Noise annoyance for a motorway compared to urban roads

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ABSTRACT

This study summarizes of the noise annoyance from road traffic noise from a motorway (M3) and two urban roads near Copenhagen. The urban roads are characterized by open urban areas with a substantial share of 3-5 storeyed residences (2870 respondents). The areas next to motorway M3 consisted mainly of 1-2 storeyed houses protected by noise barriers of 4 m height along the motorway (1410 respondents). At noise exposure levels, L_{den}, below approx. 55 dB the dose-response curves were not significantly different. At noise exposures above 55-58 dB the noise from the M3 is perceived as more annoying than the noise of urban roads at the same levels. At the high levels, this difference is equivalent to a difference of approximately 5 dB. The annoyance around the M3 motorway is significantly and substantially above the annoyance found in the European dose-response curves. The M3 study shows that at 50% annoyed the neighbours are so much more annoyed that it equivalent to 6-12 dB higher noise exposures. For the urban roads it was found that at 50% annoyed the annoyance compared the European curves was equivalent to 3-5 dB higher noise exposure.

Keywords: Road, Noise, Annoyance I-INCE Classification of Subjects Number(s): 52.3, 66.2, 68.4

1. INTRODUCTION

This paper summarizes the analyses of noise annoyance from road traffic, from two investigations: Motorway M3 around Copenhagen and the areas surrounding the urban roads Kastrupvej and Frederikssundsvej in Copenhagen. For both types of roads there have been conducted surveys of residents' perceptions of the road traffic before and after enlargement (M3) and before and after the replacement of the road surface to a noise reducing type (urban roads).

Based on these studies, it is discussed whether there are differences in perceived noise annoyance at the same noise levels, respectively, by a motorway and by urban roads, i.e. if there are different dose-response curves between noise levels and noise annoyance for motorways and for urban roads. Furthermore, the results compared with European "Miedema" annoyance curves (4).

Based on the calculated noise levels and the results of the surveys on noise annoyance, dose-response curves are constructed (7, 9-11).

2. Roads and geographical areas

2.1 Motorway M3

M3 is a 17 km long motorway with 6 lanes with a traffic volume of approx. 90,000 vehicles per day, which runs through densely populated areas. In connection with the expansion of M3 from four to six lanes, studies on noise annoyance in areas near the motorway before (in 2003) and after the enlargement (in 2009) was made, see reference (7). As part of the enlargement the noise barriers at motorway was significantly improved to a height of 4 m, see Figure 1. Before and during the enlargement a series of public meetings, informing about the changes, the noise reducing pavement and the improved noise barriers was held.

Figure 1 - Photographs from Ring Motorway M3 and neighbouring area after enlargement.

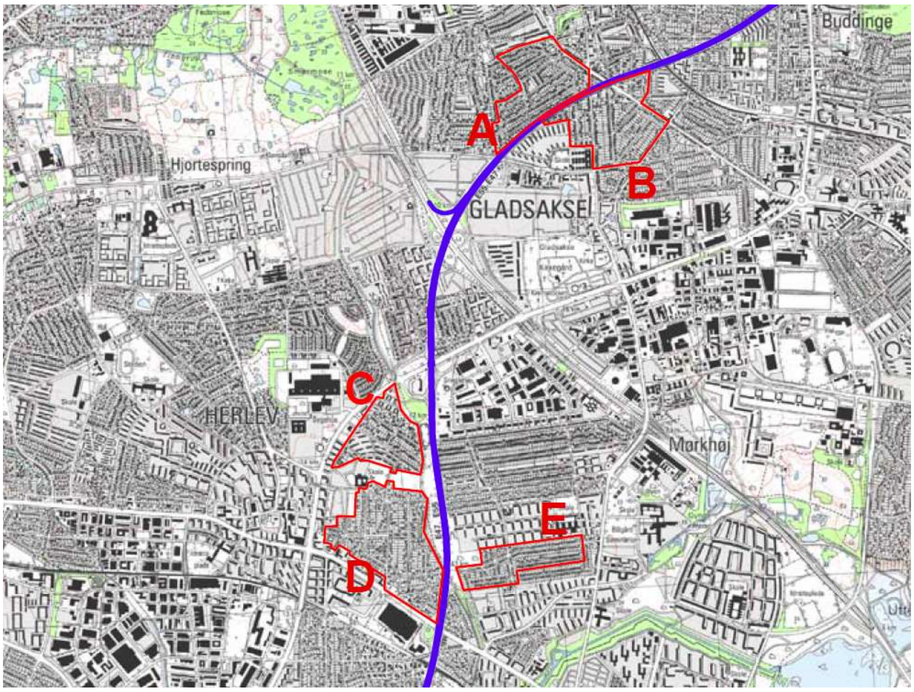

Figure 2 - Motorway M3 and 5 of the 6 areas of the survey.

