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Norwegian acoustic building criteria and socio-acoustic study on accessibility for all

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Abstract. Norwegian acoustic criteria for universal design were finalized in 2012 [1]. The work focused on room acoustics and noise conditions suitable for all in public and work buildings. A socio-acoustic survey was conducted among hearing and vision impaired [2]. Their experiences of acoustics in spaces and rooms were applied as a basis for where to focus. The selected criteria are considered more satisfactory for all. Norwegian acoustic classification, given in NS 8175 [1], concerns dwellings, hospitals, schools, kindergartens, offices, work premises etc. Updates were made for these buildings, in specific for open plan teaching environments and open plan offices. Buildings that did not have specified acoustic limits, e.g. museums, lobbies, assembly halls, etc., were evaluated for room acoustics and noise levels. Acoustic quality was defined by measures for reverberation time related to room height, acoustic absorption, noise, speech intelligibility etc. Also, sound amplification systems and devices for assisted listening were applied. NS 8175 contains noise and sound insulation criteria for indoor conditions, outdoor noise nearby buildings and in surrounding outdoor areas. In order to follow up the needs for aging population, children, hearing and vision impaired and others, the relevant criteria were adopted in NS 8175.

Keywords. Acoustic criteria, classification, socio-acoustic study, regulations, standards, universal design

Introduction

The Norwegian building codes [3] require fulfilment of needs of hearing and vision impaired in such way that no additional measures have to be taken later in the building itself. The Norwegian standard for acoustic quality classification, NS 8175 [1], is closely connected to the Norwegian building codes and the guidelines for environmental noise conditions for land use planning [4]. The standard provides the technical criteria for noise and sound insulation for indoor conditions, outdoor noise nearby buildings and in surrounding outdoor areas. As a consequence of the legal requirements, a revision of the Norwegian acoustic criteria was made.

Literature about acoustic conditions suitable for hearing and vision impaired was studied. Empirical data and experience of experts working with hearing or vision impaired were collected and evaluated. In order to find out how acoustic and noise conditions were functioning for hearing and vision impaired in work buildings and buildings open to public, a socio-acoustic survey was conducted among members of their special interest organization [2]. The study was made in order to find out which types of buildings should be regulated, and to measure the degree of annoyance in

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order to find suitable limit values. The general annoyance score was of interest, in addition to the fact that the main focus was on criteria for room acoustics, noise from service equipment and speech, and applicability of sound amplification and/or assisted listening systems. Table 1 contains a short overview of some of the results for hearing and vision impaired.

1. Audiological basis

Acoustic conditions are of utmost importance for speech communication and general behaviour. This is valid for normal hearing adults and people with normal vision, and even more critical for the hard of hearing, people with reduced vision, including elderly people. In particular, the hearing impaired children will often experience difficulties making speech communication, and the perception of e.g. alarm signals may be quite impossible.

The general welfare will also be influenced so that many subjects will avoid certain areas. Several factors will affect people's behaviour. General disturbance from noise sources may influence performance both in a working and training situation. Poor acoustic conditions will require a higher degree of efforts to handle the actual tasks. Stress and fatigue will often be a result of such environments, and combination effects are often seen. Good acoustic conditions suitable for the hearing impaired are even better for the normal hearing.

For speech communication, it is known that adults with normal hearing will require a 15 dB signal-to-noise ratio (S/N) for satisfactory conditions. With a normal speech level of 60 dB at a distance of 1 m, this will imply that maximum noise level should be 45 dB. Children and hearing impaired subjects will require a higher S/N ratio. Children in schools and kindergartens have one of the most critical situations in their training process, and we should also keep in mind that children have poorer speech discrimination than adults [5, 6]. These findings concern normal hearing children.

2. Socio-acoustic survey

In connection to revision of the acoustic classification, the Norwegian Institute for Urban and Regional Research (NIBR) was asked to conduct a survey among randomly selected sample of people with hearing and vision impairments [2]. The survey contained questions about their experience of acoustic conditions in rooms and spaces in public buildings and work premises, and some outdoor areas. The hearing impaired got a written questionnaire, whereas the vision impaired got telephone interviews of the same questionnaire. The responses came from 271 hearing impaired and 250 visually impaired.

