Managing Major Disruptions in Critical Infrastructures: Resilience-based Approaches

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Claudia Martín Maldonado
Jorge Martín Solé
Managing Major Disruptions in Critical Infrastructures: Resilience-based approaches

Author(s):
Claudia Martín Maldonado
Jorge Martín Solé

Supervisor:
Henning Boje Andersen

Department of Management Engineering
Technical University of Denmark
Centrifugevej 372
DK-2800 Kgs. Lyngby
Denmark

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Thank as well to our respective families, for supporting us in all aspects of life, personal and professional.
The evolution of Critical Infrastructures (CIs) is enabling society to improve our quality of life, and thereby, we are increasingly relying on them. Major disruptions occurred during the last few years to CIs led society to have higher awareness of the need of an efficient protection. However, the increasing complexity and interconnectedness of CIs makes it very difficult to protect them from major disruptions.

This project investigates which are the classical methods of emergency management, their limitations and how dealing with crisis can be improved by implementing resilience, particularly for unforeseen events. Moreover, the main characteristics of Resilient Organisations are described, and how they can prevent, absorb and recover major disruptions in Critical Infrastructures. We analyse the Farris-Sommersted incident, which major disruption affected the rail freight sector considerably.

To do that, we interview three key decision makers from the biggest companies affected by the disruption, Banedanmark and DB Schenker. Based on the information provided by the interviewees, we identify the main resilient features that both companies have. We observe that good communication within the company and with stakeholders, and organisational learning are key aspects to continuously enhance resilience in organisations. Moreover, we conclude that while private companies may need resilience to take advantage from their competitors, public organisations should guarantee resilience for the good of society.
# TABLE OF CONTENT

Acknowledgements ......................................................................................................... 3

Abstract............................................................................................................................ 5

Table of content ............................................................................................................... 7

Abreviations .................................................................................................................. 10

1 Introduction ........................................................................................................... 11
   1.1 Overview ........................................................................................................... 11
   1.2 Critical Infrastructures ...................................................................................... 12
   1.3 Critical Infrastructures’ protection .................................................................... 13
   1.4 Terminology: From Incident to catastrophes ................................................... 16
   1.5 Research approach ............................................................................................ 18

2 State of the art ........................................................................................................ 21
   2.1 Getting to resilience .......................................................................................... 21
   2.2 Crisis/Emergency management ........................................................................ 23

3 Introduction to Resilience ..................................................................................... 27
   3.1 From ‘bounce back’ to adaptation ..................................................................... 28
   3.2 Resilient Domains ............................................................................................ 29
   3.3 Synergy and Capabilities .................................................................................. 30
   3.4 Resilience lifecycle steps – Resilience via Crisis Management ......................... 31

4 Resilience in Critical Infrastructures .................................................................. 33
   4.1 Characteristics of Resilient CIs ........................................................................ 33
   4.2 Policies towards more resilient Critical Infrastructures .................................... 34

5 Resilience in Organisations ................................................................................... 37
   5.1 Highly Reliable Organizations (HRO) .............................................................. 37
   5.2 Adaptability and Awareness ............................................................................ 39
   5.3 Why is Resilience essential? ............................................................................ 42

6 Case Study .............................................................................................................. 45
   6.1 Transport .......................................................................................................... 45
   6.2 Railway: the most efficient solution .................................................................. 45
   6.3 Railway in Denmark: Current situation ............................................................ 48
6.4 Farris - Sommersted incident.................................................................50

7 Conclusion...............................................................................................71

References ...................................................................................................73

A Importance of national and local Governments to Ensure Resilience..........81

B Railways in Denmark .................................................................................85

C ERTMS: Boosting the use of Rail Through Europe.....................................87

D Banedanmark Maintenance Services ........................................................91

E Settlement of freight traffic.........................................................................93

F Interview Questions ....................................................................................97

G Interview Summaries ..................................................................................99

FIGURES

Figure 1: Examples of infrastructure interdependencies (Rinaldi, Peerenboom & Kelly, 2001) ........................................................................15

Figure 2: Terminology based on (Labaka, 2013)..........................................17

Figure 3: Added benefits for Critical Infrastructure Resilience Approach.
Based on (Wheatley & Barnes, 2013)............................................................25

Figure 4: Synergy of Hard and Soft Resilience (Kahan et al., 2009). ...............30

Figure 5: Relationship among crisis management phases and resilience
lifecycle stages. Based on (Labaka, 2013).......................................................31

Figure 6: Sequence of the Resilient Fundamental Properties. Based on the
sequence of the NIAC Resilience Construct (Berkeley III & Wallace, 2010) ....34

Figure 7: Relation between elements of Resilience .......................................43

Figure 8: Comparison of the unit shipping costs for the specific cargo (€/ ton-
kilometer). Data from (Bína, 2014). ..............................................................47

Figure 9: Domestic freight transport divided by type of transport (DMOT, 2012). 48

Figure 10: International transport goods by transport type (DMOT, 2012) .......48

Figure 11: Transport corridors in Denmark (DMOT, 2012)..............................49

Figure 12: Railways in Syddanmark, Denmark. (Banedanmark a).................51

Figure 13: Gantt chart of the Farris incident. ..................................................53
Introduction

Figure 14: Alternative routes ........................................................................................................ 54
Figure 15: Railways in Denmark. (Banedanmark a) ................................................................. 85
Figure 16: ERTMS trackside contracts – In percentage, by region (ERTMS, 2014 j) ............... 88
Figure 17: Global ERTMS contracted tracks (Km) in Europe (ERTMS, 2014 j) ................. 89
Figure 18: Maintenance Services. (Banedanmark c) ............................................................... 91

TABLES

Table 1: Comparison between resilience expressed as bounce back or adaptation. (Giroux & Prior, 2012). ................................................................. 28
Table 2: Dimensions and policies of Resilience. Based on: Labaka, 2013; Wheatley & Barnes, 2013. ................................................................................................. 35
Table 3: Resilience sub-policies. (Adapted from Labaka, 2013) ........................................ 36
Table 4: Presence of Resilience Characteristics in Banedanmark before the Farris incident .................................................................................................................... 58
Table 5: Presence of Resilience Characteristics in Banedanmark after applying the lessons learnt. ........................................................................................................ 59
Table 6: Resilience Sub-Policies in Banedanmark .................................................................. 61
Table 7: Presence of Resilience Characteristics in DB Schenker before the Farris incident ..................................................................................................................... 65
Table 8: Presence of Resilience Characteristics in DB Schenker after applying the lessons learnt. ......................................................................................................... 66
Table 9: Resilience Sub-Policies in DB Schenker ..................................................................... 68
# ABREVIATIONS

<table>
<thead>
<tr>
<th>Abreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATM</td>
<td>Air Traffic Management</td>
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<tr>
<td>BC</td>
<td>Business Continuity</td>
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<td>CI</td>
<td>Critical Infrastructure</td>
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<tr>
<td>CP</td>
<td>Contingency Plan</td>
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<tr>
<td>EC</td>
<td>European Commission</td>
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<td>ECI</td>
<td>European Critical Infrastructure</td>
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<td>ERTMS</td>
<td>European Railway Traffic Management System</td>
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<td>EU</td>
<td>European Union</td>
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<tr>
<td>HRO</td>
<td>High Reliable Organisation</td>
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<tr>
<td>HRT</td>
<td>High Reliability Theory</td>
</tr>
<tr>
<td>ICT</td>
<td>Information and Communication Technology</td>
</tr>
<tr>
<td>ISO</td>
<td>International Organization for Standaization</td>
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<tr>
<td>NAT</td>
<td>Normal Accident Theory</td>
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<td>NIAC</td>
<td>National Infrastructure Advisory Council</td>
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<td>SMS</td>
<td>Safety Management System</td>
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This chapter reflects the general overview of the problem to which this research aims to approach. Nowadays, societies have a high demand of quality living standards. These standards are highly related to an optimal performance of Critical Infrastructures (CIs). Therefore, CIs must be reliable and protected from hazardous events.

1.1 Overview

In recent decades, the welfare of society has increased exponentially in almost every country throughout the world. Quality in areas such as economy, political stability, safety, health infrastructures, etc. are not only wanted but also required. The vast majority of the population needs electricity, transport, water supply and communications to function properly. Critical Infrastructures (CIs) provide these services, and societies have become increasingly dependent on them. Therefore, they should be reliable as major disruptions can cause severe impacts on communities.

Disturbances in CIs can vary from a regional power outage causing congestion in a nearby power line that results in a national power outage to a major event such as an environmental disaster. Causing the complete loss of assets of even loss of life. Undoubtedly, such disruptions may lead to great inconvenience for industries and what is worse, loss of life, assets or vital services for citizens, e.g. health services to the frail and the elderly people.

Interdependency between CIs adds complexity to crises. This interdependency and interconnection makes it so that when a disruption occurs, the negative effect is not only in the focus of the CI but also can affect other important infrastructures of a country or neighboring countries. Hence, interconnectedness between the elements makes it difficult to predict how a crisis will evolve and what the outcome will be, which is known as the “cascading effect”.

Many disruptive events cannot be prevented but national policies or frameworks can prepare a country for unavoidable disruptive events. The level of protection and resilience
in developed and developing countries will change the consequences dramatically. Developing countries are more vulnerable as the infrastructures have poorer quality. Therefore, these are more susceptible to any type of natural hazard. For instance, the 7.3 magnitude earthquake in Kathmandu, Nepal (April, 2015) caused around 8000 deaths with the complete destruction of most of the buildings as the structure of the buildings was very weak. On the other hand, developed countries are more vulnerable to other attacks such as cyberattacks or terrorism.

When organizations manage public infrastructures and there is a disturbance several stakeholders can suffer the consequences. Supply chain gaps, shortages in raw materials, or loss of customers are some of the problems that can originate. The ability of organizations to keep operating in times of crisis is a significant requirement. Furthermore, it will provide reliability and confidence from the customers towards the organization. Despite this, many organizations are found to be inadequately prepared to manage an unexpected disturbance.

### 1.2 Critical Infrastructures

The term *infrastructure* is defined as:

“the basic physical and organisational structures and facilities (e.g. buildings, roads, and power supplies) needed for the operation of a society or enterprise”. ([OED](https://www.oed.com))

A *Critical Infrastructure* can be defined as:

“an asset, system and network, physical or virtual, which is essential for the maintenance of vital societal functions, health, safety, security, economy, or any combination thereof. The destruction of which would have a debilitating effect in a community as a result of the failure to maintain those functions” (EU Commission, 2008; Department of Homeland Security, 2013)

Critical Infrastructures help to enhance the advantages of societies providing electricity, water, heating, and different basic needs (Laperrouza, 2009). Furthermore, one of the key factors to become a developed country is to enhance and maintain an advanced system of infrastructures (Baldoni et al., 2014).
The European Union defines *European Critical Infrastructures* (ECIs) as:

"Critical Infrastructure located in Member States the disruption or destruction of which would have a significant impact on at least two Member States. The significance of the impact shall be assessed in terms of cross-cutting criteria. This includes effects resulting from cross-sector dependencies on other types of infrastructure." *(European Commission, 2008).*

The EU makes a distinction between four CI of European Dimension: the elected cases cover the transport, space and energy Sectors *(European Commission, 2013);*

- Eurocontrol: is designated to manage around 30000 flights every day through the EU Air Traffic Management (ATM)
- Galileo: European satellite navigation system
- Electricity transmission grid and
- Gas transmission network.

Those dimensions were selected because a disruption in one of them can affect directly to other Member States. *(European Commission, 2013).*

On the other hand, the United States has developed a more specific list of CIs sectors, with the aim of having different strategies in case any disruption occurs. The CIs are divided according to: Chemical, Commercial facilities, Communications, Critical manufacturing, Dams, Defence industrial base, Emergency services and Energy *(Department of Homeland Security, 2013).*

Many of these sectors can be included in the classification that makes the EU, but with the US division system, it is easier to see how society can be affected if one of these services fail. It is also possible to appreciate that CIs can be negatively influenced not only by physical injuries, but also by cybernetic attacks *(Brown, 2006; Ten et al., 2010; Baldoni et al., 2014)* The evolution of technology and the dependence on Internet have made that a CI can be damaged through the Internet, i.e. hacked. Companies and organizations must consider this point and must be continuously developing Security Systems for the CIs *(Ten et al., 2010)*

### 1.3 Critical Infrastructures’ protection

Critical infrastructures are linked to civilization since its inception. Important harbours and roads helped cities to develop thanks to the ease citizens had when trading. Therefore any disturbance in these infrastructures could cause a slowdown of the progress *(Brown, 2006).* That is why protection of CI has been an important issue from many centuries ago. Nevertheless, emergency plans did not appear until modern times *(Brown, 2006).*
It was not until important accidents such as Bhopal in 1984 (BBCa) and Chernobyl (BBCb) two years after, that organizations became aware of the need of emergency plans (Labaka, 2013). Those disasters revealed many deficiencies in CIs around the world. These weaknesses were dangerous not only for the integrity of the facilities, but also for human lives. However, the turning point that made governments have real consciousness about the need of protecting CIs was the 9/11 terrorist attack (Kendra & Wachtendorf, 2003), and Hurricane Katrina (SERT, 2014).

Emergency plans and protection measures usually detail how to solve specific problems, depending on the failure of the CI. However, once organisations have gained experience, they have learned that prevention measures are essential to avoid crises (Tveiten et al., 2012).

There are multiple threats that may cause major disruptions to Critical Infrastructures – considering major disruption as an event that results in an alteration or discontinuity of high complexity and with several components of the system involved. The threats can adopt different forms and may be unpredictable. First of all, organizations that specialize in protection of CIs should always bear in mind problems caused by natural disasters such as hurricanes, fallen trees, floods, etc. (Boin & Van Eeten, 2013).

Secondly, there are number of crises due to technological failures. These failures can be caused by poor maintenance of the system, the use of an obsolete technology, accidents or human error. To avoid these issues it is essential to carry out periodic reviews, monitoring as much as possible and have a strict control of what is done and what needs to be done (Tveiten et al., 2012).

Finally, another important aspect that organizations have to deal with are the intentional attacks, such as terrorism, against CIs. There are many reasons for these attacks: economy, religion or war among others, and traditionally have been physical injuries. But with the evolution of new technologies and the dependency society have on them, cybernetic attacks have become more recurrent.

"We weren’t blinded by the Soviet threat anymore. We were seeing these other threats. Those groups, because of our cyber dependence, now had a way of attacking the nation without ever encountering the nation’s defense forces.... You couldn’t fly a bomber at the United States without encountering a radar warning system. You couldn’t fire a missile at the United States, anywhere in the world, without encountering a space-based detection capability. You could, however, launch what we called a logic bomb. There are all kinds of names for them, but you could launch an attack, a cyber-attack, without ever encountering anything except the public switch network, the Internet, and the World Wide Web."

President’s Commission on Infrastructure Protection, Phil Lacombe
Oral History Interview (Brown, 2006)
Nowadays, due to globalization and the modernization of new technologies, interdependence and interrelation between CIs are growing considerably (Figure 1). This is generally favorable to society and economy, since it is a way of coordinating efforts of CIs in order to achieve faster the purpose of the Infrastructures (Baldoni et al., 2014). Interconnection between infrastructures and their complexity makes very difficult to have specific guidelines to follow if a crisis arises (Turner & Pidgeon 1997; Perrow, 1984). Cascading effects may cause numerous and unpredictable problems to face up making it impossible to have emergency plans for every specific crisis that can occur.

Figure 1: Examples of infrastructure interdependencies (Rinaldi, Peerenboom & Kelly, 2001)

Therefore, the protection and reliability of CIs has been a vital issue not only for governments, but also for stakeholders such as freight or electricity companies. It is essential to minimize the effect of a disruption in CIs and, if possible, prevent any possible accident or attack.

Some theories emerged because of the uncertainty caused by the complexity of the new systems and infrastructures. Normal Accident Theory (NAT) offers society the juncture to accept the uncertainty, bring resources to bear, or not use the technology (Perrow, 1984). Normal Accident Theory differs from High Reliability Theory (HRT), since the
latter points out that it is possible to avoid accidents with the correct organizational framework. Therefore, some organizations evolved to High Reliability Organizations (HRO), which offers society a challenge to move forward (Labaka, 2013).

