Emergency Behaviour of Ferry Passengers

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Keywords: Emergency behaviour, Mustering simulation, Crowd psychology, Human Factors, Evacuation.

Abstract
Based on interviews and a questionnaire survey with 1200 passengers on Danish ferries, stipulations were made about the emergency behaviour of ferry passengers. In this part of the MEPdesign project (MEP = Mustering and Evacuation of Passengers) a special focus was given to initial delays expected in the mustering process, to potential way-finding problems caused by misinterpretation of signs, and to the effects of "group-binding" caused by the interest in finding relatives before being evacuated. The expected delays and counter-flows in the mustering process was later tested against a large scale mustering exercise with 600 passengers, but the results have to be evaluated and adjusted through the knowledge gained from real accidents as well as general knowledge about crowd behaviour in emergencies.

Introduction

This paper is about the methodological problem of obtaining information about the emergency behaviour of ferry passengers in the context of mustering and evacuation. For obvious reasons trained observers cannot plan to be present during real accidents. We therefore have to rely on theoretical assumptions and different forms of indirect evidence about passenger behaviour. In the MEPdesign project we had the unique opportunity to compare predictions about passenger behaviour and mustering time with a large-scale mustering exercise at sea with about 600 passengers. The exercise was made possible by Scandlines Denmark who, as a partner in the project, made the Ro-Ro ferry m/f Kronprins Frederik available for the exercise. It is perhaps tempting to understand a comparison between prediction and exercise as one between "theory" and "reality", but this is where the major methodological problem arises from the Human Factors point of view. The reality of the exercise does not directly correspond to the reality of real accidents – or only to a certain subset of accident scenarios. Furthermore the theory from which the predictions were made, did also include empirical observations on walking speed, way-finding errors and effects of "group binding", and these observations are valid independent of the data of the single exercise. This theory/reality issue is a first methodological problem.

The theoretical assumptions and empirical data were used as input to the EVAC simulation model developed by Quasar and the purpose of the comparison between the predictions of the model and the data of the exercise, was also to evaluate the predictions. It is however not possible to validate a simulation model through a single test (the exercise) and it is not feasible to run a large series of mustering or evacuation exercises to test the model. This validation issue is a second methodological problem. With regard to both problems my conclusion is, that it is not enough to correct the model through the reality of the exercise. It is also necessary to correct the reality through knowledge, i.e. to correct (our understanding of) emergency behaviour as seen in exercises through knowledge of passenger behaviour in real accident scenarios.

Empirical data prior to the exercise

It was an assumption of MEPdesign, that delays and counter-streams to mustering can occur as an effect of "group-binding" caused by the interest in finding relatives before being evacuated. The mustering crowd will ideally be under the instruction and control of the crew, but as a consequence of group binding some passengers will break away from the crowd, and they can subsequently be subject to way-finding errors. In the event of an accident on a passenger ship that results in a decision to muster the passengers, group binding will initially be encountered by the crew in the form of *non-compliance* with instructions: some passengers will refuse to leave a particular place, where they had an agreement to meet again with relatives, and other passengers will refuse to go directly to the assembly station because they want to search the ship for their relatives. These parameters are not usually taken into account in evacuation simulation models.

