Atelier : Le bruit dans les bureaux : conséquences sur les performances - Traitements acoustiques

Acoustical evaluation and planning of offices

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Summary
In an investigation financed by the BAuA Germany a systematic approach for the acoustically oriented layout planning of offices has been developed [1, 2, 3, 4, 5]. Basis of this concept was the result of measurements in some hundred offices. Workplaces in offices are acoustically qualified using three criteria – the identification of source responsible for the existing level, the understandability of speaking at other workplaces and the near sound pressure level in dB (A). Emission levels of typical equipment used in offices are given to calculate approximately the sound exposure at workplaces. A layout example for an office for about 50 people is presented to demonstrate the systematic of the acoustical planning and qualification.

Résumé
Une approche systématique de l'organisation spatiale des bureaux a été développée dans le cadre d'une étude financée par l'Institut fédéral pour la sécurité et la santé au travail allemand (BAuA). Cette approche est fondée sur les résultats de relevés effectués dans des centaines de bureaux. Les caractéristiques acoustiques des postes de travail dans les bureaux sont évaluées selon trois critères - identification de la source de bruit, intelligibilité de la conversation à d'autres postes de travail, et niveau de pression acoustique en dB (A). Les niveaux d'émission d'équipements couramment usités dans un bureau ont été utilisés pour calculer l'exposition au bruit des postes de travail. Cet article présente un exemple d'agencement pour un bureau d'une cinquantaine de personnes afin d'illustrer une organisation systématique du lieu de travail selon des critères acoustiques.

Most people of the working population spend the biggest part of their working hours at offices collecting, processing and saving information. This kind of work requires modern equipment of information and communication technology. Using these technologies it is possible to highly increase the efficiency and therefore the productivity of the workforce. In order to control these technologies, hardware and software likewise, it is necessary to train the operators professionally. Furthermore these jobs demand that operators stay focussed for a long time. A ergonomic design of the working places is required and the environment should not detract the concentration by disturbing immissions. One of these immissions amongst others is noise.

The regulations such as Directive 2003/10/EC concerning the protection of employees from harmful noise that can affect the hearing, do not provide an informative basis for the assessment of office working places. In order to meet the requirements much lower target values should be applied when office working places are designed. In order to meet the increased requirements noise abatement strategies and measures should be implemented. Therefore the emission of each single source has to be kept as low as possible and the room has to be designed in a way that with a given emission the lowest possible sound level can be achieved at the working places.

However these measures are to be regarded and evaluated in combination with other requirements of suchlike office working places. Also there are quite concrete requirements regarding the sectioning of the working area, the seating arrangements of the employees and their position relative to their screen, keyboard and other operational controls as well as their position relative to other workers, which also should be taken into account within acoustic studies.

A description is given to noise layout for large scaled offices with many working places. These kinds of offices are characterized by intervisibility between the workforces. They can communicate directly without entering a different room. The gain of this easy way to communicate comes along with some disadvantages or difficulties when designing an acoustically acceptable atmosphere. When planning these kinds of office landscapes it is absolutely essential to consider acoustic aspects so that frustration

and disappointment caused by permanent distraction at workplaces can be avoided. The designer of those workplaces should make use of every possibility in order to provide employees a suitable environment for their work.

Requirements

Normally the aims of an adequate acoustic design are specified as the maximum allowable or aspired A-weighted sound pressure level or rating level [6] respectively noise-exposition level. These kind of limiting values mostly are orientated on levels, whose shortfall is at limited risk only for the occurrence of undesirable effects. The criteria "hearing loss" according Directive 2003/10/EC or "understandability of speech" – according to VDI-Guideline 2569 "Noise protection and acoustic design in offices" [7] are insufficient for the formulation of objectives for working places. They do not assure a desirable acoustic atmosphere at workplaces.

