Institute of Transport Economics
Norwegian Centre for Transport Research

ENGLISH **Summary**

Vehicle fires in Norwegian road tunnels 2008-2021

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The report maps and describes the characteristics of fires and smoke without fire (SWF) in Norwegian road tunnels in the period 2008-2021. There are well over 1200 in the country. The total average number of fires in all Norwegian road tunnels is 27 fires per year and 17 SWFs per year. The study provides four main results. The first is that the fires and SWFs generally did not involve harm to people or tunnels. The second main finding is that heavy vehicles are over-represented in fires in Norwegian road tunnels. The third main finding is that the causes of road tunnel fires involving heavy (>3.5t) and light vehicles are different. Technical problems was a more frequent cause of fires and instances of SWF in heavy vehicles, than in light vehicles. The fourth key finding is that high gradient road tunnels are overrepresented in the statistics of fires in Norwegian road tunnels. Today, there are 41 subsea road tunnels in Norway. There are at least 24 additional non-subsea tunnels with a high gradient (>5%). The tunnels with high gradient comprise 5 % of road tunnels in Norway, and had 38 % of the fires and the instances of SWF in the period 2008-2021.

Background and goal

Norway is one of the countries that constructs the most road tunnels. There are well over 1200 in the country. Road tunnels are usually at least as safe as, or safer than, similar roads in the open air without junctions, exits, pedestrians and bicyclists. Road tunnels do, nevertheless, deserve attention from a traffic safety perspective, because of their disaster potential related to vehicle fires. The goal of this project has been to collect data on fires in Norwegian road tunnels in the period 2008-2021. We have conducted two such studies previously, and in this study we update these with the years 2016-2021.

Data sources and methods

1) "Vegloggen", which is the Norwegian road traffic centrals' (RTC) systems for recording road traffic-related events. There are five RTC's in Norway, corresponding to the five regions of the Norwegian Public Roads Administration. "Vegloggen" generally has good data about the tunnels in which vehicle fires occurred, the time when the fires occurred, the number of vehicles involved, how long tunnels have been closed because of fires, harm to people and tunnels induced by the fires, and how the RTC's were alerted about the fires.

Vegloggen has no criteria when it comes to defining fires and separating them from instances of smoke without fire (SWF). In order to avoid confusion and minimize our discernments regarding which cases that are fires and not, we define all instances of open flame in vehicles as fires. We have, however, also included instances of SWF, as these also involve temporarily closed road tunnels. We exclude instances of SWF that could clearly not have turned into fire (e.g. fog, exhaust smoke, moist).

2) Road traffic central staff. While "Vegloggen" has provided us with knowledge about the prevalence of fires and SWFs, meetings and discussions with staff at the RTC's served to ensure the quality of our interpretations and to supplement our data. We have previously been given tours at three of the RTC's and received comprehensive information on the systems they use to oversee and control the traffic and the road tunnels.

3) Employees of the Public Roads Administration working on tunnel safety. We communicated with fire and safety inspectors responsible for road tunnels in each region. These supplemented and assured our data.

4) Fire services. Fire services and other emergency services are called out on suspicion of fires in road tunnels and record such call-outs over time. We cooperated with the Directorate for Civil Protection and Emergency Planning (DSB) in our inquiries to the fire services. In the last study, we also compared our own data with the DSB's own road tunnel fire statistics, obtained through their BRIS system.

5) News archives. We have also searched news archives to supplement our data collection. Road tunnel fires are extensively covered by local newspapers, and often also by the national media. In several cases where we lacked information, we got supplemental or explanatory information, often from photos obtained from for example the search engine of "www.google.no". This data source has been very important to us.

Quality assurance. In this project we have received data on road tunnel fires from each region. We have read through the records of a large number of events from the RTC's, and coded or standardised each event in spreadsheets to analyse data in our data analysis programs. We have also received information from fire departments about several of these events. After coding all the data for a region into a spreadsheet, we sent it back to our contact person at the RTC, fire managers and tunnel safety inspectors in the respective region for quality assurance.

