Evacuation of Buildings—Practice Makes Safety

GUNVOR HALLBERG
The Royal Institute of Technology
S-100 44 Stockholm, Sweden

ABSTRACT

Swedish fire protection regulations are very strict and their application - especially when they require structural alteration - involves considerable costs. Despite that strictness, people are injured or lose their lives in buildings whitch comply with the regulations of the law. Can it be that these regulations are built on behavioural assumptions which don't agree with the actual acting of man? Fire protection regulations have grown out of usage and of experience with "disasters". They seldom use knowledge from behavioural science or building function analysis. Our aim is to provide such knowledge by observing peoples' actual behaviour in evacuation exercises.

Evacuation plans are drawn up for a lot of buildings. Underlying all such plans there are also assumptions as to how people will behave when danger threatens. By analysing the course of events in evacuation drills we think that the possibility of judging whether the assumptions about behaviour are correct will improve. An evacuation drill makes the participants aware of the fact that there are evacuation problems and that there may be obstacles for a safe evacuation. Documentation and evaluation of evacuation exercises is important so the experiences from the exercise can be serviable to more than the participants.

INTRODUCTION

The main purpose of the building legislation in the fire protection field is to protect people in case of fire. A building is to be so designed that people shall be able to leave it quickly and effectively when there is a threat of fire or other danger. Swedish fire protection regulations are very strict and their application - especially when they require structural alteration - involves considerable costs. Despite that strictness, people are injured or lose their lives in buildings which comply with the regulations of the law. And we wonder why.

It seems plausible to seek the reasons for this in defective knowledge of human behaviour and in technical solutions which do not accord with human behaviour and characteristics. Both fire regulations and technical solutions for fire safety presume - explicitly or unexplicitly - a certain human behaviour. To what extent is it known whether this

FIRE SAFETY SCIENCE—PROCEEDINGS OF THE SECOND INTERNATIONAL SYMPOSIUM, pp. 531-540

presumed behaviour accords with reality? Planning practice is based on the assumption that behaviour can be manipulated through the design of the physical environment. Can this assumption be tested by research?

Studying the human behaviour in actual fires is a way to verify assumptions of behaviour in emergency situations. This method has been used in countries as USA, England etc. It is a hard method. To observe and analyse the human behaviour in evacuation exercises is another method tested by us. We have found that people in certain situations have behaved in the same way in drills as reported from actual fires. That is e.g. the choice of escape routes. People prefer a familiar route to an unfamiliar one. (Sime, 85)

Both methods are aimed to improve the safety in buildings by means of adapting the regulations and the education methods to people's capability and behaviour in emergency situations.

Evacuation plans are drawn up for a lot of buildings. Underlying all such plans there are also assumptions as to how people will behave when danger threatens. Whether people will act in accordance with these assumptions in an actual emergency cannot be tested. By recording actual behaviour in evacuation exercises one obtains at least some check of their validity. For if people do not act in accordance with the evacuation plan when evacuation takes place quietly without threat, we can hardly expect the assumptions to be verified in an actual emergency situation.

In evacuation exercises the performance and rapidity of the rescue and fire services are evaluated, but not how the occupants' actual behaviour accords with the evacuation plan other than how quickly the building has been emptied, that is if the safety of evacuation is adequate. How the occupants have got out, what difficulties they have had, which routes have been taken, any congestions, etc, are not usually recorded. There is no law and no requirement in the Swedish Building Code to accomplish evacuation exercises. Nor are there any demands for evacuation plans for buildings in the Building Code. For working sites there are some indistinct demands both for exercises and plans but they can be interpreted quite freely.

METHOD

We have observed and documented a series of evacuation drills in different types of buildings - care homes, office buildings, hospitals e.g. By analysing the course of events we think that the possibility of judging whether the assumptions about behaviour are correct will improve. Our recordings of exercises are based on evacuation plans, exercise plans and documentation plans. Behaviour is recorded by means of video, photography and records of observations.

There are different kinds of evacuation exercises. In most cases a fire drill intends only clearing out certain premises, informing the staff on which measures they shall take in the case of fire and some practice in handling fire appliance. The most extensive drills are the exercises in co-operation between all the rescue institutions of the society. Such great exercises are unusual. We have observed one exercise of this kind. It was the evacuation of the ancient theatre of Drottningholm. Our task was to document how the evacuation plan accorded with

the acting of the audience and the staff.

