



Operation and Maintenance of Södra Länken





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Introduction

On Sunday the 24th of October 2004, Södra Länken was opened to traffic. This signalled the end of seven years' construction and that the road and tunnel system was in place to link Essingeleden (E4/E20) with Huddingevägen (Highway 226), Nynäsvägen (Highway 73) and Värmdöleden (Highway 222). Södra Länken is six kilometres long, of which 4.5 kilometres run through tunnels under Stockholm's southern suburbs.

The very day of Södra Länken's inauguration marked the beginning of the extensive work on operating and maintaining the road tunnel system. Since that day it became a matter of sustaining a healthy, safe traffic environment and of preventing the deterioration of the concrete fittings and other tunnel installations. Proper maintenance is expected to make Södra Länken last a long time before having to carry out extensive renovations.



Reliable Communications – A Prerequisite for City Life

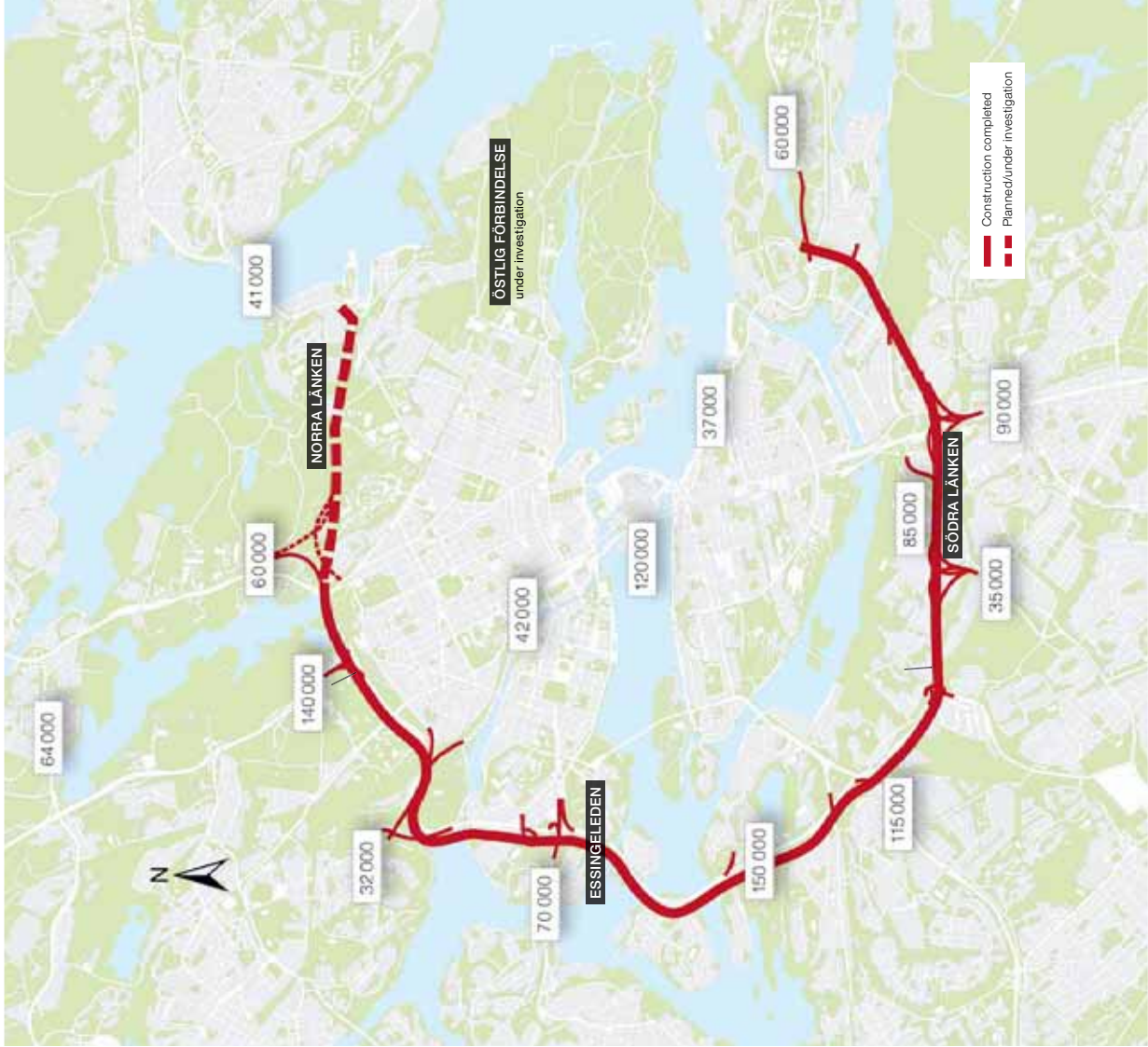
Ever since the 13th century, when Stockholm was originally founded on islands, communications was of central importance. Its accessibility was excellent for ships, the primary mode of transport at the time. Ships from all the interesting harbour towns on Lake Mälaren could make their way easily to this city situated between Lake Mälaren the Saltsjön Sea. This was equally easy for seafaring vessels from the Stockholm archipelago and ports around the Baltic Sea. Trade flourished and Stockholm grew. In no time, traffic on land was also lively.

Stockholm increasingly more popular

In the centuries since the founding of Stockholm, the city has expanded in all directions. Nowadays, its suburbs stretch dozens of kilometres in all points of the compass. Stockholm is continuing to grow. According to the County Council's Regional Planning Office prognosis, the population is expected to increase by 20 000 people per year between 2000 and 2030. This means people living in the city who will need to travel to schools, places of work and recreational activities. According to prognoses conducted in 2000 by the Swedish Institute for Transport and Communications Analysis (SIKA), road traffic is expected to increase by 25 percent by 2010. Stockholm's already overstrained traffic system will have to accommodate even more road users.

Södra Länken

In November 1997, construction was started on Södra Länken, a six kilometre long tunnel route joining Essingeleden with Värmdöleden. Södra Länken has replaced the former cross route via Hammarby Fabriksväg, Gullmarsplan, Huddingevägen and Arstalänken. This means that road users in Nacka, Värmdö and the southern city suburbs are offered a link, without intersections, to the rest of the road network in the region. The



travel time for the entire stretch has been reduced from 15-35 to about 5 minutes. The maximum speed permitted in Södra Länken is 70 km/h. On some access and exit ramps the speed is limited to 50 km/h.

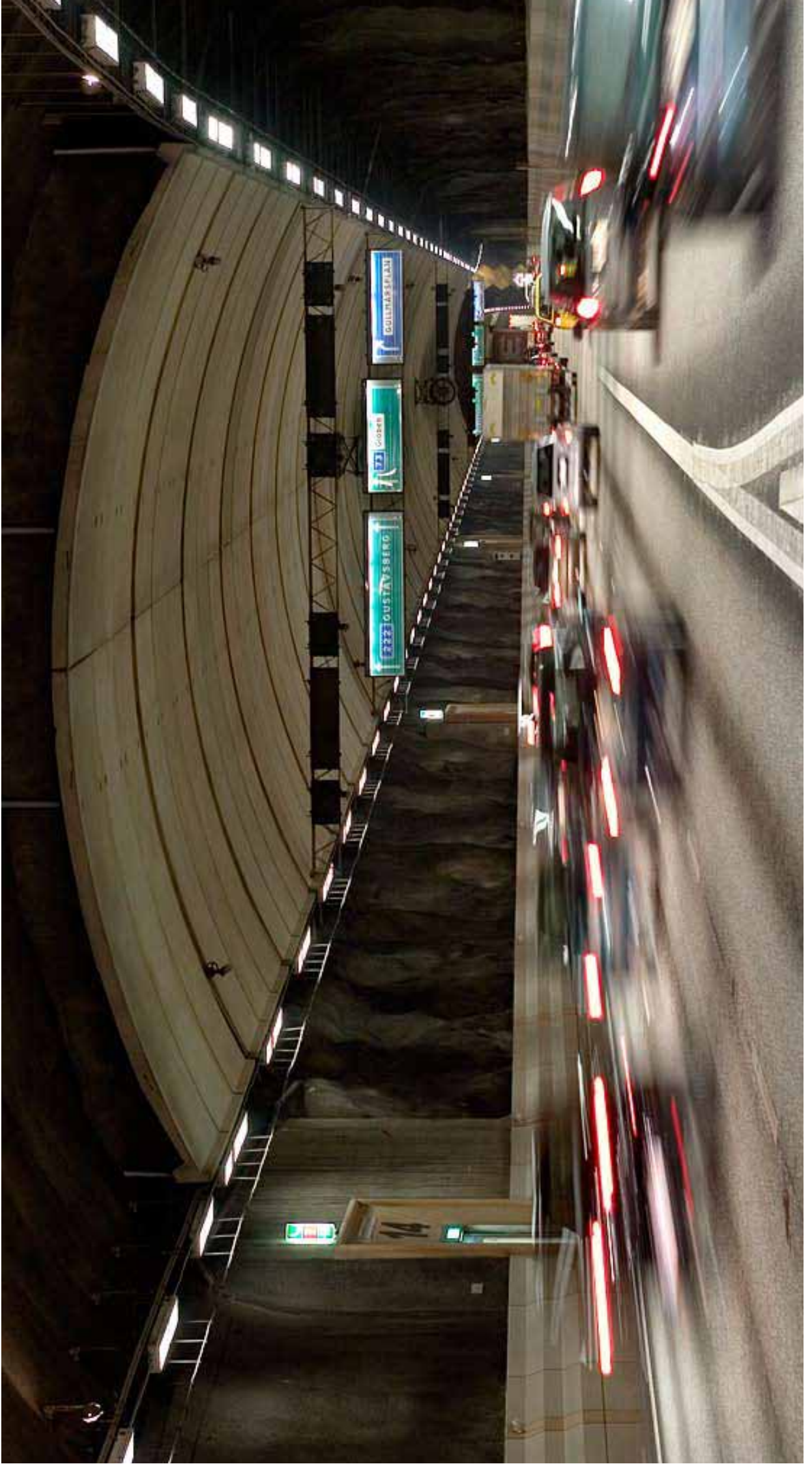
4.5 kilometres* of Södra Länken runs in tunnels under suburbs immediately south of the city limits, thereby reducing through traffic in nearby residential areas like Årsta, Johanneshov and Hammarbyhöjden. This has a positive impact on the environment in the vicinity as well as on road safety. Pedestrians and cyclists are safer on local roads. Drivers are more secure in Södra Länken's one-way tunnels.

