Sub-system Service sector)**

From Originating system(s) Public (Sub-system Not specified). Consequences that arose were Technical Loss of services. The area affected was 2 462 square km during 2 month(s) and 6 day(s).

**Impacted system Water supply (Sub-system Not specified)**

From Initiating event. Consequences that arose were Organisational Affected organisational units. The area affected was 2 462 square km during 5 month(s) and 2 day(s). Conditions affecting the consequences were Winter Timing with an aggravating effect.

**Impacted system Sewage (Sub-system Not specified)**

From Initiating event. Consequences that arose were Organisational Affected organisational units. The area affected was 2 462 square km during 5 month(s) and 2 day(s). Conditions affecting the consequences were Winter Timing with an aggravating effect.

**Impacted system Water supply (Sub-system Not specified)**

From Initiating event. Consequences that arose were Economic Direct economic costs 6 200 000 SEK. The area affected was 2 462 square km. Conditions affecting the consequences were External resources Coping capacity with a mitigating effect (UV-system from Katrineholm could be used).

**Impacted system Food supply (Sub-system Control)**

From Initiating event. Consequences that arose were Organisational Affected organisational units and Economic Indirect economic costs 650 000 SEK. The area affected was 2 462 square km during 1 month(s) and 4 week(s).



**Impacted system Governmental (Sub-system Local)**

From Originating system(s) Water supply (Sub-system Distribution). Consequences that arose were Organisational Affected organisational units. The area affected was 2 462 square km during 2 month(s) and 4 week(s).

**Impacted system Health care (Sub-system Elderly care)**

From Originating system(s) Water supply (Sub-system Distribution). Consequences that arose were Organisational Affected organisational units. The area affected was 2 462 square km during 4 week(s) and 2 day(s). Conditions affecting the consequences were Winter Timing with a mitigating effect (Christmas, time to rest for the staff).

**Impacted system Food supply (Sub-system Processing)**

From Originating system(s) Water supply (Sub-system Distribution). Consequences that arose were Organisational Affected organisational units and Economic Indirect economic costs 250 000 SEK. The area affected was 2 462 square km during 2 week(s). Conditions affecting the consequences were External resources Coping capacity with a mitigating effect (Emergency water) and External resources Coping capacity with a mitigating effect (Extra staff).

**Impacted system Food supply (Sub-system Processing)**

From Originating system(s) Water supply (Sub-system Distribution). Consequences that arose were Economic Direct economic costs 600 000 SEK. The area affected was 2 462 square km during 2 month(s) and 3 week(s). Conditions affecting the consequences were External resources Coping capacity with a mitigating effect (Emergency water).

**Impacted system Health care (Sub-system Disease control)**

From Initiating event. Consequences that arose were Organisational Affected organisational units. The area affected was 60 622 square km during 2 month(s) and 4 week(s).

**Impacted system Health care (Sub-system Hospitals)**

From Originating system(s) Water supply (Sub-system Distribution). Consequences that arose were Organisational Affected organisational units. The area affected was 60 622 square km.

**Impacted system Health care (Sub-system Hospitals)**

From Originating system(s) Water supply (Sub-system Distribution). Consequences that arose were Economic Direct economic costs 500 000 SEK. The area affected was 60 622 square km.

**Impacted system Food supply (Sub-system Primary production)**

From Originating system(s) Water supply (Sub-system Distribution). Consequences that arose were Technical Loss of production. The area affected was 0.06 square km during 1 week(s). Conditions affecting the consequences were Buffers Coping capacity with a mitigating effect (Had already equipment).

**Impacted system Food supply (Sub-system Primary production)**

From Originating system(s) Water supply (Sub-system Distribution). Consequences that arose were Organisational Affected organisational units and Economic Indirect economic costs 2 300 000 SEK. The area affected was 0.06 square km during 1 week(s). Conditions affecting the consequences were Winter Timing with a mitigating effect (Less milk is delivered during the winter).

**Impacted system Food supply (Sub-system Primary production)**

From Originating system(s) Water supply (Sub-system Distribution). Consequences that arose were Economic Direct economic costs 511 000 SEK. The area affected was 0.06 square km



during 1 week(s). Conditions affecting the consequences were Buffers Coping capacity with a mitigating effect (Had already equipment).

**Impacted system Food supply (Sub-system Primary production)**

From Originating system(s) Water supply (Sub-system Distribution). Consequences that arose were Technical Loss of production 50 % and Economic Indirect economic costs 100 000 SEK. The area affected was 0.01 square km. Conditions affecting the consequences were Winter Timing with an aggravating effect and External resources Coping capacity with a mitigating effect (Emergency water).

**Impacted system Food supply (Sub-system Primary production)**

From Originating system(s) Water supply (Sub-system Distribution). Consequences that arose were Technical Loss of production. The area affected was 0.01 square km. Conditions affecting the consequences were Winter Timing with an aggravating effect (Before Christmas).

**Impacted system Food supply (Sub-system Primary production)**

From Originating system(s) Water supply (Sub-system Distribution). Consequences that arose were Economic Direct economic costs 18 000 SEK. The area affected was 0.01 square km.

**Impacted system Food supply (Sub-system Primary production)**

From Originating system(s) Water supply (Sub-system Distribution). Consequences that arose were Economic Indirect economic costs 297 000 SEK. The area affected was 0.01 square km.

**Impacted system Business and industry (Sub-system Hotel & Restaurant)**

From Originating system(s) Water supply (Sub-system Distribution) and Business and industry (Sub-system Tourism). Consequences that arose were Organisational Affected organisational units and Economic Indirect economic costs 15 620 000 SEK. The area affected was 2 462 square km during 2 month(s).

**Impacted system Business and industry (Sub-system Tourism)**

From Initiating event. Consequences that arose were Technical Loss of supply. The area affected was 2462 square km.

**Impacted system Business and industry (Sub-system Retail)**

From Originating system(s) Business and industry (Sub-system Tourism). Consequences that arose were Economic Indirect economic costs 30 000 000 SEK. The area affected was 2 462 square km.

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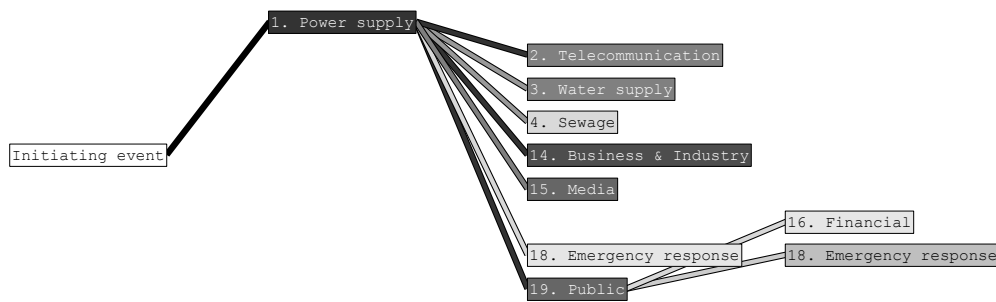
## 4.6 Kista Blackout, 2001

### Case description:

Kista Blackout occurred in the year 2001 in Europe (Sweden). The initiating event was Fire starting 11-Mar-2001 04:21:00 and lasted for 5 hour(s) and 29 minute(s), affecting an area of 0.02 square km (cable fire. The fire was out by 9:50 a.m.).

### Abstract:

The cable fire in Kista, a suburb to Stockholm, caused a major power outage for two days in March 2011, one of the largest in modern Swedish history, affecting several areas: Kista, Husby, Tensta, Rinkeby. Around 50 000-80 000 persons were affected by the outage as well as 30 000 employees that could not come to work that day. Among the hardest affected systems were the Media, all four major Swedish newspapers had troubles printing the Monday issues, and the high-tech companies situated in Kista. The outage also hit the public quite hard, the areas Rinkeby and Tensta have some the worst socio-economical situation in Stockholm which only worsened the effects.



**Figure 4.6** Impacted systems, cascade order and dependency impact from originating to impacted system. Grey scale (white 0% and black 100%) is used to illustrate system impact level (system boxes) and dependency impact level (dependency line).

### Impacted system Power supply (Sub-system Local Distribution)

From Initiating event. Consequences that arose were Technical Loss of supply 100 %. The area affected was 12 square km during 1 day(s) and 16 hour(s). Conditions affecting the consequences were Location with an aggravating effect (The backup cable was situated just a couple of centimetres from the main cable) and External resources Coping capacity with a mitigating effect (ABB cable expertise staff that happened quite fortuitously to be in Stockholm that weekend).

### Impacted system Public (Sub-system Not specified)

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of supply 30 000 People and Economic Direct economic costs 10 000 000 SEK. The area affected was 6 square km during 1 day(s) and 9 hour(s). Conditions affecting the consequences were Cold Weather with an aggravating effect (5-6 °C).

### Impacted system Public (Sub-system Not specified)

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of supply 15 600 People and Economic Direct economic costs 5 000 000 SEK. The area affected was 2 square km during 1 day(s) and 11 hour(s). Conditions affecting the consequences were Cold Weather with an aggravating effect (5-6 °C).

### Impacted system Public (Sub-system Not specified)

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of supply 34 000 People and Economic Direct economic costs 10



000 000 SEK. The area affected was 0.88 square km during 1 day(s) and 11 hour(s). Conditions affecting the consequences were Cold Weather with an aggravating effect (5-6 °C).

**Impacted system Business and industry (Sub-system Not specified)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of supply 700 Customers. The area affected was 12 square km during 1 day(s) and 11 hour(s). Conditions affecting the consequences were Weekend Timing with a mitigating effect (One of the days a Sunday, thus not a working day).

**Impacted system Water supply (Sub-system Distribution)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of supply. The area affected was 12 square km during 1 day(s) and 11 hour(s).

**Impacted system Sewage (Sub-system Storm water)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of supply. The area affected was 12 square km during 12 hour(s) and 33 minute(s).

**Impacted system Emergency response (Sub-system Rescue services)**

From Originating system(s) Public (Sub-system Not specified). Consequences that arose were Organisational Affected organisational units. The area affected was 12 square km during 1 day(s) and 11 hour(s).

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Social Social unrest. The area affected was 12 square km during 1 day(s) and 11 hour(s).

**Impacted system Telecommunication (Sub-system Telephone landline)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of supply. The area affected was 6 square km during 1 day(s) and 11 hour(s).

**Impacted system Telecommunication (Sub-system Telephone mobile)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of supply. The area affected was 128 square km during 1 day(s) and 11 hour(s).

**Impacted system Health care (Sub-system Elderly care)**

Potential Effects - From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of supply. The area affected was 12 square km during 1 day(s) and 11 hour(s). Conditions affecting the consequences were Buffers Coping capacity with a mitigating effect (Reserve power installed).

**Impacted system Financial (Sub-system Insurance)**

From Originating system(s) Public (Sub-system Not specified). Consequences that arose were Economic Direct economic costs 9 700 000 SEK. The area affected was 12 square km during 1 day(s) and 11 hour(s).



### Impacted system Emergency response (Sub-system Police)

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Organisational Affected organisational units. The area affected was 12 square km during 1 day(s) and 11 hour(s).

### Impacted system Media (Sub-system Newspapers)

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of supply and Economic Indirect economic costs 5 000 000 SEK. The area affected was 12 square km during 1 day(s) and 11 hour(s).

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- [2] Jönsson & Fischer (2005) Elavbrottet i Kista-området mars 2001 - Konsekvenser för hushåll och befolkning
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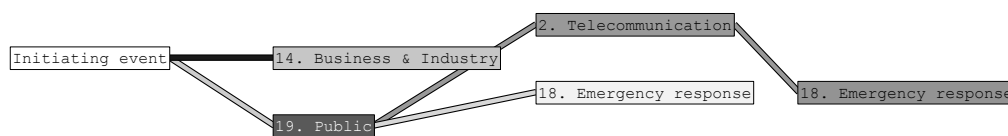
## 4.7 Myyrmanni bombing, 2002

### Case description:

Myyrmanni bombing occurred in the year 2002 in Europe (Finland). The initiating event was Physical terrorism starting 11-Oct-2002 19:36:00 and lasted for 1 second(s), affecting an area of 0.03 square km (Inside shopping mall).

### Abstract:

On the evening of 11 October 2002 a bomb detonated inside Myyrmanni shopping mall. Myyrmanni is located in Vanda near Helsinki, Finland. The bomb detonated in a crowd of spectators watching a clown performance. Seven persons were killed and 159 persons were injured, many of them children. The incident was judged as the most serious in Finland since World War II and caused social unrest, both in the Helsinki area and generally in Finland. Short after the bomb had detonated, the GSM system in the area around the shopping mall became overloaded and broke down. This partly affected the rescue service, which got problems connecting people outside the area. The break down in the GSM system also affected the hospitals, which did not receive enough information from the accident site. This resulted in poor distribution of injured between the hospitals. 400 square meters of the shopping mall were destroyed after the bombing and the costs for repairs of the shopping mall were 2 000 000 EUR.



