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Creating Quiet City Zones by noise charges and quiet vehicles. Part two: Noise reduction effects

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ABSTRACT

One important subject in the EU directive 2002/49/EC regarding noise maps and action plans is to establish or preserve quiet areas. A study within the EU FP6 project "Quiet City transport" (QCITY) have analysed the possibility of creating Quiet City Zones. The concept is to utilize noise charges and quiet vehicles for reducing traffic flow and vehicle noise source emission in the zone by use of barriers and charges for noisy vehicles.

Such measures will affect traffic in many ways. Some people will switch to other transport modes to escape the barrier or the fee. Others will choose another destination, while people normally travelling through the quiet zone may change route. Because low noise vehicles were exempted from the fee, some people will also change to a low noise vehicle. Traffic models were used to resemble the effects on traffic flow, using a prediction system modelling the travel demand and transport system of the entire Stockholm County. Traffic flow data from each simulation were used as input for creating noise maps. Results reveal that when only quiet vehicles were permitted, the noise reduction within the zone is 12-16 dB(A) units. With a 2-Euro charge, the reduction is approximately 7-9 dB(A) units. The noise reduction is partly caused by reduced traffic flow inside the zone and partly due to the lower noise emission from the vehicles operating in the zone. Due to the traffic restrictions in the quiet zone the traffic flow on boundary rerouting streets just outside the noise restricted zone will increase by 1-3 dB(A) units. The noise leakage effect into the quiet zone is though small. We believe that co-modelling traffic flow and noise effects for creating quiet zones is an interesting new concept. Therefore the information will be presented in two consecutive papers. The first paper (KTH) will report the modelling of traffic flow effects and the second consecutive paper (Acoustic Control AB), will report on the noise reduction effects.

1 INTRODUCTION

There is an urgent need for reduction of traffic noise within European cities. In many countries 20-30 % of the population are exposed to outdoor traffic noise level higher than LAeq24h > 55 dB(A). The constant increase in the traffic flow tends unfortunately to mask the reduction in vehicle source emission that has been achieved during the last decades.

One important subject in the EU directive 2002/49/EC regarding noise maps and action plans is therefore to establish or preserve quiet areas. A study within the EU FP6 project "Quiet City transport" (QCITY) have analysed the possibility of creating such low noise

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areas by the concept of “Quiet City Zones”. The concept is to utilize noise charges and quiet vehicles for reducing traffic flow and vehicle noise source emission in the zone

The effect that will result from a Quiet Zone is to a large extent determined by the change in traffic flow that will arise from the introduced restrictions. An interesting detail in this study is therefore that the effect of the Quiet Zones has been studied by first performing a careful modelling of the traffic flow effects as a foundation for the calculation of the noise reduction effects. Therefore the information from the study will be presented in two consecutive papers. The first paper (KTH) will report the modelling of traffic flow effects and the second consecutive paper (Acoustic Control AB), will report on the noise reduction effects.

2 THE CONCEPT OF LOW NOISE CITY ZONES

A quiet city zone is here defined as a confined part of an urban area in which quiet vehicles will enter free of charge. Noisy vehicles could enter the area either at a special “noise charge” or would not be allowed to enter the area at all.

Noise reduction in a Quiet Zone is thus achieved in two ways.

1. **Reduced vehicle noise source emission:** for the case where only the quiet vehicles are allowed to enter, it is obvious that the noise source emission will be set by the quiet vehicles (except in the boundaries of the Zone). For a situation where a limited number of noisy vehicles are allowed to enter the zone the emission level will be somewhere in between the normally noisy and the quiet vehicles. (See more details under chapter 3.1.)
2. **Traffic flow reduction:** Because the traffic flow will be decreased, the noise source emission will be reduced in the quiet zone. The reduction will be about 3 dB(A) units for halving the traffic flow.

The concept is thus primarily to reduce the vehicle noise source emission by ensuring that as great share as possible of quiet vehicles will make up the traffic flow in the quiet zone. As a by-product goes on top of that also a certain noise reduction due to the fact that the total vehicle flow probably will decrease in the Quiet Zone.

