# Safety challenges in train evacuation - How to keep passengers safe

**Lena Kecklund [1], Ingrid Anderzén [1], Sara Petterson [1], Johan Haggstrom [2], Bo Wahlstrom [2],**

*[1],MTO Psykologi, Stockholm, Sweden, [2],Brandskyddslaget, Stockholm, Sweden*

**Abstract**

Severe accidents in transport systems such as railways means mass evacuations often under time pressure, with immediate threats and in difficult circumstances, e.g. in case of a fire (e.g. HSE, 2001, Voeltzel, 2002). The frequency of such events is usually low but the consequences can be severe. However, mass evacuations occur quite frequently in situations where one or several trains are stopped because of track, vehicle or traffic management problem.

In these evacuations passengers and staff are exposed to risks such as the possibility of being injured by electricity or other trains passing. In these cases, where there is no initial or immediate threat to the people on board, the time spent waiting for evacuation can be long, and this can create new risks. If the environmental conditions are poor, the conditions for the people on the train can, over time, become uncomfortable and even severe due to e.g. high temperatures and crowding. When time passes, the tendency of the passengers to self-evacuate will increase.

The purpose of this study was to get a better understanding of the different types of evacuation situations that can occur as well as a better understanding of passenger behaviour by use of a system safety view addressing the interaction of Human, Technology and Organisation, and to identify areas for improvement.

The results show that areas in need of improvement are communication and reduction of time delay in taking the decision to evacuate as well as executing the decision.

Keywords: Evacuation, train, passenger, communication, risk

## 1 Introduction

### *1.1 Evacuation – what`s the problem?*

Severe accidents in transport systems such as railways means evacuations often under time pressure, with immediate threats and in difficult circumstances, e.g. in case of a fire. The frequency of such events is usually low but the consequences can be severe (e.g. HSE, 2001, Voeltzel, 2002). However, evacuations occur quite frequently in situations where trains are stopped because of track, vehicle or traffic management problems.

Research on evacuations from buildings has been more extensive as compared to research in transportation and has thus been used as a basis for developing scientific knowledge on evacuation behaviour. Mass evacuations in situations with severe threats has been studied in railway accident investigations (e.g. HSE, 2001) and also in evacuation exercises in difficult circumstances such as in subways and

road tunnels (e.g. Boer, 2005, Frantzich et.al., 2000, 2007).

There are special conditions concerning evacuation from trains compared to evacuation from buildings. The area outside the train involves risks. Risks related to electrical lines and the risk of being hit by a passing train occur when the passengers enter a non-secured railway track. Trespassing in the track area is one of the greatest risks in railway traffic, however this risk is not estimated as a very high risk by passengers (Thomas, Rhind & Robinson, 2006). Another difference compared to buildings is that people in a building are supposed to make their own decision to evacuate while passengers on a train need to wait for an evacuation decision made by the train staff. Assistance from the train staff is also often needed by the passengers to be able to get out of the train and down on the ground.

Up until now there has been no systematic gathering of data concerning how passengers and different professional companies handle evacuation situations from trains. One of the aims of this project has been to initiate the systematic build-up of such knowledge to support safe evacuation behaviour.

Many evacuations from trains occur in situations without an obvious or immediate threat and can thus be organised by the staff. Since such situations occur quite frequently and regularly they can give important information on human safety behaviour in evacuation situations.

### *1.2 Which evacuation situations can occur?*

Evacuations may occur in situations where there is no immediate threat as well as situations where there are threatening conditions such as fire. In railway settings it is necessary that the staff organize the evacuation to be able to control the risks of electricity accidents and of being hit by another train. Different types of evacuation scenarios could be identified.

Two main dimensions can be used to describe the evacuation scenarios:

- Level of threat
- Level of control (the ability to organize the evacuation)

Based on these two dimensions four types of evacuation scenarios could be identified:

- Organized evacuation (high level of control and low level of threat)
- Organized emergency evacuation (high level of control and high level of treat)
- Self evacuation (low level of control and low level of threat)
- Emergency self
- evacuation (low level of control and high level of treat)

This is also presented in Figure 1 below.