Resilient organizations have recently emerged. Resilience frameworks do not establish plans that can solve specific problems, but they suggest a way of working, a mentality for organizations and between organizations and a way of acting with the purpose to avoid, mitigate, recover and solve problems (Boin & Van Eeten, 2013). Resilience may help systems and organisations ‘survive’ an unexpected hazard (Vugrin & Camphouse, 2011).

### 1.4 Terminology: From Incident to catastrophes.

Emergencies are abnormal situations for which the evolution of events is uncertain and if they are not properly managed they can turn into a crisis or create damage and casualties (Wybo & Lonka, 2002). Several authors (Mitroff & Anagnos, 2000; Pearson & Clair, 1998; Coleman, 2004) define Crises as a consequence of an unexpected and low probability triggering event that suddenly assails all the system causing a great (Pearson & Clair, 1998).

Incidents are defined as unexpected changes from a systems’ normal behaviour with the potential of causing a crisis. (Cooke & Rohleder, 2006). On the other hand, Perrow (Perrow, 1984) differentiates between incident and accident based on the extension of the damage and if the system is disrupted or not. If the system goes back to normality without the need of being fixed it is considered an incident. Incidents are situations that are managed by already implemented safety procedures and devices (Wybo & Lonka, 2002). However, Perrow argues that if repairing the system is necessary, given that the damage disrupts the operation of the system, it will be considered as an accident. Both, incidents and accidents are seen as Emergencies.

Crises, having a higher severity, may be distinguished into disasters and catastrophes. Disasters are defined as important disruptions of the functioning of a society or community that involve human, economic, environmental or material impacts and losses, exceeding the ability of the affected society or community to cope using its own resources. (UNISDR, 2009). On the other hand, Catastrophes are the accidents that have gone out of control and that the worst case scenario of combinations of factors have occurred (Wybo & Lonka, 2002)

Quarantelli provides six characteristics for catastrophes compared to disasters: 1) most of the structure is heavily impacted 2) local workers cannot take their usual work role 3) nearby communities cannot support with help 4) most of the functions are interrupted 5) mass media is more attracted (Quarantelli, 2005)
Figure 2: Terminology based on (Labaka, 2013)

Despite all the formal definitions, throughout the thesis we will use the term Crisis and Emergency Management indistinctly as well as emergency, crisis, catastrophe, disruption, accident, disaster, and incident interchangeably. Practitioners and researchers often make the same decision (Dugdale et al., 2009).
1.5 **Research approach**

1.5.1 **Research objectives**

The primary objective of this research is to investigate how resilience-based approaches can strengthen the management of major disruptions in Critical Infrastructures. The primary objective will be decomposed into the following sub-objectives:

- Describe Critical Infrastructures and the sense in which they are critical.
- Analyse the notion of Resilience and how it applies to Emergency Management.
- Compare standard emergency management methods and Resilience-based approaches to managing emergencies
- Describe main precursor frameworks and models of Resilience
- Investigate the applicability of Resilience to operators of Critical Infrastructures
- Explore to what extent the Resilience framework captures a selected case involving the management of a major disruption event in the Danish railway network.

1.5.2 **Research questions**

Based on the research objectives we investigate the following questions:

- **What are the key differences between the classical approach to Emergency Management and Resilience-based approaches?**

- **According to the literature, what are the main features that make an organization resilient in a context of Critical Infrastructures?**

- **What is the additional value of Resilience-based Emergency Management to Critical Infrastructure operators, exemplified in the Case Study?**
1.5.3 Structure

The project is divided into seven Chapters. In Chapter 1, Critical Infrastructures are characterized including the sense in which they are critical to society.

The second chapter (Chapter 2) goes through the literature of Normal Accident Theory and analyses the strengths and weaknesses of Emergency Management, and why Resilience adds new. Coming up next (Chapter 3), the general perspective of Resilience is described. Following this, there is the differentiation of types and dimensions of resilience, and its lifecycle steps.

The next chapter (Chapter 4) focuses on which characteristics and policies CIs should have in order to be resilient. After the study of what CIs and Resilience are, and how can CIs be resilient, Resilience in Organizations is analysed (Chapter 5), highlighting which are the features these organisations share.

Finally, having understood the added value of resilience and the required characteristics of organizations and CIs to deal with trigger events, a concrete, major disruption is selected for study: the Farris - Sommersted incident (Chapter 6). To better analyze the incident, there is a brief introduction of the role and importance of rail transport, with a focus on the Danish Railway system. Based on first-hand interviews made with the Chief Managers of the organisations involved in the incident (Banedanmark and DB Schenker) resilience in both organizations is analysed.

1.5.4 Methodology

The research methodology must be tailored to the research objectives and research questions. This research has the aim to review and analyse resilience and apply it to organisations related to critical infrastructures.

A) Selection of literature

We began by reading the Doctoral dissertation by Leire Labaka: Resilience in Organisations suggested by our supervisor. While we were reading, we broadened our knowledge by reading the papers of experts to whom Labaka referenced.

Once our first contact with resilience was established, we had the opportunity to assist to the International Conference: Creating Resilience Capabilities against Critical Infrastructure Disruptions: Foundations, Practices and Challenges on the 13th of April in Copenhagen, Denmark. The conference was based defining methods, solutions and challenges on major Critical Infrastructure disruptions such as means of
communication, healthcare, power and water supply systems, electronic communications systems, etc. The following day, we assisted to the conference’s workshop, with the lecturers of the conference – Arjen Boin, Kathleen Tierney and Kurt Petersen, among others.

Further literature searches were made with the use of Google Scholar, Google and DTU findit.

B) Case Study

We selected a case that satisfied the following requirements: 1) unexpected and unforeseen event, 2) disruption of a critical infrastructure, 3) impact in public and private organisations and 4) access to information and key persons involved.

Thanks to the help of our supervisor, we interviewed the key decision makers during the incident. We developed several interview questions and sent them to the interviewees in advance. During the interview, we followed the guideline of questions and improvised throughout the interview. The interviews were recorded in order to transcribe them partially. Questions and the transcripts are included in Appendix F and G.

Furthermore, we have collected and summarized data about our case and finally we have tried to extract the presence or absence of Resilience features by studying the actions and structure of both organisations. At last, we have made a comparison between the two organisations studied.
2

STATE OF THE ART

As a result to CIs complexity, due to the interconnection between systems, theories such as NAT and HRT have emerged. In this chapter both theories are presented and compared. A core subject in this chapter is to describe Crisis Management and its stages and finally show its limitations.

2.1 Getting to resilience

Interconnection of different systems, their complexity and the dependence between them makes extremely difficult for organizations to control the multiple components of a system. As a result, some theories have emerged in the wake of this assumption.

2.1.1 Can accidents be avoided?

In 1984 the social scientist Charles Perrow published “Normal Accidents: Living with High-Risk Systems”. In this book, Perrow studied complex systems and developed the Normal Accident Theory (Perrow, 1984). He argues - based on the Three Mile Island Accident (BBCc) among others - that an accident may begin with a common event, but, due to the system’s complexity, it can evolve into a severe accident due to the “cascading effect”, and its progress is unpredictable. The combination of human and technical components can provoke small incidents. These incidents can lead to bigger accidents because of a series of technical cause-effect chains (Whitney, 2003).

Our systems are composed of a wide network of devices that work jointly to do a specific task. Perrow argues that it is possible that one of these devices fail at the same time of the failure of another device in such big networks. Thereby, a failure that is trivial by itself, interacting with other trivial failures can lead to an accident. This effect is known as “interactive complexity”.

To reduce the probability of failure, complex systems rely on technology and its improvement to the extent that in many cases we need machines to control other machines (Perrow, 1984). The new technology may fix old security flaws, but may cause new ones
State of the art

(Marais et al., 2004; Shrivastava et al., 2009). According to Perrow, technology’s innovation is not enough to minimize the risk of accidents (Perrow, 1984).

“If interactive complexity and tight coupling -system characteristics- inevitably will produce an accident, I believe we are justified in calling it normal accident, or a system accident. The odd term normal accident is meant to signal that, given the system characteristics, multiply and unexpected interactions of failures are inevitable. This is an expression of an integral characteristic of the system, not a statement of frequency [...] System accidents are uncommon, even rare; yet this is not all reassuring, if they can produce catastrophes”


However, in complex systems, a possibility of failure will always remain. Systems are influenced by several internal or external factors, such as humans, environment, design of the system, procedures, technology, etc. It is impossible to control all these variables, since these factors are also composed by many other variables (Marais et al., 2004). Following this statement, systems should try to reduce their complexity and their tight coupling. Experience, better designs, training, good organizational framework or periodic security controls are some of the key aspects to minimize the probability of accidents (Perrow, 1984).

To sum up, Normal Accident Theory does not say that accidents in complex systems are common, but are inherent in a complex system. The more complex a system is, the more likely it is to suffer an accident. Thereby, isolated systems seem to be the only ones with an option of being safe, which is impossible in today’s society.

On the other hand, Karlene Roberts (Roberts, 1990) developed the High Reliability Theory (HRT) with some colleagues from the Berkeley campus of the University of California studying what common aspects organisations with high-risk of suffering crises had. They defined “Reliability” as the ability to maintain and execute error-free operations. Roberts and Weick (Roberts, 1990; Weick et al., 2001) describe the required elements that an organisation needs in order to avoid errors. HRT is based on organisational theory and observations of organisations that are Highly Reliable (HRO) despite being very risky organisations. HROs will be described in Chapter 5: Resilience in Organisations to have a better understanding of the topic.

These two theories, NAT and HRT, differ in their perception of accidents’ occurrence and the possibility of avoiding them. On one hand, NAT determines that accidents will occur despite the situation due to tight coupling and interactive complexity of systems. Both characteristics can provoke that a chain of little incidents become a bigger accident.
On the other hand, HRT considers that it is possible to have a complex and still error-free system by enhancing its reliability.

Both theories have interesting approaches. It is true that it is impossible to take into account all the variables of a complex system and therefore have the complete control of the situation; yet increasing capabilities may decrease the likelihood of an accident.

### 2.2 Crisis/Emergency management

Crisis management is an approach to deal with crises where organizations plan for several worst-case scenarios and develop different solutions to overcome them. One of the main ways to establish a good performance of Crisis Management in a company is by trial and error since crises are usually unforeseen and the first solutions for a disruption may not be the most efficient ones. However, a common way to improve current plans is to learn from others’ mistakes (Castillo, 2005).

The main goal of Crisis Management is to avoid crises or to be able to detect them and respond fast and efficiently, having different resources and skills available to confront the threats that an organization might have (Drennan et al., 2014).

Furthermore, it is essential to work fast during the first hours of a crisis, so the planning managers have to specify clearly which the functions are for the employees and how fast each task should be performed. Therefore, Crisis Management planning sets in place predetermined plans and/or resources for the restoration of processes in the event of an acute and unexpected interruption or incident (Herbane, 2004).

Majority of authors, (Drennan and McConnell, 2014; Alexander, 2002; Wheatley & Barnes, 2013) have defined four main phases of Crisis Management: Mitigation, Preparation, Response and Recovery.

- **Mitigation:** These are the actions taken to identify possible risks, avoid their befallen and reduce possible negative effects in organizations, human beings and infrastructures.
- **Preparation:** The organisational planning activities in order to cope with foreseeable events.
- **Response:** When the crisis starts, response actions minimize the impact in order to reduce losses and negative effects to the maximum extent.
- **Recovery:** The recovery stage encloses all the activities held to restore normal functioning of an organization or to return to a normal situation.

If there is an infrastructure breakdown it is necessary to continue business as soon as possible. To achieve that, Crisis Management relies on Business Continuity.
Business Continuity

From the business perspective, Business Continuity Management puts more attention in the company’s ability to continue operations during and after a crisis situation (Wong & Shi, 2014).

“Business continuity is a management process that identifies potential factors that threaten an organization and provides a framework for building resilience and the capability for an effective response. This response must safeguard the interests of its key stakeholders, as well as the organization’s reputation, brand, and value-creating activities. Business continuity management is the subject of continuing development and research”.


Business Continuity (BC) focuses mainly in how organizations can deal with an emergency or a crisis, detailing which steps must be followed in order to maintain the critical business functions while minimizing the negative impacts. In other words, how organizations can face a disruption without interrupting their duties with themselves and their stakeholders (Wong & Shi, 2014).

The International Organization for Standardization has designed the ISO 22301 (Wong & Shi, 2014) to protect any company against crisis. It allows the company to identify possible threats and what it should do to avoid stopping the activity in a proactive approach. ISO 22301 helps organisations minimize the recovery time and it is an effective way to demonstrate consumers, partners and other stakeholders their resilience. Thereby, Business Continuity is an effective tool to better allocate the resources of the company, improve risk management and increase customers’ satisfaction. It is a cyclical process which is continuously evolving in time (Wong & Shi, 2014):

2.2.1 Crisis Management limitations

The major problem is that incidents will always happen, and it is impossible to prevent or foresee all possible crises. Even if the company has a well-resourced policy, it does not guarantee that the organization will be able to adapt to any circumstance (Smith & Elliott, 2007). The complexity of Critical Infrastructures and their interconnection makes it difficult for one specific sector to know how their business can be affected by changes or disruptions in another CI. Hence, it is not enough to have plans for the organizations’ threats. Crisis management efforts are limited due to a lack of flexibility, especially after extreme events. Resilient consciousness and some specific capabilities are needed in the company in order to be prepared to adapt, innovate and improvise for an unexpected catastrophe.
Besides, it is also difficult to learn from past mistakes and find organizational vulnerabilities. Smith and Elliott (Smith & Elliot, 2007) analysed the organizational learning from crisis literature:

- Rigidity of core beliefs, values and assumptions that create problems when things appear to be “not as expected”.
- Ineffective communication and problems with information-sharing.
- Centrality of expertise, and disregard of external stakeholders.
- Organizations and individuals may prioritize actions to cope with well-defined problems instead of dealing with ill structured problems.
- Maladaptation to threats and environmental shifts.
- A focus on single-loop learning.

In the assumption that it is possible to plan against disruptions in Critical Infrastructures, it would require multi-agency cooperation and coordination, which may be a big complication due to different goals, culture, resources, capabilities, etc. (Boin & McConnell, 2007).

The economy of a company is also an issue to take into account. Having plans for every possible threat, train the staff or do simulations or workshops can be very expensive, and a lot of time is required. Therefore, many organizations do not prioritize the planning for unprobable events in front of their daily expenses (Boin & McConnell, 2007).

Once seen that Crisis Management has limitations both at a theoretical level (it is impossible to prevent every possible event) and at a practical level (difficulty of coordination, learning and lack of resources), there is the need to enhance a resilient mindset on organizations and society.

![Critical Infrastructure Resilience](image)

**Figure 3**: Added benefits for Critical Infrastructure Resilience Approach. Based on (Wheatley & Barnes, 2013)
In the last decades, the concept of Resilience has increased its popularity. Hence, many literature is written about the subject. The intention of this chapter is to put together the different scopes in which resilience is presented. On one hand, resilience is studied based on the outcome of the incident and the way systems ‘bounce back’ or adapt to changes. On the other hand, resilience can be integrated in different 5 core disciplines representing the domains of a social system: economic, technological, psychological and societal resilience. Finally, the Resilience lifecycle steps based on Crisis Management stages are presented.

Resilience is the the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions (UNISDR, 2009). Standard operating procedures will not suffice; hence having a resilience framework may save a system from a major disruption. Furthermore, other definitions talk about the ability to emerge stronger from a crisis (Sullivan-Taylor & Wilson, 2009; Berkeley III & Wallace, 2010).

The situations in which systems are exposed to unexpected dangers vary every time and so does its complexity. There are several factors contributing to the complexity of a situation. (Petrenj et al. 2012 based on Lemyre et al., 2011)

- Impact - including the extent, severity and the moment of impact, involvement of the media and political processes.
- The uncertainty – including elements such as the novelty of the situation, anticipation and planning, lack of data/information, new organizations/partners, changing rapidly of context, and flexibility of interpretative frameworks.
- Vulnerability and resilience - which includes elements such as economic development, social capital, community competition, information and communication.
3.1  From ‘bounce back’ to adaptation

Defining and understanding what resilience is, it is relevant and important for managers to enhance and develop resilience in their system. Depending on the system, resilience will have a different shape and the accomplishment can be in some cases static and in others dynamic.

