Decision Support System Emergency Planning, Creating Evacuation Strategies in the Event of Flooding

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ABSTRACT

The Decision Support System (DSS) Emergency Planning is designed for use in the event of sea or river flooding. It makes accessible all the information related to the decision whether to evacuate an area. An important factor in this decision is the time required for the evacuation. The model used by the DSS Emergency Planning system to estimate the time required employs a strategy that prevents congestion on the road network in the area at risk. The use of the DSS Emergency Planning system during the proactive and prevention phases enables disaster containment organisations to prepare better for a flood situation. Moreover, all relevant information is saved and is therefore available for the post-disaster evaluation. The DSS Emergency Planning system can play a significant role in ensuring that the evacuation of an area at risk goes according to plan. In the future the DSS Emergency Planning system can also be used to evacuate people in the event of a nuclear, natural fire or extreme weather disaster.

KEY WORDS

Evacuation, flooding, traffic flows, decision support, decision-making, emergency planning

INTRODUCTION

It is now some 50 years since a major North Sea flood cost so many lives in the Netherlands (Zeeland), Belgium (Flanders) and England (Essex). In the years following 1953, government policy aimed to prevent future floods. The solution was sought in coastal defences and dike reinforcements and in the Netherlands this policy led ultimately to the Delta works in Zeeland. In recent years the Dutch attitude to flooding has changed; for various reasons, such as a rise in sea level due to climate change and the increased frequency of extreme weather situations, it is no longer believed that a flood disaster can be prevented.

With this in mind, the Provinces of Zeeland, West and East Flanders and the English county of Essex decided to start ESCAPE, a European project focusing on the actions that must be taken when a dike is breached or is in danger of being breached. It involves aspects such as spatial planning, risk management strategies and disaster planning. The driving forces behind ESCAPE want the project to increase public awareness of the potential dangers.

One of the four ESCAPE project themes is the development of a 'Decision Support System' for use in situations where a flood disaster is likely. This paper explains the DSS Emergency Planning system and discusses how it can be used to manage and prevent disasters.

Decision support system objectives

The DSS Emergency Planning system answers the question whether an evacuation can be carried out safely within the available time. DSS gives those who must take this decision objective support by providing an overview of the information relevant to the decision and the implementation of the evacuation. Vital to the system's advice is whether sufficient time is available to get all the residents to safety. Based on data regarding the demographics and infrastructure, DSS calculates the time required using a specially designed evacuation model. This model selects a strategy that will minimise the duration of the evacuation while avoiding congestion on the evacuation routes. When certain routes cease to be available during the evacuation, DSS suggests alternatives and indicates their impact on the duration of the evacuation. Should it appear that the available time is too short for all the residents to leave the affected area, DSS gives advice as to which residents must be given shelter and which residents can still leave the area.

instrument when the crisis situation is being evaluated. It can be used to assess whether the right decisions were made given the available information.

STATIC AND DYNAMIC INFORMATION

GIS data (static information)

In order to establish how long the evacuation will take, the DSS Emergency Planning system must have certain information about the residential areas, the number of residents in an area, the extent of their capacity to take independent action and the characteristics (capacity and speed per carriageway) of the road network. In the current version of the system, these data must be locally available. In future, it will be possible to look up the data on intranet or the internet.

Information about the affected area beyond this minimum requirement can also be entered. While this won't influence the evacuation times, it will give the decision-makers greater insight into the affected area. Such information may include the presence of, for example, industries, power stations and hospitals. The evacuation and enclosure of complexes of this nature is as yet outside the scope of the DSS Emergency Planning system.

All static information is presented in a user-friendly manner by the system and is easy to select and apply.

Weather conditions and water levels (dynamic information)

To arrive at a good recommendation, the system must obtain information during the crisis situation about the extent of the area at risk, the weather conditions, the available road network and the anticipated time of flooding. This information is entered into DSS, as far as possible, automatically. Manual entry is simplified by the system's user-friendly interface.

Information about the area at risk and the anticipated flood time is acquired using the *Rijkswaterstaat's* HIS system that provides the DSS Emergency Planning system with a prediction of the time at which the critical water level will be exceeded and a prediction of the flooded area. In DSS, the user can draw on this information to establish the areas in need of evacuation. Agreements have been made with the Royal Netherlands Meteorological Institute (KNMI) for the provision of information about weather conditions during de evacuation. The KNMI has its own calamity team and this can be consulted at moments of crisis.

EVACUATION MODULE

An organised evacuation

The evacuation model provides an estimate of the time required for the evacuation from the moment that the first people get into their cars to leave the area at risk to the moment when the last resident has reached safety outside the area. This estimate is based on the assumption that the evacuation will proceed in an organised manner. This involves the residents getting individual advice about their departure times and the route to follow to one of the area exits. This estimate also depends on a number of escape points (exits) from which the residents can leave the area. Figure 2 shows an imaginary area with a number of escape points.

evacuation time per exit is kept as similar as possible and the total capacity of the exits are used for as long as possible. In this option, the rule still applies that all residents in the same zone use just one route throughout the entire evacuation. We first estimate the optimum number of cars per exit, such that the estimated evacuation time per exit will be equal if the capacity of the exit road is used completely the whole time during the evacuation. Since most of the time the exit road is a bottleneck, we think that this is a reasonable estimate. For the assignment from zones to exits, we use heuristic methods that try to minimise the total travel time (under free flowing conditions), under the constraint of the estimated optimum number of cars per exit. For this, we used a "greedy" heuristic that first assigns the zones with the highest amount of cars by giving them the best available exit in terms of free flow travel times. Afterwards, we used a simple local optimisation algorithm by trying for all possible pairs and trio's of zones if a permutation of the assigned exits gives a better result. The second route assignment strategy where the exits are used relatively to their capacities, leads to a 26 % shorter evacuation time for the Voorne-Putten area according to our model.

