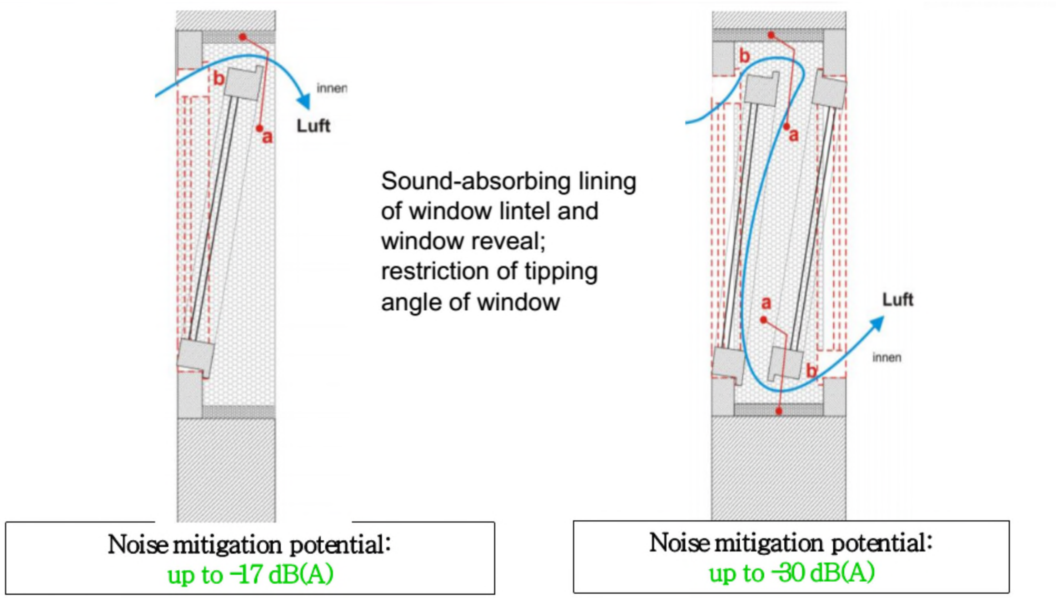
‘HafenCity Fenster’ – Sound insulation in a partially open window

‘HafenCity’ windows are made from two window layers which are combined with a small gap between them. The space between windows is lined with absorbing materials in order to increase the sound insulation of the window construction. The surfaces of both windows are divided by the special ventilation openings. These can be vertically shifted and are usually placed in bottom of the inner window and on top of the outer window. Together with the absorbing material, these windows allow sound reduction of at least 20–30 dB, allowing residents to have a good sleep next to the partly opened window.

Built-in ‘HafenCity’ windows



Source: Lärmkontor GmbH

Design and noise mitigation potential of single (left) and double (right) ‘HafenCity’ windows

Example

In the developing phase of Europe’s largest inner-city development project – HafenCity Hamburg – high noise levels at night (originating from commercial activities in Hamburg harbour) presented the biggest obstacle in achieving the required acoustical standards in planned dwellings. To address this problem, a new type of sound insulation windows better known as the ‘HafenCity Fenster’ have been developed.

The new ‘HafenCity’ sound insulation concept is focussed on reaching interior noise level of 30 dB in bedrooms with partly opened window at night time.

Further information:

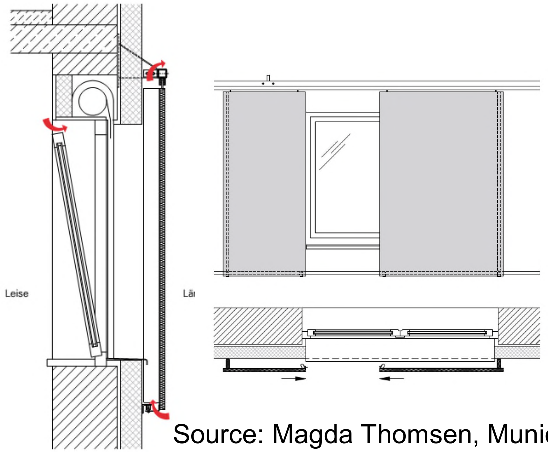
http://on-air.no/examples - Example 1

Façade improvement: noise-insolating sliding panels

Sliding shutters made of aluminium panels and mineral wool are used as soundproofing elements in front of the bedroom windows. The sliding panels run smoothly on guide rails and can be closed from the inside. Above and below are the ventilation openings.
The silencer comes into effect here: The ‘noisy’ air passes along the soft mineral fibre mat and loses its sound energy, then ‘calmed’ air passes through the open windows in the bedrooms. The panels darken the bedrooms at night and reduce the sound exposure.
The sliding panels reduce noise up to 27 dB and improve residents’ quality of living considerably.

Source: Magda Thomsen, Munich

Sliding panel detail, Middle Ring Munich



Source: Magda Thomsen, Munich

Design of the sliding panels

Example
The Middle Ring is one of the main arteries of the city of Munich.
Approximately 64 000 vehicles run daily on the Innsbruck Ring, which makes the residential quality very limited without additional sound insulation measures.
In order to improve the quality of living in ‘Mittlerer Ring’, the noise-protection concept was developed. This concept consists of four individual constructions, as follows:

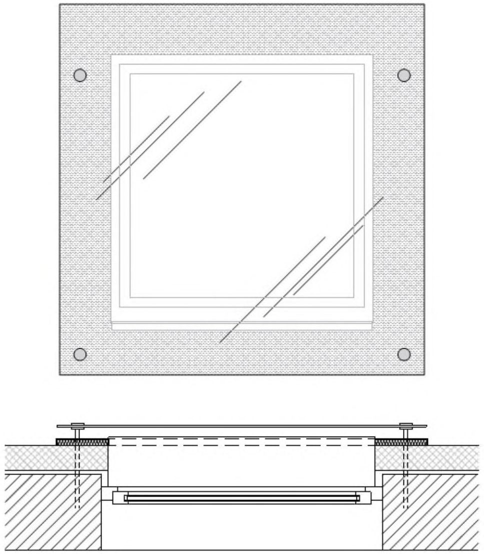
- Noise-insulating sliding panels;
- Fixed glazing in front of the windows *(see example no. 003)*;
- Glazing of balconies – Westplatz in Leipzig *(see example no. 004)*; and
- Noise protection building blocks *(see example no. 005).*

Further information:
http://on-air.no/examples - Example 2

Conférence Européenne des Directeurs des Routes
Conference of European Directors of Roads

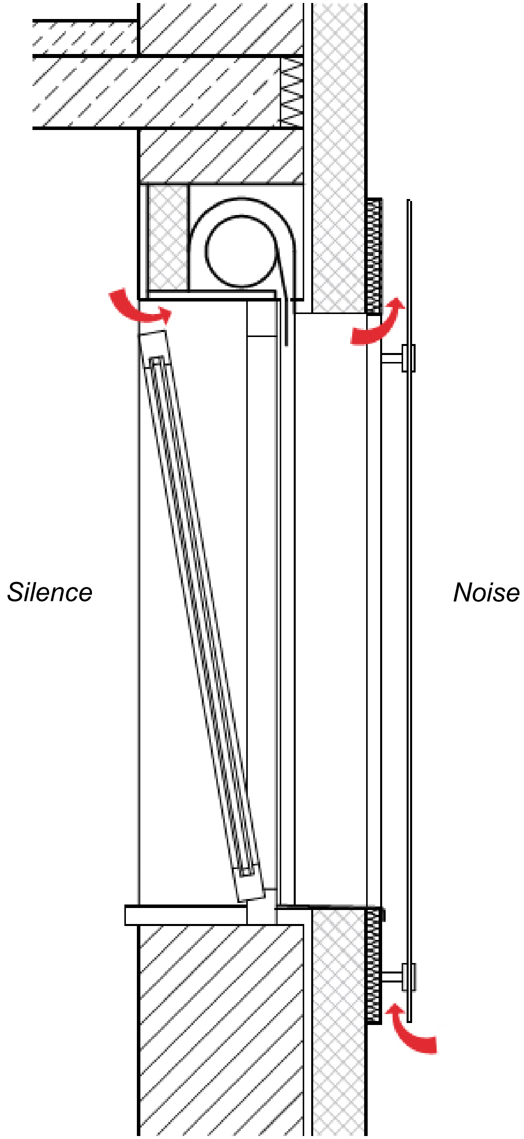
Façade improvement: Fixed glazing in front of windows

As protection from noise in bedrooms, fixed glass panels can be installed Glass panels are made of self-cleaning laminated safety glass placed at an appropriate distance from the façade. Rotating ventilation slots provide permanent ventilation of the rooms. The glass elements overlap the window opening by about 25 cm. These areas are filled with a noise reducing mineral fibre mat.
The fixed glazing in front of the windows lowers the noise by partially open windows up to 24 dB.



