A Decision Support System for Preventive Evacuation of People

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Abstract

As a densely populated country in a delta the Netherlands have to be very considered about flooding risks. Up to 65% of its surface is threatened by either sea or rivers. The Dutch government has started a research project 'Floris' (Flood Risk and Safety in the Netherlands) to calculate the risks of about half of the 53 dike-ring areas of The Netherlands. This project has four tracks: (1) determining the probability of flooding risks of dike-rings areas; (2) the reliability of hydraulic structures; (3) the consequences of flooding and (4) coping with uncertainties.

As part of the third track, the consequences of flooding, the Ministry of Transport, Public Works and Water Management has asked the University of Twente to develop a Decision Support System for analyzing the process of preventive evacuation of people and cattle from a dike-ring area.

This Support System, named Evacuation Calculator (EC), determines the results of several kinds of traffic management in terms of evacuation progress in time and traffic load. The EC makes a distinction between four types of traffic management scenarios: (1) reference; (2) nearest exit; (3) traffic management; (4) out-flow areas. The scenarios one and two represent a situation where no traffic management or limited traffic management is present. Scenario three (traffic management) calculates an optimal traffic management (given the model assumptions). Within the fourth scenario the user has the freedom to adjust the scenarios by (re)defining out-flow areas. In this way the user has the possibility to

adapt to local possibilities and restraints. The limited data need and efficient algorithms in the EC make it possible to model large-scale problems.

Targets in the EC development were twofold: (1) a safe estimate of the evacuation time and (2) to support the development of an evacuation planning. These targets are met by the development of scenarios with specific and well defined objectives. Optimization methods were developed to solve the problems and meet the objectives.

The classical framework of transport planning is used as a basis, but with extensions:

- Trip generation: a broad range of traffic categories are defined. For each category has there own departure rate in time.
- Trip distribution: the core of the EC. The objectives of the scenarios are determining the distribution. The evacuation time is calculated.
- Traffic assignment: visualization of the traffic flows.

The paper will describe the structure of the EC, its objective functions and problem solving techniques. Furthermore a case study of dike-ring Flevoland is presented.

1 Introduction

Water plays a key role in the safety of the Netherlands. Up to 65% of its area, an area in which many of the economic activities take place, is threatened by either sea or rivers. It is a condition that needs permanent attention. Moreover, the country has to cope with serious consequences of environmental changes. The climate is changing as a result of pollution and use of fossil energy. Temperatures are expected to go up, rainfall will increase in intensity and frequency, and eventually sea level will rise. At the same time the soil will sink because of gas and salt extraction. All these factors together make it more difficult to protect the Netherlands against flooding, despite dikes and hydraulic structures.

In view of these problems the Dutch government has started the research project 'Floris' (Flood Risk and Safety in the Netherlands). This project has four tracks: (1) determining the probability of flood risks; (2) the reliability of hydraulic structures; (3) the consequences of flooding, and (4) coping with uncertainties. As part of the third track, the consequences of flooding, the Dutch Ministry of Transport, Public Works and Water Management has asked the Centre for Transport Studies of the University of Twente to develop a method for describing and analyzing the process of preventive evacuation of people and cattle from a dike-ring area. The method has been implemented in a Decision Support System (DSS) called the Evacuation Calculator. Primarily, the DSS will be used for an ex ante evaluation of the process of preventive evacuation for some 26 of the 53 dike-rings[1] of the Netherlands.

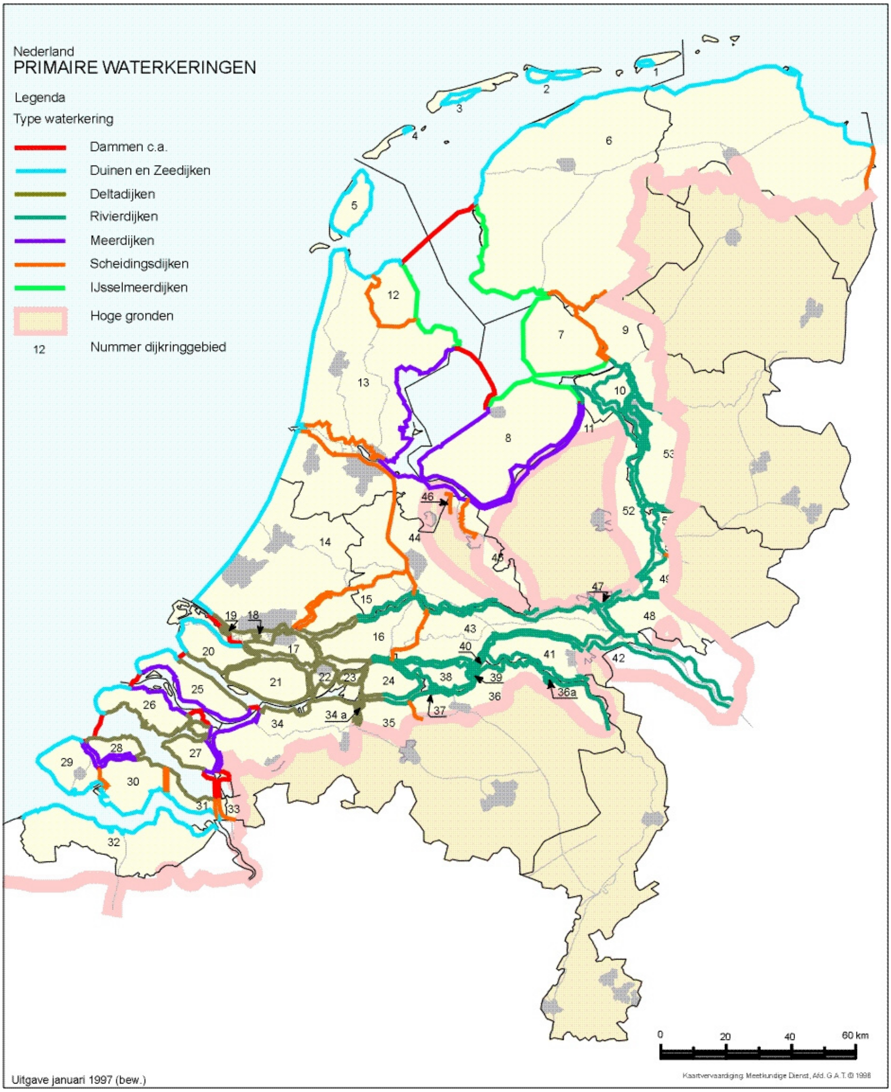

Fig. 1. The dike-rings of the Netherlands

[1] A dike-ring is an area which is protected against flooding by a system of dikes and hydraulic structures.

