EvacuAid: probabilistic evacuation model to determine expected loss of life for different strategies for mass evacuation

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Abstract

Evacuation has the potential to save lives, but could be costly in time, money, and credibility. Evacuation is a possible measure in case of a threat for flooding. Different types of evacuation can be distinguished as preventive evacuation, vertical evacuation to safe havens or shelters or shelter in place. The consequences in terms of loss of life depends on the required time related to the type of evacuation and characteristics of the area and the available time for evacuation. Available literature mainly addresses the possibility for preventive evacuation and how to improve this. Recent literature addresses the need to do research and to develop model to get more insight in different types of evacuation to reduce loss of life in situation in situation with limited available time for preventive evacuation. This paper describes the probabilistic evacuation model "EvacuAid" that determines the expected value and bandwidth for the success and loss of life of evacuation strategies based on four parameters (including taking into account the impact of uncertainties): the available time, behavior of people, the behavior of authorities and the available infrastructure and recourses. EvacuAId is developed to get more insight in the effectiveness of different types of evacuations. The model is used for a case study in the Netherlands. It is shown that for large scale areas vertical evacuation is expected to result in less loss of life then vertical evacuation For smaller areas the critical window of time can be defined when vertical evacuation results in less loss of life then other types of evacuation. Also the consequences of less or more optimal conditions as citizens response, decision making or availability of road infrastructure can be defined.

Keywords

Mass evacuation, flooding, decision making, emergency planning, risk analyses

Introduction

Although preventive measures can reduce the probability of flooding, such measures cannot completely eliminate the risk of flooding. A flood in the Netherlands caused by a breach in the flood defences is a very uncommon event. Flooding, as a natural hazard, can occur in many different scenarios that cannot be planned for in advance.

Evacuation has the potential to save lives (Kolen 2010a), but could be costly in time, money, and credibility (Bourque 2006). Evacuation is a possible measure in case of a threat for flooding. New Orleans showed that people and goods that can be moved might be saved but that not movable goods will be affected by the flood and economic processes will stop (Vrijling 2009). Evacuation has the potential to save lives, but could be costly in time, money, and credibility.

In this study, evacuation is defined as the organisation of and the movement to a (relatively) safe place in case of a threat. This articles focuses on evacuation before the onset large scale flooding. By evacuating, fewer people are (less) exposed to the direct consequences of a disaster, provided that they can leave the area in time. Within a critical time window (between early warnings based on forecasts and the onset of the disaster), it may not be possible to evacuate coastal areas in time, because of the number of inhabitants and the limited road capacity (Jonkman 2007; Kolen B. 2008), other destinations have to be used. People can reduce risk of loss of life by moving to a relatively safe place such as a shelters or safe-havens or even to prepare at home. Different types of evacuation can be distinguished related to the moment of the onset of the disaster and the destinations for evacuees (Kolen 2010a):

- Preventive evacuation: movement of people from an exposed area to a safe location outside this area before the disaster.
- Vertical evacuation: several types of vertical evacuation can be seen:
    - Vertical evacuation to a shelters: the organisation and the movement to high and strong buildings inside the potentially exposed area before the start of the disaster or moment of exposure.
    - Vertical evacuation to a safe haven: the organisation and the movement to elevated and dry area inside the potentially exposed area before the start of the disaster or moment of exposure.
    - Shelter in place: the organisation and the movement to upper levels before the start of the disaster or moment of exposure at the location of the disaster.

After the onset of a disaster, other types of evacuation are 'Rescue' (when rescue services evacuate others) and 'Escape' (evacuation of individuals without help from rescue services). An evacuation strategy is a combination of different types of evacuation.

Flood risk management in The Netherlands

The people in the Netherlands live in a delta, which is largely below sea level. The Netherlands has a long history on flood protection starting in the middle ages (van de Ven 2004). This resulted in a system with the highest safety standards worldwide based on a risk based approach that optimized costs and benefits. A consequence of this successful strategy is the low perception of flood risk of the public and no incentive to prepare mitigating measures (Terpstra 2009). The Delta commission recently advise in 2008 even for a further increase of the safety level by taken into account the increase of welfare since 1960 and the individual and group risk for loss of life (Deltacommissie-2008 2008). The strong focus on prevention in the Netherlands will remain. The National Water Plan (Ministry of Transport 2008) divides policy for Water Safety in three layers: Prevention as most important, Spatial Planning and Emergency management. Preparation for mass evacuation is related to the third layer emergency management. Preparation for mass evacuation is also related to spatial planning because the design of the environment creates the boundary conditions (for example the availability of shelters and capacity of road networks). Because loss of life is one of the parameters if the Dutch risk approach the expected success of preventive evacuation also influences floodrisk and might influence the level of prevention.