Suitable requirements take into account the human perception and the reaction of persons concerned. As a matter of principle any kind of noise exposure that is not caused by the considered person itself is to be regarded as disturbance when performing a concentrative activity. Self-induced noise, such as the own speech and that of one's conversational partner, the noise of one's keyboard and expected communicational noise (e.g. one's own telephone ringing) are perceived differently than noise from technical devices (e.g. computers), noise caused by other people and that which one does not have influence on. These noises are perceived as annoyance.

In order to describe emission and immission of noise the most important indicator for annoyance by noise is the average sound pressure level in dB(A) respectively rating level at the workplace. The term noise level will be used in the following as an abbreviation for the average A-weighted sound pressure level related to a specific time interval. At a given noise level a monotonous noise which is not assignable to a specific source, is perceived as less distracting than noise which is relatable to a source because of its temporal structure, frequency spectrum or its level difference to the background noise. The degree of annoyance is especially high, if noise is caused by understandable speech. The following three complains, which were condensed of numerous statements of everyday's life at offices meet the requirements in a pragmatic way.

- Criterion 1 (Annoyance caused by a single dominating source):
The difference between the part of the noise level caused by an individual source and the lower part of the noise level caused by the remaining sources should not exceed 4 dB. Otherwise the workplace is to be classified as "unfavourable".

- Criterion 2 (Annoyance caused by speech):
Speech from workplaces of other functional groups and from beyond should not be understandable. The difference between the part of noise level caused by the speech of people who are not linked to the same functional area and the higher part of noise level caused by the remaining sources has to be at least 3 dB. Otherwise the workplace is to be classified as "unfavourable".

- Criterion 3 (continuous noise load):
The noise level caused by all sources together should be as low as possible, in times, when the person at the considered workplace is not working, but prepared to start working,. The qualification can be made according to table 1

Noise Level (rating level at the workplace)	Acoustical quality of office workplaces
≤ 30 dB(A)	excellent
> 30 dB(A) and ≤ 40 dB(A)	very well
> 40 dB(A) and ≤ 45 dB(A)	well
> 45 dB(A) and ≤ 50 dB(A)	acceptable in large offices
> 50 dB(A) and ≤ 55 dB(A)	unfavourable
> 55 dB(A)	Noise load too high

Table 1 : Acoustical quality of office workplaces

These three requirements are applicable for different office sizes. If the criteria 1 till 3 come to different estimation the most unfavourable applies for the characterisation of the workplace.

Noise sources

The requirements refer to the noise level at workplaces caused by all sources. In order to estimate the noise levels at workplaces inside a planned office, a calculation based on the emission values of all single sources have to be done according to the methods for the calculation of sound propagation [8].

In large scaled offices with many workplaces a lot of sources contribute to an overall level which in the following will be called also background level Lb.
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- Noise from sources which are located inside the room :
These are machines and equipment such as computers, printer and copier. Further sources that often cause significant acoustical problems inside offices are other people talking as well as other noise, connected to their communication (e.g. ringing of telephones).

- Other noises particularly from outside the room :
However the bigger the floor space of the office, the smaller is the importance of noises from outside. They are primarily caused by :
- noise from outside the building (e.g. traffic noise)
- noise from neighbouring rooms (e.g. other offices, production or plant rooms)
- noise from ventilation and air condition (this has to be observed especially if the regarded office itself is ventilated and therefore air discharge openings are present) o noise from other building services such as heating installations, elevators, gates of underground parking lots.

In large size offices an important part of the resulting noise level is according to the fisrt item. The required estimation and qualification is shown in the following example.

Example

The following example shows how an acoustic design for an open-plan office inside an administrative building can be applied. Figure 1 shows the layout (only half of the room is displayed) with 56 workplaces. Each workplace is supposed to be equipped with a computer and a laser printer. The areas of different functional groups are marked with dashed lines.

