A COMPARISON BETWEEN THE NETHERLANDS AND GERMANY OF EVACUATION IN CASE OF EXTREME FLOODING

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Abstract. The North Sea floods of 1953 and 1962 caused many deaths, severe damage and heavy economic losses in the Netherlands and Germany. Since that time, technical flood protection measures have been improved. In the Netherlands, a protection system has been developed to the highest international safety standards. In Germany, attention has been paid to adaptation and prevention, for example, in the city of Hamburg. Due to improving safety, the probability of flooding has been reduced, and public risk perception has been reduced. However, the impact of a flood could nevertheless be enormous, and for the Netherlands even catastrophic. This article compares Germany and the Netherlands in terms of their preparation for flooding and mass evacuation if things should go wrong. Finally, the lessons learned are listed. The main conclusion is that the designs of the safety level and of crisis management should be based on a probabilistic approach, with attention paid to worst case scenarios and alternative strategies of response, so that a community or country can be more resilient.

Keywords. Flooding, crisis management, evacuation, worst case scenarios, early warning

Introduction

Flood protection in the low-lying areas of the Netherlands and the coastal areas of Germany began in the Middle Ages. Flooding was a part of life for the inhabitants [1, 2]. As time passed, growing attention was paid to flood protection. After each flood, the defence system was upgraded to withstand at least the latest flood. The North Sea floods of 1953 and 1962 caused many deaths, severe damage and heavy economic losses in both the Netherlands and Germany. These floods resulted in changes in policy in both countries.

In the Netherlands, the common opinion after the flood of 1953 was that should not be allowed to happen again. The current safety levels in the Netherlands and the risk approach designed by the Delta Commission in 1960 were set into law in the Flood Protection Act (Fig. 1). Although the Netherlands has never before enjoyed the levels of protection against flooding that are in place today the second Delta Commission (2008) advised [3] an increase in the safety level due to climate change and the growth of welfare. Despite the high safety level the risk of flooding remains and will always persist. The consequences, in terms of economic and social damage and casualties, could be enormous. A risk analysis by the Ministry of the Interior in 2009 demonstrated the risks of several threats (Fig. 2). Although a flood has a low probability, the consequences could be catastrophic [4].

Since 1960, Flood Risk Management has mainly focused on protection. An evaluation of the water safety policy in 2004 [5, 6] showed that the Netherlands is not prepared for extreme flooding. The collective risk of flooding exceeds the allowed exposure to external safety risks. This being the case, the need to improve preparation has been addressed by the Dutch Government [7, 8]. Concerned by the flooding of New Orleans due to Hurricane Katrina, the Dutch Cabinet decided to enhance flood preparedness [9]. Emergency planning for flood prevention and large-scale evacuation were prepared by the national and regional authorities (as in [10-12]). Drafts and first-generation plans were tested in the 2008 nationwide exercise "Waterproef".