The key issue in this respect is the progress of the evacuation with an emphasis on the total time span needed for preventive evacuation. An additional benefit of the DSS is that it can be very helpful in the design of efficient strategies for organizing the evacuation in a specific dike-ring area within the framework of setting up an evacuation plan.

This paper discusses the evacuation problems in general and those of preventive evacuation of dike-rings in particular. In detail a method is specified for trip distribution and routing that uses efficiently the potential of the network and that is transferable to the application of a traffic management scheme.

2 Evacuation of People

There is an increasing interest for modeling evacuations. Studies have been initiated by risk analysis of nuclear power plants (Sheffi, 1982) and hurricanes (Hobeika, 1985; Urbiana, 2001). There are many causes that require an evacuation. These can be natural phenomena as extreme weather conditions (hurricanes, heavy rainfall, wildfires caused by drought), springtide and geological phenomena (earth quakes, volcanism, tsunami), but also human activities as industrial accidents, failure of hydraulic structures, accidents with transports of hazardous goods and attacks by terrorists. Expansion of human activities to vulnerable areas increases the impact of extreme circumstances. There are great differences in the predictability of time, location, scale and outcome of the dangerous situation.

In the Dutch situation dangerously high water levels of rivers can be predicted several days in advance. Although it is uncertain if and when the dike-ring will be flooded there will be enough grounds to start preparations. The aim of precautionary action is to reduce the risk and the consequences. One of the possibilities of reducing risk and consequences is the preventive evacuation of the dike-ring. It is important that the preventive evacuation is well organized, efficient and will need a minimum of time in order to avoid casualties. An accurate estimate of the evacuation time is helpful in determining the start of the evacuation. It implies that the decision can be taken as late as possible, at a moment where there is a more precise picture of the threat. A superfluous evacuation should be avoided. The crisis team needs to find a balance between an early decision (where the organization is not critical, casualties are unlikely, but an evacuation could be redundant) or a late decision (where the organization is critical and casualties could happen).

The whole process of a preventive evacuation can be outlined in a timeline.

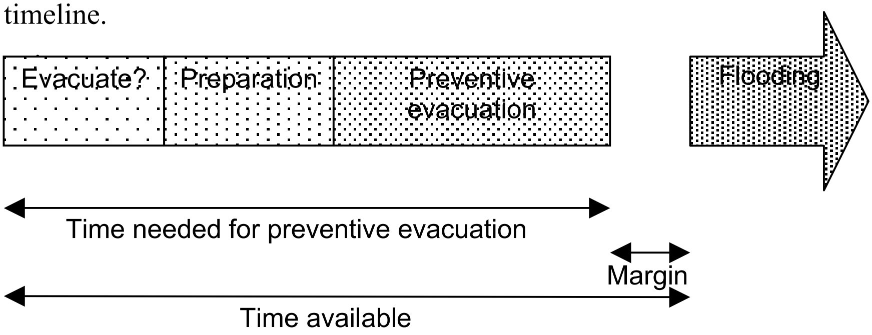

Fig. 2. Time line of the evacuation

From the point of view of the evacuee the whole process looks like: (1) organization of the departure; (2) departure from home; (3) travelling in the direction of a safe area; (4) leaving the danger area through one of its exits[2]; (5) continuation of the journey to the destination in the safe area.

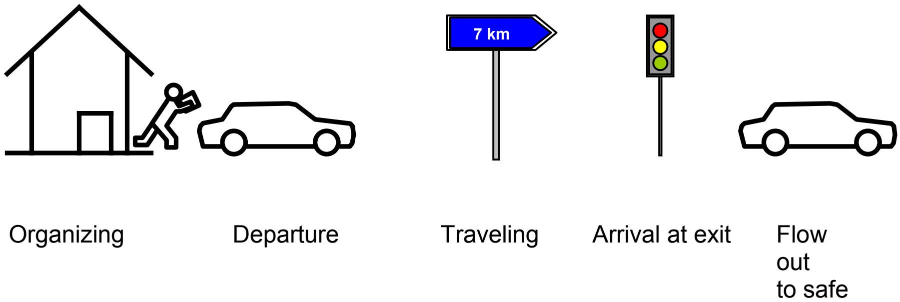

Fig. 3. Phases of the evacuation as seen by the evacuee

With a preventive evacuation there is neither actual flooding nor immediate threat. It is assumed that traffic behavior is normal and that the usual assumptions for modeling behavior are applicable. In cause of an actual flooding behavior will change from the 'normal' state to flee behavior. In the latter situation it is uncertain whether the usual assumptions are applicable.

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[2] In general the dike-rings in the Dutch situation have several roads (exits) to surrounding areas.

2.1 The Abilities of the Authorities during (Threat of) a Disaster

In the situation of a disaster or a threat of disaster the capabilities of the authorities are enlarged. Depending on the size of the area a coordinator is assigned. The coordinator could be the mayor, a coordinating mayor (if several municipalities are involved), the province or the Ministry of the Interior. The authorities are entitled to take all the necessary actions within the restrictions of the constitution.

For the organization of a preventive evacuation it not only means that the enforcement of an evacuation is allowed, but also that any action to speedup the process and to increase the efficiency is permitted. This could mean: enforcement of time of departure, choice of exit and route to the exit.

2.2 The Process of Decision Making

A disaster plan as an evacuation plan is one of the aspects of the whole process of decision making during the threat of flooding. Authorities like municipalities, province and the central government are involved. Other functional organizations as the polder-board, the department of water management and environmental affairs of the province, the directorate general of public works and water management are involved. The evacuation plan is one of the preparatory plans that form the basis of the final approach. See for this process the figure below (Martens, 2002, as mentioned in Boetes, 2003).

During a critical situation the crisis team will go through three process steps: (1) judgment of the situation; (2) formulation of a plan; (3) judgment of the functioning of the chosen approach. The quality of the chosen approach depends, partly, on available resources, well prepared plans, procedures and commitments about the organizational structure (Boetes, 2003).