**Figure 4.7** Impacted systems, cascade order and dependency impact from originating to impacted system. Grey scale (white 0% and black 100%) is used to illustrate system impact level (system boxes) and dependency impact level (dependency line).

### Impacted system Public (Sub-system Not specified)

From Initiating event. Consequences that arose were Human Fatalities 7 People. The area affected was 0.03 square km during 3 hour(s) and 24 minute(s). Conditions affecting the consequences were Preparedness plans Coping capacity with a mitigating effect (There were enough rescue staff and vehicles available at the scene and the patients were evacuated quickly to the hospitals. [3:379]) and Structural integrity Coping capacity with a mitigating effect (The building did not collapse. [3:379]) and Human vulnerability Coping capacity with a mitigating effect (Many of the injured were young with good physical properties).



**Impacted system Public (Sub-system Not specified)**

From Initiating event. Consequences that arose were Human Injuries 159 People. The area affected was 0.03 square km. Conditions affecting the consequences were Urban Location with a mitigating effect (Emergency service nearby and well-developed road net).

**Impacted system Public (Sub-system Not specified)**

From Initiating event and Public (Sub-system Not specified) and Public (Sub-system Not specified). Consequences that arose were Social Social unrest. The area affected was 158 square km during 1 week(s) and 3 day(s). Conditions affecting the consequences were Preparedness plans Coping capacity with an aggravating effect (Poor information about where to find more information about the incident).

**Impacted system Public (Sub-system Not specified)**

From Initiating event and Public (Sub-system Not specified) and Public (Sub-system Not specified). Consequences that arose were Social Social unrest. The area affected was 273 348 square km.

**Impacted system Telecommunication (Sub-system Telephone mobile)**

From Originating system(s) Public (Sub-system Not specified). Consequences that arose were Technical Loss of supply 100 %. The area affected was 1 square km during 1 hour(s). Conditions affecting the consequences were Urban Location with an aggravating effect (Many people wanted information).

**Impacted system Emergency response (Sub-system Rescue services)**

From Originating system(s) Telecommunication (Sub-system Telephone mobile). Consequences that arose were Organisational Affected organisational units. The area affected was 0.03 square km during 1 hour(s). Conditions affecting the consequences were Below normal capacity Operational state with an aggravating effect (Radio communication system was only available in trial version) and Below normal capacity Operational state with an aggravating effect (Radio shadow) and External resources Coping capacity with a mitigating effect (Could borrow a landline phone).

**Impacted system Emergency response (Sub-system Emergency health care)**

From Originating system(s) Telecommunication (Sub-system Telephone mobile). Consequences that arose were Organisational Affected organisational units. The area affected was 0.02 square km and 0.14 square km and 0.04 square km and 0.08 square km and 0.03 square km. Conditions affecting the consequences were Buffers Coping capacity with a mitigating effect (Cooperation between the hospitals) and Evening Timing with a mitigating effect (Health centre near shopping mall was open).

**Impacted system Business and industry (Sub-system Retail)**

From Initiating event. Consequences that arose were Technical Loss of critical services 100 %. The area affected was 0.03 square km during 2 week(s) and 4 day(s).

**Impacted system Business and industry (Sub-system Retail)**

From Initiating event. Consequences that arose were Economic Direct economic costs 2 000 000 EUR and Technical Damaged property 400 Square meter. The area affected was 0.03 square km. Conditions affecting the consequences were Buffers Coping capacity with a mitigating effect (Insurance covered most costs).

**Impacted system Emergency response (Sub-system Emergency health care)**

From Originating system(s) Public (Sub-system Not specified). Consequences that arose were Technical Loss of supply. The area affected was 660 square km. Conditions affecting the





consequences were External resources Coping capacity with a mitigating effect (Transportation of blood bags).

## References

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 [2] Socialstyrelsen (2005). Bombattentatet i köpcentrumet i Finland 2002. KAMEDO-rapport 87. Socialstyrelsen.  
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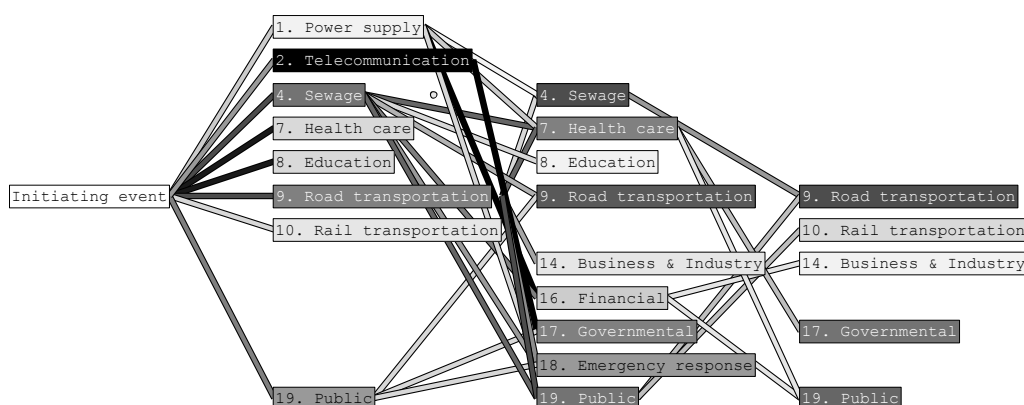
## 4.8 Malmö Flood, 2014

### Case description:

Malmö flood occurred in the year 2014 in Europe (Sweden). The initiating event was Flood starting 31-Aug-2014 and lasted for 23 hour(s), affecting an area of 92 square km (Most of Malmö affected to some extent).

### Abstract:

Malmö in south of Sweden was affected by heavy rainfall, 90-110 mm in a single day, the 31th of August 2014. The rainfall led to the city being partially flooded, which severely affected the sewage system and road transportation. These systems were also the most common originating systems, the backflow in the sewage system flooded cellars from within and the flooded roads and viaducts almost cut of the city entirely. The initial flood also affected the education system hard because of the destruction of all customized vehicles for transporting school children with special needs. An interesting phenomenon that occurred is that the public moved roadblocks and drove through the water, sometimes getting stuck and requiring help from rescue services. Other affected systems include power supply, health care, the public and more.



**Figure 4.8** Impacted systems, cascade order and dependency impact from originating to impacted system. Grey scale (white 0% and black 100%) is used to illustrate system impact level (system boxes) and dependency impact level (dependency line).

### Impacted system Power supply (Sub-system Local Distribution)

From Initiating event. Consequences that arose were Technical Loss of network 100 %. The area affected was 0.01 square km.



**Impacted system Power supply (Sub-system Local Distribution)**

From Initiating event. Consequences that arose were Technical Loss of components 1 Number. The area affected was 92 square km.

**Impacted system Sewage (Sub-system Waste water)**

From Initiating event. Consequences that arose were Technical Increased load. The area affected was 92 square km. Conditions affecting the consequences were Buffers Coping capacity with a mitigating effect (Vacation periods over).

**Impacted system Sewage (Sub-system Storm water)**

From Initiating event. Consequences that arose were Technical Loss of components. The area affected was 92 square km. Conditions affecting the consequences were Buffers Coping capacity with a mitigating effect (Vacation periods over).

**Impacted system Road transportation (Sub-system Local Network)**

From Initiating event. Consequences that arose were Technical Loss of network. The area affected was 92 square km. Conditions affecting the consequences were Weekend Timing with a mitigating effect (People stayed home, did not have to go to work).

**Impacted system Education (Sub-system Primary school)**

From Initiating event. Consequences that arose were Technical Damaged property 35 Number. The area affected was 92 square km. Conditions affecting the consequences were Buffers Coping capacity with an aggravating effect (All vehicles in the same garage) and External resources Coping capacity with a mitigating effect (Able to get some help from other municipalities and contracts with taxi firms).

**Impacted system Health care (Sub-system Elderly care)**

From Initiating event. Consequences that arose were Technical Damaged property 35 Number. The area affected was 92 square km. Conditions affecting the consequences were Buffers Coping capacity with an aggravating effect (All vehicles in the same garage) and External resources Coping capacity with a mitigating effect (Able to get some help from other municipalities and contracts with taxi firms).

**Impacted system Road transportation (Sub-system Not specified)**

Potential Effects - From Initiating event. Consequences that arose were Technical Loss of components 1 Number. The area affected was 0.01 square km. Conditions affecting the consequences were Buffers Coping capacity with a mitigating effect (2 water pumps installed in the centre).

**Impacted system Rail transportation (Sub-system Train control)**

Potential Effects - From Initiating event. Consequences that arose were Technical Loss of components 1 Number. The area affected was 0.01 square km. Conditions affecting the consequences were Buffers Coping capacity with a mitigating effect (2 water pumps installed in the centre).

**Impacted system Rail transportation (Sub-system Railway network)**

From Initiating event. Consequences that arose were Technical Loss of network. The area affected was 0.07 square km during 1 day(s).

**Impacted system Telecommunication (Sub-system Telephone landline)**

From Initiating event. Consequences that arose were Technical Loss of components 100 %. The area affected was 0.01 square km during 4 hour(s).



**Impacted system Governmental (Sub-system Local)**

From Originating system(s) Telecommunication (Sub-system Telephone landline). Consequences that arose were Organisational Affected organisational units. The area affected was 0.01 square km during 4 hour(s). Conditions affecting the consequences were External resources Coping capacity with a mitigating effect (Able to reroute critical functions to other servers) and Buffers Coping capacity with a mitigating effect (Able to call in extra personnel).

**Impacted system Public (Sub-system Not specified)**

From Initiating event. Consequences that arose were Social Social unrest. The area affected was 92 square km.

**Impacted system Public (Sub-system Not specified)**

From Initiating event. Consequences that arose were Social Mistrusting authorities. The area affected was 92 square km.

**Impacted system Water supply (Sub-system Distribution)**

Potential Effects - From Originating system(s) Sewage (Sub-system Waste water). Consequences that arose were Technical Loss of network. The area affected was 92 square km. Conditions affecting the consequences were Structural integrity Coping capacity with a mitigating effect (No sewage water managed to infiltrate water distribution (was close)).

**Impacted system District heating (Sub-system Production plants)**

Potential Effects - From Originating system(s) Sewage (Sub-system Waste water). Consequences that arose were Technical Loss of production 100 %. The area affected was 0.08 square km. Conditions affecting the consequences were External resources Coping capacity with a mitigating effect (Rescue services managed to save the plant).

**Impacted system Health care (Sub-system Hospitals)**

From Originating system(s) Sewage (Sub-system Waste water). Consequences that arose were Human Evacuated 68 People. The area affected was 0.003 square km.

**Impacted system Health care (Sub-system Hospitals)**

From Originating system(s) Sewage (Sub-system Waste water). Consequences that arose were Technical Loss of services. The area affected was 0.003 square km.

**Impacted system Health care (Sub-system Hospitals)**

Potential Effects - From Originating system(s) Sewage (Sub-system Waste water). Consequences that arose were Human Evacuated 300 People. The area affected was 0.01 square km. Conditions affecting the consequences were External resources Coping capacity with a mitigating effect (Rescue services and a local company managed to pump away enough water) and Preparedness plans Coping capacity with an aggravating effect (No premade contract with pumping-businesses) and Buffers Coping capacity with an aggravating effect (No pumps of their own).

**Impacted system Education (Sub-system Primary school)**

From Originating system(s) Sewage (Sub-system Waste water). Consequences that arose were Technical Damaged property.

**Impacted system Financial (Sub-system Insurance)**

From Originating system(s) Sewage (Sub-system Waste water). Consequences that arose were Economic Direct economic costs. The area affected was 92 square km. Conditions affecting the consequences were Preparedness plans Coping capacity with a mitigating effect (Had previous



experience with handling this type of event) and Below normal capacity Operational state with an aggravating effect (No early warning).

**Impacted system Rail transportation (Sub-system Railway network)**

Potential Effects - From Originating system(s) Sewage (Sub-system Waste water). Consequences that arose were Technical Loss of network. The area affected was 92 square km. Conditions affecting the consequences were Buffers Coping capacity with a mitigating effect (Pumps just barely managed to keep them free).

**Impacted system Road transportation (Sub-system Local Network)**

From Originating system(s) Sewage (Sub-system Waste water). Consequences that arose were Technical Loss of network. The area affected was 92 square km.

**Impacted system Sewage (Sub-system Waste water)**

From Originating system(s) Road transportation (Sub-system Local Network). Consequences that arose were Organisational Affected organisational units. The area affected was 92 square km.

**Impacted system Sewage (Sub-system Waste water)**

From Originating system(s) Political (Sub-system Local level). Consequences that arose were Organisational Affected organisational units. The area affected was 92 square km. Conditions affecting the consequences were External resources Coping capacity with an aggravating effect (Communication with municipality poor).