3 SOME GENERAL PHYSICAL FACTS RELATED TO QUIET ZONES

3.1 Quiet zones can give reduction in a short-term perspective.

There are few available noise reduction methods “at the source” that can be utilized in a short-term perspective. The ongoing noise reduction efforts by the vehicle industry may produce 1-2 dB(A) units of noise reduction per 5 years provided that the achievements are followed up by tightened governmental noise limits. However, the result of these achievements can only be expected to be utilized in a long-term perspective as Fig. 1 below shows. The reason for this is that the noise emission would be made up by all vehicles, old and new, in the traffic flow. Fig. 1 below display how the noise level of the vehicle flow would decrease assuming certain tightening of the noise limits every 5 year and a total vehicle life of 12 years. As is also shown in the diagram, we can by 2015 expect a reduction of the vehicle noise by only 1- 2 dB(A) units provided that the noise limits are tighten up by 1 -3 dB(A) units every 5 year. It can be concluded that this method for noise reduction is very slow and thus hardly an option if we want a quick noise relief.

The Quiet Zone concept is on the other hand a method that would ensure a reduction of noise immediately after its implementation.

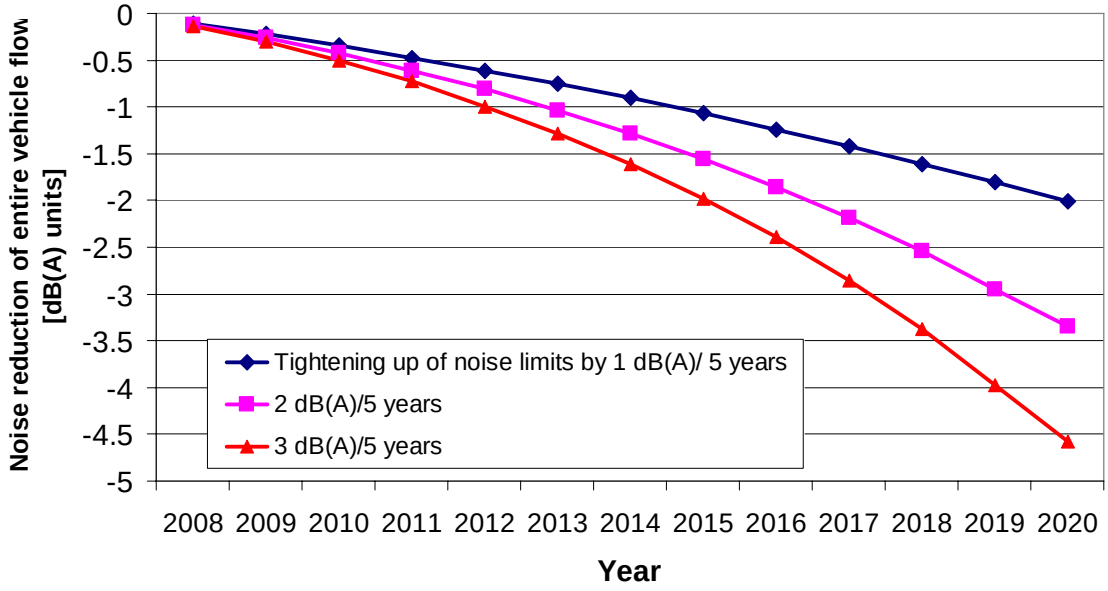


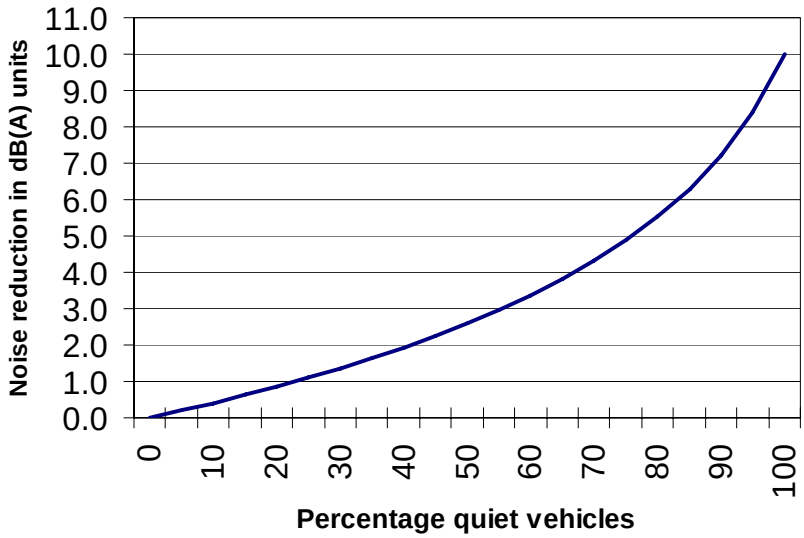
Fig. 1. Noise reduction of the entire vehicle flow assuming 12 year of vehicle life. It is assumed that a noise reduction of 0.5 dB(A) per 5 year was achieved before 2007. Different values are assumed after 2007 as shown in diagram.