Co-operation drills in a smaller scale are the exercises in rescuing patients and staff of hospitals and buildings of a similar kind. The co-operation concerns the united actions of the fire services, the police, the ambulance staff and the staff working in the building. The exercises often take place in buildings which are going to be pulled down or rebuilt. Then it is possible to make the rescue work realistic, including making a real fire and a lot of smoke. We have documented three such rescue exercises. They were part of a series in two hospitals and with different forces of the fire-brigade.

A third type of exercise is part of the training of staff in fire protection. That is the staff of the hospitals, and board and care homes, and so on. The education consists of theoretical instructions. We have taken part in three such evacuation drills at care homes for old people.

A forth type of evacuation exercise is accomplished in buildings where many people are staying every day e.g. as pupils or employees. The purpose of the drill is to test the fire preparedness especially the correctness of the evacuation plan, the knowing of escape routes and alternative routes, the required time for evacuation compared with the presumed time accessible before the escape routes may be blocked up by smoke or fire. We have analysed one exercise in a high office building and one in the school of architecture.

In the following matrix the critical features of the buildings and of the populations are shown. Together with this information the drill conditions and the course of events during the observed drills appear from the matrix. Altogether we have observed nine evacuation exercises in seven occupancies of five different types.

Critical Features of the Building and Evacuation Plan	Critical Features of the Population and Exercise Plan	Course of Events at the Evacuation Exercise	
The theatre is a wooden building from 1766 divided by a party wall into two fire areas: The auditorium and the stage house. Decorations, curtains, wall papers and theatre dust are highly inflammable. There are lots of exits from the auditorium. For the evacuation of the rear part of the auditorium on the second floor trucks with extensible staircases are put to the windows at every performance. Fire men are always on the spot. In a booklet, distributed to all staff, security provisions, duties and the evacuation plan are given.	The auditorium takes 450 persons. They were invited to a rehearsal of an opera. Two people in weelchairs should be placed in the aisles. 120 student nurses should act as injured and stay in the building after the evacuation. On the stage five singers should be accompanied by a pianist. There should be no orchestra present. The fire should start behind the stage. A smokeproducer was placed there. All people present would know that an evacuation exercise should take place.	After 45 min. of the performance, smoke began to ooze from the stage floor. The performance was cut off and the theatre manager asked the audience to leave the theatre peacefully and quitely. Some in the audience got up by the order "evacuate" and began to move towards the exits. Many hesitated seeing some persons remain sitting. Those sitting were persons who were going to act as injured. Nobody in the audience was in a hurry. There was no congestion. No exits were blocked by smoke. 3 min. after the order of evacuation all people who was supposed to leave the auditorium by themselves had done so.	THEATRE
A three-storeyed wing of a group of hospital buildings had served its time and was going to be pulled down. Horizontal evacuation was not possible. Dependent on the condition of patients, the spread of fire and smoke the patients should walk or be carried through corridors and down the stairway. If this escape route is not passable they should be rescued through the windows by skylift.	Observed drills were two out of a series of eight. At every occasion different parts of the fire service were training rescuing patients and the co-ordination of actions. Students should be acting as patients made up as injured by the fire. Nursing staff should participate too. In the wards on the 2nd and 3rd floor there are 20-25 "patients". Many of them are in plaster or so badly ill that they can't walk. No alarm should sound. The building should be filled with smoke.	A real fire was lighted strengthened by artificial smoke in the attic. 5 min. later the smoke pressed into the wards. The "patients" knew little about their originally "illness". They were supposed to stay in bed waiting for rescuing. But everybody got out of bed to look outside. They waited on the window-sill to be fetched by the skylift at the first drill. So the evacuation time was short. On the second occation the evacuation time was twice as long as the patients stayed in bed. Besides that some of them "fainted" and some "got fussy".	HOSPITAL I, two drills

