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STØJENS PRIS I PLANLÆGNINGEN!

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Abstrakt
Fokus i denne præsentation ligger på hvordan støj kan medtages i cost benefit og cost effectiveness undersøgelser af forskellige virkemidler til støjreduktion. Baggrunden er en sammenfattende undersøgelse af den eksisterende danske praksis på området, som Vejdirektoratet har udført for de statslige vejmyndigheder i Californien. Når der bygges nye veje eller bygninger i Danmark tages der særlige hensyn til vejtrafikstøj. En ny opgørelse over antallet af støjbelastede boliger i Danmark viser, at omkring 30 % af danske hjem udsættes for støj som overskrider den vejledende grænseværdi på 58 dB (L_{DEN}) og at støjproblemerne hovedsageligt forekommer i byerne.

Støjens pris er i Danmark opgjort på baggrund af undersøgelser af støjens betydning for boligpriser samt vurderinger af omkostningen ved de sundhedsmæssige konsekvenser af støj. Støjbelastningen fx for alternative linjeføringer af en ny vej beregnes og kortlægges med den nordiske NORD2000 metode. Støjniveauet for de enkelte boliger vægtes med en genefaktor, hvorefter støjbelastningstallet (SBT) beregnes. Det samlede SBT er et udtryk af den samlede støjbelastning på alle boliger i et område. SBT er beregnet som summen af de vægtede støjbelastninger på individuelle boliger i området, således at boligerne med høje støjniveauer vægtes tungere end boliger med mindre støj. For hvert alternativ løsning kan SBT opregnes. Støjbelastningstallet (SBT) er grundlaget for økonomiske analyser af støj fra vejtrafik. Prisen på en enhed af SBT opdateres løbende baseret på prisen på støj.

Som en introduktion præsenteres 14 anbefalinger for " good governance" i arbejdet med at forebygge og bekæmpe støj, som er udviklet af foreningen af Europæiske vejdirektorater (CEDR). Efterfølgende præsenteres metoder og strategier til støjbekæmpelse og der gives eksempler på hvordan støjen integreres som væsentlig parameter i VVM-undersøgelser ved planlægning af nye veje og vejudvidelser. Støj er en blandt flere miljømæssige faktorer, som tages med i en VVM undersøgelserne. Når der planlægges nye motorveje eller når en eksisterende motorvej skal udbygges, bliver en støjgrænseværdi 58 dB som L_{DEN} anvendt, hvis det er teknisk og økonomisk muligt. Grænseværdien anvendes, når samlede helårs- og fritidsboligområder er udsat for støj fra vejtrafik. For enkeltliggende boliger, tages normalt ikke hensyn til grænseværdien. Der tilbydes i stedet facadeisolering, såfremt støjen overstiger 63 dB. Forskellige virkemidler til at reducere støjen kan anvendes, når der planlægges nye motorveje. Hvis det er muligt og realistisk at finde en linjeføring for den nye motorvej, som giver den maksimale afstand til boligområder, er det normalt den foretrukne løsning. Støjreducerende asfaltbelægninger bruges normalt, når en motorvej passerer samlede bolig- eller fritidsbebyggelser.

I aftalen om en grøn transportpolitik fra 2009, blev der afsat en samlet støjpulje på 400 mio. kr. frem til 2014 til en målrettet indsats for at reducere trafikstøj fra bane og vej. I 2009 udgav Vejdirektoratet et forslag til støjhandlingsplan for det eksisterende vejnet. Formålet

med planen er bl.a. at beskrive muligheder og tiltag for at nedsætte vejstøj langs statsvejene.

Vejdirektoratet har indført et system til enkel klassificering af støjreducerende vejbelægninger, SRS-metoden, hvor den støjreducerende virkning klassificeres i A (særligt støjreducerende, 7 dB reduktion eller mere), klasse B (meget støjreducerende, 5 – 7 dB), og klasse C (støjreducerende, 3 – 5 dB). Systemet beskrives sidst i artiklen.

Da denne artikel er baseret på en engelsk sproget rapport [1] er det valgt at skrive på engelsk.

