Quiet City Transport

PROJECT SUMMARY BROCHURE

SIXTH FRAMEWORK PROGRAMME

Editorial

Community noise is one of today's most severe environmental pollutants, which makes noise induced annoyance an structural problem in our modern and complex society.

Our transportation systems constitute one of the major noise sources adversely influencing nearby residents. Only road and rail traffic noise will expose 20–30 % of European population to excessive noise levels [L_{den} ≥ 60 dB(A)]. In terms of people affected and considering its total adverse effects, these forms in our opinion one of the more severe environmental problems of today.

Access to efficient mobility remains a basic human need and is an essential prerequisite in order to maintain high employment and economic prosperity. Therefore it is essential to find technical solutions that ensure a high degree of protection against noise especially for residents in urban areas so that a high quality of the needed mobility can be maintained.

Preserving quiet areas and achieving high levels of health and quality of life are important objectives of the European Commission. In view of that the European Commission adopted an Environmental Noise Directive in 2002 to achieve comparable data and measures for all member states in order to assess and hopefully reduce noise within cities in the EU. In support to the directive the project "Quiet City Transport" (Qcity) provides tools to be used by the local authorities for evaluating noise maps and creating noise action plans. This is done by developing and disseminating a wide range of different solutions for specific hot-spot problems.

The Qcity research project started in February 2005 with 27 partners from all over Europe. The expertise of the partners covers both road and rail related technology. Public transport organisations and local authorities are also represented. With this broad range of stakeholders, the Qcity project aims to produce the most accountable result possible.

In this brochure, the project partners would like to convey to the public some of the solutions and tools for noise reduction in urban areas as a result from the Qcity research activities.

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Automated hot spot detection from noise maps

Within the Qcity project a Noise Environmental Rating System (NERS) for hot spot detection was developed. Based on building specific noise level (i.e. L_{den}) and the number of annoyed individuals per building, a specific noise score can be determined. Accordingly, weighting functions can be suggested. Hot spots are defined as small areas with a high number of unacceptable exposed persons, i.e. L_{den}. Such spots may be found by calculating for all (partially overlapping) square areas of, e.g., size 100 m × 100 m, which together cover the total area of the municipality. Subsequently, clusters of high noise score are the hot spots.

The following picture shows a comparison of a clip of a strategic noise map (L_{den}) and detected hot spots:

NERS allows not only defining the hot spots. It is also a very useful tool to quantify noise reduction measures with the noise score of the investigated area and is a basis for cost effectiveness studies different measures of an action plan.

Quiet road surface for trams and buses

The objective for this work was to design and validate quiet roads for buses combined with trams. Embedded tram tracks proved to be the quietest solution.

A discrete fastening system has been developed for the embedded tram tracks in order to significantly reduce the time required for renewal works vs. conventional embedded track systems, where renewal is only possible after breaking the road surface.

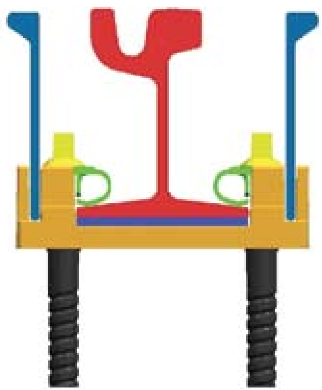


Figure 1: assembled view of the developed track system, to be poured in concrete (on site) or mounted in pre-cast concrete slabs

For absorption of noise between the rails, two solutions have been developed:

1. A noise absorbing concrete surface has been designed and tested, together with the newly developed fastening system, at Blankenberge test site.

2 A track system with an artificial grass surface between the rails has been designed. Next to the noise absorbing qualities, this system allows a faster installation, lower maintenance time and better resistance in comparison to an installation with natural grass.

Figure 2: tramway driving on the grass-track

The development offers a solution adapted to mixed tram/bus infrastructures. It has been tested in Ghent.

The results obtained are very promising, with both (concrete and grass) a global noise absorption of 3 dB(A). This is comparable to results with natural grass.

“Quiet tram tracks” The Athens tram experience

This work aims a detailed design of selected mitigation measure at Athens validation site under the topic: “Quiet tram tracks” in order to minimize wheel squeal emissions. In recent years, Athens tram has performed an extended noise and vibration study including both airborne and ground borne noise and vibration levels calculations resulting important problems raised during operation is the squeal noise parameter. This work introduces the development and implementation of a prototype “Quiet tram tracks” elastically encapsulated in a prefabricated concrete slab, at “Voula extension” of the Athens tramway line in Glyfada area of greater Athens. The relevant prototype research, realisation and evaluation included the following internal phases :

- Reference campaign of squeal noise measurements and 1/3 octave band analysis at an existed curved track in Athens Tramway network i.e. Diadochou Pavlou str. Tram section (measurement phase : “Before”)
- Model analysis of a prototype “Fastener less embedded resilient tram track for squeal noise reduction including the ROLL - SLIP excitation of the wheel and rail and a time domain analysis considering constant crabbing velocity yields wheel and rail vibrations”
- Laboratory analysis and development of an adequate new “elastomer encapsulation material” with specified vertical and horizontal stiffness
- Selection of a curve location with similar geometrical characteristics with the existed curve track measured as described above i.e. Voula curved section – Glyfada Athens and precisely at Alkyonidon Avenue crossing
- Construction of a specialized prefab slab including the new “elastomer encapsulation material” at the worksite prior to installation on site
- Installation in situ at the selected tram line section at Voula-Athens
- Campaign of squeal noise measurements and 1/3 octave band analysis at the new prefab curved track in Athens tramway network i.e. Voula (measurement phase : “After”)
- Evaluation of noise attenuation results towards a future development and use of such “prefab quite track” solutions at the forthcoming Piraeus extension of Athens tram