Source: Magda Thomsen, Munich

Fixed glazing design



Fixed glazing design and detail, Middle Ring Munich

Example
The Middle Ring is one of the main arteries of the city of Munich.
Approximately 64 000 vehicles run daily at the Innsbruck Ring, which makes the residential quality very limited without additional sound insulation measures.
In order to improve quality of living in 'Mitetlerer Ring', the noise protection concept was developed. This concept consists of several individual constructions, as follows:

- Noise-insolating sliding panels *(see example no. 002)*;
- Fixed glazing in front of the windows;
- Glazing of balconies – Westplatz in Leipzig *(see example no. 004)*; and
- Noise-protection building blocks *(see example no. 005).*

Further information:
http://on-air.no/examples - Example 3

Façade improvement: Glazing of balconies

On a loud façade, balconies can be closed with a flexible curtain façade made of glass. Glass façades consist of a rotating carrying frame and a horizontal mullion-transom system as the upper edge. Clear glass elements can be formed without rungs. The final touches can be metallic shading elements with a specific pattern which allows each tenant to personalise the view and the amount of sunlight on the balcony.
The glazing of balconies can reduce noise levels by up to 20 dB and improve residents' quality of living considerably.

Renovated building at Westplatz in Leipzig, Germany

Interior and exterior of balcony structure (left), rotating glass frame (right) at the Westplatz in Leipzig Germany

Example
The Middle Ring is one of the main arteries of the city of Munich.
Approximately 64 000 vehicles run daily on the Innsbruck Ring, which makes the residential quality very limited without additional sound insulation measures.
To improve quality of living in the 'Mitetlerer Ring', the noise protection concept was developed. This concept consists of several individual constructions, as follows:

- Noise insolating sliding panels *(see example no. 002)*;
- Fixed glazing in front of the windows *(see example no. 003)*;
- Glazing of balconies; and
- Noise protection building blocks *(see example no. 005).*

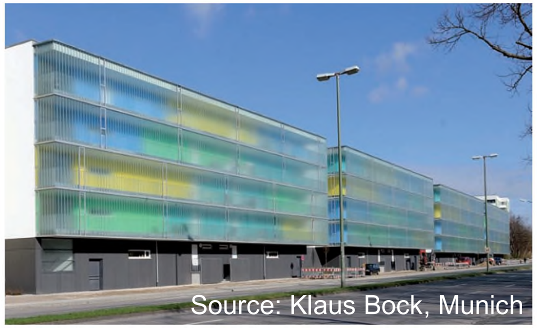
Further information:
http://on-air.no/examples - Example 4

Noise-protection building blocks

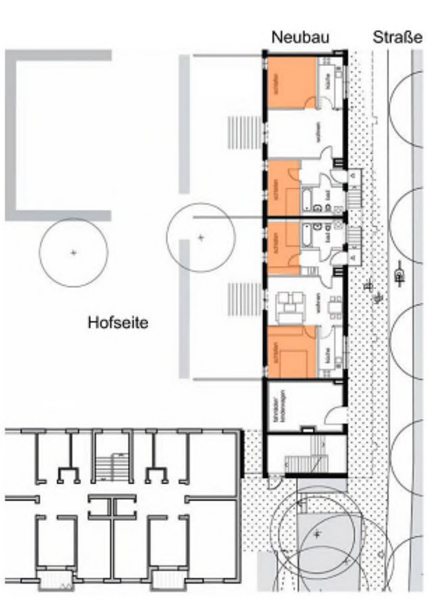
New building structures made specifically for noise reduction on existing buildings can provide good noise protection, creating a silent façade and improving residents' quality of life considerably.

In the example of the Innsbruck Ring, Munich, a new noise protection has been built in form of four 5-storey residential buildings. These enclose the open courtyards and connect the existing buildings from north to south. The floor plans are divided into three zones, as follows:

- A building entrance oriented to the street with glazed arcades. The profile glazing shields against traffic noise and provides weather protection;
- Arcades connecting the apartments to the rest of the building structure; and
- Bedrooms and living rooms are oriented to the silent façades.



Detail of glazed arcades, Innsbruck Ring 70 and 72, Middle Ring, Munich



Source: Krieger Architekten, Samerberg

Source: LHM Vermessungsamt

Rooms oriented to the silent façade (left) and noise protection buildings blocks (right)

Example

The Middle Ring is one of the main arteries of the city of Munich. Approximately 64 000 vehicles run daily on the Innsbruck Ring, which makes the residential quality very limited without additional sound insulation measures.

To improve residents' quality of life in the 'Mittlerer Ring', the noise protection concept was developed.

This concept consists of the several individual constructions, as follows:

- Noise-insolating sliding panels *(see example no. 002)*;
- Fixed glazing in front of the windows *(see example no. 003)*;
- Glazing of balconies – Westplatz in Leipzig *(see example no. 004)*; and
- Noise-protection building blocks.

Further information:
http://on-air.no/examples - Example 5

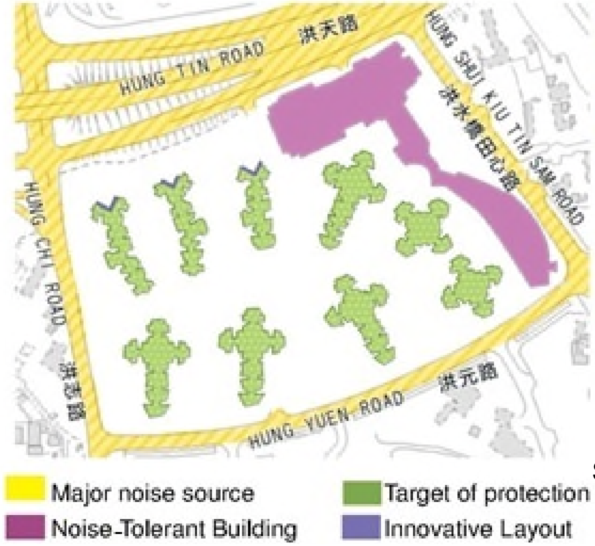
Buildings as noise shields

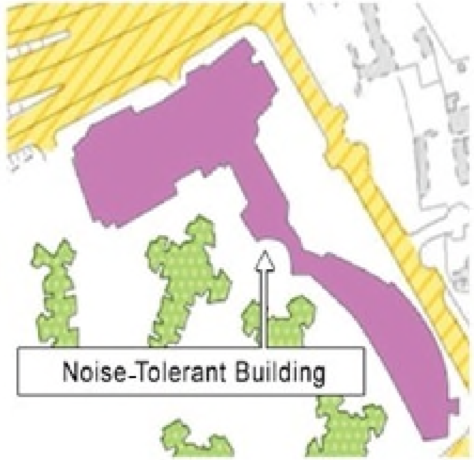
Additional noise protection can be achieved by arranging the site plan to use buildings as noise barriers. A long building or a row of buildings parallel to a highway can shield other more distant structures or open areas from noise.