The hospital building was going to be totally repaired and enlarged. Horizontal evacuation of patients and staff to a collecting point on the same floor is planned. Persons in obvious danger should be rescued at once, but most of the patients should together with the staff wait for the rescue force within the rooms. The smoke divers should take them out. The doors should remain closed until then.	The observed drill was one out of a series of four. A ward division on the 4th floor should be filled with smoke. The nursing staff should be acting as patients and staff on duty. They should be made up as injured. The "patients" are informed of the reason for their stay in hospital. There are 12 patients, 2 visitors, 4 staff and 2 manikins representing dead persons to be evacuated.	When the fire started - there were open flames from a liquid gas burner - one of the staff ran out from the ward and pressed the fire alarm button in the stair well. The hole corridor in the ward was filled with smoke. The observers were sent out from the ward to the stair well. Then the first fireman was seen A fire-hose filled with water was dragged through the doorway into the ward. The door remained open and the stair well was filled with smoke too.	HOSPITAL II
The building has the form of an E with the dwellings on the first and second floors in the wings. The wings are connected by a passage. At an emergency the residents should evacuate horizontally to another wing on the same floor. In the dwelling wings there are smoke detectors in the corridors. They start the automatic alarm to the fire station. When they react the doors to the dwelling corridors are closing. The staff know then that something has happened and they are supposed to go to the alarm board at the main entrance. On the board is shown where the alarm has been started.	There are 70 residents in the care home. Besides them many pensioners from the neighbourhood spend some time in the building during daytime. On the first floor there is a lobby, a restaurant, a library and hobby activities. As a part of the training in fire protection the warden of the care home and the fire service organized an evacuation drill. Neither the staff nor the residents knew the point of time for the drill. The drill was supposed to include only the 12 dwellings along one corridor on the 2nd floor in one wing. Most of the residents need some help to move. A smoke producer placed in the pentry was supposed to block the exits in this part of the corridor by artificial smoke.	Seven residents were in their rooms when the drill started. No staff was present for the moment in the dwelling department. Personnel came running - four of them from the smokeless direction. 15 passed through the artificial smoke. A deliberation started on the proper first action: Evacuate the residents or shut the doors and wait for the firebrigade? They decided to evacuate. When the upper floor of the wing in danger was cleared, the evacuation continued to the whole care home. This was not planned. Most of the residents were carried downstairs meeting the rescue force with its filled fire hose in the main stairway. During the whole rescue work the activities on the 1st floor went on as usually at the biljard-table, in the restaurant, etc.	CARE HOME for the aged, I

The 3-storeyed building is quite newly built and not yet in use. It is a nursing home and built according to those provisions of fire protection applicable to nursing institutions. Each floor is divided into three fire compartments. For the vertical communication within the house elevators are used. There is also a winding staircase, width 110 cm. There are two emergency staircases opening out to the ground. In the corridors are smoke detectors as well as alarm buttons and a graphic evacuation plan. The alarm is directly connected with the fire station.	There is place for 58 residents or patients. On the 1st floor there is a restaurant and hobby activities. After a theoretical instruction in fire protection the staff got practical training in two drills - one corresponding to the situation in daytime, one to night conditions regarding the number of personnel on duty. The staff should act as patients as well as personnel. During the "daytime drill" some patients should wander about, some resisting being evacuated. During the nighttime drill they should be in bed. A smoke producer should fill the place with artificial smoke.	At both drills the "fire origin room" was quickly emptied by the staff. In the daytime drill the staff tried to keep the "patients" in their rooms awaiting the rescue force behind closed doors. But the patients came out again at once, wandering about in the artificial smoke. 10 min. after alarm the divers started the evacuation. Fire-hoses were dragged into the ward department, but they were never filled with water. Some patients were brought down to the ambulance through the stair well. With a great deal of trouble the bearer turned the stretchers through the spiral staircase. Also the elevators were used.	CARE HOME for the aged II
The 14-storeyed building was erected in 1980. The extension ladders of the fire service do not reach the six upper floors of the building. The two stair wells are closed. There is no claim for automatic alarm or emergency lighting in the stair wells in office buildings. Torches are available. Each floor contains two fire compartments. The alarm is only heard on the same floor where it has been started. The fire brigade should on there arrival decide whether people on other floors should evacuate or not.	The occupants of the 6 top floors are 150 persons. Two disabled persons should be exemted from the drill. Three persons on each floor are chosen safety officers of the floor. Their task is to alarm the fire brigade, to control that everyone have escaped and shut windows and doors. At the evacuation drill the alarm should start on the 10th floor. The safety officers should alarm the other top floors. The safety officers were well informed of the evacuation drill. The other staff know that a fire drill should take place sometime during the week.	The alarm sounded at 2 p.m. A fire man kept watch in a stair well filled with smoke, driving off people trying to escape this way. In the other stair well the elevator was switched off. The safety officers were on spot anxious to alarm quickly. Other staff seemed to have figured out when the drill should be effected. They were also ready. Everybody started at once. The fastest to set off for the exit were three cleaners. They were ignorant of the drill. After some minute the stream of people became thick in the staircase. There was no congestion neither in the staircase nor at the exits. The evacuation time was 4.5 min.	OFFICE BUILDING

It is difficult to orientate oneself in the 5-storeyed building. The two stair wells, width 140 cm, are situated far from the main entrance. In connection with the entrance there is a glass surrounded spiral staircase, width 83 cm. This serves as main communication route.