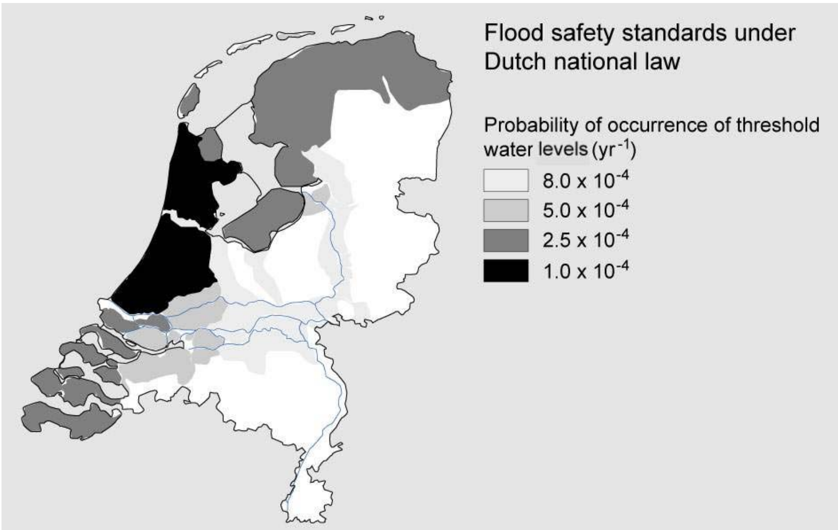

Fig. 1: Safety standards of the Flood Protection Act of 1996

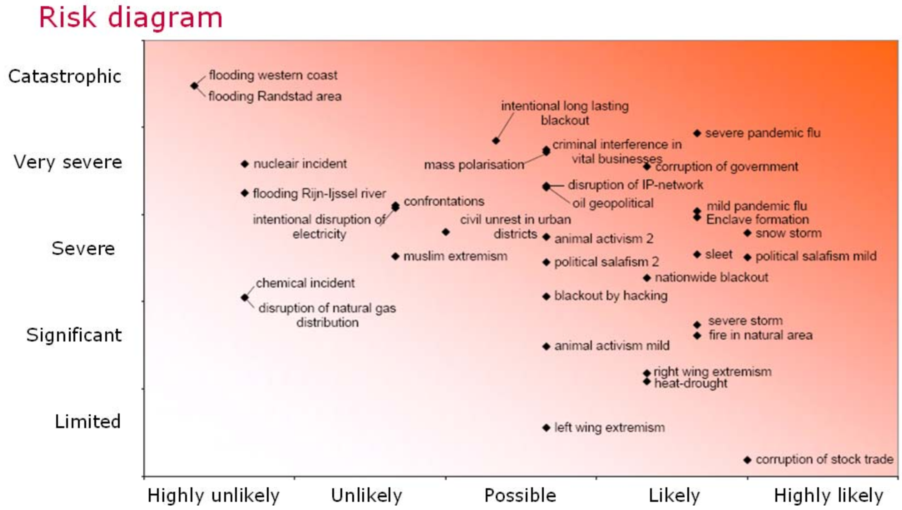

Fig. 2 Risk diagram of the Netherlands (in 2009, [4]) showing risks of different types of threats

The German response to natural hazards has similarities to the Dutch response. After the 2002 flooding in the river Elbe catchments, people rebuilt their houses immediately behind the dikes in the belief that a flood as devastating as the one that destroyed their houses, partially or totally, would not occur again during their lifetimes. A survey on the perception of various risks among the public and experts in the Middle Rhine Valley showed that civilians do not feel that flooding is a great threat. Risk experts, however, calculate a much higher chance of recurrence (Fig. 4). Another survey on confidence in technical and organizational mitigation measures showed no significant difference in the level of confidence depending on the frequency of floods [13].

In contrast to the public, experts and politicians became more risk-aware due to the threat of terrorism, natural disasters (floods) and other threats, and consequently adapted their way of thinking. German disaster management has changed over the past few years, and in 2004 a new federal authority, the Federal Office of Civil Protection and Disaster Assistance (BBK), was created.

In cases of emergencies (e.g., flooding), the federal government controls the disaster relief and civil protection programs. The local fire departments and the Federal Agency for Technical Relief (THW) are part of these programs. The German Armed Forces, the German Federal Police and the 16 state police forces will, if necessary, all be deployed for disaster relief operations.

