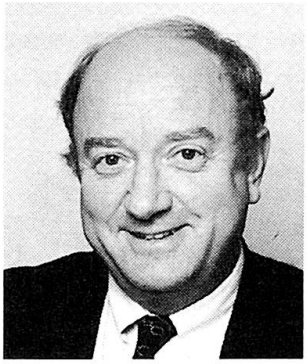
Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte
Band: 78 (1998)

Artikel: The stockholm urban road tunnels - an overall status report
Autor: Karlsson, Per-Olov
DOI: https://doi.org/10.5169/seals-59017

The Stockholm Urban Road Tunnels - An Overall Status Report

Per-Olov Karlsson
M.Sc Civ. Eng.
Swedish National Road Administration,
Stockholm, Sweden



Per-Olov Karlsson graduated from the Royal Institute of Technology in Stockholm in 1971. During the 1970's and 1980's he was engaged in fields of nuclear power development and the introduction of natural gas in Sweden. Since 1992 he has been involved in major infrastructure investments in the Stockholm region.

Summary

The lack of peripheral connections in the Stockholm region has created congestion and environmental problems in the radial road network. With respect to environmental constraints, tunnels present the only possible alternative for creating new accessibility for motor vehicle traffic. This is further enhanced by the favourable geological conditions for rock tunnelling in the region. Two major urban road tunnel systems, Södra and Norra Länken (the Southern and Northern Links), are in different stages of implementation. Construction work for Södra Länken has started. As regards Norra Länken, the further work aims at concluding necessary legal decisions. The time for construction start-up will thereafter depend on political decisions and financing.

1. Tunnels as Solutions to Urban Problems

The layout of Metropolitan Stockholm resembles a star. The nucleus consists of Gamla Stan (the Old Town) situated on the island that made travel possible in a north-south direction across the water between Lake Mälaren and the Saltsjön Sea. The city arose at the cross-roads between the seafaring route and the land route. Until the 1930's when Västerbron (the bridge to the west) was constructed, the passage across Gamla Stan was the only route across the water by land. Essingeleden, with its expansive bridges, was constructed in the 1960's thirty years later.

Fig 1. The central parts of Stockholm

The lack of peripheral connection has created congestion and environmental problems in the radial street and road network. Over the years, many proposals for peripheral traffic routes at various distances away from the city centre have been presented and rejected. In 1992, a political agreement was signed concerning the implementation of a traffic solution which in part included an urban motorway ring road orbiting the heart of Stockholm as well as an outer by-pass route further to the west of the city. The objective of this traffic solution, which also included major investments in public transport, was to create a better environment, better accessibility within the road network and enhanced road traffic safety. This would also stimulate regional growth and development.

The landscape in the Metropolitan Stockholm area, with its deep rift valleys and watercourses, poses special difficulties as far as the design and construction of peripheral routes is concerned. There is also a compelling environmental attraction radiated by the star-shaped formation of the city accentuated by the sea inlets and wedges of green belts that link the core of the city with the surrounding landscape.

As a city, Stockholm has clear age rings. The Old Town from the Middle Ages stands basically intact on its island. The present-day stone city, which is clearly encompassed within the area defined by the former toll stations at the various city entrances, was formed during the intensive period of growth around the turn of this century.

There are two basic reasons why the stone city has not overflown beyond these city limits. The first is the existence of the royal parkgrounds to the north and north-east which prevented urban developmental schemed and which today present an invaluable green belt between the inner city area and the suburbs. The other reason is that the areas immediately to the south and south-east comprised the harbours and industrial land that constituted the city's vital trade and commerce. Now that this industrial use has ceased to exist, these areas present a great potential for new urban growth and development. In similarity to many other European cities, the main theme in Stockholm's new overall city plans is "Build inwards".

Construction major traffic routes across these park areas situated immediately outside the heart of the inner city is simply not possible. This would produce barriers and disruptions that would be totally unacceptable to Stockholmers. The average inhabitant of Stockholm today is environmentally aware and concerned about reducing the disturbance created by city traffic. Instead of being subjected to the impact of additional traffic routes, people want to reduce the effects of those already in existence. Under such circumstances, tunnels present the only possible alternative for creating new accessibility for car traffic. Stockholmers have already had positive experience with urban tunnels through Söderledstunneln (Southern Route Tunnel) and the effect it has on reducing traffic within the city street network and its role in linking the western and eastern parts of Södermalm.