Departure times

To guarantee free flow on the network, it is necessary that no single route be allocated a greater load than the capacity of its bottleneck, the most limiting link in the route. This capacity is used to work out the maximum flow that may exit the zones over time for all routes in the evacuation. The residents' departure times are also calculated taking account of the travel time to the bottleneck and the fact that extra capacity becomes available as soon as all residents have left a zone (Klunder, 2004).

The algorithm developed for this performs the following steps: For each link, it is first counted how many evacuation routes (from a zone to an exit) use this link. This number divides the capacity of this link and hence equally assigned to each zone that uses it (an alternative assignment where some zones or routes have priority to others is theoretically possible). For each zone, the minimum available capacity on its route is determined. This defines a feasible flow for each zone such that the sum of the flows will not exceed capacities on any link. The capacities are then subtracted with these flows and the procedure of assigning flows to zones is repeated iteratively with the remaining capacities, such that finally all available capacity of the evacuation routes is used. Since all vehicles are assumed to drive with the same free flow speed, it is easily calculated backwards what the departure time interval is for each zone to arrive within a given time-interval at the exit. Also, all vehicles departed within these (different) departure intervals from all zones will arrive in the same time interval at common links, since their route from this link to the exit is equal and they arrive within the same time interval. This justifies the capacity assignment per link. This procedure is repeated for ascending arrival times with a given interval time. The current evacuation module is implemented with an interval time of 5 minutes. Shorter interval times of for example 1 minute did not cause computational problems, but also did not lead to much shorter evacuation times, while in practice it would be much harder to regulate.

The model is then able to establish the traffic intensities across the entire evacuation network during the evacuation, as well as the intensities of the flow at the exits and the total evacuation time. The seeds of traffic problems in the evacuation network can be localised using the intensity/capacity ratios, and extra supervision can be allocated where necessary. A traditional traffic model cannot adopt this approach and, to the best of the authors' knowledge, no similar model has been developed.

The evacuation of those requiring help

Those members of the population who do not have their own car and cannot get a lift with someone in their immediate environment will be evacuated with buses. Based on a given number of buses, a schedule is made whereby each bus rides back and forth between the (various) zones and the area exit. Free-flow traffic conditions are assumed for this operation. The number of buses deployed to evacuate those requiring help can be varied in the evacuation module, so that the effect on the evacuation times can be explored.

Shelter in the area

If there appears not to be enough time available for everyone who does have a car to leave the area before the flooding occurs, some of the population will have to be accommodated in safe centres in the area. These shelters must be identified in advance and are used as input for the evacuation module. A shelter is taken to mean a centre where a group of people can survive on their own for a certain period. These shelters should therefore be equipped with a kitchen, sanitary facilities and a telephone line; they should be accessible by air. All other buildings not fitted with these facilities are suitable only as emergency refuges.

The evacuation module establishes how much of the population can leave the area in time. The remainder of the population is directed to shelters. The assignment to shelters is performed by an equivalent heuristic approach as the assignment of exits with a "greedy" heuristic algorithm and post-optimisation for different permutations, shelter capacity

evacuation time must be anticipated. In certain areas in Australia roads have actually been raised to prevent this happening.

As well as identifying the evacuation routes, DSS can also assess whether the available shelters in the area offer sufficient capacity and are located in the right places. Finally, DSS has a role to play in the prevention phase, helping to convince residents of the value of an organised evacuation and showing them the evacuation routes that will be used in the event of flooding.

The outcome of using DSS in these ways is that a scenario is prepared for each area by which everyone will reach safety. Moreover, agreements are made with all parties about tasks and responsibilities.

Preparation and Response phase: quality and speed of decision-making

In this phase the DSS Emergency Planning system can respond well to the ongoing situation, which has a positive influence on the quality and speed of decision-making. In the first few hours of an impending situation, in particular, DSS can play an important role.

As soon as a (dike ring) area appears to be at risk, the system can be used to call up a scenario prepared earlier. Next, the current conditions, including weather conditions, and the changing high-water situation can be entered. These data may lead to one of the following situations:

1. Not all evacuation routes are available
2. Sufficient time is available
3. The available time is too short for a full evacuation of the area.

Not all evacuation routes are available

One or more of the evacuation routes may not be available as a result of roadworks, an incident or flooding. In that case the DSS Emergency Planning system can set the capacity for the route concerned at ‘0’ and start identifying new evacuation routes. This can lead to longer evacuation times, which, in turn, could necessitate the use of shelters. In this way, the DSS Emergency Planning system helps afford clarity about which routes and shelters will be used, a necessity in a crisis situation when communicating with residents and emergency services.

Sufficient time is available

When it appears that sufficient time is available, it will be decided to act in accordance with the pre-agreed strategy.

(for example a building), enough time space between alarm and the actual occurrence of the disaster and a preventive evacuation is appropriate.

CONCLUSIONS

The DSS Emergency Planning system is a decision-support system for use in a potential flood situation of disastrous proportions. It is a powerful instrument that organisations involved in preventing, limiting and containing a flood can use to limit the number of casualties. It makes accessible all information relevant to the decision whether to evacuate an area. The DSS can be used during the proactive, prevention and response phases of the safety chain, playing a valuable role in the drawing up of disaster containment plans and the implementation of an organised evacuation. It provides insight into the evacuation routes that should be used, the shelters, the activities that must be carried out and their duration in the various phases of an organised evacuation. Finally, the DSS Emergency Planning system can also be used when residents are being informed as a visual aid to clarify why an organised evacuation is essential; this increases public support for an organised evacuation and keeps the number of casualties to a minimum.

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