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# "Light is not just at the end of the tunnel!"

From art installations to smart LEDs, lighting plays an essential role in helping to make tunnels safer and less stressful. But it's far from being the only bright idea that's helping with traffic management in these confined spaces, as **Jack Roper** discovers

**Photographs: Mikael Ullén**

Whether it be improving the urban environment, traversing a body of water without disrupting navigation, bypassing miles of treacherous mountain passes, or diverting traffic beneath a site of ecological or cultural importance, tunnels around Europe provide the subterranean solution to a range of road network challenges. But their cavernous stretches also create confined and claustrophobic spaces wherein the danger to life from fire or toxic fumes is magnified, necessitating a bewildering array of escape routes, emergency power and communications systems, fixed fire systems and ventilation systems. And with new projects in the pipeline and older tunnels undergoing wholesale renovation to meet stringent new EU directives with a 2019 deadline, increasingly sophisticated tunnel management systems require a concentrated deployment of technology.

> We have about 12km of single-tube tunnels with cameras every 50m. In total we have at least 400 cameras
>
> **Tor Thomassen, installations project manager, Norra Länken, Stockholm, Sweden**

Failsafe early detection of any incident in a tunnel is imperative to safety – which means cameras, and lots of them. The Norra Länken (Northern Link) is a new section of Stockholm ring road consisting largely of tunnels. "Each tube contains only traffic in one direction


**Artwork helps improve the ambience and aids navigation in Stockholm's Norra Länken tunnel**

– that's a safety feature," explains installations project manager Tor Thomassen. "It's a two- or three-lane highway with lots of intersections. We have about 12km of single-tube tunnels with cameras every 50m. In total we have at least 400 cameras. If there's an alarm – for instance from a smoke detector – it's stamped with the best camera position and we'll automatically get a view of that area. Of course, we have image-analyzing systems in the cameras; we use them for detecting incidents, stopped vehicles, lost loads, or anything that shouldn't be there."

## Speed awareness

Average speed enforcement cameras were installed in the UK's Hindhead Tunnel following problems with wealthy young drivers making recreational 'tunnel runs' in high-performance sports cars. But in tunnels, where traffic queues cannot be allowed to form because of the potential build-up and inhalation of fumes, detecting slow vehicles is the crucial thing. In the Norra Länken, an MTM2 sign system is used whereby infrared detectors measure average speed every four seconds; if this falls below 50km/h, systems are activated and VMS signs display warnings upstream. "Infrared detectors can't detect stopped vehicles with any precision, so we have two detection systems – one for queues and one for stopped vehicles," Thomassen explains. "Trafik Stockholm is one of the Swedish Transport Administration's four traffic management centers and surveys all roads in the Stockholm region. The system architecture means that contractors can deliver several different systems in different tunnels with a common functionality. As long as there's an interface with the monitoring system, the subsystem could use any technology to fulfill functional requirements."

# Light and magic

**Light in tunnels can help to relax drivers, aid navigation and improve safety, as projects in Stockholm, Austria and Norway prove**

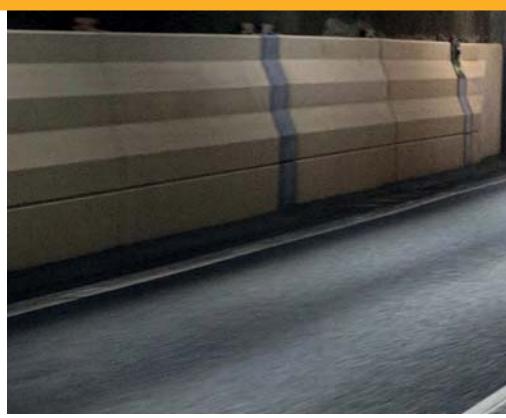
Six junctions within Stockholm's Norra Länken are embellished with art installations combining lighting, sculpture, photos and video to represent nature and the changing seasons. "If you build a tunnel in one of Sweden's most valuable environments, you have to build something pretty, for sure!" says Tor Thomassen, who is installations project manager for the facility.

But can art actually contribute to tunnel safety? "I don't have data to show this," Thomassen concedes, "but, when it's discussed among experts, we think it's better when environments are not so cold and sterile and black. Some people fear entering tunnels, so this lighting and expression shows this is a human environment after all."

The installations also orientate road users by lending a visible geography to a complex system. "You have the choice of making several exits during your ride through and this artistic expression helps you to recognize where you are," says Thomassen.