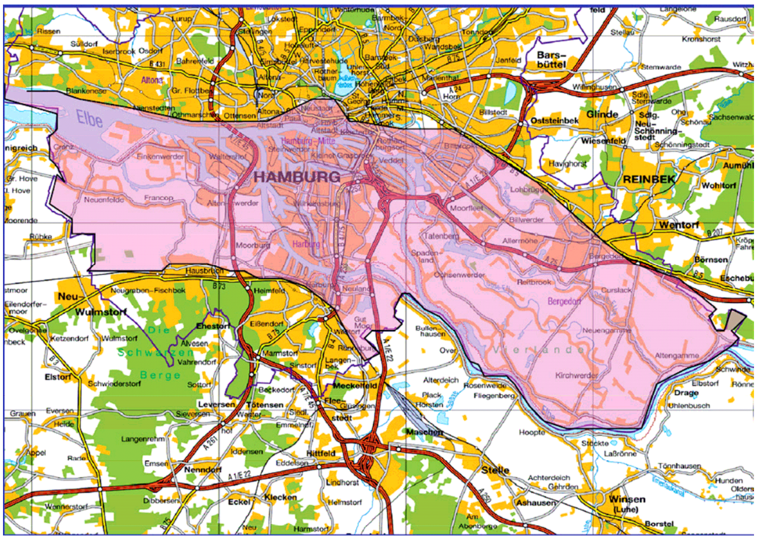

Fig. 3 Threatened area in case of a storm surge from the North Sea

Risk	Opinion survey of population		Opinion survey of experts	
	Threat [ranking]	Probability [ranking]	Threat [ranking]	Probability [ranking]
Nuclear incident	1	6	1	8
Traffic accident	2	1	3	1
Earthquake	3	4	5	7
Chemical accident	4	5	2	4
Fire hazard	5	2	4	3
Skin cancer	5	3	6	5
Aids	7	8	8	6
Volcanic eruption	8	9	9	9
Flooding	9	7	6	2

Fig. 4. Estimation of the threat and the possibility of occurrence of various risks in the Middle Rhine Valley (adapted from [14]).

In addition to actual disaster relief, major tasks and responsibilities of the decision makers include the communication of risks and emergency response. In case of an emergency (flooding or otherwise), people need to know what can happen and what to do or not to do. For example, in case of a North Sea storm surge that threatens the greater Hamburg area, the public have been informed by the municipality (brochure) that, despite the deployment of flood barriers, catastrophes may still happen, and major parts of Hamburg can be flooded (Fig. 3). The brochure describes several possible events and gives steps for how to react [15].

Aim of this conference paper

This paper compares Dutch and German preparations for flooding, especially in early warning, use of flooding scenarios and evacuation strategies, and crisis response based on forecasts prior to the start of flooding.

Use of definitions

Early warning is described as the process of detecting a possible threat using forecasting models and warning crisis managers and decision makers. Before crisis managers act, they must make sense of the possible threat. Sense making is defined as understanding the threat and being willing to think about possible responses [16].

Evacuation can be seen as a measure to reduce the loss of life. Kolen et al. [17] distinguish several types of evacuation based on a literature review. Evacuation is defined as movement to a (relatively) safe place. The movement can begin prior to a disaster and may continue to take place while the disaster is ongoing. Evacuation can be categorized into several types based on the destination or the location of the safe place.

- Preventive evacuation: movement of people from a threatened area to a safe location outside this area.
- Vertical evacuation: movement to locations inside the potentially exposed area that offer some kind of protection.
- Shelter in place: movement to higher/upper levels.

An evacuation strategy consists of one or more of the described types of evacuation, including all necessary measures to support the evacuation. One of these measures, traffic management, is defined as the way the available infrastructure is used.

The start of a flooding disaster is defined by the moment the dike fails. Crisis management starts the moment the flood threat is detected and organizations begin to discuss or prepare possible responses.

A flooding scenario describes the flooding pattern, including the characteristics of the area (e.g., land use and population), the hydraulic load and the location and severity of the breach(es).

The Dutch situation

Early warning system

Early warning is dependent on predictions made by forecasting models and experts. These models use the actual circumstances and predictions of the weather. The forecasts result in an expected water level, with a margin of uncertainty [18, 19].

