

# Safety in tunnels – Experienced safety in road tunnels

A research project in cooperation between The Swedish Transport Administration (Trafikverket) and Arkus.

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## Summary

Safety in tunnels is an important matter worldwide, and by building more self instructive and understandable tunnels, we can make them safer for the user. This project investigates the perception of long, or fairly long, tunnels from a user perspective. Almost 50 % of all drivers feel some level of anxiety or fear towards tunnel-driving (Flø & Jenssen, 2007), and if behavioural studies can point out what physical aspects create fear – there is much to gain from such studies within the field of tunnel design and construction. Reports from SINTEF in Norway tell us that 20% of drivers in general feel anxiety and uneasiness in tunnels and 50% of female drivers are anxious. This project has evaluated new road tunnels in situ with a number of users, thus it is based on an explorative and qualitative method. Users were interviewed both while watching films from tunnels and while driving in tunnels. A professional film maker followed the entire project.

The Swedish Transport Administration has prioritized safety in tunnels and the issue demands a holistic approach that addresses not only the design of the road but other aspects such as the users (driver and passengers), the car and technical support.

The standard for tunnels in Sweden is based on ATB Tunnel 2004. Evaluations of the standard are not, however, very well developed and it is important to explore what criteria are most important for the evaluation of tunnel users' experience. This project aims to highlight the effects of the standard in some tunnels, from the user's perspective. The focus will be on aspects mostly connected to the design of the tunnel, such as orientation, geometry of the road, ITS communication and signs, experienced safety in entrances and exits as well as maintenance.

There are differences in the perception of the tunnels depending on how used you are to tunnel driving and how used you are to the specific tunnel. In a complicated motorway tunnel like Södra Länken with several different traffic situations taking place inside and around it, there are obviously more risks that appear and that are perceived by the interviewees.

## **Background**

A number of studies have been conducted in Norway in order to investigate the attitudes towards tunnel driving. The calculated risk has also been compared to the accidents that have occurred. The Norwegian studies are mostly based on questionnaires, using a quantitative approach. In a paper for the First International Conference in Basel, Finn Amundsen made a brief summary in

English, of the 'findings so far' (Amundsen, 1992). More recent reports are all in Norwegian and investigate attitudes towards long tunnels and underwater tunnels.

In Sweden an evacuation experiment was performed in full scale in Götatunneln in Gothenburg in 2006. The experiment revealed that drivers do not know how to behave in dangerous situations when there is smoke in the tunnel and an accident has supposedly happened. (Frantzich et al, 2007) (Kecklund et al, 2007).

In Holland Marieke Martens at TNO Human Factor has conducted several studies on Tunnel safety and Human Behaviour. UPTUN reports from Workpackage 3 also deal with human behaviour in tunnels when accidents are at hand, under the leadership of Martens. (Martens, 2006) (Papaioanno & Georgiou, 2008).

PIARC Technical Committee C3.3 conducted a qualified compilation 2008 of facts and research findings on Human Factors and Road Tunnel Safety Regarding Users. (PIARC, 2008)

This is only a small selection of research made within the field of Tunnel Safety and Human Behaviour. Most behavioural research has been conducted in driving simulators, which is safe and secure. There still remains much to investigate regarding the feelings of fear and/or comfort from driving in tunnels. A small level of anxiety can make the driver more alert, which is good in terms of safety. On the other hand, too much anxiety can also make the driver act unpredictably and unsafe. What are the fears? And what causes confusion? What risks do drivers take? What areas are important to stress in tunnel design in order to reach safety? If we can find the factors that really cause fear and anxiety and diminish, if not delete them, the tunnels will be experienced as safer for everybody, not just worried drivers.

This project uses qualitative methods that allow the interviewees to formulate their experiences in their own words including both positive and negative aspects of the tunnels. It also takes the step from driving simulators to real tunnels, enabling a study of how drivers react in real situations and what they think of safety in the tunnels. The Swedish National Transport Administration are presently planning to build a very long tunnel, Förbifart (Bypass) Stockholm, approximately 18 km long, and the knowledge that this project can offer is of vital importance to the early phases of construction. As a result the planning team for the tunnel Förbifart Stockholm is closely connected to the project via a reference group.

### ***The three tunnels studied***

The tunnels that are studied are Södra Länken and Törnskogstunneln in Stockholm and Götatunneln in Göteborg. These three tunnels are recently built and they are also rather long and thereby a source of anxiety and fear for a number of drivers.