Fast transit

Södra Länken means faster transit south of Stockholm. However, it alone cannot solve the congestion problems found on the Stockholm city approaches. For the road traffic investments to have full effect, an eastward continuation (Östlig förbindelse) from Norrtull to the eastern end of Södra Länken is necessary, and the pressure on Essingeleden must be relieved. It is only then that the capacity on the city approaches will be sufficient to reduce the traffic load in the central parts of Stockholm.

Average number of vehicles per 24-hour weekday on Stockholm's larger city approaches.

* Södra Länken consists of a total of 18 kilometres of road tunnel when including the parallel tunnel tubes in opposite directions and the access and exit ramps.





Rock and Concrete Tunnels

Södra Länken's tunnels are mainly rock tunnels. Parts of the ramps and the underground interchanges, along with the ceiling and other fittings, are constructed in concrete.

Ground water level inspections essential

Södra Länken is subject to a water-rights decree, which sets the limits for the ground water level. In order to prevent ground water seepage, the rock was sealed through pre-grouting during the construction period. The purpose was twofold: to maintain the ground water level in the area around Södra Länken and to reduce the risk of moisture damage and ice formations inside the tunnels.

As pregrouting can never ensure complete sealing, inspection measures are required to check remaining water seepage. Special water meter chambers installed for this purpose are used for regular measurements of ground water seepage into the tunnels. The ground water levels in the surroundings are checked regularly through measurements in existing ground water pipes.

Concrete tunnels

Södra Länken's concrete tunnels are designed as cast-in-situ troughs with the roof cast in stages, so-called monoliths. The interchanges are placed underground, on bridges constructed in large caverns blasted out of the rock. Due to the fact that the concrete tunnels lie below the ground water level, they are also subject to ground water seepage. Rust-proof plate-metal chutes with heating cables between the joints of the monoliths lead away any seeping water. Grouting is also carried out to seal particularly vulnerable places.





Ceiling protects the roadway

Inside the tunnels, 100 000 m² of white concrete ceiling protects the roadway and road users from leaking water. The white ceiling is part of Södra Länken's aesthetic design and is intended to help drivers orient themselves. It is suspended like a canopy over the carriageway and shows how the tunnel curves both horizontally and longitudinally. The ceiling also has a purely practical function. It serves as a huge umbrella, catching and leading any water seepage into channels along the edge. From there it flows into downpipes and on into drainage pipes under the roadway. Drain mats comprised of insulated material, 50 mm thick, were installed at the vulnerable places found during the construction period to lead off water and prevent ice formations. These drain mats were coated with shotcrete to make them fireproof and stiff enough to remain in place.

Ice and bacteria problems

Ice formations in the winter are a common occurrence in tunnels. This problem is dealt with through a documentation of the ice situation, "scaling"

(knocking down) the icicles as well as through the installation of new drains.

Water leaking into the tunnels contains a certain amount of bacteria, which forms a gel that can block the drain pipes. During the construction period, vulnerable places were identified where special drains were installed that could be flushed every year to remove bacteria nuclei before its becoming a problem. Normal tap water from the Södra Länken fire hydrants is used for this purpose.

Metre by metre inspection

Södra Länken undergoes continual inspection. This involves close range optical inspections, at arm's distance, metre by metre. Changes such as the corrosion development in the reinforcement involving splitting, cracks in the concrete, etc are all documented. It takes six years to inspect the entire tunnel system. And then the process begins again.

The bottom of the concrete tunnels consists of a poured, insulated slab covered with a sealing coat. Potholes, crack formations, etc in the asphalt that are observed during the inspection indicate water seepage problems.

Preventive maintenance

Preventive maintenance, such as cleaning, has a decisive impact on the lifespan of the installations, fittings and concrete in the tunnel system. Dirt, salt and moisture cause corrosion in the reinforcements. Corroded reinforcement expands and takes more space, with the result that the top layer of the concrete splits loose and the lifespan of the structures is shortened considerably. In order to control dirt, salt and moisture, Södra Länken has an ambitious cleaning programme for the tunnel floor, walls, ceiling and all installations.



Inspection of the rock and rock reinforcement.

Interior design

Ceiling	100 000 m ²
Lateral safety barriers	60 000 m ²



Ventilation and Water/Wastewater Facilities

In Södra Länken stringent demands have been placed on air quality. To ensure that the planned targets for nitrogen dioxide and carbon monoxide are met, measurement stations are located at several strategic points both inside the tunnels as well as outside the tunnel openings.

The basis for the tunnel ventilation is the longitudinal currents of air that are generated by the draught produced naturally by moving vehicles. If it becomes necessary to improve the air quality, the jet fans installed in the ceiling are used. The basic principle is that polluted air is expelled and fresh air brought in.

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The draught produced naturally by moving vehicles forms the basis of Södra Länken's ventilation. Fans are used when this is insufficient for maintaining good air quality.





Ventilation tower, air supply station and jet fans.



Air supply and exhaust air

Fresh air from five air supply stations is used as needed to provide the ramps with clean air.

The ventilation towers at Årsta and Hammarby are used to suction up air mixed with vehicle emissions and rapidly disperse this into the wind instead of burdening the immediate surroundings. The exhaust air stations in the tunnels collect the emissions and connect to the ventilation towers.

In the case of fire, combustion gases are expelled using the jet fans.

Cleaning road surface water

Surface water is generated in the Södra Länken road tunnels, partly through the snow and ice brought in by vehicles and partly through the water used to clean the tunnels, an essential element in tunnel maintenance and operation.

The road is constructed so that the surface water can be collected in drains and pipes along the tunnels. From there it is led or pumped to the water treatment plant situated in a rock cavern at Hammarby.



Tunnel information sign

Inspection hatch

Insulated ceiling

Water conduit

Lighting

Jet fan

Rock

Drains

Water and wastewater pipes/
Drain pipes

Lateral safety barriers

The road surface water contains pollutants such as heavy metals, hydrocarbons, carcinogenic substances, etc. According to the agreement with the Stockholm City Environmental Administration this must be collected and purified to ensure compliance with the guidelines set for discharged road surface water. Södra Länken therefore has a highly advanced water treatment plant – perhaps the most sophisticated system in Europe.

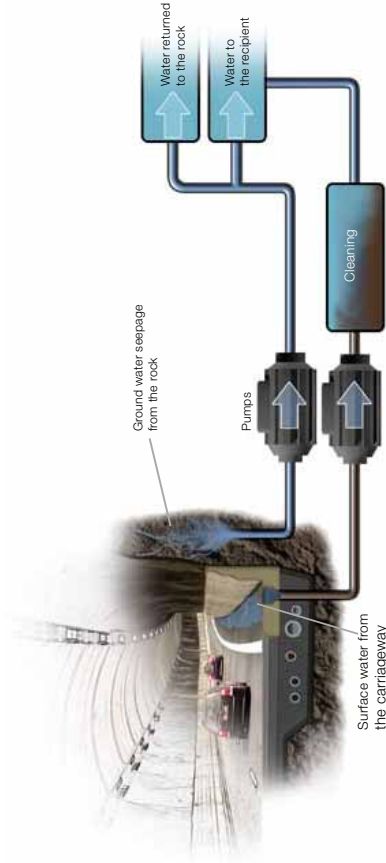


Ventilation installations

Jet fans	159
Air supply stations	5
Exhaust air stations	2

Water/wastewater facilities

Water treatment plant	1
Pump stations	5
Sedimentation tanks	5
Fire hydrants	132
Cleaning facility for drainage water	1
Ground water meter pipes	120
Water chambers	1 200



Water treatment plant – automatic cleaning in three stages

- 1 When the surface water arrives at the plant, a test sample is taken before being sent to a sedimentation tank for 36 hour detention. During that time, the heavy metals sink to the bottom and are stored as sludge on the bottom of the tank.
- 2 Before the water leaves the tank, a turbidity test is carried out. If the correct target values are not obtained, sodium hydroxide, NaOH, is used as a precipitant to bind the metals so that they flocculate and sink to the bottom. The water quality is then measured again.
- 3 If the targets are still not met, the water is then run through an ultrafilter before being released into the Hammarby Canal.

Water tests are also performed manually and sent for analysis and inclusion in the environmental monitoring programme as per agreement with the Stockholm City Environment Administration. The residual products/sludge left at the bottom of the tank is collected and sent away every five years for destruction. Research is being conducted to find alternative methods to analyse and handle the sludge.