The static approach, or ‘bounce back’, refers to the ability of systems to return back to a normal or functioning state quickly after a disturbance. It is also defined as Recovery resilience (Kendra & Wachtendorf, 2003). Whereas the Precursor resilience, is the more dynamic proposal - where adaptation takes place -, and it is seen as a change or transformation of the system providing the same service or covering the same area as before the disturbance (Manyena, 2006; Kendra & Wachtendorf, 2003). A resilient system varies and adjusts without threatening its essential functioning as a response to internal and external change in order to return to equilibrium after an unexpected event (Kahan et al., 2009).

Table 1 makes a comparison between ‘bounce back’ and adaptation including the Resilience type, results, temporal span and the entities in which each concept can be applied.

<table>
<thead>
<tr>
<th></th>
<th>Bounce Back</th>
<th>Adaptation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Resilience Type</strong></td>
<td>Recovery Resilience</td>
<td>Precursor Resilience</td>
</tr>
<tr>
<td><strong>Results</strong></td>
<td>Static outcome, where the objective is to return to an existing outcome.</td>
<td>Dynamic process that results in an adaptive response to disturbance.</td>
</tr>
<tr>
<td><strong>Temporal Span</strong></td>
<td>Normal function is reestablished quickly.</td>
<td>Longer term; characterized by social learning and reflection.</td>
</tr>
<tr>
<td><strong>Application</strong></td>
<td>Entities or system components whose value or service tied to a specific function.</td>
<td>Entities or system components whose value lies in the management and proper functioning of systems or system components.</td>
</tr>
</tbody>
</table>
3.2 Resilient Domains

Resilience, has been used in five core disciplines representing the domains of a social system in order to exemplify these descriptions: Engineering/Physical, Psychological/Individual, Business/Economic, Ecological and Community (Giroux & Prior, 2012).

- In ecology, resilience can be seen as the ability to absorb the shock, but also taking adaptation into account, gaining opportunities of improvement through renewal, reorganisation and development (Folke, 2006). The concept of resilience is based on the observation of ecology and its ability to adapt, very well expressed by Charles Darwin in 1956.

“It is not the strongest of the species that survives, nor the most intelligent that survives. It is the one that is the most adaptable to change.”

*Charles Darwin, On The Origin of Species*

*(Darwin, C.R., 1859)*

- A technological system will be considered as resilient once the structures are recovered completely after a disturbance (Haimes, 2009).

- In psychology, resilience is defined as the collection of personal characteristics that allow an individual operate normally when facing trauma or adversity. (Bonanno, 2005; Connor & Davidson, 2003; Paton & Johnston, 2006)

- Economic/Business resilience is highly related to Business Continuity Management defined as ‘a process that identifies an organization’s exposure to internal and external threats and synthesises hard and soft assets to provide effective prevention and recovery’ (Herbane, Elliott, & Swartz, 2004).

- And last, community resilience is a matter of adaptation towards disasters and natural hazards and can be influenced by the community attributes, such as leadership trust, social capital, shared learning, and attachment to place (Paton & Johnston, 2006).

Although this approach segregates resilience in five core disciplines, in many cases they overlap one and other due to their interconnectedness.
3.3 Synergy and Capabilities

As just seen, ecology serves as a model of adaptation, however, Jerome Kahan (Kahan et al., 2009) talks more specifically in resilience in human- evolving domains. Kahan mentions that an unavoidable challenge is faced when analysing resilience since such term encompasses a wide range of systems with both hard and soft aspects. Hard resilience refers to the structural, technical and mechanical capabilities, capacities and functions of institutions and infrastructures. On the other hand, soft resilience addresses family, community and society, focusing on behaviours, human needs, relationships and psychology. These two aspects of resilience may be addressed synergistically as they depend on each other. Without institutions and infrastructure people would live a disarrayed and precarious life. In the same way, institutions are meaningless if there is no people.

Figure 4: Synergy of Hard and Soft Resilience (Kahan et al., 2009).

Figure 4 shows synergy between hard and soft resilience and reflects the capacities individuals, communities, institutions and Infrastructures would enable them to survive the impacts of trigger events and to manage the consequences of those assaults.
3.4 Resilience lifecycle steps – Resilience via Crisis Management

Leire Labaka (Labaka, 2013), based on the Crisis Management phases explained above, considering resilience being precursor resilience talks about three stages of the resilience lifecycle: Prevention, Absorption and Recovery.

- Prevention: seen as the ability of a system to prevent a crisis occurrence. Resilience fights against potential threats that could lead into a crisis. Awareness of the trigger event can avoid a major crisis to occur, while preparedness, including activities to deal with unforeseeable (and foreseeable) events, will allow the response to be more rapid and effective (Castillo, 2005; Labaka, 2013).

- Absorption: being the ability to reduce the magnitude of the impact. Systems should be able to absorb the impact and avoid bigger damage. Absorption is enlarged thanks to a rapid response obtained with the implementation of the activities learned during the preparedness phase (Taback, 1991; Labaka, 2013).

- Recovery: meaning the ability to recover rapidly and efficiently to the normal state. The resilient system reduces the time of recovery and the total impact of the damage (Taback, 1991; Castillo, 2005; Labaka, 2013).

Figure 5 shows the evolution of crises and the resilience lifecycle approach.

![Figure 5: Relationship among crisis management phases and resilience lifecycle stages. Based on (Labaka, 2013).](image-url)
This chapter describes the more tangible characteristics of Resilient CIs and Resilient systems. Furthermore, it presents resilient policies and sub-policies for CIs.

4.1 Characteristics of Resilient CIs

There are several characteristics that help resilience more measurable and tangible. Disaster resilience, as described in MCEER is characterized by the following resilience characteristics (MCEER, 2006):

- Reduced failure probabilities - likelihood of damage and failures to critical infrastructure, systems and components.
- Reduced consequences from failures - the consequences in terms of loss of lives, injuries and negative economic and social impacts.
- Reduced time to recovery: the time needed to restore a system to normal functioning

In order to enhance the resilience characteristics, MCEER (2006), Berkeley III & Wallace (2010), Labaka (2013), Bruneau et al. (2003) consider four fundamental properties of resilience, the 4 R’s:

- Robustness - refers to the strength or the ability of a system to support a given stress level without suffering degradation or loss of function or without adapting its initial stable configuration (Wieland & Wallenburg, 2012). In other words, maintaining critical operations in the face of crisis.
- Redundancy - the extent to which the elements of the systems are substitutable and other elements are capable of satisfying functional requirements during the disruption or loss of function providing alternative processes for critical systems (Giroux & Prior, 2012)
- Resourcefulness - the ability to skillfully prepare for, respond to and manage a crisis or disruption as it occurs. This includes the identification of courses of action, business continuity planning, training, supply chain management, prioritizing actions to control and mitigate damage, as well as effectively communicating decisions to the people that will carry them out (Kendra & Wachtendorf,
Resilience in Critical Infrastructures

2003; Berkeley III & Wallace, 2010). Hence, Resourcefulness may improve the other properties as seen in Figure 6.

- Rapidity - the capacity to achieve goals and set priorities as quickly and efficiently as possible in order to bounce back to normal operations to reduce the magnitude of losses and avoid future disruptions. Components include carefully drafted contingency plans, competent emergency operations, and the means to get the right people and resources to the right place (Berkeley III & Wallace, 2010).

![Figure 6: Sequence of the Resilient Fundamental Properties. Based on the sequence of the NIAC Resilience Construct (Berkeley III & Wallace, 2010)](image)

4.2 Policies towards more resilient Critical Infrastructures

In order to enhance resilience, Labaka (Labaka, 2013) determines specific resilience friendly policies. Such policies are classified within the four dimensions of resilience: Technical, Organisational, Social and Economic (MCEER, 2008; Bruneau et al., 2003). We will study Internal Resilience, with the three dimensions included: Technological, Organisational, and Economic. By implementing these policies, organisations should be able to reduce the impact of triggering events. Table 2 presents the adaptation of Wheatley and Barnes to Labaka’s resilience policies and combines the definitions of both explanations.
Table 2: Dimensions and policies of Resilience. Based on: Labaka, 2013; Wheatley & Barnes, 2013.

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Policy</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical resilience</td>
<td>CI design and construction</td>
<td>It refers to the quality, redundancy, robustness, flexibility and the proper level of complexity of the CI. The design should fulfil all safety requirements.</td>
</tr>
<tr>
<td></td>
<td>CI maintenance</td>
<td>This corresponds to the activities performed periodically in order to guarantee a high reliability level in order to withstand incidents and reduce the magnitude of the impact and the time to recover.</td>
</tr>
<tr>
<td></td>
<td>CI data acquisition and transmission system</td>
<td>Monitoring the state of CIs with quality sensors and equipment to supervise and control the CI.</td>
</tr>
<tr>
<td></td>
<td>Public crisis response equipment</td>
<td>It refers to the availability, reliability, maintenance and quality of the emergency equipment in order to diminish the impact and ensure safety during crises.</td>
</tr>
<tr>
<td>Organizational resilience</td>
<td>CI capacity for crisis detection, communication and analysis</td>
<td>This policy deals with the preparation and capacity of organisations; management of the crisis and coordination with external stakeholders.</td>
</tr>
<tr>
<td></td>
<td>CI workforce training and commitment</td>
<td>Workers in CIs must be adequately trained before a crisis occurs. Top managers are responsible of promoting resilience values, culture and attitudes within the workers.</td>
</tr>
<tr>
<td></td>
<td>First responders training</td>
<td>This corresponds to the preparedness crisis managers have to face a crisis. This includes training and familiarisation of the organisation.</td>
</tr>
<tr>
<td></td>
<td>Government preparation</td>
<td>Governments must be prepared to lead and coordinate all the entities while properly communicating the situation to the public and giving advice in order to reduce public’s anxiety</td>
</tr>
<tr>
<td>Economic resilience</td>
<td>CI crisis budget</td>
<td>CI should set aside funds in order to cover repairs and replacements when a crisis occurs. This allows the CI to bounce back by reducing their response and recovery times</td>
</tr>
<tr>
<td></td>
<td>Public crisis budget</td>
<td>Public institution should also have funds set aside to assist stakeholders and society. This allows first responders, organisations and society obtain resources more rapidly.</td>
</tr>
</tbody>
</table>
### Table 3: Resilience sub-policies. (Adapted from Labaka, 2013).

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Resilience Sub-policies Supported</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Technical resilience</strong></td>
<td>Redundancy</td>
</tr>
<tr>
<td></td>
<td>Security measures</td>
</tr>
<tr>
<td></td>
<td>Maintenance tasks</td>
</tr>
<tr>
<td></td>
<td>Data acquisition and transmission equipment</td>
</tr>
<tr>
<td><strong>Organisational resilience</strong></td>
<td>Emergency management personnel training</td>
</tr>
<tr>
<td></td>
<td>Formal structure of roles</td>
</tr>
<tr>
<td></td>
<td>Incidents management</td>
</tr>
<tr>
<td></td>
<td>Operators training</td>
</tr>
<tr>
<td></td>
<td>Coordination among stakeholders</td>
</tr>
<tr>
<td></td>
<td>Understanding of Vulnerabilities</td>
</tr>
<tr>
<td></td>
<td>Organisational learning</td>
</tr>
<tr>
<td><strong>Economic resilience</strong></td>
<td>Crisis response and recovery resources</td>
</tr>
</tbody>
</table>

Using the technical, economic and organisational dimensions and ten policies of resilience, an organisation can increase their resilience level, although the policies must be integrated when the design of a new infrastructure starts (Wheatley & Barnes, 2013). In infrastructures, implementation during the design phase will ensure the life cycle of the asset as builders of such infrastructure may not be interested in considering detailed operational plans or. Resilience requirements and policies must be included in contract documentation. Furthermore, in public infrastructures, regulatory requirements are needed to increase the durability of public assets. (Wheatley & Barnes, 2013).
Resilience is a valuable aspect in Organisations. This chapter aims to collect the attributes that Resilient Organisations share. First, it presents Highly Reliable Organisations with their common aspects and main characteristics. Secondly, based on the HROs features, Resilient Organisations are defined showing their characteristics and focuses on two important aspects of Resilient Organisations: Communication and Improvisation. Finally, the advantages of having Resilience in Organisations are listed.

5.1 Highly Reliable Organizations (HRO)

As described above, HRT is based on High reliability Organizations (HROs) characteristics. HROs denote organizations that successfully avoid failures while providing operational capabilities under a wide range of environmental conditions. Hence, what makes valuable an HRO is the capacity to work under uncertainty. Uncertainty is inherent in all technical, social or organizational complex systems.

One can identify this subset by answering the question, ‘how many times could this organization have failed resulting in catastrophic consequences that it did not?’ If the answer is on the order of tens of thousands of times, the organization is ‘high reliability’.

(Roberts, 1990)

Bourrier and Rochlin (Bourrier, 2011; Rochlin, 2011) - high reliability theorists - determined that highly resilient organizations share similarities in the organizational design and response, and also in language, modes of discourse and problem definitions. The most important common aspects are:

- A high technical competence in all the organization;
- An awareness of the key events that must be avoided to happen;
- Developed and set procedures and practices that address evolving to avoid catastrophic events occurring;
- A formal structure of roles, responsibilities and reporting relationships that can become a decentralized team-based approach to problem solving under emergency conditions;
- A "culture of reliability" that distributes and instills the values of care and caution, respect of procedures, care and individual responsibility for the promotion of safety throughout the organization.
Along similar lines, K. Marais, N. Dulac and N. Leveson from Massachusetts Institute of Technology (MIT) summarise the main HRO characteristics in 4 topics. (Marais et al., 2004):

**Goal Prioritization and Consensus**

HRO have to achieve the target of the company while ensuring security. Accomplish both goals is difficult most of the times, because safety objectives usually conflict with the company’s target (despite, of course, of those companies whose primary target is safety; e.g. firefighting teams).

Sometimes organisations have pressure by stakeholders that may have some interests in achieving some goals that clash with security. Therefore, difficulty arises when the organisation has to decide how much risk is admissible (Marais et al., 2004).

**Simultaneously Decentralized and Centralized Operations**

As a consequence of this new working system there has been a complete change in the hierarchy of these companies. Rigid organizational boundaries and hierarchical structures have no place if they want to be a successful HRO. Nowadays organizations have to deal with many stakeholders with different objectives, so it is necessary to be able to adapt to different circumstances and make collaborative relationships.

Moreover, in crisis situations where acting quickly is needed, “field-workers” are responsible to make the right decision and sometimes improvisation takes place. The ability to improvise is seen as an integral building block for an effective response by crisis management scholars, whereas High reliability theorists consider improvisation as ‘the last 5%’ when everything else fails. In crisis, organizations must gather creatively its resources and partners to produce a rapid response to a unique problem. (Boin & Van Eeten, 2013)

HROs focus on training and workshops, since a rapid response is crucial to succeed in a crisis. The trainings have to be reiterative and constantly evolving, as crises can vary depending on the technology or the system (Marais et al., 2004).

To react quickly it is also necessary good information sharing within the company. Crisis managers face the challenge of making all the participants of the network be on the same page in order to coordinate an improvised response. For this, information must be collected, commissioned, analysed and shared in real time (Weick and Sutcliffe, 2001).

**Organisational Learning**

HROs make a depth analysis of past accidents, incidents and near misses in order to identify how crisis management can be improved. But it is not enough to learn from the past. In the early part of the 20th century, if there was a technical discovery it took an average of 30 years to be commercialized. In the 21st century, the average is only of 2-3 years, and in many cases the technology is obsolete in 5. (Marais et al., 2004). Because of this, some organisations do not have the experience to learn from the past, so they design complex simulations and try to avoid accidents through an extensive safety design and hazard analysis.
Resilience in Organisations

Extensive use of Redundancy
LaPorte defines redundancy as the ‘ability to provide for the execution of a task if the primary unit fails or falters’ (LaPorte, 1996). To ensure an effective redundancy it is necessary to carry out an adequate maintenance of the components of the system (Marais et al., 2004).

5.2 Adaptability and Awareness
McManus et al. (McManus et al., 2007) talks about the abilities of awareness and adaptability as key aspects for organisations to be resilient. Mica Endsley (Endsley, 1995) has contributed extensively in the concept of Situation Awareness.