When these (forecasted) water levels exceed predefined warning or safety levels, alarms will be triggered and crisis organizations will be put into place. Two approaches to initiating these crisis organizations in the case of flooding (using early warning) can be distinguished [10]:

1. Bottom up approach: in case of extreme water levels but no severe risk for flooding. When water levels are rising, the water boards will be warned by flood forecasting centres for rivers, lakes and the sea, and can take measures to prevent flooding. Water boards inform Safety Regions in case of a serious risk of flooding, which may lead to measures such as evacuation. If necessary, local and regional organisations inform national organisations.
2. Top down approach, as recently developed by the National Commission of Flooding: in case of extreme water levels that cause a realistic immediate flood risk. Due to the situation, a longer warning period is preferred; this requires more sophisticated forecasting models that generate warnings farther in advance of the actual flood, potentially leading to greater uncertainty [10]. After detection of possible extreme water levels, the national crisis organisations and the water boards will be warned of the impending danger. National crisis centres will begin crisis management and coordination between regions.

The bottom up early warning system mainly focuses on the duty of the water boards to prevent flooding. Time is sufficient for precautionary measures to be taken by the water board and for dike inspection teams to be formed. For river areas, a few days are available after the first warning for preparation. For coastal areas, only hours to a day may be available [18]. The bottom up approach is appropriate for situations with extreme water levels but no risk of flooding; it might be less effective in cases of possible flooding.

The time required to implement and execute a preventive evacuation could be more than three days for coastal areas [17]. The bottom up approach might be ineffective when time is lost for crisis management due to the time spent forming agreements between organisations, shortages and conflicting priorities. A top down approach might increase the available time for precautionary measures and reduce the time needed to make agreements between organisations. The bottom up and top down approaches can work alongside each other, as shown in exercises such as 'Waterproef' [20].

Flooding scenarios

There are several scenarios for flooding in the Netherlands, which can be divided into two types:

1. most likely scenarios and
2. worst credible floods.

The boundary conditions of the most likely scenarios are equal to the current safety levels of the local flood defence system. The defence system is designed using a probabilistic approach [21]. The event (combination of several parameters) with the highest probability related to the safety level is generally taken as a boundary condition. Most of these scenarios suppose a single breach and focus on one dike-ring (area surrounded by one defence system).

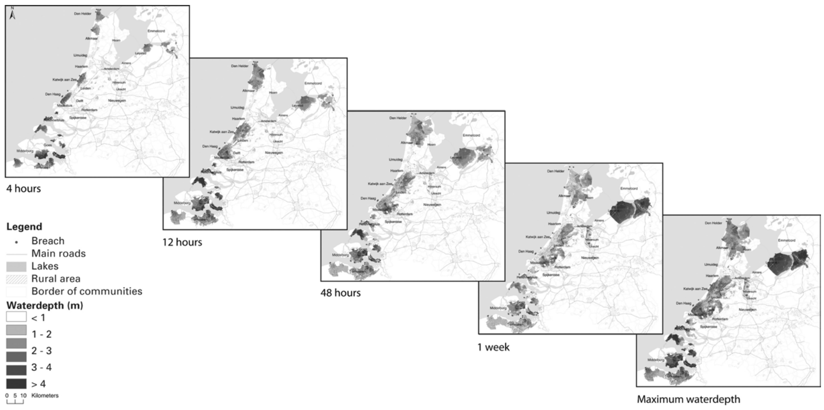

Fig. 5: Worst credible flood for the western coast

Worst credible floods give an upper limit for flooding scenarios that are still considered realistic or credible by experts and that can be used for emergency planning in addition to the most frequent scenarios. A worst credible flood greatly exceeds the safety level, with a hydraulic load that is 10 higher than the frequency of the safety level; thus, multiple breaches may occur in many different dike-rings [22]. These w orst credible flood scenarios can be seen as worst cases [23, 24] and reflect the idea of ”thinking the unthinkable” [23]. Extreme scenarios are used to learn how infrastructure networks (roads, communication) might fail and to think through possible disaster preparations. The projected worst credible flood for the western coast (Fig. 5), which would cause the flooding of approximately 10 percent (about 4,500 km^2) of The Netherlands after more than one week, by far exceeds the 2005 flooding of New Orleans after Hurricane Katrina in terms of the extent of flooding, victims, casualties and damage (about 120 billion euros and >10.000 casualties).

