TWO WAYS TO DERIVE DESIGN TARGETS FOR NOISE EMISSION

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1 INTRODUCTION

The first noise related EU-Directive was issued in 1970, for motorized vehicles (cars as well as trucks). Its intention was to put an end to using noise limits as a means to protect national industry or to limit certain imports. The initial limits were set at a high level, so no existing models were excluded from the market. An understandable outcome of the negotiations, given that at that time every member state could veto a decision.
For reasons which are not completely clear, an expert working group lead by the Commission started a process to lower these limits. Over the past 30 years, the initial limits were successively lowered in 4 discrete steps. For reasons which are not explained here (but are well documented), the effects were limited. Although for heavy trucks the limit value was lowered by 12 dB, the effect measured was only around 2 dB, while for cars the effect of the 8 dB lowering was nihil.
The same development can be seen with trains, aircraft and with outdoor machinery. Notwithstanding undeniable progress - especially for aircraft - , the overall impact on the acoustic environment has been limited, if not outright disappointing.
This has a number of reasons, and not all the same for all sources. Surprisingly, the process is set to continue, apparently indefinitely. But is it necessary to achieve 0 dB, or can we stop before that? Two different ways are explored to see how quiet the sources actually should be.

2 TWO APPROACHES

Why 2 approaches? The intrinsic reason is that the conventional cost-benefit approach is not able to express all benefits (especially the health and well being effects) convincingly in monetary terms. On the other hand, the health based approach clearly doesn’t tell the whole story. In order to avoid accusations of looking only at one side of the problem, both approaches are followed.

3 THE HEALTH PERSPECTIVE

That long term exposure to noise may affect health and well being, is taken for granted. In the literature a number of effects have been described, and for some effects reliable dose-effect relationships are established, for others at least a threshold can be found.
The problems lies in finding “reasonable” targets for protection of the population which are in line with other needs and goals in society. One influential organisation in this field is without doubt the World Health Organisation (WHO). On the basis of their advice the quality standards for air pollution have been set, for example.
Another source of information are the noise legislations in various countries. Most modern countries have some form of noise limits, which generally are set after a process of public consultation and taking into account a number of practical considerations. The curious -and comforting- observation

can be made that the noise limits for the same cases seem to have much in common. Exact comparisons however are difficult due to differences in the noise indicator used and in the way the limit values are actually implemented. On the whole there seems to be a common understanding of what is desirable and attainable in the long run. In table 1 the limits and recommendations are lined up for road traffic noise.

Table 1 Limit values for road traffic noise in residential areas[2]

Country	**planning value**	**maximum limit**	**remarks**
BRD	day **55** night **45**	day **59** night **49**	Higher value for mixed areas
Switzerland	day **50** night **40**	day **55** night **45**	Higher value for mixed areas
Austria	**55**		LAeq 24 hr
France	dag **60** night **55**	**65**	LAeq 8-20.00 hr night 22-06
Denmark	**55**		LAeq 24 hr
UK	day **55** night **45**	day **72** night **66**	day from 07.00-23.00
Netherlands	day **55/52** night **45/42**	day **56/62/70** night **48/52/60**	35 dB(A)inside 25 dB(A) at night
Sweden	**55**		30 dB(A) inside

For railway noise these figures usually are higher (the so-called railway bonus) and for industrial noise the limits are usually lower. For aircraft noise it is hard to say what the situation is because of the differences in indicators; limits seem to be higher then for traffic noise.

Another source are the WHO- guideline values from 2000[1]:

Table 2 :Guideline values for community noise in specific environments
(adapted from [1])

Specific environment	Critical health effect(s)	LAeq [dB]	Time base [hours]	LAmax, fast [dB]
Outdoor living area	Serious annoyance, daytime and evening Moderate annoyance, daytime and evening	55 50	16 16	- -
Dwelling, indoors Inside bedrooms	Speech intelligibility and moderate annoyance, daytime and evening Sleep disturbance, night-time	35 30	16 8	 45

Outside bedrooms	Sleep disturbance, window open (outdoor values)	45	8	60
School class rooms and pre-schools, indoors	Speech intelligibility, disturbance of information extraction, message communication	35	during class	-
Pre-school bedrooms, indoors	Sleep disturbance	30	sleeping-time	45
School, playground outdoor	Annoyance (external source)	55	during play	-
Hospital, ward rooms, indoors	Sleep disturbance, night-time	30	8	40
	Sleep disturbance, daytime and evenings	30	16	-

