ROAD SAFETY IN TUNNELS WITH UNI- AND BI-DIRECTIONAL TRAFFIC IN AUSTRIA

Robatsch K., Nussbaumer C.
Institute for Traffic Engineering
Austrian Road Safety Board

ABSTRACT

The probability of an accident occurring and/or a motorist being killed in an accident is lower in a tunnel than on other road sections. However, if an accident occur in a tunnel, the severity of the injuries sustained is significantly higher than on other types of roads. This means, that the cost per accident and the risk of being killed in an accident are higher in tunnels than on motorways or expressways. In tunnel with unidirectional traffic, road safety is significantly higher than in tunnels carrying bi-directional traffic. In tunnels with bi-directional traffic, the accident rate is 28% and accident costs are 66% higher than in tunnels with unidirectional traffic. The probability of being killed or involved in an accident is 65 to 71% higher in tunnels with bi-directional traffic than in tunnels carrying unidirectional traffic.

Key words: tunnels, road safety, unidirectional, bi-directional

1. BACKGROUND

In recent years, a number of spectacular traffic accidents occurred in tunnels, which triggered debates about the safety of road tunnels. Every year, an average of 71 accidents in motorway and expressway tunnels occurs in Austria which causes an average of 15 fatalities, 38 severe injuries and 91 minor injuries. The macroeconomic costs amount to a total of EUR 13 million. The study “Tunnels with Uni- and Bi-directional traffic” of the Austrian Road Safety Board by order of the Federal Ministry of Transport, Innovation and Technology (Robatsch K., Nussbaumer C., 2004) explores the traffic safety of road tunnels on motorways and expressways compared with safety on other types of roads and also compares traffic safety in tunnels carrying bi-directional traffic with safety in tunnels with unidirectional traffic.

The relative accident rates of all motorway and expressway tunnels studied are compared with the corresponding rates for motorways and expressways as well as federal roads on open sections. A detailed comparison of all motorway and expressway tunnels with unidirectional and bi-directional traffic takes place. Moreover motorway and expressway tunnels of a minimum length of one kilometre with unidirectional and bi-directional traffic are compared.

2. SAFETY IN TUNNELS VERSUS SAFETY ON OTHER TYPES OF ROADS

A variety of relative accident rates and the distance travelled in all of the tunnels studied are compared with the corresponding figures for motorways, expressways and federal roads on open sections.

In tunnels the accident rate and the casualty rate are significantly lower than on motorways, expressways and federal roads on open sections. A comparison of the accident cost rates show that cost rates of tunnels are higher than these of motorways, expressways and the open sections of federal roads. Also, the fatality rate in tunnels is higher than on motorways and expressways.
The probability of an accident occurring or road users being injured in a tunnel is lower than on motorways, expressways and federal roads on open sections. But if an accident occurs the injury severity in tunnels is especially high. Therefore the accident cost rate and the fatality rate is higher in tunnels than on motorways and expressways.

The severity of casualties in tunnels is higher than on motorways, expressways and federal roads on open sections. While 3.6% of casualties on motorways result in death, this rate in tunnels is substantially higher at 10.6%. The proportion of those severely injured is slightly higher in tunnels than on other types of roads.

3. SAFETY IN TUNNELS WITH UNI- AND BI-DIRECTIONAL TRAFFIC

This chapter compares accidents occurring in all studied tunnels with unidirectional and bi-directional traffic on motorways and expressways.

3.1. Comparison of types of personal injury accidents

In tunnels with unidirectional traffic, same-direction accidents (including rear-end collisions and accidents while changing lanes) account for about 57% of all accidents. In tunnels with bi-directional traffic, the corresponding percentage is 45%. The main cause of rear-end collision is the failure to maintain a safe distance to the vehicle in front. In tunnels with bi-directional traffic, opposing direction accidents are the second most frequent type of accidents at 41%. In tunnels with unidirectional traffic the second most frequent type of accidents are single-vehicle accidents.
3.2. Selected assessment criteria

Table 8: Number, length and traffic intensity of tunnels with bi-directional and unidirectional traffic (status 2000)

<table>
<thead>
<tr>
<th></th>
<th>Tunnels with bi-directional traffic</th>
<th>Tunnels with unidirectional traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of tunnels studied</td>
<td>21</td>
<td>115</td>
</tr>
<tr>
<td>Total length [km]</td>
<td>87,709</td>
<td>101,357</td>
</tr>
<tr>
<td>Average length [km]</td>
<td>4,177</td>
<td>0,881</td>
</tr>
<tr>
<td>Traffic intensity [ADT]</td>
<td>12,704</td>
<td>8,958</td>
</tr>
</tbody>
</table>

In the calculations below, 21 tunnels with bi-directional traffic are compared with 115 tunnels carrying unidirectional traffic. On average, a tunnel with bi-directional traffic is four to five times as long as a tunnel with unidirectional traffic. At 12,704 vehicles per day, bi-directional tunnels have more traffic intensity than unidirectional tunnels, which carry 8,958 vehicles per day.

3.2.1 Comparison of relative accident rates

In the analysis below, a variety of relative accident rates have been calculated and compared for tunnels with bi-directional traffic and unidirectional traffic. In addition to the absolute accident figures and the relative accident rates it is helpful to also include the severity of casualties. The calculations below comprise accident rates, accident cost rates, casualty rates, fatality rates and involvement rates for accidents in tunnels with bi-directional and unidirectional traffic.