1. Introduction
When constructing new buildings or roads in Denmark special consideration is given to traffic noise. A new national noise map indicates that around 30 % of Danish homes are exposed to noise levels that exceed the guideline value of 58 dB (L_{DEN}) and that noise problems are concentrated in cities. Road traffic noise may impact people in different ways such as impacting communication, and interrupting sleep. New studies show that noise can contribute to an increased risk of cardio-vascular diseases. The effects of noise are also of an economic nature because noise influence housing prices in areas exposed to noise. Furthermore, health related issues caused by noise also incur costs. The socio-economic costs related to road traffic noise have been calculated to amount to between 0.8 and 1.2 billion Euro.

2. Good governance in noise abatement
The following fourteen recommendations to National Road Administrations (NRA) for good governance regarding noise management and abatement [3] were developed by a European noise group from the Conference of European Directors of Roads (CEDR) [5]:

1. In Europe, the main noise problems occur along the existing road network and the order of magnitude of the problems is increasing with increasing traffic volume. Therefore, noise abatement along these roads is crucial in order to start a process where the noise exposure over the long term is reduced.
2. It is important to include noise issues at the early planning stage for new road developments. In adopting such an approach, future noise problems may be avoided. The basis for such an approach will normally be the national noise guidelines.
3. Noise should be included as an important parameter in projects where existing roads are improved to accommodate increasing traffic volumes or increasing speeds. This can improve the noise environment for people living in close proximity to the upgraded road.
4. When planning to incorporate noise abatement measures on new, existing and reconstructed roads, it is important to adopt a time horizon of 20 to 30 years, when predicting future noise from increasing traffic volumes and planning noise measures. This will enhance the robustness of specific noise projects.
5. When road construction work is carried out in close proximity to residential areas, it is relevant to consider construction noise when planning and realizing such works. Residents close to the construction site should get sufficient information.
6. In projects where noise abatement measures are planned and designed, it is recommended to establish a good communication strategy to ensure a two way communication process with the public. In this way, residents may take ownership of

the project and their expectations to what noise mitigation may deliver in terms of noise reductions may be more realistic.

7. Noise barriers erected on roads have not only visual impacts for the residents living in close proximity to the road but also the driver and their passengers. It is therefore, important to use barrier designs that are appropriate to the specific location where they are installed.
8. The use of noise reducing pavements should be considered when selecting noise mitigation measures because such pavements are purported to provide a cost effective tool in noise abatement. In upgrading existing roads, the use of noise reducing pavements is often a low cost measure of noise abatement.
9. Integration of noise as an active component in Pavement Management Systems can increase the optimal use of noise reducing pavements in the ongoing road pavement renewal process.
10. To enhance the current market for noise reducing pavements the development and use of a noise labeling system in member states should be considered.
11. In order to reduce noise emissions from individual vehicles, it would be invaluable if individual NRAs lobby at EU level to promote tighter noise limits for the EU type approval of new vehicles and tires
12. Like all elements of infrastructure, noise abatement measures such as pavements, barriers, façades, etc. need to be maintained on a regular basis.
13. There is a need for further research and development in improved and long time durable measures of noise abatement like optimized noise reducing pavements, tires, vehicles etc.
14. A continuation of international cooperation on noise abatement and management between the NRAs is value adding and fruitful. In the coming years issues like noise mapping and noise action plans in relation to European Noise Directive (END) [22] seems highly relevant.

3. The Noise Exposure Factor

Since the mid 1980´s noise has been integrated in municipal land use planning. In the planning process of new residential areas a land use plan has to be developed and approved by the local municipality. A noise guideline at dwellings of 55 dB ($L_{Aeq,24h}$) has to be respected. In 2007 the noise indicator L_{DEN} was introduced to replace $L_{Aeq,24h}$ and the noise guideline was changed to 58 dB (L_{DEN}) to ensure the same protection level. In the examples in the following the noise is expressed as $L_{Aeq,24h}$ and not L_{DEN}.

The Noise Exposure Factor (NEF – in Danish “Støjbelastningstal”, “SBT”) is the basis of all Danish cost-benefit analyses of noise from road and rail traffic [2]. It is an expression of the accumulated noise load on all the dwellings in an area. It is calculated as the sum of the weighted noise loads on the individual dwellings in the area, so that dwellings with high noise levels weigh more than dwellings with less noise.