2.2 Urban roads

The term urban roads is used for roads in open residential areas with partial multi-storeyed buildings, as opposed to the actual city streets, as for example known from Copenhagen city centre. Urban roads are represented by the areas around Kastrupvej (see Figure 4) and Frederikssundsvej where existing pavements were replaced with noise-reducing thin-layer asphalt. Apart from the replacement of the pavement no other noise reducing measures was made. There was no information campaign either.

Figure 3 - Photographs from Kastrupvej before the replacement of the pavement.

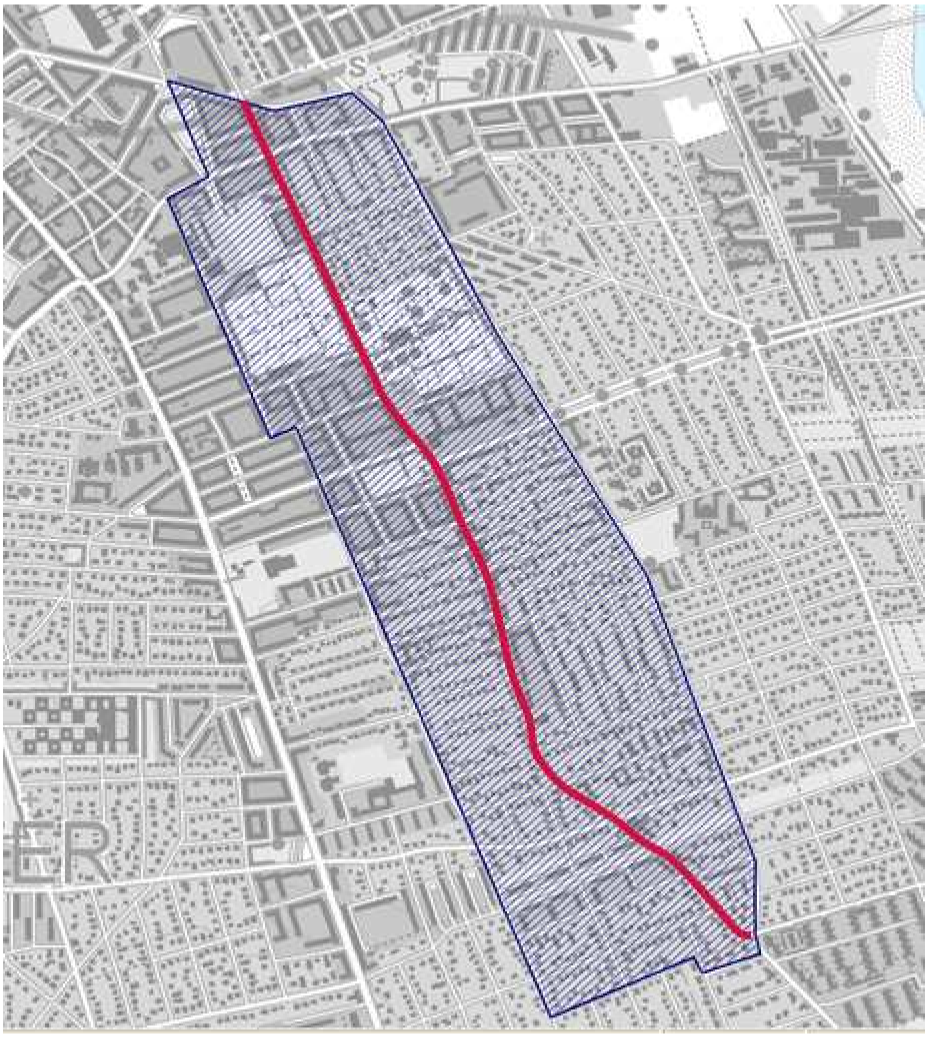

Figure - 4 Kastrupvej (red), one of the urban roads. The shaded box indicate the area of the survey.