Both “Before” reference test site and “After” Voula site measurements campaigns were ensure the following common specifications :

- Noise descriptors compared : L_{eq} (per tram/speed passage) and Lmax for the noisiest bogie
- Typical speed ranges identical fo both campaigns i.e. 10,20 and 25 km/h

- Similar geometrical characteristics regarding curve diameter in both locations
- Same tramway vehicle with no add. maintenance interventions that could affect behavior and acoustic results
- No squealing noise attenuation interventions were executed in rails (as per biodegradable component RYLER-300 BIO usually used in Athens tram network), or other maintenance actions on vehicle wheels prior to both measurements campaigns
- Use of the Standard EN ISO 3095:2005 including comparison for the distance of 7,5 m at microphone height of 1,2 m in the interior of each curve (internal direction) ensuring free sound propagation with a ground essentially flat, radical diminution of the environmental background noise levels etc.

It is therefore quite clear that the proposed new solution in Athens tram network gained an important positive effect on squealing noise levels emitted in close curves. This positive evaluation of the achieved noise attenuation results (even though those results may be less effective – taking in to account the above note) is quite important especially towards a future development and use of such “prefab quite track” solutions within the imminent “Piraeus extension” project of Athens tram network.

Squeal noise reduction of tramways in tight curves

The objective was to develop and validate a general purpose solution for squeal noise reduction for tramways in tight curves. This problem is very common and it leads to many justified complaints from residents: the high frequency squeal noise is disturbing people living close to the squealing curve and it is difficult to mitigate this noise in the transmission path and at the receiver. Therefore, a noise reduction at the source is targeted by lubrication of at the wheel/rail interface (on top of the rail). A specific problem is that most rails are embedded in the street (girder rails) and hence there is limited access for lubrication installations. Furthermore the lubrication should not create safety issues (limited braking and traction). Ease of installation and maintenance of the solution and cost price are important elements in the comparison of solutions. Basically two types of solution have been evaluated: a fixed lubrication installation at STIB (Brussels) and an on board lubrication at De Lijn (Antwerp). Both lubrication methods (on board and wayside) are very effective at eliminating the squeal noise.

The on-board lubrication is relatively low cost (less than 3000 € per vehicle investment cost, limited maintenance in the depot and limited use of lubrication fluid). It has to be installed only in maximum one out of eight vehicles running on the specific tramline. It is flexible: only the curves with a diameter below an adjustable value are lubricated. The vehicles to be equipped with the on board lubrication system need a compressor unit (available on most recent tram vehicles).

The wayside system is more expensive (at least 5000 € per installation). Its maintenance can be more problematic since hydraulic cables are embedded into the street pavement. Each curve which exhibits disturbing squeal noise has to be treated. Refilling of lubrication fluid and maintenance has to be done on site. Electric power has to be available on site.

For all the above reasons, Qcity strongly recommends the use of an on board lubrication system for solving the squeal noise problem.

Antwerp quiet road surface

The target was to demonstrate a quiet road surface with elastic properties based on a non-porous rubber-asphalt mix.

Porous road surface layers, which have potentially good acoustic absorption characteristics, are not suitable for city use because the pores in the asphalt cover get clogged up by dirt after a while. An alternative concept based on the addition of rubber crumb to a non-porous asphalt mix with a very small and uniform stone loading, for application as a road surface was developed. It successfully passed the lab scale wheel rutting tests and showed promising impedance test results.

A test stretch was realised on the Heijmans asphalt plant in Puurs. The structure and stability of this stretch proved satisfactory. Final acoustic measurements took place at this test site and indicated a noise level reduction of almost 5 dB(A) compared with measured noise levels at a reference asphalt stretch.

Low frequency noise reduction of steel railway bridges

The objective was to develop a general purpose track based solution for low frequency noise reduction of steel railway bridges. This problem is very common: the low frequency bridge noise is radiated over long distances. Therefore, a noise reduction at the source is targeted by a specific vibration isolation of the track system which reduces the relevant dynamic input forces into the bridge. Ease of installation of the solution and possibility of refurbishment of existing bridges with the solution are important elements in the development of the solution since a wide use of the developed solution is targeted.

This developed solution type is validated by evaluating the structural noise reduction by track modification of an existing new steel bridge to be used by the Belgian railways in the port of Ostend (Plassendale bridge). This type of bridge with wooden sleepers directly connected to and supported by structural steel beams has been chosen because it is representative for thousands of steel bridges use by European Railway operators and infra managers.

The noise and vibration measurements during train passage on the steel bridge have shown a very good performance of the modified (isolated) track structure: the low frequency noise and vibrations are reduced by in average 10 dB from 63 Hz to 200 Hz. This performance is very interesting and it opens wide application possibilities since mitigation measures at the receiver or in the propagation path are not effective at these low frequencies. The developed solution is relatively easy to install. Its performance is far better than the use of rail dampers or the use of damping layers on the steel structure.