The number of fires and SWFs increased over time

The data shows that the average number of fires in Norwegian road tunnels is 27 per year, and that the average number of SWF is 17 per year. Although we see annual variation, the general trend is an increase in the annual number of incidents (fires and SWF) (Figure S.1).

Figure S.1: Fires and SWFs in Norwegian road tunnels in the period 2008-2021 (N=613).

The fires and SWFs are unevenly distributed in the different regions. The average number of fires and SWF per year is 11 in the eastern region, 5 in the southern region, 17 in the western region, 8 in the central region and 3 in the northern region. These differences are related to the different numbers of tunnels in the five regions. The eastern region has over 90 tunnels, the southern region has over 140 tunnels, the western region has over 560 tunnels, the central region has over 150 tunnels and the northern region has over 180 tunnels. The relatively high number of fires and SWFs in the eastern region is probably due to the fact that this region has a high traffic volume. The study provides four main results.

The fires generally did not involve harm to people

The first main finding is that the fires generally did not involve harm to people or tunnels. In over 82 % and over 81 % of the cases, the fires involved no harm to people or tunnels respectively. The situations is different with respect to damage to vehicles, where the outcome in 53 % of the cases is recorded as "unclear" (whether there was a damage to vehicle). Although we conclude that the fires and SWFs mainly do not involve personal injury, it is important to point out that the largest fires involve smoke contamination.

Heavy vehicles are overrepresented

The second main finding is that heavy vehicles are overrepresented in road tunnel fires. 35 % of the fires involved heavy vehicle(s) (> 3.5 tonnes), while 62 % of the fires involved vehicles < 3,5 tonnes. This indicates that heavy vehicles are overrepresented in road tunnel fires, as they on average constitute 14 % of the traffic volume on Norwegian state roads with road tunnels. This finding is in accordance with both Norwegian and international research.

Different causes of fires involving heavy and light vehicles

The third main finding is that the causes of fires in heavy and light vehicles are different. Traffic accidents (single vehicle accidents and collisions) are a less frequent cause than technical problems (32 %), when we look at all the fires and instances of SWF in the period 2008-2015. More than half of all instances (61 %) has an unclear cause. This is probably due to inadequate reporting. The second most common cause is technical problems (32 %), followed by single vehicle accidents (3 %) and collisions (4 %).

The categories of causes are, however, different when we compare fires and instances of SWF involving heavy vehicles and light vehicles. Table S.1 shows the causes of fires and SWF for vehicles under and over 3.5 tonnes, in Norway 2008-2021.

Table S.1: The causes of fires and smoke without fire for vehicles under and over 3.5 tonnes, in Norway 2008-2021 (N= 592).

Causes	Vehicles <3,5 t	Vehicles >3,5 t	Number of incidents:
Unclear	66 %	50 %	356
Technical problems	25 %	45 %	191
Single accidents	4 %	0 %	17
Collision	5 %	4 %	28
Number of incidents	378	214	592

Technical problems was a more frequent cause of fires and instances of smoke without fire in heavy vehicles, than in light vehicles.

The majority of the fires and the instances of SWF did, as mentioned, not involve personal injuries. It is nevertheless of vital importance to gain insights into the causes of the instances that did involve personal injuries in order to prevent these in the future. Most of the fires involving personal injuries are caused by single accidents and collisions, and we may assume that the injuries are mostly related to traffic accidents. The number of fires and SWF caused by traffic accidents has decreased substantially in the study period (2008-2021).

High-gradient road tunnels

The fourth main finding of our study is, that high-gradient road tunnels are considerably overrepresented in the fire and SWF statistics in Norway. No other country has more subsea road tunnels than Norway. Today, there are 41 subsea road tunnels in Norway. In addition, there are at least 24 tunnels with a high gradient (defined as over 5 %) in the western region, which are not subsea. Since the degree of gradient appears to increase the risk of fire, we include these 24 road tunnels in the analyses.