It is interesting that this table doesn't differentiate to noise source, while for some important aspects like annoyance there is evidence for the need to make a distinction[3].
Comparing the WHO table with the national legislation, it is clear that effects like annoyance and sleep disturbance play an important role in the long term goals for the national governments. That is a common enough fact for any one who followed these discussions from nearby. Effects like hearing loss and cardiac diseases are to be avoided at all cost, and these play a role in discussions about improvement programs (the black spot approach).
In order to start with a realistic but ambitious value for deriving noise emission targets for individual units, in this paper I will use a target of **50 LAeq for day time** and **40 dB at night**. Although on the lower end of the ranges shown above, they still are not ideal no-effect levels, but sufficiently low to be comfortable for the large majority of the population. Looking for instance at the highly annoyed, where the best dose-effect relations are available:

Table 3. Highly annoyed by noise. Road, rail, aircraft, Industry

	Road	Rail	Aircraft	Industry
50 Lden	3%	2%	5%	5%
55 Lden	4%	4%	10%	8%

It is somewhat more ambitious then in most countries is set as planning value, but one has to bear in mind that these legislative values are compromises.
A level of 40 dB(A) at night would permit most people to sleep with windows -slightly- open. The resulting inside levels would then lie around 25 dB(A).

3.1 Deriving noise production targets

The relation between long term LAeq and individual contributions per vehicle or machine is complicated. Road traffic noise is a compound of very different acoustical situations: the city streets with relatively low amounts of traffic but dwellings at short distance and motorways with high traffic volumes approaching almost continuous noise but dwellings at larger distance. Aircraft noise and

train noise usually have fewer events per time unit, higher sound power output, but large to intermediate distances between source and exposed areas.
In the following graphs this relationship is studied in some detail. The graphs show which combinations from number of events and sound power level give an LAeq of 50 dB(A) in relation to the distance from the source. The basis is an "average day time hour"; a simplification to keep numbers within un understandable range. For the short range no excess attenuation is taken into account (over the distance-effect), for the medium distance a moderate ground and air effect is calculated and for the long distance only the additional air-effect is taken into account. Over the considered distance this corresponds within a few decibels to the observed levels.

This is done for four typical conditions:

- short range and modest number of events: urban streets
- medium range and low number of events: trains and other forms of collective transport
- medium range and high number of events: motor ways
- long range and low number of events: air planes

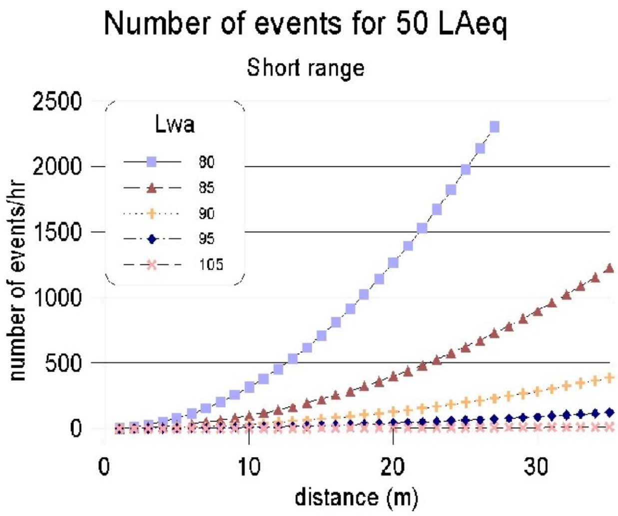

Figure 1. Relation between distance and number with sound power as parameter

The maximum capacity for a 2 lane city road - between 20 and 40 meters from facade to facade, including parking, pavement- is theoretically 2000 units/hr, but due to intersections, curbs, parking movements etc the actual limit will frequently be around 1000 units/hr. In residential areas traffic intensity is less, like around 100 units/hr, and streets are narrower. The conclusion is that an Lwa of 80 is required to achieve 50 dB(A) in most urban situations. For some delicate situations (very narrow high intensity city roads) this may not be enough, but one wonders if in those cases it is at all advisable to direct large quantities of traffic in such streets.

In the medium range, low number situation substantially higher sound power levels may be permitted. If we look at a distance of 50 meters (for new railway lines this would be considered rather close) an Lwa of 105 would be required to leave room for 20 trains per hour.

