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A survey of vehicle fires in Norwegian road tunnels 2008–2011

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ABSTRACT

Norway is one of the countries that constructs most road tunnels, and there are well over 1000 in the country today. The aim of this study is to map the prevalence and describe the characteristics of vehicle fires in Norwegian road tunnels 2008–2011. The average number of fires in Norwegian road tunnels is 21.25 per year per 1000 tunnels, and the average number of smoke without fire (SWF) is 12.5 per year per 1000 tunnels. The study provides four main results. The first is that the fires generally did not involve harm to people. This has also been reported in previous Norwegian research. The second finding is that heavy vehicles are overrepresented in fires in Norwegian road tunnels. This is in line with international research. The third main finding is that the causes of road tunnel fires involving heavy and light vehicles are different. This is also in accordance with international research. The fourth important and unique finding of the study is that subsea road tunnels are overrepresented in the statistics of fires in Norwegian road tunnels.

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1. Introduction

1.1. Background and aim of the study

Norway is one of the countries that constructs most road tunnels (Amundsen and Ranes, 1997). There are well over 1000 in the country, with a total length of more than 800 km. By European measures, Norwegian tunnels are typically long with little traffic. They are also often of lower design standard due to significantly less traffic than foreign tunnels (Amundsen and Engebretsen, 2009). There are more than 70 tunnels longer than 3000 m in Norway. The average AADT on Norwegian state roads with tunnels is about 10,000. There are however some heavy traffic tunnels in the Oslo area, with an AADT of about 100,000. The average percentage of heavy goods vehicles (HGVs) on Norwegian state roads with tunnels is 14%. The average length of Norwegian road tunnels is approximately 950 m.

No other country has more subsea road tunnels than Norway (Buvik et al., 2012). The 31 Norwegian subsea road tunnels have been constructed to uphold a scattered population, and increasing the mobility of inhabitants of islands along the coast of Norway. In 2005, it was reported that a widely scattered population of 50,000 people welcomed these projects (Blindheim et al., 2005). The average tunnel length of the Norwegian subsea road tunnels is 3900 m.

Road tunnels are usually at least as safe as or safer than similar roads in the open air without junctions, exits, pedestrians and bicyclists (Amundsen and Engebretsen, 2009). Road tunnels do nevertheless deserve attention from a traffic safety perspective, because of their disaster potential related to vehicle fires (Mashimo, 2002; Vuilleumier et al., 2002; Caliendo et al., 2013).

Although the vehicle accident risk is lower in road tunnels than it is on the remaining road network, the catastrophe potential related to tunnel fire is higher (PIARC, 2008; Mashimo, 2002). This is indicated by the three catastrophic road tunnel fires in Central-Europe, which claimed a total of 62 lives at the turn of the century; in the Mont Blanc tunnel, the Tauern tunnel in 1999 and in the St. Gotthart tunnel in 2001 (Haack, 2002; Caliendo et al., 2013).

Road tunnels comprise an enclosed space which hinders the dissipation of heat and smoke, limits access for fire fighters and rescue operations and makes safe escape difficult for tunnel users (Mashimo, 2002; Caliendo et al., 2013). Moreover, road tunnel fires may also involve huge economic losses when tunnels are unavailable for traffic, especially in extreme cases when tunnels are closed for redevelopment for weeks or months (Haack 1998, 2002; Chow and Li, 2001). It has been suggested that the risk of vehicle fires in road tunnels may increase, as traffic increases and more and longer road tunnels are being built (e.g. Haack, 1998, 2002).

The aim of this study is to map the prevalence and describe the characteristics of vehicle fires in Norwegian road tunnels 2008–2011.

1.2. Previous research on road tunnel accidents

Road tunnels have fewer accidents per vehicle/km than comparable road stretches in the open air, as several accidents occurring out on roads in the open air seldom occur in road tunnels (Mashimo, 2002; Amundsen and Engebretsen, 2009). The accident

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severity of the most common road tunnel accidents is, however greater than the severity of accidents occurring on open air roads (Nussbaumer and Nitsche, 2008). A literature study shows that road tunnels offer special safety challenges under normal conditions, related to higher accident risk in entrance zone, lack of references, fear and monotony (Nævestad and Meyer, 2011).

The vehicle accident risk and severity differs greatly in different tunnel zones (Amundsen and Engebretsen, 2009; Yeung and Wong, 2013). The vehicle accident risk of the entrance zones of road tunnels is 3–4 times higher than it is further into the tunnels, while the accident severity is highest in the central zone of road tunnels (Amundsen and Ranes, 1997). In their study of 608 accidents in three Singapore expressway tunnels 2009–2011, Yeung and Wong (2013), found that accident rates are higher in the transition zones, defined as 250 m before and after the tunnel entrance, than in the rest of the tunnel. They found that the rate of multi-vehicle crashes were higher in the transition zones than the rest of the tunnels.

The high entrance zone accident risk is probably due to impaired light conditions in tunnels compared with open air, a so called "black hole effect" (Rinalducci et al., 1979), which make drivers lower their speed, and change lateral position (Amundsen, 1994; Sagberg et al., 1999). Road users braking as they enter road tunnels may induce a higher accident risk.