The subjects were at ages from 16 to 67 years or more, representing the relative percentages of population of vision and hearing impaired in the society. The written questionnaire was sent to 1183 subjects and the percentage of responses was 23 %. The questionnaire was relatively long (about 10 pages) which may have influenced the low percentage of replies. For the telephone interviews, the number of selected subjects was originally 683, but the interviewer was able to come into contact only with 347 of these. The final percentage of responses was then 37 %. The reasons for this were for instance

that the subjects did not answer the phone, they asked the interviewer to call back later or the selected subjects did not wish to participate in the study.

The questions and scaling of replies in the questionnaire were made in accordance with ISO/TS 15666 [7]. The same types of questions were presented for different types of buildings, rooms or spaces. The questionnaire included also questions on frequency of visiting places, kind of activities that were disturbed, function of technical aids and similar. The main community noise sources such as traffic noise, neighbouring noise, noise from service equipment, speech noise, etc. that are also regulated in the building codes were one of the aims of the questionnaire. Some examples of questions are:

"How annoyed have you been by sound and noise conditions during the last 12 months in restaurants, cafés and canteens?"

"How often do you find it difficult to work and concentrate in office/school open plan spaces due to noise from the talk of others?"

"How often do you find it difficult to have a conversation in foyers or swarm areas in cultural centres or assemblies due to noise from speech?"

Some of the results on percentage of annoyed are shown in Table 1, i.e. less than 10 % annoyed are not included. The percentage is a sum of replies "very or extremely annoyed". Some spaces were clearly more annoying than others. Other questions like frequency of visiting of places, orientation, different sources of annoyance etc. were also asked. The frequency of visits in product halls that got score as the most annoying spaces, was low. The resulting data were considered in setting criteria in NS 8175 [1]. Due to limited time frame and financing of the study, the statistical analyses were limited to simple significant bivariate analyses. Additional statistical analyses and cross-correlations could be made on the resulting data sets. Since it was not possible to continue analyses in this study, possibilities for further analyses have been discussed.

There were large differences in how the hearing and vision impaired experienced noise conditions. The hearing impaired are generally much more annoyed than the vision impaired, as could be expected. Even challenges of orientation were experienced to a larger degree by the hearing impaired than by the vision impaired people.

The results in Table 1 show for example that canteens, restaurants, lunch rooms, cafés and similar are difficult spaces. About 50 % of the hearing impaired people are very or extremely annoyed by the noise and acoustics in these areas [2, 8]. One major problem is to make conversation due to noise from buzzing and chattering from other people's talk. A majority experiences this "always or most of the time", whereas another third experiences this sometimes. Only 12 % say they seldom or never find it difficult to have conversation in public dining spaces. Among the vision impaired 49 % gave that answer. Noise from service equipment such as fans and ventilators was also found to be a major source of disturbing noise, although not to the same degree.

3. Changes in acoustic criteria for buildings

As mentioned in the Abstract, the Norwegian classes for acoustic quality concern dwellings, hospitals, schools, kindergartens, offices, hotels, noisy work premises etc. Updates were made for these buildings, in particular for open plan teaching environments and offices. Additional or modified criteria were given for areas that already have requirements for room acoustics or noise level from service equipment. Room acoustics, noise levels and needs of sound amplification systems were evaluated for all buildings, also for those building types that did not have specified acoustic limits,

e.g. museums, lobbies, assembly halls, cultural buildings, terminals, station areas. Some spaces like receptions, entrance halls, dining spaces, corridors and stairways and similar have mostly the same limits in various buildings.

Requirements for sound insulation were kept unchanged, except that new requirements were added for video conference rooms. The limits for room acoustic parameters such as reverberation time, noise from service equipment, acoustic absorption and speech transmission index were made included or more stringent for several types of spaces. These types of acoustic limits were set for all new types of buildings and spaces that were added in NS 8175. The limit values were based on the annoyance scores given by the subjects in this study, and experience of which kinds of limits are suitable. In a later analysis of economic consequences, it was found that in some cases the new limits may increase somewhat the project planning costs for buildings. In these cases the costs were considered to be less than 2 % of the total costs.

Various measures for room acoustics were considered during the revision work. Reverberation time and the average acoustic absorption have already been practised for a long time in the Nordic countries. Other room acoustic criteria given in EN ISO 3382-3 [9] have been considered to be used for open plan spaces, like speech intelligibility index STI [10, 11], distraction distance (r_D), spatial decay rate of speech or A-weighted SPL of speech at a distance of 4 m. The understanding of mushy speech, and noise from speech in general, was considered to be most problematic by the hearing and vision impaired in many spaces [2]. Limits of STI are not considered to give satisfactory speech conditions alone, but STI should be balanced with reverberation time and noise level. In many spaces, noise from service equipment was considered annoying by the hearing and vision impaired, in addition to noise from speech [2].