Lighting also plays a role in improving safety and softening the driving environment upon entry and exit, when drivers transition between natural and artificial light. "Light is not just at the end of the tunnel!" quips Christoph Wanker, project manager for Austria's Arlberg Tunnel. "Brightness sensors in the Arlberg Tunnel ensure optimum lighting for human vision at all times. Lights are situated closer together near the tunnel portals, ensuring the difference isn't too extreme and allowing the eyes time to adjust to the new conditions. Integrated sensors regulate the lighting throughout the tunnel."

The shared concern with creating a benign driving environment echoes the radical design of Norway's 24km Lærdal Tunnel – the world's longest road tunnel. The Lærdal is punctuated by large caverns at 6km intervals, illuminated in blue and gold to mimic sunrise and give drivers the impression of emerging into daylight between four shorter tunnels.



Left: **A range of new technology is being installed in Austria's Arlberg Tunnel**

Right: **Another dramatic view of the artwork on display in Stockholm's Norra Länken tunnel**

## Under the mountains

Austria's Arlberg Tunnel – a 14km, single-bore bidirectional tunnel providing a vital road link under mountainous country – is undergoing a US$180m (€160m) refurbishment, encompassing new escape routes, breakdown bays and a high-pressure mist-sprinkling system, to meet new laws. This upgrade will see multiple technologies working together to detect potential incidents. "A range of high-tech systems such as video image evaluation, thermal scanners and audio tunnel monitoring will enable quick responses to any disruptions," explains Alberg Tunnel project manager Christoph Wanker. "Microphones and cameras transmit data to a database. Software is able to

Christoph Wanker photograph: ASFINAG

differentiate between the normal sound of traffic and unusual noises such as collisions or brakes."

Thermal scanners at the tunnel entrances are intended to avert potential tunnel fires before they happen. "All heavy vehicles are guided through a special portal with five scanners and two infrared cameras," he says "and, in case of over-heating, diverted in order to cool down."

The Arlberg Tunnel is monitored from a regional traffic management center at St Jakob, one of nine such centers around Austria monitoring 1,367 miles (2,200km) of road and 158 tunnels with over 4,900 cameras. "Every tunnel is monitored 24 hours a day," Wanker continues. "Data collected from around the network is displayed on a large wall of monitors. Every alarm is activated in the management center, where ASFINAG [Austrian road agency] operators check the situation and decide on further moves." They can then coordinate with local emergency response teams and drivers can be directed via VMS signs, loudspeakers and static-free radio transmission within the tunnel.

> Microphones and cameras transmit data to a database. Software is able to differentiate between normal traffic sounds and unusual noises such as collisions or screeching brakes
>
> **Christoph Wanker, project manager, Arlberg Tunnel, Austria**

## Man versus machine

Even when incorporating autonomous elements, tunnel systems are always likely to require human oversight given the catastrophic risks if things go wrong. And there are other considerations. "Personally, I think there will always be the need for a human element," says Thomassen. "Image-analyzing systems have not always been stable and can give false alarms. For instance, if it rains, cars carry water with them into the tunnel, making a wet spot. The camera sees a difference in the environment and thinks the wet spot

# Underground route

## A new tunnel in central Singapore will ease jams created by traffic coming from nearby Sentosa Island

The Sentosa Gateway Tunnel is a 1.4km, one-way tunnel carrying outbound traffic from Sentosa Island to Lower Delta Road and Keppel Road in Singapore. It was built to relieve congestion in the area and opened in April 2017.

The Singapore Land Transport Authority (LTA) utilizes an Integrated Traffic and Plant Management System (ITPMS) as a common control platform for multiple detection and response systems in the Sentosa Gateway Tunnel and other road tunnels. This is part of the LTA's 24-hour monitoring of island-wide traffic from a single control center.

Linear heat detectors and automatic incident detection (AID) cameras monitor the tunnel and, if an incident such as fire or abnormal traffic flow is detected, the control center operator is alerted and must verify the incident before making the decision to execute a specific response plan recommended by the ITPMS. In the event of fire, the ITPMS response plan will aim to provide a smoke-clear path to facilitate evacuation, firefighting and rescue operations.

Variable message signs (VMS) upon entering the tunnel keep motorists informed of traffic conditions, while lane-use signs operate inside. In the event of an emergency, an entrance ramp barrier system can prevent vehicles from entering the tunnel and FM radio re-broadcast and break-in facilities can be used to convey messages to drivers. If fire occurs, the fixed water-based firefighting system will be activated and the tunnel ventilation system will provide a tenable evacuation route by preventing back-layering of smoke.

According to an LTA spokesperson, traffic in the Sentosa Gateway Tunnel has been smooth-flowing since its recent opening and it has fulfilled its purpose of easing traffic problems at Sentosa Gateway.

