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Acoustics I: noise abatement

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annoyance experiment with road traffic noise

experiment: procedure

- situation: daytime, relaxing on the balcony at home
- presentation of 6 samples of road traffic noise of different loudness (90 second each)
- note the degree of annoyance on a scale of 0..10
  - 10: insupportable annoyance (unerträgliche Störung)
  - 8: strong annoyance (starke Störung)
  - 5: moderate annoyance (mässige Störung)
  - 3: weak annoyance (schwache Störung)
  - 0: no annoyance at all (keine Störung)

experiment: sounds

road traffic noise calibration for 65 dB(A)

- sample 1
- sample 2
- sample 3
- sample 4
- sample 5
- sample 6

experiment: evaluation

percentage of highly annoyed persons (reported annoyance 8, 9, 10):

Sample	number
1	
2	
3	
4	
5	
6	

experiment: evaluation

Leq's:

sample	Leq
1	65 dB(A)
2	50 dB(A)
3	70 dB(A)
4	55 dB(A)
5	60 dB(A)
6	45 dB(A)

experiment: evaluation

percentage of highly annoyed persons (reported annoyance 8, 9, 10):

results 2012:

sample	level	number
3	70 dB(A)	16
1	65 dB(A)	10
5	60 dB(A)	4
4	55 dB(A)	0
2	50 dB(A)	0
6	45 dB(A)	0

experiment: evaluation

percentage of highly annoyed persons (reported annoyance 8, 9, 10):

results 2011:

sample	level	number
3	70 dB(A)	12
1	65 dB(A)	10
5	60 dB(A)	2
4	55 dB(A)	1
2	50 dB(A)	1
6	45 dB(A)	0

experiment: evaluation

percentage of highly annoyed persons (reported annoyance 8, 9, 10):

results 2010:

sample	level	number
3	70 dB(A)	11
1	65 dB(A)	5
5	60 dB(A)	2
4	55 dB(A)	1
2	50 dB(A)	0
6	45 dB(A)	0

experiment: evaluation

percentage of highly annoyed persons (reported annoyance 8, 9, 10):

results 2009:

sample	level	number
3	70 dB(A)	12
1	65 dB(A)	11
5	60 dB(A)	5
4	55 dB(A)	0
2	50 dB(A)	0
6	45 dB(A)	0

experiment: discussion of the experimental set-up?

- visual impression is missing
- too short
- improper localization information
- listening room reflections that would not occur in the outdoor situation
- missing other environmental noise sources
- samples with lower levels simulate larger distances to the source, however the temporal pattern remained constant

introduction - what is noise?

introduction - what is noise?

- noise is sound, sound is not necessarily noise
- individual sensitivity relative to noise varies significantly
  - everyone has its individual scale
  - annoyance strongly moderated by attitude towards noise source
  - depends on actual activity
  - depends on the momentary psychological situation
  - ...

introduction - what is noise?