What is more, a noise-tolerant building such as a multi-storey carpark building can be used to protect residential buildings from road traffic noise. Placing a noise-tolerant building between the road traffic and the residential building causes the noise in the 'shadow zone' to be reduced. This brings about a reduction in the traffic noise affecting the residents.

Source: Hong Kong Housing Authority

Aldrich Garden at Shau Kei Wan, Hong Kong





Source: Hong Kong Housing Authority

Public Rental Housing Development at Hung Shui Kiu, Hong Kong

Example

1. Aldrich Garden at Shau Kei Wan, Hong Kong:

A 30 m high carpark (noise-tolerant building) acts as a noise-shielding structure for the residential buildings in the background. The noise reduction is about 5–9 dB.

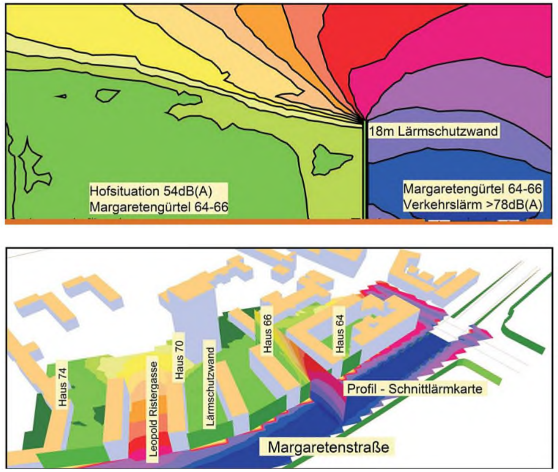
2. Public Rental Housing Development at Hung Shui Kiu, Hong Kong

Commercial centre (noise-tolerant building) of about 10 m high, plus a 3 m barrier wall on top of the building, serves as a noise-shielding structure to protect the residents at the back. Noise reduction is about 5–15 dB.

Further information:
http://on-air.no/examples - Example 6

Noise barriers and screens

Noise barriers or screens are an effective but very costly measure to reduce noise propagation alongside roads or railway lines. The main requirement is that the barrier needs to be high and long enough. For the construction of barriers, a range of materials with different characteristics regarding absorption and reflection of sound is used.
In some cases where other solutions are not possible, very high transparent noise barriers and screens are built.



Source: City of Vienna

Noise situation after the implementation of the noise screen (above), vertical noise map (below)

Source: TREUSCH architecture ZT GmbH

Glass noise screen at the Theodor-Körner-Hof: street (left) and courtyard view (right)

Example

The Theodor-Körner-Hof is an urban residential complex in Vienna Margaret and lies directly on the heavily loaded Margaret Street. The residential complex has 1356 apartments and is the largest urban residential block in Margaret. The open building structure perpendicular to the road allowed good propagation of sound. Therefore, about 90% of the residents were exposed to high noise levels day and night.

In 2007, an 18 m high noise screen was built. The screen is made of glass, allowing enough light and brightness between the buildings. In the top row of the noise screen, photovoltaic systems have been installed. The achieved noise reduction is 23 dB.

The protective noise screens improved the quality of living considerably, creating a quiet courtyard and common space for the residents. However, in the broader use of noise screens, these effects can be limited due to the sound reflection in areas with sensitive use on the opposite side of the barrier.

Further information:
http://on-air.no/examples - Example 7

Façade improvement: Double façade

Double façades can be used to control environmental noise break-in without the need for acoustic attenuation. When using a double façade, air enters the building through conventional open windows.

The acoustic protection is achieved by acoustically screening these windows by means of a secondary façade. Air enters the void between the two façades via a gap at the bottom of the outer, secondary façade.

The advantage of this type of façade is that standard windows can be used. It is also possible to form buildings with an interesting and unique appearance.

The drawbacks are clearly cost and space; for these reasons this type of noise control measure is less common. It is also important to note that secondary façades can compromise the acoustic separation between two rooms when windows are open. Acoustic splitters/absorbers may be required to maintain the sound insulation when there are two open windows.

Double façades: Leeuw van Vlaanderen (left) and Science Park (right), Amsterdam, Netherlands

Example

1. The project at Science Park was realised in 2008. The location is next to the Almere-Amersfoort railway line in Amsterdam. Some of the interesting (noise) aspects of this project are the use of double façades and noise screens to protect against railway noise.
2. Leeuw van Vlaanderen – This is a building from the 1960s which was renovated in 2005. It is situated parallel to the A10 highway behind guardrail Amsterdam-West, 10 feet behind the A10. The use of a shielding gallery, a quiet side and a double façade are some of the elements of this project.

Further information:
http://on-air.no/examples - Example 8

Façade improvement: Louvred façade

Additional façade elements can be used to control traffic noise break-in.

The main function of a louvre is to allow the flow of air into a building while inhibiting the ingress of the elements such as rain and noise.

Acoustical louvres are used as part of the intake/exhaust air system of buildings, structures or equipment to help reduce environmental noise. They have a relatively large surface area which compensates for their lack of depth. Models are available in varying depths, percentage of open area and blade configurations, yielding various results in terms of pressure loss and noise-reduction performance.

Source: IBI Group

The screen serves as a venetian blind to improve privacy between the facility and nearby houses

Source: Betina Skovbro/John Seaman

Source: IBI Group

The Hadyn Ellis Building features louvred screens which wrap around the building and reduce noise from the street

Example

In 2008, Cardiff University, a member of the Russell Group of Universities, embarked on the development of a master plan known as the Maindy Road Campus. The construction of the Hadyn Ellis Building involved several laboratory-based research groups to be housed in one building, along with exhibition and conference facilities, a lecture theatre, seminar suites and office accommodations.

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One of the challenges of the project was addressing the risk of incoming noise from the neighbouring road. To reduce the noise and maintain the required acoustic comfort levels within, a louvred screen wraps around the entire front of the building and incorporates acoustic absorbing material. In addition, the screen serves as a venetian blind to improve privacy between the facility and nearby houses.

On the outside, the block facing the housing is clad in coloured glazing which tonally responds to the brick and develops a language appropriate to the university. This is set against a backdrop of terracotta cladding, which complements the university's existing architecture.

The building was completed in 2013 and was distinguished as 'Best Higher Education Building in Wales' at the BREEAM Awards in 2012.