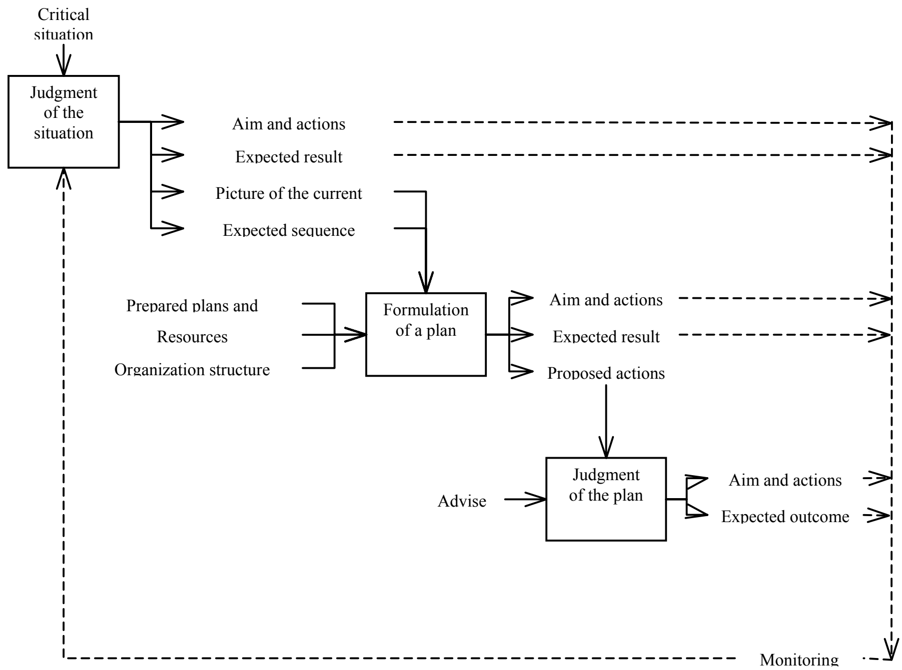

Fig. 4. The process of decision making under threat of flooding (Martens, 2002)

2.3 Modeling of a Preventive Evacuation

During a preventive evacuation there is a process of matching supply and demand as in normal traffic situations, although the setting in case of a preventive evacuation is quite specific. The matching of supply and demand can be modeled from a 'What if' or a 'How to' approach (Russo, 2004).

In a 'What if' approach a situation (or scenario) is modeled and the results of the model are analyzed. Stepwise the situation is adjusted until no further improvements seem possible. The final result is interpreted and translated in to an evacuation plan. The final result depends on the interpretation and adjustments of the modeler. The quality of the result is, by lack of a formal objective function, unclear. It is possible to use detailed and complex models in this situation. The modeler will focus on those aspects of the model that are important for the problem.

In a 'How to' approach the result is determined by the objective function, the constraints and structure of the model. Not in all cases an optimal solution can be guaranteed (due to local optima). The objective function, constraints and solving techniques could limit the complexity of the model. The focus on the objective function can overshadow other difficult quantifiable objectives.

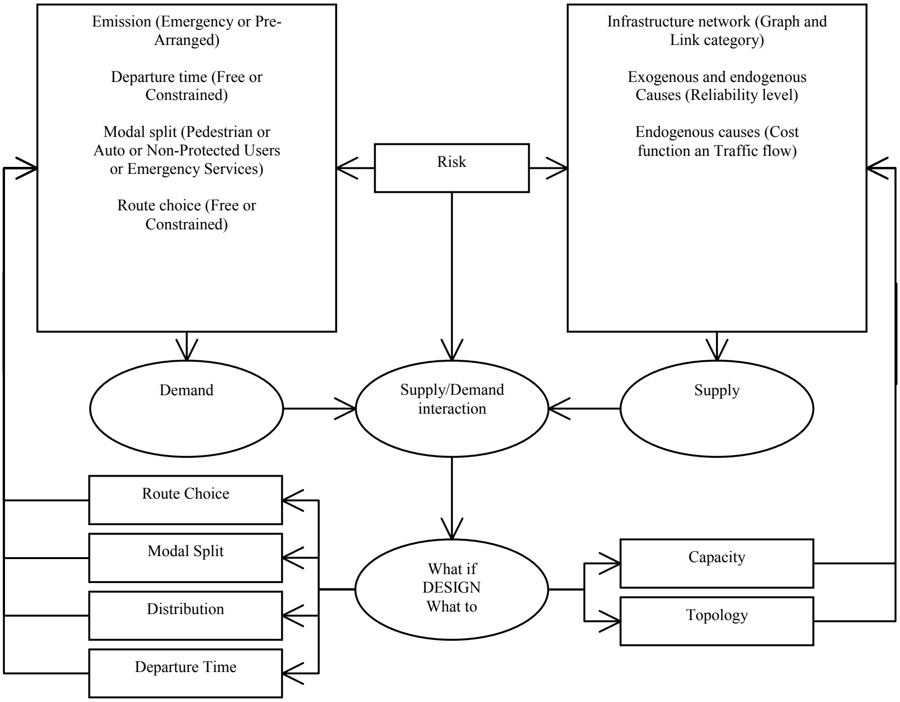

Fig. 5. Global procedure for the design of an evacuation plan (Russo, 2004)

Cova and Johnson (Cova, 2003) describe a procedure to eliminate crossing of routes and minimize the weavings on crossing, where extra distance to the safe area is allowed. They choose for this approach knowing that in many, urban, networks the crossings determine the capacity of the network. Elimination of crossing traffic and reducing weaving is a logical next step. In the approach of Cova and Johnson the distribution and route choice are the determining factors for the objective function.

Sheffi (Sheffi, 1985) handles the problem of the simultaneous trip distribution and assignment in general. Evacuation can be seen as such a type of problem. Goal is to find that distribution and assignment where a system optimum is obtained. Every change in the final solution, distribution or assignment, will affect the objective function. Sheffy proves this problem can be solved by using existing techniques and a modest adjustment of the network. The equilibrium assignment is used in a network were there is only one, spanning, destination. Chiu (Chiu, 2004) uses this pragmatic solution. Implicitly a perfect control of destination and route choice is assumed. The solution should be considered as a best-case solution that guides to (sub) optimal solutions with more realistic constrains.

For the ‘Floris’ project the focus is on a conservative and realistic estimate of the evacuation time together with a proposal for the traffic management during the evacuation. Efficiency of the method in terms of data handling and computing time is of importance as about 26 dike-rings will be investigated. From this perspective a ‘How to’ approach that uses the capabilities of the crisis team to influencing the traffic flows is preferable. The solution for this problem is found in a method that focuses on the trip distribution.