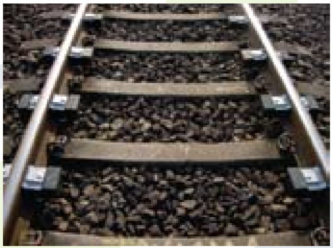
Malmö quiet track

The performance of three different mitigation actions to reduce railway noise have been measured: (1) three types of rail damper (one developed by CDM), (2) a low barrier designed by Zbloc, and (3) a VA71b rail produced by voestalpine, see Figure.

Rail dampers from CDM, Corus and Schrey & Veit were mounted on adjacent track sections. Track decay rate, rail acceleration and sound pressure 7.5 m from track centre were measured. For freight trains at 100 km/h, the Corus dampers resulted in a 3 dB unit noise reduction whereas the track with CDM dampers (after application of a correction spectrum to compensate for differences in roughness level) generated similar noise levels as a reference section without dampers.

The low barrier positioned 1.70 m from track centre (height 0.73 m above top of rail) was found to be most efficient in reducing TEL levels for urban trains with rail car sidewalls somewhat enclosing the rail car underneath. The reduction in total noise level was some 8 – 9 dB(A) units. The section of the barrier that is facing the track is covered with an absorber made of rubber and plastic.

When used together with a caoutchouc rail pad, the VA71b rail profile (weight 71 kg/m) resulted in a 1.5 dB(A) noise reduction compared to an adjacent track with 60E1 rails for all train categories and pass-by speeds.



Rail dampers developed by CDM (left), low barrier designed by Zbloc (centre), and rail produced by voestalpine (right) compared with a 60E1 rail

Amsterdam – effectiveness road traffic noise reduction measures

Strategic noise maps can be used as input in the process of formulating and evaluating noise abatement action plans. The calculated noise levels can serve as input for an environmental noise rating system, giving the rating of several noise impact indicators (e.g. the percentage highly annoyed people).

These noise impact indicators can be used to compare the noise quality in different cities or city districts; and to compare the effects of different noise abatement scenarios. This may help authorities to decide on the most effective measures and to prioritize the locations where they should be applied.

The rating system can be applied to any city in general. In this report we have evaluated road traffic noise measures for the city of Amsterdam. The evaluation is used by the municipality of Amsterdam to formulate action plans.

In the case of Amsterdam it turns out that a sizable noise reduction is obtained using the combined measures: reduction of 3 dB(A) on roads with cobbles / silent asphalt on main roads. See also the noise level reduction map in Figure 1; and the map on the noise indicator "dwellings with a noise exposure L_{den} > 63 dB" in Figure 2.

Figure 1: *Road traffic noise reduction (L_{den}) in Amsterdam as a result of the noise abatement scenario described in the text.*

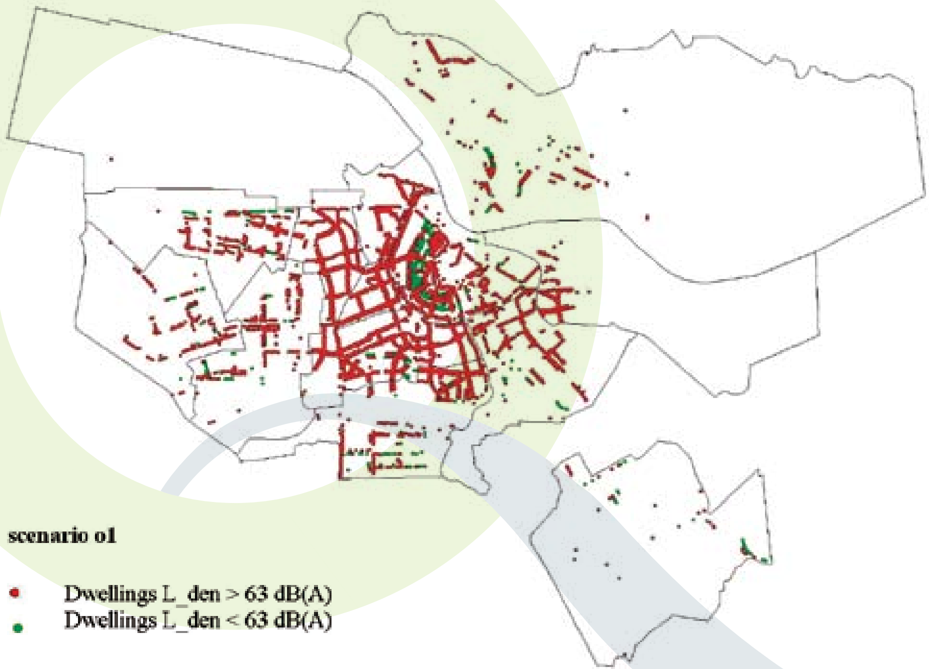


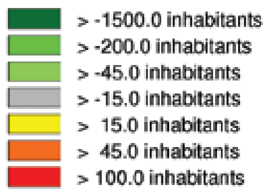
Figure 2: *Dwellings in Amsterdam with still L_{den} > 63 dB(A) and dwellings that obtained L_{den} < 63 dB(A) for the most exposed façade, after application of the noise abatement scenario mentioned in the text.*

The implementation of truck restrictions in Stuttgart

Using Stuttgart as an example the noise reduction potential of a city-wide ban on truck thoroughfare traffic was determined. It is therefore important to take account of local restrictions and the induced effects of traffic relocation. The detailed design and implementation of the selected mitigation measures for hot spots are studied and the theoretical cognitions of former project stages are implemented. The detailed statistics of the traffic and noise effects within Stuttgart as well as its surrounding communities have to be considered and predicted so that an overall performance score can be measured.