In MEPdesign it was attempted to stipulate in advance the extent of the effects of group binding in the Baltic Sea area under consideration. Data was obtained from 4 different ships on 3 different routes in order to give an impression of the variance: the Scandlines ferries m/f Kronprins Frederik (KF) on the Gedser-Rostock route and m/f Prins Richard (PR) on the Rødby-Puttgarten route and two ferries from Bornholms-Trafikken, m/f Povl Anker (PA) and m/f Jens Koefoed (JK), both on the route Copenhagen-Rønne-Ystad. The extent of group binding will be dependent on the *composition of the passengers in social groups* and this would vary with the purpose of the voyage, which to some extend can be generalised for the different routes and the particular departure time and season. At the time of the survey for instance, the Scandlines routes to Germany had tax-free sales and social events targeted mainly for the unemployed or retired population, and this was reflected in the social composition of passengers on the day-time departures, that often included groups of friends on a shopping tour and large groups of older passengers participating in social events on the ferry. From an analysis of ticket sales information available from Scandlines and from interviews and a large-scale questionnaire survey involving over 1000 passengers, it was found that 4 different categories of passengers should be distinguished: *singles, couples, extended families* and *groups of friends*. Groups of friends could typically be adult groups of a size from 2 to 7 or similar groups of teenagers travelling on their own or as part of school class. Larger groups would tend to split up and reorganise into smaller groups when on board the ship. Couples were defined as passengers travelling with their partner or spouse, whereas extended families was defined as couples or single parents (or grandparents) travelling with children and/or elderly family members (over 60). Information about age, sex, nationality, the size and the type of the group travelling together was obtained along with information about disabilities (walking disability, impaired hearing) and relevant diseases (asthma, heart trouble) on the 4 different ships and for all departures over a 3 day-period. For more details, see (May 2000). In the survey passengers was also asked about what kind of meeting agreement they made, when splitting up, if they would follow instructions from the crew in case of an emergency on board and if they had trouble finding they way on the ship. This type of information is of cause not to taken at face value, but the information was analysed on the background of structured interviews with a subset of the passengers.

In comparing the different types of ships and routes, one significant difference was, that on the shorter voyages with the Scandlines ships (KF & PR) about 75% of the passengers made meeting agreements when splitting up, whereas only half of the passengers on the longer voyage to the Island of Bornholm (with JK&PA), which involves spending the night in cabins or other rest areas, made such agreements. This was in spite of the fact, that the amount of people that did not know where their fellow travellers were at the time of the interview or questionnaire was considerable higher on JK&PA (30%) than on KF&PR (about 7%). This exemplifies the variance that should be expected across different types of voyages, different types of ships and routes, and the corresponding differences in the composition of passengers and their attitudes and behaviours. The passengers on the Scandlines routes were mainly “leisure travellers” with a focus on shopping and social events, whereas the passengers on the route to and from the island of Bornholm were more “professional travellers”, who seemed more “individualised” during the voyage. These different styles of travelling will influence group binding in the event of an emergency.

In order to stipulate the extend of group binding on the different ships the proportion of passengers who expressed a wish to find others before being evacuated was taken as a point of departure. We did however ask the same question in another way, stressing the fact, that they might have to disobey instructions from the crew. This reduced the proportion because some people will tend to follow authoritative instructions, but in fact another reduction is necessary to arrive at the subset of passengers with a potential for group binding effects, because they have to travel in one of the relevant group types in order to be affected by group binding, i.e. as a couple or as part of an extended family. Singles are not affected and groups of friends will tend to decompose into smaller groups or individuals during an emergency, since it is expected that others can take care of themselves. In fig. 1 these findings are shown in graphs. The ships PR, KF and JK&PA have been arranged in the order of growing complexity and increasing number of compartments (which affects the probability of separation from others as well as way-finding errors). JK and PA are structurally identical ships sailing on the same route and their data is therefore considered as for one ship. The first reduction is from the expressed ideal wish to find travel companions (upper graph) to the willingness to act against instructions from the crew (middle graph). The second reduction is the subset of those who will not comply with instructions, who is also presently travelling as a couple (category II) or as an extended family (category III), where there is an emotional bond and a real responsibility for others. The resulting proportion is thus reduced to about 30%. The difference between PR&KF and JK&PA turned out to be levelled out in the reduction: even though a considerable smaller proportion of passengers on the Bornholm route wanted to find others before being evacuated (consistent with the smaller proportion of meeting agreements), there was a larger proportion of passengers who indicated non-compliance; although the “professional travellers” were more individualised, they also expressed fears about what would happen in an emergency and less trust in the ability of others to cope on their own and in the efficiency of organised evacuation.