Emergency planning

Compared to other countries, e.g., the United States, mass evacuation is less common in the Netherlands or Germany. In New Orleans, emergency planning for flooding and evacuation have been tested and evaluated by decision makers and the public in real events (such as Hurricanes Ivan, Katrina, Rita and Gustav) and exercises (for example, exercise PAM). In the absence of real events, emergency planners in the Netherlands must use (small-scale) exercises and research instruments to develop, test and evaluate emergency plans. To perform a realistic exercise with about a million people, without an actual threat and only for a test, seems to be a mission impossible.

Emergency planning for flooding and evacuation is conducted by national and regional authorities. The role of national organizations in decision making is described in the National Crisis Plan for Extreme Water Levels and Flooding [11] and an emergency plan for evacuation [25, 12]. On the local level, 23 of the 25 safety regions (which combine police, fire and medical services and several municipalities) and all water boards have made preparations for flooding within the last two years [26]. As part of a national operational emergency plan for evacuation, a national concept for traffic management has been developed [27] by the National Traffic Centre, which is part of the Ministry of Public Works, Transportation and Water Management.

Evacuation

Research shows that the capacity of the Dutch road infrastructure is limited in case of an evacuation (worst case scenario). For river areas, 72 hours are assumed to be available for evacuation. In coastal areas threatened by a storm surge, 48 hours are assumed to be available, of which the last 24 hours cannot be used for evacuation due to severe weather conditions.

When a preventive evacuation is not feasible, other types of evacuation could still reduce loss of life and prevent people from being exposed during an evacuation. The necessary time for evacuation is calculated [27, 28] for a strategy that focuses on a maximum preventive evacuation and for a strategy that focuses only on a preventive evacuation of the most vulnerable people, providing shelter or hiding for others: a minimal preventive evacuation. The diversity of public behaviour is taken into account by assuming that 20% of the self-supporting people do not act in accordance with the strategy.

For each an evacuation strategy, two forms of traffic management have been taken into account: 1) optimal use of exit points and 2) no extra directions information. The first form of traffic management is defined as a best case, the second as a worst case [29].

Table 3: Number of people in each strategy (x 1.000 people)

	Preventive evacuation		Hiding and Shelter	
	Coast	River	Coast	River
Maximum preventive evacuation	3.900	900	900	200
Minimal preventive evacuation	1.200	300	3.600	800

Based on a realistic 48-hour prediction, a complete and timely evacuation of the Dutch coastal area is unrealistic, simply because of the limited available road capacity. The problem is most pressing in the North and South Holland provinces. Even with an optimal use of exits (a steady flow and not taking into account the possibility of accidents and conflicting behaviour), more than 72 hours are required for a maximum preventive evacuation. Even a minimal preventive evacuation will take 24 hours in a best-case scenario. The necessary evacuation time increases dramatically (three times longer) in worst-case situations. In smaller, less-populated areas, maximum preventive evacuation is more attractive. For example, a maximum evacuation of Zeeland would require around 24 hours with optimal use of exit points (35 hours without).

For river areas, a period of 72 hours is enough to complete a maximum preventive evacuation in both a worst and a best-case situation.

The German situation

Early warning system

Just like in the Netherlands, early warning systems in Germany rely on predictions and simulated results from forecasting models. Responsibility for flood forecasting in Germany falls on the following agencies:

- The Federal Waterways and Shipping Administration (WSV) is responsible for flood forecasting in shipping routes.
- The authorities of the federal states operate the flood forecasting for all other rivers in their state.
- The Federal Maritime and Hydrographic Agency operates the flood forecasting systems for the German coastal areas.