3.2 Noise reduction due to quiet vehicles in a noisy vehicle flow.

The physics of adding the noise from normally noisy and quiet vehicles in a traffic stream is unfortunately rather unfavourable regarding the noise reduction effect for a small share of quiet vehicles. If the quiet vehicles constitutes, say 10-30 % of the total traffic flow, then the noise reduction due to the quiet vehicles are limited to 0.4 – 1.4 dB(A) units as can be seen from Fig. 2 below.

Even when the quiet vehicles constitutes as much as 90% of the vehicle flow (i.e. only 10 % noisy normal vehicles) we do not get more than 7.2 dB(A) units of reduced emission out of the 10 dB(A) possible achievable.

The important message is: The full benefit from the quieter vehicles is not achieved until **all noisy vehicles are eliminated from the traffic flow**.



Share of quiet vehicles %	Noise reduction dB(A) units
10%	0.4 dB(A)
30%	1.4 dB(A)
50%	2.6 dB(A)
90%	7.2 dB(A)
100%	10 dB(A)

Fig. 2. Noise reduction due to a share of quiet vehicles in a noisy vehicle flow

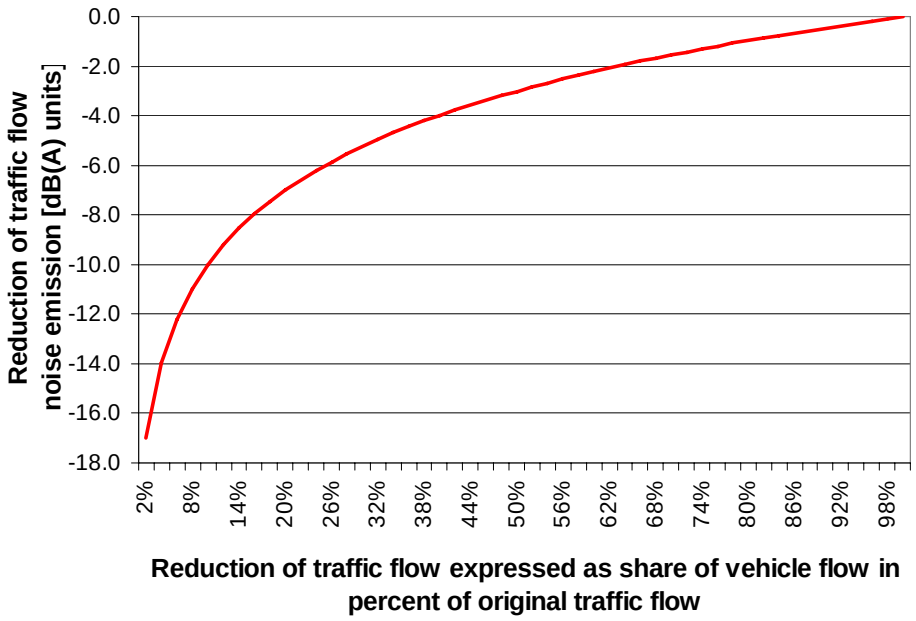
3.3 Noise reduction due to a reduced traffic flow

Calculation of the noise reduction from a reduced vehicle flow is very simple. Halving the vehicle flow rate would means that there would be half as many noise sources contributing to the total equivalent sound level. The reduction is thus

$$\Delta L_{Aeq} = -10 \cdot \log\left[\frac{0.5 \cdot F}{F}\right] = 3dB$$

where F is the vehicle flow e.g. in vehicles per 24 hours

The reduction for an arbitrarily reduced traffic flow can be estimated by the Fig. 3 below. A reduction down to 10 % of the original traffic flow result in a noise reduction of 10 dB(A).



Vehicles /24 h	Noise reduction dB(A) units
10000	0
8000	-1
6300	-2
5000	-3
3150	-5
1000	-10
315	-15
100	-20

Fig 3 Noise reduction due to a reduction in traffic flow.