The Stuttgart area has been chosen for the study of the implementation of town planning measures, in particular truck restrictions, for a number of reasons. One of them is the availability of reasonably reliable input data. However, the main reason was that truck restriction measures had already been implemented within the framework of the town's action planning against air pollution. Direct comparison between different scenarios cannot only be evaluated through the use of calculation models, but also by comparing the actual effects of its implementation. Additionally, decisions relating to further truck restrictions have already been determined so that these can readily be analysed and approved.

As a result of the study it is possible to conclude that the implementation of truck restrictions provides the greatest benefits when being designed and implemented regionally. Nevertheless, effective measures do not always imply positive effects at all locations. Applying truck-restrictions regionally does not necessarily result in the best solution for local hot spots. For 'single-building – hot spots' endemic measures such as changing the land use, the orientation of sensitive rooms within the quiet facades or the effects of building construction and noise insulation have to be defined. Nevertheless truck restrictions could be mitigation measures with great potential as the detailed studies have shown.



Effects on the number of people exposed to levels L_{den} (exceeding 65 dB(A)) by implementation of truck restrictions in Stuttgart

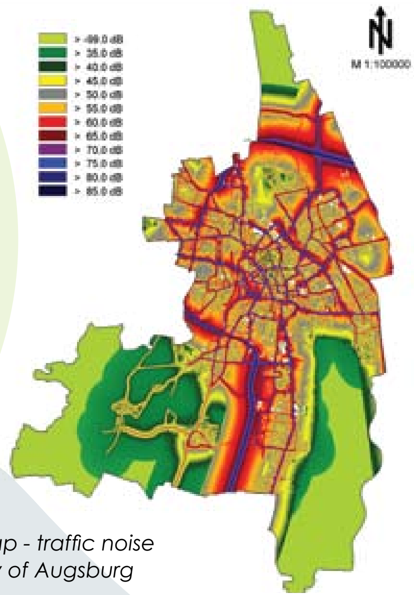
Town planning in Augsburg

Using Augsburg as an example the noise reduction potential of different town planning measures has been determined both for short-term, mid-term and long-term strategies.

Therefore different town planning measures have been compared with respect to their noise effects and costs. The town planning measures which have been analysed can be subdivided in three parts:

- Measures concerning the short-term strategy for actual situations e.g. passive sound insulation (insulated glazing and ventilation provisions);
- Measures concerning the medium-term strategy for actual situations and new development such as the orientation of building layouts with noise sensitive rooms on quiet sides; and
- Measures concerning the long-term strategy of urban areas within the scope of urban redevelopment.

As a result one can say that short-term strategies are sensible and effective when there is an acute need for action. The implementation of mid-term and long-term measures can be very effective and can at the same time ensure a high quality of life by implementing green areas for example. In general all measures do have advantages and disadvantages alike and often the costs of measures are their biggest disadvantage. Therefore it is not that easy to choose between one or another specific measure. Instead the best choice often will be a combination of different measures. Reasonable cost-benefit ratio with limited costs for cities as well as the owners of property can be realised if a combination of measures is attributed to both parties. In the long run a sustainable, positive development can be ensured through the implementation of mixed utilisation areas.



Noise map - traffic noise
L_{den} / City of Augsburg

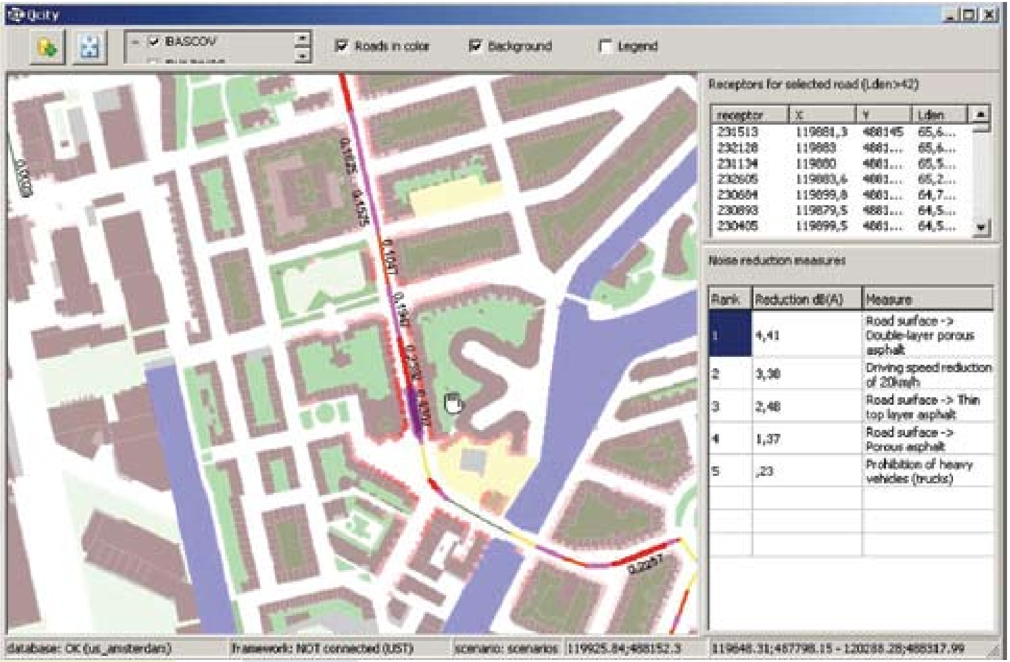
Decision support system

The European Noise Directive (END) requires assessment of noise exposures as well as the formulation of action plans for the reduction of the number of people harmfully affected by environmental noise. In view of this, TNO has developed a decision support system for evaluating noise mitigating measures. Such a system helps users to locate the noise sources that have most impact and to choose noise abatement measures that are most effective. This interactive system enables users to evaluate the effect of noise abatement measures real time.