In light of the foregoing, one prerequisite for being able to present a traffic solution including a motorway orbiting Stockholm was that the new parts of the Ring Road would be housed in tunnels. Of the total fourteen kilometres, a little more than twelve were to be in underground tunnels. A particular characteristic of the project is that the access and exit ramps are also situated below ground. It is a matter of a tunnel system that is integrated with the rest of the city's road and street infrastructure. Even if most of the road is housed in underground rock tunnels, certain works must be performed above ground. This applies to tunnel mouths, ventilation towers and the cut-and-cover concrete tunnel stretches that are built from the surface. Certain of these works are permanent while others are temporary during the actual construction period.

Tunnels are not an automatic, indisputable solution for roads in urban environments. This is a fact that the Ring Road Project has experienced in the planning and implementation process that has been going on since 1992 and in which the Swedish National Road Administration has been responsible for the road projects incorporated in the original political agreement.

Public debate has been heated. The review process has taken a long time and the original political agreement broke down in early 1997. At the end of 1997, a new political agreement was reached concerning the financing of Södra Länken. Construction work has already started on some parts.

As regards Norra Länken, the further work aims at concluding necessary legal decisions. The time for construction start-up will thereafter depend on political decisions and financing. Österleden has been excluded and the former road toll system has been cancelled.

2. The Stockholm Project - Different Types of Tunnels

The bedrock in Stockholm is highly suitable for tunnel construction. Major parts of the city infrastructure are today housed in excavated rock tunnels and caverns; e.g., the underground metro system, telecommunication cables, water reservoirs etc. It is therefore quite logical that the new road tunnels in Stockholm be located in rock tunnels, a solution that is both less expensive and which entails less encroachment on the natural environment during the construction period. The majority of both the main tunnels and the ramp tunnels will thus consist of blasted rock tunnels.

Extensive work has been spent on the special technical problems associated with road traffic tunnels in bedrock. Unlike tunnels used for certain other infrastructure purposes, road tunnels are affected by outside climatic conditions. During the winter season, for example, temperatures in the tunnels will fall far below the freezing point. This places requirements on dealing with water seepage to prevent ice formations. Furthermore, the location within the city also demands impermeable tunnels to prevent the ground-water table from sinking which would cause damage to the building foundations in the vicinity. The proximity to buildings and other tunnel systems places additional demands on particular care being take during blasting works.

As this particular conference focuses mainly on constructions in steel and concrete, this paper will offer only a few further comments on rock tunnels as a background for the function and design of concrete and steel constructions in the tunnel system at hand.

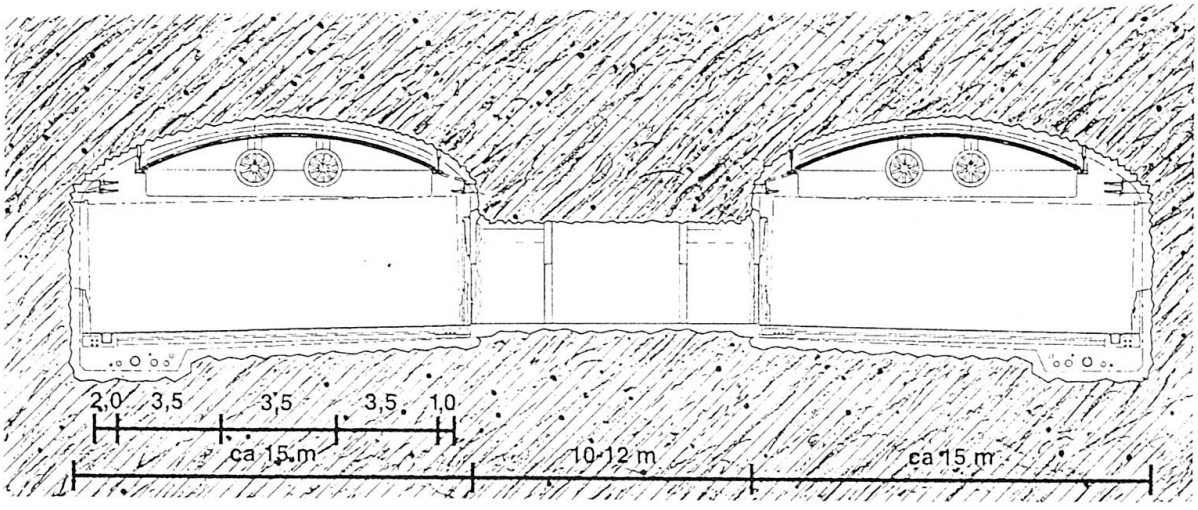


Fig. 2. The main tunnels are housed in two parallel tubes. This drawing illustrates a section where there are three carriageways in each tube as well as an emergency evacuation passage running between the two tubes.