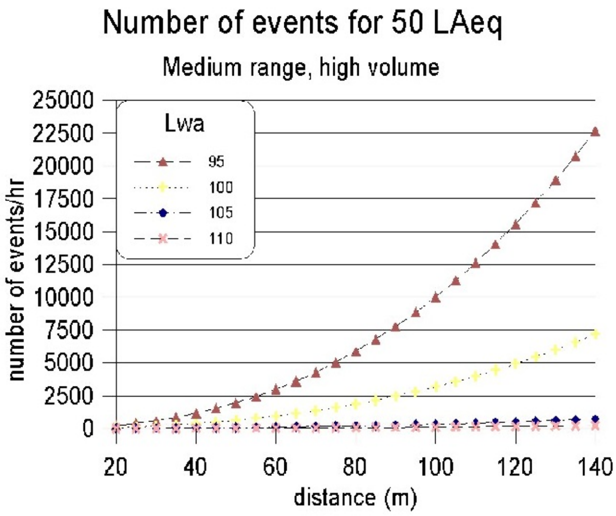

Figure 2. As figure 1, medium distances

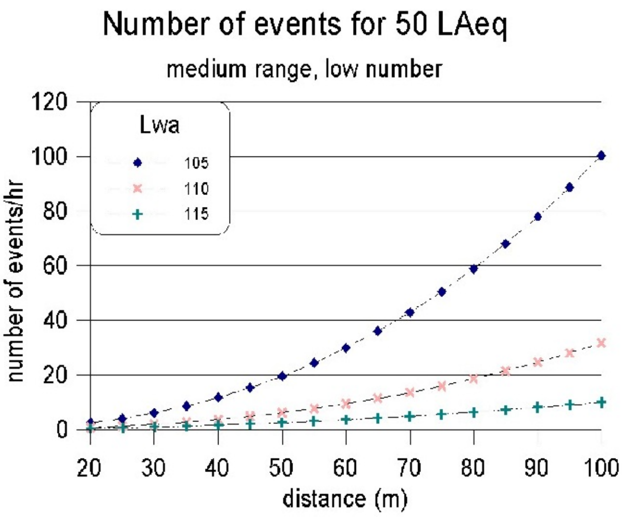

Figure 3. As figure 1, medium distances

or the medium range, high volume situation a somewhat higher level is required then in the typical urban situation. An Lwa of 95 dB(A) permits traffic up to 2000 vehicles per hour at 50 m distance, or 10000 /hr at 100 m distance. This last figure corresponds to the carrying capacity of a 6 lane motorway.

The long range situation refers to aircraft and the distance in the graph is the real distance to the aircraft. For reference the distance to the centre of the airport is indicated. The maximum capacity of a runway is between 30 and 60 planes per (rush) hour, but large airfields have more then one runway and can operate them in parallel. If all planes remain below Lwa=120 dB(A), an LAeq of 50 dB(A) is unlikely to be exceeded even at close range to the airport. A target of 125 might just do for smaller airports with lots of open space around.

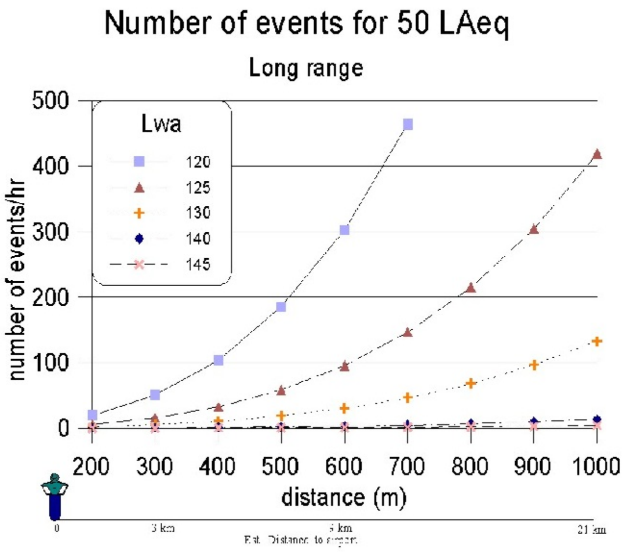

Figure 4. As figure 1, long distances

This leads to the following design targets for noise from all types of machines:

Table 4. Design targets		
Machines to be used at	design target Lwa	estimated Lmax
short range (5-25 m)	80	55 (7,5 m)
medium range (25-100m) (<20 events/hr)	105	70 (25 m)
medium range (>20 events hr)	95	70 (7,5m)
long range (>100 m)	120	60 (300m)

For the night time target of 40 LAeq the same procedure may be followed. The result will be that either the same targets will result ten times lower number of events, or 10 dB(A) lower targets. For some sources (airports, urban streets) it is indeed common to have much lower numbers at night time, for other sources - railways- this is not the case.

3.2 Are the targets achievable?

The targets derived in the former chapter look like a real engineering challenge, because they are considerably lower then the actual limits or the average values now found in practice. But that is not the issue; as these are long term design targets, we had better look at what is now the best available technology, starting by looking at the ranges in now commercially available machines.