3. Method

3.1 Calculation of noise exposures

The calculations of the noise exposures, L_{den}, at the facades of the respondents' homes were made with the road noise model in Nord2000, see reference (6). In both the before and the after the situation the calculation points, was located on the most exposed facade.

3.2 Self-reported noise annoyance

The two surveys of M3 and the urban roads had nearly identical questionnaires, which is a good basis for a comparison of the responses received. In both studies the question, in accordance with ISO 15666 (8) was included: “Thinking about the last year or so, when you are here at home, how much does noise from road traffic bother, disturb, or annoy you?”

The respondents gave their answers on both semantic and 0-10 point numerical (see Figure 5) categorical scales. A high linear correlation was found between the answers on the two types of scales.

The annoyance scores from the numerical scale are expressed as:

- The percentage of highly annoyed (%HA): Answers in categories 8, 9 and 10
- The percentage of (at least) annoyed (%A): Answers in categories 5 to 10
- The percentage of (at least) little annoyed (%LA): Answers in categories 3 to 10.

Not at all										Extremely
0	1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Figure 5 - Scale to indicate the answer to the question: Thinking about the last year or so, when you are here at home, how much does noise from road traffic annoy or disturb you?

3.3 Calculation of dose-response curves

Dose-response curves between the self-reported noise annoyance and L_{den} and 95% confidence intervals are calculated using logistic regression, see (13), where answers regarding noise annoyance are divided into 1 dB noise classes which are weighted according to the number of responses.

The dose-response curves are expressed as:

$$A = \frac{u}{1 + e^{-s(E-f)}} \quad (1)$$

Where:

- A is the percentage of annoyed (HA, A, LA) respondents
- u is the upper limit of A (i.e. u = 100)
- s is the slope of the inverse logit function
- E is the noise exposure (L_{den})
- f is the value of E for a fifty per cent annoyance response

4. Results

This section shows the main relationships between noise levels, L_{den} in dB for the dwellings and the percentage of annoyed (HA, A, LA) respondents. The curves are limited to the L_{den} intervals where observations exist.

4.1 Urban roads

There were no significant differences in dose-response curves for the areas around the two urban roads Kastrupvej and Frederikssundsvej, therefore the results from these two areas are merged. Furthermore the dose-response curves in the before situation are not significantly different from the after situation. Although the road surface has been replaced with a more noise-reducing type (the noise exposure was reduced by approx. 4 dB), it has not affected people's response to the noise in a way that changes the dose-response relationship. This means that people are responding to the noise they actually are exposed to whether it is before or after the change (perhaps with a tendency to a slightly less annoyance in the after situation than in the before situation for those who are highly annoyed). Thus, by means of curves one can directly convert a noise reduction to an annoyance reduction.

As the graphs in the before and after situation are not significantly different, it is meaningful to merge the data, which is done in Figure 6. The figure is based on the answers from 2870 respondent. The constants describing the curves according to equation (1) are listed in Table 1.