3 Formulation of the Methods

In the situation of a preventive evacuation there are many uncertainties and inaccuracies: (1) the number of people and cattle in the dike-ring during the threat of flooding; (2) the number of cars and trucks involved; (3) the time of departure; (4) the state of the network at the time of evacuation; (5) the route choice. Experiences under threat of hurricanes show a large discrepancy between expected and actual departure rate. During hurricane Opal people left their homes about three hours later than the slowest estimate of response rate (Alabama, web).

As a result of this it is not functional to focus on a maximum of model accuracy. A model with a limited complexity is appropriate for this situation. Sensitivity analysis is helpful to determine the critical processes.

Four different scenarios are developed:

1. Traffic management; within the capabilities of the crisis team a ‘How to’ model will suggest an efficient organization of the preventive evacuation. The inhabitants are directed to specific exits of the dike-ring.
2. Reference; this is a scenario where the inhabitants of the dike-ring are free in their choice of the exit.
3. Nearest exit; in this scenario the evacuees will go to there nearest exit of the dike-ring, regardless capacity and use of this exit.
4. Flow off areas; in this scenario inhabitants are directed to specific exits.

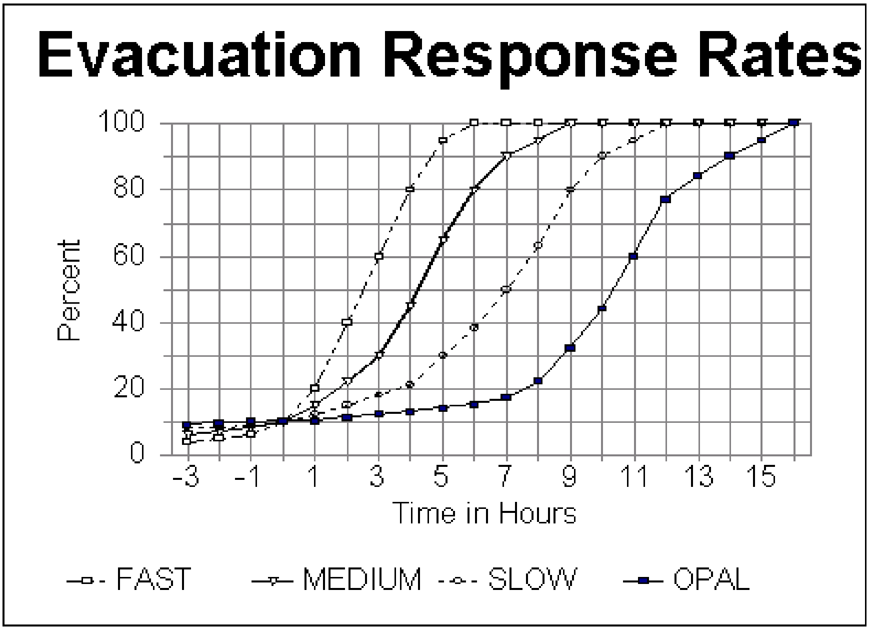

Fig. 6. Alabama hurricane evacuation response rates. Estimates (fast, medium and slow) and actual response rate during hurricane Opal (Alabama, web)

3.1 The Traffic Management Method

The capabilities for influencing behavior are important constrains for an evacuation plan as for the development of an evacuation method.
Possibilities for manipulation are:

- Time of departure. By means of information and direct orders the time of departure can be influenced.
- Trip distribution. It is possible to instruct to go to a specific exit.
- Mode of travel. In general people with a car available will use their car. For people without own means of transport the authorities will be responsible for supplying public transport.
- Route choice. By means of information and instructions it will be possible to guide the traffic.

The number of evacuees cannot be influenced.

The purpose of the evacuation plan can be defined as: a distribution and routing of the evacuees in such a way that the evacuation time is short and the possibilities of the network are utilized efficiently while the necessary traffic management can be realized.

Crossing streams of traffic is a source of waiting times and disturbances and should be avoided. Diverging traffic introduces a choice problem for drivers and the local traffic management. Diverging of traffic is not allowed in the method. In the actual implementation of an evacuation plan it can be introduced in specific situation. For the time being pure converging flow of traffic is assumed. This makes introduction of one-way traffic (reverse laning or contra flow (Urbina, 2003)) to increase capacity possible.

Using pure converging traffic flows delays at crossings are negligible. The traffic volume at the exits will be the highest (as a result of the converging flows) as a result of this it is likely that the exit will be the bottleneck. It is assumed that it is possible to assign a capacity to an exit that is appropriate for the route to the exit.

These assumptions lead to the following conceptual model:

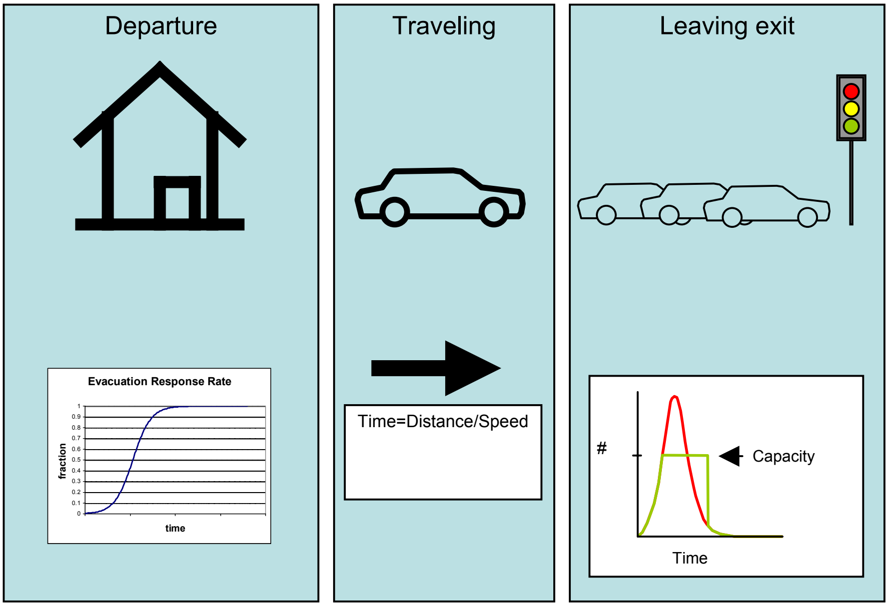

Fig. 7. Conceptual model of the evacuation

The task is now to create a trip distribution where the traffic flows are converging and the capabilities of the exits are used well. For the time being we consider the whole of traffic which will leave the dike-ring. When the trip distribution is determined it is possible to create the distribution in time by using the evacuation response rate and the arrival time at the exit.