The water treatment plant is monitored continuously by a technical maintenance operator at the Stockholm Traffic Management Centre, Trafik Stockholm. If something goes wrong, he or she initiates an appro-

priate action plan. The technical maintenance operator can also operate the water/wastewater plant by remote control from Trafik Stockholm, or otherwise dispatch a repairman for an inspection and on-site repair, if necessary.

Ground water inspection

Ground water that has leaked in from the tunnel roof, walls and drainage pipes in the road structure is also pumped to Södra Länken's water treatment plant. The purified water is reinfiltrated at several places above and nearby the tunnels. This is supplemented with city water as needed, which means that the ground water levels agreed upon in the water-rights decree can be maintained.

A database for the Swedish Road Administration (SRA) ground water inspections has been set up. This database is continuously updated with the values measured at the inspection points and infiltration facilities. This is done to prevent and avoid any lowering of the ground water level or any damage to tunnel structures and buildings above ground.

Cleaning facilities for the ventilation towers

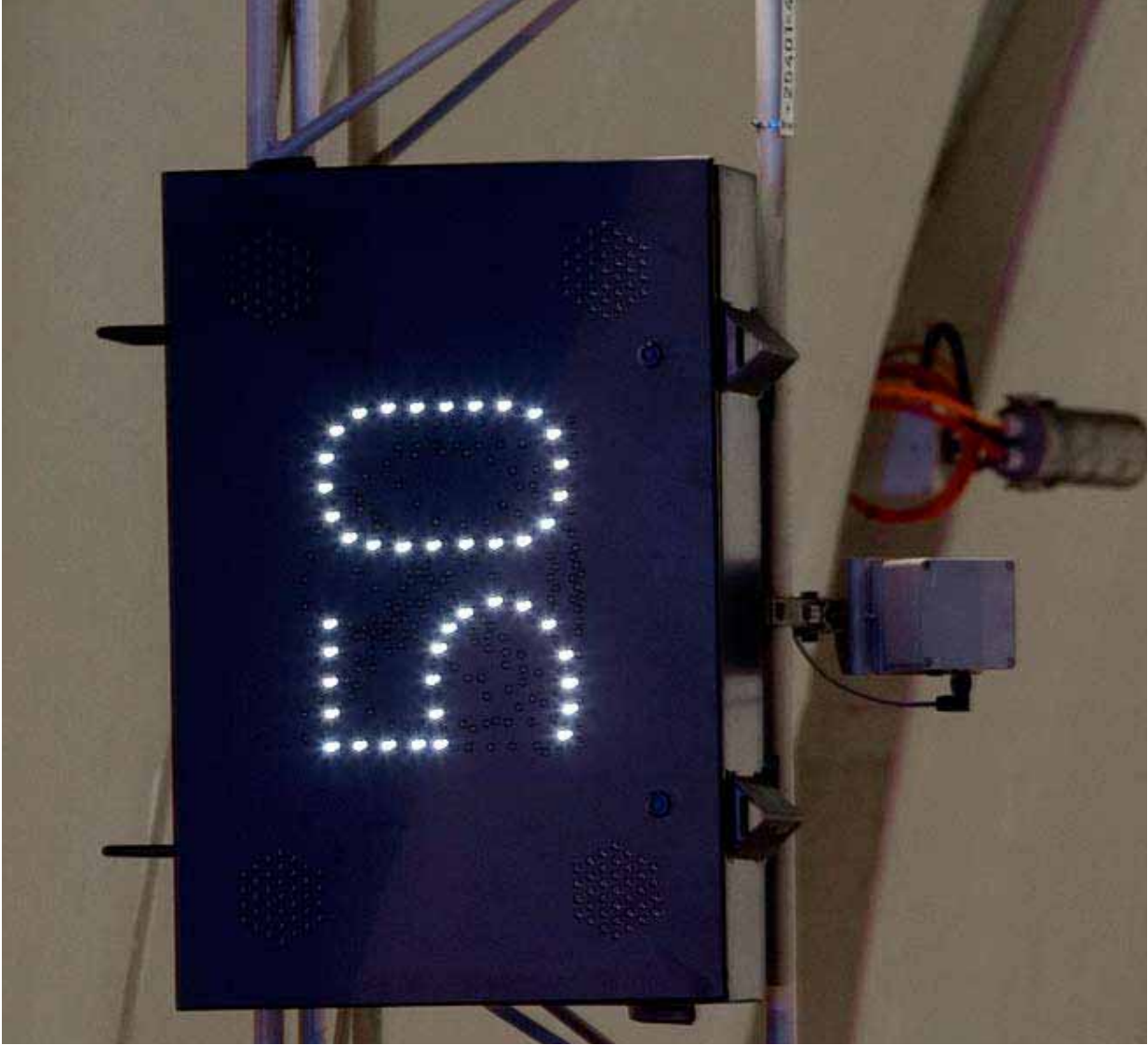
Södra Länken's two ventilation towers are located in Årsta and Hammarby. These 20 metre high towers, designed in glass and metal, are cleaned when needed. An automatic high pressure cleaning mechanism is used for the interior while the exterior is cleaned manually using high water pressure equipment. The water used for cleaning is collected and treated.

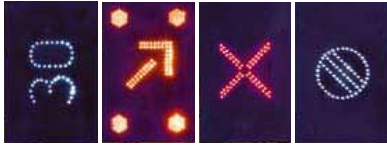
Fire-fighting water

Södra Länken is designed with parallel tunnel tubes. This means that in the event of an accident in one of these tubes, emergency rescue services can enter via the other and use water from any of the stand-by fire hydrants found at each emergency exit. Water is drawn from the fire hydrant to the fire engine where foam, etc is added and the water pressure increased. Fire-fighting water is then pumped through the fixed empty pipe system in the evacuation routes between the tunnel tubes to the tube with the fire. The proper functioning of the fire-fighting water system is inspected regularly.

Traffic Equipment

The traffic equipment used in Södra Länken can be divided into three categories: the Motorway Control System, MCS (with its lane signals and detectors), the road closure equipment and tunnel information signs. Outside Södra Länken there are traffic information panels and traffic signal installations that are not directly linked to Södra Länken. All traffic equipment is controlled and monitored by the traffic management operators and technical maintenance operators at Trafik Stockholm via designated action plans in the Central Technical System, CTS.





MCS Background

MCS was developed by the Rijkswaterstaat (Dutch Road Administration) in the 1970's and has now been installed on all motorways in the Netherlands. The Swedish Road Administration (SPA) has revised the system somewhat. In the 1990's the MCS was installed on the E4 European Highway between Haga Södra and Kista. Today it exists on Essingeleden and the E4/E20 as far as Bredäng, in Södra Länken and on Värmdöleden part the way out to Nacka. It is the intention to use MCS on Norrortsleden, Norra Länken and other road tunnel constructions.

Motorway Control System

The Motorway Control System, MCS, has two main functions: to warn drivers about traffic queues ahead, thereby reducing the risk of rear-end collisions, and to close off one or more traffic lanes. On the surface road network the traffic furniture consists of gantries, and in the tunnels of girders mounted in the ceiling. Installed on these gantries/girders are lane signals and microwave detectors that sense when vehicles drive by as well as register the type of vehicle and its speed.

The lane signals consist of information panels intended for drivers. These signals are normally switched off. However, when the speed of traffic slows down below normal the signals are activated to display information on the highest recommended speed in order to warn drivers. The lane signals are switched on upstream of the traffic flow so that when driving past one lane signal, the next one catches the eye.

The MCS can also be used to show the recommended speed in connection with maintenance works, such as tunnel cleaning operations, or to close lanes when, for example, a stationary vehicle is detected. In the event of such an incident, Trafik Stockholm is alerted and the traffic management operator on duty verifies this information via the CCTV camera and subsequently initiates an action plan in the CTS. The lane signals are switched on to display a diagonal red cross, indicating that the lane is closed to traffic. This red cross is preceded upstream by diagonal arrows instructing drivers to change lane. In addition, a lower recommended maximum speed is displayed above the adjacent traffic lanes.

The lane signals are comprised of light-emitting diodes (LED) that give off an alarm depending on the number of functioning LED circuits. If individual LEDs or lane signals are out of order, measures are taken the following night or in connection with the on-going tunnel maintenance. Otherwise, the MCS is monitored in the same way as the other computerised systems used in Södra Länken.

Road closure equipment

Included in Södra Länken's road closure equipment are variable direction signs, barrier bars, tunnel entrance signs and variable road signs. All road closure equipment is coordinated with other traffic equipment and controlled from Trafik Stockholm through action plans in the CTS and the PCMS (Plant Control and Monitoring System).



Tunnel entrance signs

Tunnel entrance signs at all tunnel entrances alert drivers when parts of Södra Länken are closed for maintenance and repair works. On such occasions, these signs use LEDs to display a crossed over tunnel symbol.

Variable direction signs

Variable direction signs are used by the traffic management operator to divert traffic. These consist of clusters of triangular prism signs mounted on gantries or on the girders in the tunnel ceiling. These prism signs can be rotated to change the route information as well as to indicate that a main road or exit is closed off completely. When traffic must be diverted, the traffic manager approves the pre-programmed action plan in the CTS. Part of the action plan is the automatic lowering of the barrier bars at the ramps that are closed to traffic.



Dynamic road information panels

On the major approaches into Stockholm dynamic road information panels have been installed. These have space for “optional text messages” and a road sign symbol and are used to inform drivers that the tunnel system is closed.