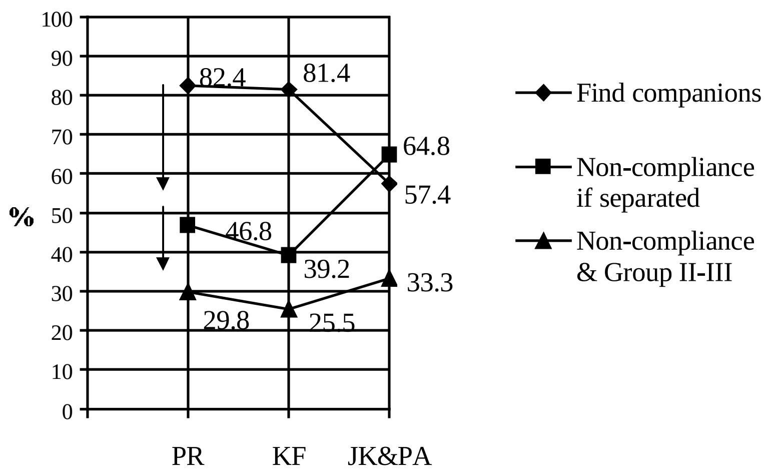

Fig.1. Reductions involved in estimating the effects of group binding.

In order to arrive finally at a stipulation of the extent of group binding, the proportion of about 30% have to be reduced further, since we also have to take into account that group binding only occurs if a group is *actually separated* at any given time. If passengers are in visual contact they are not effectively separated, because they can communicate. On ships with a simple layout like PR a passenger could be in a shopping area and still be in contact with family seated in the café area on the same deck, for instance, whereas passengers in the shop on KF would be in the aft part of the ship on a lower deck and usually separated from family seated in the middle or fore section of the ship or even on another deck.. It was difficult to assess the probability of separation, but from observations it was estimated to be about 0.2. The probability of group binding effects for passengers would be the product of the probability for non-compliance for the relevant social groups (as calculated in the lower graph of fig. 1) and the probability for these passengers to be separated at any given time during the voyage, which could be the time of an emergency:

P (Group binding) = P (Non-compliance) * P (Separation)

Prior to the exercise we therefore estimated that 6% of the passengers would be affected by group binding or expressed as probabilities 0.30 * 0.20 = 0.06.

With regard to the different initial strategies passengers would tend to apply in an emergency, many passengers believed they could remain seated in an area, where a meeting agreement was established. The second most popular strategy was to search the ship. Some passengers imagined that it would be possible to require information or assistance from the crew in finding others during an emergency! All strategies would slow down the process of mustering. For details see (May 2000).

Passenger flow during the mustering exercise

Apart from the initial stipulation of group binding effects, another set of stipulations were made to serve as input to the EVAC simulation model. Quasar was responsible for running a simulation of the mustering prior to the exercise in order for the project to be able to evaluate the predictions of EVAC relative to the observations and recordings made during the exercise. In order to arrive at a realistic prediction a paradox was encountered with regard to group binding: counter to the stipulations reported earlier, it was assumed that no group binding effects would be effective during the exercise! The reason for this was that passengers in real emergencies will behave differently than during an exercise. In the exercise on m/f Kronprins Frederik the only examples that could give rise to group binding effects occurred at the shop, which was closed after the sounding of the alarm, thereby separating some parents from their children outside the shop (but with visual contact and communication).

The obvious problem of *realism* in mustering and evacuation exercises has been reported in earlier exercises, for instance on Stena Invicta in Dover harbour. MCA reported that “the evacuation was conducted far to slowly with no sense of urgency from crew or passengers” (MCA 1996). In the full evacuation of the Stena Invicta exercise 842 passengers and crew were assembled with life-jackets in 20 min. and the abandonment phase of the evacuation (using the MES) took another 65 min. In real accidents there will generally be some perception of real danger by the passengers: if there is a fire, there will be smoke in some part of the ship; if there is a collision, passengers will usually (but not always) feel the impact and there can be a perceivable ship list. *The perceived danger and felt urgency changes everything with regard to the behaviour of passengers*. It should of cause be stressed, that too much realism in evacuation exercises will create real dangers for the passengers. Evacuation exercises for the crew alone have already proven to be a safety hazard. Prior to the exercise, the mustering time was predicted by the EVAC program based on assumed conditions discussed with Scandlines and Danish Maritime Institute (DMI). These assumptions proved to be reasonably correct. The predicted mustering time was 20 min, while the time for the exercise was 24 min. This can be considered a reasonable correspondence. After the exercise some adjustments were made to the model and the initial conditions (the distribution of passengers was changed according to observed values and the distribution function for delays at assembly stations was increased) and the EVAC simulation model was again tested 20 times with the exercise data giving a mean value of mustering time of 23.45 min.