In general, the early warning procedure follows predefined steps and alert levels. In case of a severe threat due to flooding, a crisis management group will be assembled. This group consists of experts from different fields such as catastrophe management (Ministry of the Interior), fire departments, water boards, THW and relief organisations. For example, in the City of Hamburg, the Crisis Management Group first decides which precautionary measures must be taken. These are defined as follows [15]:

- timely warning and information to the citizens about the risk of a storm surge,
- defence of dikes and flood protection systems,
- evacuation of the harbour and
- timely evacuation of the citizens in the threatened areas (see Fig. 2)

Similar to the Dutch situation, the warning time is much shorter in coastal areas than in river catchments. For the City of Hamburg, the warning time averages nine hours (City of Hamburg, 2008); in river catchments, the first prognosis can be made a few days before the peak levels will be reached. As in river catchments, the increase of the water level is relatively gradual, while the sea level in coastal areas may change very quickly.

Flooding scenarios

Flooding scenarios are determined for many German rivers and coastal areas, using design and other frequent discharges. For about ten years, it has also been common to account for higher discharges than the design discharge, so-called extreme flood events. For the simulation of flood scenarios, observed, hypothetical or forecast data are used, notably the forecast data of the Intergovernmental Panel on Climate Change (IPCC) Study [30], dealing with climate change scenarios. These extreme flood scenarios can be compared to the Dutch worst-case scenario mentioned above.

The German Armed Forces are regularly confronted with different theoretical worst-case scenarios in exercises. An example is a worst-case flood scenario in the Lower Rhine that is initiated by a storm event and followed by heavy rainfall. Thus, besides the flooding scenario, other risks, like power failures and breakdown of the traffic system, must be controlled and managed [31].

Evacuation

Evacuation has often been carried out in the past before and during flood events. Evacuation plans are often part of the emergency management plans. Fig. 7 shows an emergency plan for the harbour area of Hamburg in case of a storm surge, in which the evacuation areas are displayed. This figure is part of an information flyer for the population that is supplied to each household in the threatened areas every two years. As described for the Netherlands, large scale evacuations are not rehearsed practically in Germany.

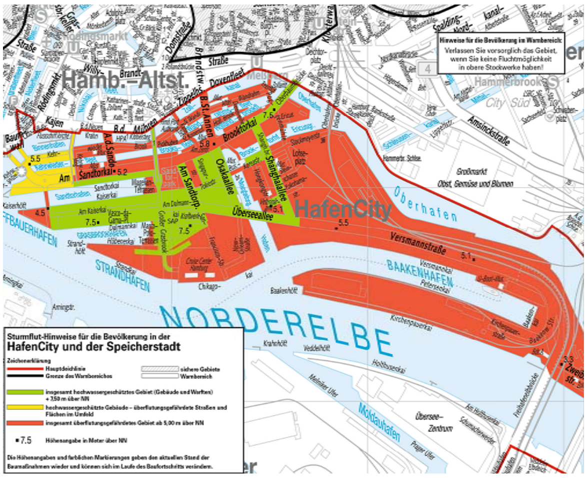

Fig. 6: Storm surge leaflet for the harbour of Hamburg [[15]]

Emergency planning

Emergency planning is done on the federal state level and municipality level. For the proofing of the emergency plans and for training purposes, flood protection exercises are arranged. The main purpose of these exercises is to test communication channels, responses and decision-making in unknown or uncertain situations, crisis management software (system itself and handling by the user) and technical flood protection devices such as mobile flood protection walls.

In a 2006 transnational flood protection exercise in the Lower Rhine area, emergency plans were used in combination with the Flood Information and Warning System FLIWAS [32]. During that exercise, several dike breaches were simulated and 7000 people had to be evacuated. The transboundary communication and cooperation between the Dutch province and the German municipality, as well as the common management system (FLIWAS), was very successful.

