

# Basic installations to provide safe operation for low traffic tunnels

## Instalaciones básicas para una operación segura de túneles de bajo tránsito



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## **Abstract in English**

Decisions about what is necessary equipment in a low traffic tunnel must be based on a process with several parties involved. Some of the decisions are based on legal regulations specific to the individual country. The rest is up to the parties involved in the decision process. It is advisable that the tunnel owner, the planners and representatives from the rescue services goes through this process together. This will also help the rescue services to understand how the tunnel functions, how they may do their job in a best possible way and the limitations they will meet for rescue possibilities in certain events.

Norway, a country with close to 1000 tunnels with a total length of more than 730 km, has the following demands for equipment on low traffic tunnels. Lighting must be installed to prevent accidents and fire extinguishers are needed to help in self-rescue. It is also compulsory to install emergency phones for giving alarms and red flashing lights outside the tunnel to warn oncoming traffic not to enter the tunnel and make the accident bigger. In addition, it is required to give the emergency services a possibility to communicate by installing the necessary communication frequencies. To make it possible to intervene in the tunnel during a fire it is necessary to have a ventilation system to control the smoke.

Once the equipment is in place, and the tunnel is open to traffic it is necessary to perform an adequate operation and maintenance to keep the equipment operable at all times. The best way to do this is to perform preventive maintenance and periodic inspections and properly document all the work and inspections.

This paper explains how the Norwegian public authority does this in a country with several hundred tunnels with low traffic, a tough climate and a beautiful but demanding landscape.

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## **Resumen**

En un túnel con bajo tránsito, las decisiones sobre cuál es el equipamiento necesario deben basarse en un proceso que involucre a varias partes. Algunas decisiones están fundamentadas en las regulaciones legales específicas dentro de cada país, pero la mayor parte de las decisiones corresponde al conjunto de los actores involucrados en el proceso. Es muy aconsejable este proceso sea encarado en forma conjunta por los propietarios del túnel, los planificadores y los representantes de los servicios de rescate. Esto será de gran utilidad para los servicios de rescate, a efectos de entender cómo funciona el túnel, cómo deberían realizar su trabajo de la manera más eficiente posible, y qué limitaciones deberían tener en cuenta ante la ocurrencia de determinados eventos desfavorables.

En Noruega, un país con cerca de 1000 túneles cuya longitud total supera los 730 km, existe una serie de requisitos sobre el equipamiento que deben tener los túneles con bajo tránsito. La iluminación debe estar instalada bajo la premisa de prevenir accidentes, y deben colocarse matafuegos como un medio de autoayuda en situaciones de emergencia. Es asimismo obligatorio instalar teléfonos de emergencia para dar la alarma, y disponer de luces rojas destellantes en el exterior del túnel para prevenir el ingreso de vehículos en estas ocasiones, lo que podría empeorar el problema. Por otra parte, los servicios de emergencia deben tener total disponibilidad para establecer las frecuencias de radio que necesiten en sus equipos de intercomunicación. Y como requerimiento de gran importancia durante las tareas de rescate, el túnel debe contar con equipos de ventilación que permitan controlar los efectos nocivos del humo producido por incendios.

Una vez que el equipamiento está instalado y el túnel se abre al tránsito, es necesario planificar y llevar a cabo un eficiente mantenimiento que garantice la operabilidad de los equipos en todo momento. La mejor forma de hacer esto es efectuando un mantenimiento preventivo basado en inspecciones periódicas, con reportes que permitan documentar apropiadamente estas actividades.