The possibility for preventive evacuation increases the available time increases although for some areas it is still impossible to evacuate completely out of the area before the dike breaches as illustrated by the expected value for the success of preventive evacuation in the Netherlands (Maaskant 2009). Literature also shows that preventive evacuation will not always succeed (Barendregt 2005; Jonkman 2007; Wolshon 2006) When the possibility for preventive evacuation is limited other strategies for evacuation might be more attractive to reduce possible loss of life (Haynes 2009; Kolen 2009a) .

Focus on preventive evacuation has to broadened: more alternatives have to be explored

Historically a lot of attention is paid on preventive evacuation and almost no attention of different strategies. Most preparations are made to get as much people out of flood prone areas as can be seen in New Orleans. Before Katrina the cornerstone of hurricane preparedness was preventive evacuation (Wolshon 2006). Experiences with preventive evacuation during Katrina and people who stayed behind and were confronted with a flood resulted in a stronger focus on preventive evacuation. After Katrina it was decided not to use shelters of last resort any more (CNN 2006). Also for the Netherlands most emergency planning documents and exercises focuses strongly on a preventive evacuation as the exercise Waterproef ((TMO) 2009).

The need to take alternative strategies for preventive evacuation into account is addresses in literature based on a comparison of the available time based on early warning and the required time in the Netherlands (Kolen 2009a) and after an analyses of 50 year flash flooding in Australia (Haynes 2009). Haynes also conclude limited research is available '*At the moment, the literature cannot unequivocally support one option over another, in part due to the fact that because evacuation is such a well-established emergency management strategy literature about policy alternatives is relatively thin on the ground. What the literature does show is that neither strategy is without risk and more research is needed to guide decision-making by emergency managers. In the end, emergency managers and the people directly at risk need to be able to assess the relative risks of alternative strategies'*.

Objective of this paper

The objective of this paper is to get more insight in the success of different strategies for mass evacuation and the impact of uncertainties. The success of an evacuation is characterized by the combination of tow parameters

- the amount of people in a certain location at the moment of occurrence of the flood and
- the mortality rate for loss of life this location.

For decision making about mass evacuation next to the success of an evacuation also the possible impact caused by the evacuation is important. This impacts depends on the strategy for evacuation but also if the area will flood or not.

Therefore a literature review has been done for available models to get more insight in the success of evacuation. Based on this literature research the probabilistic model "EvacuAid" is developed and used in a case study in the Netherlands. This paper presents and discusses this probabilistic model for the use for emergency planning and during crisis response.

This paper is part of a PhD research after the possibilities (consequences) for different strategies for mass evacuation in case of large scale flooding. Therefore the relation between response of authorities, citizen's response, the geographical situation, the threat for flooding and role of uncertainties in all these elements is analysed. The results are combined in a (probabilistic) model as input for emergency planning and decision making. The model describes a rational approach for decision making based in a risk (probability multiplied by the consequences) approach taking into account the consequences of uncertainties. The model is also used to normalize evacuation planning using known experience and expert judgement.

Literature review

Conceptual model for evacuation

A society on itself can deal with all kind of disturbances (Rasmussen 1997). Several organizations work (together) during day to day life to achieve common or own goals (Rasmussen 1991). In case disturbances can cause consequences that cannot be controlled or minimized with the normal structures these structures can be changed: crisis management.