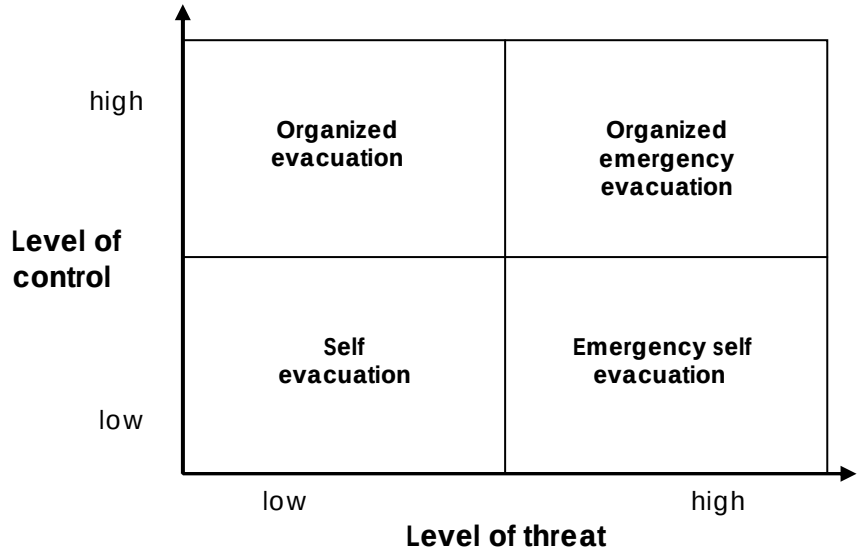


Figure 1. A model for train evacuation. Evacuations are described from two dimensions; level of control and level of threat.

### *1.3 Purpose*

The purpose of the study was to:

- get a better understanding of the different types of evacuation situations that can occur
- get a better understanding of passenger behaviour by use of a system safety view addressing the interaction of human, technology and organisation
- identify areas for improvement

A three year study was conducted from 2005-2008. This paper presents some of the general results whereas the detailed results are presented in separate reports as stated in the reference list (Kecklund et al. 2006, Kecklund et al. 2008, and Petterson et al. 2009)

### *1.4 Definitions and limitations*

An evacuation is defined as passengers getting off the train and into the track area or the area adjacent to the track. Evacuation is in most cases supervised by train staff and train traffic control centre, which means that the electricity is switched off and that the adjacent track is closed for traffic. The project has focused in particular on how the train-staff and the passengers handle such a situation.

The evacuation situations studied were when a train had to be evacuated outside the platform area while standing on the track and where the passengers had to walk from the track area or to board another train on an adjacent track. No major accidents or fires occurred during the study period and was thus not included in the study.

## 2 Method

### *2.1 Literature survey*

In the first part of the study a literature survey was performed, contacts were made

with different companies, authorities and research institutions, but also with the Swedish National Rescue Services Agency as well as with passengers. The authors have also participated in workshops on the subject carried out by the railway companies. The results have been reported in Kecklund, et. al. (2006).

### *2.2 Data collection from real evacuation situations*

In the second part of the study, data were collected from real evacuation situations by the use of questionnaires, answered by train staff and passengers, over a three year period. Some of the results from these questionnaires are reported in this paper.

Data were collected from passengers and train staff from six Swedish train operating companies, but the majority of the questionnaires came from three major train operating companies. Different questionnaires were used for the two groups, train staff and passengers. The group consisting of 160 train staff answered the questionnaires based on 113 different evacuation situations. This means that in some cases more than one person from the same evacuation situation answered the questionnaire. 51 % of the questionnaires were answered by drivers, and the rest by other train staff.

125 questionnaires were collected from passengers from 33 different evacuation situations. Most questionnaires were collected from commuter passengers in the Stockholm area.

The questionnaires contained multiple choice as well as open questions. The questions concerned communication and information, time taken to decide and conduct the evacuation, equipment to support evacuation, feelings about the evacuation, training and procedures as well as open questions on suggestions for improvements. Descriptive results are presented below as frequencies.

## 3 Results

### *3.1 Cause of evacuation and physical environment*

The majority of the data collected in this study were from situations with a low level of immediate threat. The train staff answered a question about the causes for evacuation. 38 % of the evacuations were due to vehicle problems, and 28 % due to a broken aerial line. Smoke in the train caused 14 % of the evacuations. Other causes for evacuation were hold-up the traffic (8 %), collision with a person or an animal (10 %), or other things such as fallen trees on the track (11 %).

Even if the studied situations had a low level of threat, there are other risks when people get outside the train. Also, new risks are introduced because other consequences develop over time due to difficult conditions inside the train, such as crowding, high temperatures, lack of fresh air, heat, cold etc., while the passengers have to wait to be evacuated. The environmental and weather conditions varied between the evacuations. 35 % of the evacuations were made in dark conditions. 15 % of the evacuations were carried out in very cold weather, and 15 % in warm weather. In some cases the temperature was very high.