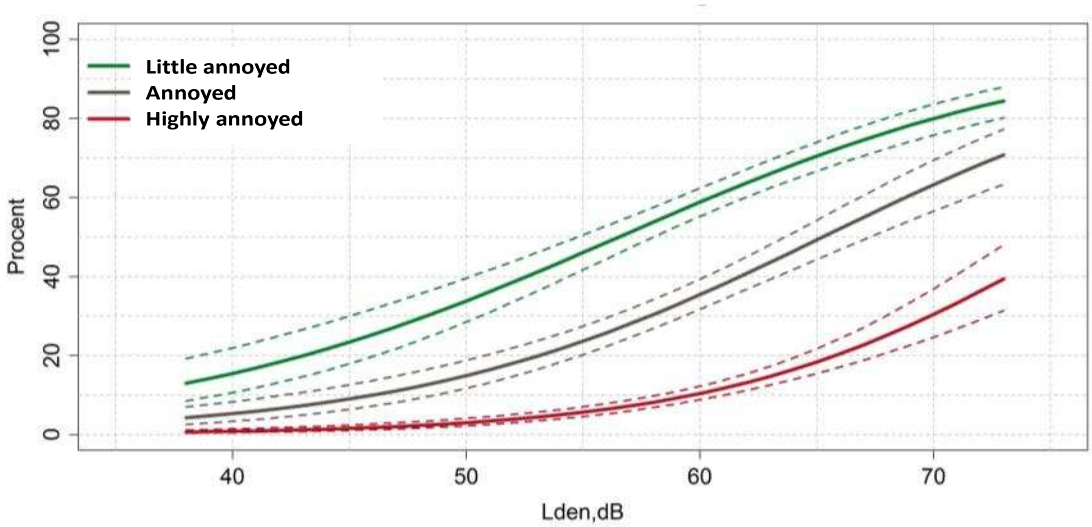

Figure 6 - Dose-response curves for data merged from both areas near the urban roads and for the pre-situation and the post-situation. The dashed curves indicate 95% confidence intervals for the curves. The number of respondents are: Highly annoyed: 563, Annoyed: 1217, Little Annoyed: 1758.

Table - 1Constants of dose-response curves in Figure 5 according to equation (1)

Constants for dose-response curves	f, dB	s
Little annoyed	56.5	0.103
Annoyed	65.3	0.114
Highly annoyed	76.2	0.133

Since there was neither significant differences between the two studied areas nor between the before and after situation we can assume that the dose-response curves in Figure 6 are representative of areas with urban roads, at least if they have the same character as the two studied areas. For more details, see References (9, 10)

4.2 Motorway M3

As the results were obtained from five relatively similar areas along the same motorway where the neighbours all have experienced the same reconstruction of the motorway, it was decided in advance to merge the results from these five areas.

Figure 7 shows the average response on the 11 point annoyance scale for different noise exposure levels. Only respondents where the exposure from M3 was at least 5 dB higher than the exposure from other roads in the area are included. The figure shows that the average response at noise exposures above about 58 dB is significantly higher in the before situation than in the after situation. The neighbours have in average, felt more annoyed (by the same noise exposure levels) in the before situation than in the after situation, especially at very high noise exposures.

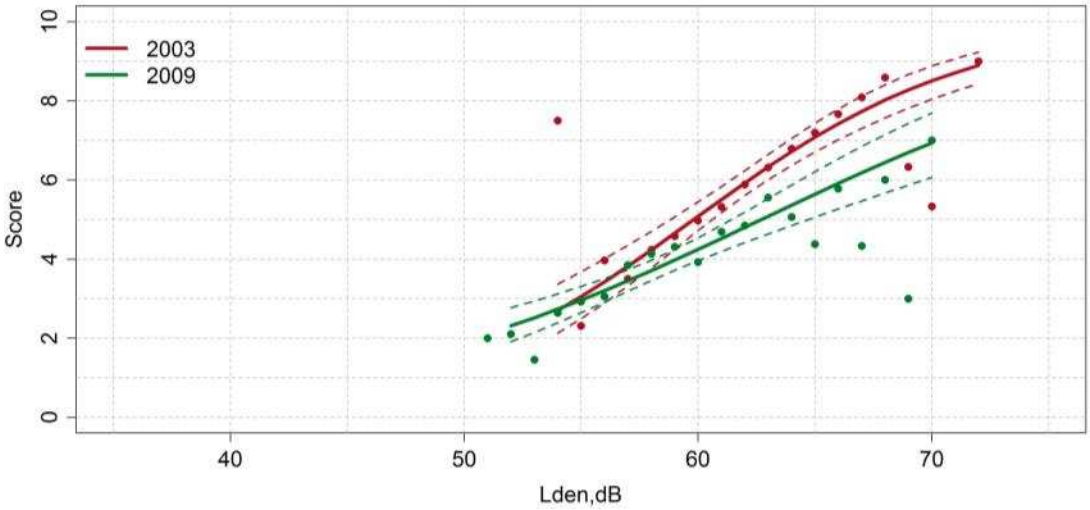

Figure 7 - The average response at the 11 point response scale in the before and in the after the study for comparison. The dashed curves indicate 95% confidence intervals for the curves.

