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## Evacuation Models and Disaster Psychology

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### Abstract

In evacuation models of buildings, neighborhoods, areas, cities and countries important psychological parameters are not frequently used. In this paper the relevance of some important variables from disaster psychology will be discussed. Modeling psychological variables will enhance prediction of human behavior during evacuations.

John Leach's Dynamic Disaster Model describes three phases and five stages: A Pre-impact phase (Threat Stage and Warning Stage), an Impact phase, and a Post-impact phase (Recoil Stage, Rescue Stage and Post-traumatic Stage). In each phase and stage specific human behavior has been supposed to be a psychological response to a disaster. These responses are remarkably consistent and transferable across kinds of disasters.

Evacuation happens during Pre-impact phase, Impact phase and Post-impact phase (Recoil Stage and, or Rescue Stage). People's cognitive and emotional states and overt behavior will be very different across the phases. During the Pre-impact phase risk estimation is very low, so evacuation is not seen as an inevitable action. Heavy stress and denial of life-threatening events during the Impact phase will hinder effective evacuation. Inactivity, apathy and childlike dependency on other people during the Recoil Stage will restrain survivors from active evacuation.

Evacuation models will be more effective if phases and accompanying human behavior are taken into account.

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*Keywords:* Human Factor, Disaster Psychology, Evacuation Models, Simulation

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### 1. The Human Factor during evacuation; an example

In the south and east of the Netherlands there is a risk of extreme flooding of the river deltas each year during spring. The risk will be greater in the near future, caused by changes of the earth climate, which are currently predicted. The climate change will bring more rain to Europe and the Netherlands. In the same time period there will be Dutch Carnival in the south and east of the Netherlands. During four days a significant part of the community is involved in drinking, eating, singing and dancing day and night. Families are scattered over many places.

It is absolutely not inconceivable that an extreme flooding will take place on the last day of the Carnival, a Tuesday. Within hours, the partying people would have to change into evacuees. These evacuees are at that moment exhausted (60% by our estimation), drunk or at least tipsy (30%), or disoriented (20%). Most people will not be able

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to drive a car. The presence of authorities will be reduced. Families are split. Most people will refuse to evacuate without their families or will not be able to evacuate.

Alcohol consumption affects cognitive, attentive, emotional, and motor functioning of people negatively, especially in unclear, stressful evacuation circumstances. From general psychology some estimates of the effects can be made: in general, cognitive processes and attention will be impaired strongly. The emotional systems will be over-stimulated. Motor functions will be hampered. Some specific effects of alcohol consumption on output variables of the evacuation (speed of the evacuation, number of casualties) can be stated.

- Most people (50% or more) are unable to make adequate risk estimations in typical evacuation situations, due to alcohol and stress. Most people are not inclined to evacuate. This will cause delayed evacuation and more casualties.
- Most people are unable to make adequate decisions in new problem situations, due to alcohol and stress.
- Most people are unable to communicate (speaking and listening) unambiguously and clearly, due to alcohol and stress.
- Most people tend to focus their attention extremely (tunnel vision), due to alcohol and stress. They do not have the overall picture of new situations needed for optimal adaptive behavior.
- Most people tend to behave as they do normally. They choose well-known behaviors or copy behaviors from others near them.
- Most people have lowered thresholds of emotional behavior due to alcohol and stress. They are easily triggered to be angry, anxious or aggressive.
- Most people are unable to control and smoothly perform motor activities due to alcohol and stress. They are prone to accidents.

The differences between an ordinary Tuesday and the Tuesday during Dutch Carnival can be seen as an example of the *Human Factor*. This factor is very well known in Disaster Psychology. It plays an important part in most disasters. The *Human Factor* may be the cause of a disaster, may worsen the situation or may defuse the dangerous situation. The *Human Factor* changes the course of evacuations. The *Human Factor* has to be represented in each evacuation model, for it to fit reality. In any case the negative effects of stress, caused by the danger and the evacuation itself, should be modeled. However, most evacuation models lack a strong *Human Factor*. Grouping of evacuees on characteristics of evacuees is a first step of introducing the *Human Factor*: e.g., young and old evacuees, healthy and handicapped people, men and women, occupants with and without knowledge of traffic routes or region maps, evacuees with stable evacuation strategies versus evacuees with instable evacuation strategies.