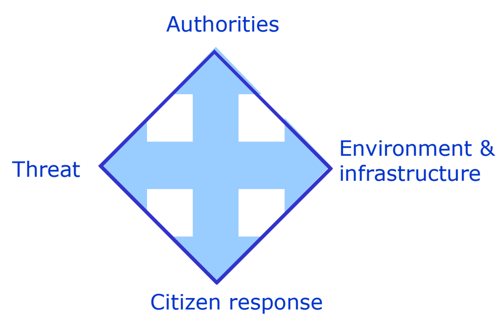

Figure 1: Evacuation related to a society

While preparing for mass evacuation assumptions have to be made to develop scenarios. Literature shows that four elements can be distinguished (after (Gwynne 2002)): 1) behaviour of people 2) implemented decisions by authorities, 3) adaptive use of infrastructure and 4) the threat (Figure 1). By combining these four elements in a graph the relation between these parameters becomes clear. In case of a threat for flooding citizens as well as authorities will act on the perception of the threat and consequences of possible measures. Citizens will act rational (Helsloot 2004; Perry 2003; Quarantelli 1999) and evacuate themselves or prepare their house for a flood based on several sources of information as internet, radio and television, (nowadays more and more) social media and information of the authorities. The response of the public can reduce the capacity of infrastructure because of inefficient use as could be seen in Houston during Rita (Security 2006) or during a traffic jam on a normal working day. Authorities will inform, warn or alarm the public about the threat. Authorities will also implement measures to support evacuation as the contra flow system in New Orleans (LA-DOTD 2009) and National Traffic Management in the Netherlands (Wegh 2008). By implementing measures the environment (including infrastructure) can be adapted to create more capacity for mass evacuation.

The result of an evacuation is determined after comparing the required time to execute a evacuation strategy and the available time (Barendregt 2005; Jonkman 2007; van Zuilekom 2005). Evacuation models can be used to describe the outcome of evacuation scenarios. These models take into account the local characteristics of the system that is affected by evacuation. After the location is known of people where they get flooded loss of life can be determined.

Scenario and models for evacuation

For preparation for evacuation traffic models are used to calculate the required time. Evacuation models can be divided in three types of models (Petruccelli 2003):

- *Dissipation rate models,* use an aggregate state formula to estimate the evacuation time based on the size of an area and its population density.
- *Manual capacity models,* use techniques to allocate the population on the (road) network while taking the road capacity into account.
- *Micro simulation models,* simulate the evacuation process on the network on a micro (individual) level.

An overview of some available models is given in Table 1. This overview is based on an inventarisation made in 2003 (Frieser 2003) and completed up to 2010.

Name	Category	Reference
Hans & Sell	Dissipation rate model	(Bellamy 1986)
EMBLEM (Empirically Based Large-scale Evacuation estimate Method)	Manual capacity model	(04 2003)
Traffic Module (static module)	Dissipation rate models	(Barendregt and Van Zuilekom 2002; van Zuilekom 2005)
Traffic Module (dynamic module)	Manual capacity model	(Barendregt and Van Zuilekom 2002; van Zuilekom 2005)
OREMS (Oak Ridge Method Evacuation Modelling System)	Micro simulation model	(04 2003)
FIRESCAP	Micro simulation model	(Feinberg 1997)
SPOEL (serious gaming for mass evacuation)	Manual capacity model	(Kolen 2009b)
DSS ESCAPE	Micro simulation model	(Windhouwer 2004)
EVAQ	Manual capacity model to Micro simulation model	(Pel 2008)
LEM (contains SPOEL and Statis traffic module and an integration of these in a planning module	Dissipation rate model and Manual capacity model	(Kolen 2010b)

Table 1: Evacuation models

All of these models can be used to develop a databank with several scenario that describe the outcome of probable scenario's. The probability for each scenario is not known but depends on the preparation in advance. Therefore the contribution of measures to a more probable worst or best case has to be estimated by experts. Available evacuation scenarios of the Netherlands indicates that the required time varies from hours for small areas to many days for coastal regions (Barendregt 2005; Jonkman 2007; Kolen 2008; Maaskant 2009). All kind of events as car-accidents, wrong route choices will happen during such an evacuation. For decision making for evacuation, and preparing for mass evacuation insight is required in the difference between several strategies (Haynes 2009) as well as estimations of the required time as was shown during the exercise Waterproef in the Netherlands (Kolen 2009c). Detailed traffic module is only required is a strategy is chosen and risks for disturbances have to be reduced. While preparing the shortage of available means has to be considered that limits the possibility to take measures (Ministry of the Interior and Kingdom Relations 2008). To develop a dataset of scenarios for a probabilistic evacuation model therefore requires a 'Manual capacity model' or a 'Dissipation rate model'.

Loss of life after a flood

None of these evacuation models also calculates the expected loss of life but separate models exist and are applies in practice. Loss of life in case of large scale flooding is related to the amount of people in area at the moment of onset of the flood can be calculated taking into account local characteristics and the location of people. Jonkman's research relates functions of loss of life to the total amount of people that are in the flood prone area at the moment of onset of a flood (Jonkman 2007). This approach is used for Water Safety Policy in the Netherlands. Literature shows that probability for loss of life is related to the local situation (Jonkman 2009; Kok 2007; Sheldon D. Drobota 2007). No literature is known that has defined function for loss of life related to several types of destinations (as in a car, in a shelter or on a roof of a house) although literature shows clearly the loss of life is related to the location (Haynes 2009; Jonkman 2005; Jonkman 2009).

