PSYCHOLOGICAL ASPECTS OF TUNNEL SAFETY

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ABSTRACT

After the big fire incidents in the Mont Blanc Tunnel, the Tauern Tunnel and the St. Gotthart tunnel we are thinking about psychological aspects of tunnel safety. We all saw, that people did not react in an expected way.

Our recent activity in this topic is, that we investigate how people could react in the case of a catastrophe and we also want to investigate how we can help people to react in the right way.

We therefore started an investigation project in co-operation with traffic-psychologists to find out how the behaviour of the tunnel users can be improved by the design.

Test persons had to drive at a section of a highway with 5 tunnels, each tunnel with other characteristics.

After the test persons had passed the testing section of the highway they had an interview with a psychological background.

1. INTRODUCTION

A large fire occurred in the Mont Blanc Tunnel on 24 March 1999, car accidents led to fire disasters in the Tauern Tunnel on 29 May 1999 and in the St. Gotthard Tunnel on 23 October 2001.

A number of accidents and fires in tunnels occurred in Austria in summer 2001 in addition to these three incidents. Human error was usually involved to a certain degree in all these incidents.

These errors can be roughly divided into three groups:

1. Errors made by a driver who causes an accident – like in the Tauern Tunnel and possibly in the Gotthard Tunnel.

2. Errors made by the operating staff who, from a retrospective perspective, serviced the ventilation system adversely or incorrectly – like in the case of the fire in the Mont Blanc Tunnel.

3. Errors made by tunnel users who are trying to flee – or who rather do not escape or try to escape too late. Examples of this are, on the one hand, the tunnel users of the Tauern Tunnel fire who remained seated in their vehicles and, on the other hand, those people fleeing from the Gotthard Tunnel who ran past the escape tunnel.

In our responsibility for the planning, construction and operation of tunnel systems, we need to deal intensively with this “weak human link”. We need to provide drivers with a tunnel that does justice to their requirements whilst driving and that does not make excessive demands of them. We need to create ideal preconditions for tunnel users so that they can react correctly in an emergency situation. And finally, we need to ensure that our employees are able to intervene correctly and efficiently in an emergency.

2 PERCEPTUAL PSYCHOLOGICAL INVESTIGATIONS INTO TUNNEL SAFETY

Together with psychologists from the Institute of Traffic Psychology of the Austrian Road Safety Board, ÖSAG has started processing a topic area from the field of perceptive psychology.
According to reports, one of the reasons for the severity of the disaster in the Mont Blanc Tunnel was the fact that lorry drivers did not observe the traffic lights that had changed to red after the fire had started. For this reason, we approached the psychologists from the Austrian Road Safety Board with the following question:

How can we ensure that a red light by a tunnel portal or in a tunnel is better obeyed?

A further question that we wanted an answer to was the placement and optical design of freely programmable information boards before a tunnel portal. One reason why we were particularly interested in these questions was that we were in the process of establishing tunnel chains on the Semmering and, in particular, on the Pyhrn Motorway in Upper Austria, which were about to have equipment of this kind installed.

The traffic psychologists from the Austrian Road Safety Board then compiled a report that was used as the basis for the planning of the equipment of the two above-mentioned projects.

I would like to mention a few of these recommendations here:

- Early advance announcement of red light, if possible 1 to 1.5 km before the entrance to the tunnel.
- Repeated advance announcement of red light.
- No fixed advance announcements of red light, but flexible announcements that can be particularly emphasised if required – i.e. in the case of a red traffic light. The comment that LED displays attract greater attention was also seen in this context. Another possibility of flexible announcements consisted of flashing yellow lights on the advance announcement that only flash when the traffic light is red.
- A further recommendation was to place as little information as possible in the area of the tunnel portal. This area starts about 150 to 200 m before the portal. This affects, for example, the signposting of the name and length of the tunnel. This information should be provided earlier on and not – as has been the case so far – immediately by the portal.

As a consequence, the planning of the guidance equipment of the two above-mentioned projects was arranged in collaboration with the ladies and gentlemen of the traffic psychology department of the Austrian Road Safety Board.