The milieu is rather inflammable. Art class rooms, workshops, studios and laboratories are filled with model constructions, pieces of cloth, sketch papers and decorations. There are candles, homemade electric fittings. Parties are often arranged.

There is a graphic evacuation plan put up all over the building. On the 1st floor there are firewalls closing automatically when the alarm starts. There are many heat detectors and some smoke detectors and acoustic alarm.

There are at least 300 occupants in the school in the daytime, students, teaching staff, researchers, technicians and visitors.

There has been many false alarms, so people are unwilling to evacuate just as an exercise. An evacuation drill was planned to test if the occupants behaved according to the evacuation plan. The idea was that fire should start in one of the stair wells. A minute after the alarm sounding the light should be switched off.

The exercise was kept as secret as possible. The observers stayed as by chance in the two stair wells and at the spiral staircase.

The alarm was started, but not until the lighting went out people started to evacuate. You are supposed to continue from the 1st floor downstairs to the garage under the building and then out to the street on the same level. Normally very few students use this exit.

In the staircase it was quite black. The corridor at the bottom of one of the stair wells was occupied by loading stools with paper bundles. There was only very narrow passages in some places. The loading stools were invisible in the dark. The top as well as the end of the staircase was impossible to discern since the photoluminescent spots at the floor level were hidden by people. The spiral staircase, not supposed to be used for escape, was taken by a number of 50 people. They went the route they used to go. Many persons had not noticed the graphic evacuation plan or had not studied it in detail.

RESULTS

We have made observations of behaviour that accords with the assumed behaviour and of behaviour that did not. The observations concern reactions on alarm, first measure when detecting a fire cue, choice of route when evacuating, the extent of the evacuation, reactions on the exercise, distribution of tasks, behaviour depending on the interpretation of the evacuation plan and in connection with technical solutions. Here are some results:

- In an exercise people will react quickly to the alarm, provided that the exercise is part of the protection education of a staff or if the exercise is expected. If people don't know that it is a question of exercise they will wait for other fire cues in addition to the alarm bell sounding.
- How soon the reaction will come depends on surronding people - if and how they will react. A longer delay may be expected in premises where people do not know eachother than in working sites.
- If there is a discrepancy between verbal and written instructions confusions probably will arise and there will be discussions delaying important measures.
- If there is some uncertainty of the tasks of different personnel categories in an emergency situation then the start of the evacuation will be delayed.
- People prefer a familiar route to an unfamiliar one. Many studies of peoples' acting in real fires have shown that (Sime, 85). People do so even in exercises without trying alternative routes. These facts are true particularly in darkness. Without evacuation training people don't choose escape routes guided by the graphic evacuation plan. At an evacuation drill it happens that someone uses the elevator.
- Artificial smoke do not stop people. People have walked through artificial smoke in those documented drills of ours where artificial smoke has been used. The most important reason for using artificial smoke is to create a stressing athmosphere in an exercise.
- Trouble can be expected if the escape route is the same as the effort route of the fire brigade.
- There are active as well as passive reactions on the tasks in an evacuation exercise, when the drill is part of staff education the staff immediately start with the measures they have learnt to start with. Even an announced and expected drill will have an early start. People want to be able and efficient. That is in a site where people know eachother, not in a public place like a theatre.
- A passiv reaction - that is when people allow themselves to be lead out without any comments - such a reaction will be expected among residents at care homes. But somebody may resist beeing evacuated.

DISCUSSION

Is it possible to predict the behaviour in actual emergency situations guided by the findings above? Only to some extent. We are here to a great deal depending on knowledge derived from studies and psychological experiments in other countries - in England, Canada, USA, Japan and West Germany above all. Such studies have shown that people are acting

according to certain behaviour pattern in emergency situations.