Situation Awareness is a measure of the understanding of the organisation and the entire operating environment’s perception. Situation awareness can be segmented in three levels: perception (“noticing”), comprehension, and projection (Endsley, 1995) It includes the ability to identify opportunities and potential crises. On one hand, the impacts may occur suddenly and make only one component fail and therefore have a negative impact. On the other, small failures in key components may lead to a large scale cascading-type failure. When the crisis arrives, being able of identifying the crisis and its consequences accurately. Organisation must have a clear understanding of the connections between components and the vulnerabilities that these might arise. Furthermore, it provides an increased awareness of expectations, obligations and restrictions regarding internal and external stakeholders. And the awareness of the available resources internally and externally. Furthermore, having a clear understanding of which are the vulnerabilities of an organisation provide them tools to make the system more redundant (McManus et al., 2007; Tavitiyaman et al., 2007; Haymes, 2009).

Adaptability measures the organisational culture and dynamics that enable such organisation to make decisions in a well-timed and maximising opportunities. Simultaneously centralised and decentralised company combined with good leadership can enhance good communication and decision making.

To adapt better the system is needed as well information and knowledge. Hence, awareness of the specific roles within the company, goles, and relationships is a very useful tool for adaptation (McManus et al., 2007; Petrenj et al., 2012; Kahan et al. 2009).

All in all, resilience gives the ability to organisations to identify opportunities in the most difficult circumstances allowing it to move forward and even grow stronger in times of adversity. To improve both awareness and adaptability are very important the ability to communicate properly as well as to improvise in time of crisis.
5.2.1 Communication

It is crucial to have a good communication between the responsibles who make decisions and stakeholders. These measures help organisations make faster decisions, work more efficiently and coordinate efforts and activities. The difficulty of coordination increases when more than one organization is involved during a crisis. Joining efforts and resources is required to reach common goals and make agreed decisions. (Kapucu, 2012). Having a strong communication system becomes one of the biggest challenges that resilient systems face. (Boin & Van Eeten, 2013).

Taylor-Powell, Rossing and Geran (Geran, Rossing & Taylor-Powell, 1998) distinguish three top levels of communication: coordination, cooperation and collaboration.

Coordination: is the process where communication, planning and division of roles are distributed between two parties or more in order to achieve common or complementary targets in a more efficient and effective way.

Cooperation: when two or more parties have shared interests and work jointly to achieve shared goals, but maintaining separate identities.

Collaboration: is the process where two parties or more have a problem, and they identify common targets and seek solutions within their differences. It is necessary to share information and resources, and organisations may require to be flexible in order to adapt to different visions of the problem (Geran, Rossing & Taylor-Powell, 1998). The term collaboration between organisations or departments is the highest level of information sharing according to the scale made by Murray Turoff (Turoff et al. 2008).

The willingness of organisations to cooperate, coordinate or collaborate during extreme events is highly dependent in assets such as; time, information resources, power and authority. (Lemyre et al., 2011).

5.2.2 When the Unexpected arrives: The Importance of Improvisation

It is well known that preparation and planning it is very helpful for crisis response, since, as previously mentioned, Critical Infrastructures are such big and complex systems makes it impossible to make a crisis plan for any possible scenario. Critical Infrastructures are dynamic systems, hence it is necessary to adapt and adjust to every current situation. That is why the aptitude to improvise is vital to cope with unforeseen events. A resilient
system has the abilities to anticipate, monitor, respond and learn (Hollnagel 2009). From this statement it is possible to conclude that resilience is an adaptive process, being improvisation one of the key characteristics.

Improvisation constitutes “reworking knowledge to produce a novel action in time to meet the requirement of a given situation” (Mendonca et al. 2001). Therefore, it is essential to have a trained and qualified team, capable to act fast and efficiently. The key point of having trained and qualified people in an organization is that those capabilities improve the ability to improvise choosing the best decision in every moment.

However, situation, culture and contextual factors are some important aspects to take into account when a crisis occurs (Rankin et al., 2013). An organization can facilitate the correct use of improvisation with the right structure, culture having the resources available among others.

5.2.2.1 Factors that influence improvisation

Language skills and communication

When a crisis emerge there is the need to coordinate and share information between people involved in most of the cases. Therefore, it is necessary to have good ways of communication within the company and with other stakeholders that can take part in solving the crisis.

Crisis in Critical Infrastructures can affect other countries, hence a clear way of communication and having language skills is necessary. The loss of information sharing within a response crisis can lead to worse consequences (Rankin et al., 2013). To avoid the loss of information and misunderstandings, information has to be given clear and precisely.

A proper use of technology can strengthen the good flow of information and monitoring, even though a previous training may be needed.

Domain knowledge

The lack of knowledge in one field weakens the person/team’s ability to improvise due to the communication difficulties. Having one or more experts in each team makes the team have a wider background on the field. Experts know better what to ask and to whom, leading to more information flowing into the organization (Rankin et al., 2013). All in all, the lack of knowledge can lead to a wrong information sharing, while on the other hand, an expert can share precise and useful information to the right people. Thereby, the lack of information can be compensated if there are good ways of communication and a good structure within the company, being that it is possible to contact with an expert that is not currently in the place of the incident (Crossan et al., 2005).
Resilience in Organisations

**Organizational structure**

Good organizational structure is one of the key aspects to share information and coordinate people and resource during a crisis. An awareness of the need of the flow of information during the performance through the higher strategic, tactical and planning level with the operational level has to be in the organization’s culture. In this way, a misunderstood or a wrong given information can be detected in early stages. However, information should be given quickly in order to respond as fast as possible (Crossan et al., 2005).

Organizational structure can be more interesting from a resilient point of view because it can give the abilities in a company to face crisis regardless of who is in charge of the crisis in a specific moment. It also enables the information sharing and the roles who have each employee (Rankin et al., 2013), so the team can rely on pre-defined structures and roles to get things done (Fussell et al. 1998).

In conclusion, it does not matter how well trained can be a person or a team because there will always be unforeseen situations with some specific abilities or knowledge needed. To prepare for these situations and be more resilient, organizational structure is probably the best way to handle those (Rankin et al., 2013).

### 5.3 Why is Resilience essential?

Many businesses are integrating every time more and more resilience objectives into their operating models as they see these measures as essential to their long-term profitability. (Kahan et al., 2009). Resilience provides organisations the opportunity to create an approach that enables them to work both inter- and intra-dependently to ensure the continuity of business objectives at the time of trigger events. David Parsons (Parsons et al., 2008) lists a number of actions in which resilience can give competitive advantage to organisations after a trigger event:

- Return to pre disruption profits more rapidly;
- Use the event as an opportunity to improve efficiency;
- Reduce the cost of the interruption to insurers resulting in reduced insurance premiums;
- Reduce exposure to losses without insurance;
- Deny the need for increased regulation to comply with the community expectations;
- Improve its reputation;
- Increase staff morale.

Nevertheless, despite this new way of acting has been growing in the last decades, it has not been implemented in all organizations yet. Organizations that set up their crisis management based in resilience have to train workers and do workshops in order to improve their ability to make spontaneous and right decisions in crisis situations (Van de Walle & Turoff, 2008).
Figure 7: Relation between elements of Resilience

Figure 7 shows that to achieve a good prevention, absorption and recovery it is necessary to have robustness, redundancy, rapidity and resourcefulness in the system. These four properties can be obtained by the main characteristics that a resilient organisation should have.
In order to analyse a mid-term disruption in the Danish railway, an introduction of railway transport is done, describing how the European rail sector wants to improve the use of rail freight. It provides a deeper analysis of the Danish rail cargo and its competitors. Secondly, the Farris – Sommersted incident is described, highlighting what Banedanmark and DB Schenker did before, during and after the incident. To conclude, based on what has been described throughout the thesis, a resilient analysis of both companies has been done.

6.1 Transport

Transport plays a major role in global economy. An efficient transport system is of vital importance for the competitive operation of the economy and the mobility of citizens (UIC), nationally and globally (PPIAF, 2011) as transport availability can be a boost or a barrier to economic development within nations (Rietveld & Bruinsma, 2012). Transportation investments link production factors in a network of relationships between consumers and producers to create a more efficient division of production, exploit the geographical comparative advantage, and provide the tools to expand economies of scale (PPIAF, 2011).

6.2 Railway: the most efficient solution

Railway systems move cargo and people within a country and between them. (Baldoni et al., 2014) Since disruptions of the railway infrastructure can have a significant negative impact on the security and economy of an individual country, the rail transport mode is considered as CI (Plant, Young & Krepp, 2013). There are very high economic interests that make the system more vulnerable to attacks. These vulnerabilities force Railway networks to be resilient while promoting safety (Baldoni et al., 2014).

Several stakeholders and players are included in the railway system. The major stakeholders, considering the European Union, are: the European Commission, that defines guidelines for railway system integration; European member states, supervisors of the system; private and public companies, which manage and implement the infrastructure (e.g., Banedanmark) and local communities that benefit from the service to transport passengers and goods. In addition, several players are included: public and private rail transportation
companies for freight and people (e.g., DSB or DB Schenker); supply companies; shipping companies; local transportation companies; etc... The economic interests are very high making the system more vulnerable to attacks (Baldoni et al., 2014).

6.2.1 Ecofriendly solution

At the first United Nations World Summit on Sustainable Development, in 1992 in Rio, transport was considered as a key area in order to reduce the effects of climate change. However, transport’s greenhouse gas emissions have constantly grown since 1990 (UIC & CER, 2008). With climate change as a main concern in economic decision making, rail transport becomes the right choice for transportation (UIC).

Railway is the most efficient transport mode with very low environmental impact on water and air and positive economic growth. It offers considerable environmental, land-use and capital investment benefits. Modern railways, if managed efficiently, have lower emissions per traffic unit (passenger/kilometer or ton/kilometer) than any other mode, e.g. CO₂ emissions in rail transport are 8 times less than in road (UIC). Furthermore, many railways throughout the world are electrified, which can reduce even more emissions depending on the energy source used to generate electricity (PPIAF, 2011). In conclusion, it is the eco-friendly solution for freight transport.

Moreover, railway has several advantages amongst other transport modes: it is dependable, highly organised, allows high speed over long distances and large quantities, it is suitable for heavy and bulky good, it guarantees safety, etc (Lowe, 1997; Nierat, 1992; Slack, 1998). For such reasons, freight cargo shipped by train has increased in the last years.

6.2.2 Main competitors of railway transport: road

Despite the efficiency and environmental advantages, Rail transport is an expensive mode of transport. Rail freight transport costs are generally around 0.120€/tkm. Price may vary according to: government policy choices, management effectiveness, design characteristics, and difference in volume, cost structures, commodity mixes, competitive environments, haul lengths and geography, among many other factors (PPIAF, 2011).

- Variant 1a - Cargo is transported by route in the entire route on toll loads;
- Variant 1b - Cargo is transported by road in the main part of the route on toll roads (375km), and in the marginal parts of the route on toll-free roads (125 km);
- Variant 2 - Cargo is transported by rail in the entire route
Variant 3 - Cargo is transported by combined transport - by rail in the main part of the route (500km), and by road on toll-free roads in the marginal parts of the route (100km).

**Figure 8**: Comparison of the unit shipping costs for the specific cargo (€/ ton-kilometer). Data from (Bína, 2014).

This chart compares the unit shipping costs for the specific cargo determining four variants of road and rail with similar movements in several European Countries. It is seen that costs in road movements are considerably lower than costs of movements including rail. Routes with combined transport have the highest shipping cost and the handicap of wasting time in changing transport mode. On the other hand, they combine the advantages of both rail and road.

The lower price, higher flexibility and suitability for short distance and small loads, etc (Lowe, 1997; Nierat, 1992; Slack, 1998) of trucks makes road the most commonly used transport mode.

Companies still choose road as their transportation mode although trucks have a higher ecological carbon footprint. Road transport continues to dominate the inland freight transport market, with a market share above 75% in the EU compared to an 18.6% for rail (Eurostat, 2014). Changing mode of transportation implies time, resources and costs that many companies are not willing to pay despite the benefits of Rail (Möller, 2015).
6.3 Railway in Denmark: Current situation

The railway is one of the most important and effective ways of travelling and commercialize in Denmark. The Danish railway system, provided by Banedanmark, has 3,103 km of railway tracks, where almost 1.2 million trains run every year. In other words, the Danish railway system transports more than 196 million passengers and 8 million tons freight annually (DMOT, 2012).

The wide railway network around Denmark attracts companies to ship their cargo by train. Considering that the sum of imports and exports in 2010 was the 57% of the Danish GDP, infrastructures related to trade become essential in Danish economy (DMOT, 2012).

Domestic freight transport is carried out basically by lorries and ships (165 million tons), while railway and air transport have a secondary role (less than 0.5% of goods measured in tonnes).

![Figure 9: Domestic freight transport divided by type of transport (DMOT, 2012).](image)

On the other hand, in terms of international transport goods, although lorries (national or foreign) and ship still are the main way of trading (99 million tones), trains have a very important role in this scenario.

![Figure 10: International transport goods by transport type (DMOT, 2012).](image)
In relation to railway freight, around 2,000,000 tones are carried every quadrimester. However, only 25% of the cargo is shipped to and from Denmark whereas the other 75% of the total is transit traffic, which is transported through the two main rail transport corridors of the country. These corridors connect Denmark with its neighbouring countries. One vertical axis, between the South of Jutland connecting with Germany and the Northern part of Jutland where it links up by ferry to Norway and Sweden. Furthermore, there is a west-east transversal axis going from the West of Jutland to Sweden linking the different regions of Denmark through the Little Belt Bridges and the Great Belt Bridge (DMOT, 2012).

The amount of cargo shipped through Denmark is expected to increase in the next years due to the ScanMed Rail Freight Corridor. ScanMed is an initiative that propose to create one of the biggest rail freight corridors in Europe, connecting Scandinavia and the Mediterranean Sea through Stockholm - Malmö - Copenhagen - Hamburg - Innsbruck - Verona - Palermo. Banedanmark is one of the Infrastructure Managers involved in the project. For the time being, the Implementation Plan has to be presented to the EU-Commission before the 10th November 2015 (ETC, 2014)

All in all, the railway network and its functionality become a very important aspect in the Danish lifestyle and economy. Therefore, a disruption in a rail track can affect many people and can cause economic losses or even become a major accident if the involved trains transport dangerous goods (3% of the total rail freight). In order withstand or avoid disruptions, Banedanmark, freight companies and other interested organizations should be resilient.
6.3.1 Looking to the furture: Implementing ERTMS

Banedanmark has committed an ambitious plan: upgrade its total network of “main lines” with ERTMS Signalling System (Appendix C) for 2024 (ERTMS, 2014 i). The current signaling system in Denmark is obsolete, since some of them date back to the 1930s. Such system has been causing many problems that provoke more than 50% of train delays, and the system was considered to life-expired by 2020. Therefore, there was a need to modernize, and the Danish Government decided to adopt a global system. Banedanmark is implementing the ERTMS (ERTMS, 2014 i) to:

- Simplify the national network;
- Reduce the life cycle and maintenance costs;
- Reduce of staff;
- Simplify and update the national operating rules;
- Optimize the national control organization;
- Increase safety levels;
- Allow high speed train movements;
- Increase network capacity;
- Improve punctuality;

All in all, the major benefits expected (beside the ones explained above) are to see an 80% reduction in train delays and a possible 25% reduction in maintenance costs (ERTMS, 2014 i). Furthermore, the ERTMS Signalling System will also benefit the railway stakeholders (both freight companies and Banedanmark) as it is very useful for disruption management. ERTMS will help the organisations the resilient features will be increased.

6.4 Farris - Sommersted incident

The information about the incident has been obtained from Banedanmark Press 2012. (Banedanmark, 2012).

“On Thursday Nov 29th 2012 one or more wagons in a freight train run by Hectorrail (HG 45685) was derailed in the stretch between Farris and Sommersted. Up to 7 kilometers of track was destroyed and around 11000 sleepers urge to be replaced.” – Banedanmark Press (Banedanmark, 2012)
The incident was a very rare event (Jensen, 2015; Hansen, 2015). Rare events are events that occur outside the everyday experience of an organisation and are seen as unique, unprecedented, or even uncategorizable (Roux-Dufort, 2007; Starbuck and Farjoun, 2005).

Organisations learn through rare events, these reveal organisations weaknesses and expose unrealised behavioral potential. Interpreting, relating and re-structuring are critical to both learning and responding as they increase understanding and reduce the ambiguity caused by the rare event. The incident was a major disruption as the incident had important consequences for the involved stakeholders and more specifically to the freight owners.