Calculations of the NEF are based on noise levels in three locations around a dwelling: inside the dwelling, outside the dwelling, and in outdoor activity areas connected to the dwelling. The noise level outside the dwelling is calculated as free-field values on the f façade and can be interpreted as the noise level to which the inhabitants are exposed, when the windows are open. The weight assigned to each of these situations depends on how often it is occupied and whether it is an ordinary dwelling or a weekend cottage/summer house. The weights can be seen in Table 1. The method to calculate NEF values has been developed when $L_{Aeq,24h}$ was used as the noise indicator. In order to use the method for noise predicted as L_{DEN} 3 dB has to be added to all the noise intervals in Table 2 and 3.

Table 1: Weight assigned to various situations when calculating NEF [3].

	Outside dwelling	**Outdoor areas**	**Inside dwelling**
Ordinary dwelling	0.2	0.2	0.6
Weekend cottage etc.	0.1	0.3	0.1

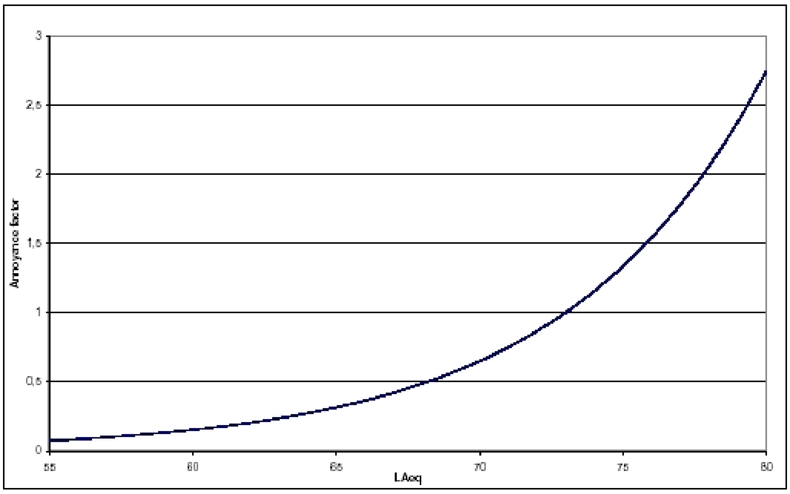

Figure 1: The relationship between the annoyance factor and the noise outside ordinary dwellings. Noise levels are free-field levels on the façade [3].

The NEF is based on a dose-response relationship given by:

Annoyance factor = $0.01 * 4.22^{0.1(LAeq - K)}$ (1)

Where
K = 16 and L_{Aeq} starts at 30 dB for noise inside dwellings
K = 41 and L_{Aeq} starts at 55 dB for noise outside ordinary dwellings
K = 36 and L_{Aeq} starts at 50 dB for noise outside weekend cottages etc.

The actual annoyance factor for a specific noise level is derived from a dose-response relationship for noise outside ordinary dwellings. The relation between the annoyance factor and the noise levels is shown in Figure 1. The number of dwellings subjected to noise in each of the three situations are calculated in intervals of 5 dB using the NORD2000 noise prediction method and multiplied by the corresponding annoyance factor (Table 2). The resulting values are summed and multiplied by the corresponding weight from Table 1 to give the NEF for the situation for the type of dwelling. Finally the total NEF is calculated by adding the values for each situation and each type of dwelling. An example for calculating the NEF for ordinary dwellings is shown in Table 3. Written as a formula, the NEF can be calculated as:

$$NEF = \sum_k \sum_j w_{jk} \sum_i a_{ijk} N_{ijk} \quad (2)$$

Where:

k = ord, wec (ordinary dwelling, weekend cottage)
j = od, oa, in (outside dwelling, outdoor areas, onside dwelling)
i = 1, 2, 3, 4, 5, 6 (5-dB intervals starting at 30 dB, 55 dB or 50 dB, see table 3.3)
wjk = {0.2, 0.2, 0.6}k= ordinary dwelling, {0.1, 0.3, 0.1}k= weekend cottage
aijk = 0.11, 0.22, 0.45, 0.93, 1.92, 3.94
Nijk is the number of dwellings in the various 5-dB intervals

Table 2: Annoyance factor for the individual dwellings [3].