In contrast of focusing on places in a city where relatively many people are harmfully affected by high noise levels ('hot spots') the decision support system focuses on noise sources that are responsible for a large number of people being harmfully affected by noise. Doing so, the decision support system points towards those noise sources where lowering noise emissions have most effect on the specific noise impact indicator used. The noise impact indicator we use presently is the number of highly annoyed people (*HA*).

On the basis of a detailed noise map, for each road segment (noise source) an indication is given for the number of *HA* per metre, the so called noise *impact* map. On the basis of the characteristics of the road segments (such as traffic intensity, traffic speed, distance of road to buildings, etc.) the system suggests possible effective noise mitigation measures. This is illustrated in the figure on the next page. This figure displays a screenshot of the system showing a part of the noise impact map for the city of Amsterdam. Pointing at a road segment that causes a relatively large number of highly annoyed people (purple coloured) results in the appearance of a short list with possible noise abatement measures and the estimated noise level reductions.

The effect of the measure chosen by the user can be interactively explored with the system. It directly shows the updated detailed noise contour maps as well as the updated noise *impact* map through the interactive interface. In the near future also other noise sources than road traffic could be implemented. Also, other impact indicators than *HA* could be used. An important step would be to extend the decision support system such that it can also consider overall noise measures such as the application of silent tires or the introduction of car free city zones.



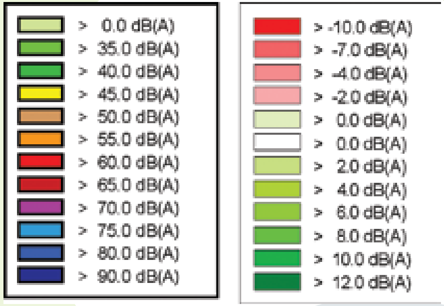
Screenshot of a zoomed in noise impact map of Amsterdam. The numbers along the road segments are the number of *HA* per meter. The purple coloured road segment causes a relatively large number of *HA* per meter. Selecting it generates automatically a list with possible effective noise abatement measures.

Stockholm quiet road system

Traffic control can be used to separate low noise vehicles such as the Toyota Prius electric hybrid car from standard vehicles to provide quite zones in limited town areas.

In the Stockholm case study, we have studied the effects of banning all standard cars as well as imposing noise fees. The effects of these policies are shown in the noise maps below.

Legends for absolute noise levels (dB(A)), and differences in noise levels (dB(A))



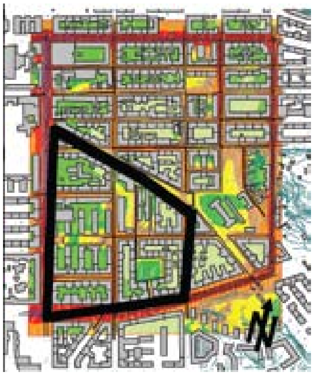


Figure 1
Current noise situation

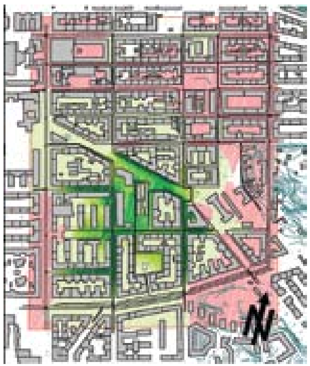


Figure 2
Difference with standard vehicle ban Figure

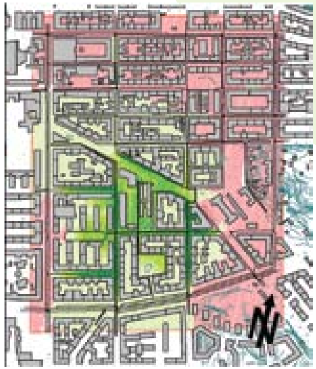


Figure 3
Difference with 1 Euro noise fee

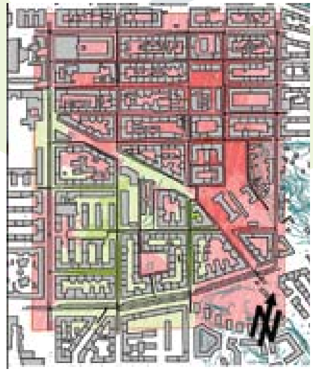


Figure 4
Difference with half Euro noise fee

A total ban of standard cars will provide a substantial noise reduction within the area. The main effect is a redistribution of moderately disturbed residents in the 50-55 dB(A) segment to noise levels in the 35-45 dB(A) segments. Residents subject to more severe noise disturbance are likely to be living on the boundary streets and will not benefit from traffic reductions within the zone.

The 1 Euro noise fee scenario will give similar but smaller effects. The half Euro noise fee scenario gives different effects in that it brings about larger noise increases in the surrounding than the other scenarios.