The derailment, which cause has not been identified yet, happened in one of the main railway lines of Denmark. With normal traffic, 2 trains per hour for passengers (336 trains per week), and for DB Schenker 200 freight trains per week. The rail track goes through the East of Jutland and connects the country with the north of Germany (Lunderskov-Padborg). See Figure 12.

Figure 12: Railways in Syddanmark, Denmark. (Banedanmark a)
All traffic was interrupted between Vojens and Vamdrup (See red cross in Figure 12) causing comprehensive problems for freight companies to and from Denmark. Passenger trains were replaced the day after the incident, 30th November, with buses following the same route (*Passenger buses* in Figure 13)

Cooperation with many stakeholders (freight operators, cargo terminal operators, Rail Net Denmark colleague companies in Germany and Sweden, such as Stena Line and DB Netz, Ministry of Transport and Arriva) was needed to offer alternative routes (*Alternative Routes* in Figure 13). The Strategy team had the allocation plans ready 12hrs after the incident (*Planning* in Figure 13). However, it took 36hrs for the Operations Center to implement the plans in order to allocate the cargo (*Implementation* in Figure 13).

At the same time, maintenance work was initiated in order to repair the damage. Such maintenance included the replacement of 11,000 sleepers, completion and replacement in the points in Farris, adjustment to the 7 km railway line, adjustment of the traction power and security installations.

Moreover, the winter season added a handicap for the restoration of the tracks. Banedanmark does not usually plan track conversions during the winter season due to the heavy storm and the low temperatures. For instance, the 11,000 sleepers had to be replaced manually due to the poor condition of the track.

Despite the challenges, Banedanmark managed to finish the repair 4 days before the initial expectation. The track was released for traffic on Saturday, December 15th at 14.00pm, and the first freight train run on the line later that afternoon (*Normal traffic resumed* in Figure 13). Passenger traffic between Vojens and Vamdrup started Sunday 16th of December in the morning (*Passenger trains* in Figure 13).

The rail tracks are owned by Banedanmark and Hectorrail and DB Schenker are the two main freight companies operating in this line. The two companies suffered from this interruption as Hectorrail cancelled all operations during the disruptions and DB Schenker had to reduce the capacity shipped during those days.

Interviews to the main representatives of Banedanmark and DB Schenker will be held in order to determine the measures they took and to analyse the resilience capabilities of the companies. Passenger companies will not be considered as people can be easily relocated with buses providing the same service.
Figure 13: Gantt chart of the Farris incident.

Figure 13 shows the evolution of the incident. The Planning and Implementation phase form part of the Absorption stage of Resilience. The managers had to find a solution and implement it as soon as possible in order to reduce the impact of the disruption to the involved stakeholders (e.g. loss of customers for freight companies or uncomfortability for passengers).

During the Recovery stage the plans were implemented and the customers were already using the alternative routes that Banedanmark provided. However, the capacity was still below the state of normalcy.

Finally, when the damaged tracks were replaced, passenger and freight trains could use the main line again at full capacity. During this stage, all the lessons learnt were analysed and some were applied in order to improve the reaction if a similar accident happens.

### 6.4.1 Alternative routes

While the tracks were replaced, Banedanmark provided the involved freight companies with alternative routes and such freight companies were then responsible of choosing the most suitable option for them.

Cargo was transported in three ways: On one hand, through the parallel railway, yet local line, in the West of Jutland that connects Denmark to Germany through the cities of Tønder (54° 56’ 34” N, 8° 51’ 50” E) and Niebüll (54° 47’ 17.16” N, 8° 49’ 46.56” E).
Nonetheless, the western line of Denmark could only carry around 50% of the capacity of the Eastern line, as there are several restrictions on weight, length, etc.

On the other hand, cargo was transshipped between road and rail in the intermodal terminals in the cities of Taulov (55° 33’ 0” N, 9° 37’ 0” E), located in the Triangular Area of Jutland, and Padborg (54° 49’ 22” N, 9° 21’ 21” E), located in the southern part of Jutland and very close to the Danish-German border.

![Figure 14: Alternative routes.](image)

Finally, Stena Line, the Swedish international ferry service company shipped extra goods to and from Germany through the connection Trelleborg-Rostock. The ship has 1120 lane meters for rolling stock which allows a capacity of up to 3330 tonnes of railway stock.

### 6.4.2 Banedanmark

Banedanmark is a public company responsible of providing a safe, attractive and efficient infrastructure for the railway in Denmark. It also provides the monitoring and traffic information for passengers and railway companies. (Banedanmark b)

After studying Banedanmark’s core processes and based on information obtained firsthand from the interviews to Martin O. Jensen (Deputy Director of Traffic Operations of
Banedanmark during the Farris incident) and Jens Jorgen Hensen (Traffic Manager of Banedanmark) an analysis of the company has been done to describe the organisation in terms of HRO characteristics (Marais et al., 2004).

**Goal Prioritization and Consensus**

Banedanmark’s objective is to offer a good service of tracks in the Danish geographical area while ensuring security. In a wide network like the rail network, it can be difficult to accomplish both goals and ensure perfect conditions of the tracks throughout the whole area. However, Banedanmark can guarantee all the quality certificates because they carry out maintenance tasks. (Hansen, 2015; Jensen, 2015) (Seen in Appendix D)

Both passenger (e.g. DSB) and cargo companies (e.g. DB Schenker or Hectorrail) should be benefitted equally from Banedanmark’s services. However, the theoretical goal may be altered as Banedanmark puts more attention to passenger trains and their commodities as there are political interests involved. In denser areas, where there are more inhabitants, such as the Metropolitan area of Copenhagen and around - Sjaelland Region - the rail tracks are in better condition and are usually comprised of a double track. In contrast, in the Syddanmark region and more extensively the Midtjylland and Nordjylland region, there is a lack of rail tracks and the existent ones are more vulnerable (Hansen, 2015).

The importance given to freight trains has increased in the last years due to the fluent communication established between the Traffic Manager in Banedanmark, Jens Jorgen Hansen, and the Head of Operations at DB Schenker, Henrik Möller Larsen (Hansen, 2015). Banedanmark has determined a new settlement of freight traffic to ensure high punctuality of freight trains in transit through Denmark by having more coordination with the different stakeholders (See Appendix E).

**Simultaneously Decentralized and Centralized Operations**

Due to the rareness of the Farris incident, there was no previous plan for a situation like that. Banedanmark has a well-defined chain of command with defined roles and responsibilities that made possible to improvise a new plan. Or as the Chief of Operations calls it, ‘improvisation within the plans’ (Hansen, 2015) as they use the information in already established plans and prepare a new one and determine how to allocate the cargo.

When the Farris incident occurred, the planning team started working right when the accident happened and were able to start the allocation process 24 hours later. “It happened Thursday night and my staff and I were working throughout the night and we already knew how to reroute the traffic by Friday morning, which I think that is a quite fast response” - said Martin Jensen, previous Deputy Director of Traffic Operations in Banedanmark (Jensen, 2015).

The planning team is highly qualified, they have different backgrounds and university studies which allow them to act rapidly. Thanks to the quality of the team, they are able
to adapt the CPs to each unforeseen incident in a very efficient way. During a disruption, executors gather in the Operations room and see what needs to be done in order to implement the new plans. Operational workers are experts as to get to the control room they have previously worked in all ranks and levels.

Last but not least, communication in an inter- and intra-organisational level must be strengthened. Information sharing within the company is not too smooth (Hansen, 2015) and it is one of the biggest challenges resilience systems face (Boin & Van Eeten, 2013).

Crisis managers are in charge of making all the participants of the network be on the same page, (Weick and Sutcliffe, 2001) this is a challenge as the personnel is used to keep the information to themselves. This problem is due to many years of lack of information sharing. Moreover, the planning team does not participate in the implementation phase, communication between planners and operational staff should be more fluent in order to create plans that can be implemented smoothly during a crisis (Hansen, 2015).

In contrast, there is a good communication in an operationally underground level (between the Infrastructure Management Operator and the train Operator Company) especially after incidents occur when there is a 24/7 coverage. (Hansen, 2015)

The Traffic Manager puts a lot of effort in making the personnel understand that information must be shared in real time (Hansen, 2015) in order to coordinate an improvised response (Weick and Sutcliffe, 2001).

Organisational Learning

In order to identify how crisis management can be improved and improve their plans and practices Banedanmark makes analysis of past accidents, incidents and near misses following a trial and error practise. Banedanmark has a clear awareness of the flaws and vulnerabilities of the areas that must be improved. Awareness is an important feature of resilient organisations (McManus et al., 2007).

As Banedanmark learns by acting, when a disruption occurs and if there is a chance that it could happen again, they prepare a new Contingency plan for a similar situation. A clear example are the two consecutive storms that occurred in 2013. During the first one, St. Jude Storm, 28th October 2013, passengers were stuck in the trains as almost 500 trees fell on the tracks, DSB expected losses of at least 5 million kroner as 25 trains were damaged. Banedanmark expected losses between 5 and 7 million kroner (DR, 2013). However, two weeks later, there was a new storm, Bodil, Danish name (Brandt, 2013), and it was successfully managed. Banedanmark learned from the first storm and applied the lessons learnt; all trains were cancelled during the afternoon in order to avoid having people stuck in the trains due to the storm (Ertman, 2013). In addition, the Planning department wrote a new Contingency Plan that is now available to use in further Storm situations (Hansen, 2015). Anyhow, if the chances of a disruption to happen again are extremely low, as in the Farris incident that was such a rare event, Banedanmark does not develop new CP for similar disruptions.
Leaders should keep their organisations in motion. Although organisations cannot anticipate rare events, they can work to widen their response repertoire for dealing with disruptions (Lampel, Shamsie & Shapira, 2009). Martin O. Jensen, suggested that more ‘what if’s’ situations should be considered. The more ‘possible situations’ that have been considered, the more prepared the organisation will be towards a disruption. In the planning area, there should also be more effort in designing specific plans for medium and long disruptions. (Jensen, 2015)

Communication is another aspect that must be improved. The Farris-Sommersted incident strengthened the ability to communicate in a higher level between departments in the German rail companies. Since the incident, Banedanmark knows better who to call on a strategic level. They have a list of contacts in every level, functions or offices (Hansen, 2015; Jensen, 2015) When a crisis happens, it is very useful in order to increase rapidity.

**Extensive use of Redundancy**

Denmark does not have a widely meshed rail network but there are only a few main lines as seen in Appendix B. If there is a disruption in the main line in Jutland, the use of the parallel, yet local line, is not an easy alternative given the different regulations and limitations of the west coast line. Alternatives to re-routing trains can be a difficult task. Therefore, more specific plans should be developed to be able to act immediately in case of a disruption in an important line (Møller, 2015; Hansen, 2015).

Nonetheless, after the Farris incident, Banedanmark started a project of building a double track in that line in order to be more redundant and therefore more resilient. It will be finished this year (Hansen, 2015). Furthermore, implementing ERTMS to the network will also make the system more redundant.

In addition, one of the most complex issues to handle is that operators and resources may not be linked to the Contingency Plan (CP) and personnel may be in locations far from where they are needed. The lack of resourcefulness may restrict a CP from being implemented (Hansen, 2015). ERTMS will also help with this issue (ERTMS, 2014 i).

Once defined the case and studying one of the ways of characterizing the HROs, an analysis of the Resilience principles of the company has been done in the moment of the accident and nowadays (after applying the lessons learned from the accident). First, the four main characteristics of resilience (4R’s) that have been described in *Chapter 4: Robustness, Redundancy, Resourcefulness* (e.g. MCEER, 2006; Berkeley III & Wallace, 2010; Labaka, 2013); Bruneau et al., 2003). Second, other four features have been included due to their influence during the disruption. Situation Awareness (e.g. Endsley, 1995; McManus, 2007)]; Adaptability (e.g. Hollnagel, 2009; Marais et al., 2004); leadership and information sharing (Rankin et al., 2013; Crossan et al. 2005). Although improvisation is a very important aspect to take into account, as explained before, is a consequence of other properties within the company.
Table 4: Presence of Resilience Characteristics in Banedanmark before the Farris incident.

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Robustness</td>
<td>±</td>
<td>±</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>They have good maintenance and offer quality certifications, but the rail tracks need to be updated.</td>
</tr>
<tr>
<td>Redundancy</td>
<td>✗</td>
<td>✗</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The network is very simple, they do not have alternative routes if an incident happens in the main lines.</td>
</tr>
<tr>
<td>Resourcefulness</td>
<td>±</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>P: Lack of “what if’s” situations. P&amp;A&amp;R: Highly qualified personnel able to skilfully manage a disruption despite the lack of training via simulations.</td>
</tr>
<tr>
<td>Rapidity</td>
<td>±</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>A: The planning was done in 12 hrs but the implementation took 36 more hours due to the lack of experience in mid-term disruptions R: It took less than expected to fix the rail tracks.</td>
</tr>
<tr>
<td>Information sharing</td>
<td>±</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>A: Slow initial contact with the German authorities and misunderstandings due to the difference in terminology and language. Personnel are not used to share information in real time in the Operations Room. R: Good communication with DB Schenker.</td>
</tr>
<tr>
<td>Adaptability</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>P: They adapt to the environment, e.g. in Winter. A: They made new plans of capacity allocation for this disruption. R: They hired more workers during the disruption.</td>
</tr>
<tr>
<td>Leadership</td>
<td>±</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>P: Lack of communication between departments during the implementation of CPs. P &amp; A &amp; R: They are very qualified and capable to lead their teams.</td>
</tr>
<tr>
<td>Awareness</td>
<td>✓</td>
<td>±</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>P: With their monitoring and control systems they are able to avoid possible incidents. They are also conscious of their flaws and weaknesses of the system. A: They were not aware of all the complications of changing routes.</td>
</tr>
</tbody>
</table>
Table 5: Presence of Resilience Characteristics in Banedanmark after applying the lessons learnt.

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Robustness</td>
<td>±</td>
<td>±</td>
<td>Idem</td>
</tr>
<tr>
<td>Redundancy</td>
<td>±</td>
<td>±</td>
<td>Idem</td>
</tr>
<tr>
<td>Resourcefulness</td>
<td>±</td>
<td>✓</td>
<td>Idem</td>
</tr>
<tr>
<td>Rapidity</td>
<td>±</td>
<td>✓</td>
<td>Idem</td>
</tr>
<tr>
<td>Information sharing</td>
<td>✓</td>
<td>✓</td>
<td>Idem</td>
</tr>
<tr>
<td>Adaptability</td>
<td>✓</td>
<td>✓</td>
<td>Idem</td>
</tr>
<tr>
<td>Leadership</td>
<td>±</td>
<td>✓</td>
<td>Idem</td>
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<tr>
<td>Awareness</td>
<td>✓</td>
<td>✓</td>
<td></td>
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</tbody>
</table>

Based on the Labaka’s Resilience policies that promote resilience in organisations so that these are able to reduce the impact of triggering events stated in Chapter 4, Resilience in Banedanmark is going to be examined:

**Technical Resilience**

Banedanmark has a high technical resilience. The maintenance activities performed periodically guarantee a high reliability and help withstand possible impacts. Around 800 employees are responsible for the maintenance. The maintenance services are divided in 3 staff units in charge of 4 different areas as seen in Appendix D.

Moreover, the network is monitored and the trains on the tracks are constantly supervised in the control room.

Resilience is achieved by being able to both "bounce back" and to adapt. In case of accident, Banedanmark has the responsibility to fix the railroad tracks in an effective and efficient way to return to “normal” operation as soon as possible. On the other hand, Banedanmark is in continuous adaptation. Being aware of the flaws and vulnerabilities
that it has, Banedanmark is constantly working to improve the network of train tracks. The Signaling System (ERTMS, 2014) that will be applied to the entire network of the country and the construction projects of double tracks in various sections of the network (Bane.dk) will make the network more robust and redundant. Banedanmark wants to be prepared for any accident and it is aware that a good way to achieve that goal is to improve the network infrastructure. This adaptability is a valuable characteristic in resilient organizations.

**Organisational Resilience**

Teams are highly qualified, especially in the higher level departments: Control, Operations and Strategy/Management. Chief Managers are responsible of promoting resilience values, culture and attitudes between workers (Labaka, 2013). Traffic Manager, Jens Jorgen Hansen is putting a lot of effort in promoting those.