This difference cannot be explained by the available data, but the very visible noise barriers, the information campaign and the change of the noise characteristics due to the screens are possible explanations. Based on the data underlying Figure 7, the dose-response curves for LA, A and HA are calculated, see Figure 8, with the corresponding constants in Table 2. This figure represents the situation where the before and after situation has been merged and the figure is based on 1350 responses.

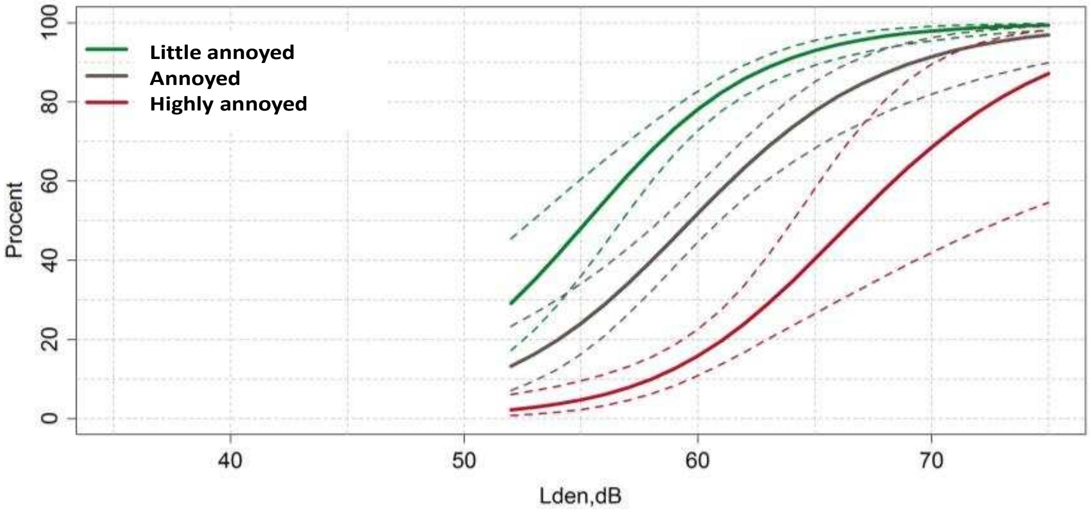

Figure 8 - Dose-response curves for M3 for pre-and post-situation overall. The dashed curves indicate 95% confidence intervals for the curves. The curve HA is based on 160 responses; A is based on 534 responses and the last curve LA is based on 778 responses. The confidence intervals around the combined curves are given as an average of confidence intervals in the before and in the after situation.

Table 2 - Constants for the dose-response curves in Figure 8 according to equation (1).

Constants for dose-response curves	**f**	**s**
Little annoyed	55.2	0.261
Annoyed	59.8	0.233
Highly annoyed	66.9	0.25

4.3 Comparisons of the two types of areas

The first very noticeable difference between the two studies is that one is concerning a motorway and the other is concerning urban roads. However, there are other differences that may have influenced the study's results. It is believed that the main differences are: An information campaign was associated with the expansion of M3 and the high noise barriers may be perceived as a promise of a good noise-reducing effect.

In conclusion this paper compares areas around a motorway surrounded by noise barriers and low residential houses with areas around urban roads where a significant proportion of the neighbouring residences are multi-storeyed buildings.

