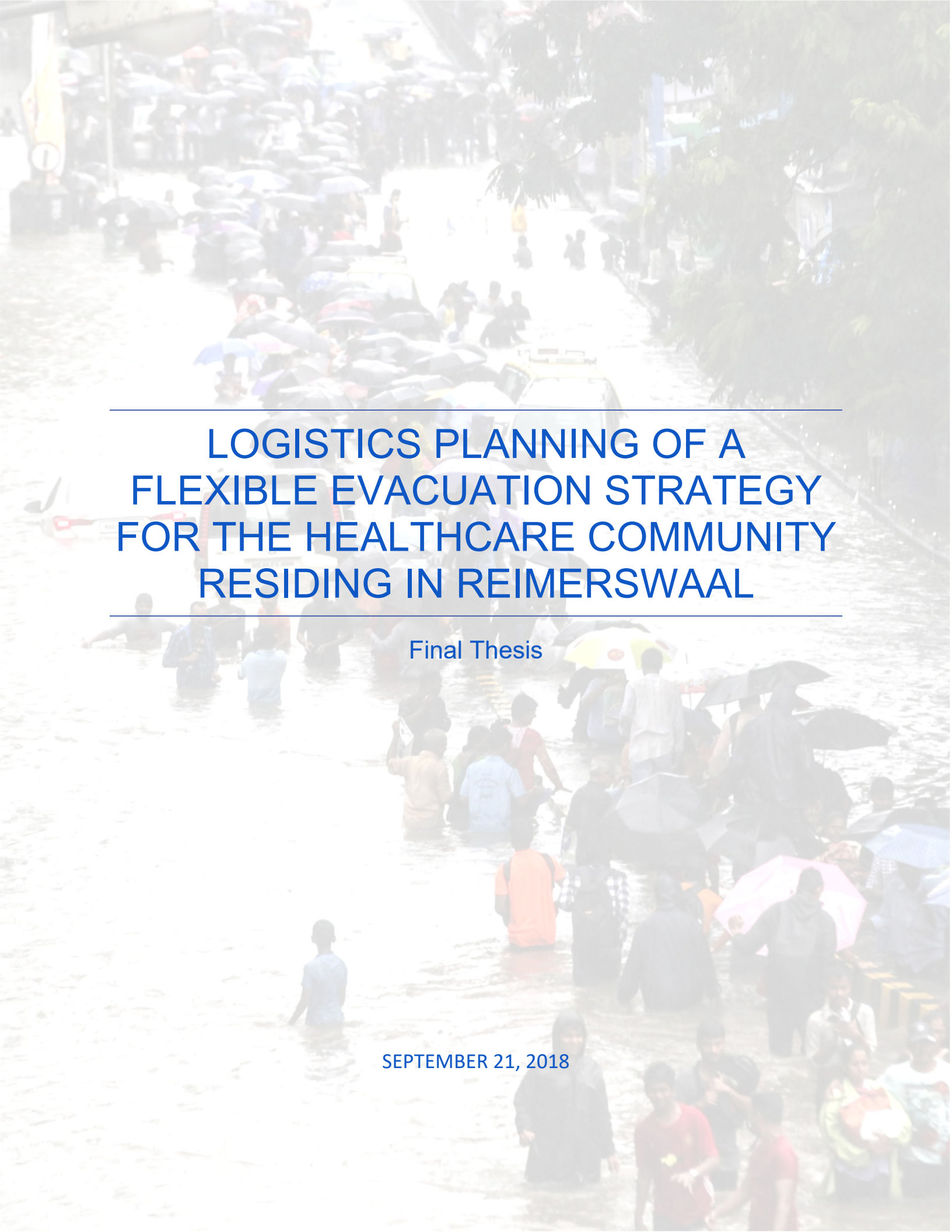

# LOGISTICS PLANNING OF A FLEXIBLE EVACUATION STRATEGY FOR THE HEALTHCARE COMMUNITY RESIDING IN REIMERSWAAL

Final Thesis

SEPTEMBER 21, 2018

# Logistics Planning of a Flexible Evacuation Strategy for the Healthcare Community Residing in Reimerswaal

## Final Thesis

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# LIST OF ABBREVIATIONS

**ACO: Adviescommissie voor het Ouderenbeleid**

**CI: Critical infrastructure**

**DPG: Director of Public Healthcare**

**FMECA: Failure mode, effect and criticality analysis**

**GGD: Gemeentelijke gezondheidsdienst**

**GHOR: Geneeskundige Hulpverleningsorganisatie in de Regio**

**GRIP: Gecoördineerde Regionale Incidentbestrijdings Procedure**

**HC1: Healthcare centres inside Reimerswaal**

**HC2: Healthcare centres outside Reimerswaal**

**IBT: Intensief Behandelteam Thuis**

**ICF: International Classification of Functioning, Disability and Health**

**KPI: Key Performance Indicator**

**MBT: Metallization-Based Treatment**

**MRAC: Model Reference Adaptive Control**

**ROT: Regionaal Operationeel Team**

**VLM: Vereniging Logistiek Management**

**VZR: Veiligheidsregio Zeeland**

**Wvr: Wet veiligheidsregio**

# SUMMARY

This research has focused on three different aspects of a possible dike breach in the municipality of Reimerswaal. Which were; what can be considered as the healthcare community in the municipality, the evacuation process of such individuals and finally, the effects that the failure of critical infrastructure can have in this process.

Human logistics, is the application of logistic theories into the 'flow of people'. Whilst in an regular supply chain process, the product is whatever is being produced, in an evacuation process the 'product' is the people that need to be evacuated. The application of different logistic theories can be useful to analyse the evacuation process and see where there can be improvements to be made. Which is why this research was focused on the *planning and control* part of the process (logistic concept).

This research developed its own definition on what the healthcare community is, in an evacuation process. Firstly there are the 'dependant individual' which are the individuals that are dependant of others to perform activities of daily life (the people who live in their own homes are considered resilient, so they are responsible for their own evacuation). Then, there are the healthcare centres inside and outside the affected area. Finally, the government entity that manages the evacuation of the 'dependant individuals'.

The current evacuation plan is developed by the evacuation team in Bevolkingszorg, who receives the assignment of the Regional Operational Team and 'on the spot' starts developing an evacuation plan, after the Rijks Team has already assessed the magnitude of the crisis (GRIP). As every situation is different, and they cannot develop a plan for every possible scenario, there is no 'sample plan', this means, that the evacuation plan is developed from scratch once the evacuation team receives the assignment.

It is very difficult to estimate the magnitude of the effect that the failure of different critical infrastructure can have in the evacuation process. The failure of each C.I. can have a different effect and the *cascading effect* can increase the number of failures.

There are methods to measure the performance; such as calculations for efficiency, time and capacity. Using historical data (data from the previous evacuation plans) it is possible to find the relations between different processes and have an idea on what is the 'standard' efficiency, time and capacity; for the evacuation process.

This measurements will be used to quantify the improvements that different logistic tools can apply. Tools like flowcharting and fishbone diagrams are a good method to analyse the different possibilities in the process. Visualising what is the current situation, what can go wrong, what can be the effect and how to prevent or mitigate it is the ultimate goal of these tools, continuous improvement.

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# 1. INTRODUCTION

For the project, the Critical Infrastructure (CI) in a Resilient Delta, the Resilient Deltas' research group (HZ Delta Academy) is interested in the time/logistic planning which is needed for evacuation. In general, people can be evacuated in two ways: horizontal (getting away from the danger) and vertical (shelter in place, for example in a higher floor in a building). With evacuating horizontally, it is important that people escape the area before a crisis situation will occur. In some cases it might not be possible (anymore) to evacuate horizontally or it might not be the most effective strategy. This is dependent on a lot of contingencies. To limit uncertainties and to be prepared for both strategies logistics planning is very important.

In the project relevant flood scenarios are available as well as a vulnerability analysis of critical infrastructure in Reimerswaal. The aim of this assignment is to compare both evacuation strategies in logistic planning and to develop improvements based on the available risk and vulnerability analysis. The student will conduct a desk study combined with interviews and logistic modelling to compile an overview of the logistics that is needed to evacuate horizontally and vertically in a predefined scenario. This study will be conducted in dialogue with our research partners (VRZ, Rijkswaterstaat Municipality of Reimerswaal, GGD).

The Reimerswaal municipality is located in the province of Zeeland, in the south-western delta of the Netherlands. It is a slim stretch of land which connects the peninsula of Walcheren and the mainland of the country; making it of great importance although being a small portion of the province. It is a low lying area, with a scattered set of inhabited villages, these general characteristics demand a solid indication of the local characteristics considering resilience in order to ensure fitting policy towards flood risk reduction.

Primary flood defences protect the back country from flooding from the major rivers, the sea or the large lakes. These barriers must comply with statutory standards. The severity of these standards varies from area to area, depending on the seriousness of the consequences in case of flooding. The flood defence systems are regularly checked and, if necessary, reinforced so that they continue to meet the standard (Nationaal Coördinator Terrorismebestrijding En Veiligheid, 2018).

In addition to the primary defences, there is also a finely meshed system of regional flood defences, such as dikes along smaller rivers or basement quays around polder areas. These regional defences must also comply with standards set by the provinces.

A large amount of CI is can be found in (and crosses through) the Reimerswaal municipality (Zeeland Province, 2016). The area of Reimerswaal has a potential threat of flooding, for being a low lying area (Algemeen Hoogtebestand Nederland, 2017). Flooding which can cause a disruption of CI sectors which

can lead to cascading effects on other infrastructures and affect the population of Reimerswaal and Zeeland (Insituut Fysieke Veiligheid, 2017).

In the RAAK project that studies the critical infrastructure, the impact that a failure in one of these CIs has on the healthcare community in an evacuation scenario is considered to be a missing link in the research. For this, it is necessary to have knowledge on the extent and the way the healthcare organisations can deliver their services before, during and after a dike breach in the Reimerswaal area (dike 31); as well as the impact on the wellbeing of the vulnerable (or less self-reliant) groups in the society.

In this research, the term ''healthcare community" will be referring to three different groups, which are considered to be directly involved in the evacuation process of the most vulnerable groups in Reimerswaal. These three groups consist of first, the people receiving medical care which (due to physical limitations) are dependant of other people for movement. The second group consists of the medical staff that are currently providing the aid to these individuals, as well as the facilities in which they are located. Finally, the facilities (and the staff within) to which the previous two groups will be translated in case of an evacuation in Reimerswaal.

To understand the impact that a dike breach may have on the evacuation of the healthcare community and the counter measures that should be developed to prevent the loss of life, the following research questions was formed:

- **Which logistic strategies should be developed to enhance the evacuation of the healthcare community before and during a flooding in the municipality of Reimerswaal?**

For answering these question, the following sub-questions must be answered.

- Which groups of people should be considered when referring to the 'evacuation of the healthcare community'?
  This will be the answer of which specific individuals and organisations will be considered in this research. Answering who is involved in the healthcare process and who to consider as a part of the healthcare community is necessary to continue this research.
- What are the current evacuation measures that the government would take in the event of a flood?
  This is to have an overview on how the government would handle a flood. What they can do well, what they believe should be improved, etcetera, to review the plan of the Nationaal Coördinator Terrorismebestrijding en Veiligheid.
- How can the failure of critical infrastructure affect the evacuation possibilities of the healthcare community?

As mentioned before, the cascading effect can have a great impact on the critical infrastructure of the Municipality of Reimerswaal. It is necessary to understand the impact that these failures will have on the evacuation process of the healthcare community.

- What logistic measures should be taken to minimise the damage to the healthcare community in the events of an evacuation in a flooding scenario?

  In case of a flood, it is necessary for the government, and the population and organisations in the healthcare community have a clear idea of what their roles are and how to execute it. And how the failure of CI may affect the role of each group.

- What contingency measures can be taken to counter the different possible scenarios that a flooding may cause?

  The best-case scenario would be the preventive evacuation (before the flood has happened), but it is not always possible to do that. So, it is necessary to have some contingency plans for the different scenarios that can be presented, for example the failure of critical infrastructure.

These questions are to be answered by referring to existent material provided by the Delta team and its partners (VRZ, Rijkswaterstaat Municipality of Reimerswaal, GGD), and consulting related bibliography. The first chapter contains the theoretical framework of this research report. Followed by the research method that will be performed. The next chapter has some background information about the Municipality, a description of the its geographic importance and other information related to the flooding scenarios, which will be needed to understand the rest of the report. Then a detailed description of the measures currently taken by the Dutch Government in flooding cases. Then, different (contingency) scenario possibilities (for example mayor road being blocked) will be presented and the measures to counter them will be explained. Finally, the report will end with a discussion about the results of the research and the conclusion of such; with a list of changes that can be made into the current evacuation plan for the healthcare community and how to apply them.

The objective for this research is to develop a logistic strategy to enhance the evacuation process for the healthcare community residing in Reimerswaal, due to the probability of a flooding happening. This strategy should have a detailed explanation of the flow of people in the case of an emergency, how the reliant public in Reimerswaal (and its surroundings) and the Dutch Government should react to prevent the loss of life during the flooding. The report should also contain some ‘contingency plans’ due to the level of uncertainty that the extend of the damage would cause (for example a main road being unavailable).

# 2. THEORETICAL FRAMEWORK

In order to proceed with the current research, 'speed' and 'efficiency' have been identified as the main aspects which have influence on the evacuation planning method; the first concerns the time in which the evacuation should take place before the situation worsens and the ladder concerns the effectiveness of the evacuation (100%) for the period of time. When an area is likely to be flooded, it is necessary to have contingency measures for all the possible scenarios, but also taking into account the challenges that the area and its residents can present.

This chapter discussed different theories on what is the best practice for enhancing the current evacuation plan. Starting with some basic analysis on how decision models can be used to think of all possible scenarios, followed by a brief explanation on what a healthcare facility needs to take into account when performing an evacuation. The next point is crisis management analysis. Ending with an explanation on the logistic concept.

## 2.1 Logistic concept

The logistic concept was chosen to be used as guide to understand the report. As is one of the most basic understandings of logistics, it explains well to the reader how to achieve the objectives of the company in the point of view of logistics.

One of the core tasks of logistics management is finding a balance between the realisation of external and internal objectives. Four points require specific attention that are vital to the successful realisation of the logistic objectives (Visser & van Goor, 2011).

- **Structure:** This concerns the physical characteristics of facilities that directly influence the internal processing, transport and storage of goods, for instance layout of the factory machinery into logistical processing locations (in other words, setting of the primary process).
- **Control:** The way in which the primary processes are managed and monitored, for example work planning.
- **Provision of Information:** It is not possible to manage the logistics without an adequate information system, for example to calculate the material requirements.
- **The Organisation Personnel:** How can effective coordination between logistics and other functions in the organisation best be achieved, for example who is responsible for planning activities?

These four points are interconnected. In an actual business situation the way in which these points are addressed determines the logistic performance: the extent to which external and internal logistic objectives are achieved (Visser & van Goor, 2011).

The four decisions depicted in figure 2.4 are extensions of each other and this is why they should be taken in this same sequence. The way in which the four elements are implemented in the organisation largely determines the logistics performance, commonly presented as key performance indicators (Visser & van Goor, 2011).