## 2. Evacuation Models; some assumptions

Many evacuation models have been proposed in the literature. For all kinds of disasters there are evacuation simulation models suggested. Concerning traffic and transport evacuations ([1],[18]), for wildfires ([2]), buildings and building fires ([3],[5],[6],[8],[10],[12],[14]), concerning hurricanes ([4],[19],[21]), for maritime evacuations ([11],[7]), evacuations during aircraft accidents ([16],[17]), evacuations from accidents in plants and regions ([13]), and for evacuations of hospitals ([20]).

In general evacuation models comprise three elements: input variables, a simulation model and output variables. Values of input variables can be specified to analyze output variables given the characteristics of the simulation model. The simulation model is aimed to be an approximation of an eventuality. The approximation may be simple or complex. A very simple example of an evacuation model is given here.

### OVERVIEW 1 - SIMULATION EVACUATION MODEL

#### INPUT VARIABLES

- Evacuation Distance in km: 100, 200, 300
- Percentage female drivers: 25%, 33%

## SIMULATION MODEL

### Traffic Parameter Estimates

- Speed in km/h: 100
- Resting time: 15 minutes after each 75 km

### Relations between Traffic Parameters

- Evacuation time = evacuation distance / speed + resting time

### Psychological Behavior Parameters

- Women more stressed than men: 20% longer evacuation time

### Disaster Psychology parameters

- Evacuation capacity of 10% of all occupants is not effective: 10% of all evacuations not or partly completed
- Before disaster 30% evacuation refusal: 25% longer evacuation time
- During disaster 5% evacuation refusal: 3% more casualties

## OUTPUT VARIABLES

- Total evacuation time (6 estimates)
- Number of casualties

Most evacuation models specify traffic parameter estimates and relations between traffic parameters to predict output variables. In this example two categories are added: Psychological Behavior Parameters and Disaster Psychology Parameters. In Psychological Behavior Parameters general knowledge of cognitive, attentive, emotional, and motor behavior of humans can be used to enrich the model and to improve the approximation of evacuation reality. Especially important are the effects of stress on evacuation performances. The influence of characteristics such as general intelligence, neuroticism, and resilience on evacuation behavior is documented in general psychology. Stress during evacuation has a great negative effect on adaptive behavior. Neurotic people are prone to stress. Intelligent and resilient people have a strong resistance to stress. Disaster Psychology, a very young branch of general psychology, has made predictions of human behavior before, during and after disasters. Evacuation can be seen as a part of a disaster.

### 3. John Leach's Dynamic Disaster Model

Most interesting for evacuation models are variables or parameters used in theories and findings of disaster psychology. In our opinion the theory described in John Leach's book [9] is the best theory in Disaster Psychology. This theory will be very useful for implementing the *Human Factor* in evacuation models.

The core of the theory is: generalized human behavior can be observed during specific phases or stages of disasters, catastrophes, dangerous events or other life-threatening events. From the viewpoint of psychology the kind of a disaster seems not to be all that important, but the threat is. It is not interesting whether the threat comes from water, fire, wind, traffic, war or terrorism, or whether the threat has a geological or cosmic cause. However, manmade disasters are more threatening than natural disasters.

Three phases can be distinguished in disasters: *before*, *during* and *after* the impact of the calamity or disaster. In each disaster these three phases can be distinguished. Sometimes a phase is very short, sometimes it takes days or months. The phase *before* the impact is very short in the case of traffic accidents. There may be months between the expected and the actual eruption of an active volcano. The impact of the disaster may take a split second (an explosion) or days (a water flooding) or months (a volcano eruption). The period after the impact can last for days, months or years depending on the adaptation of individuals to the new situation.

The human behavior is specific for each phase. During the stages *before* the impact people are aware of the coming impact but try to ignore or deny the facts, reducing uneasy feelings of danger, and they show apathetic behavior with respect to the real danger.

*During* the impact information processing is hampered and confused, emotional systems are upset and out of control, behavior is reflexive and mechanical.

During the stages *after* the impact people are aware of the damages of the impact but try to suppress realities, express strong and irrational emotions and develop emotional disorders.

A more extended taxonomy consists of three phases and five stages of disasters. Each describes two stages *before* the impact, and three stages have been distinguished *after* the impact.

During the first stage, the *Threat Stage*, signs forecast a disaster, but they are not compelling. The water is rising higher and higher but it cannot yet be called a flood. The fire is coming but is still distant. Smoke is alarming but no fire is seen. The volcano is active but there is no eruption. The wind is strong, but it is not a hurricane yet.

During the second stage, the *Warning Stage*, the disaster is imminent and the danger is convincing. The fire is seen. The first eruption has started. The first flooding is a fact. The wind is hurricane-like. The traffic accident is inevitable, a crash will take place. Evacuation is needed, but sometimes not immediately possible. Most survivors are not able to evacuate independently.