3.4 Descriptors used for characterizing the noise reduction in the Quiet Zone.

The reduction achieved by a quiet zone will depend on what descriptor is used for characterizing the reduction. In the EU Directive 2002/49 the equivalent sound level defined as $L_{Aeq,night}$ $L_{Aeq,day}$, $L_{Aeq,24h}$, L_{den}. Therefore we will in this paper only deal with the equivalent sound level and leave out other parameters such as e.g. the maximum sound level, $L_{AmaxFAST}$.

4 QUIET VEHICLE DEFINITIONS

4.1 Quiet Vehicle data used in the calculations.

We assumed the quiet vehicle to have 10 dB(A) units of lower sound emission from the drive-line. This is what can be achieved by a well designed hybrid electric car driven in electric mode, such as e.g. Toyota Prius, Toyota Camry Hybrid or Lexus GS Hybrid, Lexus RX 400 Hybrid. For the tyres/road noise it seems reasonable to assume that it is realistic to count on a 5-7 dB(A) unit reduced tyre/road noise partly due to the road surface and partly due to tyres selected to match the particular road surface. See also Chapter 4.2. below.

In order to simplify calculation we have used a 7 dB(A) reduction for the Quiet Vehicles in the entire speed range.

4.2 The need for tyre/road noise reduction

For normal passenger car vehicles the tyre/road noise will start to dominate over drive-line noise for speeds above 35 km/h. This means that if the drive-line noise is reduced by e.g. 10 dB(A) units this means that the tyre/road noise would start to dominate. The selected data for the Quiet Vehicle is 10 dB(A) units of lower drive-line noise and 5 dB(A) units of lower tyre/road noise compared to an average noisy modern passenger car. As the Fig. 4 below shows this leads to that a difference of 5-8 dB(A)-units depending on speed.

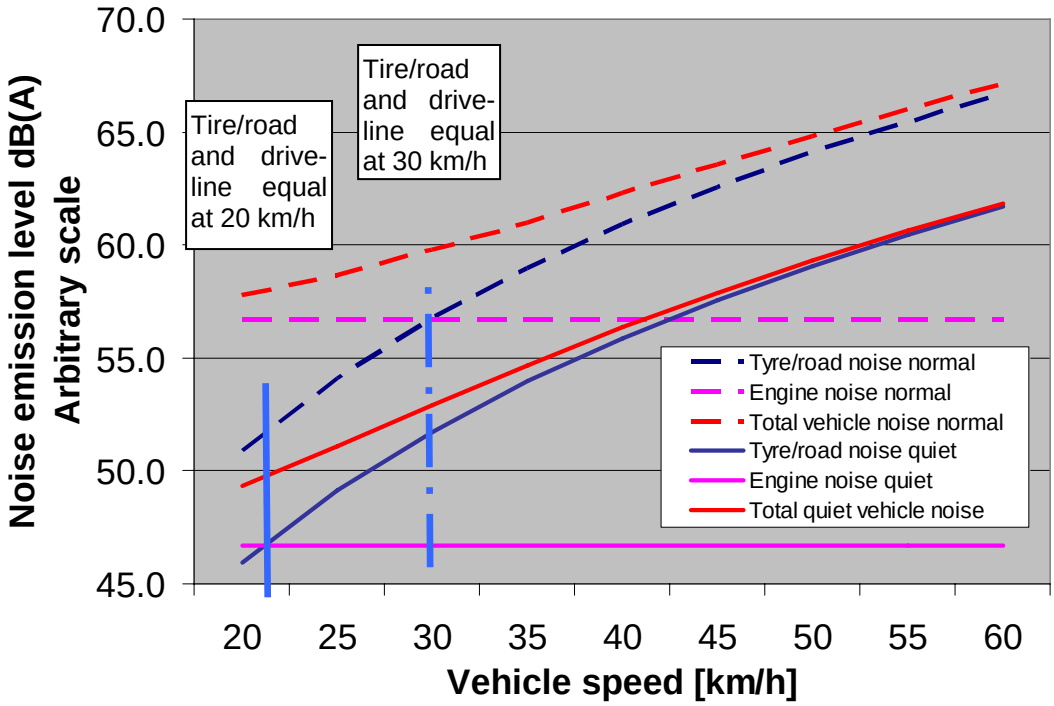


Fig 4. Conceptual diagram illustrating driveline and tyre/road noise for normal and quiet passenger cars.