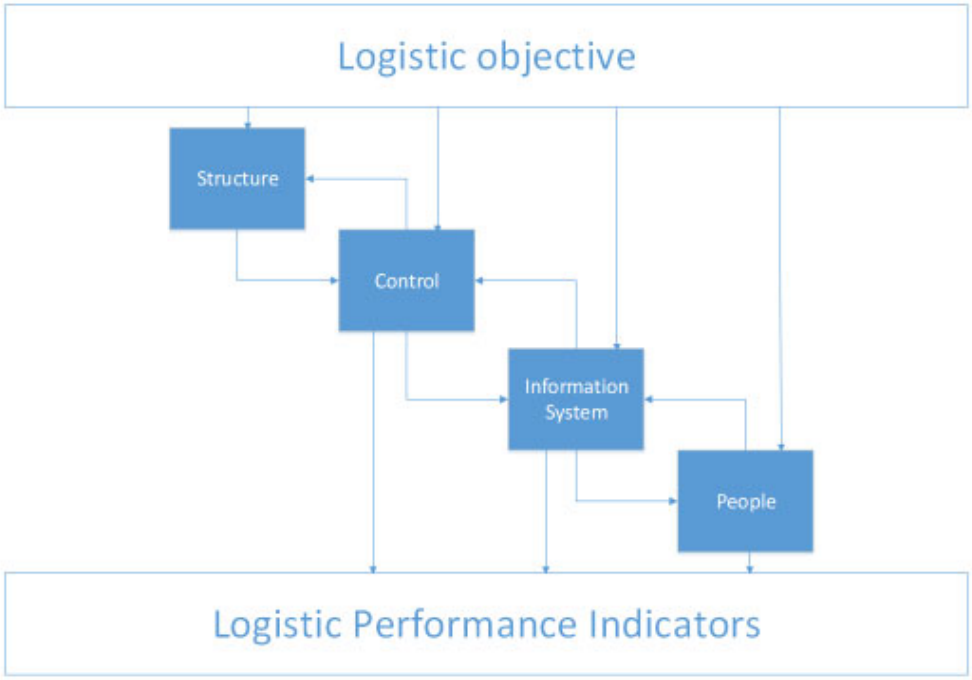


***Figure 2.1:*** *Integral logistics concept (Visser & van Goor, 2011)*

Applying a logistic concept offers a complete approach, whereby the entire supply chain has to be looked at, and not just the individual chains in the flow of goods. Thereby the organisations prevent improvements having disadvantages for another chain further in the logistic chain. It offers a common thread for a change plan, whereby you can work from step to step (VLM, n/d). A complete approach means that the management synchronizes all decisions regarding the flow of goods, the planning and guidance of the flow of goods, the supporting ICT as well as the organization. Before you can fill in the logistic concept, the goals of the company, the chosen strategy and the to be derived logistic goals have to be clear. This is a task for the management (VLM, n/d). The logistic concept is not finished until the performance indicators by which the management can follow the quality of the logistic performances are determined. All elements constantly have to connect to each other. By this we find out the coherence between the various solutions in developing a logistic concept for a company. The implementation of this concept determines the logistic performances and the profit a company can make with its logistics. Of course, the way the logistics are arranged has to suit the company's strategy (VLM, n/d).

## 2.2 Urban hospital evacuation

Every healthcare facility in the Netherlands needs to periodically present an evacuation plan, this plan will be seen by Geneeskundige Hulpverleningsorganisatie in de Regio (GHOR) and they need to approve the plan, This is for the facility to be prepared in case for an emergency, and also for the government to have a clear view on what the evacuation process of these facilities is. This theory talks about the points to have in mind when evacuating low mobility groups.

In theory, the responsibility for the evacuation of low mobility groups in facilities like prisons, hospitals, and special schools usually lies with the facility administrators. In practice, however, these administrators are often not familiar with, and not trained in, emergency management or mass transportation. Recognizing this situation, some state emergency management agencies in the U.S.A. have attempted to make special arrangements for these groups. This includes the establishment of pick-up points for the poor and elderly. Coordination of this type often requires agreements to be in place between the emergency management agencies and various Boards of Education, for use of school buses, or mass transit providers (for example tour and public bus companies) (Wolhson et al., 2014).

On June 9, 2001 there was a flood at the Memorial Hermaan Hospital in Texas due to heavy rains caused by the tropical storm Allison, which forced the hospital to evacuate.

A hospital disaster preparation plan is usually directed toward handling an **external event** that creates mass casualties, not an **internal event** that requires complete evacuation of the institution. The evacuation of a hospital is rare, but; rarer still is forced evacuation without power, which is what happened in Texas.

This experience created several points to be considered for the evacuation of any public facility, such as the following (Cocanour, Allen, Mazabob, et al.; 2002):

1. Flooding will occur in a flood plain
2. Electrical power outages are not necessarily temporary, begin evacuation when it occurs
3. Appoint a triage officer from those available
4. Have a reliable in-house communication system not dependent on telephone lines or electricity
5. Have a reliable telephone system for contacting outside facilities
6. Have flashlights available on all units
7. Have battery-operated exit signs and stairway lights
8. Maximize use of volunteers when they are available and fresh
9. Maintain a paper record of all patient transfers
10. Coordinate loading of ambulances and helicopters for patient transfer
11. Reassign staff as necessary to care for transferred patients. Emergent evacuation of a large, tertiary hospital requires extensive effort from both the hospital staff and the community

### 2.2.1 CARING FOR THE MOST VULNERABLE

Non-drivers include a diverse group of people who face various combinations of physical, economic and social disadvantages. A system designed for non-drivers must therefore be able to accommodate a wide range of needs, including poverty, physical and mental disabilities (Access Board, 2005), illnesses, inability to speak or read English, parents with young children, distrust of authority, frustration and anger. Many non-drivers lack convenient access to the Internet, and some lack regular telephone and mail service. Many had nowhere to stay outside of the city and no money to pay for housing, food or return transportation. Understanding and responding to these diverse needs is therefore important for effective disaster management and evacuation planning.

Under emergency conditions public infrastructure may be stressed. For example, a typical bus can normally carry about 50 passengers, but in an emergency, with evacuees carrying baggage, some in wheelchairs, and communication systems overwhelmed, 30-40 passengers is a more realistic load. It will therefore be important to provide a generous amount of overcapacity and redundancy.

In an article titled “Planning for the Evacuation of New Orleans” (about the evacuation during hurricanes Katrina and Rita) published in the Institute of Transportation Engineers Journal (Wolshon, 2002, p. 45) the author explains,

> *Of the 1.4 million inhabitants in the high-threat areas, it is assumed only approximately 60 percent of the population or about 850,000 people will want, or be able, to leave the city. The reasons are numerous. Although the primary reasons are a lack of transportation (it is estimated that about 200,000 to 300,000 people do not have access to reliable personal transportation), an unwillingness to leave homes and property (estimated to be at least 100,000 people) and a lack of outbound roadway capacity.*

| General | Transportation |
|---|---|
| • Failure to track the number of people at emergency shelters, and provide adequate facilities and resources.<br>• Failure to define who is in charge, conflicts over authority, and inadequate communication among top-level decision-makers.<br>• Failure to distribute food and water immediately after the hurricane.<br>• Waiting until the fourth day to deploy the National Guard and supply ships waiting nearby.<br>• Failure to provide security to rescue teams.<br>• Failure to help evacuate families of essential staff (police, fire, transit, healthcare, utility, etc.) so they could concentrate on emergency response.<br>• Failure of communications systems (telephone service stopped) and backup generators at critical facilities.<br>• Official overreaction to reports of violence, and so failing to provide help or allow evacuation of some people, particularly African-Americans.<br>• Failure to show respect and compassion to disadvantaged people. | • Failure to have an effective evacuation plan for non-drivers.<br>• Failure to prioritize evacuation to insure that the most vulnerable (residents of the riskiest areas and people with special needs) leave first.<br>• Failure to understand and address the reasons that discourage people from evacuating.<br>• Failure to offer free or subsidized evacuation transport to people who need it.<br>• Failure to prioritize evacuation traffic to favor buses, HOVs and service vehicles.<br>• Failure to implement a transit and school bus "evacuation action plan."<br>• Failure to use counterflow lanes and road shoulders for evacuation traffic, in some cases where it was possible.<br>• Failure to coordinate vehicle rentals, fuel distribution and services along evacuation route.<br>• Failure to use public transit, school buses, charter buses and trains for evacuation.<br>• Failure to accommodate pets. |

***Table 1:*** *Examples of poor decision-making encountered during hurricanes Katrina and Rita (Source: Lessons from Katrina and Rita; What major disasters can teach transportation planners; Litman, 2006)*

## 2.3 Crisis management

A good planning principle is to "hope for the best but prepare for the worst." We often have trouble imagining the worst scenario until the terrible event occurs. Only then can emergency response preparations be evaluated. This theory explains what are the disadvantages on the management during a crisis.

Crises are of a different magnitude and character. A crisis may be defined as 'a breakdown of familiar symbolic frameworks that legitimises the pre-existing socio-political order' ('t Hart, 1993: 39). It entails a threat to the core values of a system or the functioning of life-sustaining systems, which must be urgently dealt with under conditions of deep uncertainty (Rosenthal, Boin and Comfort, 2001). CI breakdowns that depart from known failure paths and 'behave' in seemingly erratic ways, jumping from one system to another, tend to generate a deeply felt sense of crisis. The breakdown of the electrical grid across the north-eastern US (2003) caused more than just an emergency; it constituted a real crisis – broadcast live on the major networks – and posed operational and strategic challenges to both governmental and private actors.

The question is whether infrastructural breakdowns can cause unprecedented damage (in terms of property and lives lost), paralysing life-sustaining functions for long periods of time. Many scenarios have seen the light (with a notable spike during the pre-Millennium months), but catastrophes caused by infrastructural breakdowns have yet to emerge. They fall in the category of 'future crises' (Rosenthal, Boin

and Comfort, 2001) and 'worst cases' (Clarke, 2005). Discussing CI breakdowns in terms of potential **catastrophes** is, therefore, somewhat of a theoretical exercise.

Yet, mapping out the sheer devastation and chaos that may ensue, we get a real sense that an infrastructural breakdown may present challenges that are well beyond the routine contingency planning and management capacities of public authorities. If we have serious aspirations to deal with the consequences of these future crises, we need to identify both the weaknesses of traditional crisis and disaster management practices, as well as the seeds of a strategy for enhancing our capacities to cope with worst-case scenarios.

### 2.3.1 LIMITATIONS OF CRISIS MANAGEMENT

Crisis management is often viewed as a holistic process involving prevention, planning acute response, recovery and learning (Comfort, 1988; Nudell & Antokol, 1988; Coombs, 1999; Fink, 2002).

#### *Contingency planning: necessary but not sufficient*

There is much to be gained from the prior specification of roles and responsibilities; the allocation of materials, equipment and information systems; and the testing of systems under 'trial' conditions through simulations and exercises (Rosenthal and Pijnenburg, 1991; 't Hart, 1997; Boin, Kofman and Overdijk, 2004). However, planning is no panacea (McConnell and Drennan, 2006). Developing plans that work for the endless array of complex, chaotic and destructive scenarios that arise from interlocking and often mutually dependent infrastructures may be all but impossible.

The planning process itself has some in-built vulnerabilities. For instance, planning requires multi-agency cooperation and coordination (Hillyard, 2000), which often strand in the realities of bureaucratic politics (Rosenthal, 't Hart and Kouzmin, 1991). The barriers to cross-agency collaboration include differences in organizational goals, professional cultures, lines of accountability, political control styles and decision-making cycles. To complicate matters, many of the organisations involved in crisis planning involve actors in the voluntary and private sectors. In the case of CIs, it should be realised that vast networks of formerly public utilities are wholly or partly in the hands of privatized or semi-privatised companies (cf. Boin and Smith, 2006).

Then there is the matter of costs. The conversion of 'paper plans' into organisational readiness through staff training and crisis exercises can be expensive and time consuming. Investing resources to plan for a multitude of extreme events that may never happen is no easy sell in a time of budget constraints. Other organizational factors such as cultural complacency, resource limitations and shifting priorities conspire to derail or dead-end a crisis plan.

This failed planning for a major hurricane illustrates the wider argument by Clarke (1999) that contingency plans often amount to little more than 'fantasy documents'. In other words, they

signal a state of preparedness that bears little relation or relevance to the challenges that emerge with a crisis. It would be unwise to completely disregard planning as a preparation tool for CI breakdowns, but we should not be overconfident with regard to the capacity of a plan to prepare operational responders and crisis managers for the vast range of extraordinary, complex and critical threats that they are sure to encounter in times of crisis.

### 2.3.2 ENHANCING SOCIETAL RESILIENCE

The United Nations International Strategy for Disaster Reduction (UN/ISDR) has adopted the term resilience and defines it with reference to natural hazards as:

> *The ability of a system to reduce, prevent, anticipate, absorb and adapt, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions (UN/ISDR, 2013, p. 13).*

Research on large-scale natural disasters strongly suggests that an effective response during the immediate aftermath (the first hours and days) critically depends on the resilience of citizens, first-line responders, and operational commanders (Barton, 1969; Dynes, 1970; Drabek, 1986). Only in the long-run (days, weeks, months) can strategic leaders make a tangible difference 'on the ground'. In preparing to deal with crises and, especially, catastrophes, efforts should therefore be focused on the promotion of resilience i.e. the ability to 'bounce back' after suffering a damaging blow (Wildavsky, 1988; Baer et al., 2005; Longstaff, 2005).

Some strategies for enhancing societal resilience can be;

- Preparing first responders
- Business continuity planning
- Working with communities
- Working with private owners of CI
- Joint preparation
- Joint training
- Training leaders

## 2.4 Damage on the critical infrastructure

It is necessary to have a clear understanding on C.I. in order to be able to answer the last three sub-question, as C.I. is the one of focus of them. This theory discusses what is considered to be critical infrastructure, which are the interdependencies between the different kinds of CI, what are the different types of failure that can occur and finally, the effect that the damage on critical infrastructure can have on the evacuation of the healthcare community.

Infrastructure provides the basic needs for a well-being nation or region. Infrastructure like roads, waterways and telecommunication provide citizens and companies with basic needs for everyday life while other kind of infrastructure protect and connect the region where citizens and companies accommodate (Rinaldi, Peerenboom, & Kelly, 2001). The infrastructure does not only connect, but also keeps a region competitive and attractive for economic activities and tourism. Cis (Critical Infrastructures) on the other hand are the products, services and processes that are vital for everyday life (like water, electricity, etcetera). When CI is disrupted, it can cause great social economic damage, because CI is most of the time interconnected with each other (as shown in Figure 6.1). The community who is dependent on CI can be greatly affected by such a disruption. The society of today is highly dependent on CI while society expects that CI keeps performing 24 hours a day (Addae, Hebbink, & Hamelink, 2015). The CI is divided into different sectors according to the services or goods the sectors provide.