Conclusion of literature review

A probabilistic evacuation model that determines an expected value and bandwidth of the success (amount of evacuees that reach their location and loss of life) based on 1) behaviour of people 2) implemented decisions by authorities, 3) adaptive use of infrastructure and 4) the threat and the uncertainty of them is not known yet. Existing models can be used to develop various scenarios for evacuation that represents classes of all possible scenarios. The probability of these scenarios can be determined by knowledge of uncertainties (as of forecasting) and expert opinion (Maaskant 2009) using event trees (as also in (Jonkman 2007)). Although no literature is available that related the destination and water depth to a function of loss of life an rough estimation can be made based on experience as Katrina. Therefore all the basic material is available to develop a probabilistic model for evacuation to determine the success of different evacuation strategies as a function of time.

Method: EvacuAid

EvacuAid (Figure 2) determines the success different strategies of evacuation (as preventive evacuation, vertical evacuation) using a probabilistic approach. EvacuAid version 1.0 estimates the success of an evacuation before the evacuation has started, therefore the model can be used for emergency planning but also for top strategic decision making in the period between detection of a threat and before capacity of the environment is reduced by mass response (as traffic jams). The model can be add with scenario's that describe an ongoing evacuation but the use of these knowledge during decision making is limited because effectiveness of measures is reduced because of command and control structures, services and resources are already in use and increased travel time (Kolen 2010a).

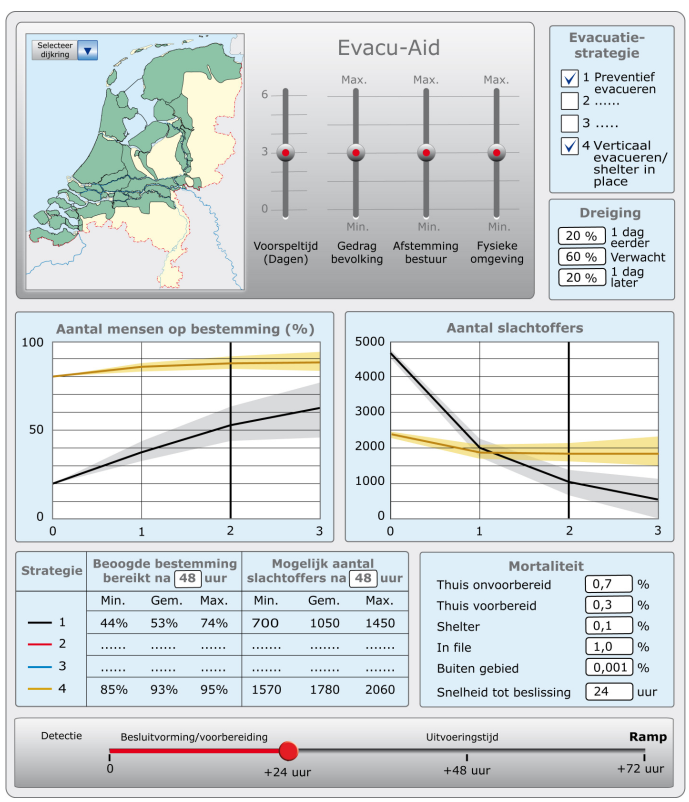

Figure 2: Interface EvacuAid

Event tree and probability

Evacuaid is based on an event tree (Figure 3) that contains scenarios that represent all possible (known) situations and a probability of these scenarios. The contribution for these scenario by the outcome can be influenced by changing the parameters:

1) Citizens response on a scale of 1 (worst case) to 5 (best case)
2) Response of authorities on a scale of 1 (worst case) to 5 (best case)
3) Adaptive use of the environment and infrastructure on a scale of 1 (worst case) to 5 (best case)
4) Available time (expected value per day including the probability for a day more or less) and including a reduction time for decision making.
5) Percentage of loss of life
6) Flooding factor as a correction that not the entire area (dike ring) might flood

Each scenario in the database contributes to the expected success of evacuation. Because no literature of research is available about this contribution it is based on expert judgement with the Delphi method. Experts on the field of forecasting, risk analyses, evacuation, citizen response and emergency management participated in this Delphi sessions. This resulted in estimated of the probability for (see appendix A):

- Relevance of scenarios to parameters 1,2 and 3 to
- Contribution of each scenario for parameter 1, 2 and 3 related to the scale 1 to 5
- Relevance of parameter 1, 2 and 3 related to each other depending the scale of 1 to 5

The relation between the scenarios and the event tree was validated in interviews with Dutch practioners. The results of EvacuAid were also validated with the latest insights of expected values for loss of life determined in Floor Risk Analyses.