The high gradient tunnels, which represent approximately 5 % of the road tunnels in Norway, had 38 % of the fires in the period 2008-2021. Thus, subsea road tunnels are significantly overrepresented in the statistics of fires in Norwegian road tunnels.

Heavy vehicles are overrepresented in fires in tunnels with a high gradient. The share of heavy vehicles in fires and SWF (33 % in tunnels without a high gradient and 40 % in high gradient tunnel fires), indicate that heavy vehicles are overrepresented in road tunnel fires. As we will discuss below, the share of heavy vehicles in high gradient road tunnel fires was even higher in the earlier studies that we conducted.

Figure S.2 shows the causes of fires and instances of SWF in road tunnels with and without a high gradient. The percentages are based on the number of fires in tunnels that are without and with a high gradient respectively, in Norway 2008-2021.

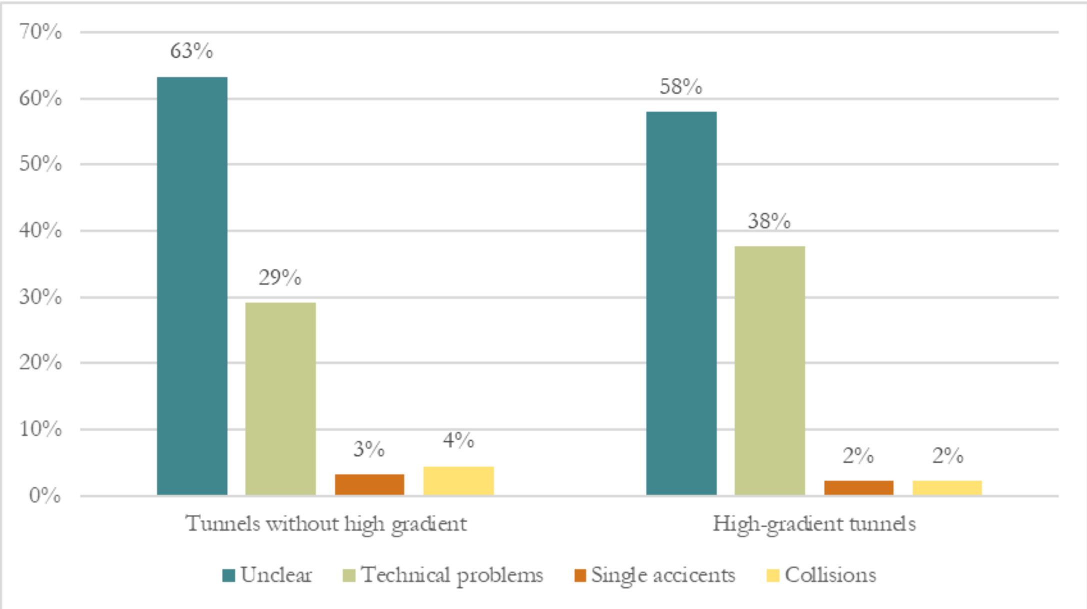

Figure S.2: The causes of road tunnel fires and instances of smoke without fire in road tunnels with and without a high gradient, 2008-2021. Percentages based on the number of fires and instances of smoke without fire in road tunnels without a high gradient (N=377) and tunnels with a high gradient (N=226).

The figure indicates that technical problems is a more frequent cause of fires in road tunnels with a high gradient than in tunnels without a high gradient.

When and where do the fires occur?

An analysis of the fires and SWF in Norway in 2008-2021, shows that 44 % of the fires 2008-2021 occurred in the afternoon. 64 % of the fires occurred between 06 and 18. Over half (59 %), of the fires occurred in the spring and summer. June is the month with the most fires (13 %). November is the month with the fewest fires (5 %).