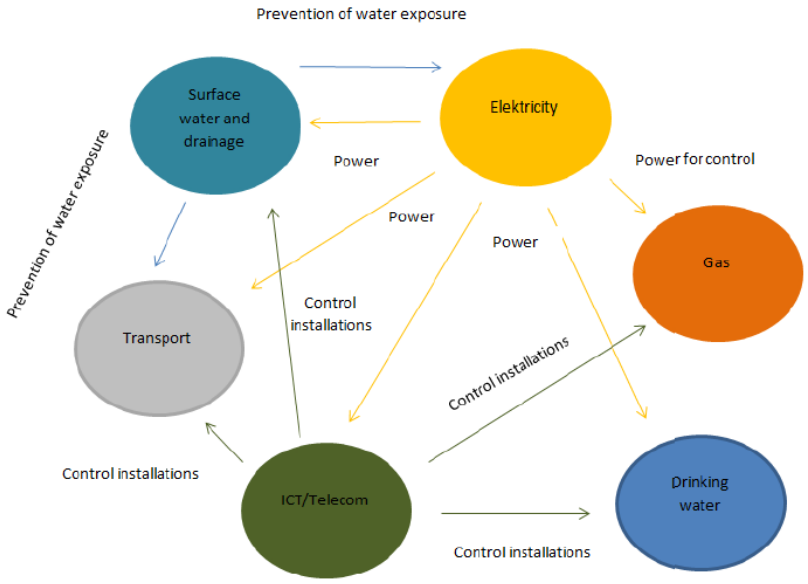


***Figure 2.1:*** *Interdependencies in CI sectors (Translated) (Instituut Fysieke Veiligheid, 2017)*

## 2.4.1 CASCADING EFFECT

The amount of socio-economic damage depends on what kind of failure is causing a disruption. There are three types of failures:

### *Escalating failure*

An escalating failure occurs when an existing disruption in one infrastructure sector exacerbate a disruption in another infrastructure sector. For instance, a failure in the electricity sector causes that the information sector is affected, but the information sector is not fully down. The weakened information sector also affects other sectors in the system like internet traffic (Laprie, Kanoun, & Kaaniche, 2006).The second type of failure is a common failure.

### *Common failure*

A common failure is a failure when two or more infrastructure sectors are affected simultaneously. This can for example happen when hurricane strikes a region and affects multiple infrastructure sectors at once. An escalating or common failure can lead to a cascading failure as well (Pescaroli & Alexander, 2015).

### *Cascading failure*

A cascading failure occurs when one system is disrupted other sectors will experience a disruption as well. A failure can become worse as it affects multiple sectors at once. A cascading failure is an indirect consequence of a disruptive event, because it is causing a chain reaction in other sectors (Stowa, 2017). A clear and relevant example is the electricity blackout in Amsterdam of 2017. A small short circuit in the electricity line caused a cascading effect in the energy infrastructure. This caused a cascade effect on other sectors as well. The traffic around Amsterdam was in chaos, trains could not drive and hospitals could not function normally. After a few hours the electricity blackout was solved, but the society around Amsterdam needed a few hours more to function normally again (Stokmans & Logtenberg, 2017). Cascading failures situations are rare; however, such situations can influence many sectors and disrupt large communities.

The Circle approach of the Deltares Company is an analyse method that analyses the possible cascading effects when CI is failing in a certain area. The Circle approach is following a stepwise approach whereby information is gathered to make a risk assessment with a risk map. Although this advanced modelling is not new, the Circle approach is more detailed and visualizes different scenarios in an interactive map (Deltares, 2015). The consortium of the Hz, province of Zeeland, municipality of Reimerswaal, Veiligheidsregio Zeeland, RWS, water board Scheldestromen uses the Circle method to identify the cascading effects in the municipality of Reimerswaal (Buijs, Hounjet, & Fundter, 2016).

If the cascading effects are known, organisations can adapt their crisis management plans in order to deal with cascading effects. A better crisis management plan leads to a more resilient organisation what can deal with cascading effects in their system (Boin & McConnell, 2007).

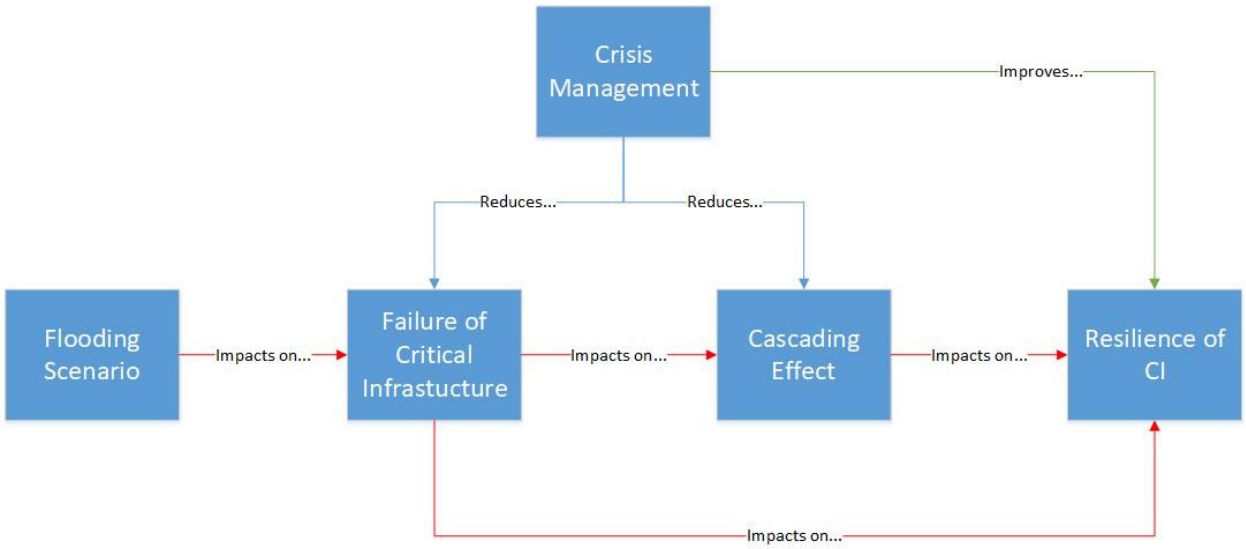


***Figure 2.3:*** *Conceptual model (Schelkens, 2018)*

## 2.5 Production planning system

Manufacturing is complex. Some firms make a few different products whereas others make many products. However, each uses a variety of processes , machinery, equipment, labour skills, and material. To be profitable, a company must organise all these factors to make the right goods at the right time at top quality and do so as economically as possible. It is a complex problem, and it is essential to have a good planning and control system (Arnold, Chapman & Clive, 2008).

A good planning system must answer four questions:

1. What are we going to make
2. What does it take to make it?
3. What do we have?
4. What do we need?

These are questions of priority and capacity.

**Priority** relates to what products are needed, how many are needed, and when they are needed. The marketplace establishes the priorities. Manufacturing is responsible for devising plans to satisfy the market demand if possible (Arnold, Chapman & Clive, 2008).

**Capacity** Is the capability of manufacturing to produce goods and services. Eventually it depends on the resources of the company- The machinery, labour, and financial resources, and the availability of material from suppliers. In the short run, capacity is the quantity of work that labour and equipment can perform in a given period. The relationship between priority and capacity should be balanced (Arnold, Chapman & Clive, 2008).

### 2.5.1 PLANNING AND CONTROL SYSTEM

There are five major levels in the manufacturing planning and control (MPC) system:

- **Strategic business plan** is a statement of the major goals and objectives the company expects to achieve over the next 2 to 10 years.
- **Production plan** (sales and operations plan) is concerned with; the quantities of each product group that must be produced in each period, the desired inventory levels, the resources of equipment, labour, and material needed in each period, and the availability of the resources needed.
- **Master production schedule** is a plan for the production of individual end items. It breaks down the production plan to show, for each period, the quantity of each end item to be made.
- **Material requirement plan** is a plan for the production and purchase of the components used in making the items in the master production schedule.
- **Purchasing and production activity control** represents the implementation and control phase of the production planning and control system.

At each level, three questions must be answered:

1. What are the priorities- How much of what is to be produced and when?
2. What is the available capacity- What resources do we have?
3. How can the differences between priorities and capacity be resolved?

## 2.6 Evacuation modelling

To have a clear view of the evacuation process is helpful to have a visual representation of the steps taken in the process. This is where the evacuation modelling takes part, as is supposed to be a model that can be adapted to the different possible scenarios. While it is impossible to be prepared for every kind of scenario, it is helpful to have a flexible model that can adapt to such situation.

Man-made or natural disasters, either predictable or not, could result in severe life losses and property damages. Emergency evacuation, a mass movement of people and their properties from disaster-impacted areas to safer ones, has been studied and practiced for decades as one means of countermeasures to mitigate these calamitous consequences. Existing evacuation research in transportation field has been mostly focusing on the planning stage, from various perspectives such as traffic management policies (Theodoulou and Wolshon, 2004), origin-destination (OD) trip estimations (Mei, 2002; Murray-Tuite and Mahmassani 2003; Fu and Wilmot 2004), and behaviour analysis (Baker 1991; Helbing et al. 2000; Fraser-Mitchell 2001). Moreover, due to the distinct features of different types of disasters, specific planning models have been developed for various evacuation scenarios, including nuclear plant crisis, hurricane, flooding, and fire, etcetera.

### *Model reference adaptive control framework*

Given all the uncertainties than an emergency evacuation for a disaster has, a model reference adaptive control (MRAC) was developed (Liu et al., 2007) shown on figure 2. This model is a real-time traffic management framework for evacuation and integrates the dynamic network modelling techniques with an adaptive control theory (Cao, Ma and Xu; 2012).

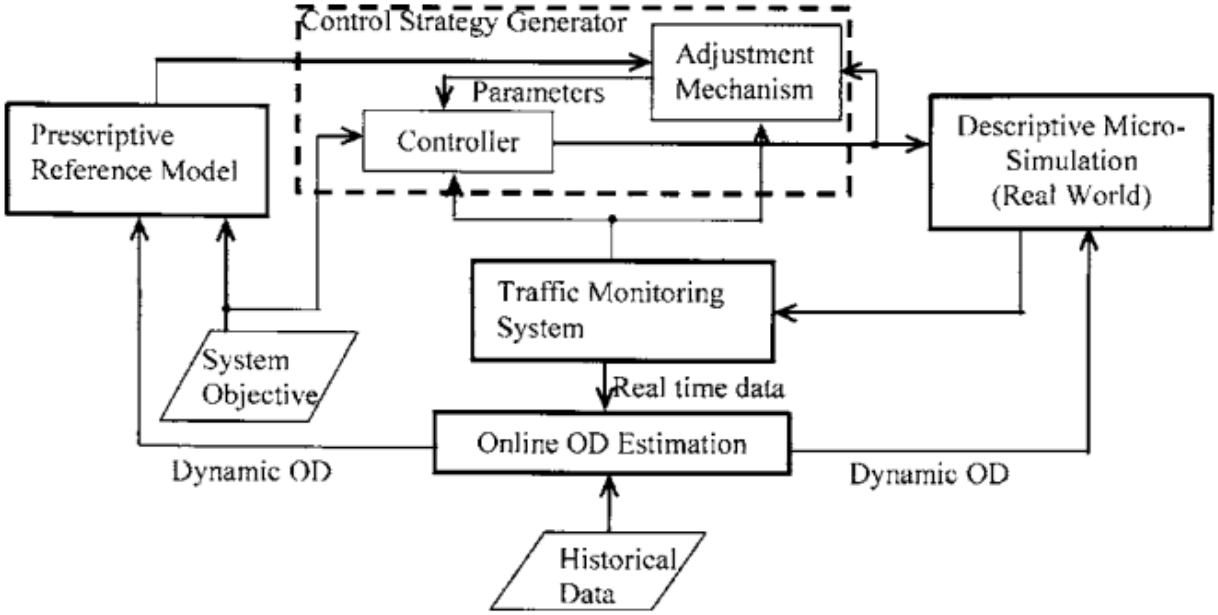


***Figure 2.4**: Framework for adaptive control-based real-time evacuation traffic management (Liu et al., 2007)*

## 2.7 Conceptual model of the report

The conceptual model to understand the report of this research will be the Logistic concept (point 2.1). In this report, the logistic concept from the evacuation process of the healthcare community will be described with its *structure, planning & control method, information system,* and *the people in the process.* The main focus of the research will be on the **planning and control**. The theories presented in urban hospital evacuation and crisis management (points 2.2 and 2.3 respectively) show a base for analysing the evacuation process by looking at standard steps taken by different countries (benchmarking). The theory on critical infrastructure (point 2.4) describes the importance that C.I. has for the community and what effects their failure can have. The theory on production planning (point 2.5) talks about the different parts that are involved in the control part of the process, how to recognised them and how to analyse them. The evacuation modelling is a possible improvement method for the planning and control of the evacuation process.

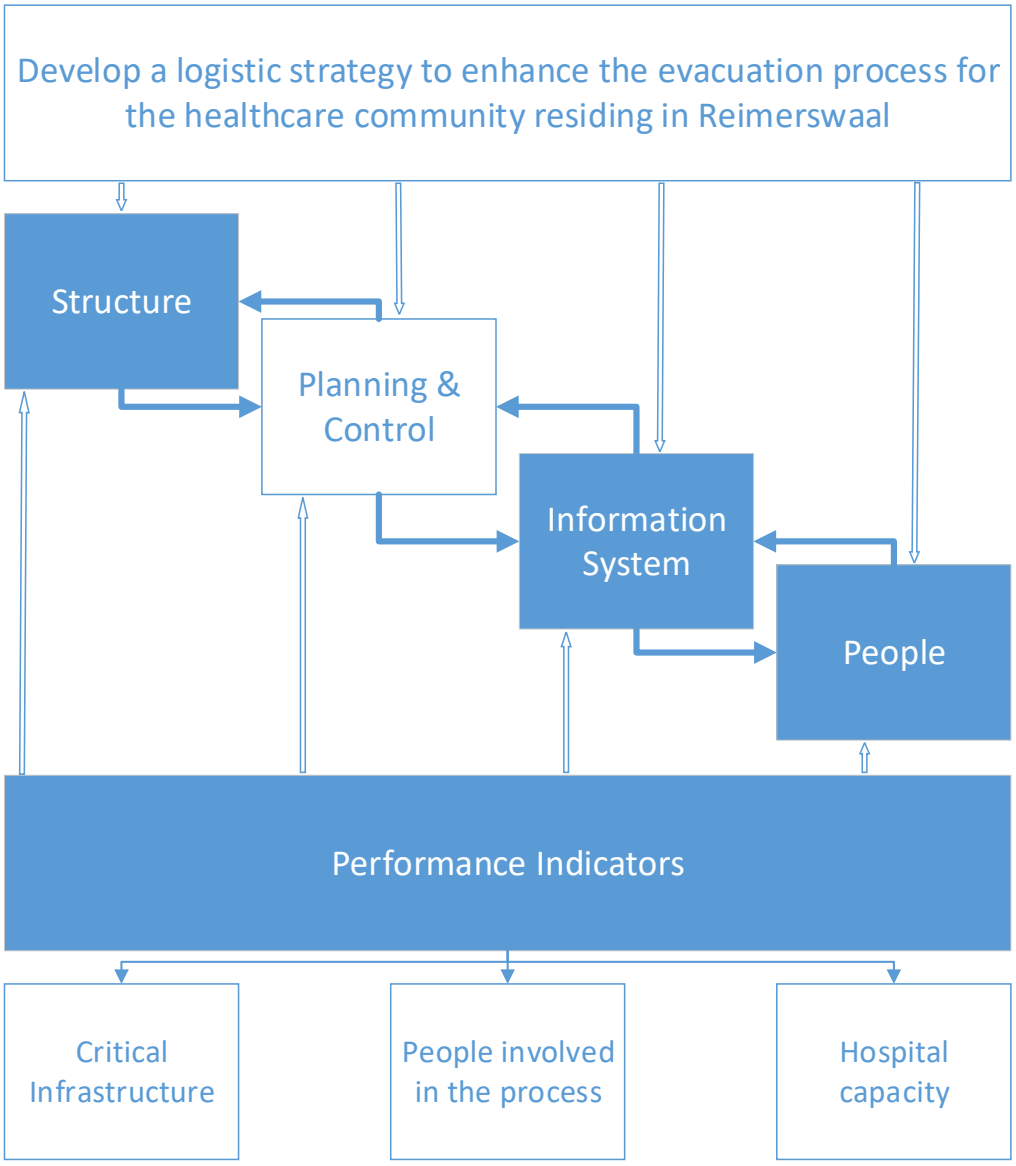


***Figure 2.5**: Conceptual model of the research report (Personal collection, 2018)*

# 3. RESEARCH METHOD

In this chapter, the research method will be explained. First, what is the goal of the research, followed by the research strategy (how the research is going to be performed). Once the strategy is clearly defined, the data collection method and how this data is going to be analysed will be explained.