Conclusion and recommendations

Emergency planning for flooding must be based on scenarios with a wide variety of scales that contain several flooding scenarios, different periods of available time after early warning and several strategies for evacuation. It requires dealing with uncertainties involving threat recognition and assessment, decision-making (including which strategies to choose, based on possible operational strategies) and movement to the safest place possible, given the circumstances.

Decision-making is coping with uncertainty

The decision-making process induced by these scenarios is influenced by short reaction times, possible life and death situations and a huge economic impact. This means coping with uncertainties. Decisions therefore must be based upon risk analyses and take uncertainties into account. They should continually be updated using actual information for several alternative strategies.

In both the Netherlands and Germany, preparing for large scale floods means preparing for extreme but very unlikely large-scale or local events. Although a prior warning system is available, it is uncertain how much time really exists for an (preventive) evacuation. Also, the economic, social and hazardous effects of carrying out an evacuation when a flood does not occur must be considered. The scenario can be reconstructed afterwards, but this information of the future is unavailable during the decision-making process for evacuation. In hindsight, we may have acted differently.

When time is limited for implementation and execution of precautionary measures in case of a threat of flooding, a possible and attractive measure is to put the highest policymaker, in the hierarchical relation with other stakeholders, directly in charge after detection. He or she will be responsible for starting up the entire crisis organisation, operational planning, communication and involving other relevant stakeholders. Others are responsible for providing input into this process, as well as for their own decision making and execution.

We recognise uncertainties in three phases in crisis management for flooding:

1. Detection and recognition (sense making) after early warning: using forecast models to determine the probability of future extreme water levels. Extreme values should be detected and recognised by experts and accepted by crisis managers and policy makers. The warning time can be up to days, hours or minutes before the start of the disaster (Fig. 7). Detection and recognition is necessary so that other phases can begin.

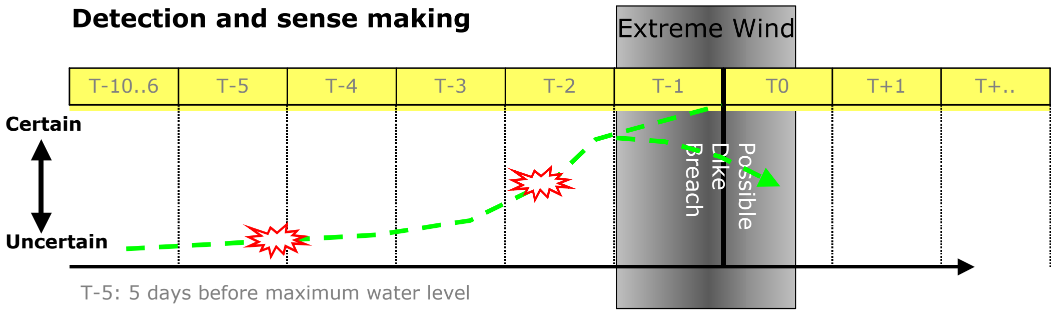

Fig. 7: Detection and recognition; early detection on T-4 and late detection on T-2

2. Organisation and decision-making by leaders and citizens (Fig. 8): Decisions for alternative strategies are based on information and perception of this information. The use of the internet and other media channels is not a monopoly of the government, but is available to everybody. The government and citizens will make decisions based on the information available to them. The effects of these decisions will result in a logistic process affecting everyone. Governmental decisions must take into account the possible reduced availability of infrastructure due to traffic jams spontaneous evacuation or unexpected citizen response. In that case, changing to a different strategy seems plausible but might well be impossible or highly ineffective. Transportation and shifting of emergency services (if available) will also require more time when confronted with congestion. For an effective response, anticipation of possible future effects is necessary.

