

Preliminary Calculation Method for Determination of the Number of Persons Exposed to Environmental Noise

(Vorläufige Berechnungsmethode zur Ermittlung der Belastetenzahlen durch Umgebungslärm (VBEB))

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1. Field of application and objective

With the Preliminary Calculation Method for Determination of the Number of Persons Exposed to Environmental Noise ("Vorläufige Berechnungsmethode zur Ermittlung der Belastetenzahlen durch Umgebungslärm (VBEB)") the number of persons exposed to noise as well as the areas affected by noise and the number of dwellings, schools and hospitals that are exposed to noise can be determined. In accordance with the 34th Federal Immission Control Ordinance (Ordinance on Noise Mapping - BImSchV) [3]) such data has to be stated in noise maps.

The calculation method is based on VDI [Association of German Engineers] Guideline 3722, Part 2 [8], but has been adapted to the requirements of the 34th Federal Immission Control Ordinance and Annexes I, IV and VI of Directive 2002/49/EC [1].

2. Definitions

2.1 Exposure level

The noise indicator levels L_{den} and L_{night} (in dB), which express the exposure of a façade or part of a façade represented by assessment points.

2.2 Assessment point

Exposure level is calculated at points (assessment points) 4 m above the ground directly on the façade¹ of a building.

2.3 City block

Part of a predominantly developed building zone, which is usually enclosed on all sides by topographic lines, especially by roads or paths, and comprises one or more buildings with a minimum of three sides.

2.4 Side of a city block

Part of a city block that represents, uninterrupted by corners or directional change, the smallest spatial unit of reference of a block, comprising one or more buildings.

2.5 Building

Structure containing one or more dwellings. Buildings can be part of a city block or side of a city block.

2.6 Façade

Section of a digital ground plan of a building that is demarcated by two consecutive points with subsequent change of direction.

2.7 Façade section

Section of a façade that arises when a façade is longer than 5 metres and has therefore to be divided.

2.8 Gross floor area

Area of the ground plan of a building multiplied by the number of floors.

2.9 Dwelling floor space

Gross floor space of a building reduced by all areas not used for dwelling (for example, walls or staircases). The dwelling floor space of a building makes up, on average, around 80 per cent of its gross floor space.

3. Determination of numbers of persons exposed to noise

In accordance with Article 4 (4), sentence 1, clause 3 of the 34th Federal Immission Control Ordinance (hereafter: 34th BImSchV), data on the estimated number of persons living in areas lying between isophone bands is required in accordance with Article 4 (4), sentence 1, clause 1 of the 34th BImSchV in tabular form (number of persons affected). Data should be provided separately for each type of noise.

3.1 Assessment points

In calculating noise indicators L_{den} and L_{night} , assessment points are set, pursuant to Article 5 (2) and (3) 34th BImSchV, 4 metres above the ground directly on façades.

At least one assessment point per façade has to be selected. In the case of façades longer than 5 metres several assessment points are determined. For this purpose, the façade is divided into equally-long sections not longer than 5 metres and not shorter than 2.5 metres. The assessment points are always set in the middle of the façade or façade section.

Several consecutive façade sections, each not longer than 2.5 metres, which together have a length greater than 5 metres, are considered to be a continuous façade and are likewise divided into façade sections.

3.2 Calculation of noise indicators

Noise indicators are calculated separately for road traffic noise, rail traffic noise, aircraft noise as well as noise from trade and industry, in accordance with

¹ Note: For computational implementation a uniform distance of 0.1 m from the façade is recommended on algorithmic grounds.

preliminary calculation methods for environmental noise [4 to 7].

3.3 Allocation of numbers of residents to buildings

Determination of the number of persons exposed to noise is based on officially available data. This can include the number of floors or the base area of a building, as well as statistical data on dwelling floor space per inhabitant.

Procedures for allocation of inhabitant figures to buildings on the basis of different data bases are described in 3.3.1 to 3.3.4.

The prerequisite for estimation of inhabitant figures per building in the case of imprecise data is always the base area of the building and the number of floors.

3.3.1 Inhabitant figures are available for different points of reference

Dependent on the type of available inhabitant figures, the number of inhabitants of a building is determined according to the method described in the following table:

Inhabitant figures are available for:	Numbers of inhabitants EZ are determined for each building under consideration as follows:
Dwellings	$EZ_{building} = \sum_{i=1}^n EZ_{dwelling,i}$
Building	The number of inhabitants is directly assigned to the building under consideration.
Sides of a city block	
City blocks	$EZ_{building} = \frac{V_{building}}{V_{total}} \times EZ_{total}$
Districts	$V_{building} = G_{building} \times GZ_{building} \times h$
Place	
<p>Key: EZ stands for number of inhabitants / V stands for volume of residential buildings / GZ stands for number of floors / G = base area of a building h stands for average height between floors (3 metres can be assumed for average height between floors). "total" stands for data related to the total area under consider (for instance, city block or place).</p>	

3.3.2 Dwelling floor space per inhabitant is available for different points of reference

The number of inhabitants of a building is determined according to the method described in the following table when dwelling floor space per inhabitant is available.