## 3.1 Research study

For the critical infrastructure project, the resilient deltas' research group is interested in the time/logistic planning which is needed for evacuation. In general, people can be evacuated in two ways: horizontal (getting away from the danger) and vertical (shelter in place, for example in higher buildings). With evacuating horizontally, it is important that people escape the area before a crisis situation will occur. In some cases, it might not be possible (anymore) to evacuate horizontally or it might not be the most effective strategy, this is dependent on a lot of contingencies. To limit uncertainties and to be prepared for both strategies logistics planning is very important

### 3.1.1 OBJECTIVE

The overall objective of this research is to develop a logistic strategy to enhance the evacuation process for the healthcare community residing in Reimerswaal, due to the probability of a flooding happening. This evacuation plan should have a detailed explanation of the flow of people in the case of an emergency, how the reliant public in Reimerswaal (and its surroundings) and the Dutch Government should react to prevent the loss of life during the flooding. The report should also contain some 'contingency plans' due to the level of uncertainty that the extend of the damage would cause (for example a main road being unavailable).

## 3.2 Research approach

Once the research objective has been defined, it is needed to determine the approach, this involves the strategy, method and analysis . This is what is the best suited type of research that will be used, for example qualitative or quantitative research.

#### *The first sub question: the healthcare community*

The first sub question focusses on the healthcare community, who is considered in it and why. As there is no specific definition on what the healthcare community is, the researcher will perform desk research about the definition of "dependant individuals" as well as interviews to the organisations that are considered to be part of the healthcare community, such as GHOR and the healthcare facilitates inside and outside Reimerswaal.

To perform this research is necessary to make a demographic analysis on the self-reliant and reliant groups living in the municipality and where they are located. Data about the amount of "dependant individuals" will be collected through desk research, and information about who is considered to be dependant during an evacuation will be acquired during the interview with

GHOR. The demography research will have a pareto analysis with the results, and an analysis of what the result represents.

### *The second sub question: the current evacuation plan*

The second sub question focusses on the current evacuation plan for the Zeeland Safety Region. The step-by-step process for the evacuation will be researched through desk research and an interview with Bevolkingszrog, which is the organisation who crates the evacuation plan during a crisis scenario.

The desk research will provide the information about what VZR currently displays as to be the evacuation measures to be taken by the public, as well as the process of the crisis management (GRIP). An interview with a representative of Bevolkingszrog will explain what the actual evacuation process currently is, how the evacuation plan is formed, and who is responsible for each task.

The existing evacuation plan that would be put in place in case of flooding that the Dutch Government has elaborated will be thoroughly analysed and compared with previous evacuations done in the Netherlands and similar regions in other countries, as presented in the theoretical framework with the case in New Orleans, Texas and theories in crisis management. The current evacuation plan of the Dutch Government will have an in-depth analysis of its performance.

### *The third sub question: failure of critical infrastructure*

The third sub question discusses the failure of critical infrastructure, and what effect it has on the evacuation process of the healthcare community. The effects that the failure of CI may have will be seen through desk research and some of the effects that this failures may cause will be discussed with the research team.

The failure of critical infrastructure (presented in the theoretical framework) can be one of the greatest uncertainties when developing an evacuation plan. As there are many possible effects, it will be analysed some of these effects this will have on three specific C.I.; electric telecommunications and transport. Through desk research, the effects that the failure of these infrastructure may bring will be displayed and also how this will affect the evacuation process of the healthcare community. Which will be presented in the form of a ‘scenario’.

### *The fourth sub question: effect and counter measures to the failure of critical infrastructure*

For this, desk research will be used to follow up on different logistic theories that can be implemented to counter/be-prepared-of effects that the damage of C.I. may have in the evacuation process.

The different measures will focus on the control part of the evacuation process, as currently there seems to be lacking a proper method to make planning/control/measurement of the current

### *The fifth sub question: contingency measures for different scenarios*

The measures discussed in the previous chapter will be put into practice in the scenarios, and the effectiveness of each measurement will be analysed. Each method's effectiveness will depend on the scenario, so even if they are not effective in this scenario, they should not be completely discarded.

# 4. HEALTHCARE COMMUNITY

This chapter will answer the first sub-question which discussed the 'healthcare community', it will be explained which groups of people will be considered in this research as a part of it. Beginning with an explanation on what is considered as a 'dependant individual' followed by the healthcare centres inside and outside Reimerswaal and ending with the government entity that manages the evacuation of the 'dependant individuals'.

## 4.1 Dependant individuals

With a population of over 22.000 individuals, 17% consists of elderly population (65 years or older), and of this, 46% is (severely) limited from activities due to their health.

### 4.1.1 CLASSIFICATION OF HUMAN FUNCTIONING

The International Classification of Functioning, Disability and Health (ICF) provides both a conceptual framework and a systematic code system for the description of human functioning and functioning problems (WHO -FIC Collaborating Center, 2002). This classification distinguishes human functioning on three levels, namely in terms of:

1. Body functions and anatomical properties (for example muscle functions);
2. Activities (for example running);
3. Participation or participation in social life (for example, maintaining relationships).

If problems arise in body functions, in performing activities or in participation, it is spoken successively of disorders, limitations and participation problems.

Volksgezondheidenzorg.info focuses on the second level of human functioning: limitations in activities related to hearing, vision, mobility and ADL .

### 4.1.2 PHYSICAL HEALTH

Physical functioning concerns the ability to perform daily physical activities. Think of walking, eating, dressing and undressing and carrying shopping bags. We indicate difficulties with 'limitations'. Restrictions in activities related to hearing (not being able to follow conversations), seeing (not being able to read the newspaper or not recognizing faces) and mobility (lifting, carrying, bending and walking).

Source: GGD health monitor Adults and Elderly 2012

*3 underlying indicators*

- Chronic disorders
- Hearing and facial limitations
- Mobility restrictions

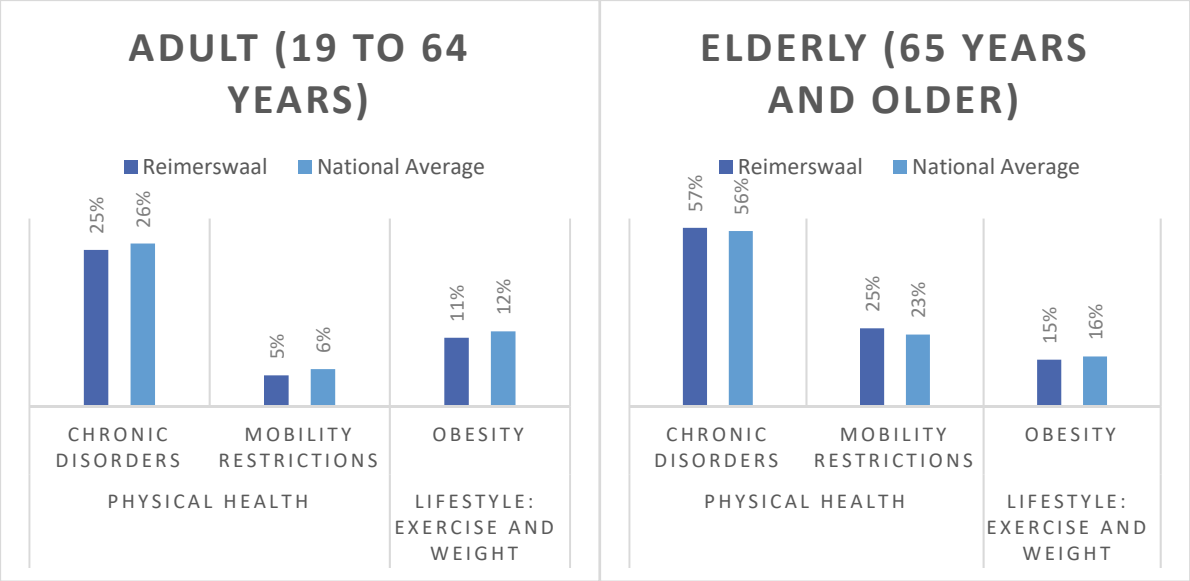


***Table 2:*** *GGD indicator of physical health and lifestyle for adults and elderly in Reimerswaal (Source: https://www.gezondheidinsociaaldomein.nl/uw-gemeente/reimerswaal/, 2018)*

### 4.1.3 INDICATORS OF PHYSICAL FUNCTIONING

In VZinfo the following limitations in carrying out activities are distinguished: limitations in carrying out activities related to hearing, seeing, mobility, and activities of daily life ( ADL ). Restrictions in hearing, vision and mobility can also be viewed together. Limitations in activities of daily life ( ADL ) are considered separately.

Definitions of four indicators for limitations;

#### *Limitations in activities related to hearing*

Great difficulty with or unable to follow a conversation with one other person; or in a group of 3 or more people (if necessary with hearing aid).

#### *Restrictions in activities related to seeing*

Great difficulty with or unable to read the small letters in the newspaper; or at a distance of 4 meters to recognize someone's face (if necessary with glasses or contact lenses).

#### *Restrictions in movement*

Great difficulty or unable to carry an item of 5 kg, for example a full shopping bag, 10 meters; bend down and get something off the ground; or running 400 meters in one piece without standing still (if necessary with a stick).

#### *Functioning problems*

Great difficulty with at least one of the above limitations.

*ADL restrictions*

Great difficulty with or only with the help of others being able to sit and get up from a chair; getting in and out of bed; and walking up and down the stairs.

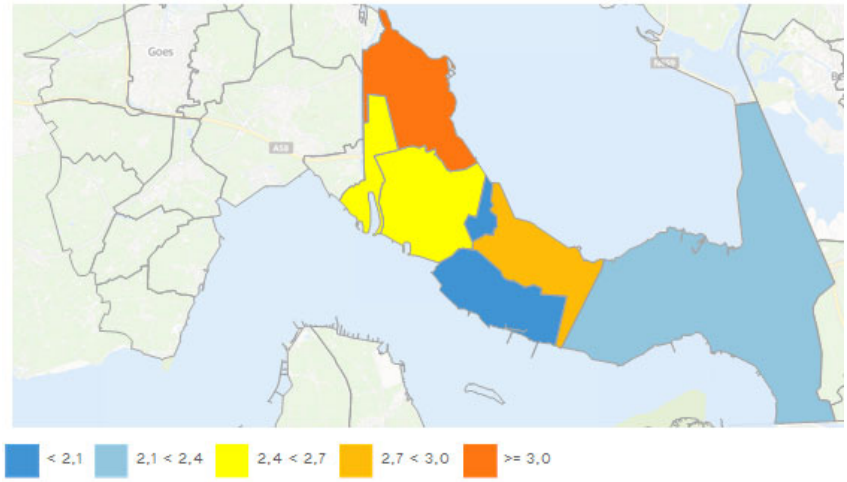


***Figure 4.1:*** *Percentage of use of primary care per district in Reimerswaal (Source: https://www.waarstaatjegemeente.nl/jive/report?id=gezondheid_wijkprofiel&input_geo=gemeente_703; 2018)*

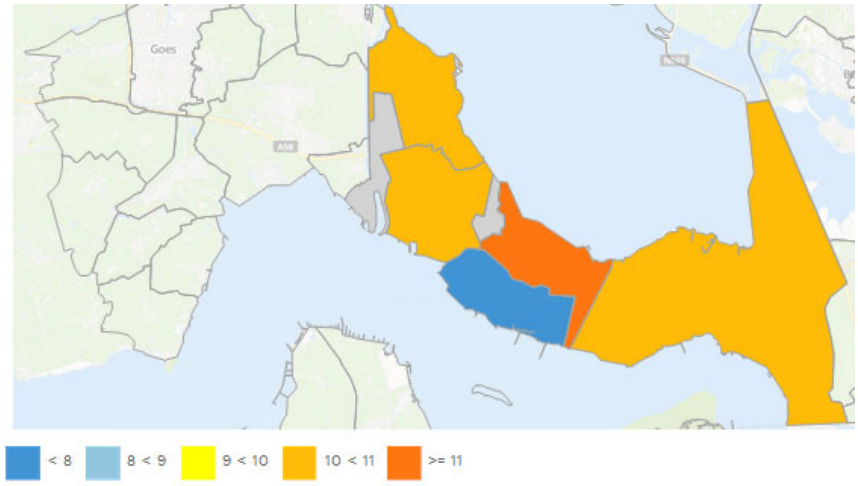


***Figure 4.2:*** *Percentage of reduced mobility per district in Reimerswaal (Source: https://www.waarstaatjegemeente.nl/jive/report?id=gezondheid_wijkprofiel&input_geo=gemeente_703; 2018)*

## 4.2 Reimerswaal healthcare centres

Many of the physically dependent individuals in Reimerswaal are located in different healthcare centers (for example nursing homes) in which they are being taken care of by specialist (for example nurses). As the municipality does not count with a hospital or clinic, the residents in a more critical condition are located in Healthcare facilities in Goes or Bergen Op Zoom.

## 4.3 Hospitals outside Reimerswaal

In a flooding scenario, the residents of Reimerswaal will most likely be evacuated to the surrounding areas, in this case, the nearest hospitals (that are currently providing healthcare services to the residents of Reimerswaal) are located in Goes and Bergen op Zoom.

The hospitals have a very important role. Which is to provide medical aid to those affected by the flooding. This can be either injuries or the dependant individuals that need to be in a specialised facility (or under monitoring of a nurse).

As mentioned before, the distribution of the people to the hospitals is administrated by GHOR, which would be in regular contact (approximately every hour, depending on the gravity of the scenario) with the facilities to be able to have an idea of how many patients the facility can receive in a certain amount of time.

## 4.4 Government

In the crisis management there is a cold phase and a hot phase, when there is no disaster and when there is an emergency respectively. Normally there is the DPG, which is the Director of Public Healthcare, this person is the Director of the GGD and the GHOR.

The GGD is the municipal healthcare organization, the GHOR is from the safety region. Normally they do not work together directly (in a cold phase) but they have to prepare, so they have some contact in the cold phase, but not direct. However, if there is a crisis, then the GHOR takes over the command and they can ask the deputy on the GGD; they can do a demand on the GGD to help them in infection treatment, medical treatment, psychological treatment, etcetera. Basically, When it comes to the hot phase they come together and GHOR takes the lead.

### 4.4.1 BEVOLKINGSZORG

The English term can be considered to be “Community Care”, as it says, Bevolkingszorg take care of the community. This community care is the task of the municipalities, in the safety region of Zeeland there are 13. Previously, each municipality had their own crisis plan. After a great emergency in 2002, the government decided that it was better to create a more centralised system, to which they came up with the 25 different safety regions, and now the 13 municipalities in Zeeland, they have 1 crisis plan.

For Bevolkingszorg, there is 1 law called “The Law on the Safety Regions”. In this law, there are a few task mentioned for Bevolkingszorg. These task are very specific to which they have their own procedures. Which is why they call them “Task Organisations”. These are:

- **Crisis Communication:** Handling the communication measures in case of an emergency.
- **Providing Shelter:** When a large area is affected and the residents need to be evacuated, they also need to be provided with shelter until they can go back to their homes.
- **Basic Needs:** Making sure to provide the people with basic necessities such as food and water.