Control systems for the traffic equipment

Traffic detectors	341
Lane signals	364
Road closure barrier bars	43
Variable direction signs	96
Variable road signs	15
Tunnel information signs	142



Tunnel information signs

Tunnel information signs are used when traffic in the tunnel is at a standstill, for example in the event of fire or the like. Using the LED signs on the girders in the tunnel ceiling, messages such as “Turn off engine” and “Evacuate the tunnel” can be displayed.

Traffic signal installations

Traffic signal installations around Södra Länken are used together with other traffic equipment in Södra Länken, and are coordinated with these through the action plans in the CTS. The traffic control functions in these installations are adjusted to different incidents in Södra Länken. This means that, when necessary, the traffic management operator at Trafik Stockholm can also direct the traffic flow at intersections affecting the traffic in Södra Länken.

System to detect a stationary vehicle

A speed discrimination system is used to sense when a vehicle in the tunnels has stopped or lost its load. CCTV cameras are used to continually compare the current traffic picture with the image recorded for an empty tunnel. When the traffic in Södra Länken flows smoothly, the system does not react. On the other hand, when a vehicle stops, the images no longer tally. An alarm is activated at Trafik Stockholm and an action plan for “stationary vehicle” is initiated. The alarm contains information that tells the technical maintenance operator what triggered it as well as advises that the information be confirmed on the monitor before continuing further.

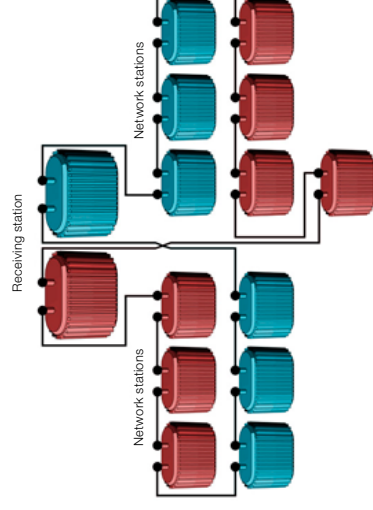


Electricity, Power and Lighting

Södra Länken is supplied with an input voltage of 33 kV via two cables from the network owner's distribution sub-station at Skanstull to a receiving station located above ground at Skärmarbrink. The incoming 33 kV supply feeders are connected directly to their own transformer, each of which is designed to manage Södra Länken's entire electric power requirements. The voltage is transformed down to 22 kV distribution voltage in the receiving station. The 22 kV network is designed as two circuits that supply all 13 network stations, where the voltage is stepped down to 690 V to supply the fans and large pumps and to 400 V for general electric power and lighting. Circuit feeders and automatic switching make the system completely redundant.

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The total power consumption for Södra Länken in one day is equal to the consumption of about 600 private homes.



Electric power installations

Network stations 13

Lighting installations

Light fittings in the traffic tunnels 7500

Guidelight fittings 850



Emergency and stand-by power supply

In order to ensure the functioning of the control and monitoring systems, barrier bars, road direction signs as well as the stand-by and evacuation lighting in the case of power failure there are UPS installations in every network station. The standby lighting works for at least 15 minutes and the other equipment for 60 minutes, which enables Trafik Stockholm to evacuate and close Södra Länken.

There are also two mobile, diesel-run reserve power units, one 690 V, 900 kVA and one 400 V, 250 kVA. These are used in the event of a breakdown in a network station or a cable fault. These mobile reserve power units can also be used during planned service of the transformers or switchgears, for example in the event of a failure in the network station or cable network.

Maintenance

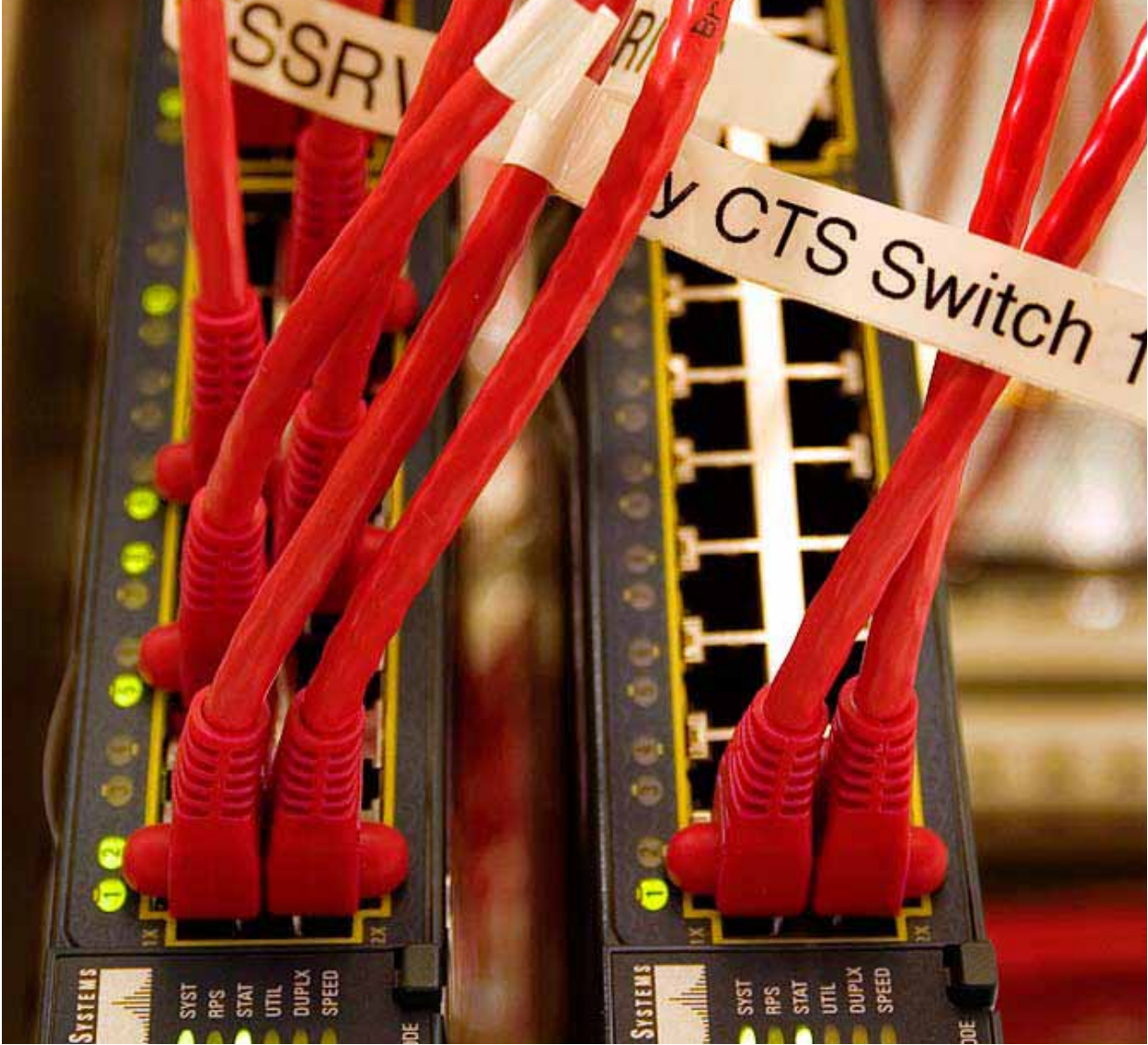
Preventive maintenance of the electrical installations is carried out with pre-determined regularity. This entails, for example, thermographing of copper busbars and connections. It is important that preventive maintenance of the electrical installations is carried out to prevent undesirable power failures.



Reserve power units.



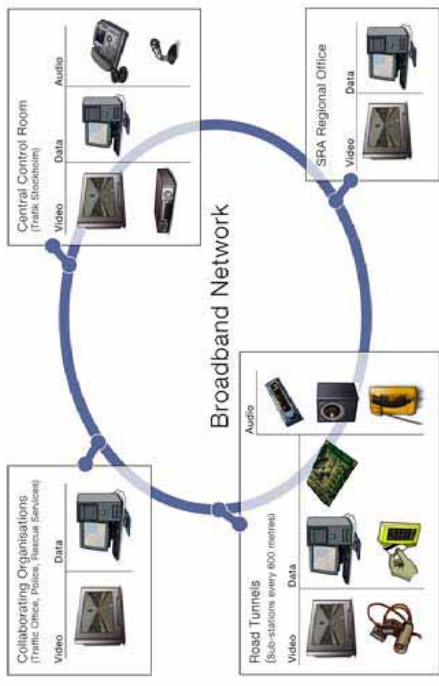
- Fluorescent strip lights are used for the road lighting to obtain the best colour reproduction and so that the tunnels will seem light and fresh-looking. At the access ramps there is entrance approach lighting intended to counteract the sensation of driving into a dark hole. This lighting is dimmed gradually.
- The lighting is reflected in the light road surfacing and illuminates the white ceiling, thereby reinforcing an overall impression of lightness.
- There is evacuation lighting along the lateral safety barriers.
- The eight art installations are specially illuminated as part of the artistic decor.