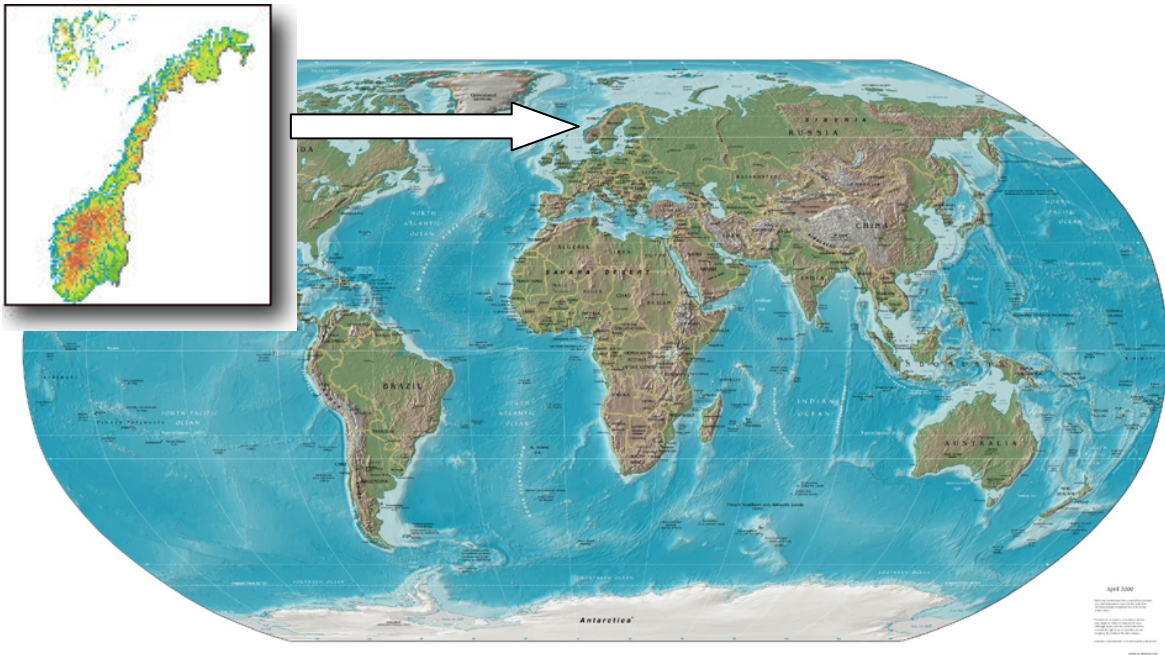
Este artículo describe la forma en que la autoridad pública en Noruega desarrolla estas tareas, en un país que posee cientos de túneles con tránsito reducido, un clima muy riguroso y un territorio con espléndidos paisajes pero de topografía sumamente exigente.

## Basic installations to provide safe operation for low traffic tunnels.

This paper describes how we in Norway deals with these questions and what we have decided is the minimum basic installations needed in low traffic tunnels.

To help you to understand our point of view I will use a few minutes to describe Norway the geography and the climatic situation we find in our country.

Norway lies in the arctic region in the northern hemisphere, (not far from the North Pole.) I am told that in many ways our country may resemble the southern parts of Patagonia in Argentina. Norway is known in many parts of the world for its beautiful scenery with fjords and mountains that goes straight into the fjords and for its many islands. A landscape that are demanding for both building new roads and for the road operators.



### Geography in most of Norway

- High mountains
- Deep fjords
- Scattered populations



### Some key figures from our road network

We have a public road network that consists of:

- 27 000 km national roads - owned by the state and operated by the NPRA<sup>1</sup>
- 27 000 km county roads - owned by the Counties and operated by the NPRA
- 36 000 km community roads - community owned and operated.

The number of tunnels is increasing every year and is now approximately 940. 515 of them are longer than 500 meters. The total tunnel length are aprx 735 km.

- Mostly short tunnels: < 1 km  
longest tunnel 24,5 km
- Varying traffic density: (Annual average daily traffic)  
AADT < 1000 for 50 % of the tunnels  
AADT > 5000 for 20 % of the tunnels  
AADT in the Oslo tunnels up to 90 000
- 24 sub-sea tunnels