Let P_i in Person Car Units, PCU, be the trip production by evacuees from zone *i*.

The evacuation time is determined by the last car leaving the dike-ring. The objective function is the defined by:

minimize(maximum(flow out time)).

Where:

- All evacuees will leave the dike-ring.
- The traffic flow to the exits is efficient.

This objective function suits a preventive evacuation. In situations where the urgency is high and casualties not avoidable this objective function is not valid. In these types of situations it is of great interest to limit the casualties given the time to flooding.

The flow out time U_j [hours] of an exit *j* is determined by the arrivals at the exit A_j [PCU/hour] and the capacity C_j [PCU/hour] of the exit:

$$U_j = \frac{A_j}{C_j} \qquad (1)$$

$$where:$$

$$\sum_i P_i = \sum_j A_j$$

The objective function is met when the flow out time of exits are identical and minimal. This is the case when the arrivals at the exits are proportional to the capacity of the exits:

$$A_j = T\frac{C_j}{\sum_j C_j} \qquad (2)$$

$$where:$$

$$T = \sum_i P_i$$

Every distribution of the productions with these attractions will match the objective function, but will not necessarily result in efficient traffic flows to the exits.

Let the distance traveled from origin *i* to destination *j* along the shortest path be z_{ij} .

Let the number of trips from origin *i* to desination *j* be T_{ij} .

Then the total vehicle distance is defined as the weighted sum of trips and distance traveled: $\sum_i \sum_j z_{ij} T_{ij}$

By minimizing the total vehicle distance, given de productions and attractions, unnecessary vehicle distances are avoided. This problem is known as the classic transportation problem:

$$\begin{aligned} &\min\left(\sum_i \sum_j z_{ij} T_{ij}\right) \\ &where: \\ &\sum_j T_{ij} = P_i \\ &\sum_i T_{ij} = A_j \\ &T_{ij} \geq 0 \end{aligned} \quad (3)$$

The transportation problem needs an initial OD-matrix. In the implementation of the Evacuation Calculator the trips form i to j are proportional to the production and attraction:

$$T_{ij} = \frac{P_i \cdot A_j}{T} \quad (4)$$

When the resulting OD-matrix is loaded to the network using an All-Or-Nothing assignment the traffic flows are convergent.

F_{tk} is the fraction of evacuee category k who will leave in time interval t. In the implementation the user is free to define the fraction for each F_{tk} or by using a logistic function:

$$F_{tk} = \frac{1}{1+\exp\left(a_k\left(t-b_k\right)\right)} - \frac{1}{1+\exp\left(a_k\left(\left(t-1\right)-b_k\right)\right)} \quad (5)$$

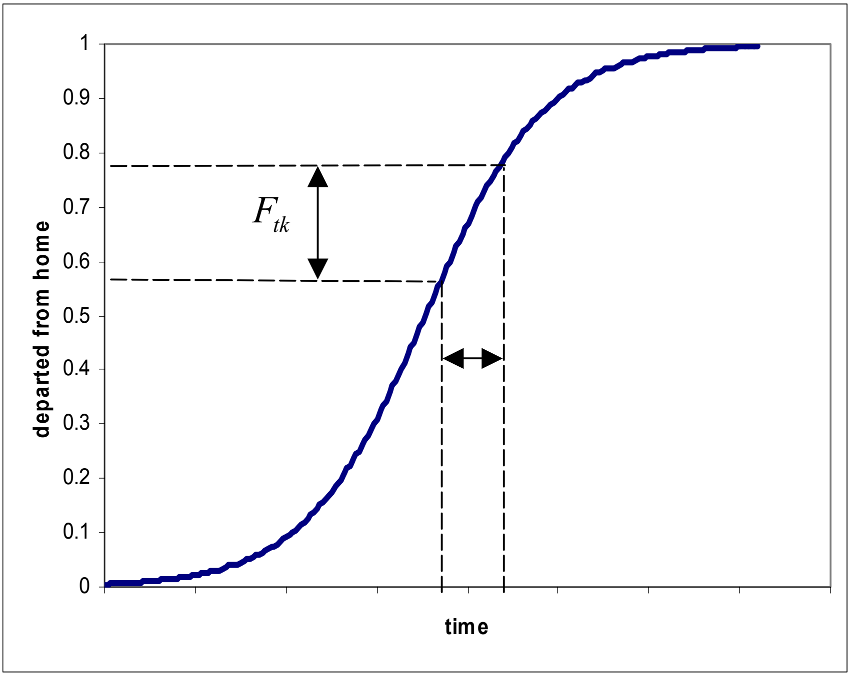

Fig. 8. Use of the logistic function for *Ftk*

The OD-matrix per time interval is now determined by:

$$T_{ijt} = \sum_k T_{ijk} F_{tk} = \sum_k T_{ij} \frac{P_{ik}}{P_i} F_{tk} \tag{6}$$

After departure from home the vehicles will arrive after r_{ij} time intervals at the exit. The travel time is dependent on the distance from origin to exit, z_{ij} [km], and the average speed, $\bar{v}$ [km/h], in the dike-ring and the number of time intervals in an hour, I:

$$r_{ij} = Int\left(\frac{z_{ij} I}{\bar{v}}\right) + 1 \tag{7}$$

Now it is possible to calculate the arrivals, ARR_{jk} [PCU] at exit j for a time interval t:

$$ARR_{jtk} = \sum_i T_{ijk} F_{t-r_{ij},k} \tag{8}$$

$$ARR_{jt} = \sum_k ARR_{jtk}$$

The vehicles that arrive at the exit will leave the dike-ring for as far capacity allows. In a time interval the number of vehicles that leave the exit are limited to.