**Impacted system Sewage (Sub-system Storm water)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of components 4 Number. The area affected was 92 square km.

**Impacted system Road transportation (Sub-system Local Network)**

From Originating system(s) Sewage (Sub-system Storm water). Consequences that arose were Technical Loss of components 1 Number. The area affected was 92 square km.

**Impacted system Health care (Sub-system Elderly care)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Organisational Affected organisational units. The area affected was 0.01 square km.

**Impacted system Road transportation (Sub-system Local Network)**

From Originating system(s) Public (Sub-system Not specified). Consequences that arose were Organisational Affected organisational units. The area affected was 92 square km.

**Impacted system Health care (Sub-system Elderly care)**

From Originating system(s) Road transportation (Sub-system Local Network). Consequences that arose were Organisational Affected organisational units. The area affected was 92 square km.

**Impacted system Business and industry (Sub-system Not specified)**

From Originating system(s) Road transportation (Sub-system Local Network). Consequences that arose were Economic Increased operating costs. The area affected was 92 square km.

**Impacted system Financial (Sub-system Insurance)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Economic Indirect economic costs. The area affected was 0.01 square km.



Conditions affecting the consequences were Preparedness plans Coping capacity with a mitigating effect (Had previous experience with handling this type of event).

**Impacted system Governmental (Sub-system Local)**

From Originating system(s) Public (Sub-system Not specified). Consequences that arose were Organisational Affected organisational units. The area affected was 92 square km. Conditions affecting the consequences were Buffers Coping capacity with a mitigating effect (Extra personnel).

**Impacted system Emergency response (Sub-system Rescue services)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Organisational Affected organisational units. The area affected was 0.01 square km.

**Impacted system Emergency response (Sub-system Rescue services)**

From Originating system(s) Sewage (Sub-system Waste water). Consequences that arose were Organisational Affected organisational units. The area affected was 92 square km.

**Impacted system Emergency response (Sub-system Rescue services)**

From Originating system(s) Road transportation (Sub-system Local Network). Consequences that arose were Organisational Affected organisational units. The area affected was 92 square km. Conditions affecting the consequences were Preparedness plans Coping capacity with a mitigating effect (Rescue services have routines for dealing with this kind of event).

**Impacted system Emergency response (Sub-system Rescue services)**

From Originating system(s) Public (Sub-system Not specified). Consequences that arose were Organisational Affected organisational units. The area affected was 92 square km.

**Impacted system Emergency response (Sub-system Police)**

From Originating system(s) Public (Sub-system Not specified). Consequences that arose were Organisational Affected organisational units. The area affected was 92 square km.

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Road transportation (Sub-system Local Network). Consequences that arose were Human Loss of services. The area affected was 92 square km.

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Financial (Sub-system Insurance). Consequences that arose were Economic Indirect economic costs. The area affected was 92 square km.

**Impacted system Business and industry (Sub-system Construction)**

From Originating system(s) Financial (Sub-system Insurance). Consequences that arose were Economic Indirect economic costs. The area affected was 92 square km.

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Health care (Sub-system Elderly care). Consequences that arose were Social Social unrest. The area affected was 92 square km.

**Impacted system Governmental (Sub-system Local)**

From Originating system(s) Health care (Sub-system Primary care). Consequences that arose were Organisational Affected organisational units. The area affected was 0.01 square km.



**Impacted system Rail transportation (Sub-system Railway network)**

From Originating system(s) Public (Sub-system Not specified). Consequences that arose were Technical Increased load. The area affected was 92 square km.

**Impacted system Road transportation (Sub-system Not specified)**

From Originating system(s) Public (Sub-system Not specified). Consequences that arose were Organisational Reduced staffing. The area affected was 92 square km. Conditions affecting the consequences were Above normal capacity Operational state with a mitigating effect (Weekend project had extra personnel) and Weekend Timing with an aggravating effect (Harder to call in extra personnel on weekends).

**Impacted system Rail transportation (Sub-system Train control)**

From Originating system(s) Public (Sub-system Not specified). Consequences that arose were Organisational Reduced staffing. The area affected was 92 square km. Conditions affecting the consequences were Above normal capacity Operational state with a mitigating effect (Weekend project had extra personnel) and Weekend Timing with an aggravating effect (Harder to call in extra personnel on weekends).

**Impacted system Power supply (Sub-system Local Distribution)**

From Initiating event. Consequences that arose were Technical Loss of supply 3 600 People. The area affected was 92 square km.

**References**

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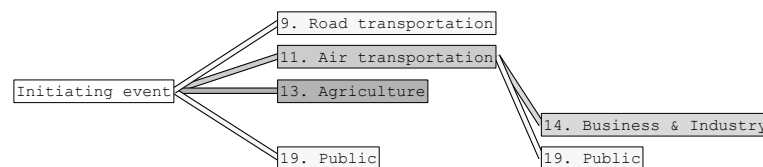
## 4.9 Eyjafjallagökull, 2010

### Case description:

Eyjafjallagökull occurred in the year 2010 in Europe (Iceland, Northern Europe). The initiating event was Volcano starting 14-Apr-2010 01:00:00 and lasted for 5 week(s) and 3 day(s), affecting an area of 49 square km (Started in the early hours of 14 April 2010).

### Abstract:

Some hours after midnight between 13 April and 14 April volcano Eyjafjallagökull, located in the south east of Iceland, had an eruption. The eruption ended the 5th of May, around 23.00. A small part of Iceland, south east of Eyjafjallagökull, was affected by the ash from the eruption. Mainly agriculture and roads were affected, but there were no huge impact. Air traffic was affected by the ash, especially since there was wind blowing towards Europe. Air traffic in Europe was affected from the 14th April until the 22nd April, with a loss of 80% of the air traffic at most. This resulted in problems in air traffic all around the world. Since there were delays and cancellations in air traffic also businesses were impacted, mostly export of crops and flowers and industries with "just-in-time" deliveries.



**Figure 4.9** Impacted systems, cascade order and dependency impact from originating to impacted system. Grey scale (white 0% and black 100%) is used to illustrate system impact level (system boxes) and dependency impact level (dependency line).

### Impacted system Air transportation (Sub-system Airplane traffic)

From Initiating event. Consequences that arose were Technical Loss of services 80 % and Economic Indirect economic costs. The area affected was 13 083 806 square km during 1 week(s). Conditions affecting the consequences were Windy Weather with an aggravating effect (Relative stable winds blowing ash towards Europe).

### Impacted system Agriculture (Sub-system Crops)

From Initiating event. Consequences that arose were Technical Damaged property. The area affected was 1 108 square km. Conditions affecting the consequences were Summer Timing with an aggravating effect (May is one of the driest months and also the time when farmers prepares the fields).

### Impacted system Agriculture (Sub-system Cattle)

From Initiating event. Consequences that arose were Technical Damaged property. The area affected was 1 108 square km.

### Impacted system Public (Sub-system Not specified)

From Initiating event. Consequences that arose were Human Injuries. The area affected was 1108 square km. Conditions affecting the consequences were Buffers Coping capacity with a mitigating effect (Stockpiled facemasks) and Structural integrity Coping capacity with a mitigating effect (Homes in Iceland are well sealed against the cold and so infiltration of ash is low. [1:6]).



**Impacted system Road transportation (Sub-system Regional Network)**

From Initiating event. Consequences that arose were Technical Loss of network. The area affected was 1 108 square km. Conditions affecting the consequences were Preparedness plans Coping capacity with a mitigating effect (Already prepared for similar incidents).

**Impacted system Business and industry (Sub-system Export)**

From Originating system(s) Air transportation (Sub-system Airplane traffic). Consequences that arose were Economic Indirect economic costs 21 000 000 USD and Human Loss of jobs 5 000 Number and Technical Loss of components. The area affected was 606233 square km.

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Air transportation (Sub-system Airplane traffic). Consequences that arose were Human Loss of services 7 000 000 People and Economic Indirect economic costs 2 600 000 000 USD. The area affected was 95 985 818 square km during 1 week(s).

**Impacted system Air transportation (Sub-system Airplane traffic)**

From Originating system(s) Air transportation (Sub-system Airplane traffic). Consequences that arose were Technical Loss of supply. The area affected was 95985818 square km during 1 week(s).

**Impacted system Business and industry (Sub-system Tourism)**

Potential Effects - From Originating system(s) Air transportation (Sub-system Airplane traffic). Consequences that arose were Economic Indirect economic costs 4 200 000 000 USD. The area affected was 95 985 818 square km.

**Impacted system Business and industry (Sub-system Tourism)**

From Originating system(s) Air transportation (Sub-system Airplane traffic). Consequences that arose were Economic Indirect economic costs 1 600 000 000 USD. The area affected was 95 985 818 square km. Conditions affecting the consequences were Above normal capacity Operational state with a mitigating effect (Stranded passengers spend monies in hotels and restaurants) and External resources Coping capacity with a mitigating effect (Tourists found alternative means of transportation).

**Impacted system Business and industry (Sub-system Export)**

From Originating system(s) Air transportation (Sub-system Airplane traffic). Consequences that arose were Economic Indirect economic costs 3 000 000 USD. The area affected was 10 600 127 square km.

**Impacted system Business and industry (Sub-system Construction)**

From Originating system(s) Air transportation (Sub-system Airplane traffic). Consequences that arose were Economic Indirect economic costs 112 000 000 USD. The area affected was 311 942 square km.

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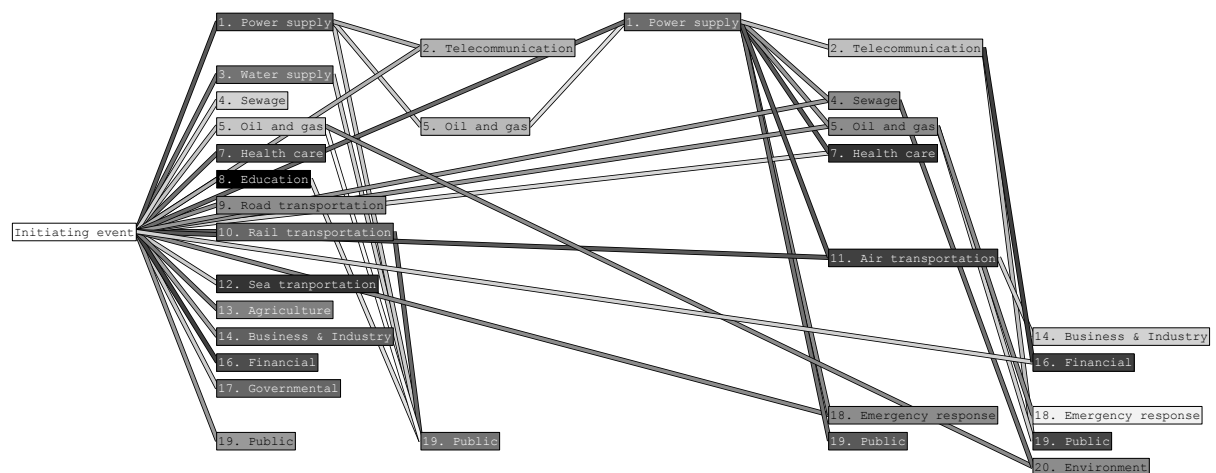
## 4.10 Hurricane Sandy, 2012

### Case description:

Sandy occurred in the year 2012 in North America (US; Canada; Jamaica; Haiti; Dominican Republic; Bahamas; Cuba; Puerto Rico; Bermuda). The initiating event was Hurricane starting 22-Oct-2012 and lasted for 1 week(s) and 2 day(s), affecting an area of 4 276 750 square km.

### Abstract:

In October 2012 hurricane Sandy made three landfalls, the 24th in Jamaica, the 25th in Cuba and the 29th in the United States. 147 persons were directly killed by the hurricane, and another 50 died because of the power outage the hurricane caused. In the United States and Canada totally 9.3 million customers were without power, most of them in the United States. Around 1.3 million homes were destroyed due to the hurricane, leaving many persons homeless. The agriculture was affected, especially in the Caribbean area, and both plantations and livestock were damaged. Train services, bus tours, flights and ferry lines were cancelled and parts of both the road and the rail network were damaged. The oil and gas industry was affected as well, and there was a lack of gasoline. In some areas schools and hospitals had to close. In Washington DC the government shut down their regional buildings and in New York the stock exchange was closed for two days.



**Figure 4.10** Impacted systems, cascade order and dependency impact from originating to impacted system. Grey scale (white 0% and black 100%) is used to illustrate system impact level (system boxes) and dependency impact level (dependency line).

### Impacted system Public (Sub-system Not specified)

From Initiating event. Consequences that arose were Human Fatalities 147 People. The area affected was 4 276 750 square km.

### Impacted system Public (Sub-system Not specified)

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Human Fatalities 50 People. The area affected was 1 779 120 square km.