Noise source	Range of values		Values for planning dB(A)
	Above dB(A)	Up to dB(A)	
Speaking person (at the phone)	55	70	65
Computer idling (fan, disk, drive)	30	50	**45**
Computer disk access	35	55	50
Computer by using keyboard	55	65	60
Laser printer idling	<< 30	46	42
Laser printer printing	**55**	60	58
Copier idling	50	60	58
Copier printing	60	70	67
Phone ringing	60	80	70

Table 2 : Sound power level LwA of noise sources that determine the noise level in office

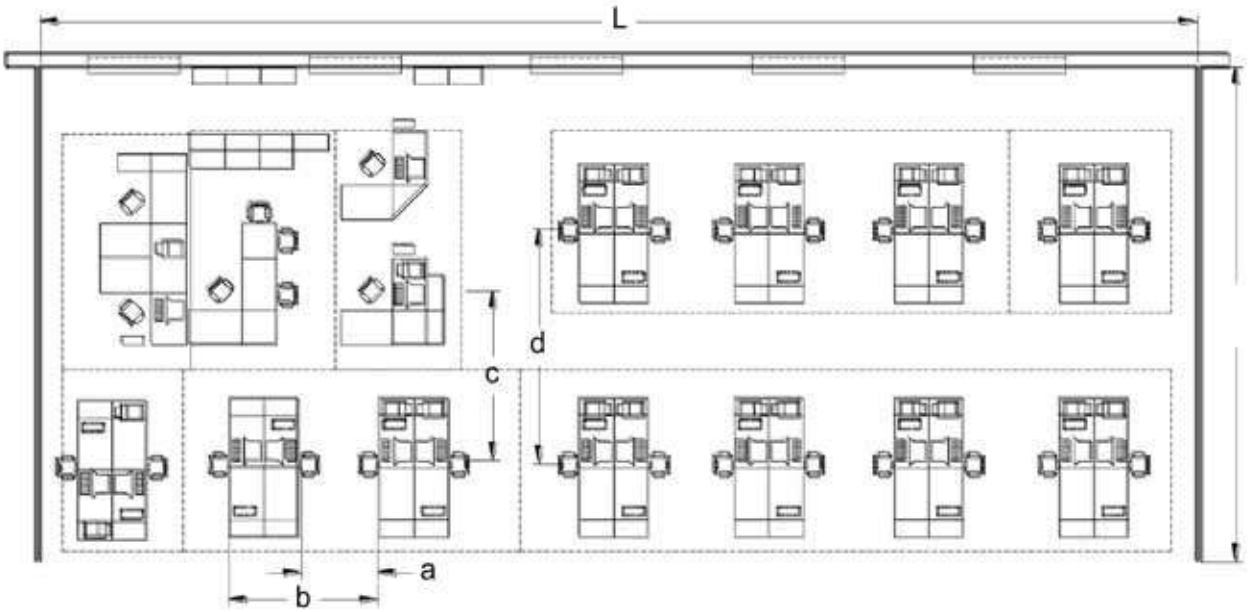

Fig. 1 : Layout of an open-plan office for administration (one half displayed only). The dimensions are L = 27 m ; B = 21 m ; H = 2,75 m ; a = 1,8 m ; b = 3,5 m ; c = 4 m and d = 5,5 m

Basic information

With the dimensions of the room mentioned above each of the 56 workplaces shares an average area of :

$$S\text{»} = (27 \times 21) / 56\ m^2 = 10\ m^2 \qquad (1)$$

The table 2 shows the sound power levels of the essential noise sources inside the office. The data approximately matches the state of the art of year 2000.

Based on the values for planning of table 2 the sound power level at a workplace with one computer (idling) and one laser printer (idling) results in:

$$L_{WA,equipment} = \{45\ (+)\ 42\}\ dB(A) = 47\ dB(A) \qquad (2)$$

(The symbol (+) indicates the energetic summation of the levels)

The sound power level of conversations per workplace can be determined according to relation (3). The determination is based on the sound power level of a relaxed talking person with approximately 55dB(A) and an added correction value dL_{part} depending on the part k of persons that are talking at the same time.

$$L_{WA,speech} = 55\ dB(A) + dL_{part} \qquad (3)$$

with dL_{part} according to following table

Office type	Part k	dL_{part}
Call center	1	0
Sales department	0,8	-1
Administration	0,25	-6
Design Office	0,1	-10