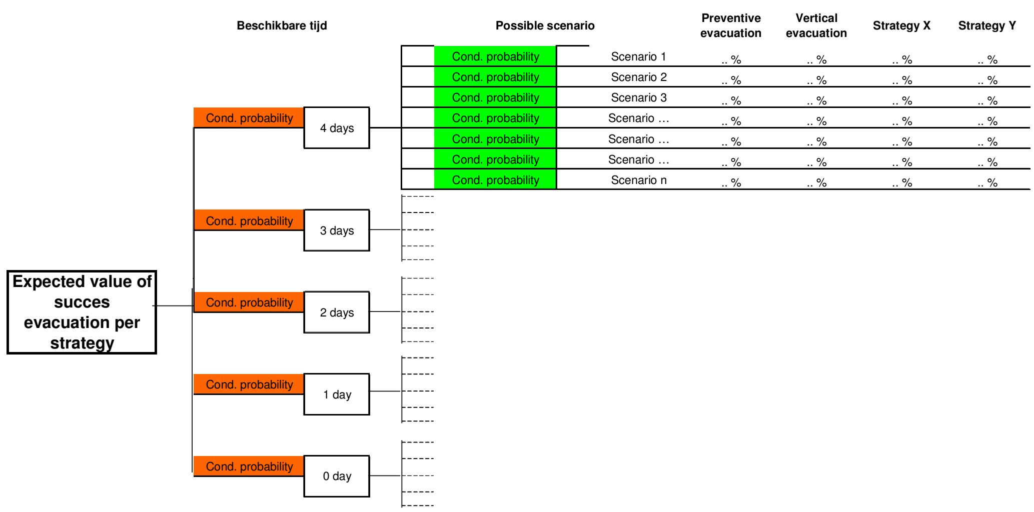

Figure 3: Event tree

Database of scenarios

The traffic modules is used to developed the necessary scenarios for the Netherlands for multiple reasons. The model offers flexibility to vary the parameters 'capacity of road network', capacity of exit points', 'the number of evacuees', 'load of a car', 'departure curve' and calculation time is limited. Also the traffic module is a standard for evacuation planning and risk analyses in the Netherlands therefore many scenario are available as a reference situation (Friso 2008; Kolen 2008). The scenarios developed for the Dutch national capability analyses by the Ministry of interior (which also have been used in a risk analyses for optimal safety levels for prevention for flooding (Maaskant 2009)) have been used as a reference situation. These scenarios are described in (Friso 2009; Kolen 2009a) and the parameters of the static model are based on a valiadiation using a dynamic model (Meinen 2006). Based on an uncertainty analyses extra scenarios have been defined that varies:

Parameter	Reference	Extra scenarios	
Departure curve	Total departure in 16 hours	Total departure in 8 hours	
Average load of traffic	2.19 people/car (based on inhabitants / number of cars)	3 people/car	1 people/car
Average travel speed	20 km / hour	40 km / hour	2 km / hour
Available road capacity	All roads available	breakdown of high way	breakdown of provincial way
Capacity of outflow of an area	0.2	0.3	0.1

Table 2: Database of evacuation scenarios

For each scenario the outcome is defined for worst and best case scenarios (based on available algorithms in the traffic module). Three possible outcomes of evacuation have been add to the event tree for each strategy for evacuation:

- Worst case scenario; evacuees leave the area equally divided over all exits
- Worst case scenario; evacuees leave the threatened area using the nearest exit.
- Best case scenario; evacuees leave the area taking into account the capacity of each exit point.

The traffic model also gives a user defined option that can be used to connect origin, route and destination.

Strategies for evacuation combining different types of evacuation

Strategies for evacuation are based on possible combination of different types of evacuation. EvacuAid distinguishes four different strategies, the most extreme are:

- Maximum preventive evacuation: 80% of the people will evacuate preventive and 20% refuses and evacuate vertical.
- Maximum Vertical evacuation 80% of the people will evacuate vertical and 20% refuses and evacuate preventive.

The other two strategies are in between and not further discussed in this paper (during implementation of scenarios in the database the user has to define possible scenarios.