The final conclusion for this case study would then be that even in the case of an already traffic zoned situation, substantial noise reductions can be brought about by banning standard cars or by imposing noise fees. It is however important to impose fees high enough to bring about mode and destination shifts and not only changes in route choice or parking behaviour. It is time to consider bans and charging systems not only for air pollution but also for noise emissions.

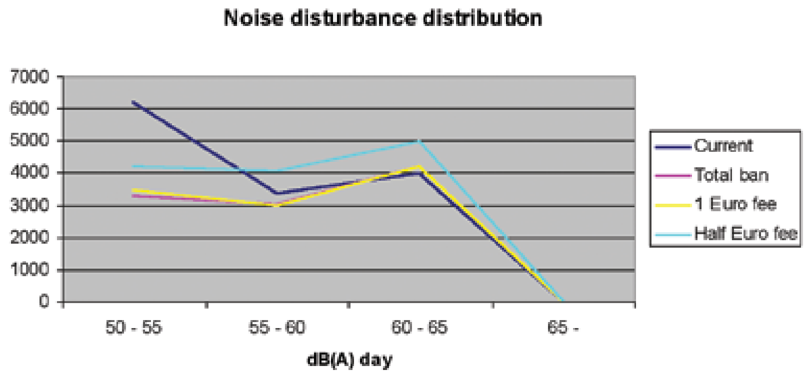


Figure 5 *Noise disturbance distributions*

Development of a perception tool for traffic noise

There were two main focuses within this work. First the development of a software tool, called Traffic Noise Synthesizer (TNS), to auralise the sound resulting of a simulated traffic scenario and second the development of a psychoacoustic metric to evaluate the human perception of the auralised sound.

The result of prior research projects (e.g. HARMONOISE and ROTRANOMO) were calculation tools that allow for the prediction of the noise generated by a given traffic scenario and measured at a specific observer position. The outputs are spectra. These spectra are sufficient to calculate the standard descriptors used in the noise map but are not sufficient for the evaluation of the human perception. For this purpose time signals are needed. The Traffic Noise Synthesiser combines traffic simulations, the third octave spectra calculated by the ROTRANOMO code and prerecorded vehicle sounds to generate the noise of that specific traffic simulation. The result is an auralised time signal. Variations in the traffic flow (e.g. traffic lights or roundabout) or source characteristics (low noise pavement) can be directly perceived by the listener. The developed psychoacoustic metric allows for the evaluation of the perceived annoyance reducing the need for listening tests.

An analytical model for calculating the vibration response and sound radiation from an in-service tyre/road system

The modelling approach for the prediction of tyre vibration and radiated noise has been firstly applied to a generic standard tyre and then used to investigate various low noise concepts. A polyurethane-filled tyre has been considered and found to be beneficial for noise but to be impractical due to its additional weight. A decrease in tyre width is particularly beneficial to reduce radiated sound because it leads to reductions in both the mechanical vibration and in the horn effect. The twin-tyre concept provides a practical way of implementing that while keeping the same load on the tyre. Such a change is predicted to lead of about 6.5-8.5 dB(A) reduction (3.5 dB(A) from the reduction in the mechanical vibration and 3-5 dB(A) in total from the horn effect, with 1-2 dB(A) of this being from changes in the shoulder curvature).

Acoustical modeling of mitigation measures

Introduction

The contribution of AKRON to the Qcity project consisted mainly in:

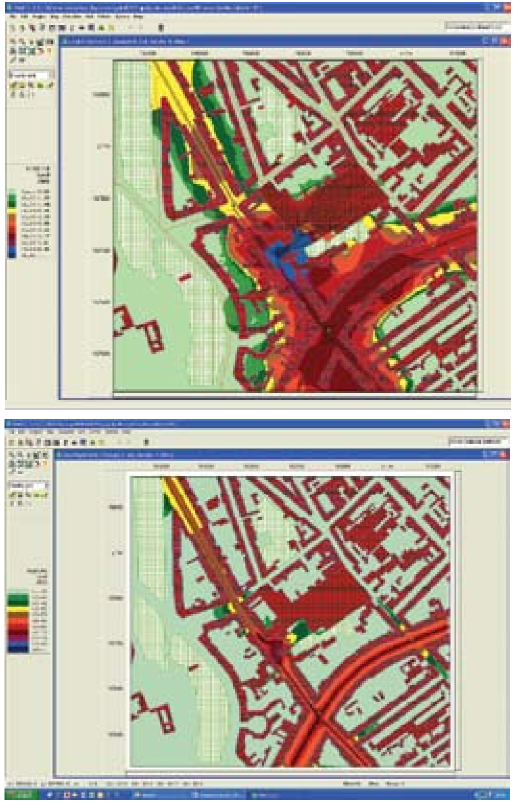
- the consolidation of mitigation measures available for noise action planning;
- the acoustical modelling of the mitigation measures into the global noise maps;
- the evaluation of noise mitigation measures and noise action plans using supplementary indicators for annoyance and sleep disturbance.

Consolidation

The consolidation report includes more than 100 mitigation measures for urban noise. The mitigation measures are first summarised in tables and then further detailed in adjoined data sheets.

The areas of mitigation measures include:

- traffic planning;
- reduction of emission from road transport;
- reduction of emission from rail transport;
- mitigation through propagation path modification: facade isolation, barriers and physical planning;
- economic incentives.