Dwelling floor space per inhabitant is available for:	Number of inhabitants EZ is determined for the building under consideration as follows:
Sides of a city block	$EZ_{building} = \frac{G_{building} \times GZ_{building} \times 0.8}{WE}$
City blocks	
Districts	
Place	
<p>Key: EZ stands for number of inhabitants / GZ stands for number of floors / G stands for base area of a building / WE stands for dwelling floor space per inhabitant. "0.8" is the conversion factor (gross floor area → dwelling floor space)</p>	

Note:

According to experience, "dwelling floor space per inhabitant" is available only from the layer "side of city block". Current data is available at federal and state statistics offices. For the year 2003 the following mean values are given by the Federal Statistics Office:

- "Old" Federal States (formerly BRD):
 $WE = 41 \text{ m}^2$ dwelling floor space per inhabitant
- "New" Federal States (formerly GDR):
 $WE = 38 \text{ m}^2$ dwelling floor space per inhabitant

3.3.3 Dwelling floor space is available for different points of reference

Dependent on the type of dwelling floor space, the number of inhabitants of a building is determined according to the method defined in the following table.

Dwelling floor space is available for:	The number of inhabitants EZ is determined for the building under consideration as follows:
Dwellings	$EZ_{building} = \frac{\sum_{i=1}^n F_{building,i}}{WE}$
Building	$EZ_{building} = \frac{F_{building}}{WE}$
Sides of city blocks	
City blocks	$EZ_{building} = \frac{V_{building}}{V_{total}} \times \frac{F_{total}}{WE}$
Districts	$V_{building} = G_{building} \times GZ_{building} \times h$
Place	
<p>Key: EZ stands for number of inhabitants / V stands for volume of residential buildings / GZ stands for number of floors / G stands for base area of the building / F stands for dwelling floor space / WE stands for dwelling floor space per inhabitant (see Note in 0)</p> <p>h stands for average height between floors (3 metres can be assumed for average height between floors).</p> <p>"total" stands for data related to the total area under consider (for instance, city block or place).</p>	

3.3.4 Neither the number of inhabitants nor dwelling floor space is available

The number of inhabitants of a building is determined according to the method defined in the following table when neither the number of inhabitants nor the dwelling floor space is known.

The number of inhabitants EZ of the building under consideration is determined as follows:
$EZ_{building} = \frac{G_{building} \times GZ_{building} \times 0.8}{WE}$
<p>Key: EZ stands for number of inhabitants / GZ stands for number of floors / G stands for base area of the building / WE stands for dwelling floor space per inhabitant (see Note in 0) "0.8" is the conversion factor (gross floor area → dwelling floor space)</p>

3.4 Determination of number of persons affected in individual noise bands

Since the position, size and ground plan of dwellings in buildings are generally not known, as an approximation all inhabitants of a building are equally distributed among the assessment points specified for the building. The thus determined value "inhabitants per assessment point" is assigned to the exposure value at this point.

The specifications for the determination of assessment points ensure to a large extent that at least one assessment point is established for each dwelling.

Exposure levels are combined with the number of inhabitants allocated to them in noise bands pursuant to Article 4 (4), sentence 1, clause 1 of the 34th BImSchV. Due to the large number of assessment points (often for relatively few inhabitants), it is necessary to consistently calculate the number of persons affected with floating point numbers.

The results per noise band are rounded off to the nearest 100 inhabitants.

4. Determination of areas exposed to noise

In accordance with Article 4 (4), sentence 1, clause 7 of the 34th BImSchV, data is required in tabular form on areas exposed to noise at L_{den} values greater than 55, 65 and 75 dB. Data has to be provided separately for each type of noise.

Determination of area shares is based on noise maps for individual sources. Depending on raster resolution, the corresponding area is assigned to each calculation point. With a 10 m x 10 m raster an assessment point represents an area of 100 square metres that is exposed to the calculated noise level. Due to the small size of individual raster points it is necessary to determine interim results with a resolution of 1 square metre.

The overall area of each noise band has to be stated in square kilometres (rounded off to the nearest square kilometre).

Raster points at which calculation of exposure level does not take place (for example, inside buildings higher than 4 metres and in water areas), are not considered in determination of area shares.