The employees have very defined ranges and everyone knows what to do in normal situations and when accidents occur. They have access to numerous CPs although these are just for short term disruptions. During crises, their expertise allows the team to adapt to new situations. In contrast, changing workers habits with the goal of improving resilience (e.g. improving information sharing) can be a challenge for the top managers (especially in the Control room). Most of the employees in the Control room have been working for the company for many years which can be a handicap as they are used to work in a specific way (Hansen, 2015).

There is a lack of training through workshops and simulations for all employees of Banedanmark (Jansen, 2015). Training helps the workers respond in a more rapid way, which is crucial to succeed in a crisis but also helps to minimize the probability of accidents (Perrow, 1984). It is one of the main characteristics of a Resilient Organisation (Labaka, 2013). Banedanmark will have a simulations room in the new offices, where training will be able as a support to the learning from trial and error method, which is currently used (Hansen, 2015).

There is a lack of training through workshops and simulations for all employees of Banedanmark, with which Organisational Resilience could be strengthened.

Finally, the lack of information sharing within Banedanmark may cause misunderstandings and lack of “smoothness” during a crisis. Resilience is achieved with a good communication within the company and with external authorities and companies (Labaka, 2013). This communication should also be improved in order to have more flexibility when disruptions involving more than one country happen (Hansen, 2015).
**Economic Resilience**

Banedanmark is a public company, therefore when a crisis occurs there should be funds available to cover repairs and replacements in the tracks in order to be resilient (Labaka, 2013). The bounce back is faster as first responders, and organisations obtain resources more rapidly (Labaka, 2013).

Moreover, Banedanmark has a clause that specifies that losses and costs caused to the Train Operators companies will be absorbed by the affected company (Jensen, 2015). Therefore, Banedanmark is only responsible for the reparation of the tracks. This agreement makes Banedanmark more resilient as all the funds are invested in the network.

**Table 6**: Resilience Sub-Policies in Banedanmark.

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Resilience Sub-policies Supported</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Technical resilience</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Redundancy</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Security measures</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Maintenance tasks</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Data acquisition and trans-</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>mission equipment</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Organisational resilience</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emergency management</td>
<td></td>
<td>±</td>
</tr>
<tr>
<td>personnel training</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Formal structure of roles</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Incidents management</td>
<td></td>
<td>±</td>
</tr>
<tr>
<td>Operators training</td>
<td></td>
<td>±</td>
</tr>
<tr>
<td>Coordination among stake-</td>
<td></td>
<td>±</td>
</tr>
<tr>
<td>holders</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Understanding of Vulnera-</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>bilities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organisational learning</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td><strong>Economic resilience</strong></td>
<td>Crisis response and recovery</td>
<td>✓</td>
</tr>
<tr>
<td>resources</td>
<td>resources</td>
<td></td>
</tr>
</tbody>
</table>
6.4.3 DB Schenker

DB Schenker Rail Scandinavia is the production company in the Danish part of Europe’s largest rail freight carrier. It is responsible for the daily production of the company’s many freight trains which travel between destinations in Denmark or contribute to connecting Scandinavia with the rest of Europe. (DB Schenker a, 2015)

In order to analyse DB Schenker structure and mindset, a deep study of the organisation has been done based on the HROs characteristics. This deep analysis it is possible thanks to Henrik Møller Larsen, Head of Operations of DB Schenker Rail Scandinavia A/S.

Goal Prioritization and Consensus

DB Schenker’s main objective is the satisfaction of their customers providing high quality and reliable services through the best rail network in Europe (DB Schenker b, 2015). However, it is not possible to always provide the same services to every customer. Therefore, DB Schenker has two criteria of prioritization:

- Have a reliable network: a fluent and not-congested network is necessary to make the system work properly.
- Importance of the customer: in the case that having all the rails available (e.g. the Farris-Sommersted case) is not possible, the company has to prioritize depending on the customer.

Hence, DB Schenker has pressure from part of its customers in order to prioritize their own needs. DB Schenker has to deal with this pressure and try to organize their resources to be as much efficient as possible in front of their customers. In order to achieve these goals, the company has good and continuous communication with their stakeholders. They are honest with the customers in order to gain reliability towards them (Lemyre et al., 2011).

Even though the state of the rail tracks does not depend on DB Schenker, they have to care about safety too. That is why the company has implemented the Safety Management
Case Study

System (SMS), in order to identify hazards and improve safety. SMS segments four codes of importance for a situation based on the probability of the event and its severity:

- **Green**: Good functioning of lines
- **Yellow**: Planned interruption (e.g. maintenance of the tracks and complete closedown of tracks)
- **Orange**: Big interruption within the line (e.g. strike in Germany)
- **Red**: Complete closure of the line. This code can be activated by the following causes:
  - Unplanned and unexpected incident (e.g. Farris-Sommersted incident).
  - Foreseen incident. Plans can be held in advance and the company can be ready for the incident (Møller, 2015).

If there is a foreseen interruption of the network, e.g. a rail strike, as mentioned before DB Schenker divide their customers in different levels according to their importance:

- **Level 1**: DB Schenker put all its effort to continue its customer operations, regardless of the incident.
- **Level 2**: Operations are cancelled only if it is a Red mode (complete closure of the line)
- **Level 3**: When the interruption arrives, the trains designated to this customers are cancelled.
- **Level 4**: Operations are cancelled before the event occurs (Møller, 2015).

**Simultaneously Decentralized and Centralized Operations**

When a disruption occurs, all the parties in the management and operational level know how to perform depending on the importance of the situation. Therefore, the Operations Center do a priority plan in order to adjust to the allowed capacity and avoid congestions in Germany or Sweden, while the head of Operations schedule meetings to plan what it should be done and the Sales Department is responsible of contacting with the customers (Møller, 2015). Hence, having prepared personnel, improvisation to adapt to any situation and communication between stakeholders takes important roles in this circumstances if the company wants to stay effective and reliable (Perrow, 1984; Castillo, 2014; Labaka, 2013; Boin & Van Eeten, 2013; Van de Walle & Turoff, 2008).
In the “field-level”, operators as can be train drivers are well trained and perfectly capable to improvise in a crisis situation. Loco drivers know the rail way, since they have to learn it in advance in order to drive the train. Consequently, it is easier for them to manage properly any undesired situation (Møller, 2015). Additionally, with the introduction of the new signaling system, their level of preparedness to drive the locomotives will increase.

Continuous communication within the company is carried out in all levels, what makes possible to perform a good and coordinated response.

All in all, although DB Schenker has a defined chain of command, the organization has the ability and the proper personnel to delegate work to the most appropriate person/group in a crisis situation (Møller, 2015).

**Organisational Learning**

DB Schenker has learned from its past incidents that it is necessary to have plans for unforeseen disruptions (Møller, 2015). It is very difficult to have plans for any possible incident, but it is easier to recover if there is a fix plan and personnel can adapt to the circumstances (Castillo, 2014). The company is aware that improvise from scratch is not a good idea, but with training and established plans the personnel can improvise to adapt the plans (Møller, 2015).

Moreover, they know that customers who need to transport their goods to other places are “loyal” to the system that they are currently using (e.g. trains), until they are not available any more. In the Farris – Sommersted incident DB Schenker lost customers because they had to transport their products by trucks or ships, and after the incident they remained in that mode of transport. Hence, it is always better to provide capacity to customers with the aim of continue being their freight cargo transporter, than focusing in one big customer. Nevertheless, this is a difficult issue to deal with due to their priority goals (Møller, 2015).

**Extensive use of Redundancy**

DB Schenker learned about the importance of having redundancy in the system. During the Farris incident DB Schenker faced several challenges. They were not able to use the potential capacity of the alternative route. The main challenge was changing trains (from German to Danish) in Tønder. Now, DB Schenker has an agreement with the Danish Ministry of Transport to run German locomotives from Germany to Esbjerg (in Western Denmark) if they need so. By using this alternative they can triple the capacity of trains run compared to Tonder, improving this way their redundancy (Møller, 2015). This agreement has been established to deal with the summer planned interruption of the main line and by applying the lessons learnt in the Farris incident.
In addition, in the rest of Europe DB Schenker offers its customers access to one of the world’s largest rail networks and fleet of trains, becoming leader in rail freight transport (DB Schenker, 2013).

**Table 7: Presence of Resilience Characteristics in DB Schenker before the Farris incident.**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Robustness</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>They have good maintenance and offer quality certifications.</td>
</tr>
<tr>
<td>Redundancy</td>
<td>±</td>
<td>±</td>
<td>±</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Highly dependent on the route through the main line but they have a large fleet of trains available.</td>
</tr>
<tr>
<td>Resourcefulness</td>
<td>±</td>
<td>±</td>
<td>±</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Employees are highly qualified but lack of previous BC planning.</td>
</tr>
<tr>
<td>Rapidity</td>
<td>±</td>
<td>±</td>
<td>±</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>They were not able to provide alternatives fast enough which lead to a loss of customers, but they kept the largest ones.</td>
</tr>
<tr>
<td>Information sharing</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>There is constant communication with their customers, Banedanmark and within the company.</td>
</tr>
<tr>
<td>Adaptable</td>
<td>✓</td>
<td>±</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>P: Fast adaptation to Banedanmark’s restrictions. A: New plans of Capacity allocation for the new restrictions but with much less capacity offered to the customers. R: Highly dependent on the route through the main line</td>
</tr>
<tr>
<td>Leadership</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Leadership was present during the Farris incident as the personnel is highly qualified and with clear role definitions and responsibilities.</td>
</tr>
<tr>
<td>Awareness</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>P: With their monitoring and control systems they are able to avoid possible incidents. They are also conscious of their flaws and weaknesses. A: They were in contact with Banedanmark to know the state of the reparation.</td>
</tr>
</tbody>
</table>
Table 8: Presence of Resilience Characteristics in DB Schenker after applying the lessons learnt.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Robustness</td>
<td>✓</td>
<td>✓</td>
<td>Idem</td>
</tr>
<tr>
<td>Redundancy</td>
<td>✓</td>
<td>✓</td>
<td>New approval with Transportministerietto run German locomotive through Denmark.</td>
</tr>
<tr>
<td>Resourcefulness</td>
<td>✓</td>
<td>✓</td>
<td>Idem and with the new Signaling System the drivers will be more qualified.</td>
</tr>
<tr>
<td>Rapidity</td>
<td>✓</td>
<td>✓</td>
<td>With the new approval with Trafikskursen and the Signaling system they will be able to provide the services to their customers.</td>
</tr>
<tr>
<td>Information sharing</td>
<td>✓</td>
<td>✓</td>
<td>Idem</td>
</tr>
</tbody>
</table>
| Adaptability          | ✓     | ✓    | ✓    | P: Fast adaptation to Banedanmark’s restrictions.  
|                       |       |      | A: New Capacity allocation plans for possible disruptions.  
|                       |       |      | R: With the new approval with Transportministeriet they can provide more capacity for their customers in case of disruption. |
| Leadership            | ✓     | ✓    | Idem |
| Awareness             | ✓     | ✓    | Idem and will be improved with the new Signaling System. |

Technical resilience

In a mid or long term disruption, like the Farris – Sommersted case, DB Schenker has to adapt to the situation immediately after the incident in order to try not to lose customers, and then bounce back once the rail tracks are available again. In order to adapt to the situation, it is essential to continue providing services to the customers (Møller, 2015). In the rest of Europe DB Schenker has a meshed network that make them reliable and capable to respond rapidly to a disruption (DB Schenker, 2013). However, in the Farris – Sommersted incident, DB Schenker was not able to keep all their customers due to the lack of redundancy they had in Denmark in that moment. Moreover, in the alternative route that they used in the West of Jutland, they could only run with the 50% of the capacity (Jensen 2015; Møller, 2015). Nevertheless, their organizational learning awareness make them improve the redundancy and resourcefulness of the system in Denmark by having another route available if a disruption occurs in the main one (Møller, 2015).
DB Schenker transports goods such as chemicals, mineral oil, metals and coal, etc. (DB Schenker b, 2015), which forces them to carry out a constant maintenance of their locomotives and in continuous contact with the train drivers (DB Schenker c, 2015). Additionally, they want to go one step further being ecofriendly by reducing the amount of CO2 (DB Schenker, 2014).

**Organizational resilience**

Their organizational resilience influenced the rapid communication within the company and with stakeholders (Wheatley & Barnes, 2013). The continuous information sharing with Banedanmark enables the company to detect short-term crisis (e.g. big storms), and be prepared for them (Møller, 2015; Hansen, 2015). As mentioned before, DB Schenker has the Safety Management System that allows them to identify hazards in order to improve safety. Furthermore, the company has established plans for the short-term disruptions, made with the aim to accomplish the goals and priorities of the company. There is a clear understanding within the company of the roles that every department should take in case of disruption. If the situation cannot be fixed with their plans, they have qualified personnel capable to adapt the system to the circumstances. Personnel are well trained, both in “high” and “field” level. On the other hand, the company does not have plans for big and long term disruptions, since those situations are rare and the vulnerabilities are many. Although there is an awareness of the importance of such plans, it is very difficult to develop plans for any possible situation (Møller, 2015).

With the implementation of the Signaling system, train drivers’ training will be easier, and capacity of the rail tracks will increase, thus favoring DB Schenker’s operational services (ERTMS, 2014 d).

**Economic resilience**

Being one of the biggest transportation and logistics companies in the world makes DB Schenker Rail have a revenue in 2014 of 4,863 million euros (DB Schenker b, 2015). That allows the company to be prepared in economic terms to face an undesirable situation, and being able to provide more resources. Therefore, it is easier to bounce back by reducing their response and recovery times (Wheatley & Barnes, 2013).
### Table 9: Resilience Sub-Policies in DB Schenker.

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Resilience Sub-policies Supported</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Technical resilience</strong></td>
<td>Redundancy</td>
<td>✗</td>
</tr>
<tr>
<td></td>
<td>Security measures</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Maintenance tasks</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Data acquisition and transmission equipment</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Organisational resilience</strong></td>
<td>Emergency management personnel training</td>
<td>±</td>
</tr>
<tr>
<td></td>
<td>Formal structure of roles</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Incidents management</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Operators training</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Coordination among stakeholders</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Understanding of Vulnerabilities</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Organisational learning</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Economic resilience</strong></td>
<td>Crisis response and recovery resources</td>
<td>✓</td>
</tr>
</tbody>
</table>

### 6.4.4 Discussion

Even though Banedanmark and DB Schenker work jointly to provide an efficient Railway service to society and customers, these two organisations have many differences. For instance, both companies have different stakeholders and pressures. On one hand, Banedanmark is a public company with no competitors which receives pressure from the government. The proper functioning of the passengers’ line is vital for the company. Therefore, due to political pressures the company puts more attention on passenger trains than to freight trains, since passengers are the ones who vote in elections. On the other hand, DB Schenker is a private company with many competitors, not only in the railway sector but also in ship, road and air sector. Hence, the level of competitiveness is extremely higher, and as a consequence, the level of pressure they endure by stakeholders.

Despite Banedanmark receives pressure from the freight companies, when unforeseen disruptions occur, and uncertainty of the evolution of the recovery is present, they choose
to be conservative. In this way, they give the impression of being an efficient company towards the passengers. On the other hand, the conservative deadlines of Banedanmark may affect negatively DB Schenker depending on the duration of the disruption. Uncertainty can change drastically stakeholders’ decisions during a disruption. In short-term disruptions uncertainty is not important as they are very common and freight companies will more likely continue with its normal functioning. Furthermore, uncertainty does not affect stakeholders’ way of acting in long term disruptions (if recovery of a long term disruption takes 6 or 7 months, it does not make a difference). In contrast, in mid-term disruptions, uncertainty is a key aspect to take into account because the variation of deadlines can vary completely the way events unfold. If DB Schenker customers’ that moved to another way of transport had known the real deadline, maybe they would have continued operations with DB Schenker.

Comparing the resilient characteristics between companies that do not share the same goals is difficult, because the target, structure and circumstances are different. However, in general terms we conclude that DB Schenker has a more resilient organisational structure. Their communication within the company is very good, while Banedanmark should improve their organisational resilience by increasing the communication between departments. However, both companies are aware of their weaknesses, and thanks to their good organisational learning they have improved their resilience since the accident. They are continuously adapting the system: DB Schenker has improved their redundancy by contracting an alternative route in case of disruption, and Banedanmark is improving the network installing the ERTMS.