Data in Fig 4 reveal that a quieter driveline must also be combined with a less noisy tyre/road system. In order to simplify the calculations we have condensed the reduction from Fig 4 into a standard reduction for all speeds of 7 dB(A)-units in the calculations.

4.3 Environmental vehicles and noise

In many countries it already exist definitions and requirements for environmental vehicles. Vehicles fulfilling the requirements to be classified as environmental vehicles can take advantage from certain economical benefits such as free parking, release from congestion fees etc. However the requirements of granting a certain vehicle type the status as environmental vehicle has up to now been focusing mainly on the chemical emissions like exhaust gases etc. In most countries *noise emission* has up to now not been included in the array of parameter values to be fulfilled for granting the rating as *environmental vehicle*. An urgent task is therefore to include also *low-noise characteristics* in *the environmental vehicle definitions*.

5 THE QUIET ZONE - CALCULATED RESULTS FOR VARIOUS SCENARIOS.

5.1 Scenario #1. Applying a fee for noisy vehicles.

In scenario #1 we assume that all vehicles both quiet and noisy vehicles will have access to the Quiet Zone. However the noisy cars will have to pay a Noise Fee of 2 Euro per passage in and out through the gates.

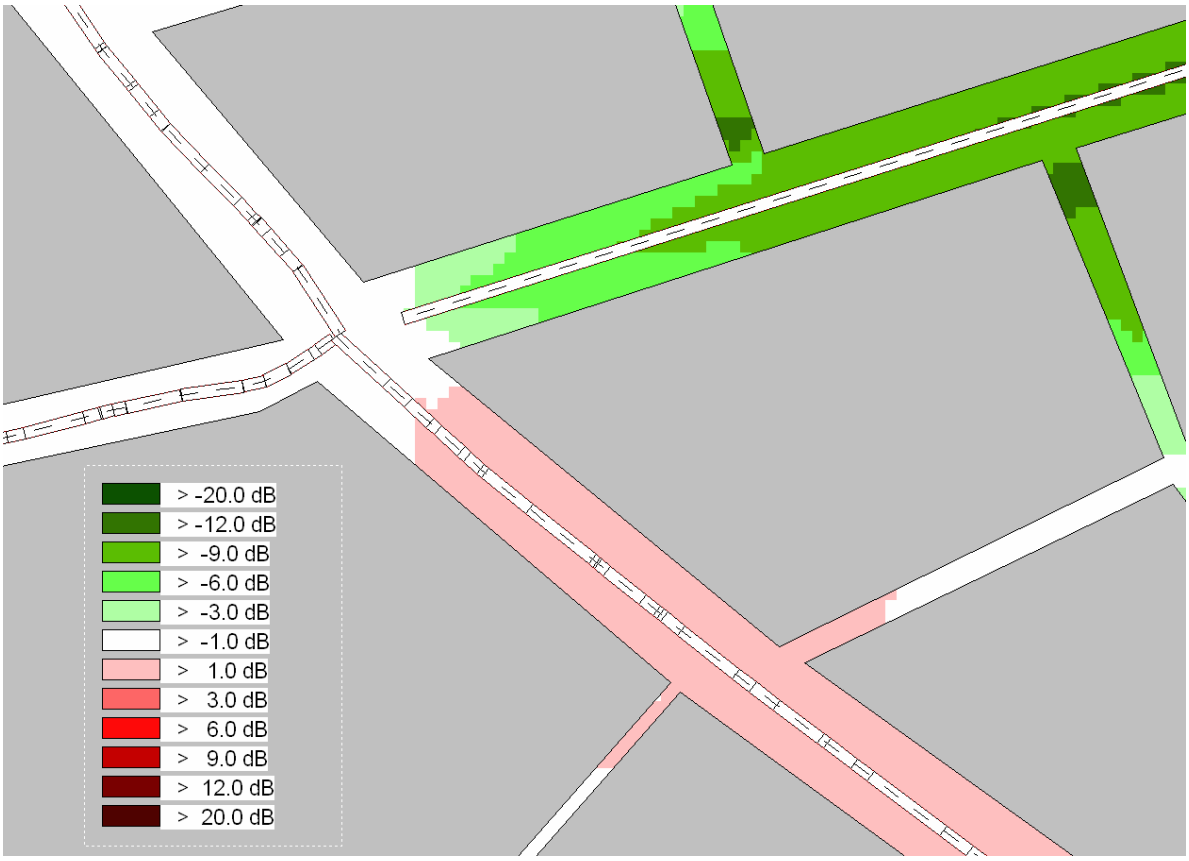


Fig. 5 Noise map near the boundaries of the Quiet Zone for the case where a fee for noisy vehicles is applied. Quiet vehicles e.g. hybrid electric vehicles will enter free of charge.