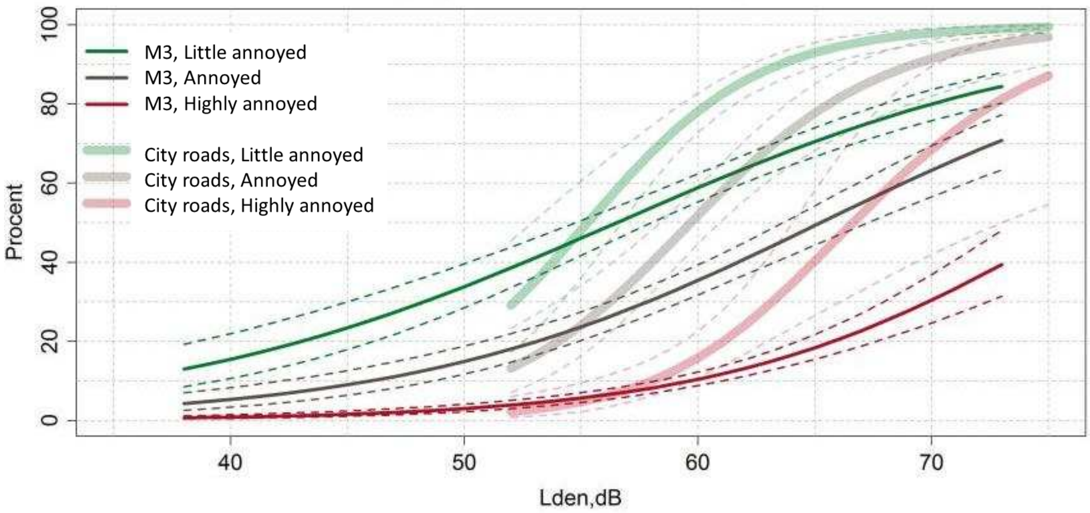

Figure 9 - Average curves before and after situation. Urban streets (thin curves) and M3 (bold curves). The dashed lines indicate 95% confidence intervals.

Figure 9 that represents the average of the before and after situation shows that above noise exposures of 55-58 dB is the noise from the M3 more annoying than the noise of urban roads.

5. Comparison with international results

In Figure 10 and Figure 11 the results from the M3 and urban roads are compared to international studies, reference (4). The international curves represent a compilation of many different studies and the proportion between motorways, roads, urban roads and city streets is not known.

Figure 10 shows that the annoyance at the M3 motorway is significant and essential higher than the annoyance found by the average of the international studies.

Figure 11 shows that the population near urban roads in Copenhagen are more annoyed by traffic noise than the international average. Table 3 shows that the steepness of the 'international' curves is generally less. This is to be expected when, as in the case of the 'international' curves, the results are the merged from many studies, with different questionnaires and contexts and with different calculation methods for noise exposures.

From the f constants (that indicates L_{den} level of 50% annoyance) in Table 3, it is seen that the people near the urban roads in Copenhagen will be equally annoyed as the international average by noise exposures that are 3-5 dB lower. For the M3 these figures are 6-12 dB.

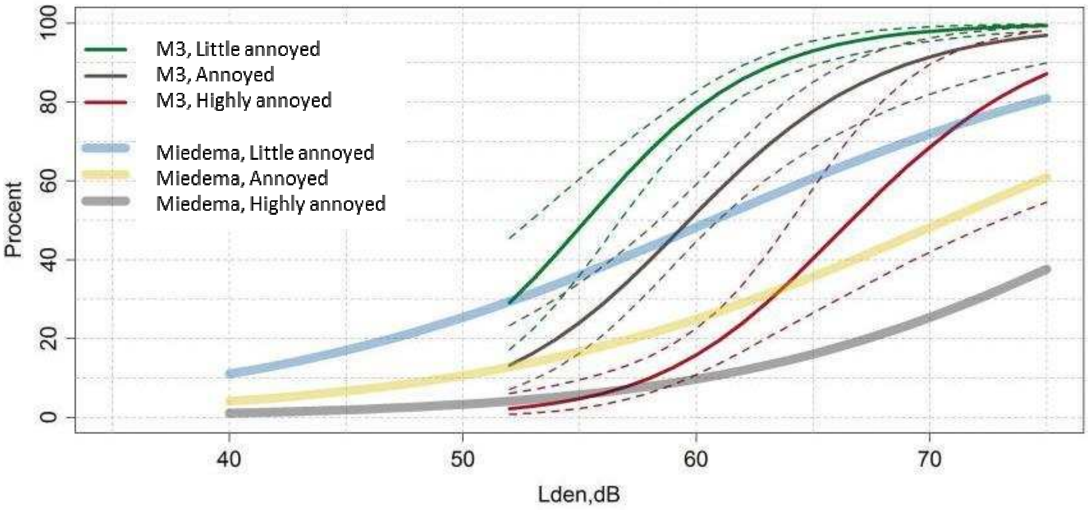

Figure 10 - Dose-response curves for road traffic noise from the M3, the average of the before and after situation (thin lines) compared to international data (bold pastel curves) from reference (4). The latter curves derived from 26 different international studies with a total of 19,172 observations. The dashed curves indicate 95% confidence intervals for M3.