### Impacted system Power supply (Sub-system Transmission)

From Initiating event. Consequences that arose were Technical Loss of components. The area affected was 1 779 120 square km.



**Impacted system Power supply (Sub-system Transmission)**

From Originating system(s) Power supply (Sub-system Transmission). Consequences that arose were Technical Loss of supply. The area affected was 1 779 120 square km.

**Impacted system Power supply (Sub-system Sub-Transmission)**

From Initiating event. Consequences that arose were Technical Loss of components. The area affected was 1 779 120 square km.

**Impacted system Power supply (Sub-system Sub-Transmission)**

From Originating system(s) Power supply (Sub-system Sub-Transmission) and Power supply (Sub-system Transmission). Consequences that arose were Technical Loss of supply. The area affected was 1 779 120 square km.

**Impacted system Power supply (Sub-system Local Distribution)**

From Initiating event. Consequences that arose were Technical Loss of components. The area affected was 1 779 120 square km.

**Impacted system Power supply (Sub-system Local Distribution)**

From Originating system(s) Power supply (Sub-system Local Distribution) and Power supply (Sub-system Transmission) and Power supply (Sub-system Sub-Transmission) and Oil and gas (Sub-system Production). Consequences that arose were Technical Loss of supply. The area affected was 1 779 120 square km.

**Impacted system Power supply (Sub-system Production)**

From Initiating event. Consequences that arose were Technical Loss of production 8 Number. The area affected was 1 779 120 square km.

**Impacted system Power supply (Sub-system Not specified)**

From Initiating event. Consequences that arose were Technical Loss of components. The area affected was 1 283 576 square km.

**Impacted system Power supply (Sub-system Local Distribution)**

From Originating system(s) Power supply (Sub-system Not specified). Consequences that arose were Technical Loss of supply. The area affected was 1 283 576 square km.

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Power supply (Sub-system Local Distribution) and Power supply (Sub-system Local Distribution). Consequences that arose were Human Loss of services 9 300 000 Households. The area affected was 2 530 420 square km.

**Impacted system Power supply (Sub-system Transmission)**

From Initiating event. Consequences that arose were Technical Loss of components 41 Number. The area affected was 16 578 square km during 5 day(s).

**Impacted system Power supply (Sub-system Local Distribution)**

From Initiating event. Consequences that arose were Technical Loss of components 996 Number. The area affected was 16 578 square km during 5 day(s).

**Impacted system Power supply (Sub-system Local Distribution)**

From Originating system(s) Power supply (Sub-system Transmission) and Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of supply. The area affected was 16 578 square km during 5 day(s).



**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Human Loss of services 460 893 Households. The area affected was 16 578 square km during 5 day(s).

**Impacted system Public (Sub-system Not specified)**

From Initiating event. Consequences that arose were Technical Damaged property 1 300 000 Number. The area affected was 4 276 750 square km.

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Public (Sub-system Not specified). Consequences that arose were Human Homeless. The area affected was 4 276 750 square km.

**Impacted system Agriculture (Sub-system Not specified)**

From Initiating event. Consequences that arose were Economic Indirect economic costs. The area affected was 925 336 square km.

**Impacted system Agriculture (Sub-system Cattle)**

From Initiating event. Consequences that arose were Economic Damaged property. The area affected was 925 336 square km.

**Impacted system Agriculture (Sub-system Plantations)**

From Initiating event. Consequences that arose were Economic Damaged property. The area affected was 925 336 square km.

**Impacted system Public (Sub-system Not specified)**

From Initiating event. Consequences that arose were Human Injuries 12 000 People. The area affected was 52 464 square km.

**Impacted system Public (Sub-system Not specified)**

From Initiating event. Consequences that arose were Human Fatalities 44 People. The area affected was 52 464 square km.

**Impacted system Business and industry (Sub-system Retail)**

From Initiating event. Consequences that arose were Economic Indirect economic costs 8 300 000 000 USD. The area affected was 24 653 square km.

**Impacted system Oil and gas (Sub-system Distribution)**

From Initiating event. Consequences that arose were Technical Damaged property. The area affected was 24 653 square km.

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Oil and gas (Sub-system Distribution). Consequences that arose were Technical Damaged property. The area affected was 24 653 square km.

**Impacted system Rail transportation (Sub-system Trains)**

From Initiating event. Consequences that arose were Technical Damaged property 368 Number. The area affected was 24 square km.

**Impacted system Rail transportation (Sub-system Trains)**

From Originating system(s) Rail transportation (Sub-system Trains) and Initiating event. Consequences that arose were Technical Loss of supply. The area affected was 24 square km during 3 week(s).



**Impacted system Rail transportation (Sub-system Railway network)**

From Initiating event. Consequences that arose were Technical Loss of network. The area affected was 1 779 120 square km.

**Impacted system Rail transportation (Sub-system Trains)**

From Originating system(s) Rail transportation (Sub-system Railway network). Consequences that arose were Technical Loss of supply. The area affected was 1 779 120 square km.

**Impacted system Financial (Sub-system Stock exchange)**

From Initiating event and Telecommunication (Sub-system Telephone mobile) and Telecommunication (Sub-system Telephone landline) and Telecommunication (Sub-system Internet). Consequences that arose were Technical Loss of supply 100 %. The area affected was 381 square km during 2 day(s).

**Impacted system Agriculture (Sub-system Fishing)**

From Initiating event. Consequences that arose were Economic Direct economic costs 2 780 000 USD and Technical Damaged property. The area affected was 42 646 square km and 16 578 square km.

**Impacted system Rail transportation (Sub-system Subway)**

From Initiating event. Consequences that arose were Technical Loss of supply. The area affected was 381 square km during 4 week(s).

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Rail transportation (Sub-system Subway). Consequences that arose were Human Loss of services. The area affected was 381 square km during 4 week(s). Conditions affecting the consequences were External resources Coping capacity with a mitigating effect (Temporary shuttle bus networks).

**Impacted system Oil and gas (Sub-system Distribution)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of components 59 Number. The area affected was 1 779 120 square km. Conditions affecting the consequences were Preparedness plans Coping capacity with a mitigating effect (Only a small number of installations remained operational that had access to backup power systems. [3:200]).

**Impacted system Oil and gas (Sub-system Distribution)**

From Originating system(s) Oil and gas (Sub-system Distribution) and Oil and gas (Sub-system Refining). Consequences that arose were Technical Loss of supply. The area affected was 1 779 120 square km.

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Oil and gas (Sub-system Distribution). Consequences that arose were Human Loss of services. The area affected was 1 779 120 square km.

**Impacted system Oil and gas (Sub-system Refining)**

From Originating system(s) Power supply (Sub-system Local Distribution) and Initiating event. Consequences that arose were Technical Loss of components 9 Number. The area affected was 1 779 120 square km during 11 month(s) and 3 day(s).



**Impacted system Oil and gas (Sub-system Refining)**

From Originating system(s) Oil and gas (Sub-system Refining). Consequences that arose were Technical Loss of supply. The area affected was 1 779 120 square km during 11 month(s) and 3 day(s).

**Impacted system Oil and gas (Sub-system Refining)**

From Initiating event. Consequences that arose were Technical Release of hazardous material 2 430 Cubic meters (1 000 litres). The area affected was 1 779 120 square km.

**Impacted system Environment (Sub-system Ocean)**

From Originating system(s) Oil and gas (Sub-system Refining) and Sewage (Sub-system Waste water). Consequences that arose were Environmental Dead animals and Environmental Affected sea. The area affected was 43 835 square km.

**Impacted system Oil and gas (Sub-system Production)**

From Originating system(s) Power supply (Sub-system Not specified) and Initiating event. Consequences that arose were Technical Loss of production. The area affected was 158 745 square km.

**Impacted system Emergency response (Sub-system Not specified)**

From Originating system(s) Oil and gas (Sub-system Distribution). Consequences that arose were Technical Loss of services. The area affected was 1 779 120 square km. Conditions affecting the consequences were External resources Coping capacity with a mitigating effect (Emergency service infrastructure was less affected by gas shortages since they could rely on government resources. [3:200]).

**Impacted system Telecommunication (Sub-system Telephone mobile)**

From Initiating event and Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of components. The area affected was 1 779 120 square km.

**Impacted system Telecommunication (Sub-system Telephone mobile)**

From Originating system(s) Telecommunication (Sub-system Telephone mobile). Consequences that arose were Technical Loss of supply. The area affected was 1 779 120 square km.

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Telecommunication (Sub-system Telephone mobile). Consequences that arose were Human Loss of services. The area affected was 1 779 120 square km.

**Impacted system Telecommunication (Sub-system Telephone landline)**

From Initiating event and Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of components. The area affected was 1 779 120 square km.

**Impacted system Telecommunication (Sub-system Telephone landline)**

From Originating system(s) Telecommunication (Sub-system Telephone landline). Consequences that arose were Technical Loss of supply. The area affected was 1 779 120 square km.

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Telecommunication (Sub-system Telephone landline). Consequences that arose were Human Loss of services. The area affected was 1 779 120 square km.



**Impacted system Telecommunication (Sub-system Internet)**

From Initiating event and Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of components. The area affected was 1 779 120 square km.

**Impacted system Telecommunication (Sub-system Internet)**

From Originating system(s) Telecommunication (Sub-system Internet). Consequences that arose were Technical Loss of supply. The area affected was 1 779 120 square km.

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Telecommunication (Sub-system Internet). Consequences that arose were Human Loss of services. The area affected was 1 779 120 square km.

**Impacted system Road transportation (Sub-system Road traffic)**

From Initiating event. Consequences that arose were Technical Loss of services. The area affected was 1 779 120 square km during 1 week(s).

**Impacted system Rail transportation (Sub-system Trains)**

From Initiating event. Consequences that arose were Technical Loss of services. The area affected was 42 646 square km during 1 week(s).

**Impacted system Sea transportation (Sub-system Passenger traffic)**

From Initiating event. Consequences that arose were Technical Loss of services. The area affected was 42 646 square km during 4 day(s) and 3 hour(s).

**Impacted system Sea transportation (Sub-system Ports)**

From Initiating event. Consequences that arose were Technical Loss of services. The area affected was 1 779 120 square km and 16 578 square km.

**Impacted system Sea transportation (Sub-system Ports)**

From Initiating event. Consequences that arose were Economic Indirect economic costs 2 000 000 000 USD. The area affected was 42 646 square km.

**Impacted system Air transportation (Sub-system Airports)**

From Initiating event and Power supply (Sub-system Local Distribution). Consequences that arose were Technical Damaged property 12 Number. The area affected was 3 516 square km and 16 578 square km during 3 day(s).

**Impacted system Air transportation (Sub-system Airplane traffic)**

From Originating system(s) Air transportation (Sub-system Airports) and Initiating event and Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of services 20 700 Number. The area affected was 2 530 420 square km during 5 day(s).

**Impacted system Financial (Sub-system Insurance)**

From Initiating event. Consequences that arose were Economic Direct economic costs 30 000 000 000 USD. The area affected was 2 530 420 square km.

**Impacted system Education (Sub-system Not specified)**

From Initiating event. Consequences that arose were Technical Loss of services 3 Pupil days. The area affected was 68 080 square km during 3 day(s).

**Impacted system Business and industry (Sub-system Hotel & Restaurant)**

From Initiating event. Consequences that arose were Technical Loss of services. The area affected was 381 square km.



**Impacted system Health care (Sub-system Hospitals)**

From Initiating event and Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of services. The area affected was 42 646 square km during 2 month(s). Conditions affecting the consequences were Below normal capacity Operational state with an aggravating effect (Generators flooded).

**Impacted system Health care (Sub-system Elderly care)**

From Initiating event. Consequences that arose were Technical Loss of services. The area affected was 42 646 square km.

**Impacted system Emergency response (Sub-system Rescue services)**

From Originating system(s) Power supply (Sub-system Local Distribution) and Initiating event. Consequences that arose were Technical Loss of services. The area affected was 42 646 square km. Conditions affecting the consequences were Below normal capacity Operational state with an aggravating effect (Generators flooded in some places).

**Impacted system Emergency response (Sub-system Police)**

From Originating system(s) Power supply (Sub-system Local Distribution) and Initiating event. Consequences that arose were Technical Loss of services. The area affected was 42 646 square km. Conditions affecting the consequences were Below normal capacity Operational state with an aggravating effect (Generators flooded in some places).

**Impacted system Sewage (Sub-system Waste water)**

From Initiating event. Consequences that arose were Technical Loss of components 3 Number. The area affected was 42 646 square km.

**Impacted system Sewage (Sub-system Waste water)**

From Originating system(s) Sewage (Sub-system Waste water) and Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of supply. The area affected was 42 646 square km during 1 week(s). Conditions affecting the consequences were Below normal capacity Operational state with an aggravating effect (Generators flooded in some places) and External resources Coping capacity with a mitigating effect (Generators).