Noise level in dB	Type of area			
	Ordinary dwelling		Weekend cottage etc	
	Indoors	Outside	Indoors	Outside
30.1-35.0	0.11	-	0.11	-
35.1-40.0	0.22	-	0.22	-
40.1-45.0	0.45	-	0.45	-
45.1-50.0	0.93	-	0.93	-
50.1-55.0	1.92	-	1.92	0.11
55.1-60.0	3.94	0.11	3.94	0.22
60,1-65.0	-	0.22	-	0.45
65.1-70.0	-	0.45	-	0.93
70.1-75.0	-	0.93	-	1.92
75.1-80.0	-	1.92	-	3.94

The NEF makes it possible to compare the benefits of different noise reducing strategies such as barriers, pavements, and sound insulation in a manner that accounts for the differences in where the noise is reduced. This accounting approach allows several different noise mitigation strategies and combinations of strategies to be compared more equitably. In practice however, NEF-calculations are usually simplified using only the noise level outside the façade of dwellings and assigning this the weight 1, thus omitting the separate valuation of indoor noise and noise on outdoor areas. By using this simplification, it is not possibly to make a correct evaluation of the effect of establishing façade insulation as a tool for noise abatement, and evaluations of noise barriers may also be misleading due to actual differences in noise levels at the façade and on the outdoor areas.

Table 3: Example of a calculation of NEF for ordinary dwellings [2]

Outside dwellings			Outdoor areas			Inside dwellings		
Noise at façade [dB]	No. of dwellings	Annoy. Factor	Noise outside [dB]	No. of dwellings	Annoy. Factor	Noise inside [dB]	No. of dwellings	Annoy. Factor
65-70	163	0.45	65-70	37	0.45	40-45	163	0.45
60-65	207	0.22	60-65	15	0.22	35-40	207	0.22
55-60	123	0.11	55-60	19	0.11	30-35	123	0.11
Weight		0.2	Weight		0.2	Weight		0.6
NEF		26.5	NEF		4.4	NEF		79.4
Sum of NEF = 110.3								

4. Socio-economic assessment of noise

In 1999, the Danish Ministry of Finance published a guide to preparing socio-economic assessment of consequences [4] of construction works etc. The aim of this was to achieve greater uniformity in socio-economic assessments of initiatives in the traffic and energy sectors and in relation to investments in administration buildings and investments in the educational sector. The choice of Cost-Benefit Analysis (CBA) or of cost-effectiveness assessment (CEA) depends on the characteristics of the initiative, but CBA is presented as the primary method [4]. The guidelines contain standards and principles for calculation of central parameters in the analyses. Valuation should be based on net present value using a calculation interest rate of 6 percent and a 20 % tax cost factor to account for the costs to society due to financing through taxes. For projects with time horizons of more than 20 years the tax cost factor can be left out if a calculation interest rate of 7 percent is used.

In 2003, the Ministry of Transport published a manual for socio-economic analysis based on the above guidelines from the Ministry of Finance [5]. The assessment of noise is based on annoyance at dwellings whereas noise at occupational buildings and institutions is not included. Noise levels below 55 dB ($L_{Aeq,24h}$) are not included and there is no differentiation between day and night time noise. This relates to the Danish guideline value for road traffic noise at dwellings which is 55 dB ($L_{Aeq,24h}$).

Valuation of noise effects are based on market prices. Ministry of Transport continuously publishes a catalogue of key values for use in analyzes. In the 2004 version of the catalogue [15], the values put on noise are based on a new house price survey (the hedonic method) [16]. The value put on noise annoyance is 35,853 DKK per NEF (2003 price level). 23,018 DKK) per NEF is added for costs to society due to health effects, which are not included in the reduced house prices. The total value of noise is thus 58,871 DKK per NEF (2003 price level).