Table 3 : dLpart for several office utilization

As this example concerns the office type “administration” it follows:

$$L_{WA,speech} = (55 - 6)\ dB(A) = 49\ dB(A) \qquad (4)$$

The overall sound power level LWA,wp of one workplace is calculated as the energetic summation according to:

$$L_{WA,wp} = L_{WA,equipment} (+) L_{WA,speech} = \{47 (+) 49\} \text{ dB(A)} = 52 \text{ dB(A)} \quad (5)$$

Determination for criterion 3 (continuous noise load)

The above calculated noise power level $L_{WA,wp}$ inside the office results in an average value of the background level Lb according to following relation. The correction values are related to the area per workplace, ceiling type and noise screens.

$$L_b = L_{WA,wp} + dLl_{ayout} + dL_{screen} \quad (6)$$

The influence of suspended ceilings with absorbing characteristics and the average area size per workplace is show in the following diagram.

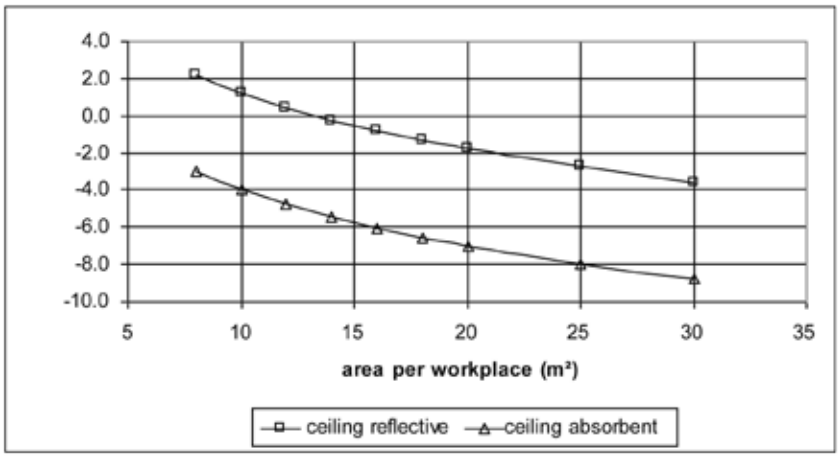

Fig. 2: Effect of area per working place on the background level for absorbent ceilings When reading the diagram figure 2 one has to bear in mind, that it shows the change in the level at a workplace that has been regarded to be in 1m distance to "its" source itself. The effect on the sound level caused by a ceiling with absorbing characteristics is bigger between different workplaces.

The background level also depend considerably on application of absorbing noise sceens. For open- plan offices with noise screens of approximately 2 m height the correction value dL_{screen} is given in the following table.

Noise screen (2 m height)	Ceiling	
	Reflective	Absorbent
Reflective	0	-2
Absorbent	-1	-4

Table 4 : dLscreen for estimation of the background level Lb

In the example it is not intended to use noise screens at first and the ceiling should be designed reflective. In this case the following values for the background level results:

$$L_b = (52 + 0 + 0) \text{ dB(A)} = 52 \text{ dB(A)} \quad (7)$$

With absorbent ceiling, but without screens follows:

$$L_b = (52 - 2 + 0) \text{ dB(A)} = 50 \text{ dB(A)} \quad (8)$$

With absorbent ceiling and absorbent noise screens following level is achievable:

$$L_b = (52 - 2 - 4) \text{ dB(A)} = 46 \text{ dB(A)} \quad (9)$$

Determination for criterion 2 (Annoyance caused by speech)

The two following pictures show the necessary distance between workplaces of different functional groups, so that communication noise does not cause unacceptable annoyance. The calculations of these diagrams take place for a sound power level of speech of 65 dB(A) and the condition, that the sound pressure level caused by speech is 5 dB below the background level.