**Impacted system Sewage (Sub-system Waste water)**

From Initiating event and Power supply (Sub-system Local Distribution). Consequences that arose were Technical Release of hazardous material 41 000 000 Cubic meters (1 000 litres). The area affected was 1 779 120 square km.

**Impacted system Public (Sub-system Not specified)**

Potential Effects - From Originating system(s) Sewage (Sub-system Waste water). Consequences that arose were Human Injuries. The area affected was 1 779 120 square km.

**Impacted system Health care (Sub-system Hospitals)**

From Initiating event. Consequences that arose were Technical Loss of supply. The area affected was 16 578 square km during 23 hour(s) and 59 minute(s).

**Impacted system Health care (Sub-system Hospitals)**

From Initiating event. Consequences that arose were Economic Direct economic costs 1 500 000 USD and Technical Damaged property 59 Number and Technical Loss of components. The area affected was 16 578 square km.



**Impacted system Public (Sub-system Not specified)**

From Initiating event. Consequences that arose were Human Injuries 291 People. The area affected was 16 578 square km during 1 week(s).

**Impacted system Health care (Sub-system Child care)**

From Initiating event. Consequences that arose were Technical Damaged property 4 Number. The area affected was 16 578 square km.

**Impacted system Education (Sub-system Primary school)**

From Initiating event. Consequences that arose were Technical Damaged property 120 Number. The area affected was 16 578 square km.

**Impacted system Education (Sub-system Secondary school)**

From Initiating event. Consequences that arose were Technical Damaged property 28 Number. The area affected was 16 578 square km.

**Impacted system Education (Sub-system Primary school)**

From Initiating event. Consequences that arose were Technical Loss of supply 3 Pupil days. The area affected was 16 578 square km during 5 day(s).

**Impacted system Education (Sub-system Secondary school)**

From Initiating event. Consequences that arose were Technical Loss of supply 3 Pupil days. The area affected was 16 578 square km during 5 day(s).

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Education (Sub-system Primary school) and Education (Sub-system Secondary school). Consequences that arose were Human Loss of services 226 000 People. The area affected was 16 578 square km during 5 day(s).

**Impacted system Business and industry (Sub-system Hotel & Restaurant)**

From Originating system(s) Air transportation (Sub-system Airplane traffic). Consequences that arose were Technical Loss of supply. The area affected was 16 578 square km.

**Impacted system Water supply (Sub-system Distribution)**

From Initiating event. Consequences that arose were Technical Loss of supply. The area affected was 16 578 square km.

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Water supply (Sub-system Distribution) and Power supply (Sub-system Local Distribution). Consequences that arose were Human Loss of services 248 612 Households. The area affected was 16 578 square km during 6 day(s).

**Impacted system Telecommunication (Sub-system Not specified)**

From Originating system(s) Power supply (Sub-system Local Distribution) and Initiating event. Consequences that arose were Technical Loss of components 279 Number. The area affected was 16 578 square km during 1 month(s) and 2 week(s).

**Impacted system Public (Sub-system Not specified)**

From Initiating event. Consequences that arose were Human Loss of jobs 65 000 Number. The area affected was 68 080 square km during 4 week(s).





**Impacted system Road transportation (Sub-system Not specified)**

From Initiating event. Consequences that arose were Technical Loss of network. The area affected was 4 276 750 square km.

**Impacted system Business and industry (Sub-system Tourism)**

From Initiating event. Consequences that arose were Economic Indirect economic costs 950 000 000 USD. The area affected was 24 653 square km during 2 month(s) and 1 day(s).

**Impacted system Governmental (Sub-system Regional)**

From Initiating event. Consequences that arose were Technical Loss of supply. The area affected was 262 square km during 2 day(s).

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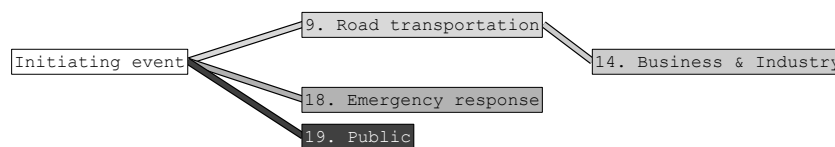
## 4.11 Mont Blanc Tunnel Fire, 1999

### Case description:

Mont Blanc occurred in the year 1999 in Europe (Italy; France). The initiating event was Fire starting 24-Mar-1999 10:46:00 and lasted for 2 day(s) and 2 hour(s), affecting an area of 16 square km.

### Abstract:

On the morning of 24 March 1999 a transport truck caught fire in the Mont Blanc Tunnel, which is one of Europe's longest road tunnel. The tunnel is under the Mont Blanc Mountain in the Alps connecting France with Italy via European route E25. Out of 50 persons in the tunnel, 39 died, including 1 fire-fighter and 1 security-guard employed by the company maintaining the tunnel. The fire resulted in the closure of the tunnel for 3 years which impacted a radius of over 300 km in central Europe from a traffic congestion point of view. The cost of repairing and renovating the Mont Blanc Tunnel was 350 000 000 Euros and the Italian Industry Association Confindustria estimated the cost of the closure of the Mt Blanc road tunnel 1999-2002 at EUR 500 million per year, for the Italian economy alone.



**Figure 4.11** Impacted systems, cascade order and dependency impact from originating to impacted system. Grey scale (white 0% and black 100%) is used to illustrate system impact level (system boxes) and dependency impact level (dependency line).

### Impacted system Road transportation (Sub-system Tunnels)

From Initiating event. Consequences that arose were Technical Loss of components 1 Number and Economic Direct economic costs 350 000 000 EUR. The area affected was 16 square km during 3 year(s) and 3 month(s).

### Impacted system Road transportation (Sub-system Not specified)

From Initiating event. Consequences that arose were Human Fatalities 1 People. The area affected was 16 square km during 2 day(s) and 2 hour(s).

### Impacted system Road transportation (Sub-system Regional Network)

From Originating system(s) Road transportation (Sub-system Tunnels). Consequences that arose were Technical Increased load 282 600 Square km. The area affected was 208 square km during 3 year(s) and 3 month(s). Conditions affecting the consequences were Location with an aggravating effect. (The tunnel is one of very few connecting France and Italy through the alps, the tunnel is one of the major trans-Alpine transport routes).

### Impacted system Emergency response (Sub-system Rescue services)

From Initiating event. Consequences that arose were Human Fatalities 1 People. The area affected was 16 square km during 2 day(s) and 2 hour(s).

### Impacted system Emergency response (Sub-system Rescue services)

From Initiating event. Consequences that arose were Human Injuries 13 People. The area affected was 16 square km during 2 day(s) and 2 hour(s).



**Impacted system Business and industry (Sub-system Not specified)**

From Originating system(s) Road transportation (Sub-system Regional Network). Consequences that arose were Economic Indirect economic costs 1 750 000 000 EUR. The area affected was 256 square km during 3 year(s) and 3 month(s). Conditions affecting the consequences were Location with an aggravating effect. (The tunnel is one of the major trans-Alpine transport routes, Italy transports as much as one-third of its freight to northern Europe through the tunnel).

**Impacted system Public (Sub-system Not specified)**

From Initiating event. Consequences that arose were Human Fatalities 37 Number. The area affected was 16 square km during 2 day(s) and 2 hour(s).

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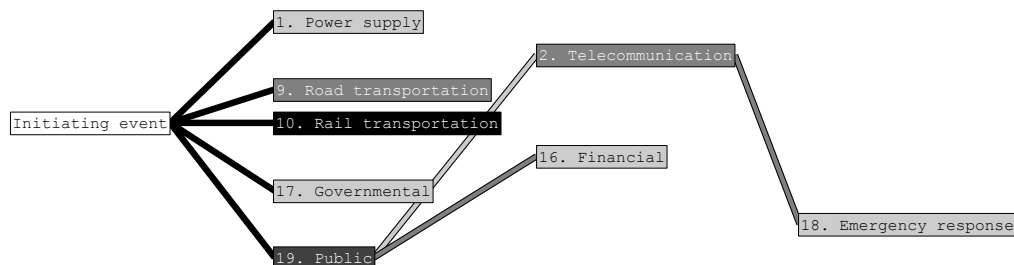
## 4.12 London bombing, 2005

### Case description:

London bombing occurred in the year 2005 in Europe (UK). The initiating event was Physical terrorism starting 07-Jul-2005 08:50:00 and lasted for 57 minute(s), affecting an area of 0.01 square km (Four separate bombings of which the first three occurred almost simultaneously at 08:50am, while the fourth one occurred at 09:47am).

### Abstract:

On the morning of 7 July 2005, a bomb exploded on an eastbound Circle Line underground train in central London. Approximately one minute later, a second bomb exploded on a westbound Circle Line train, and another two minutes later a third bomb exploded on a southbound Piccadilly Line train. Almost one hour later, a fourth bomb exploded on a bus at Tavistock Square. In total, 56 people were killed, including the four bombers, and about 700 people were injured.



**Figure 4.12** Impacted systems, cascade order and dependency impact from originating to impacted system. Grey scale (white 0% and black 100%) is used to illustrate system impact level (system boxes) and dependency impact level (dependency line).

### Impacted system Public (Sub-system Not specified)

From Initiating event. Consequences that arose were Human Fatalities 56 People. The area affected was 0.01 square km during 57 minute(s). Conditions affecting the consequences were External resources Coping capacity with a mitigating effect (Fellow passengers were the first to respond to the dead and the dying, and a number of these passengers had varying degrees of first aid training) and External resources Coping capacity with a mitigating effect (One of the bombs detonated close to a hospital where numerous medical doctors were present) and External resources Coping capacity with a mitigating effect (London's Air Ambulance was holding a clinical governance day, which enabled them to deploy 27 physicians and paramedics (compared to the normal of having one team on duty)) and Metropolitan Location with an aggravating effect (Because the first two explosions took place underground, there were very few 999 calls reporting the explosions on the trains) and External resources Coping capacity with an aggravating effect (Passengers on the three bombed trains were unable to communicate with the drivers of the trains to alert them to the explosion) and External resources Coping capacity with an aggravating effect (At Russell Square, the 'leaky feeder' cable that enables the British Transport Police's radios to function was damaged by the blast) and Metropolitan Location with an aggravating effect (At Russell Square it took long time for the emergency services to establish what had happened due to the location of the explosions) and External resources Coping capacity with an aggravating effect (As a result of the emergency services focusing on the incident at Aldgate, communications was less effective at Edgware Road (which was reported just a couple of minutes before)) and Preparedness plans Coping capacity with a mitigating effect (The emergency plans that had been put in place and exercised during the preceding months and years contributed to what was, in many respects, an outstanding response).



**Impacted system Public (Sub-system Not specified)**

From Initiating event. Consequences that arose were Human Injuries 700 People. The area affected was 0.01 square km during 1 month(s). Conditions affecting the consequences were External resources Coping capacity with a mitigating effect (Fellow passengers were the first to respond to the dead and the dying, and a number of these passengers had varying degrees of first aid training) and External resources Coping capacity with a mitigating effect (One of the bombs detonated close to a hospital where numerous medical doctors were present) and External resources Coping capacity with a mitigating effect (London's Air Ambulance was holding a clinical governance day, which enabled them to deploy 27 physicians and paramedics (compared to the normal of having one team on duty)) and Metropolitan Location with an aggravating effect (Because the first two explosions took place underground, there were very few 999 calls reporting the explosions on the trains) and External resources Coping capacity with an aggravating effect (Passengers on the three bombed trains were unable to communicate with the drivers of the trains to alert them to the explosion) and External resources Coping capacity with an aggravating effect (At Russell Square it took long time for the emergency services to establish what had happened due to the location of the explosions) and Metropolitan Location with an aggravating effect (At Russell Square it took long time for the emergency services to establish what had happened due to the location of the explosions) and External resources Coping capacity with an aggravating effect (As a result of the emergency services focusing on the incident at Aldgate, communications was less effective at Edgware Road (which was reported just a couple of minutes before)) and Preparedness plans Coping capacity with a mitigating effect (The emergency plans that had been put in place and exercised during the preceding months and years contributed to what was, in many respects, an outstanding response).

**Impacted system Public (Sub-system Not specified)**

From Initiating event. Consequences that arose were Human Mental health injuries 3 000 People. The area affected was 1 616 square km during 1 year(s) and 11 month(s). Conditions affecting the consequences were Intentional Initial event with an aggravating effect (To many people, it may have been a traumatic condition that the event was intentional).

**Impacted system Public (Sub-system Not specified)**

From Initiating event. Consequences that arose were Human Social unrest. The area affected was 1 616 square km during 1 week(s) and 3 day(s). Conditions affecting the consequences were Preparedness plans Coping capacity with an aggravating effect (Initially, it was unclear to many people how to get in contact with relatives).