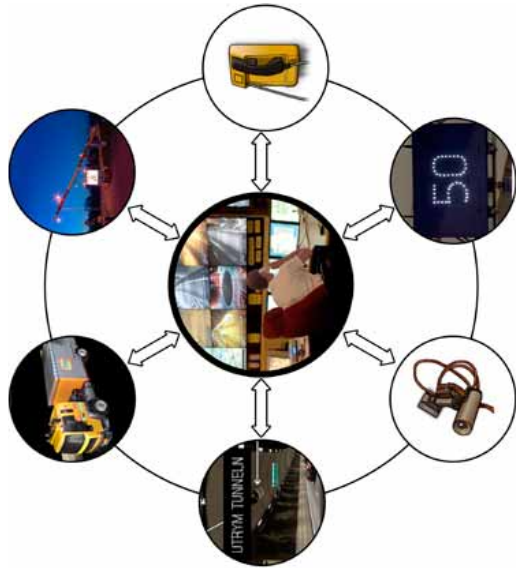
General Communications Platform, GCP

The General Communications Platform, GCP, is a broadband network for data, video and audio communications developed by the SRA. Control and monitoring functions via Trafik Stockholm are also built into the system. All communication within the road tunnel and surface road sections, as well as between these and Trafik Stockholm goes via the GCP. The idea behind the GCP is to get a handle on all communication on road sections in the region where there is a high concentration of in-stallations. This also includes future tunnel systems such as Norrortsleden, Norra Länken, etc.

All the systems in Södra Länken, such as the control system, safety system, telecommunications system and traffic system use the GCP to communicate, in part between each other, within and between



Broadband network for data, video and sound.



the sub-stations, as well as with Trafik Stockholm. In this way the traffic managers and technical maintenance operators at Trafik Stockholm can monitor traffic and the technical systems around the clock. The local monitoring systems automatically set off an alarm in the event of a malfunctioning installation or traffic disruption. When incidents occur, it is the traffic managers who operate the systems. They can, for example, remotely close the barrier bars, start up the fans and configure the signs. They can also distribute information to others concerned. All system functions depend on a reliable communications network.

The GCP also has built-in functions for the distributed handling of digital video. Video images from all the cameras can be received by internal operations monitoring sites, including Trafik Stockholm, the SRA regional office and Södra Länken's local control centres in the tunnels. Trafik Stockholm is also able to distribute video images to the emergency rescue services, SOS Alarm and the police.

Infrastructure

The GCP primarily uses the SRA's own fibre optic cables and radio relay links as its communication media. Canalisation and fibre optic cables have been laid in conjunction with the reconstruction of the major highways in the region like Södra Länken and along the E4 between Häggvik and Bredäng. Radio relay links are used for installations where it would be unreasonable to install fibre optic cables due to the distances involved, for example down into the Muskö Tunnel. In a few cases, leased

fibre optic cables have been used. The active equipment required to implement the communication network is placed out in the different sub-stations/server halls within each respective installation.

High capacity and accessibility

The principle behind the logical structure of the GCP is that every local construction (tunnel/road stretch) is built in a local ring structure, in other words with redundant, connected coupling points. The local main sections are connected to a global ring. This design enables very high accessibility. For example, Södra Länken's local ring structure makes it possible to have three totally independent communication lines to Trafik Stockholm.

The capacity of every main link in the GCP between the data switches is 1 GB. Apart from the high basic capacity, there are functions built in to assure transmission quality. For example, a heavy video load can never block out vital alarm communication.

The GCP is monitored around the clock by both Trafik Stockholm and the operation/ maintenance contractor, who is strictly obliged to carry out repairs or exchange defective components without delay.

Video installation

Cameras connected to the system	615
of which Södra Länken	450
Cameras	
Fixed, PTZ (pan, tilt, zoom), mobile	
Some also with an image analysis	
Monitors	
Trafik Stockholm (31, 10 split screen)	
Local control centre (LLC) in tunnels	
SRA regional office	
Emergency rescue services	
Police	
SOS Alarm	
Full digital handling and transmission	
MPEG2/4	

Network components

Routers	15
Switches	44
Fixed Ethernet ports (100 Mb/s) installed	1 476
GB Ethernet ports (1000 Mb/s) installed	21
Radio link connections 155 Mb/s	2
Radio link connection 34 Mb/s	4
Sub-stations/cabinets with active equipment	41
Fire walls	2
Over a 24-hour period, an average of some 580 Mb/s or 5.97 Tb/day is transmitted.	
Sound	
Audio channels installed	27
Connections to telephone exchanges	4



Central Technical System, CTS

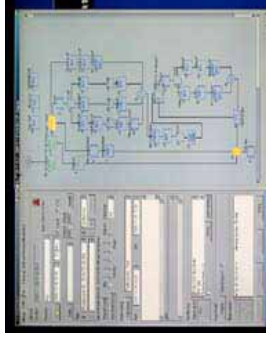
The SRA has developed a sophisticated operator support system that is used by Trafik Stockholm to monitor and control traffic and the technical installations in the entire region. The Central Technical System, CTS, is an incident reporting system used by the traffic managers and technical maintenance operators at Trafik Stockholm. It is the traffic managers who handle traffic disruptions and the technical maintenance operators that handle defects in the technical systems, as for instance the pumps, telecommunication systems and water/wastewater facilities in Södra Länken that are connected to an alarm system. Trafik Stockholm monitors systems and traffic twenty-four hours a day all year round.

Uniform interface for the systems

Information comes from Södra Länken's local control systems to the master control system, CTS. This means that the traffic managers and technical maintenance operators are provided a common interface where all alarms are presented in the same way.

Decision support has been built into the system. When something happens, the traffic management operators are alerted and then verify the incident, either via camera or through a telephone call. The decision support system in the CTS proposes an action plan that has been pre-designed by traffic engineers and other technicians. This is to ensure that everyone takes the same action and that nothing is overlooked in a stressful situation. The system contains some 1 500 different action plans that are being constantly updated. These are always supplemented with reset plans that ensure that all systems revert to standard operation and that the information is given to staff that traffic is back to normal.

Decision support with a fault log and action plan.





Automatic incident handling

One example of an automatic incident chain of events is if a car stops in Södra Länken with a puncture. The car blocks traffic and constitutes a danger for other road users. One of Södra Länken's 500 cameras registers a change in the situation and therefore sets off an alarm. The traffic management operator looks at the closest camera and confirms that a car is actually stopped there.

The CTS then proposes an action plan that runs through a number of steps; e.g. informs "Radio Stockholm", the public service channel, as well as SRA internet services and "www.trafiken.nu" that there is an obstruction in Södra Länken. The closest Road Assistance vehicle is dispatched to the site to help the driver move away his or her car.

Appropriate MCS signs are used to divert traffic. The traffic management operator approves the action plan proposed, subsequent to which everything basically runs automatically.

The system is also designed so that automatic measures are triggered if the system is temporarily out of order or in the event that a traffic management operator should be indisposed.

Another example of an action plan is the "Night-time closures of Södra Länken". In this case a message is sent to the police and other relevant parties that Södra Länken will be closed for maintenance. After this, signs are switched on to inform drivers that the tunnels will be closed between certain specific hours. The number of measures undertaken steadily increases as the time for the actual closure approaches up until there is no more traffic in Södra Länken and it is closed.

Steady development

Both the world around us and the demands put on the CTS change constantly. All static/dynamic data in the CTS must be correct. This is why the system is continually being maintained and further developed.

Many different types of input are needed to keep the CTS functional:

Further development In the maintenance contract signed with the original supplier of the CTS it is stipulated that the supplier must be prepared to investigate any faults that might arise as well as modify and improve the functionality of the system.

User support There is an internet-based tool for reporting faults and defects in the CTS/Trafik Stockholm system. Staff are available around the clock for troubleshooting. The system operators have a high level of education, training and accreditation.

Maintenance of CTS data For the CTS decision support system to be able to propose the correct action plan it is mandatory that the road network hierarchy, as an example, is always up to date, both as concerns road nodes and the equipment installed. Moreover, it is necessary that all routines are documented and registered in the CTS action plans.

Maintenance follow-up Maintenance follow-up is carried out continually via a special reporting tool. All data is saved. This data can be multiprogrammed for different reports and easily distributed to those concerned.

The reporting tool has been used to follow up tests conducted at the time when Södra Länken was opened to traffic, for example.

Operative system

- Windows 2003 server
- Windows XP clients
- Client Server programming
- Microsoft Visual Studio
- Database handler
 - ORACLE version 9.2
- Communications protocol
 - ASN.1 on TCP/IP
- Server cluster and RAID5 disks
- Biometric login (fingerprint)
 - 3rd party support applications
 - Graphics -> Ilog Views
 - Decision support-> Gensym G2
 - Reports-> Business Objects



Control, Monitoring and Telecommunications

Södra Länken is monitored and controlled using the Plant Control and Monitoring System, PCMS. When something out of the ordinary happens, the PCMS automatically sends an alarm to the CTS.

Södra Länken is divided into 13 operations areas, each with its own local control equipment. In addition there are two redundant master control systems with common control equipment for the entire tunnel. These can manage the operation of Södra Länken if the control equipment in a sub-station is faulty or even completely out of order.

Information from the various sensors in the operation areas is handled via the control system and local control equipment. Information is collected, processed and transmitted. If something is wrong, certain measures are initiated automatically. Other failures can cause an alarm to be sent to the CTS, in which case an operator activates the proposed action plan. The alarms are ranked in different categories according to degree of seriousness. The traffic managers and technical maintenance operators use the CTS action plans to control the Södra Länken systems through the PCMS.



Network station.



Examples of control, monitoring and alarms:

- "Leaking cables" for all mobile networks, radio frequencies, radio interruptions, etc.
- Emergency telephones connected to 13 mini-telephone exchanges, known as MD exchanges, and on to Trafik Stockholm.
- Fire detection cables in the tunnel ceiling register temperature variations every eight metres.
- Fire centre in every sub-station.
- Environmental sensor to control ventilation.
- Some 500 video cameras – fixed cameras connected to image interpretation computers in the traffic tunnels, and PTZ cameras outside the tunnels.
- Public address system for such things as tunnel evacuation.
- Control of all signs and barrier bars.