Further information:
http://on-air.no/examples - Example 9

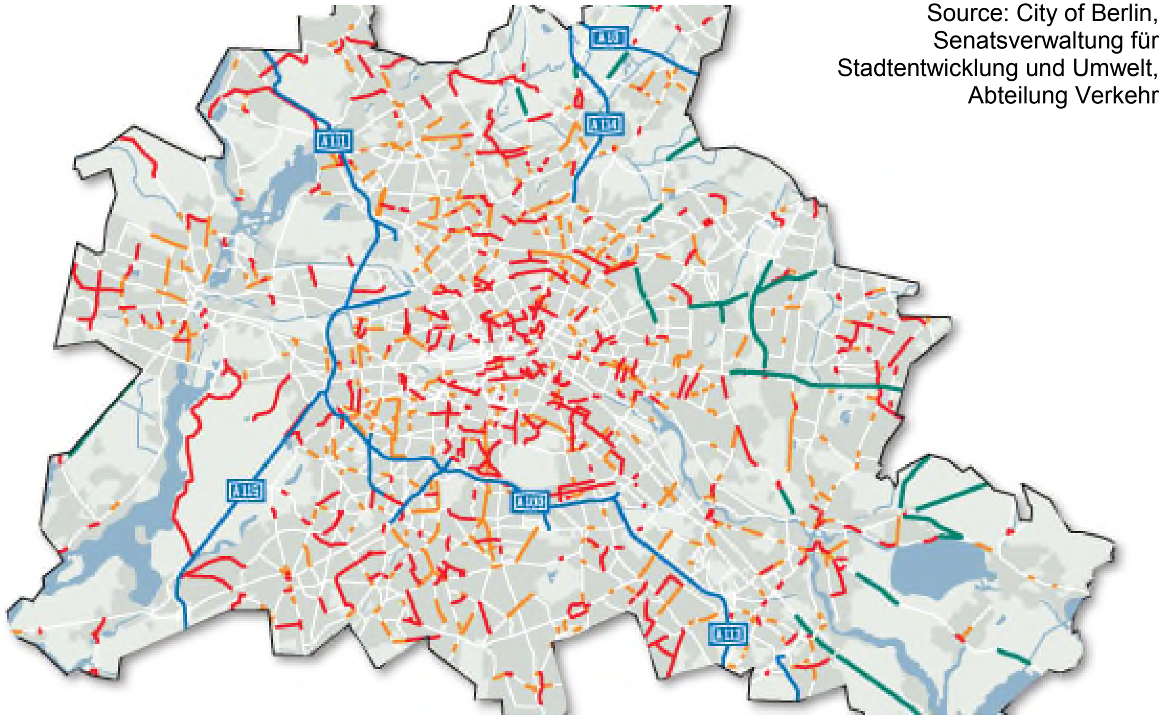
Speed limit of 30 km/h on major roads

A speed limit of 30 km/h is a simple and inexpensive way to reduce noise and has other positive results, including increased road safety, decreased air pollution and increased residential quality.
When the speed limit is lowered from 50 km/h to 30 km/h, the personal perception of noise-level reduction is high. In the case of pilot projects in Berlin, a measured reduction of the noise level was ‘only’ 1.4 dB. However, the proportion of strong and extremely strong annoyance decreased by 26%. Similar effects were seen in studies in Rostock.

Example

In Rostock, the framework of the noise abatement plan examined the effects of speed reduction from 50 to 30 km/h at night (2200–600 h) on the two main major streets. Assessment was conducted through traffic and noise measurements, surveys and so on. Noise measurements showed a decrease in the noise of level between 1 and 1.5 dB, while residents’ subjective feeling of annoyance decreased and their life quality increased. Based on the positive results, the City Council decided to introduce a permanent speed limit of 30 km/h on both examined streets.

The Berlin Senate Department introduced a pilot project on six major roads in 1999/2000 where a speed limit of 30 km/h at night was introduced. The pilot project involved computational screening of noise pollution, accompanied with traffic surveys, noise measurements and a survey of residents.
On the examined roads, a significant reduction in traffic was detected (around 11–17% at night), and a noise reduction between 0.2 and 2.7 dB was found.



Source: City of Berlin, Senatsverwaltung für Stadtentwicklung und Umwelt, Abteilung Verkehr

The figure shows that on almost every route, there are sections with 30 km/h – on roads marked in red, the speed limit of 30 km/h is enforced all day; on roads marked in orange, this speed limit is temporary (night). On green roads, speeds of more than 50 km/h are allowed.

To obtain the best results, the Senate recommended the following support measures: reduction of the lane widths, optical narrowing of the cross-section, adjustment of traffic lights and speed monitoring.
Currently, around three-quarters of Berlin’s major roads (5340 km) have speed limits of 30 km/h at night.

Further information:
http://on-air.no/examples - Example 11

Solar energy and highway – Enclosures

The latest trend in highway noise mitigation is a combination of photovoltaics and noise protection. Solar cells are usually installed alongside road lanes in the form of the photovoltaic noise barriers. Solar cells can also be placed on top of the existing noise protection tunnels and/or enclosures.
The main criteria in the selection of the location where this dual system can be combined are the age and condition of the existing structure, climate conditions and costs.

The Federal Highway Research Institute (BAST) created a nationwide cadastre of existing noise barriers to determine which of them are suitable for potential photovoltaic application.

Detail of a noise-protection tunnel with solar panels, Aschaffenburg, Germany

Noise-protection tunnel with a solar power plant on the roof, highway A3 near Aschaffenburg, Germany

Example
Construction of the 2.8 km long noise protection enclosure (tunnel) on highway A3 between Frankfurt and Würzburg in Germany was completed in 2005.

The construction of the tunnel was the best solution. Since the first houses are just 50 m from the road, there was not enough space for the earth banks. In addition, noise barriers used to achieve necessary noise protection would have been too high and unstable in their construction.

On top of the tunnel, a photovoltaic power plant containing 16 000 solar modules from Evergreen Solar was installed in 2008. The photovoltaic power plant has a total length of 2.7 km and produces 2.6 million kilowatt hours of electricity per year.

The estimated 11 million Euro investment costs are expected to be amortized within 16 years.

On the German highway network, there are several suitable areas for solar power generation. Still, they are rarely used for this purpose.

Further information:
http://on-air.no/examples - Example 13

Traffic bans for certain types of vehicles

The composition of traffic in terms of vehicle categories is important in determining noise levels.

On most urban roads, heavy vehicles only account for a small percentage of the total traffic. In combination with the usually higher speed of light vehicles, the effect is that the light vehicles usually dominate the noise emissions. On most high-speed roads, particularly motorways, the speed of light vehicles is considerably higher, and these therefore also dominate the noise emission in these situations, even though the percentages heavy vehicles are often fairly high.

At night, the peak levels caused by the heavy vehicles represent noise events which may wake people living along the road or cause alterations their sleep pattern.

A temporally and spatially limited ban for certain types of vehicles, such as night banning, of heavy vehicles brings different results on urban roads and highways. Since the proportion of heavy vehicles in the overall noise level on urban roads is low even at night, a traffic ban leads to reduction of L_{eq} of about 1 dB. On rural roads, the reduction potential is between 2 and 3 dB. However, the noise peaks are greatly reduced by this measure.

Trucks waiting at a motorway lay-by during driving ban.

Example
On weekends and on holidays, driving bans for heavy goods vehicles (HGV) are in force in Germany, Austria and Switzerland. These traffic bans apply to different time periods and gross vehicle weight: Whilst Switzerland banns all vehicles over 3.5 tonnes on the whole Saturday (midnight to midnight), Germany and Austria only ban vehicles with more than 7.5 tonnes. The ban time is from midnight to 2200 h in Germany, in Austria the ban starts at 1500 h on Sundays until 2200 h on Saturday.

Such measures are sometimes also used in France, Italy, Luxembourg, Romania, Poland, Liechtenstein, Greece, Slovenia, the Czech Republic and Hungary.

A night driving ban is in force between 2200 and 0500 h in Switzerland for HGV over 3.5 tonnes and in Austria for HGV over 7.5 tonnes.

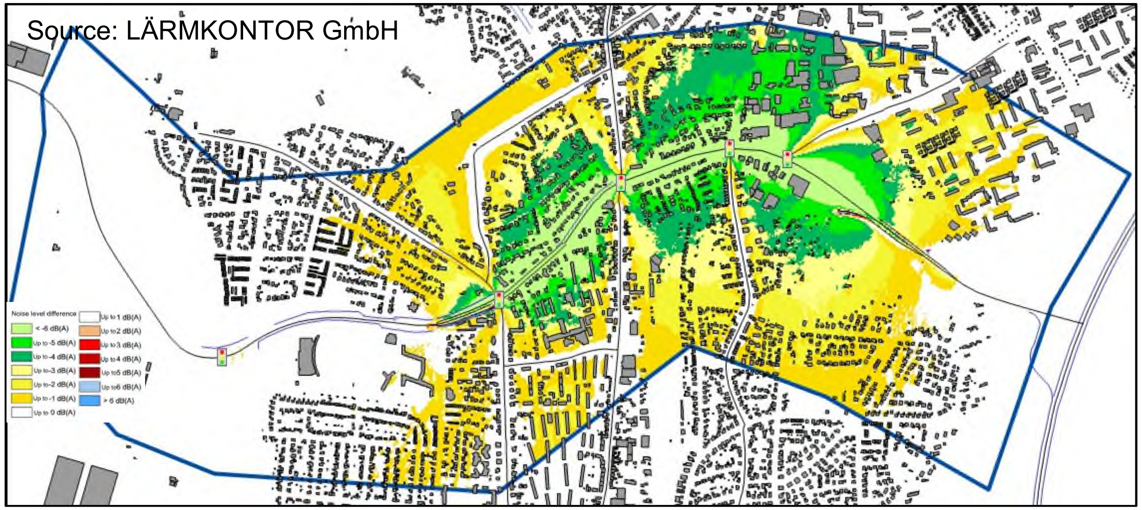
Further information:
http://on-air.no/examples - Example 15

Detailed planning for Cherbourger Street, Bremerhaven, Germany

Detailed planning is an integral part of all highway construction and reconstruction projects. Environmental protection elements have an important role in the decision-making process. In some projects, existing and potential noise and air pollution can be decisive in the selection of the final corridor.