Due to the favourable bedrock conditions in Stockholm, the requirements on dry tunnels demanded by ground water considerations can be met through careful grouting in connection with

a drainage system when needed. Lining of the tunnels has therefore not been an issue. The purpose of the installations and other measures implemented in the blasted rock tunnel tubes is to create safe conditions in the tunnels for road-users. The inner ceilings prevent even minimal amounts of water seepage through the rock from dripping on the carriageway or forming overhanging icicles in the winter. The light-coloured ceiling also serves a visual guidance function for motorists as it shows how the tunnel moves horizontally and vertically ahead.

Along the tunnel walls, 1.6 metre high safety barriers will be installed. These function both as collision protection and as reflectors of the light from the ceiling fixtures due to the fact that they consist of material which is highly resistant to dirt-coating and which can easily and regularly be cleaned. The different colours used on these roadside barriers in various sections of the tunnel serve to provide driver orientation as well as information on the speed limit, etc.

The tunnel wall above the safety barriers will remain natural as far as possible. Drains that have been frost-insulated and covered with shotcrete will be installed on those parts where there can be water leakage.

The original Ring Road project included a submerged tunnel under the Saltsjön Sea to the east. As mentioned in the foregoing, this link has been eliminated in the current project layout.

The project in its current form incorporates concrete constructions in certain specific parts. This applies to most tunnel mouths ahead of where there is sufficient rock cover to blast a rock tunnel. There are also certain stretches where tunnels are constructed from above ground as the tunnel depth is shallow. These concrete sections are relatively short parts of the entire system. For the benefit of the road-user, the inner design of the concrete tunnels is therefore similar to that of the rock tunnels. The following presents examples of concrete constructions and the special conditions that apply in these cases.

3. Troughs and Concrete Tunnels

That which is shared in common between different sections with concrete tunnel accesses and mouths is the placement below the ground-water table. Measures must therefore be taken to safeguard these constructions against heave or flooding during construction period. The completed construction must also be sealed from ground-water leakage. Moreover, the proximity to existing buildings places great demands on maintaining the ground-water level to avoid the risk of settlement. Consequently, different techniques, including sheet piling and diaphragm walls, have been examined.

On Södra Länken there are extensive concrete constructions at Åbyvägen and Nynäsvägen for example. At Åbyvägen the concrete trough and concrete tunnel leading into the rock tunnel are being built in clay soils that are highly settlement-prone. An area almost 500 metres long and 50 metres wide will be delimited with steel sheet piling. In order to meet the requirements on maximum water penetration, grouting is needed between the foot of the sheet piling and the bedrock. Curtain grouting is also necessary in other parts of the rock. The sheet piling is braced with lime cement pillars. The excavation is situated extremely close to existing buildings - fourteen-story residential towers. The works on Åbyvägen are expected to be in progress during the four years between 1997 and 2001.

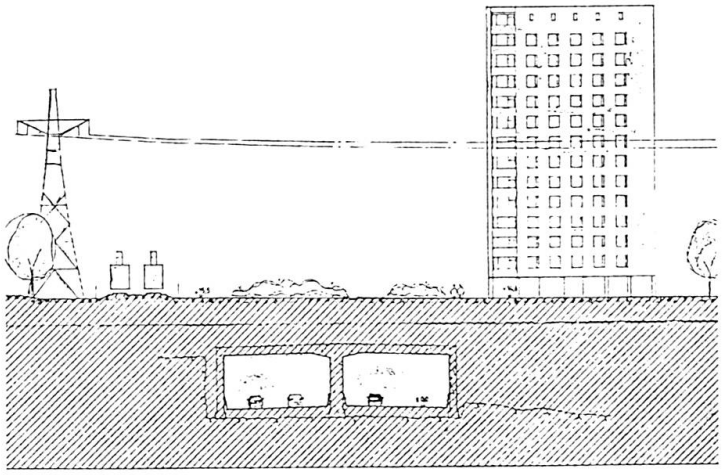


Fig. 3 Picture on Åbyvägen

The works on Nynäsvägen are also very close to existing buildings. In one particular case, the grouted sheet piling will be driven only three metres from a residential building. This area is composed of esker rock materials that are not settlement-prone as the clay at Åbyvägen. That which complicates the works at Nynäsvägen is the extremely narrowly confined construction site where there are over 90000 vehicles driving past per day. This places high demands on the work site organisation and means a prolonged construction period - about five years. In principle, works must be performed on one side at a time. There will be demands placed that the entire area be marked off by steel sheet piling that will subsequently remain in place.