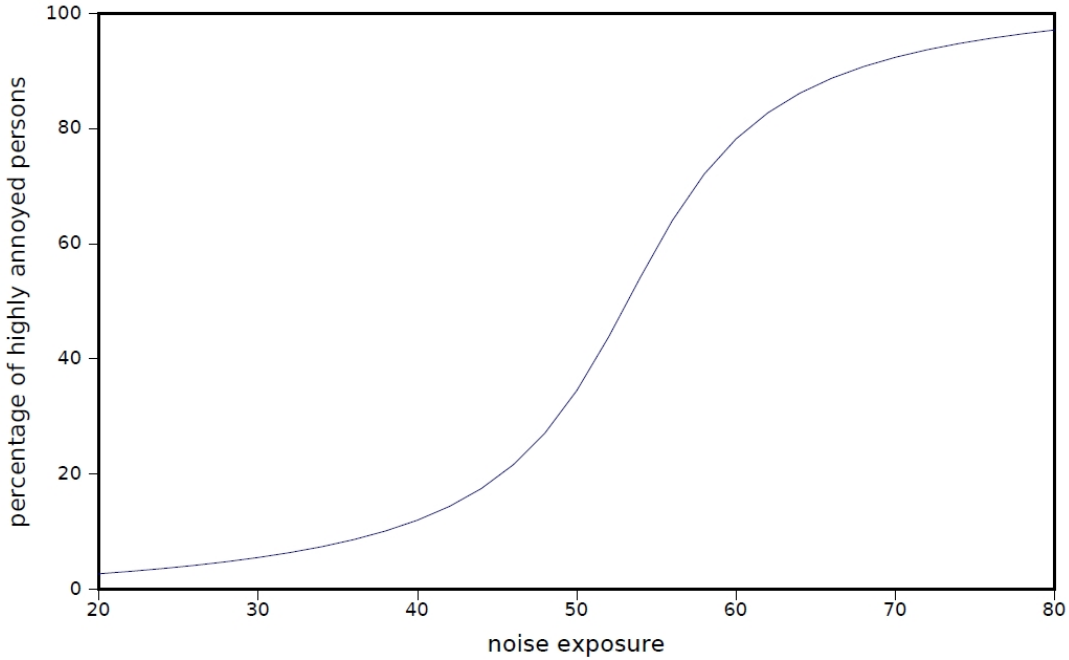
noise is unwanted sound

introduction - what is noise?

- noise can't be measured
- noise has to be assessed
- definition of objective assessment procedures for certain, well defined noise sources (for an average person)
- method: questioning of people regarding their annoyance and comparison with the noise exposure

introduction - what is noise?

exposure - annoyance curves:



- very sensitive persons
- very noise resistant persons

effects of noise

noise effects

physiological effects such as headache, cardio-vascular diseases, increased blood pressure, extensive pouring out of stress hormones, sleep disturbances and hearing defects in extreme cases

psychological effects such as stress and nervousness, reduction of productivity

social effects such as obstruction of communication, social segregation (those who can afford live in quieter areas)

economical consequences

prices of real estates noise burden has relevant influence on the value of a real estate

noise abatement measures costs for noise abatement measures such as installation of noise barriers ...

health problems and loss of productivity noise induced health problems cause health costs and loss of productivity

general aspects of the assessment of noise

assessment of noise

- general assumption: noise annoyance = f(exposure)
  - exposure = f(intensity, number of events)
- exposure $\rightarrow$ average values
  - reference time period = 1 year
- assessment process: comparison of noise exposure with limiting values

assessment of noise

- sensitivity to noise = f(time of day)
- strategies to account for:
  - several limiting values = f(time of day)
    - L_d: level during day
    - L_n: level during night
  - one integral level with penalties = f(time of day)
    - L_{den}: *day-evening-night* level
    - L_{dn}: *day-night* level

assessment of noise: L_{den}

$$L_{den} = 10 \log \left(\frac{1}{24} \left[12 \cdot 10^{0.1(L_d)} + 4 \cdot 10^{0.1(L_e+5)} + \right. \right.$$
$$\left. \left. + 8 \cdot 10^{0.1(L_n+10)} \right] \right)$$

where

L_d: average receiver level during the day (12 h)

L_e: average receiver level during the evening period (4 h)

L_n:average receiver level during the night period (8 h)

assessment of noise: L_{dn}

$$L_{dn} = 10 \log \left(\frac{1}{24} \left[15 \cdot 10^{0.1(L_d)} + 9 \cdot 10^{0.1(L_n+10)} \right] \right)$$

where
L_d: average receiver level during the day (7:00 till 22:00)
L_n:average receiver level during the night period (22:00 till 7:00)