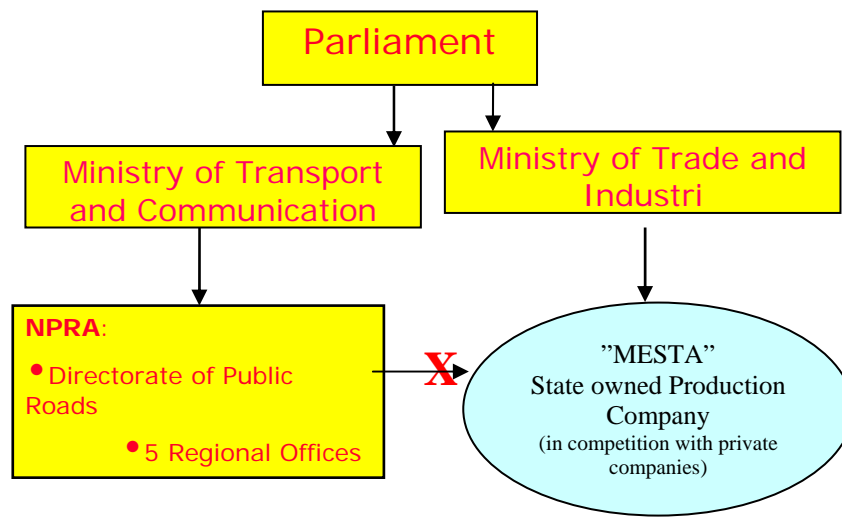
Norwegian world records in tunnels:

- The longest road tunnel, The Lærdal tunnel 24,5 km
- The deepest subsea road tunnel, The Eikesund tunnel, - 287 mbsl (m below sea level)
- The longest subsea tunnel, The Bømlafjord tunnel, 7,8 km at depth -260 mbsl.
- The oldest subsea tunnel, the Vardø tunnel from 1981

Now bear in mind that we are **only 4.5 million inhabitants** living in this country. It is a political goal in most parties that the population should stay in every part of our long country. We do not want too much centralisation.

The result? – It is a demand that there is roads to every fjord and larger island of this very long and for larger parts a very narrow country. 25 sub sea tunnels some down to 250 meters below sea level. As part of the road network we, the NPRA charter some 100 car and passenger ferries operating as part of the road network across fjords and out to bigger islands.

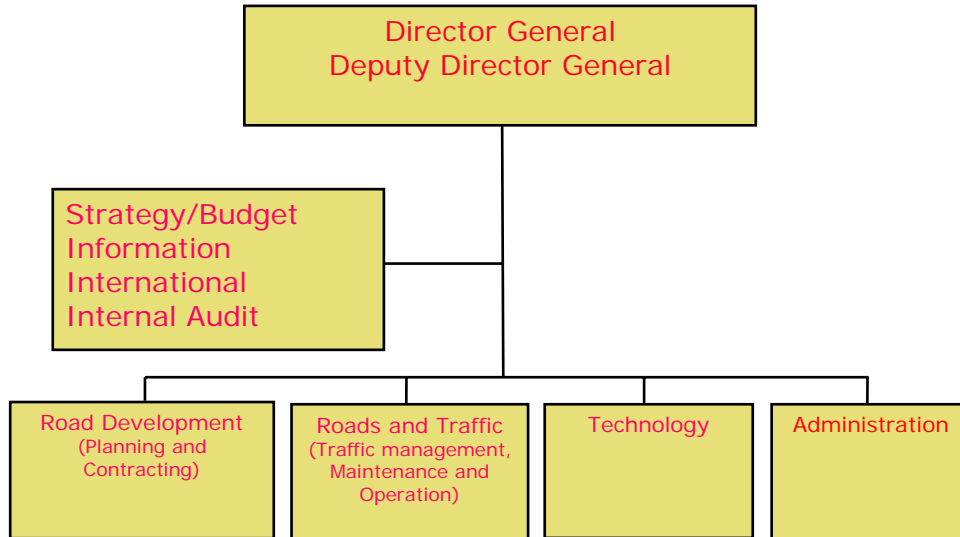
### Organisation of the Naorwegian Public Roads Administration (NPRA)



<sup>1</sup> NPRA = Norwegian Public Roads Administration

In 2003 the production department was politically removed from the NPRA and established as a state owned company, but with no links to the NPRA. This was a big challenge for the NPRA. Everything has now to be done in contracts that have to be subject to tendering.