From Fig. 5 can be seen that the lowering of noise is achieved also rather close to the boundaries of the Quiet Zone. The leakage effects are here masked by the high traffic noise levels before the introduction of the Quiet Zone. Note also that there is a slight increase of about 1 dB (A)-unit at “get-around-streets” at the boundaries of the Quiet Zone. Another interesting detail is that there is a small leakage effect for the pedestrian streets.

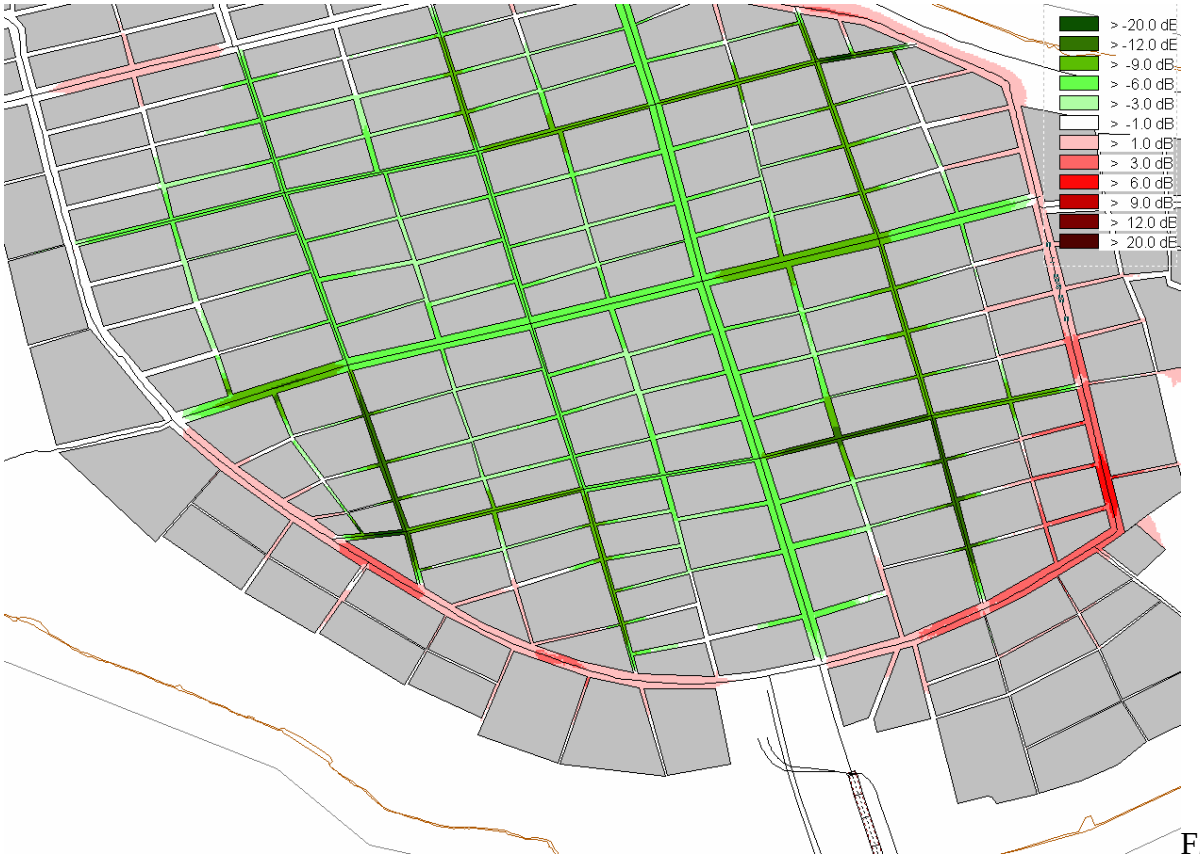


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Fig. 6. Overview difference map where owners of noisy vehicles need to pay a charge of 2 Euro to enter or leave the Quiet Zone. Quiet Vehicles such as hybrid cars can enter free of charge.