Road tunnels comprise a "poor sensory environment" compared with roads in the open air, and this may lead to monotony, lowered driver attention, disorientation and/or fear (Jenssen et al., 2006: 26). Marec (1996) suggests that driver claustrophobia and boredom may be the most restrictive length limiting factor of road tunnels. The lack of references in road tunnels may also make drivers' assessments of speed and distances poor (Martens, 2005). Finally, drivers rate road stretches in the open air higher than tunnels when asked about desirable road environments. Subsea tunnels are rated lowest among road users (Jenssen et al., 2006: 12).

Amundsen and Engebretsen (2009) have studied accidents in Norwegian road tunnels 2001–2006 and conclude that the three most common accident types in road tunnels are: collisions between vehicles driving in the same direction 43% (rear end or changing lanes), single vehicle accidents 35% and head on collisions 15%. A previous analysis of Norwegian tunnel accident data 1992–1996 conclude that rear end collision is the most common road tunnel accident type, occurring twice as often in tunnels as in the remaining road network (Amundsen and Ranes, 1997). The shares of the different accident types are dependent on whether the tunnels have one or two tunnel tubes.

Norwegian studies indicate that heavy vehicles are overrepresented in road tunnel accidents. The percentage of HGVs involved in road tunnel accidents (22%) is twice as high as the AADT and accident share on roads in the open air would imply (Amundsen, 1996).

1.3. Previous research on road tunnel fires

Haack (2002) states that in Dortmund, with about 500,000 inhabitants, an average of 250 vehicle fires occurred each year over a 10 year period. In Hamburg, with 1.8 million inhabitants, about 700 vehicle fires occurred each year. The vehicle fire risk for the central European road network in general is two vehicle fires per 100 million vehicle kilometers (Haack, 2002).

When it comes to vehicle fire in road tunnels, Haack (2002) states that the Gotthart tunnel had 42 vehicle fires in the period 1992–1998. Cars were involved in 21 fires, buses in seven cases and lorries on 14 occasions. Thus half of the fires involved heavy vehicles. In contrast to this, the percentage of HGV using the tunnel was 15% of an AADT of 17,000. Haack states that in this period 4 fires occurred in the tunnel per 100 million driven kilometers for all vehicles. The fire risk for lorries was six per 100 million driven kilometers (Haack, 2002).

International research indicates that the most common causes of vehicle road tunnel fires are mechanical or electrical defects in vehicles (PIARC, 2008: 61). A 1992 publication from the NPRA sums up the road tunnel fire research to conclude that the risk of road tunnel fire is 0.01 instances of fire per 1 million vehicle hours. These data indicate that most of the fires occur in cars, and that the fires usually are extinguished by the driver or by other people. The 1992 publication from the NPRA asserts that the most frequent causes of vehicle tunnel fires are defects in the electric system, or the petrol supply. Moreover, it is reported that the fires seldom cause personal injuries (NPRA, 1992: 2).

The investigation report of the fire brigade of Søndre Follo Brannvesen (2011) following the subsea Oslofjord tunnel fire 23.06.2011 shows that this subsea tunnel experienced 11 fires in the three years preceding the 23.06.2011 fire. Eight of the fires were in heavy vehicles, while three of the fires were in personal cars. Two thirds of the fires in the heavy vehicles were caused by overheated brakes, while one third was caused by overheated engines (Søndre Follo Brannvesen, 2011: 9). This report suggests that the steep gradient in this subsea road tunnel seems to involve a higher vehicle fire risk for heavy vehicles, as their brakes may overheat driving down into tunnels, and as their engines may overheat driving up and out of the subsea tunnels.

2. Method

2.1. Road tunnel vehicle fire characteristics

In this study both fires and instances of smoke without fire (SWF) are included. The Norwegian collegium for fire terminology defines a fire as an "Unwanted or uncontrolled combustion process characterized by release of heat, combined with smoke, flames or glowing."[1] 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 instance 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). The study includes 135 instances of fire and SWF and we generally refer to these instances as fires in the rest of the paper.

The study has collected data on the following fire characteristics:

(1) Time of the fires (2) location of the fires, (3) consequences of the fires: people and vehicles involved, personal injuries, tunnel damages and for how long the tunnels were closed, (4) cause of the fires and (5) subsea tunnels.

2.2. Data sources

The project is based on the following data sources: (1) "Vegloggen", which is the five Norwegian road traffic centrals' (RTC) system for recording road incidents, (2) road traffic central personnel, (3) Norwegian Public Roads Administration (NPRA) personnel working with road tunnel safety, (4) fire services in all municipalities with road tunnels and (5) news archives.

(1) *"Vegloggen" (road log).* Our main data source have been the five Norwegian road traffic centrals' (RTC) system for recording road traffic-related incidents. Vegloggen was put into use in 2008, and is still used today. The RTCs monitor and control all road tunnels in their regions, except the tunnels

[1] http://www.kbt.no/faguttrykk.asp?ID=3418.

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