

Sound beacons support safer tunnel evacuation

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Can sound beacons be used to support evacuations from smoke-filled tunnels? Yes, says research. Picture taken during an experiment conducted in a cavern at Ladehammeren in Trondheim. Credit: Thor Nielsen.

Research conducted as part of the project EvacSound demonstrates that auditory guidance using sound beacons is an effective aid during the evacuation of smoke-filled road tunnels. This is good news. It is a fact that vehicle drivers and passengers cannot normally expect to be rescued by the emergency services during such accidents.

Researchers at SINTEF have been testing a so-called auditory guidance system to support evacuations from smoke-filled tunnels following vehicle fires. The project is being conducted under contract for the Norwegian Public Roads Administration (Statens vegvesen) and the company Trafysys, which develops and supplies [intelligent transport systems](#).

"When a [fire](#) breaks out, queues will form, vehicles will collide with each other and drive into the tunnel walls. Some will be abandoned in the middle of the road", says Gunnar Jenssen at SINTEF. "This makes it difficult for the fire and rescue services to

provide any assistance. Fire and rescue response times may be up to 30 minutes in the most remote Norwegian tunnels", he says. Jenssen has worked on tunnel safety issues in a variety of contexts.

A universal rescue system is key

"The aim of the EvacSound project is to develop a universal and language-neutral system that can be used as a supplement to existing signage and lighting systems", says Tron Vedul Tronstad, a research scientist at SINTEF, who is heading the project.

Some drivers and passengers may have visual or hearing impairments, or other forms of disability. This is why the scientists have been testing both visual and auditory guidance systems.

"During the fire in the Gudvanga tunnel in 2013, 67 people found themselves trapped by the smoke. More than 60 percent of these were foreign tourists from a number of different countries", says Jensen.

"If we want to help everyone involved in such a situation, it's important to have a language-neutral auditory guidance system. There is no time to play the same emergency announcement in 15 or 20 languages. Time is precious when you're trying to escape from a tunnel fire", he says.

In the worst case, you will only have a couple of minutes before you are no longer able to walk any farther. This will depend on how close you are to the source of the fire, how extensive it is, and whether or not you are standing on a slope where petrol fires can spread fast. You may find that the fire extends over a kilometre or more of the length of the tunnel.



Here we see one of the research subjects being led through the tunnel, wearing glasses that make it impossible for him to see where he is going. The sound system developed by the researchers simulates the noises made by the tunnel fans during a fire, while at the same time testing the new auditory guidance system. Credit: Thor Nielsen.

Two in three found their way out

The experiments were carried out in a cavern excavated under the Ladehammeren hill in Trondheim. Thirty people of all ages were equipped with tight-fitting glasses that simulated smoke and impaired their vision. They were then asked to find their way out of the tunnel with the help of sound beacons. They were provided with no other information about what was happening.

The sounds came from loudspeakers located at 20-metre intervals along the entire length of the tunnel, and which were used to test two different auditory beacons. The researchers' objective is to identify a sound that causes people intuitively to select it to guide them out of the tunnel, because the beacons are directional.

"In order to make this experiment as realistic as possible, we also simulated the noises made by the tunnel fans during a fire", says Tronstad. We tested this using two different noise levels", he says. The two levels simulate the two situations that arise when a fire breaks out. Immediately after a fire begins, the fans cut out in order to reduce the

supply of oxygen to the fire. After a while, the fans switch to full speed in order to force the smoke out of the tunnel.

The research subjects had to repeat the experiment, but without the beacons to help them. So, all of the subjects had to undergo five experiments.

The data from the experiments have been analysed, and the results are very positive. Two-thirds of the research subjects who understood that the beacons were there to help them, found their way correctly out of the tunnel with the help of the auditory guidance system.

"We also noted a tendency for younger subjects, aged between 20 and 30, to find their way out faster than those who were 50 or older", says Tronstad. "We expected this because we know that hearing deteriorates with age and the beacons thus have less effect. This also illustrates the importance of providing multiple guidance signals to help people out of smoke-filled tunnels", he says.

Refining the signals

It is now important to advance this work. Trafysys and SINTEF are currently planning more experiments that will take place in a [test facility](#) in a cavern in Åndalsnes. Here they plan to refine the sound signals to make it easier for people to understand exactly where the beacons are leading them, in spite of other noises they may hear in addition to the hollow reverberations that are unique to tunnels. The researchers also want to find out if more information is needed to optimise the system, such as might be provided by light beacons.

An important element of uncertainty that must be taken into consideration in the light of the evacuation experiments, involves situations in which people are tempted to follow a person who assumes the role of a safe leader, but who walks in the wrong direction. In fact, this is not an unusual situation because the smoke that develops around a fire is often most dense at some distance from the flames. This means that smoke sometimes accumulates right in front of [tunnel](#) openings.

"If someone assumes the role of leader, but guides others in the wrong direction, the consequences could be fatal", says Tronstad. "It is thus vital to get a universal system in place that as many people as possible can understand", he says.

Provided by Norwegian University of Science and Technology

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