Simple apparatus – sophisticated program

The apparatus used consists of personal computers and a standard model Programmable Logic Controller. In addition to this is a sophisticated computer program specially designed for the monitoring and control of Södra Länken's approximately 200 000 components.

Technical areas, with examples of action plans:

LIGHTING The control system monitors the lighting according to a pre-programmed function night and day. At tunnel entrances the lighting is regulated progressively according to the light situation outside the tunnel opening. A presentation is given of the current connected lighting stages. If any of the lighting equipment is faulty, an alarm is sent via CTS to the technical maintenance operator, who proposes an action plan, which means sending a repairman to the site concerned.

TRAFFIC EQUIPMENT Barrier bars, signs, lane signals and cameras to detect stationary vehicles are controlled and monitored. The traffic management operator can use the system to lower the barrier bars, vary/change the message on signs and close road lanes. If the communication with any of the equipment fails to work, an alarm is sent to the technical maintenance operator who sends out a repairman.

FIRE In the event of fire in the tunnels, the detectors send an alarm to the PCMS which in turn alerts the CTS for action. To limit the oxygen supply, the ventilation system dampers and fans in the sub-stations are closed automatically. An alarm is sent directly to the operator at Trafik Stockholm who can check the cameras to ascertain that there is a fire, dispatch the fire brigade to the tunnel in question and activate pre-programmed measures to close off the tunnel.

ELECTRIC POWER Information collected includes the status of circuit breakers, effective power and current. If defective, an alarm is sent to a technical maintenance operator whose action plan means to manually have parts of the system concerned disconnected, use the redundant electrical system to open and close the circuit breaker and thereby measure the current from the other direction.

WATER/WASTEWATER Pumps and valves for the fire-fighting water system and the separate wastewater system are monitored and controlled by the PCMS. Any deviation from the specified levels sets off an alarm. If, for example, a tanker overturns and oil spill runs out into the wastewater system, an oil detector gives off an alarm. The pump in question is closed automatically and a repairman is dispatched to

The system includes control of:

- Lighting
- Traffic equipment
- Fire detectors
- Electric power
- Water/wastewater
- Ventilation
- Computer system
- Telephony
- Telecommunications
- Access control system
- CCTV cameras
- Radio
- Loudspeakers

verify the accuracy of the damage on site. Ground water levels and infiltration are also monitored and controlled by the system.

VENTILATION Nitrogen dioxide, NO₂, carbon monoxide, CO, and the air flow in the tunnels and outside the tunnel openings are measured. High levels of these gases cause the system to set off an alarm, which automatically turns on the jet, air supply and exhaust air fans to reduce the concentration if the ventilation system is malfunctioning or to alert a technical maintenance operator in the event of high pollutant concentrations. If the ventilation system is malfunctioning, or in the event of high pollutant concentrations, a technical maintenance operator is alerted.

Each sub-station has a special cooling ventilation system. When the temperature in a sub-station exceeds a certain level, the fans start automatically in order to cool down the area. It is only when a pre-programmed measure does not help that the technical maintenance operator is alerted so that he or she can handle the situation according to the action plan proposed by the CTS.

COMPUTER SYSTEM This system monitors itself and continuously checks that all communications are working. If not, an alarm is sent directly to the technical maintenance operator who implements action plans.

TELEPHONY Emergency telephones and local telephones are connected to mini-exchanges and on into the system. Regular automatic control is conducted through a computer calling all the phones. If no answer is received, the system's operators send out a repairman.

ACCESS CONTROL SYSTEM All the evacuation routes are monitored via door indicators. As soon as a door is opened an alarm is sent to an operator. The sub-stations and local control centres have card readers that allow access without activating an alarm.

CCTV CAMERAS Every metre of the road traffic system is monitored by closed circuit television. There are fixed cameras inside the tunnels and PTZ (pan-tilt-zoom) cameras outside the tunnel entrances. Cameras are also found in the evacuation routes and in the rescue rooms for road users. The system checks that all cameras are in working order.

RADIO Radio systems have been installed for the benefit of the police,

emergency rescue services and ambulances as well as for the distribution of commercial and public services channels. In an emergency, a traffic management operator can activate an action plan through which pre-recorded messages are transmitted via the commercial radio channels to road users in Södra Länken.

LOUD SPEAKERS In the long evacuation routes there are loudspeakers on which pre-recorded messages can be played through the operator activating an action plan during a tunnel evacuation.

Operation and maintenance of the system

Södra Länken's control and monitoring system is constantly being evaluated and updated. The software is checked and documented regularly.

Urgent faults in the system are taken care of immediately. Preventive maintenance is also carried out. Routine measurements and inspections are conducted regularly according to a specially designed timetable to ensure the proper functioning of all signals. This involves checking the communication between computers as well as the communication between different sensors and the computers. For example, the fire alarm is checked at random using special simulators. Periodicity, documentation and follow-ups are carried out via the Maximo system.

Structure	Measurement systems	Monitoring system
Tunnel, 4 lanes	Air speed sensors in tunnels	CCTV cameras
Tunnel, 3 lanes	CO sensors	Fire detectors
Tunnel, 2 lanes	NO _x sensors, tunnel	Access control equipment
Tunnel, 2 lanes	NO _x sensors, surface road network	
Emergency exits	Sight sensors	Telecommunication facilities
Sub-stations	Temperature sensors in the roadway	Emergency push buttons
Rescue rooms	Flow meters (Water/wastewater)	Emergency telephones
	Luminance meters	Local telephones
	Autonomous control systems	Loudspeakers (in evacuation routes)



Tunnel Cleaning for Better Safety, Security and Comfort

The conditions under which the Södra Länken road tunnels must be maintained and operated are unique throughout the whole world. The white ceiling, artistic decor, heavy traffic volume, dust particles, unfavourable winter climate with salt and studded tyres are just a few of the highly unusual combination of attributes. In order to maintain a good traffic environment, with good sight conditions and as low a level of particulate matter as possible, an ambitious cleaning programme was developed. Careful cleaning of the tunnels and the technical safety equipment ensures that all systems are visible and functioning. While increasing their technical lifespan. The intention is that the cleaning will as far as possible keep the use of chemicals preparations at a minimum.

Wet vacuuming for a good road user environment

The basis for Södra Länken's cleaning and scrubbing concept is wet vacuuming, which is a system whereby a "super suction device" is used

A clean and fresh-looking tunnel environment contributes to road user safety, security and comfort.





The "super suction device" flushes, sweeps and sucks up dirt, grime and particles from the roadway.

to flush, sweep and suction up dirt and grime from the carriageway and shoulders. At a pressure of approximately 200 bars, particles are broken loose from the asphalt skeleton. The particles and cleaning water is suctioned up and the sludge is emptied for purification at Södra Länken's water treatment plant.

Cost-effective handling

The heavy metals and other particles that are suctioned up along with the cleaning water are purified through several stages. An initial separation occurs first inside the "super suction device". Further separation occurs in the Södra Länken water treatment plant. The frequent tunnel cleaning and scrubbing using this device means that the collection of heavy metals in the sediment will be very low.

Both the cleaning water and sediment are analysed continually. The intention behind the frequent cleaning is that there will be such a low proportion of heavy metals in the sediment that it can be used as fill on roadside embankments instead of being transported away for expensive destruction.

Tunnel cleaning while open to traffic

Most of the cleaning is carried out at night, without closing the tunnel to normal traffic. Every other time the shoulders are wet

Cleaning programme	
White ceiling	twice a year
Shotcrete	twice a year
Emergency exits	twice a year
Art installations	once a month
Carriageways	twice a year
Signs	twice a month
Technical safety equipment	twice a month
Lateral safety barriers	twice a month
Shoulders	once a week



The cleaning of the walls and ceiling is performed under low pressure (8-10 bars) and large quantities of water (some 700 litres/min).



Tunnel cleaning is done both mechanically and manually.

vacuumed, and on the other occasions the lateral safety barriers, signs and technical safety equipment such as emergency lighting, emergency exits, cameras, road closure barrier bars are also cleaned.

The MCS in Södra Länken along with TMA protection is used to warn drivers and control traffic approaching from the rear as well as to protect those working on the cleaning.