Cherbourger Street in Bremerhaven, Germany, is the main connection between the port and highway A27. With a high percentage of heavy goods vehicles, it is burdened with high noise (78 dB in the day and 72 dB at night) and air pollution levels.

The final solution: The tunnel south from Cherbourger Street (marked red) with the east and west ramp (marked blue)



Difference noise map showing improvements along the current alignment

Example

The Port Tunnel on Cherbourger Street in Bremerhaven, Germany, is the result of a planning process spanning many years. The plans for efficient port services in the field of Cherbourger Street began in 1997 during the fourth stage of expansion of container terminal IV. In the following years, various versions were developed, discussed with the citizens and political decision makers and partly rejected. Amongst these were two northern bypasses, several tunnel solutions such as a short tunnel and the tunnel route under the Cherbourger Street and a partly covered road in the cut.

The tunnel is to run from east to west and will be located south of Cherbourger Street. It will serve as an efficient road link, connecting the international port and business parks located close to the port with the highway A27.

The two-lane road tunnel will be constructed using an open cut construction method, together with all entrance and exit ramps, two operation buildings and 10 escape staircases. The structure will be 1195 m long and will consist of a tunnel tube with two-way traffic; at the eastern end, this will divide into two separate tubes where the respective traffic flows are in one direction. The total length will be 1848 m (north side) and 1659 m (South side). The tunnel is scheduled to be completely built by the end of June 2018, and it will considerably reduce the traffic volume around Cherbourger Street.

Further information:
hhttp://on-air.no/examples - Example 16

Handling of noise in a policy package

Policy packages are structures used to combine different policy measures and address multiple objectives. In Norway, they have been used for the integration of land-use and transport-system development in all of the larger urban regions. The Environmental package in Trondheim is one of these; one of its goal is to reduce the number of people plagued by traffic noise by 15% by 2018 (Municipality of Trondheim, 2008)[1]. An investment of €200 million will be used on noise mitigation between 2011 and 2024. Before the policy package was implemented in 2008, both indoor and outdoor noise levels were mapped. The central areas and those close to the main roads were the most exposed.

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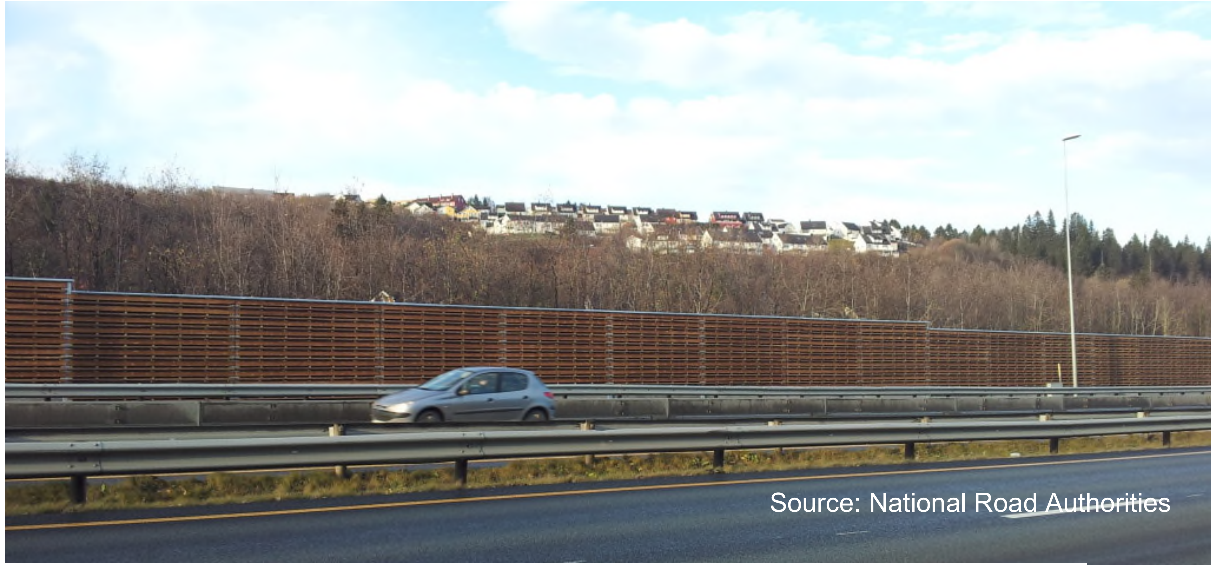
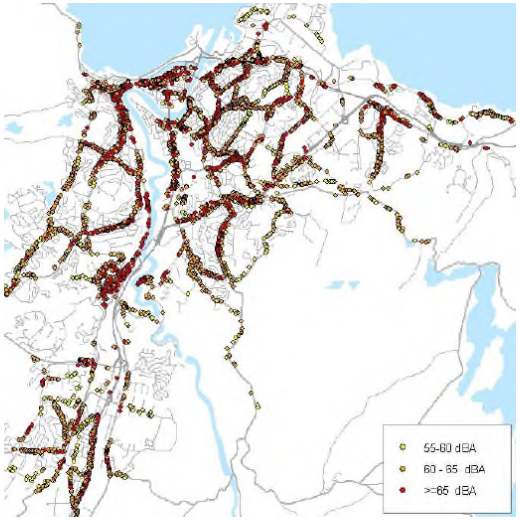


Noise barrier on a major road south of Trondheim



Outdoor noise levels for 2007, Trondheim

Example

Noise is addressed in different ways in Trondheim. First, barriers are raised (in accordance to the noise mapping) and façade insulation is used for specific houses in central areas. Second, several of the road projects financed through the policy package (including a tunnel) are considered to reduce noise in specific areas. Third, regulation is used to direct car drivers to certain roads, thereby reducing traffic and noise on others. Regulation (e.g. toll-road and parking schemes) is also used to reduce traffic volumes in general, potentially also reducing noise levels.

When integrated in a policy package, the handling of noise in Trondheim is high on the political agenda.

It is part of the overall urban development strategy. Still, the environmental package illustrates the challenge of conflicting aims within policy packages: To reduce climate gas emissions, Trondheim aims for urban densification. With the concentration of new dwellings in noise-exposed central areas, the number of people affected by noise is expected to rise (Municipality of Trondheim, 2012).

Further information:
http://on-air.no/examples - Example 17

[1] In relation to 2007 numbers.

CEDR Conférence Européenne des Directeurs des Routes Conference of European Directors of Roads

Noise reduction through green façades

When building façades on both sides of a street are of hard material, the noise from road traffic will propagate in a zigzag pattern horizontally across the street. It will also reflect vertically upwards towards the ceiling level. These reflections increase the overall noise. One way to reduce such reflections is through green façades.

Housing surfaces covered with vegetation reduces noise at each reflection. Such vegetation can be placed either on the house front facing the noise source or on the short sides of apartment buildings (see the figure below). The underlying logic of the latter approach is that while the backyards of adjoining housing quarters protect well against noise, openings between buildings will reduce the noise protection (for example in backyards).

Green façade on a side wall in London. Designed by Gary Grant at GRC

Examples of module-based green façades

Example

Two different techniques can be described for the greening of façades. First, there is vegetation, for example ivy, climbing up the housing façade. The disadvantages of this approach are that it takes time before the vegetation reaches a sufficient height and that it hinders maintenance of the façade.