In fig. 2 the layout of the relevant decks on KF can be seen as well as the points of observation (“invisible man” icon), video-recording (video camera icon) and electronic recording stations (server icon). For details see (May, Jørgensen & Østergaard 2000 & 2001a). Assembly stations are labelled A (on deck 5/7) and B, C, F and E (on deck 9). From electronic counters passenger flow was obtained. Fig. 3 shows the number of passengers per minute being guided from the Baltic Room area to assembly station “A” on deck 5/7 counting from 1. minute (= mustering alarm at 21.19) to 25. minute (= end of exercise at 21.43). Dark = port side exit (PS), light = starboard side exit (SB). Total mass count of passengers from the area was 219.

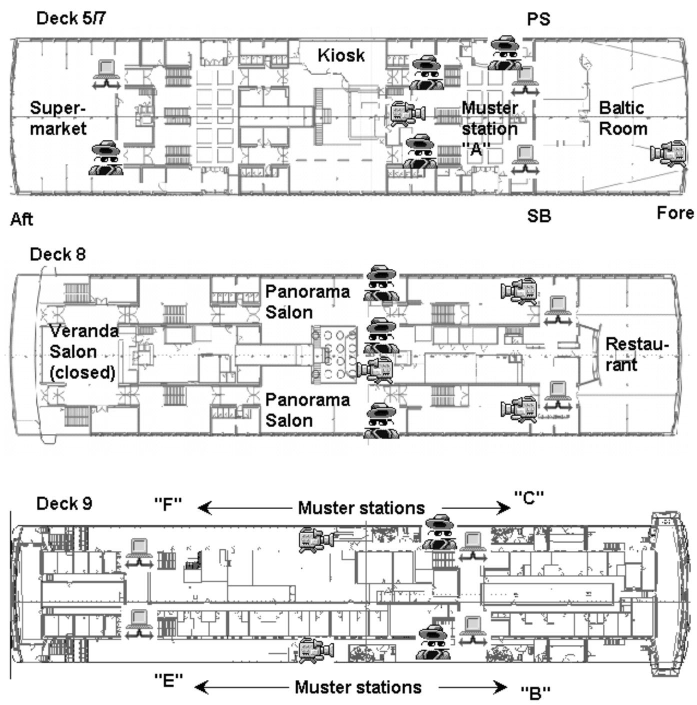

Fig. 2. The decks on m/f Kronprins Frederik involved in the exercise.