5. Determination of dwellings, schools and hospitals exposed to noise

In accordance with Article 4 (4), sentence 1, clause 7 in connection with Article 4 (6) of the 34th BImSchV, data in tabular form is required on the estimated number of dwellings, schools and hospitals that lie in areas exposed to noise with L_{den} values in excess of 55, 65 and 75 dB. Data has to be provided separately for each type of noise.

The assignment of dwellings to exposure levels takes place analogous to the method for determination of the number of persons exposed to noise (see 3). If the number of inhabitants per dwelling is not known, a value of 2.1 inhabitants per dwelling can be assumed.

For assignment of schools and hospitals to exposure levels, an energetic average of individual values is applied analogous to the method for calculation of the number of persons exposed to noise.

6. Bibliography

- [1] Directive 2002/49/EC of the European Parliament and the Council of 25 June 2002 relating to the assessment and management of environmental noise
- [2] Gesetz zur Umsetzung der EG-Richtlinie über die Bewertung und Bekämpfung von Umgebungslärm vom 24. Juni 2005, BGBI. Teil I Nr. 38 vom 29. Juni 2005
- [3] 34th Ordinance on Implementation of the Federal Immission Control Act (Ordinance on noise mapping – 34th BImSchV) of 6 March 2006, German Federal Law Gazette (BGBI), Part I No. 12 of 15 March 2006
- [4] Vorläufige Berechnungsmethode für den Umgebungslärm an Straßen (VBUS), Vorläufigen Berechnungsverfahren für den Umgebungslärm vom 22. Mai 2006, Bundesanzeiger Nr. 154a vom 17 August 2006
- [5] Vorläufige Berechnungsmethode für den Umgebungslärm an Schienenwegen (VBUSch), Bekanntmachung der Vorläufigen Berechnungsverfahren für den Umgebungslärm vom 22. Mai 2006, Bundesanzeiger Nr. 154a vom 17. August 2006
- [6] Vorläufige Berechnungsmethode für den Umgebungslärm an Flugplätzen (VBUF), Bekanntmachung der Vorläufigen Berechnungsverfahren für den Umgebungslärm vom 22. Mai 2006, Bundesanzeiger Nr. 154a vom 17. August 2006
- [7] Vorläufige Berechnungsmethode für den Umgebungslärm durch Industrie- und Gewerbe (VBUI), Bekanntmachung der Vorläufigen Berechnungsverfahren für den Umgebungslärm vom 22. Mai 2006, Bundesanzeiger Nr. 154a vom 17. August 2006
- [8] VDI 3722 Part 2 Draft: Effects of traffic noise – characteristic quantities in the case of impact of multiple sources, February 2007

7. Example: Determination of numbers of persons exposed to noise

7.1 Establishing the position of assessment points

In order to better illustrate the basic rules for establishing the position of assessment points, the setting of assessment points is considered exemplarily for a more structured building (Figure 1).

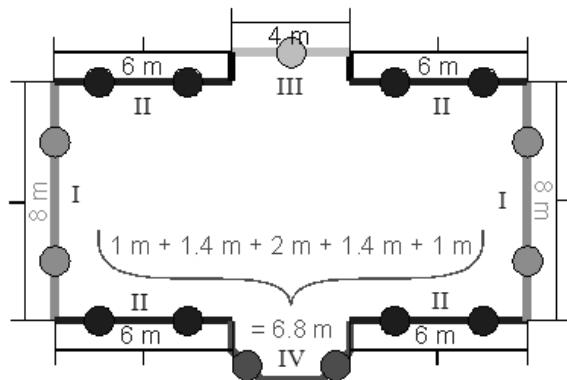


Figure 1: Example of establishment of the position of relevant assessment points

The position of relevant assessment points is determined according to the following procedure:

- All façades longer than 5 metres are divided into sections. An assessment point is calculated for each façade section. (I and II).
- For each remaining façade longer than 2.5 metres an assessment point is calculated (III).
- For all other façades it is examined whether several consecutive short façades together make up a length greater than 5 metres. Where this is the case (IV), they are treated as one façade and assessment points calculated accordingly.
- For the remaining façades assessment points are not determined.

7.2 Input data

In order to better illustrate determination of the numbers of persons exposed to noise, the procedure is examined for an exemplary building (Figure 2).