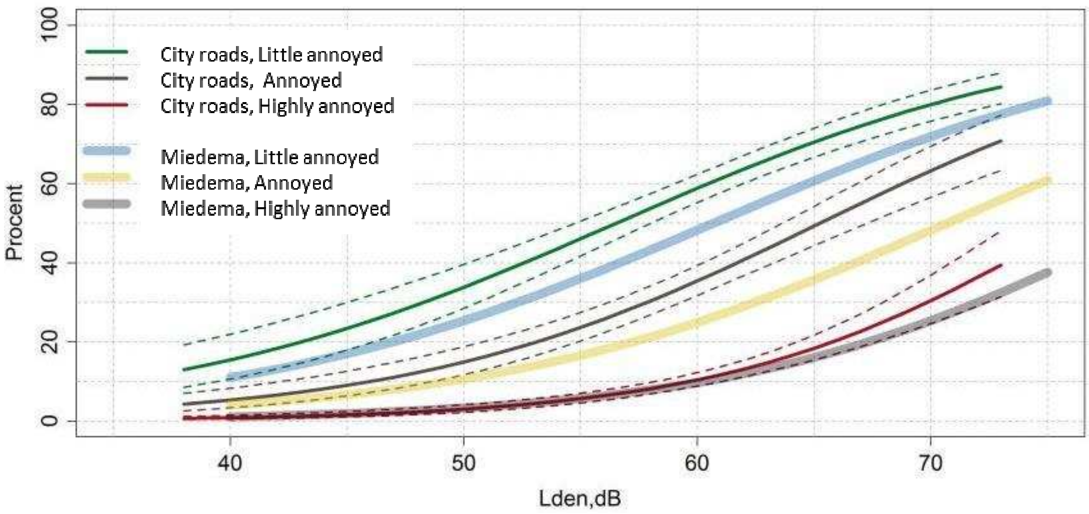

Figure 11 - Dose-response curves for road traffic in the two Copenhagen areas (thin lines - the same data as Figure 7) compared to the international data (bold pastel curves) from reference [11]. The latter curves derived from 26 different international studies with a total of 19,172 observations. The dashed curves indicate 95% confidence intervals for the Copenhagen results.

Table 3 - Constants for the dose-response curves in Figure 10 and 11 according to equation (1).

Constants for dose-response curves	**Urban**		**M3**		**Int.**		**Int. minus urban**	**Int. minus M3**
	f, dB	**s**	**F, dB**	**s**	**f, dB**	**s**	**f diff, dB**	**f diff, dB**
Little annoyed	56.5	0.103	55.2	0.261	60.7	0.101	4.2	5.5
Annoyed	65.3	0.114	59.8	0.233	70.7	0.103	5.4	10.9
Highly annoyed	76.2	0.133	66.9	0.25	79.4	0.115	3.2	12.5

6. CONCLUSIONS

For the urban roads there were no significant differences between the two areas or no significant differences between the pre-situation and the post-situation. Therefore we may assume that these dose-response curves are representative of areas with urban roads; at least if they have the same character as the two studied areas, i.e. open urban areas with a significant proportion of 3-5 storeyed residences. The change to a noise reducing pavement reduced the exposure with 4 dB corresponding to decrease of approximately 10% in the percentage of highly annoyed persons.

For the motorway M3 it was found that the average response was significantly higher in the pre-situation than in the post-situation. The neighbours had in average felt more annoyed in the pre-situation than in the post-situation by the same noise exposure levels especially at high noise exposures. This difference cannot be explained by the available data. We know that people’s expectations affect the perception so the 4 m high and very visible noise barriers, the information campaign and knowledge about the noise-reducing pavement may be plausible explanations for less experienced noise annoyance in the post-situation.

The most noticeable difference between the two studies is that one is concerning a motorway and the other is concerning urban roads. However, there are a number of other differences that may have influenced the results. The main one being that the areas next to M3 consists of villas and townhouses, as opposed to urban roads which are more characterized by blocks of flats. The residences next to of M3 have a slightly greater percentage of ownership. The self-reported noise sensitivity is slightly larger at M3. Other studies (5) show that annoyance is less when there are noise barriers, compared with the same levels of noise from a motorway without noise barriers. There were no noise barriers on the urban roads. In conclusion this report compares the areas around a motorway surrounded by noise barriers and low buildings with areas around urban roads where a significant proportion of neighbouring populations lives in multi-storey residences.