Norra Länken affects a major park area in Stockholm that has been placed under the protection of a new law on a national heritage city park that was passed during the course of the planning and design work. The design of Norra Länken at Norrtull as specified in the city plan and in the enquiry tender documents has been interpreted by the Supreme Administrative Court to stand in conflict with the new law. This court decision was passed during the final negotiations on the contracts for the rock and concrete works. Construction had been planned to start in the beginning of 1997. Norra Länken consists of three city plans: Norrtull, Värtan and Frescati. Norrtull has been repudiated, Värtan has been approved and Frescati has not yet been processed.

The court decision has meant a postponement in the time schedule for Norra Länken. Different ways to reduce the encroachment from above ground have been examined.The present work aims at securing necessary legal permits. The time for construction start-up will thereafter be depending on political decisions on financing.

On Norra Länken, there will be concrete constructions both at Värtan and Norrtull for example. The conditions at Värtan resemble those at Åbyvägen. It is a former sea bed and the ground-water table lies immediately under the surface. There will be a twenty metre deep excavation here. The different sheet piling or diaphragm wall alternatives have been studied to provide the prior conditions necessary for the works.

Norrtull incorporates a longer concrete tunnel as well as an earth tunnel element. The concrete monoliths at Norrtull must be adapted to the adjacent constructions. Part of a new railway bridge

will be founded on the tunnel. Provisions will be made between the tunnel tubes for driving foundation piles for future buildings above the tunnel. The main tunnels will run under a park area where old trees of natural and cultural value will be preserved. The excavation works here will not be carried out from the surface. The enquiry documents presented an example of a temporary tunnel support structure comprising drilled-in tubes that expand, after which excavations are done step-by-step in conjunction with the strengthening of the tunnel vault with a sprayed concrete construction. The permanent tunnel structure is then constructed under the protection of this provisional vault structure.

4. Technical Requirements

All the concrete tunnel constructions are procured as design and construct contracts; i.e., the contractor is required to present design proposals as well as assume total responsibility for the constructions. The Swedish National Road Administration performance specifications contained in the enquiry documents are based on general regulations in addition to special requirements and standards that have been drawn up for the project.