For those who evacuate vertical it is assumed that they are reach their destination directly. In reality this will take some time therefore the results of EvacuAid give realistic figures after more then 16 hours (equal to the departure curve). After this period it is assumed that all those who evacuate vertical have reached the aimed destination. No literature or Dutch experience is available about the number of people that will evacuate to a certain destination as a shelter, upper floor and how well they are prepared. Based on expert opinion it is estimated that 50% of those who evacuate vertical will go to a shelter, 40% will shelter in place and is somehow prepared and 10% will shelter in place while not prepared.

Loss of life

Already we concluded that the mortality rate (percent of people that will loss their life) is related to the local circumstances. To compare loss of life for different strategies for evacuation different locations are defined. For each a mortality rate has to be defined. Because no detailed functions exist yet for each destination. EvacuAid uses an average mortality rate for each destination that can be varied by the (expert)user. Based on the information of New Orleans and expert opinion of Dutch emergency managers the following classes of locations and destinations are distinguished including an (user defined) estimated mortality rate for the Dutch situation:

- 0,001 % mortality rate for those who leave the area preventive (car accidents for example)
- 0,1% mortality rate for those who evacuate vertical to a shelter or safe haven
- 0,3% mortality rate for those who evacuate vertical to upper floors and have been prepared
- 0,7% mortality rate for those who evacuate vertical to upper floors and have not been prepared
- 1% mortality rate who are not in above locations (for example in a car when they get hit)

These mortality estimated the total number of people who loss their life because of a flood event. For example for those who evacuate vertical the percentage of people who loss of life also contains the success of the rescue operation.

Case study for dike ring areas in the Netherlands

To get more insight in the possibilities for preventive and vertical evacuation as a function of time and the influence of the parameters citizens response, response of authorities and environment and infrastructure EvauAid has been applied for three dikering areas in the Netherlands:

- South Holland (dikering 14); One of the largest dike ring areas along the coast with a high economic value. The impossibilibity for preventive evacuation is often addressed in literature (Barendregt 2005; Jonkman 2007; Kolen 2009a).
- Friesland en Groningen (dikering 6); Large dike ring area along the coast in the Netherlands but less populated than south Holland.
- Rivieren (dijkring 43); Large dikering area in a river area.

While evacuating these area it is taken into account that the cause of the evacuation (threat for flooding) also threatens surrounding areas that will also evacuate (and use the limited available road capacity and resources). Further it is taken into account for the available time a probably of 15% to be a day less or more.

Figure 4 presents the expected amount of people and loss of life for preventive and vertical evacuation as a function of time. The dotted lines represent a best case situation (parameters citizens response, response of authorities and environment and infrastructure are all maximum, class 5 on a class of 1 to 5). The other line is an average situation (all parameters on class 3).

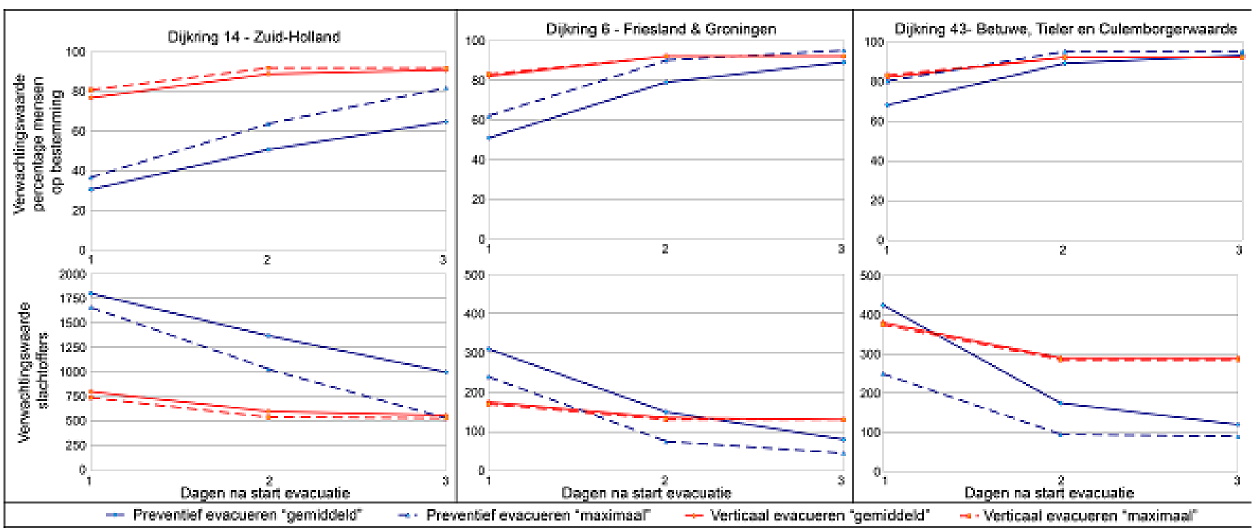

Figure 4: Verwachtingswaarde voor resultaat evacuatie bij preventieve en verticale evacuatie