$$\frac{C_j}{I} \tag{9}$$

The flow out DEP_{jt} at exit j for time interval t depends on the available traffic (delayed and just arrived) and the capacity of the exit:

$$DEP_{jt} = \min\left(ARR_{jt} + DEL_{j,t-1}, \frac{C_j}{I} \right) \tag{10}$$

$DEP_{j,t-1}$ are those vehicles that could not pass in earlier time interval(s) using exit j. For the first time interval there are no delayed vehicles:

$$DEL_{j,0} = 0 \tag{11}$$

Vehicles that cannot pass in time interval t will be delayed and will use a later time interval:

$$DEL_{jt} = \max\left(ARR_{jt} + DEL_{j,t-1} - DEP_{jt}, 0\right) \tag{12}$$

The number of departing vehicles for category k is calculated by assuming that at arrival the categories are spread homogeneous over all vehicles. A fraction of all delayed and just arrived vehicles will eventual leave the dike-ring eventually:

$$DEPRATIO_{jt} = \frac{DEP_{jt}}{ARR_{jt} + DEL_{j,t-1}} \tag{13}$$

The departures for category k in time interval t are now:

$$DEP_{jkt} = DEPRATIO_{jt}\left(ARR_{jkt} + DEL_{jk,t-1}\right) \tag{14}$$

The delayed vehicles for category *k* in time interval *t* are:

$$DEL_{jkt} = ARR_{jkt} + DEL_{jk,t-1} - DEP_{jkt} \tag{15}$$

Central unit of measurement in the model is the PCU. The number of evacuee in PCU Q_k can be transformed into the number of persons (or cattle) N_k by using the occupancy degree μ_k and the PCU-value of the used type of vehicle PCU_k:

$$N_k = Q_k \frac{\mu_k}{PCU_k} \tag{16}$$

For each exit and all exits together the resulting output of the model is:

- Arrivals and flow out [PCU/time interval].
- Arrivals [PCU/time interval] for all categories together and for each category.
- Flow out [PCU/time interval] for all categories together and for each category.
- Flow out [number/time interval] for all categories together and for each category.

The resulting OD-matrix (whole evacuation or per time interval) is available for (dynamic) assignment.

The method has some relationship to the first stages of the classic one-mode traffic model:

- The trip end calculation. Where trip production is determined by the social economic data of the zones. There is a difference in calculation of the attractions. Here the capacities of the exits are leading.
- The trip distribution. Special for this method is the minimization of total vehicle distance.

The results (graphs and OD-matrix) are available in seconds. Assignment of the OD-matrix give a better insight in the resulting traffic flows.

The Traffic management scenario uses the 'How to' approach. The other implemented scenarios (Reference, Nearest exit and Flow out areas) use the 'What if' approach.

3.2 The Reference Scenario

The differences between the Reference scenario and the Traffic management scenario are:

- Trip end calculation: the user is free in setting the (relative) attraction of the exits. In general these will be determined by the traffic volumes on the exits on normal working days.
- Trip distribution: the distribution is identical to the initial distribution of the Traffic management scenario. There is no minimization of total vehicle distance.

3.3 The Nearest Exit Scenario

Here the differences with the Traffic management scenario are:

- Trip end calculation: the attractions are not explicit chosen, but are a result of the distribution.
- Trip distribution: all productions of an origin are allocated to the nearest exit.

$$
\begin{aligned}
& t_{ij} = P_i \\
& \text{for that } j \text{ where:} \\
& z_{ij} = \min\left(z_{ij} \forall j\right) \\
& t_{ij} = 0 \text{ for all other } j
\end{aligned} \tag{17}
$$

3.4 The Flow Off Scenario

The Traffic management scenario will result in sets of more or less independent flow off areas which use one or more exits. It is not likely that this flow off areas can be transferred to an evacuation plan without change. Geographic, jurisdictional and other local constraints will make adjustments necessary. With the Flow out scenario the user is free in defining sub areas with one or more exits. Within every sub area the trip end calculation and distribution is solved with the Traffic management method: (1) attractions proportional to capacities and (2) minimizing the total vehicle distance given the productions and attractions.

The minimization of the total vehicle distance for all flow out areas is solved by manipulating the distance matrix z_{ij} before the actual minimization. Those relations that are not part of an flow out area are flagged with an extreme large value. The further procedures are identical to the Traffic management scenario. The deviation to the Traffic management scenario is:

- Trip distribution: manipulation of the distance matrix z_{ij} .

$$
\begin{aligned}
& z_{ij} = \infty \forall i \in D_m \wedge j \notin D_m \\
& z_{ij} = \infty \forall j \in D_m \wedge i \notin D_m \\
& \text{where:} \\
& D_m = \text{the set of } i \text{ and } j \text{ defining sub area } m
\end{aligned}
\tag{18}
$$

4 Case Study of Flevoland

Flevoland is one of the larger dike-rings in The Netherlands. Its surface is about 98 square kilometers. With about 258 thousand inhabitants (102 thousand households) the area is not very densely populated, at least to Dutch standards. The two larger cities are Almere and Lelystad. Others are considerably smaller.

Fig. 9. Flevoland

The Network

For demonstration purpose we use just three of the eight exits[3]. The capacities of the exits [PCU/hour] are set to 6600 for the south-west exit, 4300 for the north-east exit and 1500 for the south east exit. This leads to a total capacity of 12400 [PCU/hour].

Trip End Calculation

We define two categories: (1) person cars (2) people who need assistance or public transport to leave the dike-ring.
We assume that[4]:

- All passenger cars will leave the dike-ring. Passenger cars have a PCU of 1.
- 10% of the inhabitants in the age of 35 to 64 and 50% of those in the age of 65 and more will use a bus. Busses will transport on average 20 passengers. A bus has a PCU-value of 2.

This will result in 93630 PCU for the category passenger cars and 2079 PCU for the category of bus users, 95708 PCU in total. The evacuation will need at least seven and a half hours (95708/12400).

Departure Rates

For each category the departure rate is defined with a logistic curve. The characteristics of these curves are:

- Cars: 50% will have been departed in 5 hours, 90% in 6 hours.
- Bus users: 50% in 8 hours, 90% in 9 hours.

For both categories it implies that 40% of the population will leave home in one hour. During the peak hours about 38000 PCU will enter the network. This exceeds the capacity of the exits three times (38283/12400).

[3] With eight exits Flevoland has a relative large capacity of exits.

[4] Up till now the trip end calculation, departure rate as the average speed in the dike-ring are not yet defined in the Floris research project. Further research on these topics is needed.