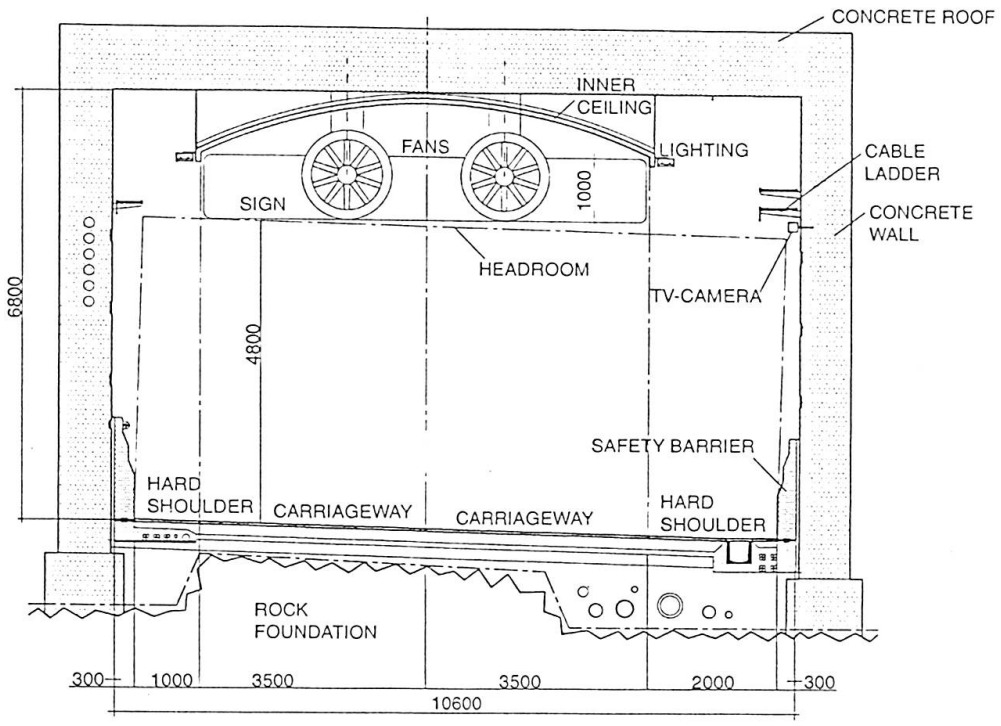


Fig. 4 Concrete Tunnel Section

In addition to requirements related to the ground-water table, there are requirements on the explosion capacity. Concrete tunnels must be able to withstand a detonation of 50 kilograms of explosives. The maximum permissible amount of explosives that can be transported without restrictions is 30 kilograms. Furthermore, the tunnels have been designed to withstand a fire with an intensity equal to 100 MW. A burning car has an intensity of about 3 MW. The tunnels will also be fire-proofed so that the temperature in the concrete surface will never exceed 450 degrees centigrade.

Since most concrete tunnel sections consistute short parts of a rock tunnel system, installations and fittings are adapted to the conditions in the rock tunnels; e.g., fire-proofed cables are placed in trench wells running underneath the tunnel floor. In longer concrete tunnels, electrical cables can be placed in the fire-proofed space between the two parallel tunnel tubes. In many cases where concrete tunnel constructions are the necessary alternative, the vertical height is so limited that there is no room for fans and signs in the normal tunnel tube. To solve the lack of space problem, recesses must be made to serve the purpose at hand.

Comprehensive studies have been conducted in reference to the Stockholm project concerning the subject of road traffic safety and the environment in tunnel systems. The general design concept in reference to these considerations also applies to the concrete tunnel sections. The false inner ceiling and lateral safety barriers are erected in the same way as in the rock tunnels. In confined sections where space is a problem, the inner ceiling is flat rather than curved. The concrete walls above the safety barriers are given a simple geometric pattern as a guidance assistance function for motorists.

5. Through Walls and Tunnel Mouths

As described in the foregoing examples, the construction of most tunnel mouths entails sinking the road into an uncovered concrete trough which leads into the mouth of the tunnel. From here the road continues through a concrete tunnel section until the point where the bedrock is sufficient for blasting a rock tunnel.

The walls in the open trough are sloped to create an impression of space and light. A 700 mm high lateral barrier in granite is erected immediately adjacent to the roadway. To prevent the high trough walls from giving an overbearing impression, they are broken up by landscaped terraces or by the odd touch of non-concrete materials worked into the concrete. The painting and staining of these materials is being considered. Full-scale tests are underway to ensure suitable methods.

Considering the space available, the tunnel mouths cannot normally be designed as large impressive archways; they must therefore be made distinctive through more restrained means. As part of the idea of uniformity, they will be designed with a distinctive frame which is given a surface of polished cement mosaic. Bearing in mind the urban location and the effort to create characteristic forms and transitions between the environment inside and outside the tunnels, there will not be any light screens outside the tunnel mouths. Special additional lighting in the tunnels near the mouths will be used to help the eye adapt to the change in light.

At Värtan, a special steel and glass construction will be built to limit the noise in the immediate neighbourhood.

6. Concrete Constructions inside the Tunnel System

Special types of concrete construction are the bridges and concrete structures built inside the tunnels. One such category is the bridges that must be built to accommodate the intersections between the road tunnels and other parts of the city's underground infrastructure. For example, on

Norra Länken bridge structures are needed where the Stockholm metro system cuts right through the system of main road and ramp tunnels. This is also the case where a telecommunications tunnel crosses Södra Länken necessitating special reinforcement measures.

Underground concrete constructions are also needed for building the substations, water and wastewater plants and the fan control centres.

7. Bridges Outside Tunnels

Bridges will be constructed outside the tunnels in connection with the interchanges included in the project. Two specific bridges deserve mentioning.

A bridge, at Sickla on Södra Länken, will replace an existing two-lane road bridge. The new one will consist of two parts, with three and four traffic lanes respectively. The bridge will be equipped with high glass noise shields to be able to combine it with the ambition of creating a new city suburb in close proximity to the road.

Sickla is the only part of Södra Länken that is not housed in a tunnel and great effort is being exerted to reduce its barrier effect. Ecoducts, which are 40 metre wide green passages for people and animals are being built over the road on each side of the Sickla Canal.