The results show clearly that a preventive evacuation can cause more loss of life then a vertical evacuation. In case of limited time a vertical evacuation results in less loss of life in all situations. Less people get hit while evacuating in their car (the destination with the highest mortality rate). The moment that the dotted lines crosses the other lines in the lowest figures (turning point) a vertical evacuation results in more loss of life then a preventive evacuation. The moment of occurrence of this turning point depends on

- Characteristics of the dike ring
- Citizen response, response of authorities and capacity of the environment and infrastructure.

The required time for each strategy can be related with the possible available time based on forecasts, early warning and interpretation of them. If the window of available time might contains the turning point decision makers and emergency planners have to deal with different possible strategies. This will result in an extra dilemma (which strategy for evacuation in addition to the moment of deciding) for decision makers.

For coastal areas in the Netherlands the available time is limited (hours to a few days in a best case situation), for river areas more time is available because forecasts are more reliable. For river areas the decision making for evacuation will also be influence by the availability is visuals of flooded areas in Germany, Belgium and France. For coastal areas this information is not available although there will be clear signals (but no visuals) for an extreme storm. The probability for a storm will not be equal to the (expected to be far lower) probability for flooding. The warning procedure in France in case of storm surge Xynthia showed this. A clear warning was given for storm, the known possibility for flooding was not addressed in warnings resulting in preparation of the people for storm (close all windows with electric rolling shutters) that limited their resilience in case of a flood (people were locked in their bungalows because electricity broke down).

Discussion

EvacuAid is developed for emergency planning and for use during top strategic decision making when different strategies for evacuations are evaluated and compared with other parameters (as the probability for the disiaster, the economical consequences etc). Top strategic decision making is the decision making process that creates the boundary conditions to execute an evacuation and multi party, decentralized, decision making. Top strategic decision making changes the system for a day to day to a period of evacuation. Top strategic decision making is only effective in the period after recognition of a threat and the moment that response of citizens or authorities starts and central command and control has no effectiveness any more (Kolen B. 2010). Therefore the model EvacuAid is relevant to apply in situations where the window of time for travel is more important than the window of time for departure.

Evacuation means dealing with uncertainties and lack of data. The results of EvacuAid are based on the scenarios in the database and the probability given to them. The relevance of scenarios depends on several parameters and will be based on expert judgement. The model EvacuAid makes it possible to take expert judgement and the knowledge of uncertainty into account to determine the expected success of evacuation. In a situation as the Netherlands with a very high safety level mass evacuation for flooding is a unique event. Even in areas that face a mass evacuation every five years (for example New Orleans) there will be a lack of data. After each evacuation procedures will be updated, but also public perception will change. This means the next evacuation will take place in other (uncertain) conditions for 1) citizens response 2) response of authorities and 3) environment and infrastructure. During Hurricane Gustav many people left New Orleans with the consequences of Hurricane Katrina a couple years ago fresh in mind. During Katrina less people left the area although they had experience with evacuation a year ago (hurricane Ivan that did not cause a flood) and also with flooding after Hurricane Betsy in 1965 (Jonkman 2009). During Ivan the contra flow system was tested, for shown bottlenecks measures were put in place (Wolshon 2006). After Katrina is was chosen not to open shelters of last resort any more (CNN 2006).
Scenario and probabilities of them have to be reconsidered over time after experience with evacuation. In case of a crisis the evacuation expert (using EvacuAid) has to estimate the actual conditions of the parameters and use them as a reference for decision making and to evaluate measures.

Probabilities and scenarios for evacuation have to be based on the local situation. EvacuAid can be applies worldwide but implementation with scenarios and probabilities is necessary. The current probabilities are estimated by a certain group of experts. To improve the relevance for emergency planning and decision making all users have to agree on the basis. Therefore it can be questioned is a normative approach describing how scenarios are used and how measures or event contribute to the success of evacuation is important. A normative approach could create the conditions that realistic emergency planning of multiple organizations is based on a common decision tree that can be executed.