The results for the floor size of 567 m² are :

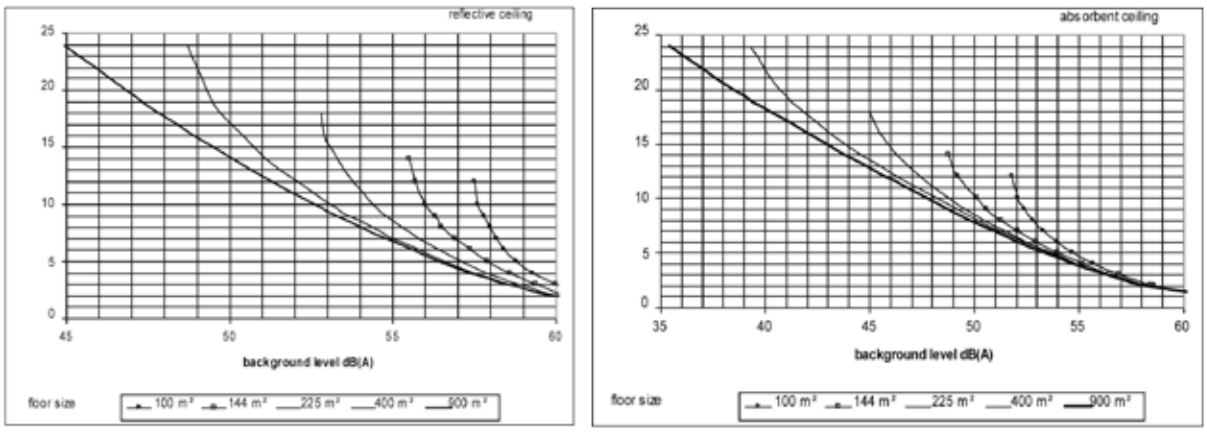

Fig. 3: Determination of the necessary distance between different functional groups, so that communication noise does not cause unacceptable annoyance (with reflective and with absorbent ceiling)

- a necessary distance of 12 m when the background level is 52 dB(A) (case with absorbent ceiling but without noise screens)
- a necessary distance of 8 m when a background level is 50 dB(A) (case with absorbent ceiling but without noise screens)

If an absorbent ceiling and additionally absorbent noise screens are present, the background level drops to 46 dB(A). In that case the necessary distance can only be determined with the inclusion of the reduction of the communication noise from other functional groups, caused by the absorbent noise screens. For this purpose the following diagram can be used:

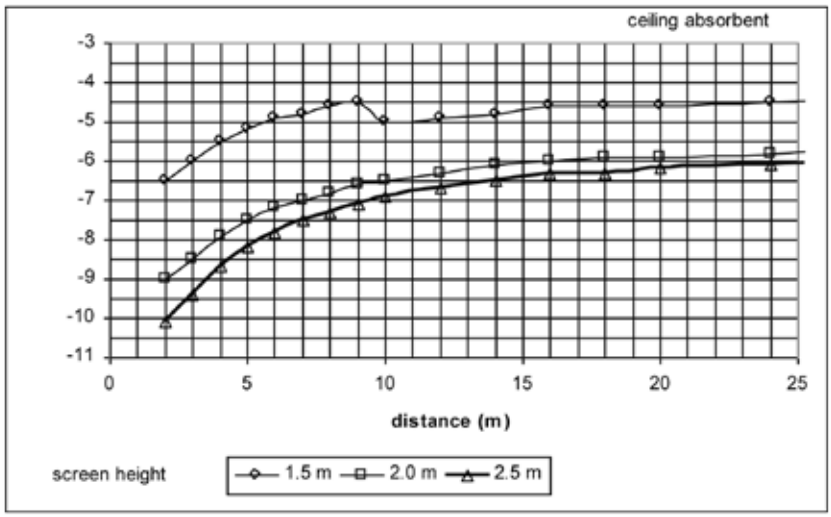

Fig. 4: Level mitigation by a noise screen (room with absorbent ceiling)

For distances of 4 to 5 meters between workplaces of different functional groups, which are present in the given example, follows a reduction of 8 dB, if absorbent ceilings and noise screens of 2,2 meters height are present.

This additional reduction barely reach the requirements.