Singapore's newest tunnel, the Sentosa Gateway, is keeping traffic flowing in the city center

is a stopped car. Around 90,000 vehicles use the Norra Länken each day and, if you close the tunnel on a false alarm, it has a huge impact."

Verification is essential – but, once an alarm is confirmed, the complexity of interconnected systems involved means response must be pre-programmed. "The system has action plans for every possible event – stopped vehicle, accident, car fire, and so on. In theory, the operator shouldn't do more than accept there is a car fire and the location is correct. Then they push a button, messages are sent to systems, managers and assistance crews. A pre-programmed series of actions takes place."

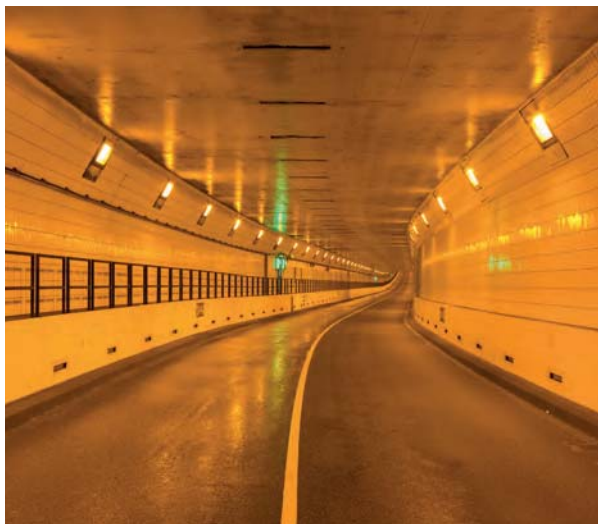
> The speed within the tunnel should be at least 15km/h because that's the speed at which fumes and exhaust gases are ventilated in the direction of the traffic
>
> **Erik-Sander Smits, consultant, Arane**

### Adaptive flow management

Rotterdam's 0.6-mile (1km) Maastunnel – taking traffic beneath the Nieuwe Maas shipping channel – was opened in 1942 and now requires renovation to meet new European rules. Part of the challenge is preventing queues since the tunnel forms part of a busy urban network. Alongside conventional tunnel management systems, the City of Rotterdam is working with Arane Consulting to provide an innovative solution known as adaptive flow management (AFM).

The challenges are threefold. "First, the speed within the tunnel should be at least 15km/h because that's the speed at which fumes and exhaust gases are ventilated in the direction of the traffic," explains Arane consultant Erik-Sander Smits. "Secondly, there cannot be any spillback toward the tunnel; downstream of the tunnel are traffic lights and intersections; queues here can spill back into the tunnel. Thirdly, it should be possible to evacuate the tunnel, so we must always ensure sufficient space is available downstream."

The proposed system is an integrated network management solution aiming to satisfy all three imperatives – while also being fully automated. "Within the tunnel there



Right and below: **The interior and entry/exit of the Maastunnel in Rotterdam, which is now undergoing refurbishment**

## Go with the flow

**From July 2017, at any one time, most of the Maastunnel in Rotterdam will be closed for a two-year refurbishment. It will include the installation of an adaptive flow management (AFM) system. Here's how it will work...**


will be detector loops that measure speed and count vehicles; outside there will be more than 80 radar installations – a new way to measure queue length at intersections," Smits continues. "We continuously measure available space downstream and speed within the tunnel. Before a situation becomes problematic, the AFM system increases throughput by giving more green-time at traffic lights downstream. It can also hold vehicles upstream."
For an outline of how the system works see *Go with the flow*, box, above.

Data from the detection systems is processed by proportional-integral-derivative (PID) controllers, which calculate the green-time variations needed to maintain appropriate network outflow. This is transmitted to the surrounding signalized intersections, where green-time is adjusted accordingly. In this way, tunnel traffic flow is smoothly maintained without the inefficient tunnel closures and vehicle metering currently needed to avert queuing in some Dutch tunnels at peak times.

> Our goal is to finish the AFM system in 2018. We then have a year to test whether it is a stable, working system before the tunnel is ready
>
> **Robert Kooijman, traffic management advisor, City of Rotterdam**

"We are building the central system and placing radars outside the tunnel," says City of Rotterdam traffic management advisor Robert Kooijman. "Our goal is to finish the AFM system in 2018. We then have a year to test whether it is a stable, working system before the tunnel is ready. It will improve throughput on the whole network and liveability in Rotterdam." And further innovation is envisaged, with Kooijman already speculating that radar detection may eventually be superseded by floating car data.