In this scenario the car ownership of low noise vehicles is assumed to be 20% inside the area and 5% outside. Note in Fig. 6 that many streets seem to get a noise reduction of 6 dB(A)-units. However there are streets with 9 dB(A) and even up to 12 dB(A)-units and higher. Since the percentage quiet vehicles in the Quiet Zone are only about 25 % out of the total traffic flow, we can conclude from Fig. 2 in ch 3.2 that the reduction of vehicle noise emission is about 1 dB(A)-unit. The rest of the reduction is due to the reduced traffic flow. Note also that most of the boundary street “Ringvägen” will obtain only 1 dB(A)-unit of increase. However there are parts with increase up to 3 dB(A) and some spots of up to 6 dB(A)-units.

Pedestrian streets get a reduction of approximately 2 dB(A) but also a small leakage effect at the boundary.

5.2 Scenario #2 – Applying closings gates for noisy vehicles and free enter for quiet vehicles.

As mentioned above we have in our calculations assumed that the Quiet Vehicles are 7 dB(A)-units less noisy in the entire speed range.

When road gates were applied the low noise vehicle share was assumed to be 5% outside the restricted zone and 100% for people living inside the restricted zone.

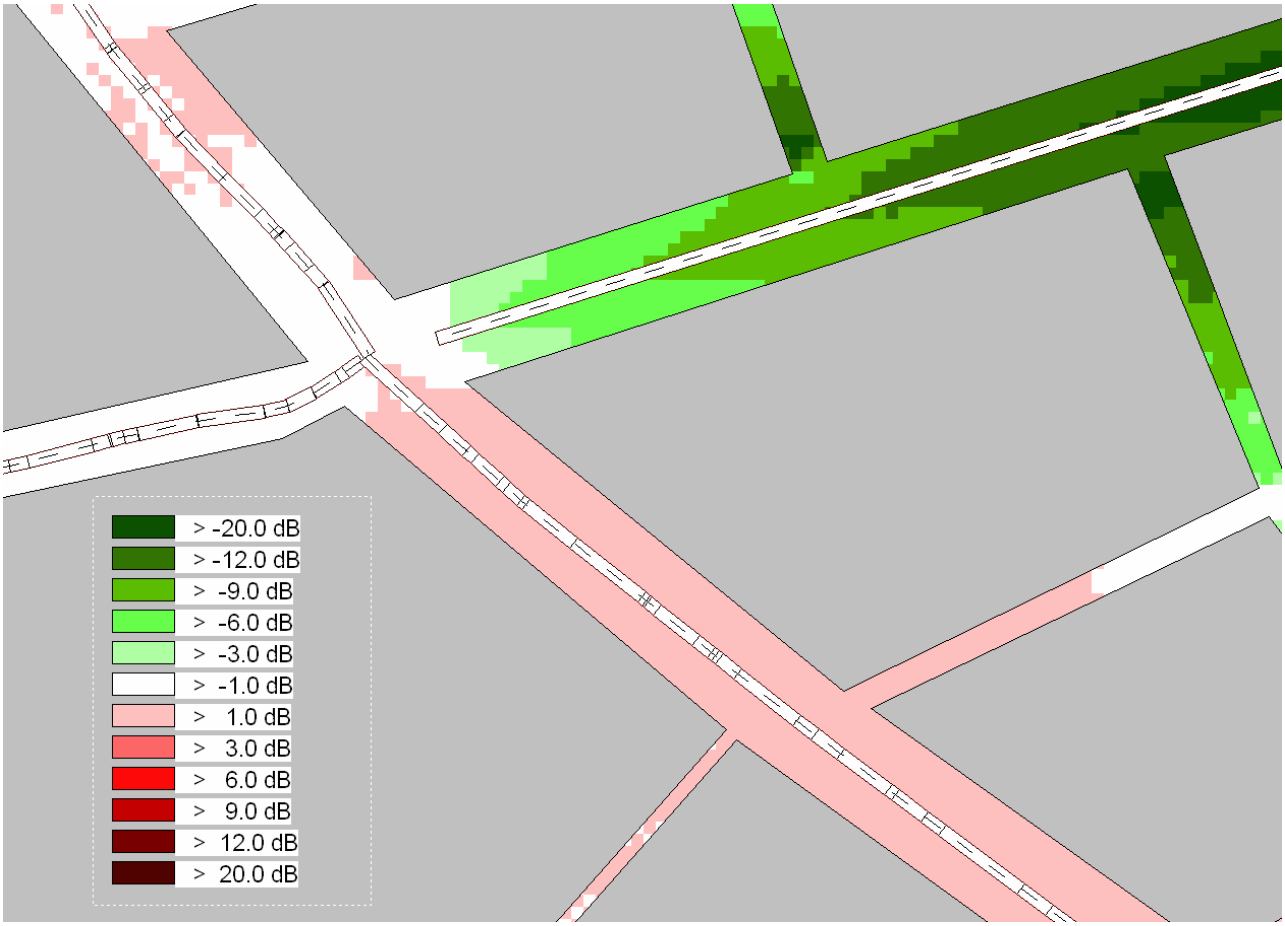

Fig. 7. Noise difference maps for Scenario #2 – applying closing gates for noisy vehicles.

From Fig. 7 it can be seen that some 100 metres into the Zone, the reduction will be raised to 12-16 dB(A)-units. It can also be seen that the increase just outside the Zone at the "get-around-streets" is modest, only 1 dB(A)-unit. It can also be noted that the pedestrian streets will obtain a slight leakage effect from the boundaries.

Fig. 8. Difference map for the entire Quiet Zone for Scenario #2. Application of closing gates for noisy vehicles.

From Fig. 8 can be seen that many streets in the Quiet Zone now will get 12 – 16 dB(A)-units of noise reduction. Not also that the major part of the boundary "get-around-streets" will obtain an increase of around 1 dB(A)-unit while there are some limited street sections part that will obtain an increase of 3-6 dB(A)-units due to rerouting. There are small leakage effects near the boundary on pedestrian streets but no leakage close to the car streets.

For the scenario with closed gates for noisy vehicles it was assumed that all residents (100 %) in the Quiet Zone are owner to Quiet Vehicle (a hybrid car or similar).

6 DISCUSSION ON FURTHER POSSIBILITIES AND POTENTIALS ON QUIET ZONES