- **Environment:** Making sure that the plans they develop do not have a negative effect on the environment.
- **Evacuation:** Evacuation measures in case of a large scale emergency.
- **Aftermath:** All the developments that need to be taken care of after the crisis has passed.
- **Services:** Providing the community with legal, financial and protocol services.
- **Information (SIS):** Information about the victims. So they can link the people who are trying to contact the victims with the victims themselves.

In this Law on the Safety Regions it is also written that there needs to be 1 Coordinator. There is a representative for each municipality of the safety region, and one of them is the Coordinator (currently from Noord-Beveland).

In Zeeland there is an agreement, the 13 municipalities need to work together to cope with a crisis. There are 300 people that work for the Bevolkingszorg. This work can be called a “side-job” as these 300 people can have their own jobs (financial or social work) and when something occurs, they gather to work in the Task Organisations. Basically, when Bevolkingszorg needs to develop a plan, all the municipalities provide the personnel, because they do not have personnel to do the preparation.

# 5. CRISIS EVACUATION PLAN

The Veiligheidsregio is a collaboration network that includes disaster- and crisis management, emergency services, public security and public order. The Veiligheidsregio Zeeland (VRZ) is responsible for the physical safety of Zeeland residents, visitors and organisations and thus also the physical safety of Reimerswaal (Veiligheidsregio Zeeland, 2015).

The VRZ establishes a risk profile (in accordance with the established requirements of the Wet van de Veiligheidsregio (Wvr. Art. 15) and updates it if necessary once every four years, whereby all relevant vital partners are informed and asked to contribute (Wvr, art. 46) (Ministerie van Veiligheid en Justitie, 2016). The Regional Risk profile forms the basis for preparation of crisis management within the VRZ. The VRZ encounters a variety of risks from ICT systems to diseases to flooding's. All the possible risks are stated in the regional risk profile. The goal of the regional risk profile is to prevent risks, but if the risks are escalating, limiting the risk as much as possible. In total, it is about 23 multi-disciplinary plan figures including 14 disaster control plans for companies.

The VRZ invites at least once a year the possible disaster and crisis concerned parties to joint consultation about the risk in the region. This is obligated and is stated in the Wvr, art. 5. The meetings are used to acquire information and data what can be used in the regional risk profile. The VRZ made an incident map where all risky locations and vulnerable objects are put into. The risk chart gives a clear overview of the risks present in the province of Zeeland (Veiligheidsregio Zeeland, 2015). The national guide of regional risk profile states four steps in order to make a regional risk profile:

1. Risk inventory: the relevant risks are fully inventoried. This is supplemented with information, such as information about the CI;
2. Risk chart: the context and the spread of risks are further explained and visualized;
3. Risk analyse: the selected scenarios are determined on the probability of the risk and the impact of the risk. This is done on the basis of expert judgements;
4. Result of the risk analyses: the results of the risk analyse are put into a risk diagram.

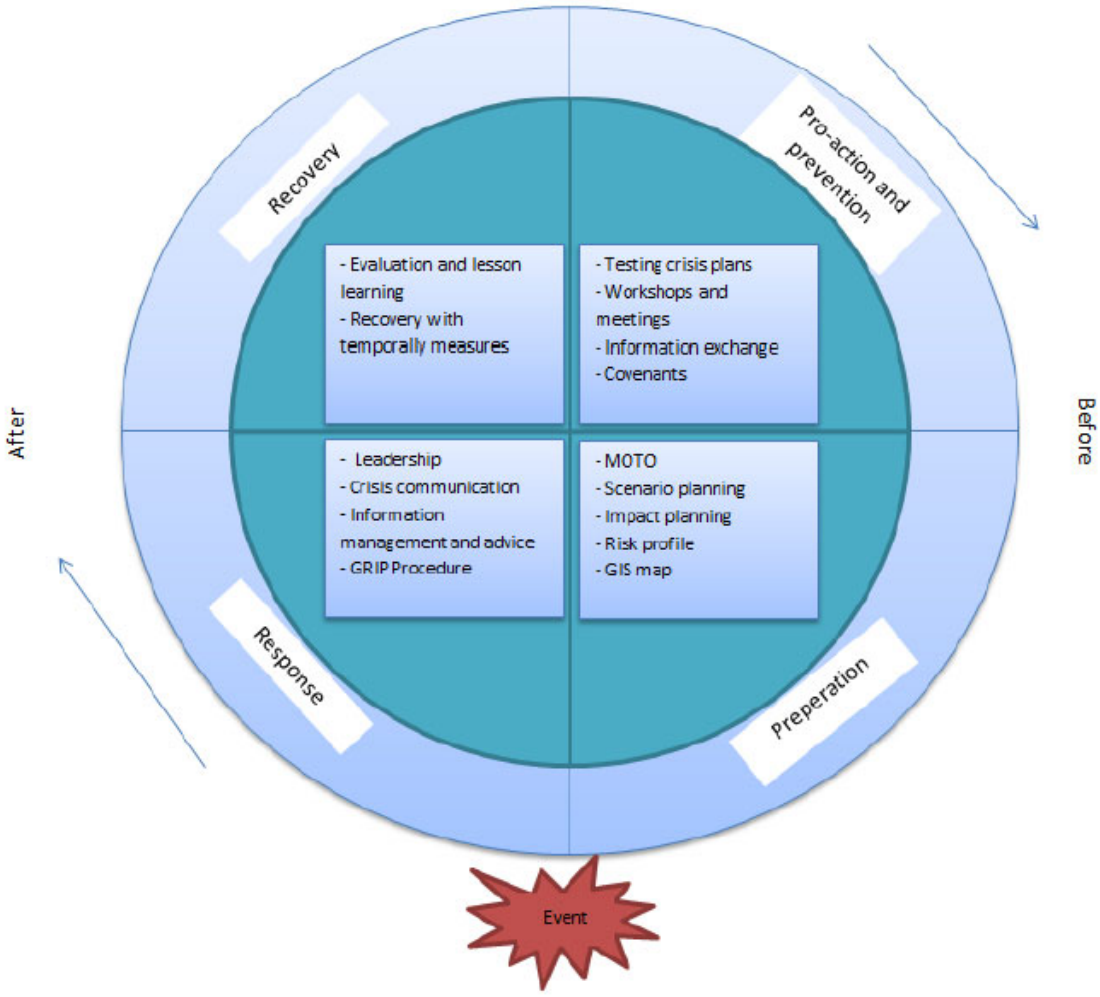


***Figure 5.1:*** *Crisis phases in the governmental institutions (Schelkens, 2018)*

### 5.0.1 EVACUATION

They call it “Move people and animals”. Before it became a responsibility of Bevolkingszorg, it was a responsibility of the police, but a few years ago they made the decision for Bevolkingszorg to take over.

What they decided to do was; they now make a Generic Plan, instead of a specific plan. When people need to be evacuated, they can create a plan in case of a flood but they also have the nuclear plant, if something goes wrong they use the Generic Plan as well, so it is not a plan which is written in detail of “what to do“ step-by-step.

The Evacuation Team gets their assignment from the Regional Operation Team, and they get their alert from the Rijks Team, who monitors the situation and judges whether an evacuation will be needed.

The time to develop the plan and the clearance time on what is happening at the scene of the crisis at the moment, which can change at any moment (Bevolkingszorg, 2018). For example (See Appendix 1)*:*

*"They sometimes ask if the small roads can be used, but it depends on the situation. If there is a fire and then the smoke covers the road we had decided to use, then we need to change the plan. That's why we call it **generic**, we come together with a structure, but it all depends on what is happening at the scene, and more importantly, how much time we have. People want to know in detail, but what have we done for preparation; I already said we collaborate with organisations, for example the post office, we know the post codes and in a particular area, we know there are (for example) 1000 people, the ages, etcetera."*

## 5.1 Structure

For the administrative work, the Law on the Safety Regions describes:

During a disaster the mayor of the municipality concerned has the supreme command. In the case of municipal border-crossing disasters, the Head of Security Region takes over that task. That is usually the mayor of the capital of the region.

He is supported by two teams:

The Policy Team focuses on policy making, recording and prioritization of decisions, contacts with other government bodies and information to the general public and the press. A Policy Team can act on a municipal and regional level. This depends on the appearance that a disaster can have on the surrounding municipalities (see Figure 5.2).

The Operational Team translates decisions into assignments for the emergency services on site and arranges the logistical matters. The Operational Team is always a regional team.

When a disaster exceeds municipal boundaries, the Kings's Commissioner (CdK) of the province in question can take over the supreme command and give mayors policy directions. Ultimately, the Minister of Home Affairs can give the various CdK's instructions if the disaster is even larger (see Figure 5.2).

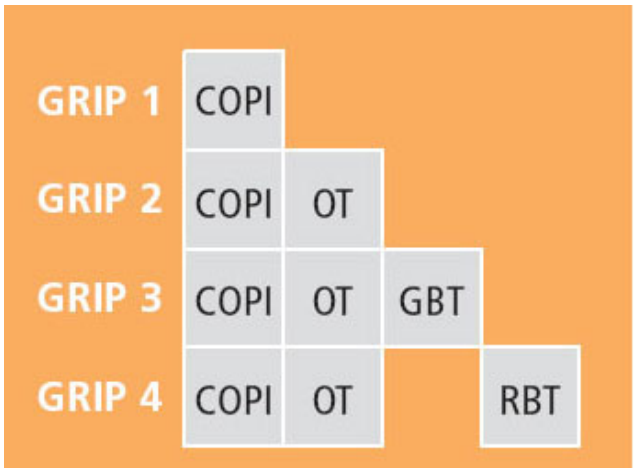


***Figure 5.2:** GRIP brochure (Brandweer Amsterdam, 2018)*

The operational management is in the hands of the fire service commander, who would in fact also manage the other operational services. In practice there are various levels of consultation where the emergency services meet:

- The bonnet consultation is the consultation that takes place first and closest to the location of the incident. The commander of the first arriving vehicle, the first ambulance crew and the first police officers on the spot first determine the strategy here. This consultation will be converted into the Incident Coordination Team (CTPI) during the initial scaling, under the command of the Regional Fire Service Officer (OvD) of the fire brigade.
- With further scaling up, the CTPI is registered in the COmmando Plaats Incident (COPI). The command is now, depending on the type of incident, conducted by a Chief Public Prosecutor (HOvD) of one of the emergency services. If it is unclear who should take the lead, this is by definition always the fire department.

In the case of major disasters, the disaster site is determined first: This is the location of the incident, the immediate environment where expansion is possible, and the "effect area" where the disaster caused serious damage caused by debris, water or heat or toxic substances.

Within the disaster area, independently operating teams are deployed in separate inset boxes , each with their own command line: COmmando RampTerrein (CoRT).

The police will set up a Command Environment Disaster Area (ComRT). This command focuses on law enforcement, traffic measures and possible evacuations in the area around the disaster site. Usually these areas are divided into circles. Within each circle, specific measures apply.

Each operational service will also set up its own command post or action centre in or near their control room or offices. From here the business is coordinated per service. These Operational Teams take care of the execution of assignments from the Municipal Disaster Station and the situation reports towards GRS.

Due to the regionalization of the police, fire brigade and healthcare, the operational structures are in larger contexts than the municipality in which the disaster occurred, while the mayor actually has the direct final responsibility as head of the Municipal Disaster Station and the Municipal Policy Team.

## 5.2 Planning & control

In the scenario where the is a flood in the Municipality of Reimerswaal, the municipality is responsible for taking the lead in its own emergency response, but with the Law on the Safety Regions, many emergency response tasks are accommodated in such a region.

The overall performance of the emergency response will depend on the outcome of these tasks which are in outline:

- Assess the situation / Explore the disaster area
- Receiving and taking care of injured people
- Clear areas and evacuate people and animals
- Maintain order and regulate traffic
- Meet the need for food, drinking water, gas and electricity facilities
- Information, information reporting and accountability

### 5.2.1 PREPARATION FOR DECISION MAKING ABOUT EVACUATION ON THE NATIONAL LEVEL

The National Operational Staff prepared three possible alternative strategies for evacuation and presented them for the ACO, IBT and MBT. The consequences of each strategy were presented to the decision makers in terms of loss of life in the case of a flood combined with operational advice. These were not related to the probability of flooding.

The preparation strategies were as followed (and presented in Figure 5.2) (Berghuis 2008):

1. Maximum strategy: preventive evacuation of only highly threatened areas, vertical evacuation and shelter in place for others. In the case of a possible flood, two thousand casualties were estimated;
2. Medium strategy: preventive evacuation of non-self-supporting citizens in highly threatened areas, vertical evacuation and shelter in place for others. In the case of a possible flood, six thousand casualties were estimated;
3. Minimum strategy: Vertical evacuation and shelter in place for everyone, which made it possible to continue normal processes but no measures should be implemented by the authorities. In case of possible flood, ten thousand casualties were estimated.

To be able to implement the emergency measures in time (early morning of D-3), the go or no-go decision had to be made before 18:00 h on D-4. Communication to the public about the strategy and use of networks was foreseen during prime time. Afterwards, citizens could prepare themselves and start to evacuate. In the meantime, emergency service workers and road workers could evacuate their families.

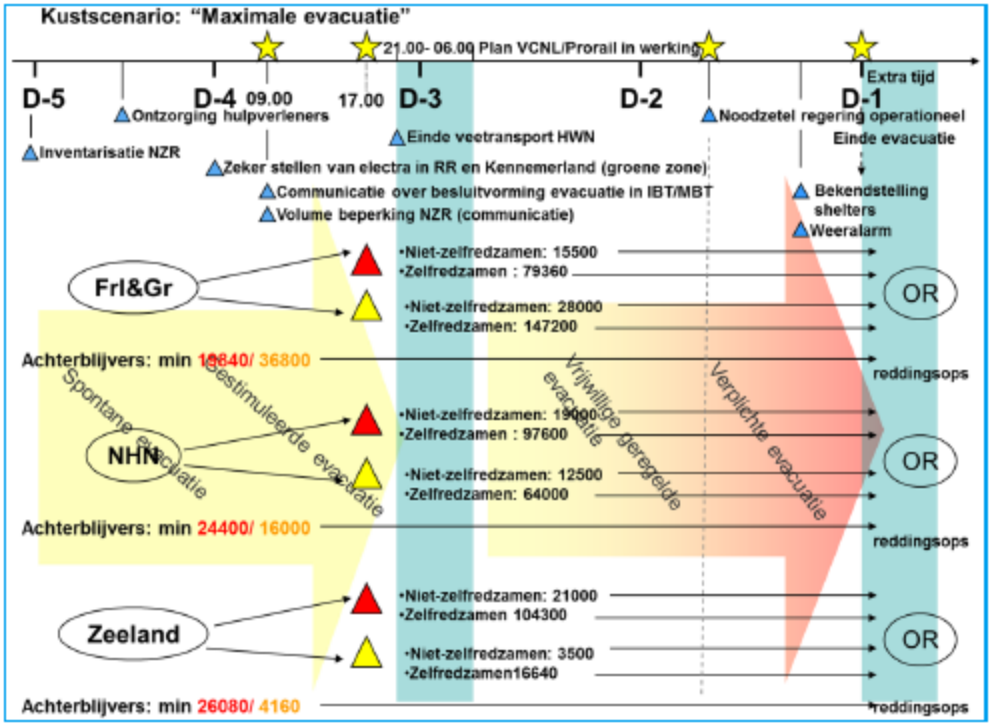


***Figure 5.2:*** *Strategy (in Dutch) for preventive evacuation presented by national operational staff for the areas Fryslan and Groningen (Frl&Gr), Noord Holland Noord (NHN) and Zeeland (Berghuis, 2008)*

### 5.2.2 HEALTHCARE SERVICES EMERGENCY RESPONSE ORGANISATION

During a crisis, the different departments have their own **responsibilities to fulfil**. Each department has a different role to take; the fire department is the designated organisation that forms the core of the emergency response, the police handles crowd control and evacuation, defence provides extra manpower and emergency equipment, and so on. This sub chapter will briefly explain what the is the role of the healthcare services in the event of a crisis.