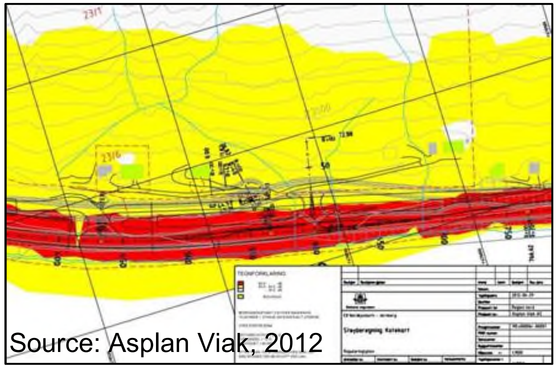
Second, a module system could be put up using steel grids. To avoid moisture on the house wall, space is maintained between the vegetation and the façade. In a research project, the noise-reducing effects of green façades were calculated. In situations where the green façade faced a road with traffic, the noise reducing effect was found to be 1 dB (Klæboe and Veisten, 2014).

When the green façade was on a side wall between buildings (for example the entrance of a backyard), the effect was 4,5 dB.

Further information:
http://on-air.no/examples - Example 19

Handling of noise through planning zones

The way in which dwellings and workplaces are located around existing roads influences people's exposure to noise. This highlights the benefits of integrated planning, connecting the use purpose of new buildings to the existing noise values at a given location. Cautious municipal planning in accordance with such principles provides an effective measure to reduce exposure to road noise for both dwellers and workers.



Source: Asplan Viak, 2012

Example of noise zones along a road

Noise source	Noise zone			
	Yellow zone		Red zone	
	Outdoor noise level	Outdoor noise level during the night period 23 – 07	Outdoor noise level	Outdoor noise level during the night period 23 – 07
Road	L_{den} 55 dB	L_{5AF} 70 dB	L_{den} 65 dB	L_{5AF} 85 dB

Outdoor limits for road noise (yellow and red zones) Source: Modified after T-1442/2012

Example

In Norway, limit values have been set for the handling of noise in land-use planning through national guidelines (T-1442/2012). Road noise is one of several noise sources considered. In the guidelines, land is divided into three zones – red, yellow and green. Within each of these, limit values have been established for both indoor and outdoor noise.

The red zone is the area closest to the noise source. Here, the highest limit values are allowed (see figure), but there are also limitations in relation to which purposes are recommended. Built structures intended for noise-sensitive purposes are to be avoided in red zones

Within the **yellow zone**, the limit values are lower. Here, structures intended for noise-sensitive purposes could be accepted, providing that documentation of mitigating measures giving acceptable noise values at the location is collected.

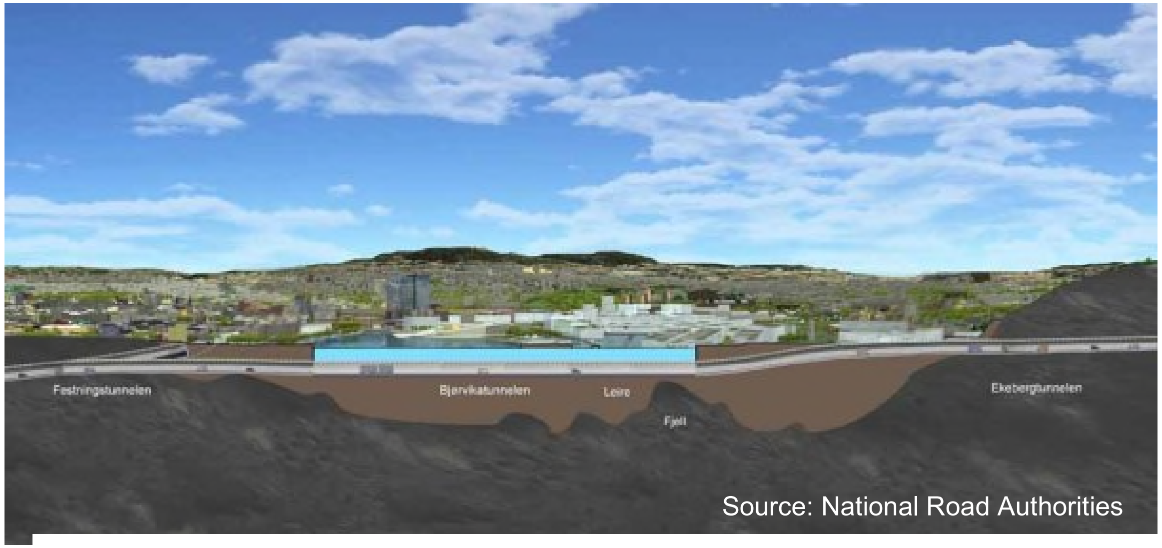
The green zone describes areas where one wishes to keep noise at a minimum, such as in shielded city parks or natural parks. The guidelines are not legally binding, but substantial deviation may result in objections from national authorities (stopping the planned activity until an agreement has been reached).

Further information:
http://on-air.no/examples - Example 20

Urban districts relieved from noise exposure by road tunnels

Road tunnels are built for several reasons. In addition to goals of increasing traffic efficiency, the reduction of traffic's negative side effects on the surface is a typical argument for new construction. Hence, road tunnels are built to reduce the local population's exposure to traffic accidents, emissions and road noise. With traffic put underground, new opportunities open for urban development on the surface.

The redevelopment of Bjørvika tunnel



Cross-section of Bjørvika tunnel

Example

In Oslo, Norway, there has been a long-term political goal to redevelop the seafront around the central train station. This involves the creation of a whole new urban landscape. Important cultural institutions are being relocated in the area, alongside a large number of new dwellings and workplaces. Such a change would not have been possible without extensive restructuring of the road system. This means that the new urban development requires the surface to be redistributed for purposes other than car driving and the area being relieved from noise and traffic emission exposure. The most important measure in this regard has been the creation of the Bjørvika tunnel, a 675 m long immersed tunnel on the seabed.

The tunnel, illustrated by the green line in the figure on the left, was opened in 2010. While Norway has many subsea tunnels bored through bedrock, the Bjørvika tunnel is the first lying on the seabed.

With a major road put underground, traffic volumes in the Bjørvika area has been reduced substantially. The new urban district, which is in the making, is characterised by compact city development; dwellings and workplaces are substituting the former traffic machine at the seafront.

Further information:

http://on-air.no/examples - Example 21

Noise control using barriers, speed reduction and porous asphalt

Highway E4 passes close to residential buildings near Husqvarna in Sweden. Over the past 15 years, there has been a large increase in traffic, which has also resulted in increased noise levels at residential buildings. On the background of complaints from residents, in 2008, the Swedish environmental court decided that the national road administration should reduce the noise by 10 dB at the façades of residential buildings.

Calculations showed that a very long, high noise barrier was needed to fulfil the 10 dB requirement. Cost-benefit analysis showed that this was an expensive solution. Instead, a combination of the following measures would be used:

1. A low noise barrier,
2. Noise-reducing two-layer porous asphalt on a 2.8 km long section. The performance of the porous pavement is monitored by CPX noise trailer measurements every year and
3. Speed reduction from 110 to 90 km/h. Sign have been put up reading ‘Reduced speed because of noise’

The noise abatement measures were implemented in 2010.

Further information:
http://on-air.no/examples - Example 22

Source: Danish Road Directorate


Source: Danish Road Directorate


Source: Danish Road Directorate

Source: Danish Road Directorate

The Melbourne Noise Tube

Some years ago, a new 6-lane motorway called the 'City Link' was constructed in Melbourne, Australia. This connects downtown with the airport. On a long section, the new motorway is constructed on a bridge crossing existing roads.

At one location, the motorway bridge passes two 20-storey residential buildings and some huge green areas. The noise design criterion for the highway was that 63 dB was not to be exceeded at the façade of residential buildings.