In 34 % of the instances we lacked data on how the fire was extinguished, in 47 % of the cases, the fire services extinguished the fires, and in 16 % of the cases the driver extinguished the fires. In 2 % of the cases other road users extinguished the fire. Most of the fires are registered in the middle zone of the tunnels. The length of time the tunnels have been closed due to fire mainly group themselves into two parts. The first is between 1 and 45 minutes (43 %), and the other is 106 minutes or more (18 %).

We lack data on how the RTCs were notified of the fires in 13 % of the cases. The police (27 %) represent the most frequent actor to warn the RTC's of road tunnel fires. Combining the two options for road users to notify their local RTC about road tunnel fires (own telephone and tunnel telephone), we get a share of 17 %. A share of 24 % of the fires were reported by means of automatic alarm in road tunnels. Fire services notified about the fires in 15 % of the cases. The fire warning technology in road tunnels fills an important function. If we combine the shares of automatic tunnel fire detection and warnings communicated by means of tunnel telephone, we get a share of 31 %.

Suggestions for further research

How can we explain that the annual number of incidents has increased?

Our study shows that both fires and SWFs have increased gradually in the 14 years for which we have data. Investigating whether the increase in the number of fires and SWFs is in line with what we could expect, given the increase in traffic, or changes in other factors that affect the occurrence of vehicle fires in road tunnels, is an important question for future research.

Why has the share of fires in tunnels with a high gradient decreased?

Our analyses of fires in the period 2008-2021 indicate that the proportion of fires in high-gradient road tunnels has decreased over time, from 41 % in the period 2008-2015, to 31 % in the period 2016-2021. Identifying factors that might explain this is an important question for future research. This may be due to both an increase and/or a decrease in fires in high-gradient tunnels.

First, we must make reservations about relatively small numbers, which may fluctuate over time. In addition, we must note that the proportion of the fires in high-gradient tunnels relative to the total number of tunnel fires, is affected by the number of fires in tunnels without a high gradient. If special conditions lead to an increase in the number of fires in road tunnels without a high gradient (and not in high-gradient tunnels), this will lead to a lower proportion of fires in high-gradient tunnels.

We suggest that the decrease of fires in high-gradient tunnels may be due to three factors that should be investigated in future research:

1) Vehicle-related factors, for example the standard of brakes, engine, etc. It is possible that the standard of the heavy vehicles driving in Norwegian road tunnels has improved over time.
2) Driver-related factors, for example more experience with and higher competence/skills in driving in steep road tunnels.
3) Measures introduced by the authorities, for example information on how to drive in such tunnels to reduce the risk of fire, reduced speed limits, signs that encourage you to keep a low speed in the tunnel, correct use of brakes, use of retarders, etc.

Why has the share of heavy vehicles in high-gradient tunnel fires decreased?

It is important to examine the importance of the three above mentioned possible explanations, not least because it may shed light on the fourth trend that we have observed in our data: The proportion of vehicle fires involving heavy vehicles in high-gradient road tunnels has decreased slightly in the last period we are studying (2016- 2021), compared to the period from the previous study (2008-2015). In the first period (2008-2015), the share of heavy vehicles was 45 %, while it was 35 % in the second period (2016-2021). It is important to investigate whether the three measures mentioned above may have contributed to this decline.

Fire exposed subsea road tunnels

Four subsea road tunnels account for half (112 out of 226) of the fires and SWFs in subsea road tunnels in Norway: 1) the Oslofjord Tunnel (40), 2) the Byfjord Tunnel (23), 3) the Bømlafjord Tunnel (32) and 4) the Eiksund Tunnel (17). It seems important to do a detailed study of the causes of fires and SWFs in these specific tunnels and, based on that, discuss possible counter measures. This is an important area for future research. Relevant and effective measures in these four tunnels could contribute to a significant reduction in fires and SWFs in Norway.