When an ambulance is the first to arrive at a large-scale incident, this crew performs the medical coordination in the first instance. To this end, each ambulance is equipped with a green flashing light and will not be used for injured transport. From the MeldKamer Ambulancezorg (MKA) or the Common Reporting Room (GMK), if necessary, reinforcement comes in the form of a Commando vehicle with a Medical Leader Disaster Area, which takes over this task from the ambulance crew.

The Health Services can provide the Large-scale Medical Assistance in disaster situations (GGB) calls. By means of an automated system, the regional ambulance staff who have not been called up in active service are immediately taken care of. They come to the crash site with special emergency vehicles with extra medical equipment.

At the same time, the deployment of large numbers of extra ambulances and Mobile Medical Teams is also being started at national level, so that the ambulance coverage in the various regions can remain within the norm.

This assistance must be operational within 1 hour for the reception of seriously injured victims in the disaster area. In this plan, these victims are transferred to hospitals as quickly as possible according to a fixed spread plan for targeted medical care.

For the reception of light or uninjured victims, the Red Cross will call their Emergency Response Teams.

Within 2 hours, additional logistics equipment, such as containers with first aid sets, stretchers and tents for the formation of wound nests, will be transferred to the crash site.

## 5.3 Information system

In a cold scenario (when there is no crisis), the different healthcare centres have periodical meetings with GHOR (approximately once a year). In these meetings, the healthcare centres will provide GHOR with information about their capacity, such as the general flow of the patients, the availability of machinery, how many patients can be admitted in an emergency, their evacuation strategies and other information that will be needed to have during a crisis period. In a hot scenario (when there is a crisis), GHOR will frequently contact the healthcare facilities (the actual frequency of the contact will depend on the crisis level) and they need to provide all that information in order for GHOR to know which hospital can take in the patient.

During a crisis scenario, the most likely communication network to be used will be the **C2000** (a closed communication network and intended for use of the Dutch emergency and security services).

## 5.4 People

The evacuation process is very dependent on quick response and the amount people that can help. In this process there are several departments working together to perform the evacuation.

- **Policy Team**; who focuses on policy making
- **Rijks Team**; which makes the assessment on the disaster 'grade'
- **Regional Operational Team**; which translates decisions into assignments
- **Bevolkingszorg**; who gets the assignment from the regional operational team and needs to create the evacuation plan
- **Police Department**
- **GHOR**
- **Fire Department**
- **Defence Department**
- **Rijkswaterstaat**

- **Zeeland Port**
- **Agriculture Department**
- **Crisis Communication Department**

# 6. FAILURE ON CRITICAL INFRASTRUCTURE

Bevolkingszorg currently does not have any kind of contingency measures in the event of failure of critical infrastructure in a crisis scenario. To which, is very important to understand the effects that these failures may have. As mentioned in the theoretical framework; if one of these infrastructures fails during a flooding, it would cause a great disruption in the evacuation process. And with the threat of the cascading effect, it is possible that the failure of CI can have a greater impact than expected. The interdependence of several of these CIs can have a great impact on the developments during the evacuation, as its measures are also dependant of many of these CIs.

In this chapter, it will be introduced, what is the effect that the failure of critical infrastructure can have on the evacuation process (more specifically, the *planning and control*) in the events of a flooding in the municipality of Reimerswaal. The chosen scenario will be **a breach in *dijkring 31, dp 200***; shown in appendix 5. And then, there will be given a some contingency logistic measures for this failures. The analysis will be set in the event of failure of three different CI; electricity, telecommunication and transport.

In this scenario, the dijkring 31, which is the dijkring that surrounds the municipality of Reimerswaal, has a breach in dp 200, which is located nearest to Kruiningen; as shown on the appendix 5, the flood will stop expanding throughout the municipality after around 36 hours; however, the more than half of the total affected area will be flooded after only 10 hours (after 3 hours, the area of Kruiningen will have already flooded).

For this analysis is necessary to understand what is the priority of the evacuation team. Priority relates to what products are needed, how many are needed, and when they are needed (Arnold, Chapman & Clive, 2008). In human logistics, in a flooding scenario, the priority is established by the people affected, then GHOR triages with the information they get from the hospitals and evacuation vehicles. Bevolkingszorg is responsible for devising the plans to 'satisfy the demand', this means to develop the evacuation plan.

## 6.1 Effects of failure on critical infrastructure

The following paragraphs will list **some** of the general effects that the failure of critical infrastructure can have on the evacuation process of the healthcare community in Reimerswaal in a flooding scenario. The scenario will focus on the failures of three kinds of CI: Electricity, Telecom and Transport.

### *Electricity infrastructure*

These are some of the effects that the failure on electricity infrastructure can have on the evacuation process.

- **Healthcare facilities do not receive electricity**: These facilities have a lot of equipment which is dependant of electricity, if the facility fails to receive a source of power, it might affect the health of the residents (patients).
- **Telecom Infrastructure without electricity**: If the telecom centres do not have energy, this will create a failure in the communication systems.
- **Drinking Water infrastructure does not receive electricity:** If the drinking water centres do not have energy, this will create a failure in the distribution of one of the basic necessities to the public.
- **Transport infrastructure does not receive electricity**: During an electrical failure, it is possible for it to have a great effect on the roads. Lights may not work and bridges may not be able to move.

### *Telecommunication infrastructure*

These are some of the effects that the failure on telecommunication infrastructure can have on the evacuation process

- **Unable to have contact with the victims**: If there is a failure in the communication system, it would be more difficult to contact and locate the victims and/or people who were unable to evacuate.
- **Unable to contact healthcare facilities**: GHOR needs to be in constant contact (approximately every hour) with the healthcare facilities, to know their capacity during the crisis. If they are unable to contact them, the victims may even arrive to a facility that cannot attend them.
- **Unable to coordinate all parties (transport, police, fire fighters and so on)**: The evacuation team needs to also be in constant contact with many parties to coordinate the evacuation. If they were unable to communicate this coordination will not be able to happen.

### *Transport infrastructure*

These are some of the effects that the failure on transport infrastructure can have on the evacuation process.

- **Unable to use roads:** During a crisis some roads will become unusable, not only due to a direct effect (flooded road), but it can also occur from an indirect source (tunnel has no electricity).
- **Damaged infrastructure** During a flood, there might be some damaged infrastructure due to the water, if so this becomes a liability for its use.

- **Congestion**: Failure in transport infrastructure may affect the evacuation plan and so complicate the evacuation. Ultimately, if the roads are limited during the evacuation, this will cause congestion.

### 6.1.1 EFFECT ON CONTROL

Once the plans are made and teams have been dispatched, the process must be monitored to learn what is actually happening (Arnold, Chapman & Clive, 2008). The results are compared to the plan to decide whether corrective action is necessary.

No calamity is the same, there are many variables that can affect the evacuation process and the calamity itself can affect the process, as mentioned in appendix 1 (Bevolkingszorg, 2018). So, it is important for the evacuation team to keep monitoring the process. The failure in C.I. can have a great impact in the monitoring, if electricity or telecom infrastructure is damaged during the flood, then the communications would be disabled in the affected area. When this happens, the evacuation team has no communication with the emergency vehicles until they leave the affected area, causing for the decision-making time to be shorter.

### 6.1.2 EFFECT ON EFFICIENCY

It is possible for the evacuation team to utilise 24 hours, but not to produce 24 standard hours of work (Arnold, Chapman & Clive, 2008). The workers might be working at a faster or slower pace than the standard performing pace (or the pace planned by the Evacuation Team), causing the **efficiency** of the evacuation to be more or less than 100%.

Some calculations for efficiency include (Arnold, Chapman & Clive, 2008):

- $Utilisation = \frac{hours\ actually\ worked}{available\ hours} x\ 100\%$
- $Efficiency = \frac{actual\ rate\ of\ perfromance}{standard\ rate\ of\ performance} x\ 100\%$

### 6.1.3 EFFECT ON TIME

The **available time** is the amount of hours a work centre can be used (Arnold, Chapman & Clive, 2008). In this scenario, for example, the flood will finish covering the total area that will be flooded in 50 hours. The available time is dependent on the number of equipment (emergency vehicles), number of workers (emergency workers and volunteers) and the hours of operation (within 1-36 hours of the dike breach, and then the vertical evacuation).

Some calculations for time include (Arnold, Chapman & Clive, 2008):

- $Available\ time = Flood\ time\ x\ Number\ of\ evacuation\ vehicles$
- $Total\ standard\ time = (loading\ time + unloading\ time) + travel\ time$

In an evacuation process, time is one of the most important factors that can affect the outcome of the disaster. In this scenario, the first evacuation (in Kruiningen) has to be made within 1 hour, and within 50

hours the flood would have covered the total affected area. If they want to evacuate all the residents before the flood reaches their location (and to avoid vertical evacuation) the evacuation team needs to be acting within that time limit.

The time in which each evacuation can be performed is dependent on the performance of the hospitals, emergency vehicles and the C.I., as mentioned before, failure in electric or telecom infrastructure can affect the communications between the evacuation team, the emergency vehicles and the hospitals. Triaging is greatly affected when there is a lack in communication, again, affecting the decision-making time.

Failure in transport infrastructure can also have a great impact in the evacuation process. If the route that the evacuation team had planned to use has been affected by the flood, it may be necessary to take an alternate route, which can affect the evacuation time. And if communications are also down in that area, then it would take even more time.

### 6.1.4 EFFECT ON CAPACITY

Capacity is the capability of manufacturing to produce goods and services. Eventually it depends on the resources of the company- the machinery, labour, and financial resources, and the availability of material from suppliers (Arnold, Chapman & Clive, 2008). In the short run, capacity is the quantity of work that labour can perform in a given period. In an evacuation process, the capacity can be translated to the availability of emergency vehicles, the patient capacity for the hospital and the production capacity of the CI.

Some calculations for capacity include:

- $Rated\ capacity = available\ time\ x\ efficiency\ x\ utilisation$
- $Capacity\ required = actual\ time\ x\ efficiency\ x\ utilisation$

The capacity of the C.I. is the performance of the infrastructure during the flood, for the telecom infrastructure, this means the range in which their signal reaches, this can be affected by water if the flood reaches the infrastructure. For the electric infrastructure, this means the areas which still have electricity, if this infrastructure is flooded, then this area can be limited or null. Finally for transport, the capacity of it can be translated to the amount of vehicles that can transit through the roads, if the water level in the road is (for example) 3 meters high, then the evacuation vehicle cannot go through.

The capacity of the hospital is the amount of patients that the hospital can treat during the crisis. The triage is handled by GHOR (or in its defect the DPG) which keeps regular contact (for example every hour, depending on the amount of injured) with the healthcare facilities near the affected area, and these facilities need to provide GHOR with information on how many patients they have treated and how many they can take in at that moment (d'Haens, 2018). However, the failure of critical infrastructure can affect this process. As mentioned in the theoretical framework, when during a flood, the electrical infrastructure

can be damaged, causing electrical power outages, which are not necessarily temporary, so it is necessary to begin evacuation when it occurs. Secondly, if the telecom infrastructure fails, it is possible that communications hospital-GHOR-emergency vehicle can be affected, making triaging more difficult.

Finally, the capacity of the machinery, in this case it would be the number of evacuation vehicles that are available and the amount of people each vehicle can handle (According to Wolshon, 2002; this is around 35 people per bus). The capacity of this vehicles can also be affected by the failure of critical infrastructure. If the triage process is affected (for example, telecom infrastructure fails and communications are limited) the time wasted will affect the efficiency of the evacuation process, and ultimately affect the capacity of the vehicles, given the tight time frame. Failure in transport infrastructure can also cause disruption in the time and efficiency of the evacuation process by re-routing, but more importantly, the water level can renderer several kinds of vehicles useless. There will be areas which would not be reached with the current vehicles (due to the water level) and so, they need to either quickly evacuate the area before the water level reaches that height, or coordinate a vertical evacuation for the people in the area.

The general effects that the failure of critical infrastructure can have on the evacuation process of the healthcare community in Reimerswaal in a flooding scenario was listed with three different C.I.; Telecom, whose failure would have a great effect on the 'planning and control' of the process, as contact with all the parties involved would be limited. Electricity infrastructure failure can influence also the communications and data collection, but also, if another dependant infrastructure (like telecom) is in the affected area, this infrastructure will also present failures. During a flood it is normal for the roads to be flooded, making the vehicles unable to use those roads, this causes a disruption in the evacuation plan, so then the evacuation route (or the evacuation plan) now has to adapt to the current situation, and constant contact needs to be made to keep track of the situation and react accordingly.

## 6.2 Measures for the failure on critical infrastructure

The failure of critical infrastructure can have a great negative impact in the evacuation process, which can lead to an increase in the number of injured and dead due to the flood. Given their unpredictability in matters like when it can happen, which infrastructure may fail, what is the magnitude of the damage and so on, it can be very difficult for the evacuation team (and all the people involved in the process) to adjust the plan given the situation. However, when encountering a situation like that occurs, the one of the most decisive factors is how well **prepared** all the people involved in the process are. Although it is impossible to create an evacuation plane for every possible scenario, it is possible to develop measures to be prepared for the uncertainties. Next, there will be presented different measures to be taken to improve the current process, more specifically, tools that can be used in order to analyse, measure and ultimately improve the process.

### 6.2.1 TOTAL QUALITY MANAGEMENT (TQM)

TQM is an approach to improving both customer satisfaction and the way organisations do business. TQM brings together all the quality and customer-related process improvement ideas (Arnold, Chapman & Clive, 2008). It is people oriented. According to the eleventh edition of the *APICS Dictionary (2004)*, "it is based on the participation of all members of an organisation in improving processes, products, services, and the culture they work in".

There are six basic concepts of TQM (Arnold, Chapman & Clive, 2008):

1. *A committed and involved management* directing and participating in the quality program. TQM is a continuous process that must become part of the organisation's culture. This require senior management commitment.
2. *Focus on the customer*. This means listening to the general public, to understand what are their needs during an evacuation, and how to provide them at low cost. It means improving design and processes to reduce defects and cost.
3. *Involvement of the total workforce.* Total quality management is the responsibility of everyone in the organisation. It means training all personnel in the techniques of process improvement and creating a new culture. Especially, all employees would be constantly looking out for improvement methods for the process.
4. *Continuous process improvement.* Processes can and must be improved to reduce cost and increase quality.
5. *Supplier partnering.* A partnering rather that adversarial relationship must be established.
6. *Performance measures.* Improvement is not possible unless there is some way to measure the result.