Törnskogstunneln was inaugurated 2008, Götatunneln 2006 and Södra Länken 2004. They are long tunnels according to Swedish measures. As they are newly built they are planned according to the Swedish standard for tunnels *Tunnel 2004* (Vägverket, 2004) and this project is an evaluation and follow-up of the standard. Thus the findings can, if they are relevant, have an influence on the standard.

### ***Södra Länken in Stockholm***

Södra Länken is a 6 km long city-motorway-tunnel with a complicated system of tunnels connecting different parts of the southern area of Stockholm city. It is the longest road tunnel in Sweden and building it took 6 years (1998-2004). The traffic situation in the tunnel with several connecting tunnels is difficult for the driver to overview. The experienced driver can easily manage, but a novice driver often drives under a lot of stress. The traffic situations at the different entrances to Södra Länken are also something that causes stress.

Södra Länken is famous for its artistic design of the ramifications with stone sculptures and huge sculptured arches meant to support the orientation in the tunnels. The tunnels are showing the rock-face on the walls, while the lower parts of the walls are covered with elements of concrete. The ceiling is made of huge curved white concrete building elements designed to make a light impression of the tunnels.



Figure 1. Interior from Södra Länken.

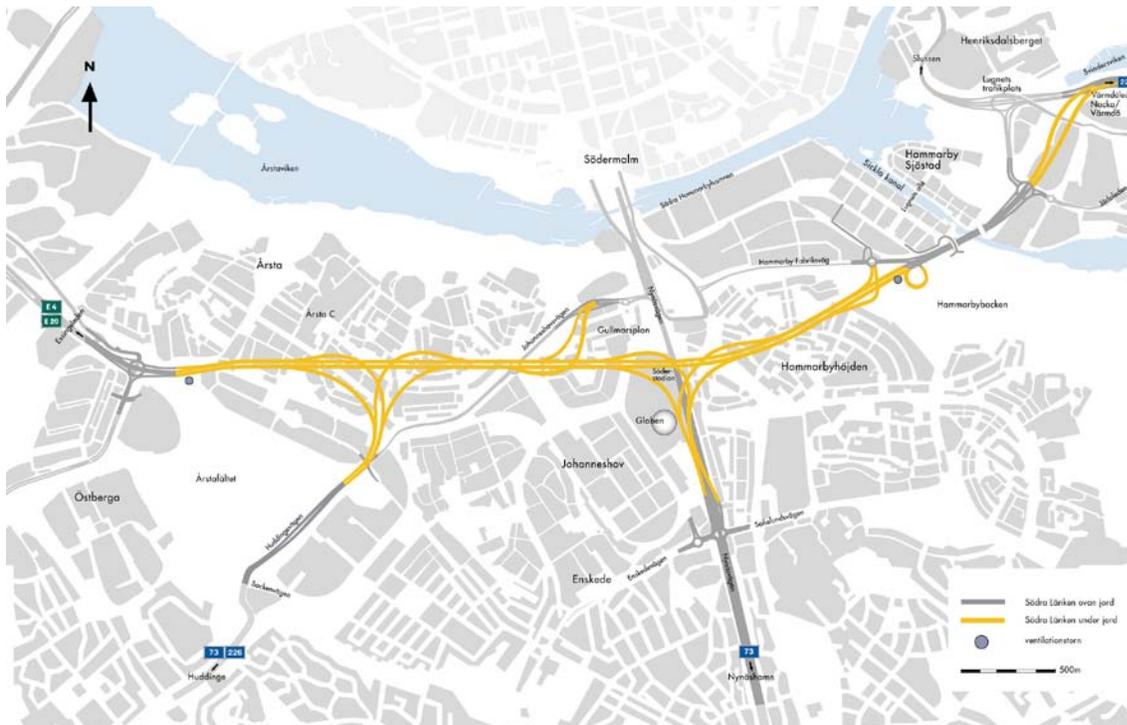


Figure 2. Map from Södra Länken.



Figure 3. Interior from Törnskogstunneln.