We presume that these statements are true in Sweden too. We have had no opportunity to test them in actual fire situations, so instead we have to confine ourselves to analysing evacuation exercises.

Training evacuation is important for many reasons. An evacuation drill makes the participants aware of the fact that there are evacuation problems and that there may be obstacles for a safe evacuation. Thereby it probably will give ideas for improvements and a better planning. A more carefully prepared evacuation plan will be tested in a repeated drill so the participants get routine and assurance in acting.

Testing combinations of technical and human tasks can be done simultaneously as a drill. It also goes for testing how technical solutions accord to the human behaviour.

When planning an exercise it is necessary to make clear some important things - such as what is the purpose of the exercise. That is what is to be trained and who shall be trained and how realistic will it be or how realistic does it need to be. Because the extent of realism is an important and difficult part of the planning.

Sometimes there are deficiencies in realism in certain respects and they are so serious that they will affect the outcome of the drill. For instance we have noticed a case when some persons were exemted from the drill: It was two disabled persons who were judged not to be incommodated because of their condition. Instead their condition and their possibility to escape should have been discussed and trained with special care.

Other seemingly petty examples are the exercises with empty fire-hoses. The fire-fighters nearly always bring their own fire-hose when approaching the seat of fire. They can't trust the local fire-hose to be functioning. An empty hose is not a barrier as a filled one is. Doors can be kept closed to the fire room as the hose is flat. So, the fire-hose shall be filled with water, if the exercise shall correspond to reality.

Obstructing details such as blocked exits and black-out should be part of the exercise plan. Artificial smoke is often used to increase the realism. But thick smoke has negative effects on documenting the course of events. Darkness and the amount of smoke as realistic complications of the exercise has to be balanced against the possibility to study the behaviour during the evacuation if that is one of the aims of the drill.

Documentation and evaluation of evacuation exercises is important so the experiences from the exercise can be serviceable to more than the participants and their training in rescuing and evacuation. Internal documentation are effected sometimes. More often they don't reach anyone outside what we may call the exercise circle.

Evaluation of exercises is important as basis of improvements and for comparisons between different exercises and between buildings and operations of similar type. Our experiences, gathered from observed evacuation drills aim to facilitate the planning, the realization and the evaluation of the evacuation drills. They may be complementary to the advice from the fire service for people planning evacuation exercises.

Studies of human behaviour during evacuation drills is part of the research project Evacuation Problems in the Built Environment financed by the Swedish Fire Research Board, BRANDFORSK. By studies of human characteristics and behaviour as the ground for building design we intend to improve the basis of fire protection provisions and the adjustment of technical solutions to people.

REFERENCES

1. Bryan, J., Implications for Codes and Behavior Models from the Analysis of Behavior Response Patterns in Fire Situations as Selected from the Project People and Project People II Study Programs, NBS-GCR-83-425, March 1983.

2. Johnson, B., Evacuation Techniques for Disabled Persons, National Research Council of Canada, March 1983.

3. Fire at the Dupont Plaza Hotel and Casino, NFPA fire investigation report, December 1986.

4. Keating, J.P., Human Response during Fire Situations, Dep of Psychology Ni-25, University of Washington, Seattle WA 98 195.

5. Latane, B. and Darley, J.M., Group Inhibition of Bystander Intervention in Emergencies, Journal of Personality and Social Psychology, vol 10 no 3, 1968.

6. Levin, B.M., Human Behavior in Fire - What we know now, SFPE Technology Report 84-3.

7. Okishio, S. and Handa, T., An example of human behavior in a wooden hotel fire, Fire Science Technology, vol 5, no 2, 1986.

8. Pauls, J., Evacuation Drill held in the B.C. Hydro Building, National Research Council, Canada 1971.

9. Pauls, J. and Jones, B., Building Evacuation - Research Methods and Case Studies. In D. Canter (ed) Fires and Human Behaviour chapter 13, John Wiley & Sons Ltd, 1980.

10. Seeger, P. and John, R., Evacuation Tests in High-rise Office Buildings and in Large 2-storeyed Buildings, NBS 80-2070, June 1980.

11. Sime, J., Movement toward the Familiar. Person and Place Affiliation in a Fire Entrapment Setting, Environment and Behaviour, vol 17 no 6, 1985.

12. Swedish Building Code, Fire Protection, Chapter 37, 1980. National Swedish Board of Physical Planning and Building.