During the third stage, the *Recoil Stage* after the impact of the disaster, the direct cause of the threat has faded away or has disappeared or ended. The flood stopped. The storm died down. Eruptions of the volcano stop. The crash ended. Mostly, survivors are not safe yet.

During the fourth stage, the *Rescue Stage*, the survivors are more or less safe. If needed, evacuation was successfully carried out or will be carried out very soon.

## OVERVIEW 2 - PHASES OR STAGES OF DISASTERS AND HUMAN BEHAVIOR

### *THREAT STAGE*

- Threat identified but ignored
- Perceived personal risk lower than actual risk
- Unknown potential consequences of the disaster
- Active reducing of uneasy or uncomfortable feelings
- Apathetic behavior

### *WARNING STAGE*

- Denial of real threat of loss, injury and death
- Ignoring or misperception of warning signals
- Feelings of uncertainty and uncomfortableness

### ⇒ *IMPACT PHASE*

- Sensory information too much to comprehend
- Disbelief and denial of accidents and casualties
- Stunned and bewildered feelings, stress
- Reflexive, automatic or mechanical behavior
- Specific behaviors:
  - Overactive, noneffective behavior, out of emotional control (15%)
  - Apathetic and nervous behavior, lack of initiative (75%)
  - Calm, with overall picture, vigorously, potential leadership (10%)

### *RECOIL STAGE*

- Confusion, denial of the actuality of the disaster
- Slow realization of damages, casualties, injuries, losses
- Gradual return of awareness, reasoning and recall
- Childlike emotional dependency
- Increased emotional expression, irrational anger
- Increase in activity and simple social behavior

### *RESCUE STAGE*

- Confusion and denial
- Strong and irrational anger, anxiousness and feelings of guilt
- Need to talk, need for contact, need for comfort
- Apathetic and exhausted behavior

### *POST TRAUMA STAGE*

- Survivors try to rebuild their life
- Overcoming the disaster fosters psychological strengthening and resilience
- Some survivors (20%) develop psychological disorders

Acute psychological dysfunction develops into chronic disorder (PTSD)  
 Vivid memories, dreams and nightmares about trauma  
 Intensive fear, anxiety, helplessness, sadness, feelings of guilt, shame, anger, depression  
 Phobia for environments, situations, sounds, images, people connected with trauma  
 Passiveness and apathetic behavior  
 Difficulties in re-socialization and re-integration

#### 4. Model specifications from the Dynamic Disaster Model

With Leach's Dynamic Disaster Model it is possible to offer model specifications about the participation of (potential) victims in the course of evacuation during the stages of a disaster. Most of the evacuation models take this stage as a starting point for evacuation. But is that based in reality? Most people like to postpone evacuation till more convincing observations are available. Leaving home is very uneasy and risky. At the first two stages of the disaster the price of evacuation is too high for a large proportion of inhabitants. In evacuation models this problem is not represented in simulations of evacuation procedures. During the impact and the recoil stage a significant proportion of survivors is not able to participate in evacuations independently. They are cognitively, emotionally and behaviorally not ready or they are injured. Most healthy survivors are able to evacuate at the rescue stage.

A summary of possible reactions on an official call for evacuation during stages of a disaster is described as follows (Overview 3).

#### OVERVIEW 3 - EVACUATION IN PHASES/STAGES OF DISASTERS

##### *THREAT STAGE*

Recognizable signs forecast a disaster  
 Evacuation is possible  
 Potential victims are not cognitively and emotionally ready for evacuation  
 Low risk perception, suppression of uneasy feelings, apathetic behavior  
*A significant proportion of potential victims refuses to evacuate*

##### *WARNING STAGE*

Danger of a disaster is imminent and will strike  
 Evacuation is needed  
 Potential victims misperceive warning signals, show noneffective overactive behavior  
 Threatened people are not ready for evacuation  
*A significant proportion of inhabitants refuses to evacuate*

##### ⇒ *IMPACT PHASE*

Disaster is a fact  
 Evacuation is inevitable, but difficult because of the enduring impact of the disaster  
 Survivors are over stimulated and confused, have high stress levels, are emotional instable and dependent, behaviorally inactive or show mechanical behaviors  
*A significant proportion of the survivors is unable to evacuate independently*

##### *RECOIL STAGE*

Initial dangers have ended, survivors are not safe  
 Evacuation is sometimes acute, because of injuries and physical damage  
 Cognitively, emotionally and behaviorally survivors are not ready to evacuate  
*A significant proportion of the survivors is unable to evacuate independently*

##### *RESCUE STAGE*

Survivors are more or less safe.  
 Evacuation is sometimes acute, because of injuries and physical damage  
*Now, survivors are ready to evacuate or to be evacuated*

##### *POST TRAUMA STAGE*

Survivors try to rebuild their lives  
 Some survivors will evacuate permanently to another (part of the) country.