The one at Norrtull on Norra Länken is actually a railway bridge rather than a road bridge. When constructing the concrete tunnels, it will be necessary to demolish an existing bridge and replace it with one that will be designed with steel arches founded on concrete base slabs. A pedestrian and cycle path will be adjoined on the one side of this railway bridge through a system of cantilevers. This new railway bridge forms part of a new entrance into the centre of Stockholm.

8. Ventilation Towers in Steel and Glass

There are five ventilation towers in the Norra and Södra Länken projects. Their function is to discharge and disseminate the air in the tunnels to avoid high concentrations of air in the areas immediately outside the tunnel mouths. There will be a uniform ventilation tower construction based on the results of a design competition.

The towers will be constructed in glass mounted on a stainless steel framework. The structure is characterised by a minimum of materials, and it has been studied, for example, with respect to movements in the framework and how this is transferred to the glass panels. The ventilation towers will be between 25 and 40 metres high and have an interior diameter of five to six metres. In order to maintain good transparency, there will be an installation for automatically cleaning the inside surface.

9. Costs and Time Schedule

The total cost of Södra Länken is calculated to 6,5 GSEK. The time schedule means that most parts of Södra Länken will be opened for traffic in 2003 and the rest in 2004.

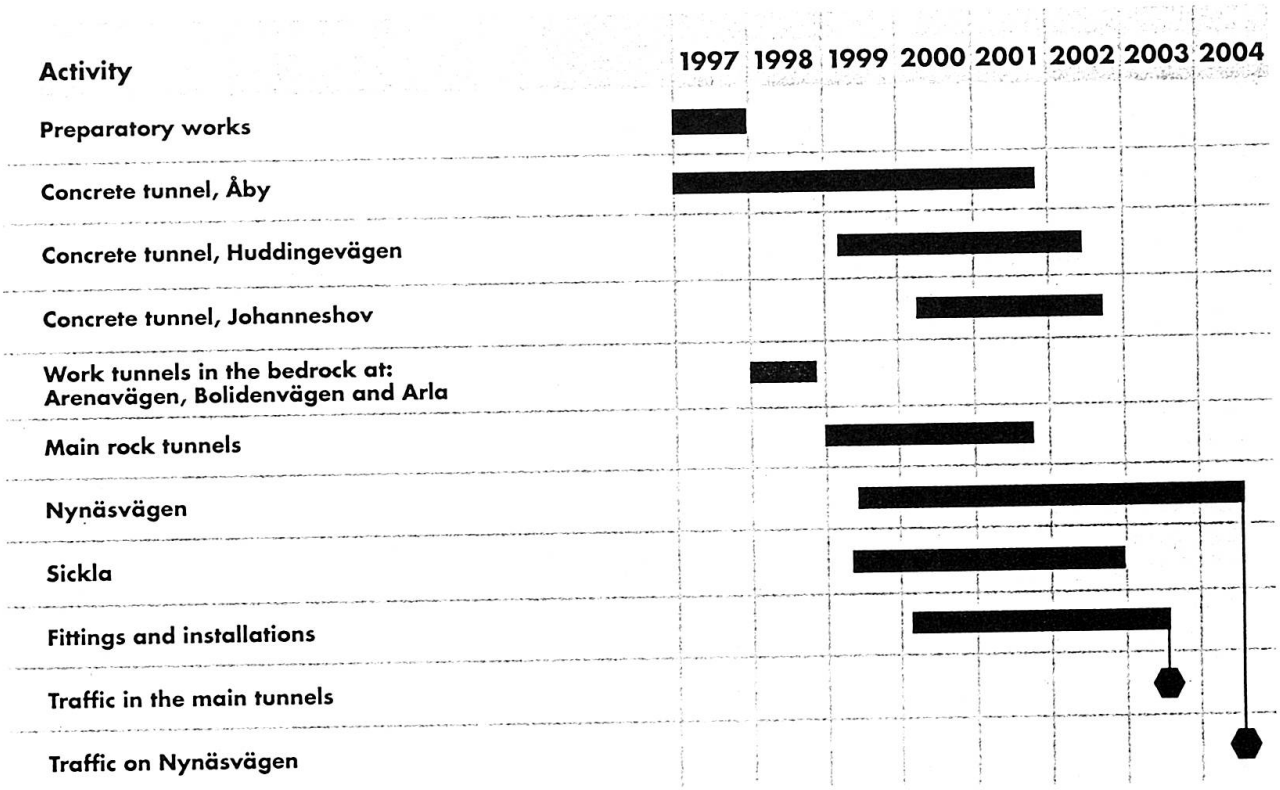


Fig.5 Time Schedule