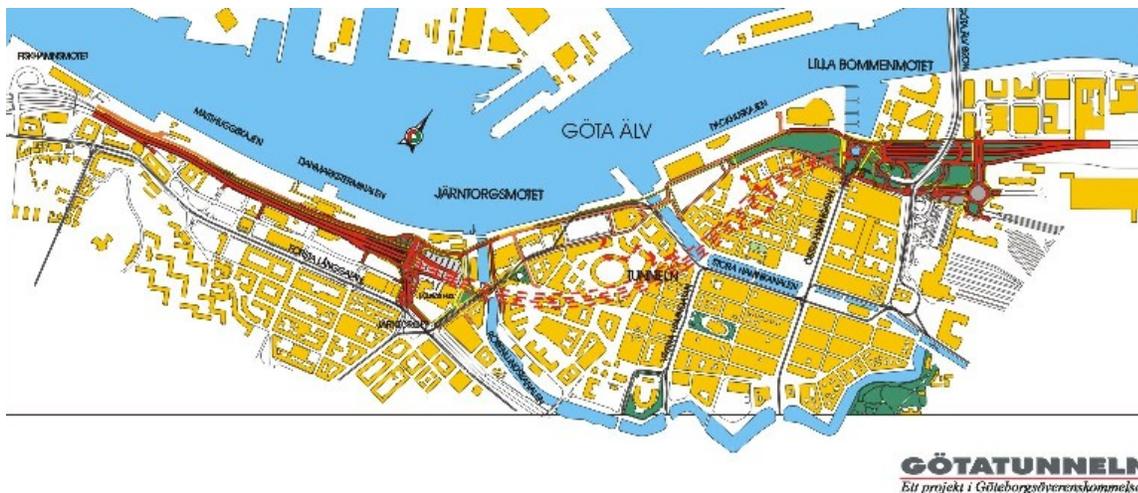
Figure 4. Map from Törnskogstunneln.

### ***Törnskogstunneln in Stockholm***

Törnskogstunneln is a 2 km long tunnel north of Stockholm City as part of Norrortsleden, a new motorway connecting the northern suburbs. Törnskogstunneln was built 2004-2008. It is not a complicated tunnel, just a straight tunnel without any connections and subsequently few traffic problems. The only problem pertaining to the planning of the tunnel is that the sun shines right in through the southern mouth of the tunnel at certain hours some days of the year, causing temporary blinding. The tunnel is formed as a traditional tunnel with the rock-face only covered with concrete, giving the impression of a very dark tunnel.



*Figure 5. Interior from Götatunneln.*



*Figure 6. Map from Götatunneln.*

### ***Götatunneln in Göteborg***

Götatunneln is a 1,6 km long tunnel in the city heart of Göteborg. It was built 2000-2006 with the aim of eliminating some of the heavy city traffic. The tunnel is not particularly complicated, except for the entrance from the north-east near the Central Railway Station which can be extremely confusing. Only the habituated driver who knows Göteborg very well will find the way to the tunnel easily.

Götatunneln is decorated with huge numbers besides the emergency exits. It is also decorated at the lowest point with blue light on the ceiling marking that the tunnel passes under the canal Södra Hamnkanalen. The walls are covered with white tiles which gives the tunnel a light appearance. The ceiling is black.

### ***The methods used***

As previously mentioned, the methods used in this project are all qualitative and they have been chosen in order to let the interviewees formulate their answers with the least possible influence from the researcher. This is always difficult, because you can never completely eliminate your influence on the people around you. Still we have tried to let the interviewees speak freely and now and again just stimulated them to talk by asking them to look around and share their reflections on the tunnels and the perceived safety that they experience at the moment. The research area is called POE *Post Occupancy Evaluation* (Preiser, Rabinowitz & White, 1988) and is established in the Environmental Psychology field.

The 28 driving test persons were selected to represent men and women, young, middle aged and older drivers, and more or less experienced tunnel drivers. The four focus groups (about 10 persons per group), were chosen to represent younger people, students and children who have not yet learned to drive.

### ***Driving and talking – a method used for spontaneous comments***

This method is a variation of walk-through evaluation – conducted in a car, “driving-through” the tunnels. The interviewee drives a car and is asked to comment everything that he or she sees and feels with special focus on safety and tunnel safety. All is documented on a tape recorder and some of the interviews are also video-filmed. A short video-filmed interview follows each driving session. Some of the driving-tours are also documented on video as an outside view.

### ***Interviews with the driver after driving***

After the driving session we stopped the car and a semi structured interview was conducted and filmed – to catch and document safety questions that did not appear spontaneously in the “driving and talking”. The driving and interview sessions embraced 28 persons, 14 men and 14 women representing all the categories mentioned above.

### ***Focus group interviews***

Focus groups have been interviewed in combination with showing video film sequences from the tunnels. The semi structured interview guide was used and the focus group was asked to comment on tunnel safety while watching the film sequences. The four focus groups of 10 persons each represented different ages of young people. Two focus groups consisted of students aged 20-25 at KTH respective Chalmers University. One focus group consisted of students at upper secondary level aged 16-19 and the last focus group consisted of schoolchildren at 5<sup>th</sup> grade of compulsory school, aged 10-11.