Becoming resilient gives to DB Schenker an advantage over its competitors, since they can easily adapt to unforeseen disruptions and guarantee reliability. On the contrary, Banedanmark has to be resilient in order to offer to society an efficient and reliable Critical Infrastructure. Therefore, any Critical Infrastructure owner should be resilient for the good of society.
In order to improve the traditional methods used in Organisations managing Critical Infrastructures, the application of resilient features when dealing with major disruptions has been studied in this report.

Protection of Critical Infrastructures is a big issue nowadays, which is one the reasons such area is in continuous evolution. The traditional techniques to managing crises have been shown to be very useful to deal with foreseeable events, however, as they rely on a very rigid structure such techniques are unable to cope with the unexpected. Resilience-based approaches, in contrast, intend to prepare organisations for the unforeseeable by enhancing their continuous adaptability.

Moreover, resilience approaches must be adapted to every organization as the willingness of applying resilience may differ according to the organization. It has been found that the goals and pressures of public and private organisations influence in their behavior.

In the Danish railway, the main concern of Banedanmark, the major owner of the tracks is a public organization, is to provide a reliable and safe network of tracks. However, there is a parallel political interest; they prioritize passenger trains as they have the legitimacy to decide in the elections. Furthermore, being almost a monopoly, Banedanmark is probably slower in improving the organization as their interests are safeguarded.

Private organizations, on the other hand, have external pressures. The existence of competitors (rail, road, ship...) that threaten DB Schenker’s profitability as customers may opt using another mean of transport. The resilient characteristics help DB Schenker maintain its status, provide an outstanding service, be reliable and able to manage any situation, especially when unexpected disruptions occurs, as they can emerge stronger and be one step ahead of competitors.

Sometimes, as in the Farris incident, unexpected disruptions may be useful to present organisations their weaknesses. In the two companies studied, it has been shown that in a long term view it was beneficial. They have both improved several aspects of the organization’s resilience. Banedanmark now has a better knowledge of the main rail owner in Germany. DB Schenker, is aware of the limitations of the alternative routes and has an approved permission from the Danish Government to use the alternative routes if needed.
After finding the advantages and weaknesses of Banedanmark and DB Schenker, the future work could be focused in implementing tangible resilient processes in order to improve their weaknesses.
REFERENCES


References


References


References


A IMPORTANCE OF NATIONAL AND LOCAL GOVERNMENTS TO ENSURE RESILIENCE

The following information is based on the National Infrastructure Advisory Council (US), (NIAC, 2009).

Protection of Critical Infrastructures is a matter that especially concerns both owners and operators of CIs (who can be private companies) and the government, since the disruption in any of them can affect all the society. That leads society and owners of Critical Infrastructures to have a resilient mindset in the organizations to face an all-hazard environment. The main objective of resilience in Critical Infrastructures is to deliver the goods of the infrastructure by reducing the magnitude and/or duration of any adverse event by absorbing, adapting or recovering from it.

Resilience is a tool to be reliable and redundant, therefore organizations are motivated to be resilient. That is why owners and operators of CIs are paying attention to identify operational risks and cross-sector risk. An incident in a specific CI can affect directly to another CI sector. Considering that every owner is the most qualified to prepare internally for possible disruptions, all sectors should work together in order to share information and prepare internally for possible disruptions and provide to each other needed services. This way, a more redundant global system will be acquired.

However, interconnection and complexity of the CIs system make it very difficult to organizations to foresee all consequences of any disruption in another sector to their own business, since many of the possible scenarios and impacts will be based on past experience.

Government should play an important role in protecting Critical Infrastructures. They are the ones who have to bridge the gap between public and private sector. There are some areas where the government should encourage the private operators to achieve resilient goals, even though the market forces may not support this achievement because it is not economically profitable.

All in all, the National Infrastructure Advisory Council (NIAC) of the United States have summarized in 6 findings and recommendations how resilience in CIs should be strengthened.
1) **Fortify Government Policy Framework to Strengthen Critical Infrastructure Resilience**

First, a clear definition of resilience is needed to have a basis to strengthen it. Secondly, public and private sector have to work jointly to find which areas need some incentives and then start a dialogue between owners and operators and the government. Private sector has to perceive that the government is involved receiving mechanisms to support resiliency practices. The government should also stimulate of fund maintenance and sustainability, thereby showing their commitment to resilience.

A national framework for coordinated planning, prioritization and performance should be developed in order to be able to achieve pre-established goals. These goals can be employee and public health and safety, environment protection, etc.

2) **Improve Government Coordination to Enhance Critical Infrastructure Resilience**

To support the established resilience goals, the government should coordinate and solve disputes between regulatory agencies that are responsible of the regulation of Critical Infrastructures.

3) **Clarify Roles and Responsibilities of Critical Infrastructure Partners**

If a disruption occurs in a CI, a clear structure of how recovery efforts and resources will be addressed, and by whom is needed. Leaders from both government and CIs owners and operators should be continuously communicating and sharing information in order to guide response actions, as well as being able to ongoing business activities and provide the services of each sector.

However, this communication should be done before and after the incident too, with the aim of prepare unforeseen incidents and learning about previous ones. A useful way to learn from past events is being able to monitor as much as possible.

4) **Strengthen and leverage public-private partnership**

Development of resilience is only achieved by mutual collaboration between public and private organizations. It cannot be improved just with stringent regulations, but with bidirectional communication. This can only be accomplished with a government capable to adapt to each sector’s needs, and flexible to coordinate efforts toward improving resilience.

Senior leadership is a useful tool to enhance executive relationships, set priorities, and ensure cross-sector collaboration during crisis situations. Government should take an important role ensuring high-level relationships between different sectors.

5) **Encourage Resilience Using Appropriate Market Incentives**

There are sectors such as water, energy or telecommunications that requires high levels of resilience due to market mechanisms. On the other hand, there are sectors where the economic costs of ensuring resilience may exceed the predicted benefit. The government should give a push to resilience practices in these situations by tax incentives or increasing funding for repair and maintenance.
6) **Implement Government Enabling Activities & Programs in Concert with Critical Infrastructure Owners and Operators**

As each sector and organization understand better which are their specific risks and cross-sector vulnerabilities, government should bridge a gap between sectors and identify interdependencies and improve preparedness, and make all the findings and practices available to all related sectors.
Figure 15: Railways in Denmark. (Banedanmark a)
ERTMS: Boosting the Use of Rail Through Europe

In order to increase the use of trains around Europe, in the early 1990s the European Rail industry boosted the European Railway Traffic Management System (ERTMS) to develop a common signaling system for Europe (ERTMS, 2014 c). This Signaling Program allows the railway sector to become a true competitor to roads. Nowadays, there are several constraints, especially for rail freight, that prevent this sector to be more widely used. Different electrification systems or administrative procedures and more than 20 legacy signaling systems in Europe among other limitations make the cross-border traffic for trains complex and difficult to manage (ERTMS, 2014 a).

Rail freight operators suffer this lack of a unified signaling system in Europe. In the past, each country or supplier tended to develop its own signaling system, and these systems were not interoperable between countries (ERTMS, 2014 c). This situation forces locomotives to be changed at each boundary or need to be equipped with the appropriate signaling system (ERTMS, 2014 a). Therefore, the driver’s cab must have a screen for each signaling system - especially in locomotives designed for long-distance freight - which has a bad impact on the ergonomics of the Driver Machine Interface (ERTMS, 2014 c). These constraints are costly and increase the technical and operational complexity for train operators.

ERTMS enables easier cross-border traffic movements across the EU, since coordination of domestic and international train services can be better performed. Moreover, the capacity on railway networks can increase significantly, as more trains can run on the same track. In the best-case scenario, the capacity can increase up to 40% more. That is one of the reasons why countries all over the world are using ERTMS, with nearly 50% of the total ERTMS sales made outside Europe (ERTMS, 2014 d).
ERTMS: Boosting the use of Rail Through Europe

Figure 16: ERTMS trackside contracts – In percentage, by region (ERTMS, 2014 j)

From the economic point of view, it entails a reduction of costs for freight operators, since they will only need ERTMS as the onboard system and staff’s training will be easier, as drivers will not need to know every signaling system (ERTMS, 2014 e). Furthermore, the increased capacity will benefit customers, consumers and the economy.

It is also a step forward for train operators. ERTMS monitors all operational modes (full supervising, shunting…). Hence, enriched data will be available for both drivers and control centers, which are continuously in contact by text messages (operation information) or voice communication calls (ERTMS, 2014 h). The system will also become more redundant since the emergency brakes are automatically applied if a driver misinterprets a signal (ERTMS, 2014 f), reducing this way the risk for human errors. Besides, it is possible to know the track condition everywhere, and drivers have more time to observe the track ahead (ERTMS, 2014 h).

In Europe 22,000 Km of route have already been contracted to work with ERTMS, developing 6 freight corridors along Europe (Rotterdam-Genoa; Stockholm-Napoli; Antwerp-Basel; Budapest-Valencia; Dresden-Constanta; Aachen-Terespol) (ERTMS, 2014 g). Those corridors will be operable in short and medium term, and the equipment of ERTMS will be mandatory through them (ERTMS, 2014 e). In order to develop this project efficiently, it is essential that the countries involved in the same Corridor work in a coordinated way and with a similar timeframe (ERTMS, 2014 g). Furthermore, some countries have gone beyond these obligations, as in the case of Denmark.
**Figure 17**: Global ERTMS contracted tracks (Km) in Europe (ERTMS, 2014)
**D** BANEDANMARK MAINTENANCE SERVICES

![Diagram of Maintenance Services](image)

- **Maintenance Services:**
  - 900 employees

- **Management Support**
  - Strategy
  - Operational
  - Development
  - Operational

- **Production Planning**
  - Optimize maintenance planning

- **Business Development**
  - Change initiatives for more efficient performance

- **Maintenance West:**
  - Jutland and Funen
  - Forestry task throughout DK

- **Maintenance East:**
  - Zealand and Copenhagen
  - Responsible for high voltage/power current
  - Ensure the traction system

- **Maintenance Nationwide:**
  - Land surveying and ultrasonic measurement
  - Continuous maintenance of track positions
  - Renewable tasks within Security/Traction and Tracks

- **Maintenance Machines:**
  - Rental and maintenance of the machinery
  - Management efforts in relation to safety

**Figure 18:** Maintenance Services. (Banedanmark c)
SETTLEMENT OF FREIGHT TRAFFIC


Agenda

1. Indledning
2. Samarbejdsfore
3. Disponeringsværktøjet
4. Ny Togleder Gods funktion
5. Lidt dokumentation
6. Vestfyn
7. Spørgsmål?

Samarbejdsfore med særlig fokus på afviklingen af godstogtrafikken gennem Danmark?

- Lokalitets i den daglige drift
- Bilaterale møder med jernbanevervshandlerne
- Godskorridermøder
- Pils-møder

Bilaterale møder med DB Schenker

- Fremtid
  - Operative mode (telefon)
  - Takstiske møder (fysisk)
  - Strategiske møder (fysisk)
- Frekvens:
  - Operative mode = dagligt (toggles, driftsleder)
  - Takstiske møder = månedligt (Teamleder)
  - Strategiske møder = kvartalsvis (Trafficchef)
- Godsfokus:
  - Godstogspenetration
  - Årsager til dårlig performance
  - Omsætningsprocenter
  - Brugen af disponeringsplan Gods
  - Samarbejdet generelt

Bilaterale møder med Hector Rail

- Form:
  - Operative mode (telefon)
  - Takstiske møder (fysisk)
- Frekvens:
  - Operative mode = dagligt (toggles, driftsleder)
  - Takstiske møder = halvårligt (Trafficchef)
- Godsfokus:
  - Godstogspenetration
  - Årsager til dårlig performance
  - Omsætningsprocenter
  - Brugen af disponeringsplan Gods
  - Samarbejdet generelt

Godskorridermøderne

- Form:
  - Fysisk mode
  - Telefonmode
- Frekvens:
  - Praksis mode - ca. hvert halve år
  - Telefonmode - hver uge (mandage)
- Deltager:
  - Banedanmark,
  - Trafikkeret,
  - DB Netz
- Relevante jernbanevervshandler (ud af fysiske mode)
- Godsfokus:
  - Afvikling af godstogtrafikken fra Hamburg til Stockholm
  - Godstogspenetration
  - Årsager til dårlig performance
Pøls-møderne

- Form:
  - Fysisk møde

- Frekvens:
  - Ca. hver 6 uge

- Deltagere:
  - Bæredanmark,
  - Trafikverket,
  - Øresundsbrosen,
  - Sund og Bælt,
  - relevante jernbanevirksomheder

- Godsfookus:
  - Afvikling af godstogstrafikken over Øresund
  - Godstogsspercentage
  - Årsager til dårlig performance

"Værktøj": Dispøneringsplan Gods

- Formål:
  - Sikre en høj rettelighed for gods-tog under transit gennem Danmark ved blandt andet at omlægge så mange forsinkede godstog fra udlænding som muligt

- Mål:
  - KPE Sverige: Omlægge mere 75% af forsinkede godstog fra Sverige (hviere end 60 min.)
  - KPE Norskland: Omlægge mere 75% af forsinkede godstog fra Norskland (hviere end 30 min.)

- Modeler:
  - Dialog med Trafikverket og DB netz
  - Værkelig dialog med jernbanevirksomhederne
  - Intensiv dispønering fra Driftcenter Danmark
  - Effektiv trafikstyring fra kommunadepartementer

Togleder Gods i Driftcenter Danmark

- Hvis:
  - Tjek af en ny togleder Gods-staffel i Driftcenter Danmark

- Fra:
  - Bæredanmark
  - Trafikverket
  - Øresundsbrosen
  - Sund og Bælt
  - Jernbanemængdrækt

- Mål:
  - Øjeblikksrettelighed
  - Godstogsspercentage
  - Årsager til dårlig performance

- Udviklingsplan Gods:
  - Dialog med Trafikverket, DB netz, kommandosætter og jernbanevirksomheder

- Udviklingsplan:
  - Fokus på godstogsrettelighed
  - Konstante ændringer i godstogsspercentage

- Mål:
  - Øjeblikksrettelighed
  - Godstogsspercentage

- Beskæftiget:
  - Tidlig 2015

- Hvad siger jernbanevirksomhederne?

Udvikling fra midtvejsvurderinger:

- Vi er meget tilfredse med den nye Togleder Gods.
- Vi har fået nemmere kommandoværk
- Vi har fået øget fokus på vores produktion
- Vi har fået kortere ekspeditionstid
- Vi har fået de samme få folk der bemandes toglederfunktionen
- Vi støttede fuldt og helt op om at beholde toglederfunktionen

Performance for transitgodstog

(ændet transitgodstog der kommer i deres laneafhængigt af og som ikke taber den)
Settlement of freight traffic

De foreløbige erfaringer - Togleder Gods

- Godsbyggerformance?
- Identificer årsager til dårlig performance og løs en på dette
- Øge kvaliteten af omlastninger
- Forbedre kvaliteten af omlastningerne
- Øget forudsigelighed og validitet
- Øget servicekvalitet for jernbaneselskaberne
- Bedre samarbejde indenfor både lokalt og ekstern

Way ahead - Togleder Gods

- Overvej at gøre testen permanent funktionen
- Overvej Øgro-bemannet Togleder gods funktion
- Udtætte/justere mål (KPI) for godsrettighed, omlastningsprocent m.v.
- Tidsskift (DeSk) med mål, milepæle og aktiviteter
- Apskrive de nye vilkår med Togleder Gods på den nye model for ledelsesafhæng i Danmark

Vestfyn 2015

- Aftale med jernbaneselskaberne:
  - at godskanalerne på Vestfyn bliver udnyttet optimalt.
  - at hvis den enkelte godssporer kommer for sent til "kim" kanal, så er det stadig muligt at passere Vestfyn inden for en passende tidshorstort.

Enighed i godsbranchen om en midlertidig opførelse af principippet om, at "et rettidigt tog skal forblive rettidigt."

Det betyder, at et forsinket godstog "skubber" et rettidigt godstog til næste kanal, hvorved det efekt rettidigt godstog bliver en time forsinket.

Og så fremdeles...
INTERVIEW QUESTIONS

The questions were slightly adapted to match with the interviewee (if Banedanmark or DB Schenker) and further questions were improvised during the interview.