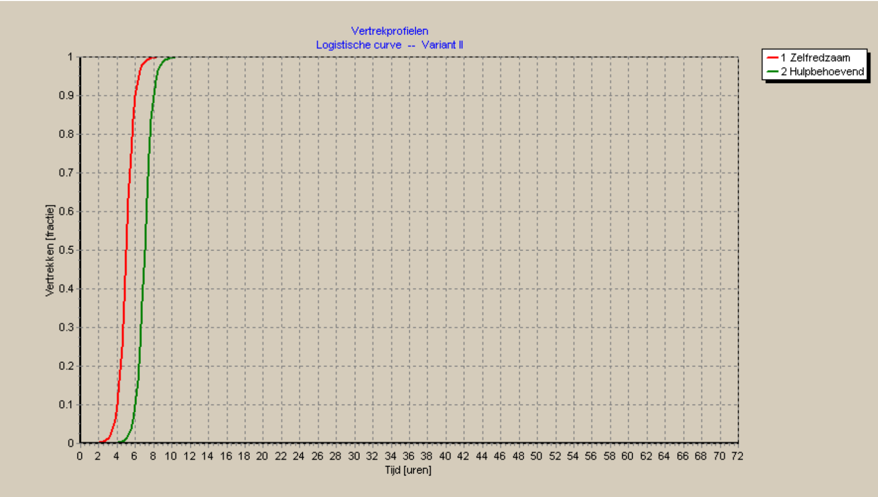

Fig. 10. The departure rate in the Flevoland Case.

Average Speed

The average speed in the dike-ring is set to 25 km per hour.

Results of the Evacuation Calculator

In the Reference scenario all three exits have the same relative weight. This will result in overload of the south-east exit particularly as this exit has the least capacity. With the Reference scenario the dike-ring is empty in 25½ hours. During 4 hours the maximum flow out of 12400 PCU/hour is reached. The bottle neck is at 4:30 till 25:15 at its maximum capacity, other exits are 9:15 and 12:00 hour below their capacity. Clearly this is a worst case scenario that can be improved easily.

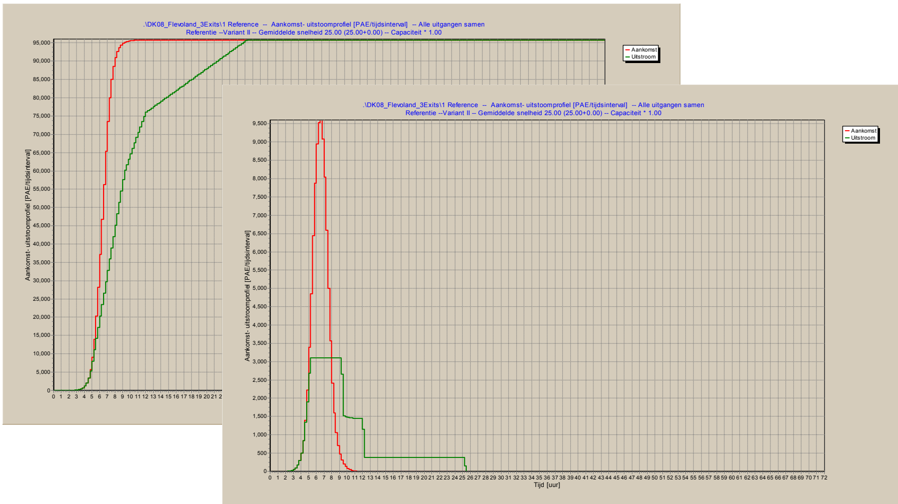

Fig. 11. Evacuated PCUs in time per time interval and cumulative for the Reference method.

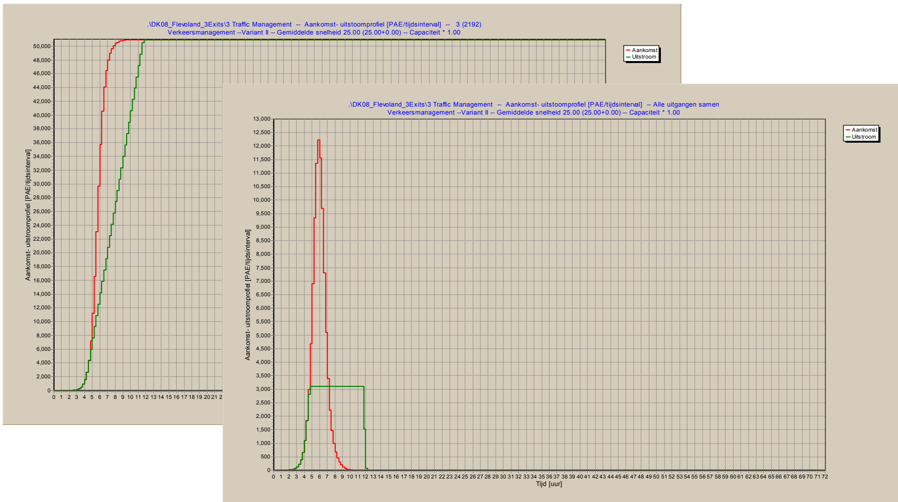

Fig. 12. Evacuated PCUs in time per time interval and cumulative for the Traffic management method.

The Nearest exit scenario performs better than the Reference scenario, but the evacuation time is still high. The dike-ring is empty after 20 hours. Bottle neck is still the south-east exit. At the north-east exit the load drops below capacity at 9:15, at the south-west exit at 12:00 hour.

With the Traffic management scenario the dike-ring is empty at 12:15 hour. From 4:45 till 11:45 all exits are loaded at maximum capacity.

The resulting OD-matrices can be loaded to the network. In this case an All-Or-Nothing assignment is performed using OmniTrans[5]. The plots give an idea of the complexity of the traffic flows.

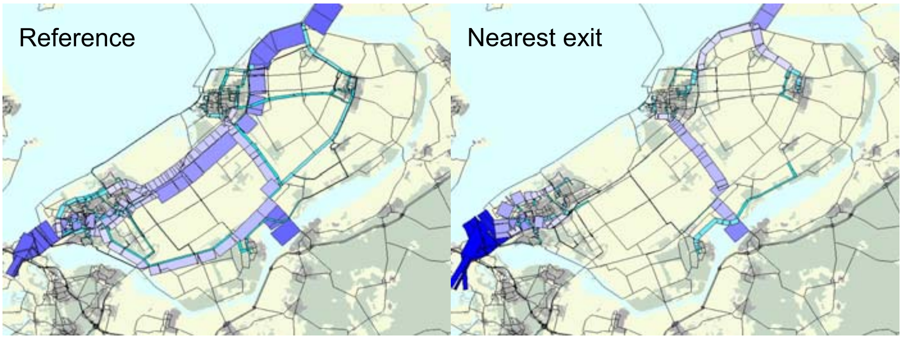

Fig. 13. All-Or-Nothing assignment of the methods Reference and Nearest exit

Typical for the Reference method is the crossing traffic flows. These crossing traffic flows will result in waiting times and delays. The Nearest exit method will lead to converging traffic flows. The use of the exits is in most cases unbalanced which will lead to relative long evacuation times.