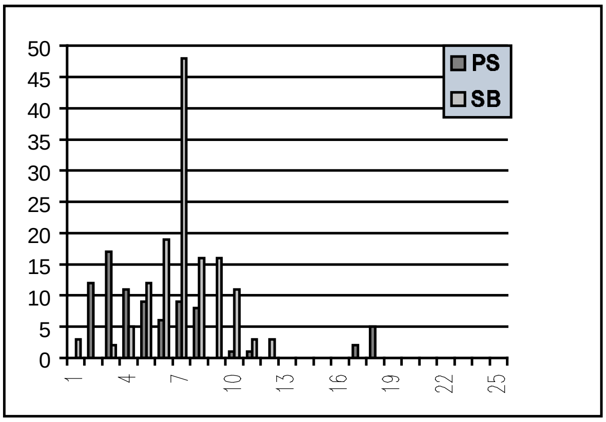

Fig. 3. Passenger flow from Baltic Room during the exercise

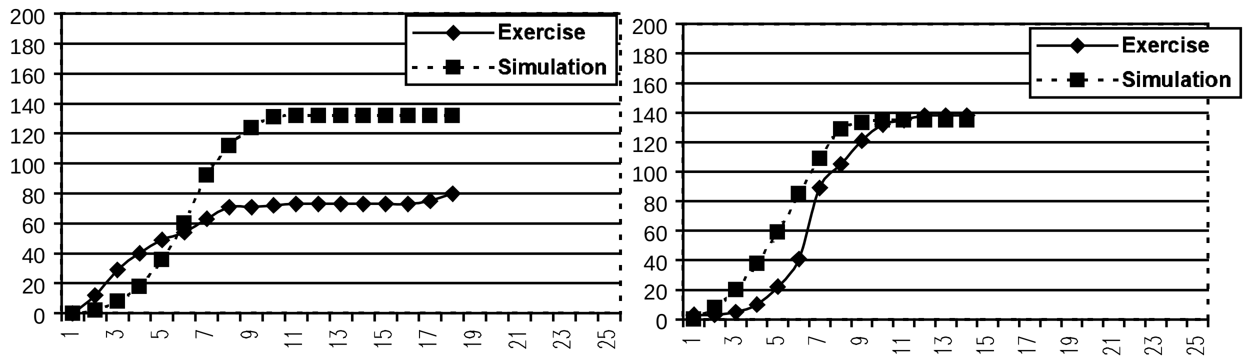

Fig. 4-5. Cumulative graphs for passenger flow from Baltic room, port side (left set of graphs) and starboard side (right set of graphs)

In fig. 4-5 the passenger flow data from the exercise and the simulation have been compared. In the starboard side the simulation follows the exercise data very closely, but on the port side the simulation assumes a normal distribution that does not correspond to the data. On the deck above, the simulation data for mustering from the Restaurant area fits very well with the exercise data (not shown here, see May, Jørgensen & Østergaard 2001b). Assembly A on deck 5/7 takes place two decks below mustering on deck 9, from where all passengers will eventually be evacuated. This means that passengers who happen to bee in the Baltic Room area at the time of an accident, will have to muster here and await the mustering and evacuation of the rest of passengers assembled on deck 9. A "delay" is imposed by the crew and the ship layout as an extra waiting time (after the passengers have put on their life-jackets), because there is not room on deck 9 for them until the abandonment phase have been initiated. Passengers from Baltic Room were all assembled at A in 11 minutes counting from the alarm and the process of putting on life-jackets (overlapping in time with mustering) was finished 5 minutes later. The imposed waiting time was 3 min. counting from the time when the last passenger had put on the life-jacket. The imposed waiting could pose a problem with *non-compliance* in a real emergency, because some passengers would be afraid to be the last ones evacuated from the ship or because they would insist on finding relatives first and thus be left to find their own escape route through the ship.

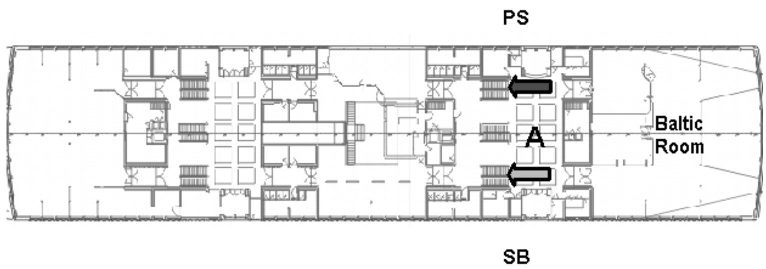

Fig. 6. Flow from assembly station A up the stairs to deck 8 & 9.

The flow form assembly station A up the stairs (fig. 6) to deck 9 have been recorded as shown in fig. 7 for port side stairs (dark) and starboard side stairs (light). Because of this delay in the flow of passengers from A, the recorded flow to assembly stations B and C on the fore part of deck 9, consisted in two waves of passengers: the first flow coming from the restaurant area below on deck 8 (see fig. 2) and the second flow coming from the Baltic Room area on deck 5/7.

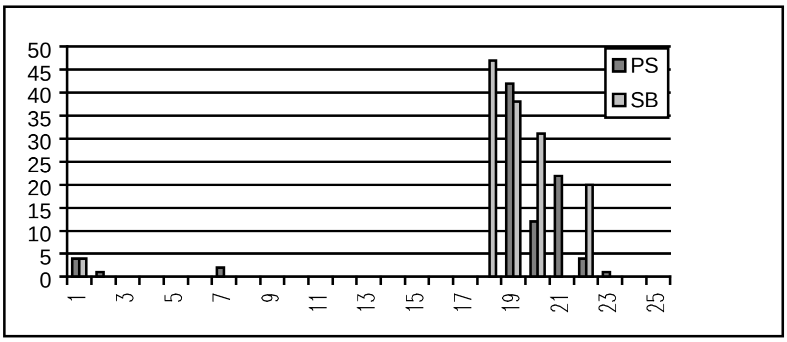

Fig. 7. Graphs for passenger flow from assembly station A up the stairs to deck 8 & 9.