It was decided to construct a noise screening that partly covers the motorway facing the residential buildings. This noise barrier has got the local nickname 'the Noise Tube'. At the four top floors of the residential buildings, it was also necessary to provide façade insulation in order to fulfil noise guidelines.

Further information:
http://on-air.no/examples - Example 23

Source: Danish Road Directorate

Source: Danish Road Directorate

Source: Danish Road Directorate

Residential or industrial buildings used as noise barriers

In some cases, buildings have been used as noise barriers along the motorways around Melbourne, Australia.

Two- and three-storey row house buildings constructed as a long closed row of houses function as a noise barrier protecting green areas and other buildings behind the first row. Good façade insulation is needed in the first row of buildings in order to create a reasonable indoor noise environment!

Industrial buildings, together with the short sections of noise barriers, have been constructed to create a closed combination of buildings and barriers functioning as a noise barrier along the motorway. Parts of the barriers and buildings are used as commercial billboards.

Further information:
http://on-air.no/examples - Example 24

Residential and industrial buildings in combination with the noise barriers along motorway in Melbourne, Australia

Noise barriers constructed in cement concrete

The acoustic function of noise barriers is briefly described in Section 3.7.2 – Noise abatement under propagation of the guidance book.

Noise barriers constructed of cement concrete can be given different visual appearances by the use of structures and 'prints' on the surface, as well by using different colours.

Examples:
Concrete noise barrier in Tallinn, Estonia, with a profiled surface.

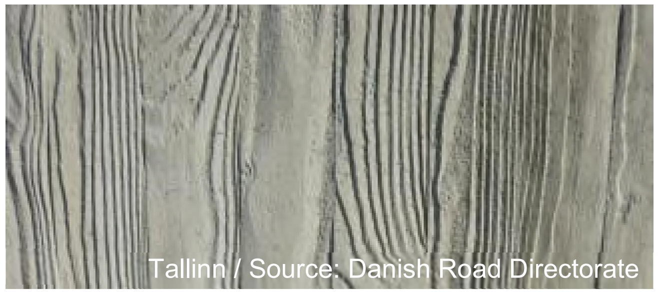
Concrete noise barriers in Melbourne, Australia, with 'text prints', different colours and a transparent top barrier.


Melbourne / Source: Danish Road Directorate


Melbourne / Source: Danish Road Directorate


Tallinn / Source: Danish Road Directorate


Melbourne / Source: Danish Road Directorate


Tallinn / Source: Danish Road Directorate

Green noise barriers

Various strategies for the adaptation of noise barriers and embankments to urban and rural surroundings can be used. One strategy is the planting of trees and other vegetation so that the noise barrier fits in with the surrounding environment.

Noise barriers with a green appearance are considered attractive at some locations. The road can be given a new visual quality through planting. Climbing plants or bushes growing up against a barrier will make the barrier less conspicuous. Planting along the base of a barrier in plant boxes can break up the monotony of the barrier and make a high barrier seem lower.

It is necessary to give vegetation good growth conditions, including access to sufficient water. At dry locations, irrigation systems might be needed. Vegetation must have plenty of soil to grow in and protection from salt water used in the winter maintenance of the road.

Examples:
Top: Absorbing steel noise barrier with a steel grid to support vegetation on the barrier at highway M14 in Denmark

Middle: Brown wooden noise barrier adapted to the green surroundings on highway M11 in Denmark

Bottom: Concrete barrier with vegetation on highway 680 in California, USA

Further information:
http://on-air.no/examples - Example 26

Source: Danish Road Directorate

Source: Danish Road Directorate

Source: Danish Road Directorate

A noise barrier with two front sides facing the road and the residents!

The noise barriers have two front sides – one facing the road and one facing the neighbours and the urban environment adjacent to the road.

The drivers will possibly pass the noise barrier at least twice every day and the people living at the other front side will have to look at the noise barrier every day as long as they live near the barrier.

In the design phase of noise barriers, it is important to prioritise both front sides of the noise barrier equally. The requirements for the barrier design might be different seen form the road and drivers' point of view as opposed to the residents' perspective. Therefore, a solution might be to design a barrier that has two different appearances seen from the road and by the residents.

Source: Danish Road Directorate

Source: Danish Road Directorate

Example:

The pictures show the solution selected at the M3 motorway around Copenhagen.

The front side facing the road is constructed of steel and some glass sections. At the front side facing the residents, wooden ribs have been placed vertically on the barrier to allow plants to grow on it.

Further information:

http://on-air.no/examples - Example 27

Source: Danish Road Directorate

Tall noise barrier integrated as element in urban sculpture

Just north of the Melbourne 'Noise Tube', a three-lane motorway ramp has been constructed. The ramp passes very close to one- to four-storey residential buildings. In order to provide noise screening for these buildings, a 10 m high yellow noise barrier has been erected.

Adjacent to the ramp, a rainwater basin has been constructed. Some large red steel posts with a length of more than 10 m have been mounted. Together, the yellow noise barrier, the water basin and the steel posts exhibit remarkable sculptural performance in the urban environment.

Further information:
http://on-air.no/examples - Example 28


Source: Danish Road Directorate


Source: Danish Road Directorate


Source: Danish Road Directorate

Transparent noise barriers

Transparent material can be used where a transparent barrier is needed, for example, when a barrier is situated close to a building, and thus significantly blocks the residents' view. These materials are best suited to urban surroundings and will often mean that the noise barrier is relatively anonymous in appearance. However, they can also be used in the countryside to allow road users to see a view or a landmark.

Glass or another transparent material can also be used to reduce the visual effect of a noise barrier in an open landscape. Transparent noise barriers need cleaning to prevent them from appearing soiled and dull. The acoustic function of noise barriers is described in Section 3.7.2 of the guidance book.

Examples:
Top: A transparent section of a steel noise barrier in the Netherlands

Middle: Transparent noise barriers with steel frames along a motorway and ramp in Rome, Italy

Bottom: A transparent noise barrier with steel posts on an embankment along a motorway in Denmark

Further information:
http://on-air.no/examples - Example 29


Source: Danish Road Directorate

Source: Danish Road Directorate


Source: Danish Road Directorate

Large steel noise barrier bending over the road

The motorway connection between Vienna Airport in Austria and the city centre passes by a residential area. A tall steel noise barrier has been constructed. The barrier bends over the road in order to increase the noise reduction by having the top of the barrier as close to the noise source as possible. Steel plates with small holes are used to make the barrier noise absorbing.

A green belt of vegetation is situated between the barrier and the residential buildings.

Further information:
http://on-air.no/examples - Example 30

Source: Danish Road Directorate

Source: Danish Road Directorate

Source: Danish Road Directorate

Source: Danish Road Directorate

Graffiti-free barriers with wooden slats

Dirt, weather and graffiti are the most common challenges related to noise barriers. In particular, graffiti on noise barriers can be a problem. Effective methods for removal are available, but it is resource-consuming to inspect noise barriers and remove graffiti.


Source: Danish Road Directorate


Source: Danish Road Directorate

Noise barriers are very conspicuous elements along a road, and the large visible surfaces attract graffiti painting. To avoid graffiti, as well as to improve the general aesthetic quality of a standard noise barrier, the Danish Road Directorate is now using wooden slats mounted on the roadside and neighbouring side of a standard barrier. After three years, no graffiti is evident on any of the noise screens with wooden slats. The primary structural elements, consisting of foundations, steel columns and bolt groups, have a lifespan of at least 50 years. The secondary structural elements, which can be removed and replaced, have a life span of at least 25 years, however, the wooden slats are only expected to last 15 years or more.