### 3 EMPIRICAL OBSERVATIONS ON THE PYHRN MOTORWAY

In order to test the efficacy of the recommendations that were implemented in the planning, the Austrian Road Safety Board was commissioned, in May 2001, to carry out a test programme, which took place in autumn 2001 during the renovation work in the Bosruck Tunnel in September and October.

The aim of this test programme was:

- To work out psychologically meaningful and perceptually appropriate design criteria for designing tunnels
- To recognise perceptual defects and emotional disturbance factors
- To increase the objective and subjective safety of drivers
- To encourage desired driving behaviour

The project was carried out in five stages:

- General preparation stage
- Preparation phase for field inquiry
- Implementation of field inquiry
- Evaluation of journeys and people surveyed
- Reporting

The test was carried out as follows:

Of the 69 test subjects, 23 were inexperienced tunnel drivers, 23 were experienced tunnel drivers and 23 were senior citizens.
36 test subjects drove during the day and 33 test subjects drove at night. Every test subject drove for 1 – 2 hours and was interviewed for about 1 hour.

The test section was on the Pyhn Motorway and was 70 km long. It started in Spital/Pyhrn, then went north to St. Pankraz, where people turned round and drove south to Rottenmann and then back to Spital.

The following tunnels formed part of the test drive: short St. Pankraz Tunnel, Lainberg Tunnel (length about 2.8 km), short Rossleiten Tunnel, Bosruck Tunnel of about 5.5 km length and Selzthal Tunnel (1 km in length).

The test subjects essentially had to deal with the following test conditions:
- They had to drive through a building site with stop signals before the tunnel
- Some tunnels on the test section had one tube and others had two tubes
- The test subjects also had to drive through washed and unwashed tunnels
- There was also a tollbooth on the test drive

The SAF program (driving behaviour analysis system) and comments on the drive were used as test methods.

The SAF program (driving behaviour analysis system) allows the investigation of individual behaviour when driving cars in field experiments.

The main characteristics of SAF are:
- It is a system that is easy to install; in this case it was installed in a small car belonging to the Austrian Road Safety Board that the test subjects were driving.
• An observing passenger compiles complicated behavioural and situational characteristics and enters these into the computer by means of a click of the mouse
• The apparative data serves to complement the observations of the passenger. Data analysis then occurs based on the recorded speed, the longitudinal and transverse acceleration, the status signals of the vehicle and the keyboard entries of the observer.

4 video cameras were used for the video analysis to record the face, the feet when using the pedals and the road in front and behind. These recordings are made using split screen technology.

The comments on the drive are based on a special interview technique where questions are asked on certain topics after the test drive is over:

Questions are asked on following thematic points of focus in this test:

General section:
• Sociodemographic data
• General questions about tunnels and the test drive

Specialised section:
• Questions about traffic signals
• Tunnel entrance
• Lighting
• Tunnel walls
• Road markings
• Safety equipment
• Tunnel exit
• Tollbooth
• Building site
• Behaviour in an emergency
• General safety questions

Characteristics to be observed:
• Subjective perception
• Subjective driving quality
• Subjective safety
• Orientation
• Taking in information
• Registration of tunnel design elements
• Acceptance
• Visual conditions
• Recollection
• Distinctive features

4 RESULTS OF THE INVESTIGATIONS
Here, I would only like to emphasis a few significant results:

4.1 Perception of the test subjects
93% of the test subjects responded to the question “How did you perceive this drive?” with positive or very positive.

74% of the drivers responded to the question about whether the test person felt safe during the drive with at least quite safe.

Assessment of traffic signals
The question about which traffic and warning signs the test subjects felt were important in the tunnel area led to a sobering result. Over 90% of the test subjects thought the speed limit was important, however, only 36% considered the traffic light system to be important, which allows conclusions to be drawn about the acceptance of traffic light systems.

Only about 15% of the test subjects thought that non-observance of a traffic light system was of great importance, while about 75% of them attributed great danger to non-observance of the speed limit. It is also interesting that the ban on overtaking was assessed as less important than the speed limit.