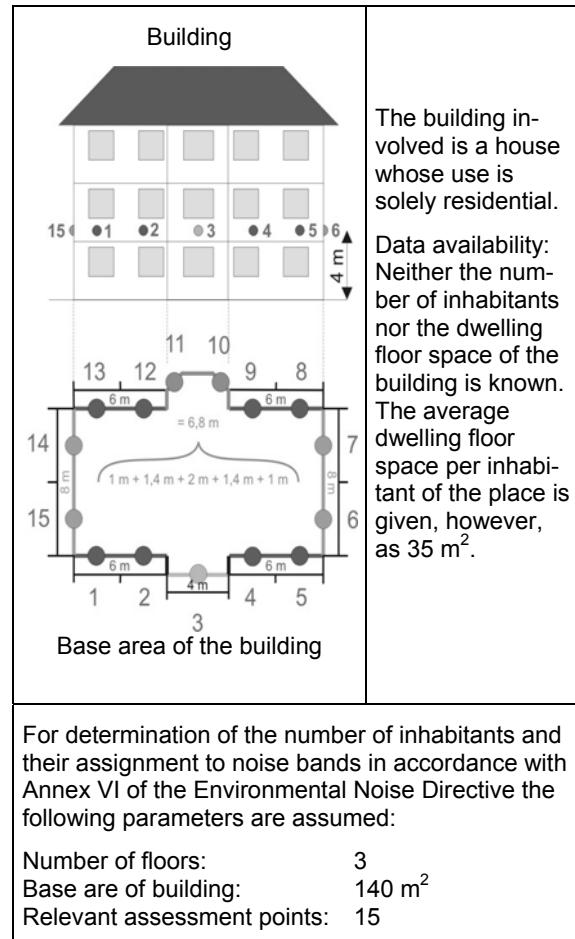


Figure 2: Exemplary determination of the number of affected inhabitants of a building

7.3 Determination of numbers of persons affected in individual noise bands

Determination of the number of inhabitants

The number of residents is calculated in accordance with 0 based on the equation:

$$EZ_{\text{building}} = \frac{G_{\text{building}} \times GZ_{\text{building}} \times 0,8}{WE_{\text{building}}}$$

$$EZ_{\text{building}} = \frac{140 \text{ m}^2 \times 3 \times 0,8}{35 \text{ m}^2/\text{inhabitant}} = 9.6 \text{ inhabitants}$$

Assignment of inhabitants to assessment points

$$\frac{9.6 \text{ inhabitants}}{15 \text{ Immission points}} = 0.64 \text{ inhabitants/immission point}$$

Assignment of inhabitants to noise bands

The calculation of exposure levels produced the following results:

Assessment point	L _{den} (dB)	L _{night} (dB)	Noise band	
			L _{den} (dB)	L _{night} (dB)
1	64	58	60 – 64	55 – 59
2	64	58	60 – 64	55 – 59
3	65	59	65 – 69	55 – 59
4	64	58	60 – 64	55 – 59
5	64	58	60 – 64	55 – 59
6	60	54	60 – 64	50 – 54
7	58	52	55 – 59	50 – 54
8	55	49	55 – 59	(45 – 49)
9	55	49	55 – 59	(45 – 49)
10	55	49	55 – 59	(45 – 49)
11	55	49	55 – 59	(45 – 49)
12	55	49	55 – 59	(45 – 49)
13	55	49	55 – 59	(45 – 49)
14	58	52	55 – 59	50 – 54
15	60	54	60 – 64	50 – 54

In accordance with Article 4 (4.1) of the 34th BlmSchV the number of inhabitants affected in the noise bands is as follows:

Noise band (dB)	Inhabitants affected L _{den}	Noise band (dB)	Inhabitants affected L _{night}
		(45 – 49)	(3.84)
		50 – 54	2.56
55 – 59	5.12	55 – 59	3.20
60 – 64	3.84	60 – 64	-
65 – 69	0.64	65 – 69	-
70 – 74	-	> 70	-
> 75	-		
Total:	9.60	Total:	5.76 (9.60)

8. Example: Determination of dwellings exposed to noise

8.1 Ascertainment of the position of assessment points

The position of assessment points is ascertained in accordance with the example in 7.1.

8.2 Determination of the number of dwellings in individual noise bands

The assignment of inhabitants to assessment points is carried out in accordance with the example in 7.2.

Since the number of inhabitants per dwelling is not known, the standard value of 2.1 inhabitants per dwelling is applied.

$$\frac{0.64 \text{ inhabitants/assessment point}}{2.1 \text{ inhabitants/dwelling}} = 0.30 \frac{\text{dwellings}}{\text{assessment point}}$$

The following dwellings thus lie within the noise bands:

Noise band	Dwellings
L _{den} (dB)	
55 – 64	4.20
65 – 74	0.30
> 75	-
Total	4.50

4.50 dwellings lie in the noise band greater than 55 dB; 0.30 dwellings lie in the noise band greater than 65 dB.

9. Example: Determination of schools and hospitals exposed to noise

9.1 Establishing the position of assessment points

The position of assessment points is established in accordance with the example in 7.1.

9.2 Determination of the continuous sound pressure level at a school and a hospital

Values for L_{den} were determined for individual assessment points on the basis of the table in 7.3.

For the school and the hospital the result is an energetic-averaged continuous sound pressure level of 61 dB.