The NPRA internal organisation..



This means that all norwegian tunnls, except on private and local roads, must be equiped acording to NPRA standards.

Tunnel tecnology in low traffic tunnels

- Hard rock tunneling
- The rock itself is the building material
- Drained concept
- Drill and blast
- Pregrouting
- Support methods: rock bolting and shotcrete
- Spiling or cast concrete only in dangerous weakness zones
- Water and frost protection where necessary

This means that we are not afraid that the tunnel will have a total collaps in case of fire like tunnels built of concrete.

Our policy in tunnel construction was for many years to get cheap tunnels so that more and more people could travel with their own cars without having to wait for the local passenger boat to get their supplies. The slogan "High tech – low cost Norwegian tunnels" was often heard. The country was being rebuilt after the Second World War and communication was essential to do that.

At that time 50 - 60 years ago, safety was not an issue and therefore we are still upgrading tunnels from that time. Regrettably I have to tell you that even if it was mandatory to have light in every tunnel, old and new, from about 1990 we still have some black holes with no light and no equipment at all that are more than 1000 meters long. Instead of upgrading these tunnels, the local politicians want to use the money on new roads. Very few people complain – they are used to it, and the tourists may find it exotic. These tunnels are however, safe because everybody drives with care and the cars have light. It must all the same be upgraded to a new standard.

From the late 1980s there was a change in attitude in the road administration. Risk was not only considered as the probability of an accident, which in tunnels was very low, but the consequences was now taken into account. This resulted in the need for a national design guide that now applies to all new tunnels on national and county roads. When an upgrade is due we also uses the same guidelines as new tunnels regarding equipment.

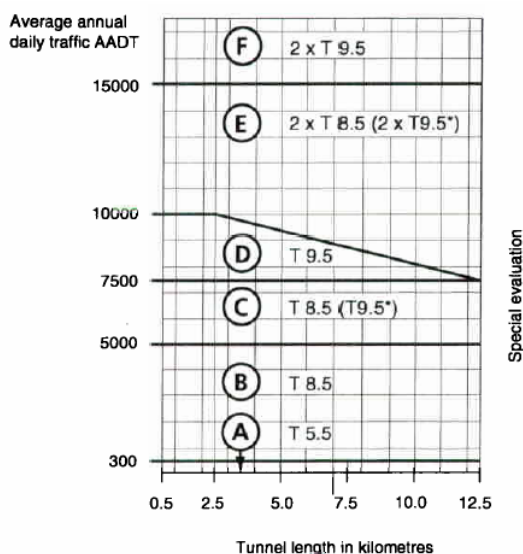
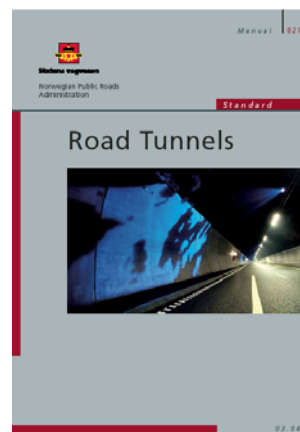
### Norwegian design guide.

Norwegian tunnels are built according to national guidelines for tunnel construction.

Two other countries, Iceland and on the Faroe Islands, also uses the Norwegian guideline for their tunnels. Due to many questions from abroad we also translate this manual to English, and this was last done in 2004. This guideline is available through the following link.

[http://www.vegvesen.no/vegnormaler/hb/021/021\\_e\\_05\\_w.pdf](http://www.vegvesen.no/vegnormaler/hb/021/021_e_05_w.pdf)

In this design guide the tunnels are classified in 5 groups from A and to F based on the length of the tunnel and the traffic volume. This in turn defines the safety equipment that we have decided is the minimum that we will accept in a new tunnel or when upgraded existing tunnels. That table is shown to the right, but you will find both of them in our guidelines if you use the link above.



The philosophy behind this table is the following: Most of our low traffic tunnels lie in areas where there are long distances to the nearest village or houses, and there is no professional rescue service available.