EU has given requirements for speech signals in elevators, and the technical details are given in EN 81-70 [12]. Speech signals in elevators shall be adjusted to a level of 60 dB to 70 dB, i.e. natural speech voice. In order to have audible sound signals for persons with reduced hearing ability, the Norwegian standard requires in addition a broadband character of signals.

For outdoor noise sources, limit values are mainly the same as before, with a few exceptions when the noise level from service equipment is very stringent and the annoyance of outdoor noise level becomes dominant. Limits for outdoor levels are still based on the guideline for noise in land use planning from the Ministry of the Environment [4]. The survey on annoyance outdoors did not give very high scores, except for terminals, outdoor station areas and similar [2].

Sound transmission devices are often necessary for improving acoustic conditions of some spaces or buildings for vision and hearing impaired people, elderly people, children, etc., for example by using induction loops or wireless sound transmission devices in addition to the acoustic measures. Individually adapted devices for assisted listening may be relevant, e.g. when work places are adapted for hearing or vision impaired. The building codes [3] require implementing of sound transmission devices in all work buildings and buildings open to public. The builder has to document whenever he/she thinks it is not necessary to implement sound transmission devices in work buildings and buildings open to public. The classification standard includes additional instructions regarding when to apply such devices.

Rooms or spaces in buildings that were studied by the questionnaire survey [2] showed that public address systems and induction loops often were out of order, worked insufficiently or were not used in a proper way. Better follow-up and in-service

training systems should therefore be established. Relevant spaces for such systems are reception areas/desks, waiting rooms and spaces, terminals, station areas, restrooms, cafeterias, common corridors, entrances, staircases and similar.

Table 1. Percentage of extremely and very much annoyed hearing and vision impaired people in different spaces (sorted by annoyance of hearing impaired)

Space	Percentage of annoyed hearing impaired people %	Percentage of annoyed vision impaired people %
Production hall	61.2	16
Cafeteria/Restaurant/Café	49.8	12.8
Exposition and congress halls	47.6	16.3
Sports halls	46.8	15.7
Swimming pools	44.7	13.7
Indoor terminals/stations for public transport	38.9	16.6
School yards	37.1	4.7
Culture centre/Assembly halls	36.8	8.1
Cinemas	33.6	16.4
Outdoor restaurants	31.5	8.6
Auditorium/Meeting halls	29.4	8
Theatre halls	28.4	10
Concert halls	28	11.9
Meeting rooms	27.7	5.3
Open plan offices/Schools	27.6	
Open plan offices		6.2
Open plan schools		8.9
Shopping centres/Enterprises	24.6	14.6
Outdoor terminals/areas for public transport	23.3	12.3
Entrances with waiting room	20.6	6.1
Court rooms	20.2	6.9
Counter/Reception/Expedition	19.9	5.6

4. Conclusions

The Norwegian standard for acoustic quality classification, NS 8175 [1], is closely connected to the Norwegian building codes [3] and the guidelines for environmental noise conditions [4]. The standard provides the technical criteria for noise and sound insulation for indoor conditions, outdoor noise nearby buildings and in surrounding outdoor areas.

Accessibility to all, or universal design, gives new challenges for acoustic quality of buildings. Acoustic quality shall apply to all inhabitants; accessibility to all is the aim. In order to follow up the needs of the aging population, children, hearing and

vision impaired and others, new criteria were adopted in NS 8175. Norwegian acoustic criteria for universal design have focus on room acoustics and noise conditions suitable for all in work buildings and buildings with public access. Results from the socio-acoustic survey conducted among hearing and vision impaired on their experiences of acoustics in spaces and rooms were applied as the basis for where to focus. The selected criteria are considered to give more satisfactory sound conditions for all users.

The acoustic classification was updated for all types of buildings, specifically for open plan teaching environments and open plan offices. For new types of buildings that were classified, acoustic quality is defined by using measures like reverberation time related to room height, acoustic absorption, noise level and speech intelligibility index. Provisions for sound amplification systems and devices for assisted listening are required whenever relevant.

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