This type approach is people oriented, this means, to bring together all the quality and customer (patient) related process improvement ideas and with the participation of all the member of the organisation (healthcare community). By working together, they can obtain a great amount of quality improvement ideas, so the end product and even the development process (evacuation planning and process) are has the highest quality and efficiency possible. This type of approach has many tools that can be used for answering different questions about the entire evacuation process (Oakland & Sohal, 2001);

#### *Measure: Process flowcharting*

The use of this technique ensures a full understanding of the inputs on flow of the process. Without that understanding, it is not possible the correct flowchart of the process. In flowcharting it is important to remember that in all but the smallest tasks no single person is able to complete a chart without help from others (Oakland & Sohal, 2001).

Process flowchart helps creating a clear view on what the necessary steps are in the process, what are the dependencies of each part of the process, and where the bottlenecks can be found.

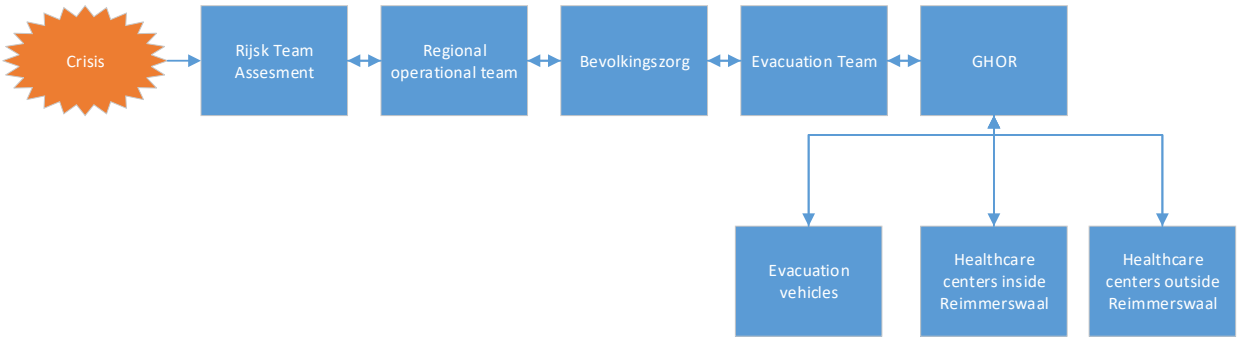


***Figure 6.1:*** *Information flow. Evacuation process of the dependent individuals in Reimerswaal*

The evacuation process for the dependant individuals is in constant need of communication between, the evacuation team (to create and adapt the evacuation plan), the healthcare facilities (to provide information on their capacity and the state of the patients), GHOR (or DPG in its defect, for triaging) and the evacuation vehicles (which carries out the evacuation for these individuals). The failure of C.I. can have an effect on this process, so when making the flowchart, it is important to have an idea of what can go wrong, why, what the effect would be and how to prevent or fix it.

### *Measure: Histogram*

Histograms show in a very pictorial way, the frequency with which a certain value or groups of values occurs. They can be used to display both attribute and variable data, and are an effective mean of letting the people who operate the process know the results of their efforts.

For the evacuation process, historical data (information from previous evacuations) can be used to provide the information about the tendencies in the process.

### *Measure: Scatter diagram*

Depending on the technology, it is frequently useful to establish the association, if any, between two parameters or factors. A technique to begin such an analysis is a simple X-Y plot with two sets of data (for example, for evacuation buses: *roundtrip time – number of people in the vehicle)*. The resulting grouping of points on scatter diagrams will reveal whether or not a strong or weak, positive or negative, correlation exists between two parameters.

### *Measure: Cause-and-effect diagram*

A useful way of mapping the inputs that affect quality is the cause-and-effect diagram (Arnold, Chapman & Clive, 2008). The effect or incident being investigated is shown at the end of the horizontal arrow. Each arrow may have another arrows entering it as the principal factors or causes are reduced to their sub-causes, and sub-sub-causes by brainstorming.

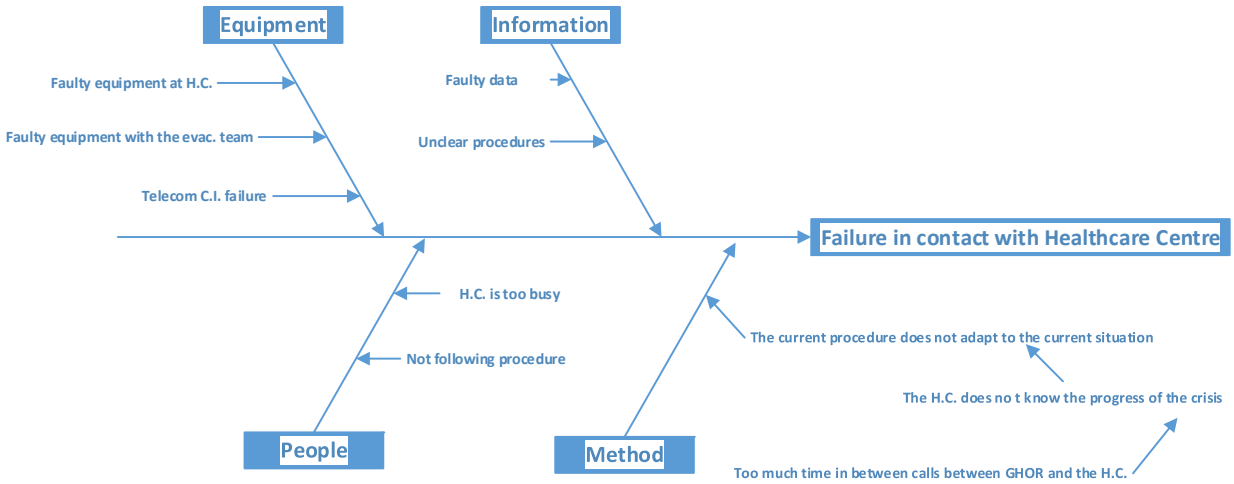


***Figure 6.2:*** *Cause-and-effect diagram example. Breach in dijkring 31, dp200*

The cause-and-effect diagram is a great way to brainstorm the different possibilities that a scenario can cause, even within one perceivable failure (as the example above) it is possible to unveil its root cause, and along, to find the different areas where there might be trouble.

### 6.2.2 FAILURE MODE, EFFECT AND CRITICALITY ANALYSIS (FMECA)

FMEA is the study of potential product, service, or process failures and their effects. When the results are ranked in order of criticality, the technique is called FMECA. Its aim is to reduce the probability of failure.

The elements for a complete FMECA are:

- **Failure mode**: The anticipated conditions of operation are used as the background to study the most failure mode, location and mechanism of the product or system and its components.
- **Failure effect**: The potential failures are studied to determine their probable effects on the performance of the whole product, process, or service, and the effects of the various components on each other.
- **Failure criticality**: The potential failures on the various parts of the product or service system are examined to determine the severity of each failure effect in terms of lowering of performance, safety hazard, total loss of function, and so on.

The elements of a complete FMECA are to study failure mode, effect and criticality. It may be applied at any stage of design, development, production, operation or use.

FMECA is set out in steps of the analysis as follows:

1. Identify the product or system components, or process function.
2. List all the possible failures of each component.
3. Set down the effects that each mode of failure would have on the function of the product or system.

4. List all the possible causes of each failure mode.
5. Asses numerically the failure mode on a scale of 1 to 10. Experience and reliability data should be used, together with judgement, to determine the values, on a scale 1-10 for:
   ***P*** the probability of each failure mode occurring (1=low; 10=high).
   ***S*** the seriousness or criticality of the failure (1=low; 10=high).
   ***D*** the difficulty of detecting the failure before the product or service is used by the consumer (1=easy; 10=very difficult).
6. Calculate the product of the ratings $C = PxSxD$, known as the criticality index or risk priority number (RPN) for each failure mode. This indicates the relative priority of each mode in the failure prevention activities.
7. Indicate briefly the corrective action required and, if possible, which department or person is responsible and the expected completion date.

When the criticality index has been calculated, the failures may be ranked accordingly. It is usually advisable, therefore, to determine the value of C for each failure mode before completing the last columns. In this way the action required against each item can be judged in the light if the ranked severity and the available resources.

| Process input/step | Potential failure mode | Potential failure effect | Severity | Potential causes | Probability | Current controls | Detection | Risk priority number | Actions recommended | Responsible |
|---|---|---|---|---|---|---|---|---|---|---|
| 10 | Telecom breaks down | No communication with HC2 | 8 | Flood | 5 | Telecom workers | 2 | 80 | Use alternate mean of communication | Evacuation team/ Telecom workers |
| 9 | Telecom breaks down | No communication with evacuation vehicles | 10 | Flood | 5 | Telecom workers | 3 | 150 | Use alternate mean of communication | Evacuation team/ Telecom workers |
| 4 | Telecom breaks down | No communication with HC1 | 7 | Flood | 5 | Telecom workers | 2 | 70 | Use alternate mean of communication | Evacuation team/ Telecom workers |
| 11 | Unable to access roads | Unable to evacuate patients | 7 | Flood | 9 | Evacuation team | 3 | 189 | Develop alternate routes/Vertical evacuation/Use different vehicles | Evacuation team |

***Table 6.1:*** *FMEA example. Breach in dijkring 31, dp 200*

In the example above, it is demonstrated how an FMEA can be used to analyse the severity, probability and detection of C.I. failure during a flood. As it was mentioned before, the depth of the analysis will dependant of the brainstorming done for it. The more suggestions and possible failures that can be listed and quantified, the more ready the team can be for these failures.

# 7. ANALYSIS

This research has focused on three different aspects of a possible dike breach in the municipality of Reimerswaal. Which were; what can be considered as the healthcare community in the municipality, the evacuation process of such individuals and finally the effects that the failure of critical infrastructure can have in the process.

Human logistics, is the application of logistic theories into the 'flow of people'. Whilst in an regular supply chain process, the product is whatever is being produced, in an evacuation process the 'product' is the people that need to be evacuated. The application of different logistic theories can be useful to analyse the evacuation process and see where there can be improvements to be made. Which is why this research was focused on the *planning and control* part of the process (logistic concept).

This research developed its own definition on what the healthcare community is, in an evacuation process. Firstly, there are the 'dependant individual' which are the individuals that are dependant of others to perform activities of daily life (the people who live in their own homes are considered resilient, so they are responsible for their own evacuation). Then, there are the healthcare centres inside and outside the affected area. Finally, the government entity that manages the evacuation of the 'dependant individuals'.

The current evacuation plan is developed by the evacuation team in Bevolkingszorg, who receives the assignment of the Regional Operational Team and 'on the spot' starts developing an evacuation plan, after the Rijks Team has already assessed the magnitude of the crisis (GRIP). As every situation is different, and they cannot develop a plan for every possible scenario, there is no 'sample plan', this means, that the evacuation plan is developed from scratch once the evacuation team receives the assignment.

It is very difficult to estimate the magnitude of the effect that the failure of different critical infrastructure can have in the evacuation process. The failure of each C.I. can have a different effect and the *cascading effect* can increase the number of failures. No calamity is the same, there are many variables that can affect the evacuation process and the calamity itself can affect the process, as mentioned in appendix 1. So, it is important for the evacuation team to keep monitoring the process. The failure in C.I. can have a great impact in the monitoring. For example, if electricity or telecom infrastructure is damaged during the flood, then the communications would be disabled in the affected area. When this happens, the evacuation team has no communication with the emergency vehicles until they leave the affected area, causing for the decision-making time to be shorter.

There are methods to measure the performance; such as calculations for efficiency, time and capacity. Using historical data (data from the previous evacuation plans) it is possible to find the relations between different processes and have an idea on what is the 'standard' efficiency, time and capacity; for the evacuation process.

The different methods used were: Flowcharting, is used to have a visual representation of how the complete process looks like and what is the order of each step (example, appendix 6); histograms are used for the comparison of historical data (for example, total evacuation time throughout the years); scatter diagrams are used for comparing two different aspects in order to see how strong their relationship is (for example, water depth & vehicle speed); cause-and-effect diagrams are used to find the root cause of a problem (example, figure 6.2). Finally, the failure more, effect and criticality analysis studies potential product, service, or process failures and their effects (example, table 6.1).

With the data of the scenario provided by the program Lizard (such as, flood time, water depth and estimated loss of life, in appendix 5), the scenario was analysed and the different measures that can be acquired were used to roughly quantify the improvements that different logistic tools can apply. Tools like flowcharting and fishbone diagrams are a good method to analyse the different possibilities in the process. Visualising what is the current situation, what can go wrong, what can be the effect and how to prevent or mitigate it is the ultimate goal of these tools, continuous improvement. As there was a limited amount of data for accurate measurements, these missing data was replaced with assumptions. However, these tools are used to measure the performance of a process, and so, when there is no data, these are the measurement tools to be used for analysing the scenario.

# 8. DISCUSSION

The initial goal of this research was to improve the current evacuation process using logistic tools. The goal was to see how it can be improved, and then how can the failure of critical infrastructure affect this process.

After that, there was the decision of focusing in the healthcare community. The research team was not sure on what the evacuation process for the more 'dependant' individuals would be, and so, this research changed to the development of counter measures against the effect that the failure of critical infrastructure can have on the evacuation process of the healthcare community.

Once the scoped was designed, interviews with the members of the healthcare community were scheduled. One, was with representatives of a healthcare centre outside Reimerswaal (Bergen Op Zoom), where they explained what the hospital's evacuation measures were, what is their capacity during a crisis and how is their contact with GHOR. And the other interview (appendix 1) was with representatives of GHOR and Bevolkingszorg, which explained how he evacuation process is, how the plan is developed, who is involved and what is the role of each member.

With this information, the report was written, and a conclusion was drawn from the research. Unfortunately, the conclusion was still lacking the logistics aspect in the improvement tools for the process. And so, it was decided to again narrow down the scope of the research to the 'planning and control' of the evacuation process.

Once the scope of the research was defined, different methods to analyse and measure the evacuation process were researched can be applied to the evacuation process and explained. And finally, it was explained some planning and control logistic improvement tools, to counter the effect of critical infrastructure failure.

During this research, it was not possible to obtain all the calculations for the flooding scenario. Using the program Lizard, there was access to the information showed in appendix 5, meaning, the research obtained the time in which the flood would cover the different zones, the average injured (deceased) per area, water and water depth, as well as the general location of the dependant individuals residing in Reimerswaal (figures 4.1 & 4.2). Due to this, the measurements for capacity, time, efficiency and control were only assumptions and so, results can be considered as inconclusive (which is the reason why the calculations were omitted and only the equations were shown).

Having this data already, the from the theoretical framework (and other sources) had to be used (data, evacuation times, vehicle capacity, hospital capacity, and so on), and with these, make 'assumptions' on what could happen during a flood and the failure of critical infrastructure. Possible methods were described to measure the performance in order to see the steps in the evacuation process that can be improved. As the evacuation plan is currently developed only at the sight of a crisis, it was not possible to

find the different historical data from the previous evacuations, and so, there cannot be a real possible comparison until the measurements are defined and the process is measured after applying the different improvement methods.

It is relevant to point out, that this was an interdisciplinary research, were the Delta Academy collaborated with the Logistics department to work on this project. For this, in the research had to have enough relevant information to satisfy the needs of both departments as well as the subject itself was an interdisciplinary work, with aspects of human logistics (healthcare community), Civil Engineering (failure of CI) and Water Management (breach in dijkring 31, dp 200). This gave it complexity to the task but also, made it more interesting, as these topics are related, and so it shows it is necessary to put different perspectives into the projects.

# 8. CONCLUSION

This chapter will contain the answer to all the sub questions presented in the introduction of this report, and it also answers the research question that this report had. It begins answering the questions about who is the healthcare community and what is the current evacuation plan, then, the effect that the failure of critical infrastructure would have on the evacuation process, and counter measures, and finally, which logistic strategies should be developed to enhance the evacuation of the healthcare community before and during a flooding in the municipality of Reimerswaal.