Outside the bigger cities, only voluntary firefighters with limited resources are available. Due to the long distances, the time before the rescue service arrives may be up to an hour or even more. Because of this, we focus on 5 areas, and we are now not talking about the tunnel design, but the necessary equipment.

#### 1. Prevention.

First of all we must try to make the tunnel as safe as possible so that accidents do not happen, and one of the ways to do that is to have light in the tunnel to make the driving easier.

Table 6.1 Safety equipment in tunnels

EQUIPMENT	TUNNEL CATEGORY						NOTES
	A	B	C	D	E	F	
● Obligatory ⊙ Evaluated							
Emergency lay-bys		●	●	●	●	●	See Ch. 4 "Geometric design"
Turning points		●	●	●			
Escape possibility by foot					●	●	Interconnections every 250 m
Power supply, lighting and ventilation	See Chapter 10 "Technical equipment"						
Emergency power supply		●	●	●	●	●	Lighting in the event of power failure See Sections 602.201 and 1003.6
Emergency exit lighting			⊙	●	●	●	Approx. every 62.5 m. See Sec. 602.202
Emergency Exit sign					●	●	Also obligatory in other categories if the tunnel is constructed with alternative emergency exits, e.g. interconnections. See Sections 602.203
Emergency telephone		●	●	●	●	●	Category B: Approx. every 500 m <sup>1)</sup> C: Approx. every 375 m <sup>1)</sup> D: Approx. every 250 m (both sides) <sup>1)</sup> E: Approx. every 500 m <sup>1)</sup> F: Approx. every 250 m <sup>1)</sup>
Fire extinguishers		⊙	●	●	●	●	Category B: Approx. every 250 m <sup>1) 2)</sup> C: D: Approx. every 125 m <sup>1) 2)</sup> E: Approx. every 125 m <sup>1)</sup> F: Approx. every 62.5 m <sup>1)</sup>
Water for fire extinguishing		●	●	●	●	●	Alternative solutions in Section 602.206
Flashing red stop signal		●	●	●	●	●	See Section 602.207
Remote controlled barriers		⊙	⊙	⊙	⊙	●	Evaluated on basis of expected frequency of use. See Section 602.208
Changeable signs		⊙	⊙	⊙	⊙	⊙	See Section 602.209 and 603
Lane signals				⊙	⊙		See Section 602.209
CCTV surveillance				⊙	⊙		See Section 602.210 and 603
Communication and broadcasting equipment		●	●	●	●	●	See Section 602.3
Mobile telephone		⊙	⊙	⊙	⊙	⊙	Determined in conjunction with mobile teleph. company
Height control barrier		●	●	●	●	●	See Section 602.211

1) Emergency telephone and fire extinguisher additionally installed outside each tunnel entrance (See Section 414.2)

2) Fire extinguishers mounted on one side at given intervals. In addition, fire extinguishers are located together with all emergency telephones on the opposite side.

2. Self-rescue is the most important issue if an accident happens, and therefore we must equip the tunnel with fire extinguishers. We, in Norway, have 10-15 car fires in our tunnels every year, and the driver himself or drivers of passing cars extinguish most of them before the fire service arrives.
3. Warning.  
It is important to alarm outside – that is to call for help using emergency phones mounted either in phone boxes or in small rooms in the tunnel wall. We do not want people to use mobile phones even though we have more mobile phones than people in Norway. The reason? Mobile phones are not safe in an emergency, because the net may be overcrowded. Secondly, normally drivers do not know in which tunnel they are. When the Traffic Control Centre receives an emergency call they also immediately know the location of that phone.