Ill. 4: Important traffic and warning signals in the tunnel area

International Conference „Tunnel Safety and Ventilation“ 2002, Graz
4.2 Tunnel entrances

The tunnel entrances were also assessed. Of the five entrances displayed here:

- Entrance D was seen as the most informative, clearly laid out and as having the best guiding properties
- Entrance B was assessed negatively in terms of being informative, clearly laid out and having good guiding properties
- Entrance A was mentioned most frequently in the context of having a slowing down effect, being confining and dangerous
- Entrance E was also assessed as having a slowing down effect, without, however, the terms confining and dangerous being applied
- Entrance B was rated as having the least slowing down effect
- Entrance E was not assessed as confining
- Entrance D was named as the least dangerous
In summary, it can be said that Entrance C was assessed in the most neutral terms and that Entrance E has a special position in that it was assessed as having a slowing down effect, but not as being confining.

4.3 Speed developments

Essential insights:
- Drivers who approached at speeds below the speed limit, drove faster in the tunnel, while drivers who were above the limit slowed down.
- It was observed that speed limits were broken more frequently in bidirectional tunnels than in unidirectional tunnels.
- The test subjects’ assessment of the effect of the design of the tunnel entrance on speed – use of “having a slowing down effect” – correspond to the speed developments actually observed.

4.4 Lighting

Lighting was seen to be of great significance in terms of driving behaviour. However, the test subjects also recognised that a tunnel that is too light can lead to excessive speed. The distance behaviour is also different in dark tunnels to in light tunnels.

4.5 Reflectors

The kerbs that were illuminated with LED were assessed as much more visible and with better guiding properties, while the fear that they might distract or disturb was not confirmed.

4.6 Dirty walls

In this context, it was noted that lane adherence errors occurred more frequently in unwashed tunnels than in washed tunnels. It was also ascertained that there was no significant difference between the number of times the speed limit was exceeded between the washed and the unwashed tunnel.

4.7 Height of light spots

A comparison was made between driving behaviour in tunnels with an intermediate ceiling (light spots at a low height) and in tunnels without an intermediate ceiling (light spots at a great height). The only significant difference was the greater number of times the speed limit was exceeded in the tunnel with the interim ceiling.

4.8 Perception of safety installations

The following diagram shows which safety installations the test subjects could remember after the drive.

![Safety installations recalled from the tunnel](image.png)
90% of the test subjects can remember the emergency telephone equipment, while only 4% remember fire detectors and 10% fire extinguishers.

83% of the test subjects answered the question about how they would behave in the case of smoke development by saying they would switch off their engine, about 65% would close the window and switch off the ventilation in the vehicle. Only 11% thought of switching on the radio, between 1 and 4% thought of alerting the fire brigade, switching their lights on/off, turning off the heating, switching on their mobile phone or waiting for instructions.

4.9 Unidirectional vs. bidirectional traffic

As expected, the test subjects felt considerably safer in unidirectional tunnels (97%) than in bidirectional tunnels. 69% felt that speed limits were better adhered to in bidirectional tunnels. However, in bidirectional tunnels, the speed limit was exceeded significantly more frequently than in unidirectional tunnels. It was also noted that lane adherence errors and distance errors occurred more frequently in bidirectional tunnels.

5 CONCLUSIONS

The study shows that tunnel operators in Austria have been heading in the right direction over the past years, but that there are still possibilities to improve tunnel safety through design. Drivers perceive many tunnel characteristics extremely consciously and also react to the different design of tunnels in terms of their behaviour. The lack of recognition of the significance of traffic light systems on the motorway shows a perceptual superimposition through routines. Things that are required to drive through a tunnel under normal conditions are perceived, while the emergency installations are not. There is a particular need for tunnel operators to take action in this area by passing on the corresponding information to drivers whether on the spot or through the media and via driving schools.

In connection with the testing of the tunnel portals it was shown that what is experienced as positive leads to positive and safe reactions. The aim must be to use design to achieve a homogenous and appropriate speed. Because this alone will probably not be adequate, this speed will also need to be monitored.

Drivers desire a comfortable tunnel. Tunnels that are assessed as positive by drivers, e.g. through good lighting or good guiding properties by means of illuminated kerb reflectors, do not have a negative effect on driving behaviour.

I believe that the unanimous opinion is that tunnel safety is an extremely important topic.

It must, however, be emphasised again and again that there is no absolute safety in tunnels – the same applies outside tunnels, too. Ultimately, human beings play an extremely decisive role. Technicians can, to a considerable degree, contribute to improved safety, but this can become even more successful in collaboration with other specialist areas!