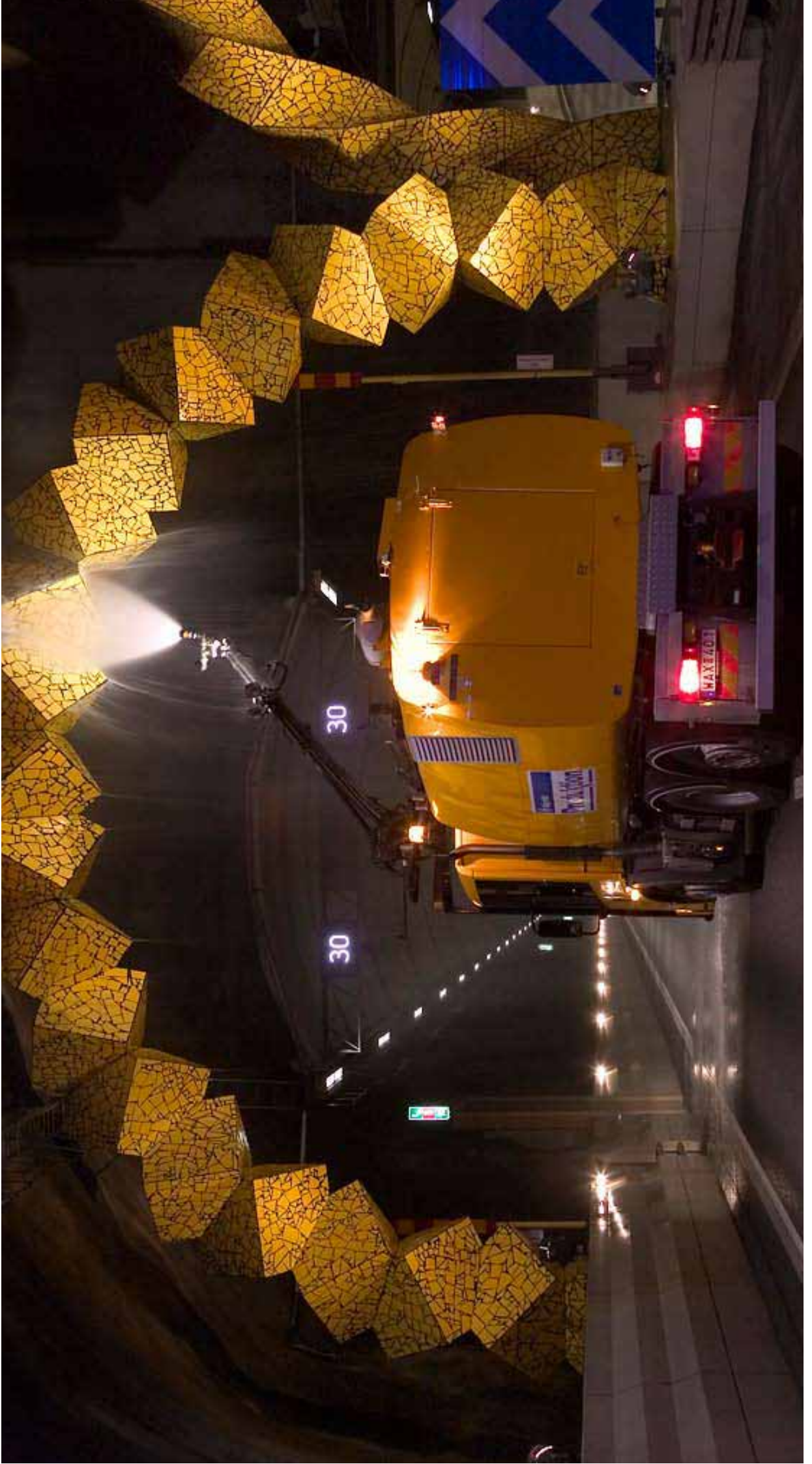
Night-time closures for maintenance

Once a month Södra Länken is closed at night for maintenance and operation works. On these occasions all the areas and equipment that cannot be attended to with traffic passing by are cleaned; e.g., jet fans and the art installations in the tunnels. Moreover, Södra Länken is closed for "total cleaning" twice a year, which includes everything from the ceiling, walls, roadway, emergency exits, lateral safety barriers, fans, traffic equipment, art installations to the emergency lighting, etc.

Continuous evaluation and development

Continuous cleaning is a way to prevent grime and particles from getting baked in. Less frequent cleaning would reduce the lifespan of the technical equipment, jeopardise its functioning and necessitate considerably stronger chemicals and more expensive methods to recover the original appearance of the interior design. This is why the SRA works systematically to find sustainable methods that are both cost-efficient and kind to the environment.

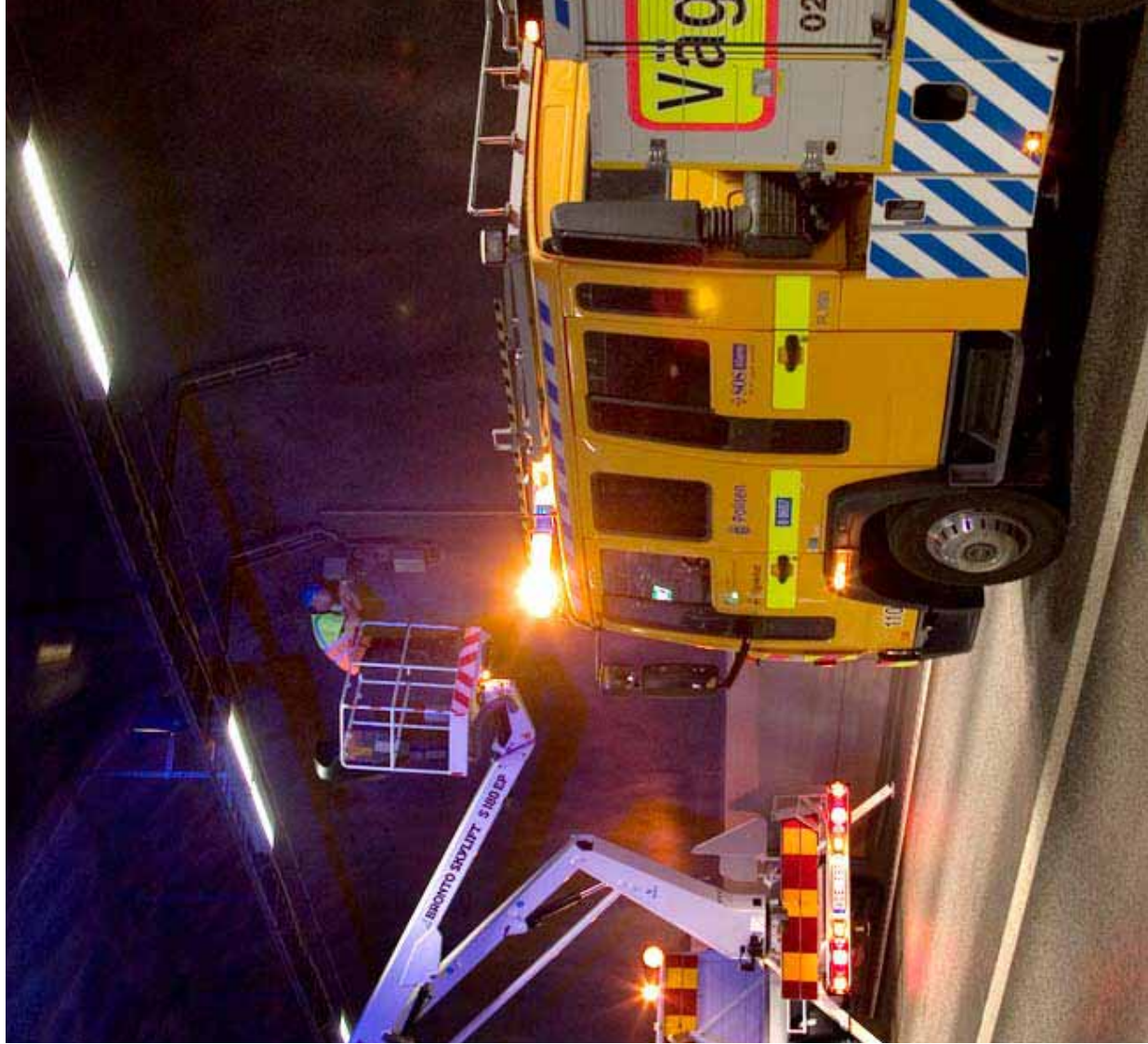
Scope and benefit
 Large quantities of water, some 2500 m³ per total cleaning occasion (equal to about five 25-metre pools) is used to clean everything: 100 000 m² white ceiling, 350 000 m² shotcrete walls, car-riageways, shoulders, art installations, cable ladders, etc. All in all, some 300-500 tonnes of particulate matter are collected every year.