Most of our emergency phones are terminated in our own Traffic and Tunnel Control Centres (TCC) and a few are terminated at alarm centres operated by the fire department. When the TCC receives an emergency phone, the operators are able to connect the nearest fire alarm central to the same line. If there is an accident the fire and rescue service continues the dialogue with the one in the tunnel while our operator starts his emergency procedures which includes

- Closing the tunnel if possible
- Put on full light
- Start the predefined fire ventilation if such exists
- etc

4. Warning. To be able to close the tunnel it is necessary to have twin-flashing red lights outside the tunnel to warn traffic from entering.
5. Intervention.  
When the rescue service arrives, they have the possibility at both portals to both communicate with the TCC and to control light and ventilation if they want to do that after they have an overview of the situation. When this is said I must also add that not all tunnels do have mechanical ventilation. It is however my advice to the rescue services that if there is no ventilation they have nothing to do inside the tunnel unless they have control of the situation. That is in case of a very small fire and the natural ventilation is such that they may reach the fire without going into smoke.

Now we have the minimum required equipment we, NPRA means is sufficient.

Light, fire extinguishers, emergency phones, red stop signals and everything connected to a TCC, which normally is far away from the tunnel and may connect to 300 tunnels or more. In addition, we want to install communication systems and may be ventilation.

#### More work is needed

Are we then ready? - - - NO - - there is much more to be done. We will continue the process and calls in the rescue services and start making the emergency plan. The result of this cooperation will make it clear if extra equipment is needed. In this process risk assessment is an essential tool.

Let us presume that we all agree that the minimum equipment is sufficient. It is still some more work to be done before we are ready to install the equipment.

#### Safety of the equipment

How secure do we want the different types of equipment to be against failure? This is done by describing the necessary function of each type of equipment in these situations.

- during normal operation
- in an emergency
- for evacuation
- during intervention

This may result in special protection and sectional cabling. It may also result in battery backup for some of the light etc etc. I will not go further into the result of this process and the discussions, because the result may be a little different every time. The main thing, however, is to always have the important cables protected in the ground. You must also make sure that if there is a break somewhere due to a fire that only that section of the tunnel “dies”. The rest of the equipment must still function.

If there is a ventilation system, and the fire knocks out part of it, the rest of the system must still be able to comply with the demands. To accomplish this it may be necessary to install some over capacity.

Many will say that this is way to little equipment to make the tunnel safe. They may be right, and I will ask them: what is the alternative?

How can we liv with this minimum equipment.

Let us go back and look at the alternative in Norway. The country with the fjords, the mountains, and the tough weather. As mentioned earlier, avalanches and mud slides are of great concern both to the public and the politicians. The same goes for rock falls. Both these pictures are from 2005.



Lets also take a short look at some weather results.



Far left: Snow depth on mountain roads.

Left: Global warmin gives more exstreme rainfalls when we earlyer havd snow.

These pictures shows some of the difficulties that the terrain and the weather gives us as operators of the road network . The pictures below shows a tunnel portal that was to short. An avalanche blocked the entrance and avalanches comes where non has come before due to the changing climate.



The result: Demand for more tunnels and cheap tunnels are stronger and stronger. It is now up to us as tunnel builders and operators to demand the minimum safety level.





The rock on the picture to the above fell off a hill a few kilometers outside Trondheim the third largest city last fall. It was calculated to be at least 73 tons and blocked the road for quite some time before it could be blasted to smaller rocks and transported away. Luckily no one was hit in this incident.

The focus on safety in Norway from the public and the political arena is more on protection against these avalanches and rock falls than safety in tunnels. There are more people lost in avalanches than in tunnel accidents in our country. Although many people have tunnel phobia, I could tell you amazing stories about what people do in our tunnels.

In the world's longest tunnel, the 24 km long Laerdal tunnel, we have to put up signs that prohibit parking in the tunnel. People park and have picnics in the tunnel. One farmer parked his trailer with frozen grass in one of the lay bays to thaw it. Others have put up their tent and gone to sleep in the bottom of one of our sub-sea tunnels, just to mention a few episodes.

#### Maintenance is essential to have a safe operation

To an operator of tunnels, it is of vital importance that the installed equipment is functional whenever it is needed. Incidents and accidents happen when you least expect it. Earlier I mentioned the process of describing the needed function in different situations and the need for safe installation.

During the operation period it is equally important to maintain and test the equipment to ensure and document these procedures. The fire departments in Norway have an obligation to inspect and satisfy themselves that the tunnel is safe in respect to an accident with fire in the tunnel. They will ask us for documentation for proper maintenance and inspections on that type of equipment.