Our analyses show that the concept of Quiet Zones has a large noise reduction potential. However an implementation could require considerable budgets. Additional parking space outside the area must probably be supplied as well as developing and applying a system to register passing vehicles. On the other hand a well-designed charging system will in the long

run give important life quality revenues to the residents by a very quiet and refreshing environment.

Toyota/Lexus already market six models of low noise hybrid electric cars and Honda one. General Motors and Ford (Saab and Volvo) and others are close to launching new hybrid electric cars. Volvo Truck and other manufacturers of heavy vehicles have introduced hybrid electric trucks (which would facilitate delivery of goods into the Quiet Zone). Together with the demand for a better air quality and less emission of CO_2 it seems like the right time has come to introduce to concept of Quiet City Zones.

Further investigations and developments therefore seem to be appropriate. Among other things we believe that a thorough cost-benefit analysis should be undertaken in a wider perspective also considering other environmental benefits from a Quiet Zone, than noise. Estimation how the concept would affect the consumer willingness to by quiet cars would also be urgent as was pointed out in the first paper.

7 CONCLUSIONS (OR SUMMARY)

A study utilizing modern techniques for prediction of traffic flow in and around the Quiet Zones has led us to draw the conclusions presented below:

- Applying a fee of 2 Euro for noisy vehicles lead to typical 6-7 dB(A)-units of reduction compared to the base scenario with unrestricted traffic.
- Applying closing gates for noisy vehicles so that there are only Quiet Vehicles in the Zone, lead to 12-16 dB(A)-units in reduction (9-11 dB(A) means that the subjective impression is reduced to half).
- A substantial part of the noise reduction is due to a reduction in vehicle flow.
- For the “closing gate”-scenario the reduction is composed about equally of reduction due to source emission and reduction due to vehicle flow reduction.
- For sound emission reduction is only 1 dB(A)-unit in the noise fee scenario, while the remaining 5-6 dB(A)-units in noise reduction is due to vehicle flow reduction.
- There is a slight leakage effect from boundaries through the pedestrian streets while streets with traffic will not display any leakage effect.
- There is a slight increase of the sound levels of 1-2 dB(A)-units at the get-around-streets on the boundaries to the Quiet Zone. Some limited street sections can obtain 3-6 dB(A) in increase due to rerouting.

8 ACKNOWLEDGEMENTS

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9 REFERENCES

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