To verify the results with diagram 3 the background level can be risen by 8 dB up to 54 dB(A) which results in a necessary distance of 4 to 5 meters with a background level of 46 dB(A) (case with absorbent ceiling and absorbent noise screens)

Assessment without acoustical measures

The distance c between the functional groups is 4 m, the distance d is 5,5 m (figure 1). The criterion 2 (Annoyance caused by speech) is not fulfilled with the original layout without acoustical measures, because the minimum distance should be 12 m. In accordance to the background noise level of 52 dB(A), the workplaces would have to be classified as “unfavourable”.

Measures for improvement

A room setup with an absorbent ceiling is insufficient on itself. The workplaces should have a distance of at least 8 m in order to fulfil criterion 2 (Annoyance caused by speech). This however is not viable.

With an additional arrangement of the room by placing absorbent noise screens (see figure 5) between the various functional groups, the planned distances of 4 to 5 meters between the workplaces will be acceptable according to criterion 2 (Annoyance caused by speech). Overall, the workplaces with the described acoustic measures bases on the estimated background noise of 46 dB(A) would be classified as «acceptable» in accordance with table 1.

Open-plan offices in the best case are able to reach the acoustical qualification «well».

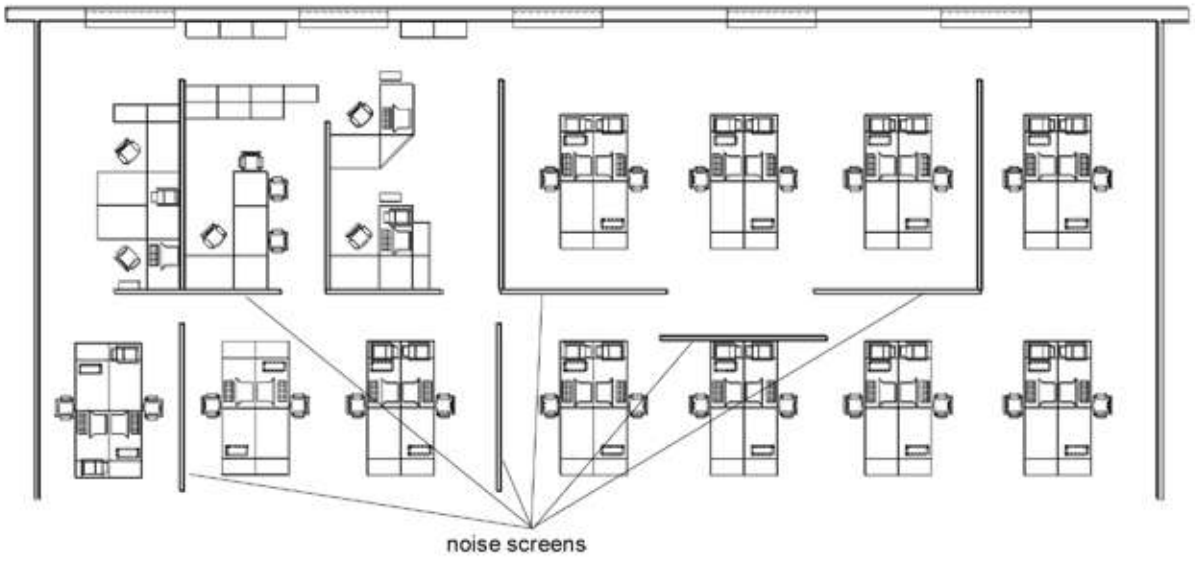

Fig. 5 : Acoustic «isolation» of several functional groups with noise screens

An examination of criterion 1 (Annoyance caused by a single dominating source) has not been performed for this office example. It gets performed in a calculative way within the detailed planning by determining the noise levels at the working place for different situations.

Other noise sources – e. g. from outside the building — have not been taken into account for this office example. The procedure referring to this is described in detail in the literature [3].

Conclusion

The developed systematic approach for the acoustically oriented layout planning of offices will be a basic part of a new VDI-Guideline 2569. All results of the research are available in the literature [1, 2, 3, 4, 5].

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