The flow to deck 9 at assembly station B and C (see fig. 8) is shown below in fig. 9-10 for the exercise and the simulation.

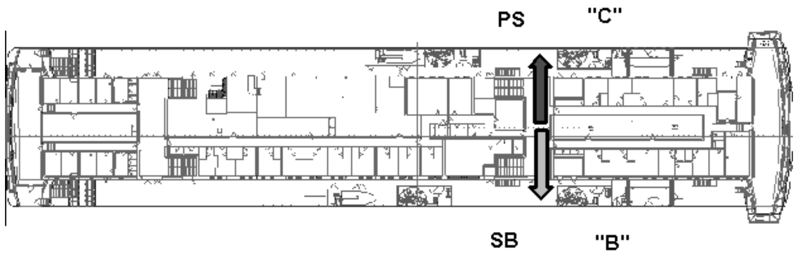

Fig. 8. Flow to fore part of deck 9 at assembly B and C

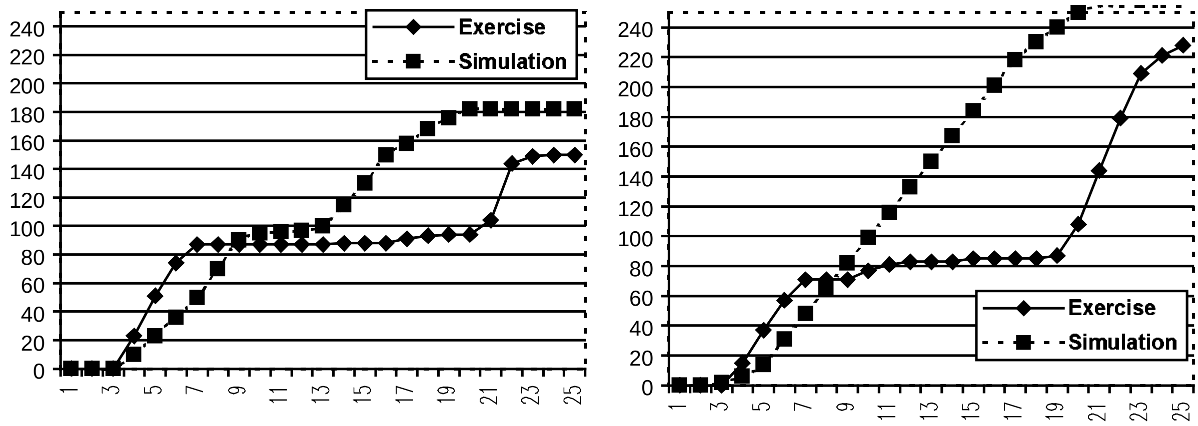

Fig. 9-10. Cumulative graphs for passenger flow to the fore part of deck 9 at port side (left) and starboard side (right).

The EVAC model cannot at present simulate the structurally determined composition of the flow in two waves from deck 8 & 5/7, but assumes a more constant and evenly distributed flow. The simulation does not mimic the process of mustering in detail although it produces a close fit for the overall mustering time (see May, Jørgensen & Østergaard 2001b). It is also important to recognise that the model cannot be validated through a single exercise. It is however necessary to know, what would happen under different circumstances. Important questions are what predictions would arise for:

- a rising number of passengers up to the maximum allowed for a given ship
- different values of ship list and ship roll movement
- different types of passenger vessels such as HSCs and Cruise Ships
- other types of simulated accidents (not collision as in the case of KF, but fire where smoke would reduce visibility and fire doors would be closed)