### *3.2 Time spent waiting for evacuation*

The train staff was asked to estimate the time from the train stopped until the evacuation started. In 16 % of the cases the time was estimated to less than 10 minutes, and in 57 % of the cases to more than 30 minutes. When the time to the start of the evacuation was short this was due to for example smoke in the train. The

cases where the time until the evacuation started was longer than 30 minutes, the reason for evacuation was in most cases vehicle problems or a broken aerial line. In some extreme cases the time from the train stopped until the start of the evacuation was three to four hours.

Several members of the train staff stated in the questionnaire that the time waiting on the train was often too long. The reasons for that were often that the decision about evacuation took too long and that it took a long time for the staff who is specially trained to take care of broken aerial lines to get to the train. In cases where train staff and the passengers had to wait on the train for a long time the risk of self evacuation greatly increased. A person from the train staff commented the following on this risk:

> *"Thank God it was 6 o'clock in the morning. If it would have been later in the day it would have been impossible to keep 200 passengers in the train the whole time."*

Many passengers accentuated that the time spent waiting for evacuation was long. For some of the passengers the conditions were also difficult, which made the waiting unpleasant. In some cases the train was standing still for hours in winter cold, which caused a very low temperature inside the train when the power supply ran out. In other cases very high summer temperatures caused heat inside the train which almost caused people to faint. Passengers that were stuck in the train for hours reported about the need to get water to drink and to have access to a toilet.

Some passengers on a commuter train described the situation as presented below.

> *"It was terribly hot on the train, for a while I thought I was going to faint"*

> *"It was extremely hot in our carriage since it was very crowded and people everywhere. The situation could have been improved if the firemen, as they passed through the carriage after we had waited for an hour, had broken a few windows. This would have given us fresh air. One and a half hours of waiting standing up in a tilting train is more than most people can handle. Fresh air would have made it easier"*

A person from the train staff on a train that had been waiting for two hours made the following comment:

> *"Hot sun,…, two hours of waiting for evacuation…it is a wonder that no one started a revolution"*

### *3.3 Communication with professionals and passengers*

In the case of an evacuation decisions have to be made by the train staff and the train dispatching centre. For that reason the train staff and the train dispatching centre have to be able to communicate.

In most of the evacuations the staff experienced that the communication with other train staff worked well. In some cases there were problems with communication. In 8 % of the situations the staff experienced problems in the communication with other train staff. In about 24 % of the evacuations there were problems in contacting the train dispatching centre. The causes were problems with telephones, radio and/or speaker systems.

According to the train staff the evacuation in 38 % of the cases was announced in the loud speaker system on the train. Another way of communicating the evacuation to the passengers was that the train staff announced the evacuation verbally in the carriages. In 6 % of the evacuations the evacuation was not announced at all. In 22 % of the evacuations the train staff experienced that there were problems in the communication with passengers. Causes for problems in the communication with passengers are in several cases non-working loudspeakers or microphones. A person from the train staff expressed:

> *"the importance of a functioning information system became more than obvious in the evacuation situation"*

66 % of the passengers stated that they received the information about evacuation on the loud speakers, while 25 % of the passengers received the information from the staff on the train. 10 % of the passengers got the information from fellow-passengers, in some other way, or did not get it at all. Many of the passengers emphasized in the questionnaires the importance of information, and pointed out problems such as lack of information, unclear information and that there was no staff easy to approach. Quotes from passengers about information were:

> *"even if there is nothing new to say in the loudspeakers, you still want continuous reports about the situation, and honesty"*

> *"the first reactions were fear and anxiety but after the loudspeaker message it felt safe, that the situation was under control".*

## 4 Conclusion

The results from this study showed that most evacuations occurred in situations with a low level of threat, and that the train staff in most cases had a high level of control over the situation and were able to organize the evacuation. Most evacuations worked out well, but the results also indicate that improvements can be made in several areas, such as reduction of time delay for decision and onset of evacuation, but also better communication.

The results also show that time is an important factor related to the model in Figure 1. The longer the time spent waiting for an evacuation the more difficult for the staff to keep a high level of control. The risk of self-evacuation increases.

There must be strategies and support to manage all four types of evacuation situations. There are several risks that must be managed. Problems related to the interaction between people, technology and organisation that occur in a situation with a low level of threat are probably even more evident in a situation with an immediate threat where the evacuation has to advance quickly. Therefore it is important to build a system and a strategy that works without disruption in non-threat situations, since this makes it more probable that evacuations in threat situations will go according to plan.