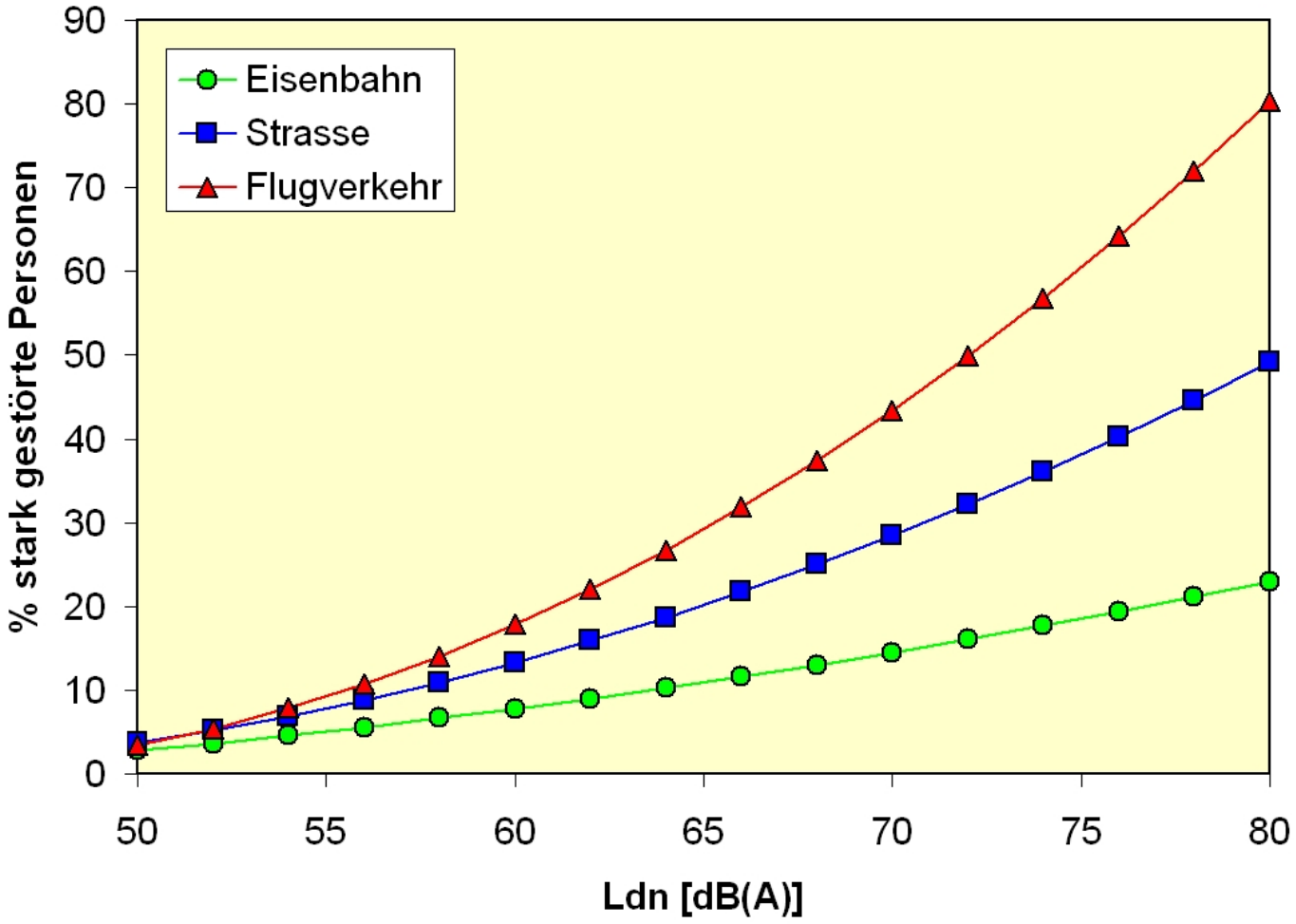
influence of the source type

influence of the source type

- annoyance differs for different noise sources (for identical A-weighted sound pressure level)
  - spectral content
  - temporal pattern
  - attitude towards the noise polluter
  - ...
- $\rightarrow$ consequence: assessment is performed separately for each noise source type

influence of the source type

meta study of Miedema and Vos:



definition of limiting values

definition of limiting values

- data basis: response of annoyed people with corresponding exposure values
- evaluation of the category "highly annoyed" (8..10 on the 10 point scale)
- development of a functional relation between exposure and percentage of highly annoyed persons
- limiting value: value of the exposure for 15. . .25 % highly annoyed persons

legal basis in Switzerland

legal basis in Switzerland

- Environment Protection Law USG
- Noise Abatement Ordinance LSV

legal basis in Switzerland: USG

- implementation of the Environment Protection Law: 1985
- aim: protection of humans, animals and plants against harmful and annoying impacts
- principle of precaution: detection of potential impacts in advance
- limitation of the emission at the source
- assessment by comparison of the exposure with impact thresholds
  - separate definition for most important types of noise sources
  - impact threshold guarantees that the population is not sincerely annoyed
  - law is further detailed in the Noise Abatement Ordinance LSV

Noise Abatement Ordinance LSV

- LSV has been put into force in 1987 (several extensions since then)
- aim: defines specific rules and precedures for the application of the Environment Protection Law with respect to noise
- contains declarations:
  - regarding construction, operation and rehabilitation of facilities
  - regarding construction of new buildings with noise sensitive usage

LSV principles

scheme of limiting values

scheme of limiting values

- 3 limiting values:
  - impact threshold (IGW): limit of the noise exposure that has to be tolerated
  - planning value (PW): implementation of the principle of precaution
  - alarm value (AW): identification of severe situations with urgent need for the realization of noise abatement measures
- 4 sensitivity levels (differentiation according to usage):
  - ESI: special zones for recreation
  - ESII: zones for living
  - ESIII: zones for living and industry (often centers of cities and villages)
  - ESIV: zones for industry only

construction, operation and sanitation of facilities

$\longrightarrow$ noise sources

construction, operation and sanitation of facilities

- fundamental principle of the LSV: all noise sources have to reduce their emissions as much as possible at least to a degree that is affordable

construction, operation and sanitation of facilities

- requirement for new or heavily altered installations:
  - planing values in the neighborhood have to be satisfied
  - possible relaxations for private installations:
    - up to impact threshold (in case of public interest or disproportional effort)
  - possible relaxations for public installations:
    - no limitation (however above impact threshold installation of sound-proof windows is mandatory)

construction, operation and sanitation of facilities

- requirements for existing installations:
  - impact thresholds in the neighborhood have to be satisfied (if necessary improvement of the installation)
  - possible relaxations for private installations:
    - up to alarm value (in case of disproportional effort)
  - possible relaxations for public installations:
    - no limitation (however above alarm value installation of sound-proof windows is mandatory)

construction, operation and sanitation of facilities

- requirements for significantly altered installations:
  - impact thresholds in the neighborhood have to be satisfied (if necessary improvement of the installation with no delay)
  - possible relaxations for public installations:
    - no limitation (however above impact thresholds installation of sound-proof windows is mandatory)

construction permits

$\rightarrow$ receivers

construction permits

- LSV principle: prevention that new buildings with noise sensitive usage are built in areas with high noise burden

construction permits

- condition for new zones for buildings: in accordance with planing values
- condition for buildings in already developed zones: in accordance with impact thresholds
  - exceptions in case of public interest, e.g. if a gap in row of houses is closed to create a quiet backyard
- position of assessment: center of the most exposed open window of a room with noise sensitive usage
  - noise abatement strategies:
    - reduction at source
    - shielding of direct sound
    - orientation away from the source
    - windows that can't be opened

assessment of road traffic noise

LSV: road traffic noise

- rating level Lr for day(6-22) / night(22-6)
  - $Lr = Leq + K1$
  - Leq: yearly average A-weighted sound pressure level
  - $K1 \leq 0$: level correction for low traffic densities

LSV: road traffic noise

scheme of limiting values (d=day, n=night):
PW: planning values
IGW: impact thresholds
AW: alarm values