The Traffic management method will show converging routes to the exits. All exits have similar workload in relation to there capacity. Needless long trips are eliminated due to the minimization of total vehicle distance. Flow out areas are identifiable.

In some aspects the flow out areas that are suggested by the Traffic management scenario are difficult to realize due to local circumstances. The flow out area method makes evaluation of flow out areas possible. To illustrate this method the city of Almere is assigned to the south-west exit, Lelystad to the north-east exit and all other origins to the south-east exit.

5 OmniTrans (www.OmniTrans-Internation.com) is an application for traffic planning.

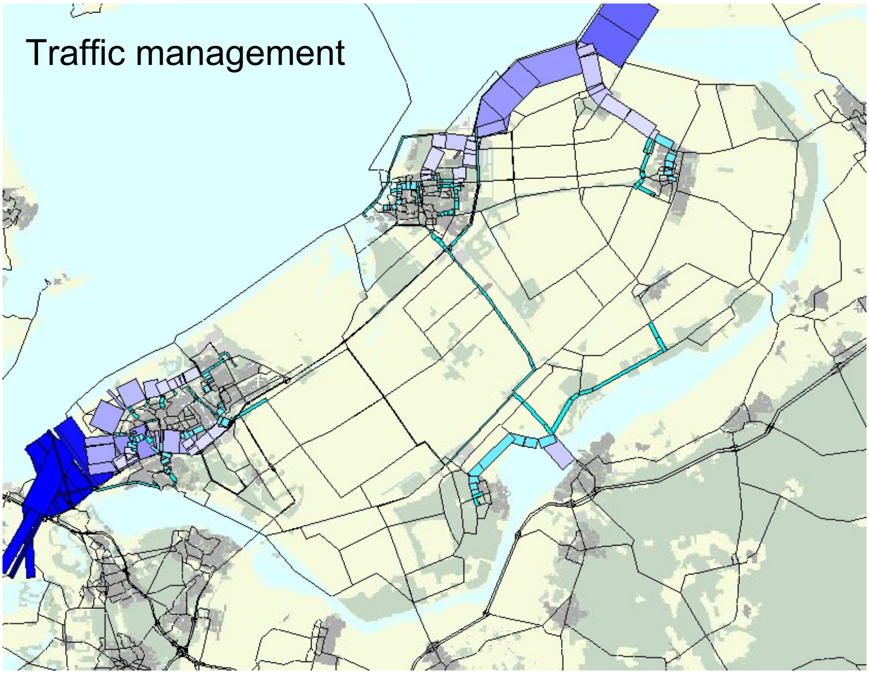

Fig. 14. All-Or-Nothing Assignment of the method Traffic management

The result has hardly any impact on the south-west exit, but shifts traffic from the north-east to the south-east exit. The total evacuation time will be 18:45 minutes. If for some reason this would be preferable special attention should be paid to the routes to the south-east exit. Reverse laning and special attention to the merging traffic near the exit is necessary.

Defining the dike-ring and running the methods, including the All-Or-Noting assignment, will take a few hours. For a re-run of a method several seconds is needed for the Evacuation Calculator and some minutes for the AON assignment. This is made possible by using a network for the whole of the Netherlands[6]. All dike-rings are defined within this network. This makes the data handling uncomplicated. The Evacuation Calculator will create a directory with data for each dike-ring.

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6 The network is part of the NRM (New Regional Modal) which is developed by the AVV Transport Research Center of the Ministry of Transport, Public Works and Water Management.

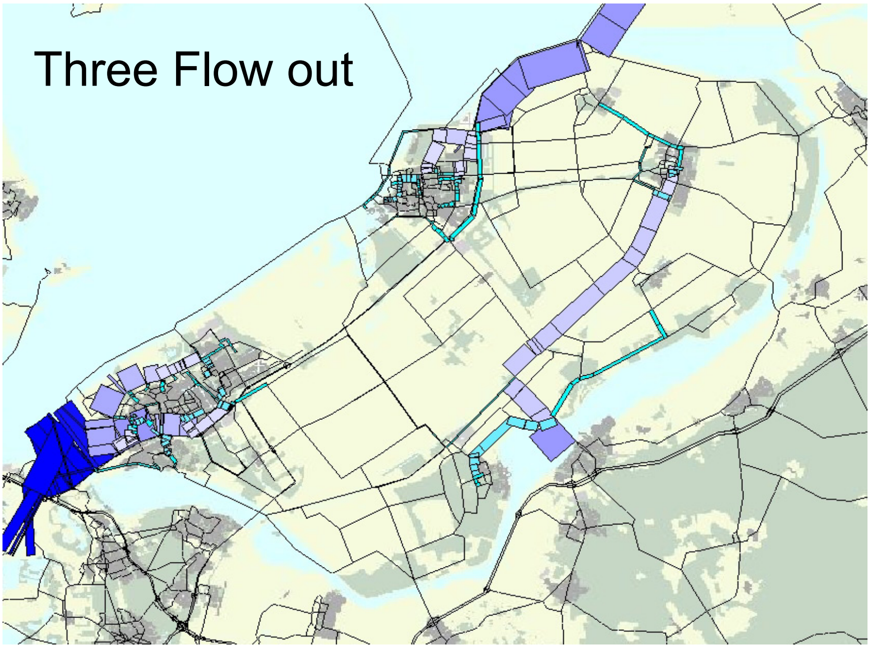

Fig. 15. All-Or-Nothing assignment of the flow out method

5 Conclusions

The developed Traffic management model for preventive evacuation follows a ‘How to’ approach. It produces more or less independent outflow areas which will assist in the development of an evacuation plan. The scenarios Reference and Nearest exit are especially useful in determining a safe estimate of the evacuation time.

The model is relatively simple in terms of complexity, data need, preparation and run time. Its accuracy is appropriate for this situation where many of the process steps can have very different outcomes.

For a better understanding of the capabilities of the Evacuator Calculator further research is needed with respect to dynamic macro (or micro) assignment.

Preventive evacuations of dike-rings in the Netherlands are quite rare. As a consequence important behavioral parameters in the model are not yet based on actual data. It is suggested to develop a monitoring program for in case a crisis situation occurs. Elements of this monitoring program should be at least: (1) the trip generation for the several categories; (2) the departure rates for the categories; (3) speed and traffic volumes during the evacuation; (4) supporting activities of police, fire brigade and army; (5) guiding information (radio and television); (6) perception of the situation by the evacuees.

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