It was found that in the before situation the annoyance near the M3 motorway is significantly higher than for the Urban roads. In the after situation M3 was significant more annoying for exposures above 56 dB.

Compared to the average dose response curves for a large number of foreign studies, the study of M3 shows that at 50% annoyed (HA, A or LA) the neighbours were so much more annoyed that it corresponds to 6-12 dB more noise. The same is true, albeit to a lesser extent around urban roads. For highly annoyed there is no significant difference, but the percentage annoyed at L_{den} = 65 dB is 15% higher in Copenhagen (from 35% to 50%) than the international average. Persons near the urban roads in Copenhagen seems to be so much more annoyed that it is equivalent to 3-5 dB more noise.

It is unknown whether the dose-response for the urban roads also are representative for city streets with dense high buildings, as in the centre of Copenhagen.

REFERENCES

1. Bendtsen. H., Andersen, B. Thomsen. S. Optimized thin layers – urban roads – the Kastrupvej experiment. Danish Road Directorate, Danish Road Institute. Technical Note 66. 2008. See: http://www.vejdirektoratet.dk
2. Bendtsen. H, Christensen. E. C. Beboernes opfattelse af støjen ved Ringmotorvejen. Undersøgelse før og efter udvidelsen af M3. Sammenfatningsrapport. (Citizens perception of noise by the ring motorway. A survey before and after the enlargement of M3. Concluding Report (in Danish)). Vejdirektoratet. Report 187. 2010. See: http://www.vejdirektoratet.dk
3. Christensen. E. C. Noise annoyance from Motorway 3. A pre and post study. Danish Road Directorate Technical note 79-2010. See: http://www.vejdirektoratet.dk
4. European Communities. EU Position paper on Dose-response relationships between transportation noise and annoyance. ISBN 92-894-3894-0. European Communities. 2002.
5. Kastka. J., Buchta. U., Ritterstadt. U., Paulsen. R., Mau. U. The long term effect of noise protection barriers on the annoyance response of residents. Journal of Sound and Vibration 184 (5). 823-852. 1995
6. Kragh. J., Plovsing. B., Storeheier. S. Å., Jonasson. H. G. Nordic Environmental Noise Prediction Methods. Nord2000 Summary Report General Nordic Sound Propagation Model and Applications in Source-Related Prediction Methods. DELTA AV 1719/01. 2001 (revised 2002) http://www.madebydelta.com/imported/images/DELTA_Web/documents/TC/acoustics/av171901.pdf
7. Le Ray. G., Pedersen. T. H. Noise from Motorringvej 3. Dose-response curves with confidence intervals.

DELTA Technical Note AV 1030/11. 2011.
8. ISO 15 666 Acoustics. Assessment of noise annoyance by means of social and socio-acoustic surveys. 2003
9. Pedersen. T. H., Le Ray. G. Befolkningsreaktioner på støjreducerende vejbelægninger. (Citizens reaction to noise reducing pavements (in Danish)). DELTA SenseLab 001/12. 2012
10. Pedersen. T.H., Le Ray. G. Bendtsen. H., Kragh. J. Community response to noise reducing road pavements. Internoise 2014
11. Pedersen. T. H., Le Ray. G. Støjgener fra byveje og motorvej M3 (Noise annoyance at urban roads and motorways (in Danish)). Vejdirektoratet. Rapport 447. 2013. See: http://www.vejdirektoratet.dk
12. Pedersen. T. H., Plovsing. B., Backalarz. C., Le Ray. G. Forskel mellem genevirkning af motorvejsstøj og støj fra andre veje (Difference in annoyance of motorway noise and noise from other roads (in Danish)). Arbejdsrapport fra Miljøstyrelsen. Nr. 1. 2013
13. Pedersen. T.H. The “Genlyd” Noise Annoyance Model. DELTA report AV 1102/07. 2007. www.madebydelta.com (search for the title)
14. THE EUROPEAN PARLIAMENT. DIRECTIVE 2002/49/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 June 2002