## 5. Implementation of parameters from (Disaster) Psychology in evacuation models

There are various approaches to estimation of parameter values to be used in evacuation models. Most psychological variables do not have a very clear relation to behavioral criteria like evacuation effectiveness (time to reach a safe place, number of accidents and number of casualties during evacuation). However, several starting points can be identified. Grouping people is a first step in modeling the *Human Factor* (a); grouping phases of disasters is a first step in modeling disaster parameters (b); there are effects mentioned in the psychological literature (c); simple plausible mathematical functions may be derived from psychological theory (d); empirical data from psychological and sociological research can be gathered to estimate parameter values (e); empirical data from designed evacuation situations can be collected by direct observations and interviews (f); estimates can be sought from experts in psychology, sociology and disaster research (g); and use your own smart estimates and evaluate the effects in the output of the model analyses (h).

(a) Grouping of evacuees on characteristics is a first step in introducing the *Human Factor*: e.g. young and old evacuees, healthy and handicapped people, men and women, occupants with and without knowledge of traffic routes or region maps, evacuees with stable evacuation strategies versus people with instable evacuation strategies. In most cases known weights are available for the differences in evacuation behavior between the groups. For example, old evacuees have an evacuation velocity 0.6 times the velocity of young evacuees.

(b) Specifying the phase or stage of the disaster provides a lot of information about what behavior of potential victims can be expected. During the *Threat stage* about 20% of the inhabitants refuse to evacuate. During the *Impact phase* about 10% of the survivors stay calm and is alert.

(c) In psychological literature a lot of meta-analyses and literature reviews are available for estimates of effects (correlations between variables or effect sizes over treatments). These estimates can be used to get the essence of how important the variable in question is. For example, the variable intelligence correlates 0.4 with job performance and school achievement. A first estimate of the relation between intelligence and success during evacuation (also an achievement) is  $r=0.4$ . This can be interpreted as a large effect. Most personality variables have a small correlation with job performance. Personality variables have small effects on many variables. So it is very likely that specific personality characteristics will have a small effect on evacuation effectiveness ( $r=0.2$ ). Psychological states of evacuees, like anxiousness, depression, and stress will have a large, negative effect on cognitive functions such as attention, which is needed during effective evacuation ( $r=-0.4$ ).

(d) Based on psychological theories or calamity research, simple mathematical functions can be derived to estimate relations between variables. The relation between anxiety and achievement is described by an inverted u-function. So the best estimate of the relation between anxiety and evacuation performance is likely to be an inverted u-function.

(e) Empirical data from traffic research, research of routing behavior or research on social psychology gives direct evidence for parameter values to be used in evacuation models. About 5% of bystanders will help victims of disasters or accidents, even if they are risking their own lives.

(f) Designing pseudo-evacuation conditions provides the opportunity to observe people playing the role of evacuee and to interview them about their experience, in order to get estimates of parameter values. Real evacuees can be interviewed to inform researchers about real-life parameter values.

(g) Experts of disaster research are able to give parameter value estimates and suggest relations between parameters based on their experience in the research field.

(h) In most evacuation models with a *Human Factor*, model specifications are smart guesses by the researcher him or herself.

All these procedures give tentative estimates that can be used as starting values for the construction of an evacuation model. Output variables of simulation models will give information about the validity of the chosen parameter values and relations between parameters. Also, evaluation of the fit between empirical data and model estimates will validate the simulation model.

## 6. Discussion

In the article we have asked attention for the possibility of implementation of more, or more complex, theory and knowledge of Disaster Psychology in existing evacuation models. The *Human Factor* has to be represented in an evacuation model for it to fit reality better. Predictions from simulations of evacuation models will be more realistic. Especially, in complex cases, implementing the *Human Factor* will give a good opportunity to find unlikely combinations of factors that could lead to disasters during evacuation.

However, in the young scientific enterprise of civil engineering, there are already a lot of interesting traffic parameters that can be used to predict the course and the results of evacuation. This abundance of possibilities for modeling does not leave much room for problematic variables from Disaster Psychology. But *human* disasters and *human* evacuation demand the use of specific *human* characteristics in evacuation models aimed at realistic predictions and realistic problem solving.

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