Figure 4: Relative accident rate for tunnels with bi-directional traffic and tunnels with unidirectional traffic (1999-2001)
In tunnel with unidirectional traffic, the accident rate and the involvement rate are higher than in tunnel with bi-directional traffic. The casualty rate is approximately equal in tunnels with unidirectional and bi-directional traffic. The fatality rate and the accident cost rate are higher in tunnels with bi-directional traffic than in tunnels with unidirectional traffic.

![Figure 5: Relative accident rates for tunnels with bi-directional traffic versus tunnels with unidirectional traffic (tunnel with bi-directional traffic versus tunnels with unidirectional traffic) (1999-2001)](image)

It is not possible to draw a conclusion about the safety of tunnels with bi-directional traffic and those with unidirectional traffic, as the relative accident rates have different characteristics and other factors (such as traffic intensity, length of the tunnels) also have to be taken into account. The impact of traffic intensity and tunnel length on relative accident rates will be explored below.

### 3.2.2 Relationship between relative accident rates and traffic intensity

![Figure 6: Average annual daily traffic (vehicles per day) and accident rate (personal injury accidents per 1 million vehicle-km) of tunnels with bi-directional and unidirectional traffic (1999-2001)](image)

Both in tunnels with bi-directional traffic and in tunnels with unidirectional traffic the accident rate rises with increasing traffic intensity, as in tunnels with bi-directional traffic. In tunnels with bi-directional traffic the risk of a head on collision and in tunnels with unidirectional traffic the risk of a rear-end collision becomes higher.
3.2.3 Relationship between relative accident rates and tunnel length

![Graph showing accident rate vs tunnel length for tunnels with bi-directional and unidirectional traffic](image)

As shown in Figure 7 the length of the tunnel has a strong influence on the accident risk. Up to a tunnel length of 1 kilometre the values are significantly higher than in longer tunnels. Due to the major differences in length of tunnels with bi-directional traffic and unidirectional traffic, the relevant data are not comparable. While 84 tunnels with unidirectional traffic are less than one kilometre long, only two tunnels with bi-directional traffic fall into this category. Therefore, further restrictions have to be introduced to enable a comparison of tunnels with bi-directional traffic and unidirectional traffic.

Accident rate, casualty rate, involvement rate, fatality rate and accident cost rate depend heavily on the length of the tunnel. This is particularly evident when comparing tunnels of less than one kilometre length with longer tunnels. The highest risk for a tunnel accident to occur is at the entrance area of a tunnel. At short tunnels this risk introduces more heavy in the relative accident rates.

3.3 Selected assessment criteria for tunnels of more than one kilometre length

The length of a tunnel has a very substantial influence on relative accident rates. Particularly tunnels of less than one kilometre length have very high accident rates. As the share of short tunnels varies greatly, a comparison of safety is not possible. 73% of all tunnels with unidirectional traffic (84) and 10% of all tunnels with bi-directional traffic (2) are shorter than one kilometre. The question of whether tunnels with bi-directional traffic or tunnels with unidirectional traffic are safer arisen, only with regard to longer tunnels, as short tunnels are usually built as twin tube tunnels. For statistical reasons it seems meaningful to compare only tunnels of a length of one kilometre and more.

The tables below compare 19 tunnels with bi-directional traffic and 31 tunnels with unidirectional traffic after various relative accident rates. On average, tunnels with bi-
directional traffic that are longer than one kilometre are 2.3 times as long as tunnels with unidirectional traffic.

A comparison of tunnels of more than one kilometre length with bidirectional traffic and unidirectional traffic shows that all of the relative accident rates selected are higher in tunnels with bidirectional traffic than in tunnels with unidirectional traffic. The figures for tunnels with bidirectional traffic include the Tauern tunnel accident (29th May 1999), which cause 12 fatalities, 4 severe injuries and 35 minor injuries. This accident is a rare catastrophic event, but even when this accident is disregarded or given less weight, the relative accident rates for tunnels with bidirectional traffic are still higher than those for tunnels with unidirectional traffic.

Figure 8: Comparison of relative accident rates of tunnels of over 1 kilometre length with bidirectional traffic and unidirectional traffic (1999-2001)

Figure 9: Relative accident rates in tunnels of over 1 kilometre length with bidirectional traffic versus relative accident rates in tunnels with unidirectional traffic (tunnels with bidirectional traffic versus tunnels with unidirectional traffic) (1999-2001)

4. SUMMARY

The probability of an accident occurring and a road user being injured is lower in a tunnel than on motorways, expressways and federal roads on open sections. However, if an accident occurs in a tunnel, the severity of the injuries sustained is significantly higher. This means, that the accident cost rate and the fatality rate are higher in tunnels than on motorways or expressways.
In comparison of tunnels of over 1 kilometre length, the accident cost rate and the involvement rate are higher in tunnel with bi-directional traffic than in tunnels with unidirectional traffic.

In a tunnel of more than one kilometre length with bi-directional traffic the probability of being

- injured is 69% higher
- killed is 71% higher and
- involved in an accident is 65% higher

than in tunnels with unidirectional traffic.

Accidents in tunnels are not the main problem within the Austrian road network. The lacking traffic morals regarding to maintain the speed limits and the failure to maintain a safe distance between vehicles are fundamental problems. Every second tunnel accident can be attributed to the short driving distance between vehicles. Instruments measuring driving distances between vehicles as well as speed radar or section control equipment contribute to increased awareness and a reduced accident risk. These measures have to be introduced in the entrance area of a tunnel where the highest risk for accidents exists.

Since tunnel accidents are quite seldom and the reasons for their occurrence are not exclusively due to the specific situation in a tunnel, problems with statistical significance of accident data for tunnels are possible.

5. BIBLIOGRAPHY