**Impacted system Public (Sub-system Not specified)**

From Initiating event. Consequences that arose were Human Social unrest. The area affected was 425 765 square km during 1 month(s). Conditions affecting the consequences were Intentional Initial event with an aggravating effect (The bombers were identified as British Muslims, which caused an increased number of incidents against members of the Muslim community in the following month).

**Impacted system Public (Sub-system Not specified)**

From Initiating event. Consequences that arose were Human Social unrest. The area affected was 425 765 square km during 6 month(s) and 1 day(s). Conditions affecting the consequences were Intentional Initial event with an aggravating effect (To many people it may have been a traumatic condition that the event was intentional. In addition, new attempts to detonate bombs on the tube were made two weeks after the attacks).



**Impacted system Rail transportation (Sub-system Subway)**

From Initiating event. Consequences that arose were Technical Loss of supply 100 %. The area affected was 1 616 square km during 1 day(s). Conditions affecting the consequences were Intentional Initial event with an aggravating effect (Due to the risk of additional terrorist attacks, the entire system was shut down (which would not have been the case if the event was accidental)).

**Impacted system Road transportation (Sub-system Local Network)**

From Initiating event. Consequences that arose were Technical Loss of supply 100 %. The area affected was 1 616 square km during 5 hour(s). Conditions affecting the consequences were Intentional Initial event with an aggravating effect (Due to the risk of additional terrorist attacks, the entire system was shut down (which would not have been the case if the event was accidental)).

**Impacted system Telecommunication (Sub-system Telephone mobile)**

From Originating system(s) Public (Sub-system Not specified). Consequences that arose were Technical Increased load 1 000 %. The area affected was 1 616 square km during 13 hour(s) and 10 minute(s). Conditions affecting the consequences were Metropolitan Location with an aggravating effect (Many people potentially affected, which means that many calls were made).

**Impacted system Emergency response (Sub-system Emergency health care)**

From Originating system(s) Telecommunication (Sub-system Telephone mobile). Consequences that arose were Organisational Reduced staffing. The area affected was 0.01 square km during 3 hour(s) and 10 minute(s). Conditions affecting the consequences were External resources Coping capacity with an aggravating effect (Heavy reliance on mobile phones).

**Impacted system Governmental (Sub-system Court system)**

From Initiating event. Consequences that arose were Social Mistrusting authorities. The area affected was 425 765 square km during 8 month(s) and 3 week(s). Conditions affecting the consequences were Intentional Initial event with an aggravating effect (The controversial content of the law was proposed as a result of the terrorist attacks).

**Impacted system Financial (Sub-system Central banking system)**

From Originating system(s) Public (Sub-system Not specified). Consequences that arose were Economic Economic valuation 1 %. The area affected was 425 765 square km during 1 day(s) and 9 hour(s). Conditions affecting the consequences were Preparedness plans Coping capacity with a mitigating effect (The market values increased again on 8 July as it became clear that the damage caused by the bombings was not as great as thought initially).

**Impacted system Power supply (Sub-system Transmission)**

From Initiating event. Consequences that arose were Technical Loss of supply. The area affected was 0.01 square km during 1 hour(s). Conditions affecting the consequences were External resources Coping capacity with an aggravating effect (Darkness made it more difficult for people trapped in the tube system to evacuate and assist others).

**References**

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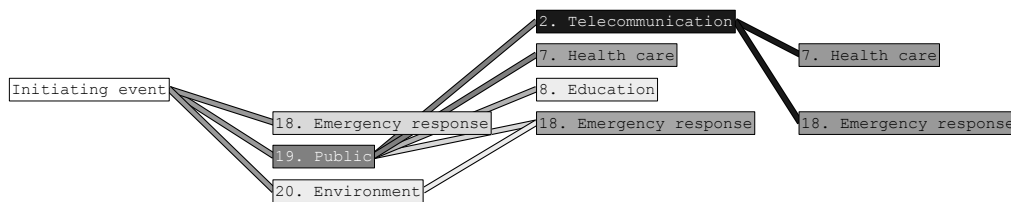
#### 4.13 Enschede firework accident, 2000

##### Case description:

Enschede firework occurred in the year 2000 in Europa (The Netherlands). The initiating event was Fire starting 13-May-2000 15:05:00 and lasted for 11 hour(s) and 45 minute(s), affecting an area of 0.84 square km (Area for explosion).

##### Abstract:

The 14th of May 2000, a fire broke out in a firework storage facility in the city of Enschede, Netherlands. Thirty minutes later, the whole facility exploded, damaging everything in an 800-meter radius. The blast killed 24 people and injured 947, including the first responders on site, which affected the early response phase. It also caused thousands of people to call their loved ones, resulting in total collapse of the phone system, further affecting the rescue operation. Asbestos as well as a damaged ammoniac tank caused uncertainty about the safety of the rescue personnel. The event put most strain on the rescue services, the telephone system and the public.



**Figure 4.13** Impacted systems, cascade order and dependency impact from originating to impacted system. Grey scale (white 0% and black 100%) is used to illustrate system impact level (system boxes) and dependency impact level (dependency line).

##### Impacted system Public (Sub-system Not specified)

From Initiating event. Consequences that arose were Human Fatalities 24 People. The area affected was 0.84 square km. Conditions affecting the consequences were Warm Weather with a mitigating effect (Fewer people in houses) and Mid-day Timing with a mitigating effect (Fewer people in houses).

##### Impacted system Public (Sub-system Not specified)

From Initiating event. Consequences that arose were Human Injuries 947 People. The area affected was 0.84 square km. Conditions affecting the consequences were Warm Weather with a mitigating effect (Fewer people in houses) and Mid-day Timing with a mitigating effect (Fewer people in houses)

##### Impacted system Public (Sub-system Not specified)

From Initiating event. Consequences that arose were Human Homeless 1 500 People. The area affected was 0.84 square km. Conditions affecting the consequences were Buffers Coping capacity with a mitigating effect (New housing found quickly).



**Impacted system Public (Sub-system Not specified)**

From Initiating event. Consequences that arose were Technical Damaged property 600 Buildings. The area affected was 0.84 square km.

**Impacted system Emergency response (Sub-system Rescue services)**

From Initiating event. Consequences that arose were Organisational Affected organisational units. The area affected was 0.28 square km during 2 day(s). Conditions affecting the consequences were Structural integrity Coping capacity with a mitigating effect (Tank intact).

**Impacted system Environment (Sub-system Not specified)**

From Initiating event. Consequences that arose were Environmental Affected land. The area affected was 0.84 square km.

**Impacted system Emergency response (Sub-system Rescue services)**

From Originating system(s) Public (Sub-system Not specified). Consequences that arose were Organisational Affected organisational units. The area affected was 0.84 square km during 1 day(s).

**Impacted system Emergency response (Sub-system Rescue services)**

From Originating system(s) Environment (Sub-system Not specified). Consequences that arose were Organisational Affected organisational units. The area affected was 0.84 square km.

**Impacted system Telecommunication (Sub-system Telephone mobile)**

From Originating system(s) Public (Sub-system Not specified). Consequences that arose were Technical Loss of supply 100 %. The area affected was 28 square km.

**Impacted system Telecommunication (Sub-system Telephone landline)**

From Originating system(s) Public (Sub-system Not specified). Consequences that arose were Technical Loss of supply 100 %. The area affected was 28 square km.

**Impacted system Health care (Sub-system Hospitals)**

From Originating system(s) Public (Sub-system Not specified). Consequences that arose were Organisational Increased load 500 %. The area affected was 0.04 square km. Conditions affecting the consequences were Below normal capacity Operational state with an aggravating effect (Renovation of operation rooms) and Preparedness plans Coping capacity with a mitigating effect (Chief medical on call was involved with development of plan).

**Impacted system Education (Sub-system Primary school)**

From Originating system(s) Public (Sub-system Not specified). Consequences that arose were Technical Loss of supply. The area affected was 28 square km during 3 year(s) and 7 month(s).

**Impacted system Health care (Sub-system Hospitals)**

From Originating system(s) Telecommunication (Sub-system Telephone landline) and Telecommunication (Sub-system Telephone mobile). Consequences that arose were Organisational Reduced staffing. The area affected was 0.04 square km. Conditions affecting the consequences were Accidental Initial event with a mitigating effect (Explosion worked as a signal for medical staff to go to work).

**Impacted system Emergency response (Sub-system Not specified)**

From Originating system(s) Telecommunication (Sub-system Telephone landline) and Telecommunication (Sub-system Telephone mobile). Consequences that arose were Organisational Affected organisational units. The area affected was 0.84 square km.





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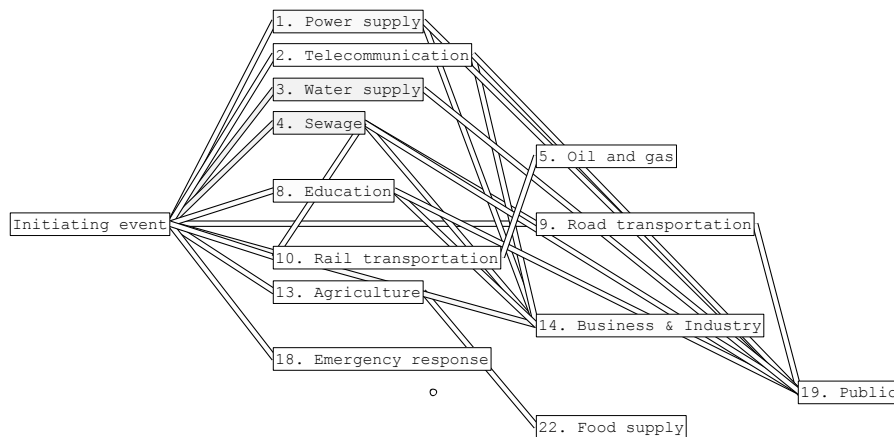
## 4.14 UK floods, 2007

### Case description:

UK floods occurred in the year 2007 in Europe (England, Wales). The initiating event was Flood starting 20-Jun-2007 and lasted for 1 month(s) and 6 day(s), affecting an area of 82 712 square km (Affected geographic area was taken from [4] p. 5, the areas with more than 2 times normal rain).

### Abstract:

The UK Floods in 2007 occurred in the summer months due to extreme rainfall during late Spring and Early Summer. The flood mainly affected three areas in England: Yorkshire and Humberside, Gloucestershire and Worcestershire, and Oxfordshire, but other areas across UK and Wales were also affected. The heavy rainfall lead to overload and discharge of surface and subsurface drainage systems as well as overtopping of river defence systems. The consequences of the event include large property damages for private housing and business, large scale disruptions of water supply (350 000 persons) and sewage services (2 600 000 persons) as well as disruptions in power supply and road and rail transportation. The consequences of the event were magnified by cascading effects such as inadequate drainage systems, loss of critical services (power, water and telecommunications) to the public and to businesses, and delays due to transportation failures.



**Figure 4.14** Impacted systems, cascade order and dependency impact from originating to impacted system. Grey scale (white 0% and black 100%) is used to illustrate system impact level (system boxes) and dependency impact level (dependency line).

### Impacted system Agriculture (Sub-system Crops)

From Initiating event. Consequences that arose were Economic Loss of production 45 000 000 GBP. The area affected was 82 712 square km during 1 month(s) and 6 day(s). Conditions affecting the consequences were Summer Timing (However, as the flooding occurred in the summer months, the impact was magnified as growing crops are more vulnerable [3:8]).

### Impacted system Agriculture (Sub-system Crops)



From Initiating event. Consequences that arose were Economic Damaged property 5 000 000 GBP. The area affected was 82 712 square km during 1 month(s) and 6 day(s). Conditions affecting the consequences were Summer Timing (However, as the flooding occurred in the summer months, the impact was magnified as growing crops are more vulnerable [3:8]).

**Impacted system Food supply (Sub-system Primary production)**

From Originating system(s) Agriculture (Sub-system Crops). Consequences that arose were Technical Increased prices. The area affected was 138 261 square km during 6 month(s) and 3 day(s).

**Impacted system Water supply (Sub-system Water treatment plants)**

From Initiating event. Consequences that arose were Technical Loss of supply 350 000 People and Economic Economic valuation 23 500 000 GBP. The area affected was 3 160 square km during 2 week(s) and 2 day(s).

**Impacted system Water supply (Sub-system Water treatment plants)**

From Initiating event. Consequences that arose were Economic Direct economic costs 164 500 000 GBP. The area affected was 3 160 square km during 2 week(s) and 2 day(s).

**Impacted system Power supply (Sub-system Local Distribution)**

From Initiating event. Consequences that arose were Technical Loss of production 13 000 MWh and Economic Economic valuation 125 000 000 GBP and Technical Loss of supply 142 000 People. The area affected was 30 931 square km during 5 day(s).

**Impacted system Power supply (Sub-system Local Distribution)**

From Initiating event. Consequences that arose were Economic Direct economic costs 13 900 000 GBP. The area affected was 30 931 square km during 5 day(s).