*Which groups of people should be considered when referring to the 'evacuation of the healthcare community'?*

Currently, the Government considers the individuals that are living at their own homes as 'resilient', as they can live a certain period of time without any assistance and they live alone, they are considered to be capable enough to evacuate themselves. On the other hand, the people that reside in nursing homes, hospitals, hospices, etcetera, are to be taken care of by the organisations themselves. The government will lend aid if necessary, but the evacuation must be handled by the own organisation.

As mentioned in chapter 4, given there is a limited number of ambulances and equipment, it is necessary to prioritize the use of such. GHOR will oversee the decision of prioritizing is the scenario of a small incident; in the scenario of a large-scale crisis, then DPG will take the responsibility of deciding which individuals will be prioritized during the evacuation. The evacuation and prioritizing decisions are considered with the concept of; "*which decision will prevent the greatest number of casualties*" (Bevolkingszorg, 2018) shown in appendix 1.

*What are the current evacuation measures that the government would take in the event of a flood?*

In the scenario where the is a flood in the Municipality of Reimerswaal, the municipality is responsible for taking the lead in its own emergency response, but with the Law on the Safety Regions, many emergency response tasks are accommodated in such a region.

The current emergency plan is handled by Bevolkingszorg. In the scenario of a crisis, (as one of their tasks) they will be in charge of developing an evacuation plan for the situation. Currently, there is no evacuation plan for any scenario, as it was explained in chapter 5, this is because of the many different variables that can occur during a crisis, it is impossible to develop a plan that will tackle all the possible scenarios.

The current evacuation measures consist of; first, after the crisis occurs the Rijks Team assesses the situation and reports about the magnitude of the crisis (for example, GRIP 4) to the Regional Operational Team; they then, give the assignment to the "Evacuation Team", which consists of different representatives of several departments (such as police & fire department).

The Evacuation Team takes the role of developing an initial evacuation plan. They have to discuss which roads will be used, which transport method, to where the people will be transported, etcetera. Once the plan is put in practice, they will continuously assess the situation of the crisis, and improve the plan accordingly.

*How can the failure of critical infrastructure affect the evacuation possibilities of the healthcare community?*

Bevolkingzeorg currently does not have any kind of contingency measures in the event of failure of critical infrastructure in a crisis scenario. To which, is very important to understand the effects that these failures may have. If one of these infrastructures fails during a flooding, it would cause a great disruption in the evacuation. Due to the cascading effect, it is possible that the failure of CI can have a greater impact than expected. The interdependence of several of these CIs can have a great effect on the developments during the evacuation, as the evacuation measures are also dependant of many of this CIs.

As mentioned in the interview in appendix 1, no calamity is the same, there are many variables that can affect the evacuation process and the calamity itself can affect the process (Bevolkingszorg, 2018). So, it is important for the evacuation team to keep monitoring the process. The failure of C.I. can have a great impact in the electricity or telecom infrastructure is damaged during the flood, then the communications would be disabled in the affected area. When this happens, the evacuation team has no communication with the emergency vehicles until they leave the affected area, causing for the decision-making time to be shorter.

The general effects that the failure of critical infrastructure can have on the evacuation process of the healthcare community in Reimerswaal in a flooding scenario was listed with three different C.I.; Telecom, whose failure would have a great effect on the 'planning and control' of the process, as contact with all the parties involved would be limited. Electricity infrastructure failure can influence the communications and data collection as well, but also, if another dependant infrastructure (for example, telecom) is located in the affected area, this infrastructure will also present failures. During a flood it is normal for the roads to be flooded, making the vehicles unable to use those roads, this causes a disruption in the evacuation plan, so then the evacuation route (or the evacuation plan) now has to adapt to the current situation, and constant contact needs to be made to keep track of the situation and react accordingly.

*What contingency measures can be taken to minimise the damage to the healthcare community and to counter the different possible scenarios that a flooding may cause?*

The failure of critical infrastructure can have a great negative impact in the evacuation process, which can lead to an increase in the number of injured and/or dead due to the flood. Given their unpredictability in matters like when it can happen, which infrastructure may fail, what is the magnitude of the damage and so on, it can be very difficult for the evacuation team (and all the people involved in the process) to adjust

the plan given the situation. However, when encountering a situation like that occurs, the one of the most decisive factors is how well **prepared** all the people involved in the process are. Although it is impossible to create an evacuation plane for every possible scenario, it is possible to develop measures to be prepared for the uncertainties.

Total Quality Management is an approach for improving both customer satisfaction and the way organisations do business, as described in the sub sub-chapter 6.2.2. This type approach is people oriented, this means, to bring together all the quality and customer (patient) related process improvement ideas and with the participation of all the member of the organisation (healthcare community). By working together, they can obtain a great amount of quality improvement ideas, so the end product and even the development process (evacuation planning and process) are has the highest quality and efficiency possible.

***Which logistic strategies should be developed to enhance the evacuation of the healthcare community before and during a flooding in the municipality of Reimerswaal?***

Although it is that it is impossible to prepare a plan beforehand for every possible scenario, it is dangerous to rely only on the quick response of the crisis management team. It was discussed (appendix 1) that the evacuation team starts to develop the generic evacuation plan once they get the assignment from ROT, which get the warning from the Rijks Team. Basically, they can start developing the plan weeks before the crisis, or after the crisis already started. The latter scenario gives the evacuation team very little time to prepare a proper evacuation plan.

As mentioned in the theoretical framework, the logistic concept shows the correlation between all four points (Structure, Control, Information, People), but there is an special correlation between planning and control and information gathering and sharing. Basically, to develop or improve the plan, it is necessary to have control on the process, to know how each department is performing and why (data gathering and data analysis). However, for this you need to have information, without the information, the planning can only be based on 'brainstorming' sessions on how their performance was. For developing a proper evacuation plan, and to improve the current evacuation process it is necessary to gather the information about the performance of the different departments and in every step of the process (information gathering), then the data is analysed using different control methods, depending on what the evacuation team needs to know about the process. And finally, a plan is developed based on the information gathered (planning).

Given the many variables that a crisis scenario may present, which is the reason why there is not a 'standard' evacuation plan, the most effective method to be prepared is to have brainstorming sessions about what the different scenarios can present and what can be done about it. For this, the failure mode and criticality analysis can be used to discuss, measure and rate the different scenarios that can be presented. In the table 6.1, a short FMECA was made for the current evacuation process shown in

appendix 6. However, there are only four examples in that table. An FMECA can be as long as the brainstorming session allows the team to think of; this means, that there can be as many FMEAs as there can be situations during a crisis, and so, this can be a great way to analyse as many scenarios as possible and also, have an action plan for when it happens.

One of the most important elements during an evacuation is how well prepared the town, municipality, country, etcetera is for a crisis and the different factors that can influence the evacuation process. For being prepared, it is necessary to have an idea to what to do during a crisis and how to do it. If an evacuation plan is only developed once threat is imminent, then there will be limited time to be prepared for every possible scenario. However, with constant control, communication, brainstorming sessions, it is possible to be prepared for several different situations, reducing its impact and reaction time, and increasing the effectiveness of the solution.

# 10. ADVICE

In this chapter, there will be an explanation on how the different logistic methods can be used in the to further measure and improve the current planning & control aspect of the evacuation process of the healthcare community residing in the municipality of Reimerswaal. First, a description of what can be considered as the KPIs of an evacuation; then, how the planning & control of this process can be described and how to implement Total Quality Management tools into this process. Followed by an explanation on how the FMECA can be used, and finally, how can a model be implemented in such a variable scenario and final advise.

## *Key performance indicators*

Key performance indicators (KPIs) are measurable values that demonstrates how effectively a company is achieving key business objectives. In the evacuation process, the overall performance of the emergency response will depend on the outcome of these tasks which are in outline:

- Assess the situation / Explore the disaster area
- Receiving and taking care of injured people
- Clear areas and evacuate people and animals
- Maintain order and regulate traffic
- Meet the need for food, drinking water, gas and electricity facilities
- Information, information reporting and accountability

These will be considered the KPIs of the evacuation process, the method in which these performance indicators will be measured or calculated is to be decided depending on the need of the evacuation team. For example, *receiving and taking care of injured people* can be measured for effectiveness as $\frac{\text{Ammount of injured taken care of}}{\text{Total ammount of injured (deceased)}}$. Or, *Assess the situation / Explore the disaster area*, can be measured for the percentage of known factors, such as $\frac{\text{Size of the reported area}}{\text{Size of the total affected area}}$. The evacuation team can decide on which are the most relevant factors for then when making an evacuation plan, and with these, create the KPIs.

## *Planning & control*

As mentioned in the theoretical framework, arranging all the necessary steps for developing an evacuation plan (or any production plan) is a complex problem, and it is essential to have a good planning and control system. A good planning system must answer four questions framework (Arnold, Chapman & Clive, 2008);

1. **What are we going to make?** For this specific research, that would be, to develop an evacuation plan for the healthcare community rescinding in the municipality of Reimerswaal, in the scenario of a breach in the *Dijkring 31, dp200*. However, the evacuation team can also think about different areas, dijkrings and communities when asking this question. In this research's scenario, the 'product' is the evacuation of the dependant individuals.

2. **What does it take to make it?** There are many different factors to focus on when creating an evacuation plan, that why it is necessary to have a visualisation of how the process should look like, what it is necessary to have for each step (machinery, personnel and so on) and finally, how is each step going to be measured (KPIs).
3. **What do we have?** This can be considered as a brainstorming session in which the evacuation team discusses about all the assets they currently have. For example, what is the current availability of firefighting equipment (discussed with the fire department), what is the availability of ambulances (discussed with GHOR) and so on.
4. **What do we need?** Once it is described all the assets that are needed (information, materials, personnel, etcetera) and it has been listed all the assets that are currently available, then the evacuation team needs to see which assets they are missing, and need to think of a way to acquire them or replace them. For example, currently GHOR (2018) does not have access to the location of the dependant individuals rescinding in their own homes, as they are considered resilient, so, if there is a possibility that, that person cannot evacuate by him/herself and the evacuation team or GHOR considers that individual resilient, then there is a problem due to lack of information.

### *Total quality management*

Total Quality Management has many tools that can be used for answering different questions about the entire evacuation process, such as;

1. **What is done?**; using ***process flowcharting*** it is possible to create a complete flow of the entire process that you are trying to analyses and improve (example, appendix 6). Using this method it is possible to find what is the flow of information like, what is the flow of people, or just what are the different tasks that need to be done in the evacuation process (and who does what).
   This tool can be used at any part of the process, to create a visualisation of the entire plan, which steps are taken, what are the dependencies and bottlenecks.
2. **What overall variations look like?**; data collection and data analysis is a very important aspect of process improvement. This is because, with the use of historical data you can analyse the different variations that have happened throughout all the evacuations that have happened with a ***histogram***. with this data, it is shown, in a very pictorial way, the frequency in which a certain value or group of values occurs (for example, average roundtrip time of evacuation vehicles). The data in this histograms can be the measurements from the previously defined KPIs.
3. **What are the relationships between factors?**; when analysing how to improve a process, it is necessary to also know the association between different factors (for example, water depth/vehicle average speed). For this, it is possible to use a ***scatter diagram***, which consists in a simple X-Y plot of the two sets of data. The resulting grouping of points would show whether there is a strong or weak relationship between those two factors.
   When developing a plan, if you know about the relationship between two factors, it is easier to be prepared for the different conditions the situation may present, for example; if there is close relationship between water depth and average vehicle speed then, during a flood, it is possible to expect the vehicle speed to drop as the water depth grows.
   The relationship between two different factors can also be considered as KPIs depending on the result that the evacuation team is looking for.
4. **What causes the problems?**; The ***cause-and-effect diagram*** is a useful way of 'mapping out' the different inputs that affect quality. The effect or incident being investigated is shown and then

different root causes are displayed to then be reduced to their sub-causes, and sub-sub-causes by brainstorming. This diagram is for brainstorming different possibilities and scenarios that can have an effect on the evacuation process (like the example in figure 6.2).

### *Failure mode, effect and criticality analysis*

The failure mode and effect analysis (FMEA) is the study of potential product, service, or process failures and their effects. When the results are ranked in order of criticality, the technique is called FMECA. Its aim is to reduce the probability of failure.

The elements for a complete FMECA are:

- **Failure mode**: The anticipated conditions of operation are used as the background to study the most failure mode, location and mechanism of the product or system and its components. For example, what is the likelihood for the telecom infrastructure to flood and fail, when there is a breach in the *dijkring 31, dp 200*.
- **Failure effect**: The potential failures are studied to determine their probable effects on the performance of the whole product, process, or service, and the effects of the various components on each other. For, example, what can be considered as the magnitude of the failure in telecom infrastructure, what does this do to the entire evacuation process and how does it affect different factors outside the evacuation planning process (like other kinds of infrastructure).
- **Failure criticality**: The potential failures on the various parts of the product or service system are examined to determine the severity of each failure effect in terms of lowering of performance, safety hazard, total loss of function, and so on. For example, what is the severity of the failure of telecom infrastructure, what does it mean to the process when the telecom infrastructure fails, how difficult would it be to detect and mitigate the problem (if possible) before the evacuation process is greatly affected.

These three elements are measured in a scale of 1 to 10, and the multiplication of the three together will give the criticality rank. For example, the flooding of telecom is unlikely due to the position of the telecom infrastructure (2), it can have an effect in the evacuation commination process, which would cause disruption in data collection, planning and control of the evacuation process (8), and it would be difficult to detect or mitigate, as the failure of communication can make detecting and mitigating the problem more difficult (7). This would give a total of criticality = 112 (on a scale of 1 to 1000).

### *Model reference adaptive control framework*

It might be useful to create an adaptive model such as the Model Reference Adaptive Control Framework (MRCF) mentioned in the theoretical framework (Liu et al., 2007). Creating a model will give a clear structure to the evacuation plan as well as the measures that can be taken to prevent different scenarios. In appendix 6, it is shown how the current evacuation process looks like. This process can be seem a bit simple, but in each part of the process, there are many different aspects that need to be taken into

account and many different factors that can affect the step. For example, if GHOR cannot make contact with HC2 (with failure of telecom infrastructure), then it is more difficult to triage, as GHOR no longer has access to the current capacity or priority of the healthcare centre to which the evacuation vehicle would sent the patient. This can cause for the healthcare centres to work either under or over their capacity during a crisis. If instead of a regular flowchart, an MRCF is developed, then an adaptable factor would be added to this process, for example, the use of a different mean of communication.

Finally, it is advisable to make further research on this topic. This research focused on the planning & development aspect of the evacuation process of the healthcare community and the effects of critical infrastructure failure to this process. There are still many unknown factors which can also affect this process, so they need to be further researched, such as; the information-sharing and acquisition, the entire process structure and also all the people involved in the evacuation process (Logistics Concept, in the theoretical framework) . The failure of critical infrastructure is also another factor that is currently unforeseen by the evacuation team (Bevolkingszorg, 2018), which is why, this topic needs to also be researched in depth, in order to be prepared for when a calamity occurs. This particular research is already a small step taken in the development of the understanding of the project, as this was a collaboration between Logistics Engineering and the Delta Academy, there was more extended research that would not have been possible to obtain if the collaboration had not had happened. This is why it is also important to be open to these types of collaborations for projects between different departments, because at then of the day, they all have insight that will be relevant for the project development.

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