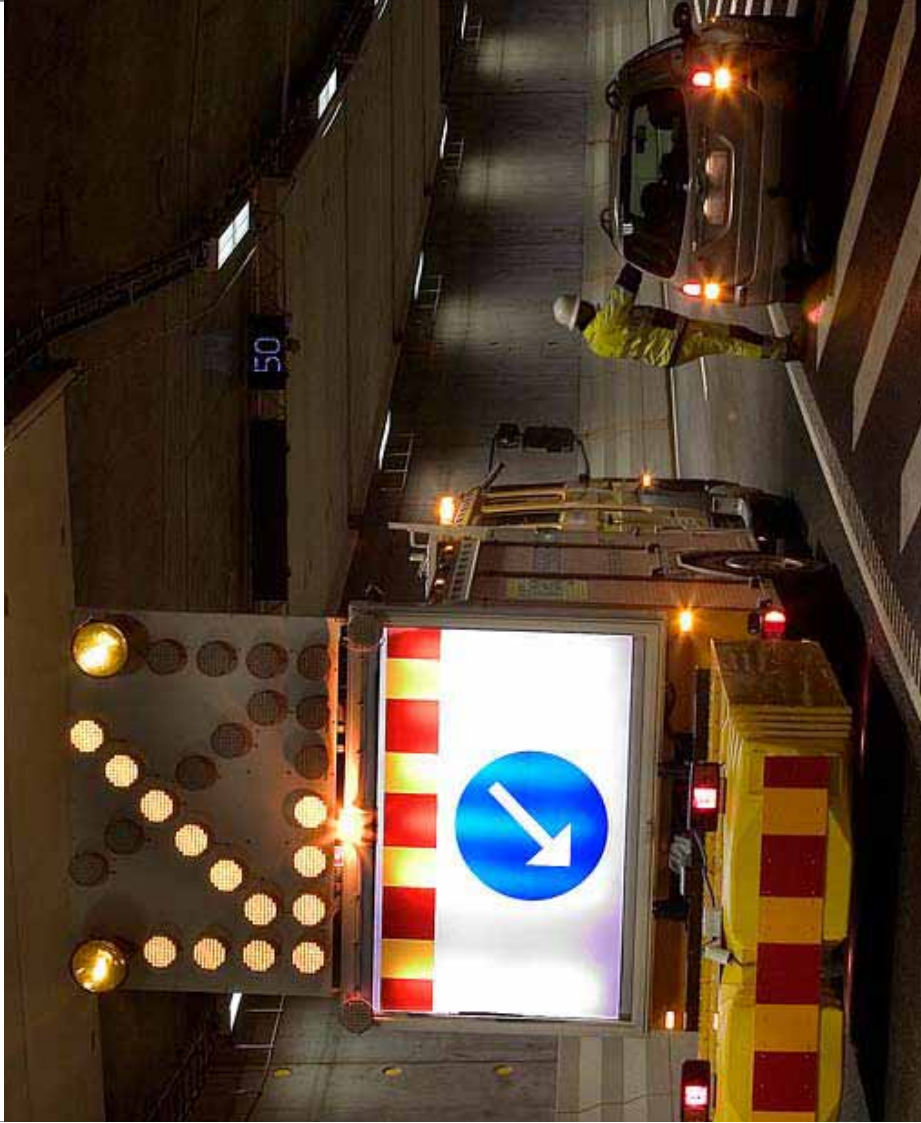


Road Assistance

The Road Assistance project was initiated to alleviate disruptions in Stockholm's traffic and the congestion this causes. The intention is to reduce accidents, not least of all rear-end collisions. Relieving congestion benefits the environment, improves access and mobility and shortens travel times.

Road Assistance is a joint venture between the SRA, the City of Stockholm and the police. Road Assistance operates on the major approach roads within a radius of some ten kilometres from the heart of the city and is managed and directed from Trafik Stockholm. Road Assistance operations are profitable. Socio-economic calculations have shown that the extra cost involved for a vehicle to be standing still during rush hour and blocking a lane on Essingeleden for example, is SEK 40 000/min, SEK 240 000/hour and about SEK 250 million/year (in





1993 monetary values). Added to this is the detrimental impact of emissions on the environment.

Warn, protect, assist

The Road Assistance vehicles are equipped to be able to assist in connection with minor engine failures, empty petrol tanks, etc or to arrange for a broken-down vehicle to be towed away to the closest safe place. The Road Assistance vehicle drivers are specially trained and can administer first aid if necessary. The vehicles are equipped with defibrillators that can be used in the event of heart failure.

Since the opening of Södra Länken there have been four Road Assistance vehicles in total: two stationed in Södra Länken and two on the surface road network. One of these vehicles is on duty twenty-four hours a day, all year round. During morning and afternoon rush hour traffic additional reinforcement is available in the form of two breakdown lorries.

In connection with emergency maintenance operations in Södra Länken while open to traffic, the task of the Road Assistance vehicles is to:

- 1 get to the site
- 2 warn other road users
- 3 protect those performing the repair.

The MCS lane signals also warn drivers if a lane is closed for maintenance operations.

In connection with emergency maintenance operations, Road Assistance is on site for warning and protection purposes. This means that they make their way to the site, park the vehicle equipped with a huge warning sign and TMA* protection. The intention is to warn road users and protect those working on repairing the emergency fault.

* Road Assistance uses Truck Mounted Attenuators (TMA) for crash impact protection. Two deformation zones at the back of the Road Assistance vehicle provide protection in the event of a rear-end collision. TMA also reduce the collision force for the vehicle crashing in from behind.



Preventive Maintenance and Troubleshooting

From a safety point of view, faulty equipment must be taken care of immediately. Södra Länken has a special service team of electricians on call that can be at the site within an hour for troubleshooting. Other maintenance contractors can also be summoned when necessary.

All measures are ranked in order of priority:

- Priority 1** emergency measures that must be taken immediately, e.g. a broken road closure barrier bar. Action is to be initiated within 1-2 hours.
- Priority 2** important measures that can wait until the following night; e.g., a defective door at an emergency exit.
- Priority 3** measures that can be postponed and planned for later; e.g., if one of the 450 cameras is out of order.

The traffic managers and technical maintenance operators at Trafik Stockholm carry out the monitoring and can see via the control system if anything has broken down, is over-heated or if the water level is too high. These operators dispatch the service team to investigate what has happened and at the same time generate a work order via Maximo, which is a both a planning and monitoring tool used for maintenance works.

Maximo

Maximo is a standard-based, IT assets management system which the SRA has procured first and foremost for the Södra Länken road tunnel system. Maximo primarily handles work orders for troubleshooting and preventive maintenance on the components in Södra Länken. The components registered in the system currently number some 50 000. Maximo also provides access to the care and maintenance instructions and appurtenant drawings for these components.



Preventive maintenance

Throughout the year the system signals when it is time to service different components. The system also indicates what actually must be done. A few weeks ahead of time, a work order is despatched automatically to the contractor concerned. Both the SRA and the maintenance contractors work in the same system in which the contractor adjusts the planning and consults the SRA for approval.

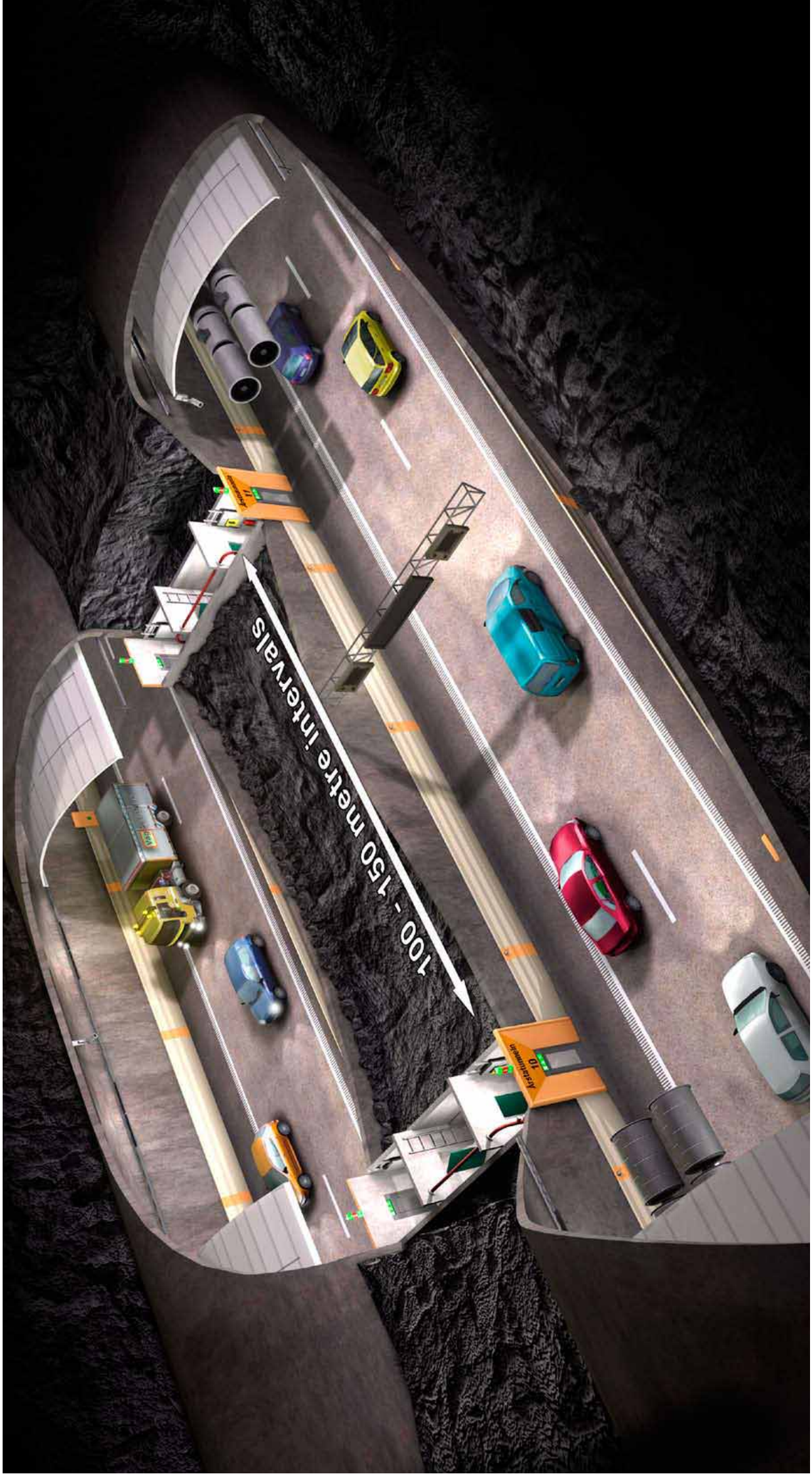
Trouble shooting

The monitoring system alerts the staff at Trafik Stockholm if anything in Södra Länken has become defective. The staff then generate a work order directly in Maximo for action on a component with a specific ID number. The work order is sent via the system to the relevant contractor, who is authorised to take action up to a certain amount. For measures costing more than that, the work order must first be prepared and approved by the SRA before the fault can be remedied. After completed action, the contractor reports what has been done directly in Maximo.

Follow-up and control

In the system work orders can be coordinated, planned and followed-up and invoice details can be examined and approved.

In the long term, this way of handling work orders in Maximo will result in a historical documentation of the measures undertaken. This enables a businesslike evaluation of the durability of components so that those that demand frequent costly repair can be replaced by other alternatives.



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