### ***Interview watching tunnel-video***

For interviewees who feel claustrophobic in tunnels, watching a video sequence proved to be a valuable alternative enabling the documentation of their opinions on perceived safety – or unsafety. Two persons were interviewed, a woman and a man.

### ***Documentation with video film***

Film as a working method and tool has been vital for this project and proved very fruitful for the outcome. The entire project has been followed with a video camera, documenting reference group meetings, focus group discussions, interviews made while driving and while standing still, and to document the researchers own reflections during the project. The camera was also used to make tunnel-films, used both in interviews and at meetings. The filmed interviews were used both as documentation but could also be used as a basis for discussion and analysis of the interviewees experiences. In other words filming served multiple purposes and the collected film material enabled both the writing of a final project report *and* the making of a [project movie](#).

### ***Results and discussion***

A striking fact is that very few of the interviewees knew anything about how an evacuation of the tunnel should take place. They have no idea what happens if there is an accident or fire. Thus, one conclusion that can be drawn from the project is that there is need for further education of tunnel evacuation in case of emergency both for experienced drivers and within driver's license courses.

The traffic situation in city-motorway tunnels and their entrances are troubling for some of the interviewees and especially for “first timers”. There is the situation with the “first timer” in every tunnel and a complicated tunnel like Södra Länken is very stressful for them, with new traffic situations throughout the entire tunnel. They asked for more signs to be able to find their way.

The experienced tunnel drivers discussed other problems that they have previously encountered in the tunnel and reflected on situations that have occurred. In the complicated tunnel Södra Länken they pointed out dangerous places where they had had different problems. Many of the problems were about changing lanes in the tunnel and anxiety due to other drivers taking risks.

Some persons were worried about the blinding at the entrances and exits of the tunnels. No one was worried about both entrance and exit blinding. It seems that elderly drivers were more irritated over being blinded in the entrances than the young drivers. But the considering the small amount of test persons it is difficult to draw any general conclusions.

Big vehicles worry many of the drivers. They feel captured driving next to long-distance lorries and even worse driving between two lorries. Also driving behind a long vehicle felt unpleasant. The usual strategy is then to try to overtake the long vehicle sometimes even irrespective of the traffic situation in general. This can of course cause dangerous situations.

The problem of feeling sleepy and drowsy in a long tunnel was mentioned by some interviewees. They also came up with creative proposals to make the tunnel more interesting. The dullness in a long dark tunnel was mentioned and fearsome for the claustrophobic. According to the interviewees, artistic decoration and other things happening in the tunnel makes you think of other things than your fears.

Signs telling you where you are and how far away the exit is – was asked for both by experienced tunnel drivers and from those who are claustrophobic. It would make them feel safer. Signs indicating that you are approaching a tunnel were also asked for by a number of participants.

Such sign would give you the opportunity to choose another road if you feel anxiety when driving in tunnels.

Better city maps, showing the tunnels as well as the roads, could assist all drivers to better orient themselves and help claustrophobic drivers to avoid tunnels in cities.

The sense of having the situation under control is very important for the drivers. The claustrophobic drivers generally speak of 'losing control', and the drivers that like driving in tunnels speak about different aspects of control. Every moment that you lose control causes worry, like not being sure of the speed especially when the tunnel has a steep gradient downwards. The blinding in the entrances can also make you lose control. Another factor influencing control is the queue situation, being stuck in the car was annoying for all interviewees.

As mentioned above, there is need for tunnel-education, how to handle a dangerous situation and how to evacuate the tunnel, both for professional drivers of heavy vehicles and for the ordinary car driver.

There is also need for further research on tunnel safety:

- A larger survey could check the parameters that we have identified in this project, in order to verify our results. The project has identified indications of problems, but further verification is needed before you can state that the problems are general and should cause change in tunnel regulations.
- Further studies on accident and incident statistics in complicated tunnels as for example Södra Länken is needed. The existing statistics are not reliable.
- Further research on what actually is tunnel phobia is also needed in order to find strategies that prevent problems in the tunnel environment and eventually help tunnel phobic people therapeutically to overcome their worries and panic. Much can perhaps be overcome simply with the help of information and education.
- To analyze the tunnel using video film has been fruitful for us. Further studies of tunnels with a video camera is something we would recommend as it is easy to study the different factors that have an impact on tunnel safety when you can watch and analyze a filmed sequence from the tunnel in natural traffic speed.

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