Further information:
http://on-air.no/examples - Example 31
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Source: Danish Road Directorate


Source: Danish Road Directorate


Source: Danish Road Directorate

'Green Noise' – Reduced indoor noise levels and better air quality

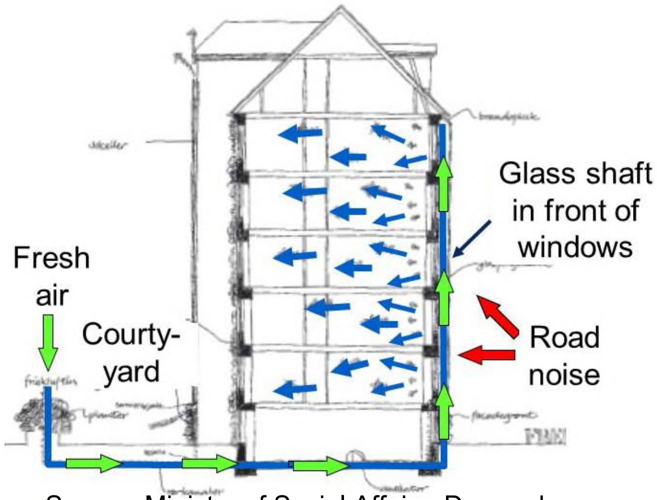
Fredensgade is a highly traffic-congested street in the central part of Copenhagen. Housing in Fredensgade went through an extensive renovation. In this context, the 'Green Noise' project was carried out, with the aim of finding a relatively simple, non-space-consuming, technical solution to reduce traffic noise indoors and provide a fresh clean air supply for the dwellings.

The main elements of the project are as follows:

- Façade noise screen in the form of a glass shaft and fresh air supply towards the street;
- Solar panels for an additional power supply for fans; and
- Heat recovery.

A solution was chosen to place a soundproof glass shaft in front of selected windows on the street façade; according to the project report, this would meet all of the criteria. The design is outlined in the figure to the left. Residents can get fresh air by opening the window, and the soundproof glass shaft in front of selected windows contributes to passive solar heating when the sun is shining. The air in the glass shaft comes from the courtyard where the air is cleaner than the air from the street.

One criterion was that the traffic noise indoors in the renovated house needed to meet requirements in the Building Regulations, at a maximum of 33 dB L_{den} indoors with the windows closed.



Source: Ministry of Social Affairs, Denmark

Reduced indoor noise

Pre- and post-measurements of the façade insulation were carried out in two apartments, one on the ground floor and one on the second floor, with closed and open windows, respectively.

On the ground floor, the indoor noise level was reduced by 11 dB with closed windows and by 17 dB with open windows (behind the glass shaft). On the second floor, the indoor noise level was improved by 7 dB with closed windows and 15 dB with open windows (behind the glass shaft).

Further information:
http://on-air.no/examples - Example 32

Source: Danish Road Directorate

Source: Danish Road Directorate

Non reflective noise barriers

The barrier may also reflect the noise. This may have the unfortunate consequence of increasing the noise for the people living on the opposite side of a road.

How much the noise level on the other side of the road will be increased depends on site conditions, the height of the barrier, and the nature of the building opposite it. If these consist of an unbroken line of multi-storied buildings, the erection of the barrier will form a “closed” canyon, in which the sound is repeatedly thrown back and forth. Sound reflection can theoretically increase the noise level by up to 6 dB when there are reflecting surfaces on both sides of a road. For low, open housing areas the noise level on the opposite side can theoretically be increased by up to 3 dB due to reflections form a barrier.

If noise screening is established on both sides of the road, the noise can be reflected back and forth between the barriers. The screened effect for the reflected noise is not effective as for the direct noise. The total noise-reducing effect will be considerably diminished. The further the reflecting surface is from the road, the slighter the contribution from reflection will be, in as much as noise reduction occurs as a result of the long distance that the sound has to travel.

There are different solutions to reflection problems. These solutions involve different visual impacts, which can make their mark on the surroundings of the road. The barrier can be erected at a slant so that the noise is reflected up into the air, where it will not disturb anyone.

Vegetation can be planted between the road and the barriers. Vegetation will disperse the noise both before and after reflection from the noise barrier. Vegetation should be as dense (all year), broad and high as possible.

Finally, there is a third solution, in which a noise barrier is provided with sound absorbent material on the side facing the road, so that reflection is reduced or entirely eliminated.

Further information:
http://on-air.no/examples - Example 33

Source: Danish Road Directorate

Source: Danish Road Directorate

Grants for façade insulation of dwellings

The Danish Road Directorate have a scheme for façade insulation of recidential buildings. The scheme includes grants for façade insulation along existing roads and new roads.

Façade insulation typically includes changing windows and doors to new and better noise reducing types (and often also heat insulation saving energy).

Grants can be given to noise insulation of bedrooms, living rooms and kitchens with a dining table. An indoor noise reduction of at least 5 dB must be obtained and the resulting indoor noise level must not exceed 33 dB (Lden).

The Road Directorate does not carry out work on private properties. Instead the Road Directorate contacts the owners of the impacted dwellings and offers grants for noise insulation. If the owners accept the offer the procedure is the following:

1. An acoustical consultant inspects the building and describes what kind of noise insulation has to be carried out.
2. The owner gets a price for the work from a private contractor.
3. The Road Directorate has to accept the the proposed solution for facadeinsulation and the price.
4. The owner orders the contractor to carry out the work.
5. An acoustical consultant inspects and approves the work carried out.
6. The owner pays the contractor.
7. The owner sends the invoice to the Road Directorate for reimbursement.

There are not given grants to unlimited large insulation expenses. The maximum grant that can be obtained is 16,800 € including VAT per dwelling (price level 2015). The grant depends on the actual noise level as can bee seen in the table below. It´s not possible to obtain grants with a facade noise level below 63 dB (Lden).

Noise level on façade (Lden)	Percentage grant of total costs
>73 dB	90 %
68-73 dB	75 %
63-68 dB	50 %

The Road Directorate has carried out a minor survey to evaluate the scheme for noise insulation for dwellings exposed to noise over 68 dB (Lden) at the facade.

It showed that 90 % of the respondents meant that the noise insulation have improved their housing situation from moderate to very much. Around 2/3 of the respondents were surprised of the positive effect of noise insulation. Nearly 2/3 were very or highly annoyed by traffic noise indoor before the noise insulation, while approx. 1/10 where very or highly annoyed after the noise insolation.

Further information:
http://on-air.no/examples - Example 34

Source: Danish Road Directorate

Source: Danish Road Directorate

An example where new windows are provided with sound proof glass. Compared with the original windows it gave a noise reduction of 13 dB in the living room

Enlarging ring road around Copenhagen from 4 to 6 lanes

A combination of measures of noise abatement can be necessary to fulfil noise limit values decided for a road project.
Due to the increase in traffic, it was decided to widen Motorway 3 (M3) from four to six lanes on a 17 km long section. The traffic volume was 90,000. M3 is an urban motorway passing through a heavily populated area. 14,000 dwellings are located in a belt of 500 meters on both sides of the motorway. Before the widening of M3, there were old 1.5-2 metre noise barriers. If the old low noise barriers along the M3 were kept until 2010, there would have been 6,300 dwellings exposed to more than 55 dB.
On the background of the EIA and an evaluation of cost effectiveness, it was decided in this specific project to use 60 dB ($L_{Aeq,24}$) as the noise guideline. 60 dB represents a significant reduction in noise for many of the dwellings. In order to achieve 60 dB, the following measures have been implemented:

1. 17,900 m of noise barriers
2. Noise reducing thin layer pavements

Where these measures have not been enough to achieve 60 dB, façade insulation has been offered to the owners. After the M3 was widened and new noise barriers constructed, only 2,200 dwellings were exposed to noise higher than 55 dB.

Source: Danish Road Directorate

Source: Danish Road Directorate

Reduced noise annoyance

A pre-, post - questionnaire study showed that among the people living around the M3 there has been a reduction in the perceived noise annoyance. The total percentage of very and extremely annoyed respondents decreased from 37% to 16%. The total percentage of slightly annoyed and not at all annoyed increased from 33% to 57%.

Further information:
http://on-air.no/examples - Example 35