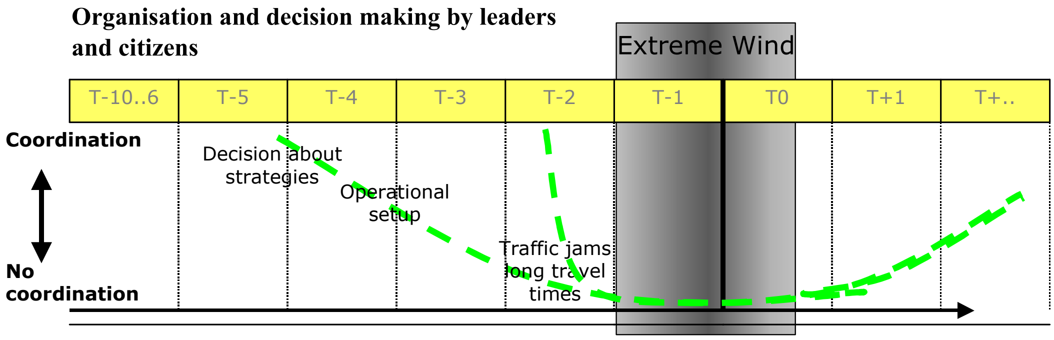

Fig. 8: Organisation and decision making by leaders and citizens after early detection and sense making on T-4 and late detection and sense making on T-2

3. Transit time between locations (Fig. 7): the time needed for evacuation depends on the destination, the available road capacity and the number of evacuees.

Preparation, available infrastructure and risk perception can improve the success of evacuation. This can be seen as a fourth phase, but during a crisis it will be a boundary condition.

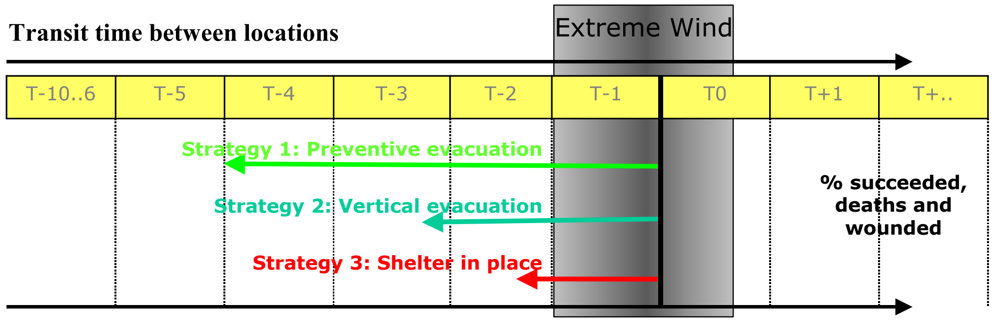

Fig. 9. Transit time between locations: necessary time for each strategy.

Probabilistic approach

It is necessary to obtain knowledge about more advanced strategies, focusing on a combination of different types of evacuation. The primary goal is to save lives; secondary goals are to prevent damage and build resiliency to recover after the crisis. Facilitating self-reliance in the public and encouraging them to move to the safest place possible prior to a flood event helps to achieve these aims.

All of these strategies require operational planning, decision-making and measures such as traffic management – on a national scale – and good communication based on threat assessment. By using different scenarios for planning and exercises, including worst case scenarios and the amount of time available for evacuation, we can prepare for possible future disasters.

Based on a probabilistic approach, a set of classes can be defined that can be prepared for by all stakeholders. This set of classes represents classes of possible scenarios and strategies (and the consequences), including worst cases and several options for response by the public and government. During a crisis, this framework can be used by adding the known circumstances. The most effective response can be made clear and used as a starting point for detailed planning and the start of operations.

A probabilistic approach is not yet very common due to the design (current methods or focus) of crisis management. In most cases, only one scenario is considered and used for emergency planning. To support decision-making, and to be able to choose the most efficient scenario, a framework must be developed and provided that includes these scenarios. This framework must be built using a probabilistic approach with several scenarios (including worst cases) and alternative strategies.

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