The results from this study clearly shows that problems in the interaction between humans (passengers, train staff), technology (train design), organisation (different companies and contracts) and situations (crowding/high density of people) may create new risks to railway passengers, in particular if they have to wait for a long time on a very crowded train under difficult conditions. The division of responsibilities between

infrastructure managers, train operating companies etc. complicates the evacuation situation. If the cooperation and strategies are not clear, the communication and arrangements between the different parties will take time and thus increase the possibility of worsening conditions for the passengers.

The time delay until the decision to evacuate is made and the time delay until start of evacuation is a problem. Train staff considers this to be the most important area for improvement. Time delay leads to unpleasant and in the worst cases even unhealthy situations and therefore causes a risk situation for the passengers as well as the train staff. This also creates new risks for self-evacuation. When passengers see other possibilities to get to their destination on time, there is a risk that they will get out of the train on their own.

The passengers need information whenever they are exposed to a new kind of situation. Information should be given in advance as well as in the present evacuation situation. Trespassing in the track area is one of the greatest risks in railway traffic, but passengers do not perceive this to be a great risk. It is therefore important to increase passengers' knowledge in advance about risks in railway traffic from a general point of view, and evacuation situations in particular. It is also important to give information in the actual evacuation situation. Information about what has happened and what the passengers are supposed to do (and not do) has to be given frequently. The train operator companies have to develop a standardised information strategy that clarifies who gives information, what information should be given, and how it should be given. To make this possible it is important to have adequate and functioning communication equipment. Correct information to passengers requires access to the right information, and good communication between staff is therefore of great importance.

**Acknowledgements**
This project has been funded by Swedish Rail Administration, Sweden. The authors would like to thank the participants in the study as well as the contact person at Banverket, Erik Lindberg.

**References**

Health and Safety Comission HSE. (2001) *The Ladbroke Grove Rail Inquiry. Part 1 report*, (Norwich: HSE Books).

Boer, L.C., 2005 , Getting Passengers Out – Evacuation Behaviours. In J.R. Wilson, B. Norris, T. Clarke and A. Mills (ed.) *Rail Human Factors – Supporting the Integrated Railway*, (Ashgate, Aldershot, UK), 462–472.

Canter, D. (1980). *Fires and human behaviour*, (John Wiley).

Canter, D. (1985). *Studies of human behaviour in fire: empirical results and their implications for education and design.* (BRE Report Building Reasearch Establishment, Fire Research Station Borehamwood).

Canter, D. (1990). *Fires and human behaviour* (2nd edition David Fulton Publ. Ltd. London).

Canter, D., M. Comber, et al. (1989). *Football in its place: an environmental psychology of football grounds*, (London, Routledge).

Frantzich, H. (2000). *Utrymning av tunnelbanetåg, Experimentell utvärdering av möjligheterna att utrymma i spårtunnlar*, (Lund: Lunds tekniska högskola).

Frantzich, H., Nilsson, D., Kecklund, L., Anderzén, I. and Petterson, S. (2007). *Utrymningsförsök i Götatunneln, Report 3140,* (Lund: Lunds tekniska högskola).

Health & Safety Executive (2002). *Guidance on the provision of equipment and arrangements for evacuation and escape from trains in an emergency.*
Kecklund, L., Anderzén, I, Häggström, J & Wahlström, B. (2006).*Evacuation from trains. Man-Technology-Organisation. A literature review.* (In Swedish). (Stockholm: MTO Psykologi).
Kecklund, L., Anderzén, I, Häggström, J & Wahlström, B. (2008).*Evakuering från tåg – erfarenheter från verkliga evakueringar.* Stockholm: MTO Psykologi.
Lotsberg, G. (1999). *Mont blanc tunnelen.* http://home.no.net/lotsberg/artiklar/brann/mblanc.html.
Petterson, S., Anderzén, I., Kecklund, L., Häggström, J & Wahlström, B. (2009).*Evakuering från tåg – en studie av hur personal och resenärer upplever och hanterar evakueringar*. Stockholm: MTO Psykologi.
Thomas, L.J., Rhind, D.J.A. & Robinson, K.J., Rail passenger perceptions of risk and safety and priorities for improvement, Cogn Tech Work (2006) 8: 67-
Voetzel, A. (2002). *Compared analysis of the Mont Blanc Tunnel and the Tauern Tunnel Fires*, (PIARC).