A major concern is how the model would perform under circumstances where *group binding effects, way-finding problems or even panic could occur*. In the exercise these effects were not seen to any measurable extend, but they could occur under other circumstances. The exercise that took place on the 28th October 2000 on KF does give a realistic estimate of assembly time under the given favourable conditions. Real evacuations do of cause also occur under favourable weather conditions, a recent example being the evacuation of over 1300 passengers from Prinsesse Ragnhild in Skagerak 1999 following a fire on board. One elderly person died from a heart failure

after the evacuation, but otherwise there was no causalities. This was a happy case of evacuation, but the conditions were also favourable: visibility was good, the weather was nice, the event took place close to a large city (Göteborg, Sweden) and there was no panic among the passengers – some singing the tune from the popular movie "Titanic", while being evacuated!. All evacuations cannot be expected to happen under such favourable conditions and knowledge of Human Factors aspects learned from real accidents (i.e. under less favourable conditions) should therefore be build into the simulation, when evaluating future ship designs through simulation of evacuation time. This was done to some extend in the MEPdesign project, but due to the circumstances of the exercise Human Factors parameters like group binding or ship movement dependent walking speed (with experimental data provided by TNO) could not be tested. The evaluation and validation of evacuation simulation programs, of which EVAC is an example, should in general include considerations of *different scenarios* in order to estimate evacuation times under radically different conditions –
such as would be done in Formal Safety Assessment (FSA).

Assumptions about emergency behaviour of passengers

As stated earlier, the perceived danger and felt urgency changes everything with regard to the behaviour of passengers. During the exercise on m/f Kronprins Frederik parents did not care to go look for their children because they knew that there was no real danger. In a real accident parents cannot be trusted to comply with instructions from the crew, if they are separated from their children (or elderly family members). In other words: we have to correct the reality of the exercise with knowledge of human behaviour under real emergencies.

Group binding have been described in earlier research in the context of sociological aspects of disasters and evacuation of citizens from disaster areas. Ronald Perry established a model of *compliance behaviour during evacuations*, where the focus is on the individual definition of the situation with respect to several parameters of a perceived warning (confirmation, credibility, content), the perceived risk, the possession of an action plan, and the family context. The family context here refers to the extent to which family members are safely accounted for at the time of a warning: "unless family members are safely accounted for, citizens will not comply with an evacuation warning" (Perry 1994).

There are however many misconceptions about crowd behaviour. Perhaps as a reaction to the misuse of the term "panic" in the media, reports like (Habst & Madsen 1992) on ferry passengers have been influential in re-evaluating previous fears about panic (that have been known to lead to an attitude of withholding information about emergencies from passengers), with the result that panic is now often considered non-existent in emergencies. This is not a true picture. Crowd behaviour in ship accidents will be dependent on the nature of the accident and the circumstances it produces for escape (visibility, smoke, list, flooding etc.), the level of information given by those in command, the perceived risk, the family context and the time available for escape. The figure of 1-3% given by (Habst&Madsen 1992) for panic reactions is based on invalid generalisations over different types of accidents and refers to a psychiatric conception of panic states as an individual reaction, i.e. not to a type of crowd behaviour. Panic needs to be addressed as a real issue but on the sociological level of a particular type of crowd behaviour ("escape crowds"), which will occur under certain circumstances and can be prevented under other circumstances as well as through rational *crowd management* and *crowd control*.

Crowd behaviour is often understood as a homogenous entity. Quite the contrary it is vital to rational crowd management and crowd control, that distinctions are made about crowds and circumstances of crowd behaviour (Berlonghi 1993). Classical work on collective behaviour (Brown 1965, Smelser 1962) will at least give reasons for distinguishing passive crowds (*spectator crowds*) from active crowds, and to differentiate active crowds in *hostile crowds* ("mobs"), *escape crowds* ("panic"), *acquisitive crowds* ("crazes") and *expressive crowds* ("mass hysteria"). Using detailed case histories it should be possible to evaluate different conceptions and models of crowd behaviour. An example is the case studies on escape crowds by (Chertkoff & Kushigian 1999). For the cruise and ferry industry a re-evaluation of the implicit assumptions made about emergency behaviour of passengers (Poole & Springett 1998), could be an important safety commitment.

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