Noise map of L_{night}, versus noise maps %HSD

ref. GM-RAIL-	location	action	noise reduction [dB(A)]	cost [€]	site specific limitation
GM-RAIL-9	vehicle	wheel truing	7 to 10	60,00 per wheelset	Single most important treatment, because wheel flats are most significant cause of impact noise
GM-RAIL-11		slip-side control	7 to 10	5 000,00 to 10 000,00 per vehicle	Reduces flat occurrence by about 50 %, and thus reduces wheel truing costs proportionally
GM-RAIL-10	trackwork	rail grinding	7 to 10	4 000,00 per km track	Must be done in conjunction with wheel truing
GM-RAIL-12		defect welding and grinding	0 to 3	200,00 per defect	Noise reductions depend on number of defects. Costs are subject or local labour rates and field conditions
GM-RAIL-13		joint maintenance	2 to 3	200,00 to 400,00 per joint	Primarily relevant to older transit systems with steel elevated structures
GM-RAIL-14		field welding of joints	5	600,00 per joint	Ancillary cost benefits in reduced maintenance
GM-RAIL-15		eliminate rail support looseness	5	250,00 per m	Achieved with resilient direct fixation fasteners or concrete ties with spring clips Primarily relevant to steel elevated aerial structures
	wayside	treatments for normal and excessive rolling noise			

Table *Treatments for impact noise due to rail defects*

Acoustical modeling of mitigation measures

An extensive list of mitigation measures has been established in Qcity project for different kind of sources (road, rail) as well as propagation paths and receivers.

One of the project's objectives is the evaluation of the possibility to integrate mitigation measures into noise maps. Some mitigation measures can be integrated directly into noise maps because the considered items (such as road surface, vehicle speed, ...) are specific input variables in the noise calculation methods.

Other parameters (such as rail quality, rail lubrication, traffic flow fluidity, specially shaped barriers, ...) are not specific input variables and need an indirect input. The possibility to integrate those parameters in actual (and future) calculation aspects is studied hereafter.

Further, the aspect of loosing the effect of smaller and local mitigation measures into a global noise map was studied.

Out of the study, it can be concluded that the actual calculation methods are mostly not designed to take this kind of mitigation measures into account. Some of the mitigation measures, although not foreseen or defined in the actual computation method could be included. But, in general, future calculation methods, being described as 1/3 octave spectral transfer function calculation, yield all the flexibility to add 1/3 spectral correction functions, apt to include all types of mitigation measures.

Use of supplementary indicators for annoyance and sleep disturbance

In order to get an overview of adverse effects of environmental noise, Miedema & Borst (2006) developed a noise rating system. The first two indicators in this noise rating system, %HA and %HS are indicators for the health impact of noise:

- %HA, the expected percentage of people being highly annoyed due to noise as supplement to Lden;
- %HS, the expected percentage of people being highly sleep disturbed due to noise as supplement to L_{night} .

Based on calculation tables and noise/annoyance maps, the different indicators are compared.

From sound level map to noise problem map

The most important objective when prioritising noise measures is to prioritise for those areas that are in most need for noise relief. The availability of a tool that can pinpoint where noise problems (so called hot spots) most likely will occur, would be of great help in making this order of priority.

Using the calculated noise levels, i.e. in the sound level map, as input for decisions for noise reduction measures can be enough in many cases. However, we also need to account for the influence from number of inhabitants for each building, mean facade sound insulation as well as calculated facade levels. These factors drastically enhance the understanding of the noise situation experienced by residents.

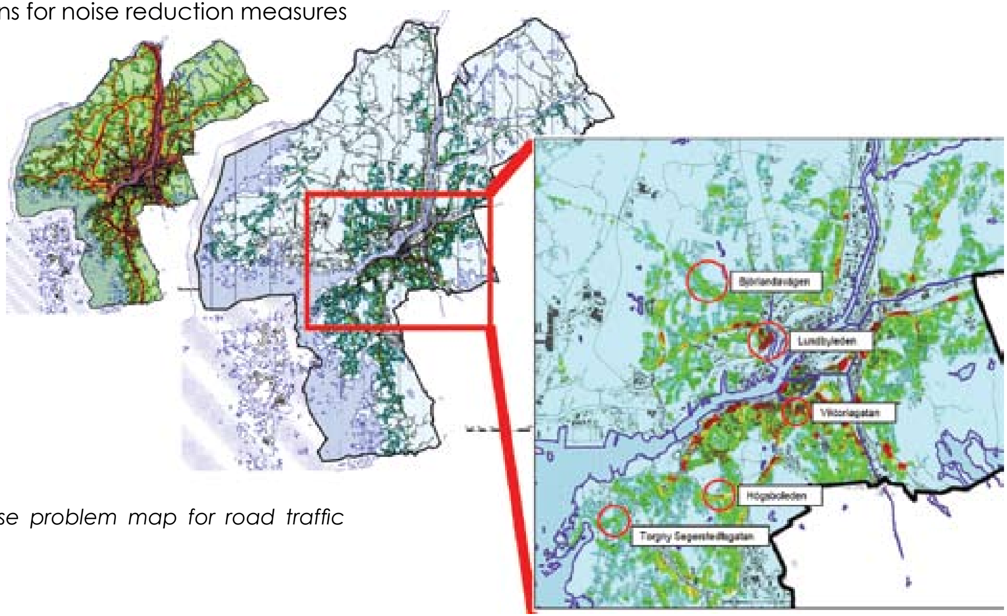


Figure 1

Sound level map and noise problem map for road traffic noise in Gothenburg.

Areas with high noise score, hot spots, are easily pinpointed in the noise problem map and five of them are marked in figure 1.