**Impacted system Power supply (Sub-system Local Distribution)**

Potential Effects - From Initiating event. Consequences that arose were Technical Loss of supply 500 000 People. The area affected was 30 931 square km during 5 day(s). Conditions affecting the consequences were External resources Coping capacity.

**Impacted system Sewage (Sub-system Combined Waste/Storm)**

From Initiating event. Consequences that arose were Technical Loss of supply 2 625 000 People and Economic Economic valuation 12 300 000 GBP. The area affected was 16 734 square km during 2 day(s).

**Impacted system Road transportation (Sub-system Not specified)**

From Initiating event and Sewage (Sub-system Combined Waste/Storm). Consequences that arose were Technical Damaged property 92 000 000 GBP and Economic Economic valuation 98 000 000 GBP. The area affected was 82 712 square km during 1 month(s) and 6 day(s).

**Impacted system Telecommunication (Sub-system Telephone landline)**

Telecommunication (Sub-system Telephone mobile) From Initiating event. Consequences that arose were Economic Direct economic costs 1 000 000 GBP. The area affected was 82 712 square km during 1 month(s) and 6 day(s).

**Impacted system Business and industry (Sub-system Not specified)**

From Initiating event and Sewage (Sub-system Combined Waste/Storm). Consequences that arose were Economic Direct economic costs 740 000 000 GBP. The area affected was 82 712 square km during 1 month(s) and 6 day(s). Conditions affecting the consequences were Above



normal capacity Operational state (effective flood defences saved 100 000 houses and businesses).

**Impacted system Business and industry (Sub-system Not specified)**

From Originating system(s) Power supply (Sub-system Not specified) and Telecommunication (Sub-system Telephone landline) and Telecommunication (Sub-system Telephone mobile). Consequences that arose were Technical Loss of production. The area affected was 82 712 square km during 1 month(s) and 6 day(s).

**Impacted system Emergency response (Sub-system Police)**

Emergency response (Sub-system Rescue services) From Initiating event. Consequences that arose were Economic Direct economic costs 8 000 000 GBP. The area affected was 82 712 square km during 1 month(s) and 6 day(s).

**Impacted system Education (Sub-system Not specified)**

From Initiating event. Consequences that arose were Technical Loss of production 400 000 Pupil days and Technical Loss of supply 170 000 People and Economic Economic valuation 9 000 000 GBP. The area affected was 82 712 square km during 1 month(s) and 6 day(s).

**Impacted system Education (Sub-system Not specified)**

From Initiating event. Consequences that arose were Economic Direct economic costs 40 000 000 GBP. The area affected was 82 712 square km during 1 month(s) and 6 day(s).

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Road transportation (Sub-system Not specified). Consequences that arose were Human Increased operating costs 98 000 000 GBP. The area affected was 82 712 square km during 1 month(s) and 6 day(s).

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Education (Sub-system Not specified). Consequences that arose were Human Loss of critical services 400 000 Pupil days and Human Loss of critical services 170 000 People. The area affected was 82 712 square km during 1 month(s) and 6 day(s).

**Impacted system Public (Sub-system Not specified)**

From Initiating event and Sewage (Sub-system Combined Waste/Storm). Consequences that arose were Human Fatalities 13 People and Economic Economic valuation 15 000 000 GBP. The area affected was 82 712 square km during 1 month(s) and 6 day(s).

**Impacted system Public (Sub-system Not specified)**

From Initiating event and Sewage (Sub-system Combined Waste/Storm). Consequences that arose were Human Mental health injuries 48 000 Households and Economic Economic valuation 225 000 000 GBP. The area affected was 82 712 square km during 1 month(s) and 6 day(s). Conditions affecting the consequences were Below normal capacity Operational state (More mental health issues due to badly handled in the recovery process).

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Sewage (Sub-system Waste water). Consequences that arose were Human Loss of critical services 2 625 000 People. The area affected was 16 734 square km during 2 day(s).



**Impacted system Business and industry (Sub-system Not specified)**

From Originating system(s) Education (Sub-system Primary school). Consequences that arose were Technical Loss of production. The area affected was 82 712 square km during 1 month(s) and 6 day(s).

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Power supply (Sub-system Not specified). Consequences that arose were Human Loss of critical services 42 000 Households. The area affected was 30 931 square km during 5 day(s).

**Impacted system Public (Sub-system Not specified)**

From Initiating event and Sewage (Sub-system Combined Waste/Storm). Consequences that arose were Human Direct economic costs 1 100 000 000 GBP. The area affected was 82 712 square km during 1 month(s) and 6 day(s).

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Power supply (Sub-system Not specified) and Telecommunication (Sub-system Not specified) and Water supply (Sub-system Distribution). Consequences that arose were Human Mental health injuries. The area affected was 82 712 square km during 1 month(s) and 6 day(s).

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Water supply (Sub-system Distribution). Consequences that arose were Human Loss of critical services 350 000 People. The area affected was 3 160 square km during 2 week(s) and 2 day(s).

**Impacted system Rail transportation (Sub-system Railway network)**

From Initiating event. Consequences that arose were Economic Direct economic costs 10 500 000 GBP. The area affected was 82 712 square km during 1 month(s) and 6 day(s).

**Impacted system Rail transportation (Sub-system Railway network)**

From Initiating event. Consequences that arose were Economic Economic valuation 25 600 000 GBP. The area affected was 82 712 square km during 1 month(s) and 6 day(s).

**Impacted system Oil and gas (Sub-system Distribution)**

From Originating system(s) Rail transportation (Sub-system Railway network). Consequences that arose were Technical Loss of supply. The area affected was 82 712 square km during 1 month(s) and 6 day(s).

**Impacted system Power supply (Sub-system Not specified)**

Potential Effects - From Originating system(s) Sewage (Sub-system Not specified). Consequences that arose were Technical Loss of components. The area affected was 126 square km during 1 month(s) and 6 day(s).

**Impacted system Oil and gas (Sub-system Distribution)**

Potential Effects - From Originating system(s) Sewage (Sub-system Not specified). Consequences that arose were Technical Loss of network. The area affected was 126 square km during 1 month(s) and 6 day(s).

**Impacted system Road transportation (Sub-system National Network)**

Potential Effects - From Originating system(s) Sewage (Sub-system Not specified). Consequences that arose were Technical Loss of network. The area affected was 126 square km during 1 month(s) and 6 day(s).



## References

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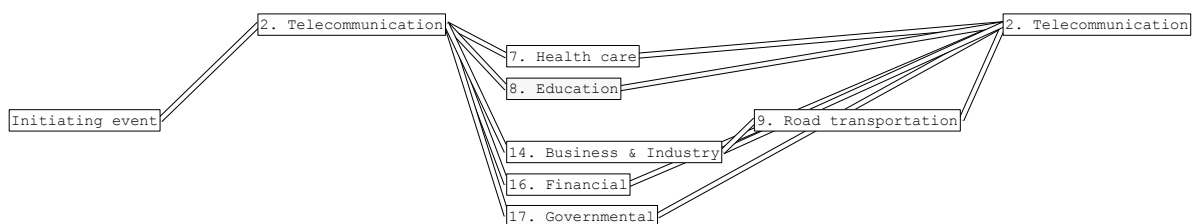
## 4.15 Tieto IT-failure, 2011

### Case description:

Tieto occurred in the year 2011 in Europe (Sweden). The initiating event was Internal failure starting 25-Nov-2011 15:00:00 and lasted for 2 day(s), affecting an area of 236 square km.

### Abstract:

Two concurring hardware failures in a server hall belonging to the IT services provider Tieto in November 2011 gave rise to momentary IT disturbances for about 50 Swedish customers, both private and public. The event took place just before a weekend which meant the IT provider could alleviate some of the problems that arose, but in spite of that many of the customers lost many of their IT services and data. Even though the hardware failure was repaired after two days many of the customers hadn't regained their services until much later, some even up to two months after the event. The main cascading effects included major problems for three municipalities (and minor problems also in additional municipalities), e.g. with financial transactions, loss of access to electronic information in secondary schools and delayed permits. In addition, the pharmacy company Apoteket AB lost their IT system for prescribed medicines, a major logistics company lost their entire IT system rendering them inoperable, the car inspection organization Bilprovningen lost their IT system which e.g. lead to many vehicles being banned although they had passed the inspection. The total consequences of the event were not significant but it shows the inherent potential of IT-related event to give broad, geographically independent consequences.



**Figure 4.15** Impacted systems, cascade order and dependency impact from originating to impacted system. Grey scale (white 0% and black 100%) is used to illustrate system impact level (system boxes) and dependency impact level (dependency line).

### Impacted system Telecommunication (Sub-system Internet)

From Initiating event. Consequences that arose were Technical Loss of supply 50 Customers. The area affected was 236 square km during 2 day(s). Conditions affecting the consequences were Weekend Timing with a mitigating effect.

### Impacted system Health care (Sub-system Medicine and material supply)

From Originating system(s) Telecommunication (Sub-system Internet). Consequences that arose were Technical Affected organisational units 1 Number and Technical Increased operating costs 350 Buildings. The area affected was 481 365 square km during 4 day(s) and 21 hour(s).



Conditions affecting the consequences were External resources Coping capacity with a mitigating effect and Buffers Coping capacity with a mitigating effect (Apoteket AB could partially restore an older system and use supplementary manual routines).

**Impacted system Health care (Sub-system Medicine and material supply)**

From Originating system(s) Telecommunication (Sub-system Internet). Consequences that arose were Technical Affected organisational units 2 Number. The area affected was 481 365 square km during 6 day(s) and 21 hour(s).

**Impacted system Financial (Sub-system Central banking system)**

From Originating system(s) Telecommunication (Sub-system Internet). Consequences that arose were Technical Loss of services 1 Number and Technical Affected organisational units 1 Number. The area affected was 481 365 square km during 4 day(s) and 21 hour(s). Conditions affecting the consequences were Weekend Timing with an aggravating effect.

**Impacted system Financial (Sub-system Credit cards)**

From Originating system(s) Telecommunication (Sub-system Internet). Consequences that arose were Technical Loss of production and Technical Affected organisational units 1 Number. The area affected was 481 365 square km during 2 day(s) and 21 hour(s). Conditions affecting the consequences were Buffers Coping capacity with a mitigating effect (the company is saved by backup copies and can relatively quickly resume normal operations).

**Impacted system Business and industry (Sub-system Service sector)**

From Originating system(s) Telecommunication (Sub-system Internet). Consequences that arose were Technical Loss of services and Technical Affected organisational units 1 Number. The area affected was 481 365 square km during 2 month(s). Conditions affecting the consequences were Preparedness plans Coping capacity with a mitigating effect.

**Impacted system Business and industry (Sub-system Service sector)**

From Originating system(s) Telecommunication (Sub-system Internet). Consequences that arose were Technical Affected organisational units 1 Number and Technical Loss of services 180 Buildings and Economic Increased operating costs. The area affected was 481 365 square km during 1 week(s) and 2 day(s).

**Impacted system Financial (Sub-system Financial transactions)**

From Originating system(s) Telecommunication (Sub-system Internet). Consequences that arose were Technical Affected organisational units 3 Number. The area affected was 1 303 square km during 2 week(s) and 5 day(s). Conditions affecting the consequences were Weekend Timing with an aggravating effect.

**Impacted system Education (Sub-system Secondary school)**

From Originating system(s) Telecommunication (Sub-system Internet). Consequences that arose were Organisational Loss of production 6 000 People. The area affected was 69 square km during 2 week(s) and 3 day(s).

**Impacted system Governmental (Sub-system Local)**

From Originating system(s) Telecommunication (Sub-system Internet). Consequences that arose were Technical Loss of production and Economic Increased operating costs. The area affected was 69 square km during 2 week(s) and 5 day(s).



**Impacted system Governmental (Sub-system Local)**

From Originating system(s) Telecommunication (Sub-system Internet). Consequences that arose were Economic Increased operating costs 7 500 000 SEK. The area affected was 105 square km during 2 week(s) and 5 day(s).

**Impacted system Education (Sub-system Secondary school)**

From Originating system(s) Telecommunication (Sub-system Internet). Consequences that arose were Technical Loss of services 1 Number. The area affected was 236 square km during 5 day(s) and 17 hour(s).

**Impacted system Road transportation (Sub-system Not specified)**

From Originating system(s) Business and industry (Sub-system Service sector). Consequences that arose were Technical Loss of services. The area affected was 481 365 square km.

**Impacted system Health care (Sub-system Not specified)**

From Originating system(s) Health care (Sub-system Medicine and material supply). Consequences that arose were Technical Loss of services. The area affected was 481 365 square km.

**Impacted system Telecommunication (Sub-system Internet)**

From Originating system(s) Health care (Sub-system Not specified) and Financial (Sub-system Not specified) and Education (Sub-system Secondary school) and Governmental (Sub-system Local) and Road transportation (Sub-system Not specified) and Business and industry (Sub-system Service sector). Consequences that arose were Economic Direct economic costs 45 000 000 SEK. The area affected was 481 365 square km during 1 month(s) and 5 day(s).