The assessment of health effects is based on a study of the international literature on the subject [17]. It is concluded that the documentation of actual health effects of noise from road traffic is weak and without clear evidence, and the estimates of costs are therefore done with reservation. There is some evidence of a connection between noise and ischaemic heart disease, although the risk factors related to it are uncertain. A risk factor of 1.09 per 5 dB increase in noise levels is adopted, and it is decided also to use this factor for hypertension. Other possible health effects are left out of the assessment of costs.

The catalogue [6] also presents marginal costs of noise from transportation. The noise costs per driven vehicle kilometre (2003 price level) can be seen in Table 4. The uncertainty on these values is estimated to be minus 50% to plus 100%.

Table 4: Danish estimated noise costs per driven vehicle kilometre (2003 price level) [6].

Vehicle type	DKK/km
Passenger cars	0.12
Light Goods Vehicle	0.17
Heavy Goods Vehicle	0.25
Bus	0.55

5. Planning of widening existing highways

The Danish highway network is primarily developed as four lane roads. Due to increase in traffic, some of the highway sections are being increased to six lanes. One of the projects that was finalized in 2008 is the enlargement of the M3 highway [7]. The M3 is a highway, which functions as a ring road around Copenhagen as well as being part of the E47/E55 European corridor, which connects Sweden and Germany. Being the only ring road around Copenhagen, which is built fully as a motorway, the Average Daily Traffic on the two lanes in each direction is as high as 75,000 vehicles. Congestion is frequent, and during rush hours travelling speeds of 25-30 km/h are normal. In order to improve the traffic situation, it has been decided to widen the M3 from four to six lanes.

The M3 highway passes through densely populated residential districts. As part of the planning of the extension, an Environmental Impact Assessment (EIA) has been carried out, including noise mappings and planning of noise abatement measures. The Road Directorate, which is responsible for the extension, has made a great effort to inform and reach out to the neighbours of the highway.

6. Environmental Impact Assessment

An Environmental Impact Assessment study has been carried out in relation to the road enlargement project considering factors like population, landscape, culture and history, flora and fauna, water resources, green areas, energy and CO_2, air pollution, health effects, noise and vibrations, use of resources and waste production, light and reflections and soil and contaminated soil.

Noise mapping has been performed for the existing situation including the noise contribution from other main roads in the area. In this example $L_{Aeq,24h}$ is used as the indicator for noise. On the background of the noise mapping, the consequences of using noise barriers with different height have been analysed. Table 5 shows a summary of the results. In the exiting situation 10,305 dwellings were exposed to more than 55 dB equivalent to a Noise Load Factor (NLF) value of 1717. By using noise barriers of respectively 3, 4 and 5 meters height, reductions of NLF by 149, 630 and 769 can be achieved.

Table 5: Evaluation of the effect on noise exposed dwellings and the NLF value to use 3,4 and 5 m high noise barriers along M3 [8].

Scenario	Number of noise exposed dwellings				Total noise exposed dwellings	Total NEF	∆NEF
	55-60 dB	60-64 dB	65-69 dB	≥70 dB			
Existing	6503	3244	482	76	10305	1717	-
3m barrier	5472	2985	526	78	9061	1568	149
4m barrier	4766	1890	253	36	6945	1087	630
5m barrier	4027	1663	238	35	5963	948	769

Table 6: Evaluation of the price and cost effectiveness of the different barrier solutions [8].

Scenario	Price per m^2 in DKK	Total price in mill. DKK	∆NLF	∆NLF per 1 mill. DKK
3m barrier	2600	138	149	1,1
4m barrier	2380	169	630	3,7
5m barrier	2400	212	769	3,6

In order to evaluate the cost effectiveness of noise barriers with different heights, the ∆NLF per mill. DKK invested has been predicted (see Table 6). The predictions show that a 1 mill. DKK investment in a 3 m high noise barrier gives a NLF reduction of 1.1 and for a 4 m high barrier the reduction in NLF is 3.7 per million DKK invested. The 4 m high noise barrier is in this prediction slightly more cost effective than the 5 m barrier and the total investment needed for 4 m barriers is 169 mill. DKK whereas the total investment for 5 m barriers will be 212 mill. DKK. The cost effectiveness study supported a decision to use a combination of 3 and 4 m high noise barriers. The consequence of this solution was a reduction of the total NLF value by 677 at a total noise barrier cost of 162 mill. DKK and with a NLF reduction of 4.2 per 1 mill. DKK invested in noise barriers. On the background of the Environmental Impact Assessment and an evaluation of cost effectiveness, it was decided in this specific project to use 60 dB ($L_{Aeq,24}$) as the noise guideline for the noise exposure from the M3 highway. 60 dB represents a significant reduction in noise for many of the dwellings situated along the M3 highway. In order to achieve 60 dB, the following measures have been implemented:

- 17,900 m of noise barriers have been constructed.
- Noise reducing pavements have been used.