Conclusions and recommendations

The probabilistic model 'EvacuAid' determines the success (expected people that arrive at a certain location and loss of life) of different strategies for evacuation as preventive evacuation or vertical evacuation. EvacuAid is based on several possible scenarios that all contribute to the success of evacuation. The probability of each scenario can be influenced by 1) the available time 2) citizens response 3) response of authorities and 4) capacity of environment and infrastructure. EvacuAid can be used for emergency planning and top strategic decision making for mass evacuation

Because EvacuAid is a probabilistic model it can be used to evaluate measures that improve forecasting, citizen response, response of authorities and to improve the use of the environment and infrastructure for different strategies for evacuation.

More insight is needed in the loss of life for different location inside a flooded area. It is recommended that the probabilities and scenarios inside the model are based on a accepted picture by experts (the uncertainty of experts can also be taken into account). Therefore a validation of the current model in the Netherlands is advised by experts. Because the (worldwide) lack of experience and the need for preparation it also recommended that a normative approach will be developed for evacuation planning based on realistic scenarios and expert opinion. This normative approach mainly described the relation between organisation.

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Appendix A

Table: Relevance of scenarios to parameters 1,2 and 3 to and contribution of each scenario for parameter 1, 2 and 3 related to the scale 1 to 5

		Citizen response					**Response of authorities**					**Environment and infrastructure**				
	Value	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
reference		0.25	0.36	0.48	0.39	0.30	0.25	0.39	0.53	0.41	0.30	0.20	0.33	0.45	0.33	0.20
departure curve	departure in 8 hours	0.15	0.11	0.08	0.09	0.10	0.15	0.11	0.08	0.14	0.20					
Average load of traffic	3 persons / car	0.25	0.16	0.08	0.04	0.00	0.25	0.18	0.10	0.05	0.00					
	1 persons / car	0.00	0.04	0.08	0.14	0.20	0.00	0.05	0.10	0.18	0.25					
Avarage travel speed	40 km / hour	0.25	0.16	0.08	0.04	0.00						0.35	0.23	0.10	0.05	0.00
	2 km / hour	0.00	0.04	0.08	0.14	0.20						0.00	0.05	0.10	0.20	0.30
capacity of outflow of an area	factor 0.3 (+ 50%)						0.35	0.23	0.10	0.05	0.00	0.25	0.18	0.10	0.05	0.00
	factor 0.1 (-50%)						0.00	0.05	0.10	0.18	0.25	0.00	0.05	0.10	0.15	0.20
Average road capacity	breakdown a a highway	0.05	0.06	0.08	0.09	0.10						0.10	0.09	0.08	0.11	0.15
	breakdown a a regionalway	0.05	0.06	0.08	0.09	0.10						0.10	0.09	0.08	0.11	0.15

Table: ·Relevance of parameter 1, 2 and 3 related to each other depending the scale of 1 to 5

Parameter			**Conditional probability**			**Parameter**			**Conditional probability**			**Parameter**			**Conditional probability**		
Citizens response	Resonse of authorities	environment and infrastructure	Citizens response	Resonse of authorities	environment and infrastructure	Citizens response	Resonse of authorities	environment and infrastructure	Citizens response	Resonse of authorities	environment and infrastructure	Citizens response	Resonse of authorities	environment and infrastructure	Citizens response	Resonse of authorities	environment and infrastructure
Max	Max	Max	0.5	0.25	0.25	Ave	Max	Max	0.3	0.4	0.3	Min	Max	Max	0.5	0.25	0.25
Max	Max	Ave	0.4	0.2	0.4	Ave	Max	Ave	0.3	0.4	0.3	Min	Max	Ave	0.4	0.3	0.3
Max	Max	Min	0.4	0.2	0.4	Ave	Max	Min	0.3	0.4	0.3	Min	Max	Min	0.4	0.3	0.3
Max	Ave	Max	0.4	0.2	0.4	Ave	Ave	Max	0.3	0.2	0.5	Min	Ave	Max	0.4	0.3	0.3
Max	Ave	Ave	0.6	0.2	0.2	Ave	Ave	Ave	0.33	0.33	0.33	Min	Ave	Ave	0.6	0.2	0.2
Max	Ave	Min	0.4	0.3	0.3	Ave	Ave	Min	0.3	0.2	0.5	Min	Ave	Min	0.4	0.2	0.4
Max	Min	Max	0.4	0.3	0.3	Ave	Min	Max	0.3	0.4	0.3	Min	Min	Max	0.4	0.2	0.4
Max	Min	Ave	0.4	0.3	0.3	Ave	Min	Ave	0.3	0.4	0.3	Min	Min	Ave	0.4	0.2	0.4
Max	Min	Min	0.5	0.25	0.25	Ave	Min	Min	0.3	0.4	0.3	Min	Min	Min	0.5	0.25	0.25