<table>
<thead>
<tr>
<th>Company</th>
<th>Employee</th>
<th>Position during the disruption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banedanmark</td>
<td>Martin O. Jensen</td>
<td>Deputy Director of Traffic Operations</td>
</tr>
<tr>
<td></td>
<td>Jens J. Hensen</td>
<td>Traffic Manager</td>
</tr>
<tr>
<td>DB Schenker Rail Scandinavia A/S</td>
<td>Henrik M. Larsen</td>
<td>Head of Operations</td>
</tr>
</tbody>
</table>

Concerning general preparedness planning for unintended, sudden and major disruptions of rail tracks or train services:

- Do you have plans for the unexpected?
  - If so, which are the key points in your preparedness or contingency plans for such events in regard to informing and coordinating with your clients and customers?
- Judging from your experience of past events, which are the most difficult (complex) issues to handle during such disruptions?

Concerning the incident on 29.11.2012 between Farris and Sommersted:

- To which extent were you able to apply a preparedness or contingency plan for this event to inform and coordinate with your clients and customers (passenger and cargo)?
- Was communication and coordination with clients and customers (cargo operators) satisfactory from your point of view?
- Can you give us a brief sketch of how the interruption was handled in terms of re-routing and re-loading during the repair period?
- What were the main problems you faced during the disruption?
- How were the additional costs distributed by you and clients?
- What were the main lessons you learned from the incident?
- Is it your impression that your customers/operators were satisfied with the way in which the disruption was handled (here we do not mean the repair of tracks, but the coordination with clients and the handling of rerouting/reloading etc.)
A) Interview to Martin O. Jensen, Previous Deputy Director of Traffic Operations. 21st of May 2015, Copenhagen, Denmark.

**Communication:** Can be divided in two parts:

- Communication that happens operationally underground: usually happens after the incident. It is carried out efficiently between the Infrastructure Management Operator of Banedanmark and the train operator company. It is conducted very smoothly and there is 24-7 coverage. There is a extend knowledge of which is the correct person to inform when an incident occurs.

- Strategic communication: Covers the preparedness and planning, as well as strategic and tactical response when a disruption cannot be solved in a short period of time. It can become a political issue depending on the scope of the disruption. After the incident, Banedanmark has strengthened the ability to communicate between departments. However, communication with authorities can be difficult, because considering that the incident was in a Critical Infrastructure, not only Denmark was affected. Hence, Banedanmark had to deal with German railway authorities. There was the need of moving extra German staff to the north of Germany to open some stations to reallocate trains.

**Dealing with uncertainty:** One of the key points for dealing with the customers is to be honest about the forecasts. Banedanmark is usually conservative giving the estimation of what they think that a problem can last, but it is not positive to do it always because then they can lose credibility.

There is the need to be precise in short and medium term forecasts, because the way of acting of the customers can change drastically depending on the estimations. On long term disruptions there is no need of being so accurate, because the planning probably will be the same.

**Planning:** Have improved a lot doing plans for interruptions, but there is still the need of more improvement, especially for medium and long term interruptions. Taking into account that Denmark has not a meshed rail network, and that there are few main lines, alternatives to re-routing trains can be a difficult task. Therefore, more specific plans should be developed in order to be able to act immediately in case of disruption in an important line.

On the other hand, in relation to short interruptions Banedanmark has a lot of experience in handling them. There is a lot of preparedness in this field since it is common in Denmark to have snowfalls that can interrupt the circulation of trains during short periods of time.
Response: Very good response in terms of planning the alternative routes, but difficulty implementing the plans (less than 12 hours). It is difficult to move traffic from the east coast of Denmark to the west coast because of different regulations and limitations, e.g.: what kind of trains can go through a track, which weight, length, etc. One of the reasons it is because authorities have to check the plans and in some cases move extra staff to key points.

Difference between freight – passengers: It is easier to reallocate passengers than freight since passengers can be shifted easily into buses. On the cargo side, there is a lot of freight traffic coming from Sweden to Germany through Denmark that is heavy and big. There were basically 3 alternatives for the freight: ferries, tracks and the west route of Denmark. Nonetheless, the western line of Denmark could only carry around the 50% of the capacity of the eastern one, being that there were a number of restrictions of weight, and the lowest number of rail tracks. The cargo companies are the responsible of choosing which the best option is.

Other Difficulties: It can exist lack of motivation to move extra German staff due to the different priorities. Compare to Germany, Denmark is very small. Therefore, a problem in Denmark for them is minor.

How it is possible to gain reliability: In the railway system always can happen accidents. Therefore, the only way to gain reliability is to do a high maintenance of the tracks and get quality certificates.

B) Interview to Jens Jørgen Hansen, Traffic Manager in Banedanmark. 28th of May 2015, Copenhagen, Denmark.

Key points when a disruption occurs: They have Contingency plans (CP) in all tracks where there is more than one operator running the tracks. These are prepared in cooperation with the operators. Those plans detail exactly what to do depending on the traffic information, and the personnel is instructed and trained to carry out the CP. If a disruption occurs, Banedanmark is who inform the passengers.

For Unforeseen events, they use the principles of the established CP and try to adapt them to the situation.

Most complex issues to handle? Sometimes operators and resources are not in the correct place when a CP must be carry out. Therefore there is a limitation of resources.

Weakness
Training and educating people from the Operational level in this center and in the Signal boxes. Before, personnel would gather for two days and run through some scenarios. Due to the lack of resources in the last years now they gather one day and have an instructor teach the personnel.
In the new center they will have computer driven simulations of possible scenarios. *Use more the Operations Room.* There is a lack of communication. People tend to make their plans and do not share them to the signal boxes or other operators. Leadership must push them to improve communication. It is a cultural problem.

Training and educating is the solution to make them understand the importance of sharing information.

*Communication with Germany.* Communication is very good with Sweden but worse with Germany. Germany gives less importance to Denmark as it is a small country. Currently, there is much more communication but in a leadership level. There are problems with language and terminology too. More communication with Germany is needed in order to optimize the traffic to Germany. In Padborg they have much more communications daily as it is in the border.

*Intra-communication.* Planners are not in touch enough with the operations team. There should be more communication and involvement of the Operations Center. Implementation of plans is not always easy, therefore the planning sector should be more involved.

**Farris-Sommersted:** Plans used in the incident: Normal unplanned plans. They do not have a plan where it is a closure of the lines during three weeks involving 50% of the capacity. If the disruption had lasted only 6 hrs they could have waited.

Once they had enough data, they offered a path with the weight, speed and length of the trains to the freight companies.

For the long term disturbances the workers in the Control room are not working because there’s nothing to do, as the lines are closed. If there is a big incident they do 8 hours shifts because it requires a lot of concentration (in a normal situation they do 12 hours shifts).

Communication with Germany was smooth but they had some problems at the beginning. Now they have learnt who to call and what to ask for, e.g. if freight trains are involved who and where to call. Now they have a list with contacts in every level, functions, and offices in Germany.

Communication with Sweden is very good. Every two months one goes or comes to Denmark for a meeting.

On the other hand, they have meetings with Germany every one or two years. Before the Farris incident they never talked with Germany.

**Planning. Operations room.** Banedanmark and DSB are in the Operations room when a disruption occurs. DB Schenker and freight operators attend via phone or Skype.

Updated CPs are found in their intranet and every department has its own area in the management system. The personnel must follow the procedure as there are many instructions.

The plans are segmented by the route the train follows and the track where the disruption has occurred. The limit is of ten minutes of duration.

Banedanmark evaluates the plan after using it and then they correct it. Try and error practice.
Plans include how to use it, what to do with the different trains, traffic information, and what to cancel or not cancel (number of the passenger trains). Depending on the time of the day the number of trains cancelled will change.

If there is an incident causing a disruption in more than one track the plan would be combined manually. Try to adapt both plans but there is no current plan saying how to combine it. But it is a rare situation (it would be totally new and would have to do it from scratch).

This is an example of the Storm plan which was written after the two consecutive storms in 2013. During the 1st storm they did not have a contingency plan. However, they applied the lessons learnt in the storm that happened 2 weeks later. With the lessons learnt they wrote a Storm contingency plan in 1 year.

- **What to do:**
  - 36hrs before - Warning via telephone call to the personnel. Sms is sent. Contact freight operators and make everybody aware.
  - 24hrs - meeting and plan how to scale down the capacity in that area. Also consider the people and machine that are going to clean up, so that they have access to the area.
  - 20hrs - Same as 24 hrs. They have a 4 hrs margin. If it’s level 3, where there is a complete closure, the boss is involved.
  - 4hrs - Make into effect the plan

- Plans divided according to the wind speed. Green, yellow and red.
- The plan includes Prioritized Tracks in order to clean up those tracks before the rest.
- For every geographical area there are different plans.
- Bridges have different rules.
- Planners are in charge of planning after the first 48hrs.

**Traffic of goods:** They dialog with the operators and study the cases train by train. However, they do not involve cargo operators in the decision making, they just inform them. Freight trains have to be parked in advised stations.

CP for ordinary disturbances. If a train that has to pass through Denmark is delayed they make a new timetable for every train that is 30 mins delayed from Germany (⅓ of the total trains (200 trains per week)) and freight trains get a new timetable through the company. In Sweden the margin is of 60 minutes, due to the system they use. It takes 30 mins to create a new plan. They need a better warning to warn them more time in advance. Warnings are not always accurate and the new timetables are not used and they need new timetables.

The limitation of Sweden involves the use of Danish resources to stop the trains when going through Denmark in order to avoid a collapse in the Swedish border.

Hansen would like to reschedule the timetable with a delay of 5 mins.

They have big problem with trains that are not coming on time. Approximately 40% of the trains coming from Germany are delayed because Germany does not give importance to Denmark.
C) Interview to Henrik Møller Larsen, Head of Operations at DB Schenker Rail Scandinavia. 22nd May 2015, Høje Taastrup, Denmark.

SMS - Safety Management System: SMS segments three codes for importance of a situation based on the probability of the event and its severity. Green, yellow and red are used to visualise if the event is acceptable, tolerable/Undesirable, and unacceptable respectively.
- Green: Good functioning of lines
- Yellow: Planned interruption. E.g. Maintenance of the tracks and complete closedown of tracks. Margin of 4 hours of closure of the lines.
- Very dark yellow. E.g. Strike in Germany
- Red: Complete closure of the line.
Red code is usually activated by the following causes, both including the complete closing of lines:
- Unplanned and unexpected incident. Operations have to start right when the incident has occurred, e.g. Derailment of a train such as in the Farris-Sommersted incident.
- Foreseen incident: Plans can be held in advance and be ready for the incident. E.g. A weather hazard such as a strong storm where Banedanmark alerts that there will be a complete closure of the lines at 6.00pm.

The Head of Operations activates the Contingency management plan. All the parties in the management level are informed and aware that the system has entered a Red Code and they know exactly how to proceed by following already planned instructions:
- Safety manager:
- Public Affairs communication: Statement in regards of what is happening
- Sales department: Informs the customers.
- Operations center: Do a priority plan in order to adjust to the allowed capacity and avoid congestions in Germany and Sweden.
- Head of Operations: Schedule meetings to plan what is going to be done. With the management department.

Prioritization: Capacity allocation on the rails is affected depending on the code. DB Schenker has to prioritise which cargo is going to be allocated and when. There are two criteria of prioritization:
- Importance of the Customer: Volvo in Sweden puts a lot of pressure.
- Total network impact: If the system is not working correctly it can congest network and impact other trains.

Level 1. This level continues operation
Level 2. Red mode. Trains are cancelled
Level 3. When the strike has arrived
Level 4. Previous to the strike
Planning. Easy to act because the plans are exactly defined.

- Short: Weekly plans.
- Long: After one week Operation Center manage the disruption. In the Sommersted case planners tried to merge Danish plans with Germany and Sweden. It was a very rare case.
- Annual: Plans are updated every year.
- Strategic: High level planning.

They have their plans and once Banedanmark tells them the capacity they have, they shrink the plan to that capacity. Improvise within the plans.

Traffic in the main line involved in the accident:

- DSB 2 times / hour – 336 trains/week.
- DB Schenker 200 freight trains per week.

On Monday from 9.00 to 21.00 there was the complete closure of tracks due to construction of the double track line started after the accident. Tinglev-Padborg remains single track and still offers less capacity, and it is more vulnerable and in bad state part of the track.

Bottleneck /Difficulties:

There were 12-14 freight trains/day planned during the Farris incident and DB Schenker was only able to materialize 50%.

It takes 3-4 days to settle the system and match what you have planned after the disruption.

Channels - Get permission to drive via other tracks.

Sommersted incident: Banedanmark provided the alternative solution of running via Tonder but there was still the need of getting channels in the German side. Banedanmark was very fast in giving channels in Denmark, but Germany DB Netz, much slower due to rigidity.

Real line is run by a locomotive that can run in the three countries. When the track was switched, its Diesel locos permitted to run the tracks in Denmark, but they were more than 40 years old. The train had to be switched in Tonder and it is almost impossible. You need to have the German loco and the Diesel Danish one and they have to change wagons and go back the other way.

Limitations were severe in the new route:

- Farris route: trains of 835m to Fredericia and of 700m to Sweden. 2500 tons of weight capacity.
- New route: Northbound: 490m and South bound: 400m. Less capacity because it is single track but also less capacity on the trains. Weight limitations due to two bridges in Germany in the West coast. In one, where the most traffic goes you can only have 800 tons and on the other one with limited amount of traffic (but a high amount of passenger traffic) you have 1600 tons. It could be okay as the length is also reduced but there can be heavy cargo such as steel that may weigh 800 tons in 200m, what is very expensive.
Changing trains in Tonder was the main problem. However, they have learned from the incident and now they change locomotives in Eisbjerg, which have more capacity for changing trains.

Collective agreement for safety. Denmark was more flexible but very rigid in Germany.

Training
Loco drivers. They know perfectly the line they are driving, as they have to drive out and drive back with an instructor and an advisor. One day in DK and two days in Germany held to Regulation. Therefore, Operators learn by doing.

Alternative routes
First, they max out the capacity via ferries in Trelleborg- Rostock. It is a challenge because you buy capacity and the ferry has 600m maximum to take in but not in all the ferries because they have trucks and cars.
Banedanmark provides high level plans with weight and length and then DB Schenker adapts their production system to these capacity limitations.
Second, Intermodal terminal in Taulov and Padborg.
DB Schenker provides the allocation available for each customer. If the cargo cannot be shipped it’s the customer who has to find alternative routes.

Lessons learnt since the Farris incident.
- There are other opportunities that they can run but with limited capacity.
Last summer there was a planned closure of the tracks for three weeks and they planned with a German locomotive running up to Esbjerg. They come from Fredericia with a Danish loco and change there. There is more space and it is better to change. The German locomotive must be approved to run in the Danish rails by Ministry of Transport (10,000euros to check that the loco is in good state.) They are considering to have it every year. Also ask the Ministry of Transport how long it takes to have this certificate. One day would be good, one week is too much.
- Now they have a permanent permission to drive so if anything happens, they have this alternative route. They could triple the capacity of trains run compared to changing in Tonder. If something happens tomorrow and DB Schenker calls the German counterparts they would get the certificate very easily.
- The more plans they have and the more time to plan, the more capacity they can use.
- What you plan to what you materialise is very difficult to match.
- Now they have more experience and they can run more capacity.
- Improvisation is not a good idea. Planning is what will make the system work better.
- If you have a timetable planned but you change locomotives, you have to reorder to use that track. Safety rules.
All the costs were absorbed by DB Schenker.
**Communication**
With customers: Try to be honest and transmit the answer from Banedanmark. Banedanmark is very conservative to do calculations and clients are not happy with that because it is important to know precisely: 5 days they can wait but maybe they cannot wait 7 days. If they find another way of transport they have to check the extra costs. Companies using rail know that the infrastructure company is in charge to fix it. Now, planners know what they should ask for but the communication during the incident was very smooth.

**Capacity allocation after a disruption**
They do not have a problem in getting the capacity they like. More trains during the night (less passengers) and less during the day (more passengers). The percentage during a disruption is the same as in a normal situation. During 6-9a.m and 15-18p.m. no freight trains. Hectorrail canceled all the trains.

**Loss of customers**
They find a different mode of transport and then they stick with that. If a customer has a certain mode they will stick. If you force them into change them you also force them to stick with that. Always provide capacity so that they do not switch completely. If they have suppliers they also have to adapt to the new methodology so it is not so easy. Some customers never come back, others will come back gradually and other will come back just after the incident.
Department of Management Engineering
Technical University of Denmark
Centrifugevej 372
DK-2800 Kgs. Lyngby
Denmark