Where these measures have not been enough to achieve 60 dB noise levels from the highway noise exposure, façade insulation has been offered to the owners.

7. Evaluation of noise reducing pavements

In order to evaluate the effect of using a noise reducing pavement on M3 instead of the normally used Dense Grade Asphalt Concrete or a Split Mastic Asphalt, some calculations have been performed on the background of the noise mapping analysis along highway M3. The background for these calculations is the noise mapping of all the dwellings affected by noise levels exceeding 55 dB in the initial situation after the (widening) enlargement of the M3 highway with a standard pavement. Four scenarios with a noise reduction of 1, 2, 3 or 4 dB have been included. Special types of noise reducing pavements were not specified in this evaluation.

Table 7: Results of using noise reducing pavements on the noise exposure along M3. The results are given as the number of dwellings exposed to different noise levels and the corresponding noise exposure factor (NEF) [9].

Scenario	Number of noise exposed dwellings				Total noise exposed dwellings	Total NEF	∆NEF
	55-60 dB	60-64 dB	65-69 dB	≥70 dB			
Standard	4343	1815	292	34	6484	1040	-
-1 dB	3811	1788	197	34	5830	933	107
-2 dB	3285	1705	196	34	5220	856	184
-3 dB	3165	1376	189	34	4764	768	272
-4 dB	2860	1368	188	34	4450	732	308

The results can be seen in Table 7. A total of 6484 dwellings are exposed to noise over 55 dB in the situation using the standard pavement. This represents a total NEF value of 1040. By using a 2 dB noise reducing pavement, the number of noise exposed dwellings is reduced by 933 and the NEF value is reduced by 184 to 856. Using the pavement with 4 dB noise reduction, the number of noise exposed homes is reduced to 4450 and the NEF value is reduced by 308.

The economic benefits from using noise reducing pavements are calculated, based on the reduction in the NEF value achieved for the four scenarios for noise reducing pavements. The calculations are done for noise reductions of 1 to 4 dB. The annual value of the noise reductions is predicted by using the price per NEF unit presented in section 4. The results can be seen in Table 8. A 2 dB noise reducing pavement is in this project equivalent of a yearly saving of 9.7 mill. DKK due to reduced noise exposure on the dwellings around the highway. This corresponds to a net present value of 146 mill. DKK. These figures can be used in a Cost Benefit Analyses.

Table 8: Value of noise reductions caused by the use of pavements with different noise reduction along the M3 expressed as the annual value in (2001 price level) and the net present value [9].

Scenario	∆NEF	Annual value of noise reduction	Net Present Value
		Mill. DKK	Mill. DKK
-1 dB	107	5,7	85
-2 dB	184	9,7	146
-3 dB	272	14,4	216
-4 dB	308	16,4	244

8. System for tendering noise reducing pavements

In order to facilitate the use of noise reducing pavements, a system for tendering such pavements has been developed in Denmark. In 2006, Danish road authorities in conjunction with pavement industry and consultants worked out a system for the specification and documentation of noise reducing asphalt pavement [10], the SRS-system, SRS being the acronym for the Danish wording of Noise Reducing Surfacing (Støj Reducerende Slidlag). The system is based on the Close Proximity Method (CPX) for detailed noise measurements. In order to ensure reliability and transparency, it allows various independent providers of CPX measurements to offer their service as long as they participate in an annual field calibration of equipment. The system encompasses:

- A guide to the use of asphalt surfacing in traffic noise abatement
- A system for the documentation and declaration in classes of the noise reduction of the asphalt surfacing
- Three classes A, B & C, where class A surfacings exhibit the highest noise reducing effect and class B & C exhibit lower noise reducing effects as compared to regular dense graded asphalt surfacings at eight years of age.
- Reference values of the noise emission as determined by the CPX method
- A description of the CPX method including the definition of method variables and requirements on supplementary calibration of the measuring device
- A paradigm for the contracting and preparation of tender documents

This is the first Danish attempt to provide a process for contracting noise reducing asphalt surfacings. The intention is for the classification system to certify the noise reduction ability of road surfacings including new products as well as to improve the ability of the local road administrations (which typically lack expertise in noise considerations) to purchase proven solutions fit for use. A contractor who wants to declare a SRS (Noise Reducing Surface) must work out a declaration form. In this form the contractor declares the actual noise class and presents the documentation achieved during CPX measurements on a trial section. The contractor must build a test section of at least 100 m length. The CPX-trailer must run over the trial section at the appropriate reference speed while recording the noise levels with its two standard reference tires.

The system to declare the noise reducing ability enables the contractor to produce documentation of the noise reduction of a specific SRS by comparing measured values with a national reference value. The reduction in noise emission (compared to the reference) is used by the contractor in the declaration of the SRS in a specific noise class. The first generation system describes three noise classes (A, B, and C).

The reference values were derived as pass-by noise levels calculated for reference conditions using the Danish noise emission data of the Nordic prediction method for road traffic noise, Nord2000. Using data between vehicle pass-by noise levels and CPX noise levels, the Nord2000 pass-by noise levels were transformed to their corresponding CPX_{DK} values, which are used in the first generation system. When declaring the noise reduction of an asphalt surfacing (by comparison to the reference used in Denmark), one of the following noise classes A, B, or C should be used.

Table 6.4: Noise classes in the Danish "SRS" (Noise Reducing Surface) *system for noise labeling of asphalt pavements [10].*

Noise class	Description	Noise reduction in dB
A	Very good noise reduction	$x \geq 7.0$
B	Good noise reduction	$5.0 \leq x < 7.0$
C	Noise reduction	$3.0 \leq x < 5.0$

The noise reductions in Table 6.4 is given in relation to a 7 years old dense asphalt concrete. The noise emission of pavements increases over time. Around 3 dB has to be deducted form the reductions to get a comparison of new pavements.

The Danish SRS-system is a voluntary road standard for contracting of noise reducing pavements. In the contract for a specific job, the voluntary standards become legally binding. However, at present the system is in an experimental phase with no legal ramifications if the pavement fails to fulfill the noise performance requirements.

References

1. Highway noise abatement. Planning tools and Danish examples. Vejdirektoratet, Vejteknisk Institut, report 173, 2009. (http://www.vejdirektoratet.dk/pdf/rap173vi.pdf)
2. Cost-benefit analysis on noise-reducing pavements. Vejdirektoratet, Vejteknisk Institut, rapport 146, 2005. See: www.roadinstitute.dk
3. Støjhensyn ved nye vejanlæg, Vejdirektoratet, 1989. See: www.vejregler.dk.
4. Vejledning i udarbejdelse af samfundsøkonomiske konsekvensvurderinger, Finansministeriet, 1999. See: www.fm.dk.
5. Manual for samfundsøkonomisk analyse – anvendt metode og praksis på transportområdet, Transportministeriet, June 2003. See: www.trm.dk.
6. Nøgletalskatalog – til brug for samfundsøkonomiske analyser på transportområdet , 2nd version, Transportministeriet 2004. See: www.trm.dk.
7. Motorring 3 – en moderne bymotorvej. Vejdirektoratet. Report, 2007. www.vd.dk.
8. Udbygning af Motorring 3. VVM-redegørelse – Støj og vibrationer. Vejdirektoratet. Report 264, 2004. www.vd.dk.
9. Støjdæmpende vejbelægninger på Motorring 3. Teknisk og samfundsøkonomisk analyse. External note no. 19, Vejdirektoratet, Vejteknisk Institut, 2004. www.vd.dk.
10. Noise classification- asphalt pavement, Danish Road Institute/Road Directorate, Technical Note 61, 2007. www.roadinstitute.dk.