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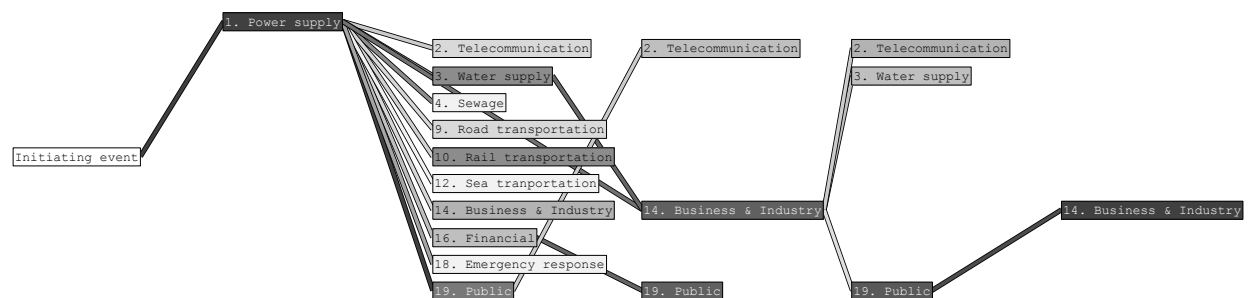
## 4.16 Auckland power outage, 1998

### Case description:

Auckland occurred in the year 1998 in Oceania (New Zealand). The initiating event was Internal failure starting 20-Jan-1998 and lasted for 1 month(s) and 4 day(s), affecting an area of 2 square km.

### Abstract:

In 20 January 1998 two out of four electric cables connected to Auckland Central Business District, New Zealand, was temporary disconnected due to damage. Two days later, in January 22, one of the four cables is damaged, and the 9th of February a second cable is damaged. The 19th February the third cable is damaged and the 20th the fourth cable is overheated and breaks. This resulted in no power incoming to the Central Business District, except from a 22kV cable with a capacity of 40MW compared to the former capacity of 285MW, until the 27th of March. The power outage had consequences for both public and businesses, leaving them without power for almost five weeks. Since there was no power supply water pumps didn't work, affecting the water supply in high buildings. Also the telecommunication system was affected and the mobile system had problems with their capacity. Many people and businesses moved during the crisis, resulting in fewer customers in the restaurants, service and retail businesses that stayed in the area.



**Figure 4.16** Impacted systems, cascade order and dependency impact from originating to impacted system. Grey scale (white 0% and black 100%) is used to illustrate system impact level (system boxes) and dependency impact level (dependency line).

### Impacted system Power supply (Sub-system Local Distribution)

From Initiating event. Consequences that arose were Economic Indirect economic costs 150 000 000 NZD and Technical Loss of supply. The area affected was 2 square km during 1 month(s) and 4 day(s). Conditions affecting the consequences were Summer Timing with an aggravating effect (Air-condition did not work that might have aggravated the effect) and External resources Coping capacity with an aggravating effect (Generators).

### Impacted system Public (Sub-system Not specified)

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Human Loss of services. The area affected was 2 square km during 1 month(s) and 4 day(s). Conditions affecting the consequences were Urban Location with a mitigating effect (Business area, small number of people living here) and Human vulnerability Coping capacity with a mitigating effect (Inhabitants used to similar situations).

### Impacted system Business and industry (Sub-system Retail)

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Economic Increased prices. The area affected was 632 950 square km.





**Impacted system Rail transportation (Sub-system Railway network)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of network. The area affected was 650 square km during 3 day(s).

**Impacted system Rail transportation (Sub-system Trains)**

From Originating system(s) Rail transportation (Sub-system Railway network). Consequences that arose were Technical Loss of supply. The area affected was 650 square km during 3 day(s).

**Impacted system Financial (Sub-system Central banking system)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of supply. The area affected was 2 square km. Conditions affecting the consequences were Weekend Timing with a mitigating effect (Time during the weekend to plan).

**Impacted system Water supply (Sub-system Distribution)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of components. The area affected was 2 square km.

**Impacted system Water supply (Sub-system Distribution)**

From Originating system(s) Water supply (Sub-system Distribution). Consequences that arose were Technical Loss of supply. The area affected was 2 square km.

**Impacted system Business and industry (Sub-system Not specified)**

From Originating system(s) Water supply (Sub-system Distribution) and Power supply (Sub-system Local Distribution). Consequences that arose were Organisational Affected organisational units. The area affected was 2 square km.

**Impacted system Water supply (Sub-system Not specified)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Organisational Affected organisational units. The area affected was 2 square km during 4 week(s).

**Impacted system Water supply (Sub-system Distribution)**

From Originating system(s) Business and industry (Sub-system Not specified). Consequences that arose were Technical Loss of supply. The area affected was 2 square km.

**Impacted system Public (Sub-system Not specified)**

Potential Effects - From Originating system(s) Water supply (Sub-system Distribution). Consequences that arose were Human Injuries. The area affected was 2 square km.

**Impacted system Sewage (Sub-system Waste water)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of supply. The area affected was 2 square km. Conditions affecting the consequences were Buffers Coping capacity with a mitigating effect (Backup system).

**Impacted system Telecommunication (Sub-system Not specified)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of supply. The area affected was 2 square km. Conditions affecting the consequences were Buffers Coping capacity with a mitigating effect (Generators (backup)) and Preparedness plans Coping capacity with a mitigating effect (The telephone operators were already alerted and used backup generators).



**Impacted system Telecommunication (Sub-system Telephone mobile)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Organisational Affected organisational units. The area affected was 2 square km.

**Impacted system Telecommunication (Sub-system Telephone landline)**

From Originating system(s) Business and industry (Sub-system Not specified). Consequences that arose were Technical Increased load. The area affected was 650 square km.

**Impacted system Telecommunication (Sub-system Telephone mobile)**

From Originating system(s) Public (Sub-system Not specified). Consequences that arose were Technical Increased load. The area affected was 2 square km. Conditions affecting the consequences were Buffers Coping capacity with a mitigating effect (enlarged capacity in some stations).

**Impacted system Telecommunication (Sub-system Telephone mobile)**

From Originating system(s) Telecommunication (Sub-system Telephone mobile). Consequences that arose were Technical Loss of supply. The area affected was 2 square km.

**Impacted system Emergency response (Sub-system Police)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of supply. The area affected was 2 square km during 1 hour(s). Conditions affecting the consequences were Buffers Coping capacity with a mitigating effect (Backup system).

**Impacted system Emergency response (Sub-system Police)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of supply. The area affected was 2 square km during 3 hour(s). Conditions affecting the consequences were Buffers Coping capacity with a mitigating effect (Backup system).

**Impacted system Road transportation (Sub-system Local Network)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of components 30 Number. The area affected was 2 square km. Conditions affecting the consequences were Evening Timing with a mitigating effect (During night time it's worse not having traffic lights).

**Impacted system Road transportation (Sub-system Local Network)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of supply. The area affected was 2 square km during 1 month(s) and 4 week(s). Conditions affecting the consequences were Below normal capacity Operational state with an aggravating effect (More heavy traffic than normal due to transport of fuel to generators. Also generators and material correlated to them in the streets).

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Financial (Sub-system Central banking system). Consequences that arose were Human Loss of services. The area affected was 2 square km.

**Impacted system Sea transportation (Sub-system Ports)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Technical Loss of supply. The area affected was 1 square km during 2 week(s) and 3 day(s). Conditions affecting the consequences were Preparedness plans Coping capacity with a mitigating effect (Preparedness plans were already prepared).



**Impacted system Business and industry (Sub-system Hotel & Restaurant)**

From Originating system(s) Business and industry (Sub-system Not specified) and Public (Sub-system Not specified). Consequences that arose were Technical Loss of supply and Economic Indirect economic costs. The area affected was 2 square km.

**Impacted system Business and industry (Sub-system Service sector)**

From Originating system(s) Business and industry (Sub-system Not specified) and Public (Sub-system Not specified). Consequences that arose were Technical Loss of supply and Economic Indirect economic costs. The area affected was 2 square km.

**Impacted system Business and industry (Sub-system Retail)**

From Originating system(s) Business and industry (Sub-system Not specified) and Public (Sub-system Not specified). Consequences that arose were Technical Loss of supply and Economic Indirect economic costs. The area affected was 2 square km.

**Impacted system Business and industry (Sub-system Not specified)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Organisational Reduced staffing 28 %. The area affected was 2 square km.

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Power supply (Sub-system Local Distribution). Consequences that arose were Social Social unrest. The area affected was 2 square km.

**Impacted system Public (Sub-system Not specified)**

From Originating system(s) Business and industry (Sub-system Retail) and Business and industry (Sub-system Service sector) and Business and industry (Sub-system Hotel & Restaurant). Consequences that arose were Human Loss of services. The area affected was 650 square km.

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## 5 Discussion

In this report the method to describe and characterise cascading effects in past events, as given in Deliverable 2.1, was recapitulated in Chapter 2. The method has been developed to enable the coverage of a broad range of cascading effect characteristics. The aim has further been to enable the extraction of as much relevant information as possible from written accounts of past events, and by doing so, enabling large array of subsequent ways to analyse the data. The method is developed through an iterative process, where successive applications in case studies are used to further develop and refine it.

Through the use of the method in the review of the selected cases, some alterations to the method has been made, as described in Section 2.3, in order to increase the granularity of the data gathered and better describe the uncertainties inherent in the data. By using the method to study past events it is apparent that it is not possible to retrieve all the information about the characteristics included in the method, hence giving rise to data gaps. This will have an effect for subsequent analyses of the nature, processes and patterns of cascading effects, which must be able to account for these data gaps. It is clear that written accounts often do not focus on cascading effects, but rather on the initiating event and the direct impacts, and if there is information about cascading effects there is generally not enough details provided. In Deliverable 2.1 we suggested and discussed some additional data collection methods, such as in-depth case studies using interviews and counterfactual reasoning in a workshop setting. However, due to time limitations in the CascEff project these methods will not be possible to apply within Task 2.1-2.3 and we must rely on written accounts of the events.

Although the performed reviews have strengthened our belief that the same method can be used to explore events of very different types, there are some challenges. Primarily this has to do with the balance between the level of detail and the number of pre-specified categories (e.g. concerning system consequences or sub-system categories). The purpose of categorising in the first place is to enable the comparison between different cascading effects and events. The downside of too detailed (and many) categories is that comparisons will be difficult to perform as the cascading effect for an event will be described with for that event unique categories. The downside of too coarse (and few) categories is that in many cases there will not be a category that is well-suited to described the particular consequence of interest. We have tried to find an appropriate balance between these two extremes, but it is clear that it is sometimes difficult to interpret the meaning of a particular impact that is described using the pre-specified categories and measures. Hence free-text information that describes the particular impact in detail are also stored which, to some extent, alleviates the described challenge.

We have so far identified 74 potentially relevant events involving cascading effects and of relevance for the CascEff project, see Chapter 3. Some of these will be addressed during the time until the delivery of the database in Delivery 2.3. The identification of cases aimed at covering as wide variety of cascading effects as possible in terms of e.g. types of initiating events, systems involved, spatial extent, and event duration. From these events, a sample of 16 cases was selected, thoroughly analysed, and reviewed in Chapter 4. While some challenges of applying the method in these case studies has been identified, such as the need for discussions among the analysts in order to achieve a consistent result and slight alterations to the method, the method has proven to be highly suitable for its purpose.

The data collected by applying the method to additional past events in Task 2.3 will give a sound basis for subsequent analysis of cascading effects. As stated earlier, how to analyse this data is not part of Task 2.1 to Task 2.3, but is considered to be an integral part of the CascEff project as a whole. Through systematic analyses of the data, metrics could be developed that



describes the incident and consequences that typically arise in cascading events, individual systems (e.g. coping capacity), or relationships between systems (e.g. the likelihood of cascading effects between systems). Examples include in which cascade order different systems typically are affected, the relative duration of an effect in a originating system and a dependent system, cascade rapidity in terms of how quickly effects from one system cascade to another system, and how cascading effects migrates spatially between systems.

## 6 Conclusions

The main conclusion of the present report is that by using the method, data regarding the nature, processes and patterns of cascading effects can be collected, as was illustrated through the review of selected cases in Chapter 4. Such information is argued in the CascEff project to be very valuable input to an Incident Evolution Tool and in the end for strategic emergency response of events that have the potential for cascading effects, e.g. consideration of how to prioritise different lines of action. The next step in the project, Task 2.3, will be to apply this method in further case studies from those indicated in Chapter 3. It is our current belief that our method has matured to a satisfactory level and no further methodological alterations will be made in Task 2.3.



## 7 References

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