ES	PWd	PWn	IGWd	IGWn	AWd	AWn
I	50	40	55	45	65	60
II	55	45	60	50	70	65
III	60	50	65	55	70	65
IV	65	55	70	60	75	70

assessment of railway noise

LSV: railway noise

- rating level Lr for day(6-22) / night(22-6)
  - $Lr = Leq + K1$
  - Leq: yearly average A-weighted sound pressure level
  - $K1$: level correction as a function of train density:
    - -15 dB for less than 8 trains per day or night
    - -15...-5 for 8...80 trains per day or night
    - -5 dB for more than 80 trains per day or night
- scheme of limiting values identical to road traffic noise $\rightarrow$ 5 dB bonus for railway noise

assessment of industry noise

LSV: industry noise

- rating level Lr for day(7-19) / night(19-7)
  - large variation of the noise character $\rightarrow$ separation in *phases i*
  - $Lr = 10 \log \left(\sum 10^{(0.1 Lr_i)} \right)$
  - $Lr_i = Leq_i + K1_i + K2_i + K3_i + 10 \log \left(\frac{t_i}{t_o} \right)$

LSV: industry noise

- $Lr_i = Leq_i + K1_i + K2_i + K3_i + 10 \log \left(\frac{t_i}{t_o} \right)$
- Leq_i: equivalent A-weighted sound pressure level during phase i
- $K1_i$: source type dependent correction for phase i (5 or 10 dB)
- $K2_i$: tone correction for phase i (0..6 dB)
- $K3_i$: impulse correction for phase i (0..6 dB)
- t_i: average daily duration of phase i in minutes, where $t_i = \frac{T_i}{B}$
- T_i: yearly duration of phase i in minutes
- B: number of days per year the plant is in service
- $t_o = 720$ minutes
- scheme of limiting values identical to road traffic noise $\rightarrow$ at least 5 dB malus

LSV: industry noise

examples of tone and impulse correction:

Sample	tone	impulse
1: squeaking	4..6	0..2
2: water jet	0..2	0
3: junk iron processing	0	2..4
4: unloading of a truck	2	0..2
5: bottles	0..2	4..6
6: motor saw	6	0
7: corona noise	4..6	0

assessment of noise from shooting ranges

LSV: noise from shooting ranges

- rating level Lr
  - $Lr = L + K$
  - L: average maximum level (A-Fast) of a single shot
  - $K = 10 \log(Dw + 3 \cdot Ds) + 3 \log(M) - 44$
    - Dw: number of half-days with activity during the week per year
    - Ds: number of half-days with activity at Sundays per year
    - M: number of shots fired in one year

LSV: noise from shooting ranges

scheme of limiting values:
PW: planning values
IGW: impact thresholds
AW: alarm values

ES	PW	IGW	AW
I	50	55	65
II	55	60	75
III	60	65	75
IV	65	70	80

assessment of aircraft noise

LSV: aircraft noise

- rating level Lr for
  - day period (6-22)
  - first hour of the night (22-23)
  - second hour of the night (23-24)
  - last hour of the night (5-6)
  - $Lr_{day} = 10 \log(10^{0.1 Lr_k} + 10^{0.1 Lr_g})$
    - Lr_k: A-weighted average sound pressure level for a day with average peak service and a correction based on the number of flight operations from small aviation
    - Lr_g: A-weighted, yearly average sound pressure level (6-22) from large aviation
  - Lr_{else}: A-weighted, yearly average sound pressure level from large aviation for the corresponding hour

LSV: aircraft noise

scheme of limiting values:

- limiting values during day similar to values for road traffic noise
- impact thresholds for the second and last night hour identical to night time values for road traffic noise
  - however "evaluation per hour" is stricter $\rightarrow$ no smearing over whole night period

preview Acoustics 2

topics of Acoustics 2

- Electro-mechanical-acoustical analogies
- Microphones
- Loudspeakers
- Sound storage media
- Recording technique
- Reproduction of audio signals
- P.A. systems
- Audio signal processing
- Loudspeaker demonstration

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