One way to provide a tool like that, is to use the Noise Environmental Rating System analysis (NERS-analysis). The NERS-analysis is one of the methods developed within the Qcity project for this purpose where a noise score is derived, specific for each building.

The noise problem map is generated by colouring the buildings according to the calculated noise score of each building. Areas where the buildings have high noise score are easily pinpointed in this noise problem map.

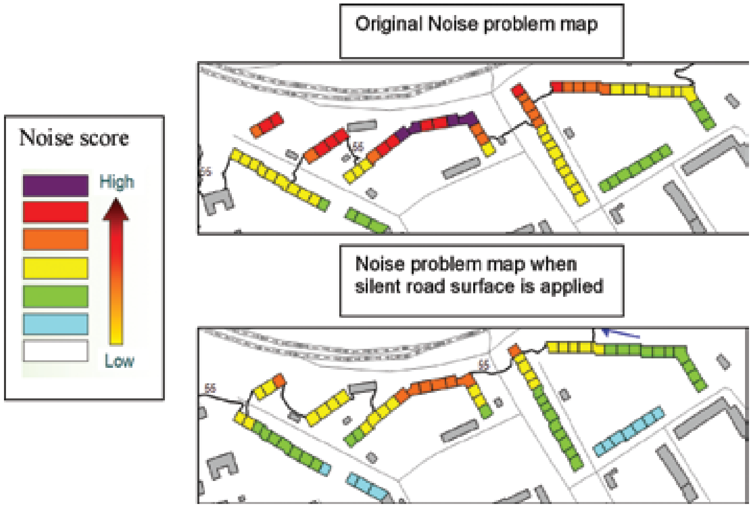


Figure 2 *Noise problem map of different scenarios.*

The NERS-analysis and noise problem map for the original traffic situation and the situation where silent road surface is applied are shown above. When the silent road surface is applied, the area is no longer a hot spot since the noise score is significantly reduced by this measure.

A quiet poroelastic road pavement tested in Gothenburg

The objective of this study was to evaluate a new poroelastic road pavement with added rubber granulate. In order to be able to mix the rubber with the asphalt surface the crumb rubber was pretreated weeks before the plant mixing.

Measurements have been performed in order to study the tyre/road noise reduction for the poroelastic pavement using the single wheel trailer for CPX-measurements. The measurement results revealed that the tyre/road noise for the 40 mm thick poroelastic pavement was reduced by 5.1 dB(A) units compared to a standard ABS 16 pavement in good condition.

For the tests the single wheel trailer developed by Acoustic Control within the Qcity project has been used (see picture). This trailer offers a very low background noise due to the big distance between the support wheels and the single measurement wheel.

As reference tyre a Goodyear Hydragrip 215 mm wide has been used both for the reference surface and for the poroelastic road surface under test.

A low platform screen design for trams evaluated in Gothenburg

Measurements have been performed in order to evaluate the noise reduction for the low Z-bloc platform screens, mounted close to the tram tracks in Gothenburg. Microphone positions were chosen similar to the ISO 3095:2005 Standard for external pass-by noise.

For the new M32 tram the screen insertion loss was measured to IL = 7 dB(A) units. For the older tram types the insertion loss was in average IL = 6.4 dB(A) units.

The M32 tram body has a smaller gap between the lower edge of the car body and the ground. Therefore the screens become more effective for this tram type. The difference is nevertheless rather moderate.

It has been shown that the platform screens are an effective solution to produce a substantial reduction of noise from tram traffic.

The 7 dB(A) achieved in noise reduction is comparable to what can be gained from much higher screens at a distance from the track.

Traffic noise reduction by smooth road surface combined with selected quiet tyres

The objective of this study was to investigate the emitted noise from a limited population of passenger car tyres when driving on a smooth road surface. Sound measurements were performed with a single wheel trailer, which enables a separation of the tyre/road noise from other vehicle related noise sources. The measurement results were used to investigate the noise reduction potential achieved by low noise tyres combined with smooth road surfaces. In close cooperation with Goodyear, Luxembourg, five tyres were selected for testing.

From the measurement results, it could be concluded that among the tested tyres, the Goodyear Eagle Vector is the quietest tyre at both urban and country road driving conditions (30–90 km/h). The Goodyear Eagle Vector tread band has relatively soft rubber (60 Shore A) which may be one reason (together with the tread pattern design) why it is the quietest tyre. The difference in emitted noise between the noisiest and the quietest tyre is about 4.0 dB-units in the speed range of 40–70 km/h. By banning the 75 % noisiest tyres a certain gain in noise reduction could be achieved. This noise reduction potential (the arithmetic average of all tested tyres minus the sound level for the quietest tyre) is about 2.0 dB(A) units. By e.g. implementing a requirement for environmental vehicles allowing to use only the 25 % quietest tyres out of the total population thus a 2 dB(A) reduction could be achieved. Since this reduction is achieved only if smooth surfaces are used a further 2.5 dB(A) in noise reduction will be achieved by introducing a smooth instead of a coarse surface (by e.g. a reduction from 16 mm to 8 mm max stone size). Smooth surfaces in combination with selected quiet tyres could thus give about 4.5 dB(A) in total noise reduction.:

Upper: Test site pavement.

Lower: Selected test tyres from left to right: Goodyear Eagle F1 Asymmetric, Goodyear Eagle Vector, Goodyear Excellence, Michelin Primacy HP, Pirelli P7

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