Table 5. Comparison design targets with actual levels.			
	Target	Range of Lwa	Effect of Best practice
Short range: cars, vans at low speed (<50 km/hr)	80	85-95	quiet tyre: -3 quiet road surface: -5
Short range: streetcars, metro	80	90-100	smooth rail/wheel: -5
Short range: outdoor machinery	80	82-108	Electrically operated equipment usually below 90, combustion engine average 100, lowest 90
Medium range passenger trains	105	110-130	smooth rail/wheel surfaces: -3 auxillary equipment: -5
Medium freight trains	105	125-130	smooth surfaces: -10 wheel damping: -3 wheel screens: -5
Medium range cars (120 km/hr)	95	100-105	quiet tyres:-3 road surface: -5
Medium range heavy duty	95	105-115	quiet tyres:-3 road surface: -5
airplanes (>20000 kg)	120	125-170	

An important aspect is the test-method. The requirement for test methods make them in some cases less suitable for use in predicting schemes. A test method must be reliable and reproducible. That means that sometimes a choice is made for operations that don't occur (often) in practice. The above ranges are mostly based on observed ranges in everyday practice (except the outdoor machinery which are based on the published test results; these tests are relatively close to reality and are presented directly in Lwa). A better test method would take into account al the different operational conditions of a machine, where necessary corrected for the time in each mode and the amount of annoyance it causes. As this will turn out to be a complex system, vulnerable to all kind of trickery, this is a direction to avoid. Instead, it would be wiser to state that the target must be met in all operational conditions the machine allows. This could off course mean that modes of operation which are by nature very noisy (slamming a door, or accelerating at full power) would have to be made impossible by the designer is they exceed the target.

Figure 5 Fundamental redesign?

In many cases the targets seem to be within technological reach. Already motorcars and air planes are available which (almost) meet the long term targets. In other cases there is a long way to go, and probably (like in the case of the heavy duty transport vehicles) a fundamental redesign will be necessary.

If all fails or leads to clumsy designs, it may be efficient to leave the last decibels to other measures, like operational control, reducing speeds and numbers at local levels, keeping distance to heavily used infrastructure and so on.

4 COST-BENEFIT APPROACH

Basically, in this approach the cost of reducing noise (eg the extra cost of a quiet vehicle or quiet tyre) is set against the monetary benefit of reducing the noise at the receiver. This works best in a scenario procedure like the following:

- Build scenarios with different grades of noise measures
- Perform impact calculations on a number of model areas
- Calculate cost-benefit ratios
- Limit values adapted to best performing scenario....

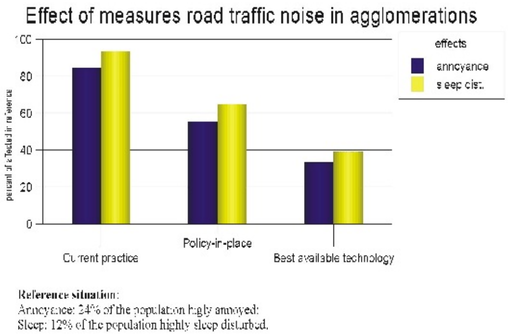

Figure 6. Reduction of annoyance and sleep disturbance in 3 scenario's[5]

Such a study has been performed on behalf of the EU-Commission by Lärmkontor in Germany[4]. Without going to deep into the backgrounds of this study, for each of the sources road traffic, railway traffic and air traffic 3 scenarios[1] were calculated:

I. Extension & implementation of current practice: extended current practice like speed reduction on urban roads and new brake blocks for freight trains

II. policy in place and pipeline: extensive application of current practices and modest source measures

III. best available technologies

Using the modest 25€/per dB/household benefit figure from the EU, the outcome was that almost all studied measure packages were cost effective. The most far going scenario's applying best available technology sometimes only slightly positive or somewhat negative. Another remarkable outcome is that in none of the studied cases the noise effects were reduced to zero. The best overall reduction was achieved in urban areas for road traffic noise (60% reduction), but that was with a hefty combination of local (speed limits, quiet surfaces) and global (quiet cars, trucs) measures. In the train and aircraft scenario's reductions were limited to 20-40%.
This doesn't necessarily mean that further noise reduction couldn't be cost-effective: it is just not studied because the technology is not available, and it is not available because there are no incentives to do so.

5 CONCLUSION

Long term goals for a healthy environment can be translated in design targets for vehicles, planes and machinery. Although the resulting sound power levels seem low, these targets are not beyond the reach of our technology. From the designers an open mind is needed because in some cases an non orthodox approach is required to produce machines that may be used without disturbance

[1] In Effnoise the 3 scenarios are distinguished as: medium realistic, maximum realistic and maximum fantastic

to others. From scenario studies it is shown that application of the best available technology still leaves a huge gap, demonstrating the need for specifying targets which in turn challenge the manufacturers.

6 REFERENCES

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