To have this quality system and for documentation it is necessary to have either a manually system or a data based system. We will suggest to you to use a data based MOM system. (Management Operation and Maintenance). This is bought off the shelf in many variations.

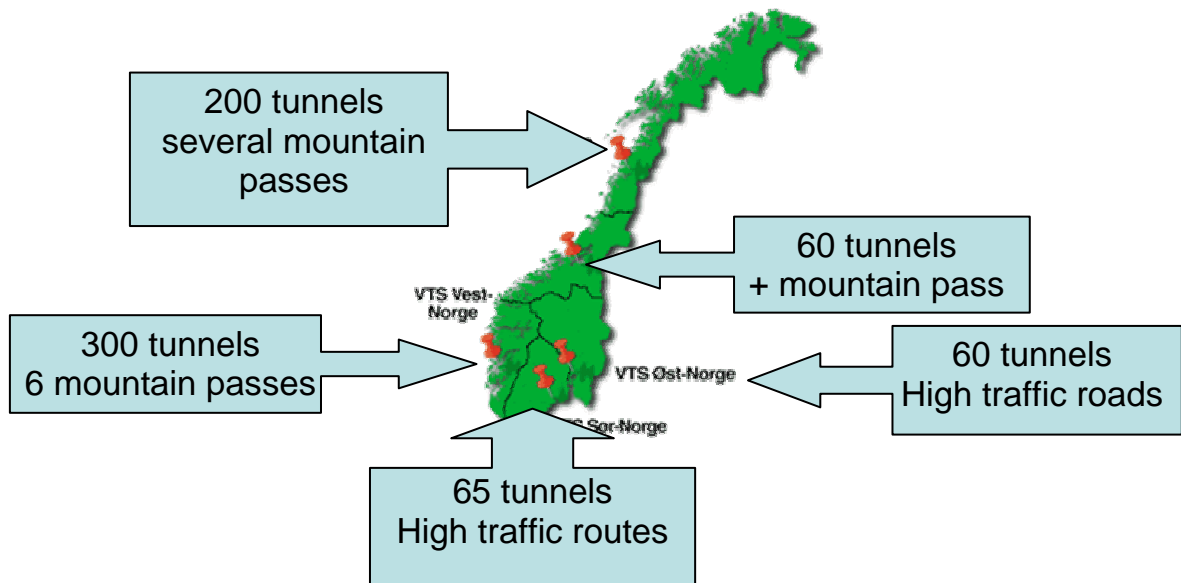
It is based on different modules and take care of the inventory, interval for inspections and work orders. The workers have to confirm that the job is done otherwise the system keep track of assigned jobs that have not been done in time. This system is however a theme for a completely new paper, so I will leave it at that.

#### Traffic control centres.

All tunnels in Norway with more than lights are connected to traffic control centers and they are issued with instructions how to react and whom they will call out when something happens. They are also part of the testing procedure at regular intervals to confirm that everything is functional.

In today's modern age of communication distances between the tunnel and the TCC is not important. It is however important to choose only the necessary alarms for the TCC. The other alarms must go to the maintenance people and their organization. In this way every TCC in Norway has many tunnels in a large geographical area. An example of distance is up north. The NORTH CAPE tunnel is 1222 km with an estimated time for driving at 19 hours and 45 minutes.

Map of the 5 regional TCCs and the number of tunnels each one are connected to.



Conclusion

The NPRA have established a minimum safety package, that contains fire extinguishers, emergency phones, and red flashing lights, and how to make them safe to operate. However, it is my advice to establish a close relationship with the rescue services and work together towards a common understanding what will be the necessary equipment in each case. In this cooperation, some form of risk analysis is very useful to separate the nice to have from the need to have.

References:

- The Norwegian design guides for tunnels.  
[http://www.vegvesen.no/vegnormaler/hb/021/021\\_e\\_05\\_w.pdf](http://www.vegvesen.no/vegnormaler/hb/021/021_e_05_w.pdf)