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THE SOUND ENVIRONMENT IN PRESCHOOLS
- A Guide to Acoustical Improvements with Regard to Health and Learning

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MASTER'S DISSERTATION

THE SOUND ENVIRONMENT IN PRESCHOOLS

A Guide to Acoustical Improvements with Regard to Health and Learning

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The Sound Environment in Preschools

- A guide to acoustical improvements with regard to health and learning

Ljudmiljön i förskolor

- En guide i akustisk design för god hälsa och inlärning

Keyword/nyckelord: Sound Environment, Preschool, Noise, Sound strength, Speech clarity, STI, Speech intelligibility, learning, hearing impacts, acoustical improvements

Nyckelord: Ljudmiljö, Förskola, buller, sound strength, speech clarity, STI, taltydlighet, inlärning, hörselskador, akustisk design

Abstract

A dissatisfactory sound environment can cause several consequences such as increased blood pressure level, defects in hearing, voice problems, sleeping disorders and decreased learning abilities. It is also a fact that the Swedish Environment Work Authority receives a significant amount of complaints that are apportioned to the sound environment in preschools.

The environment of a preschool should, according to the Swedish National Agency for Education, be an enjoyable place where children get the opportunity to develop their knowledge and their abilities for speech and communication.

Considering these facts and statements makes it obvious that it is of great importance that the sound environment in a preschool is experienced as satisfactory. This context laid the foundation of this thesis which sets out to question´ the following;

- What consequences does a dissatisfactory sound environment have upon the health, wellbeing and learning abilities of preschool children?
- What method of preschool design minimizes the negative consequences of the sound environment?

The purpose was to investigate the consequences of a dissatisfactory sound environment and the implications upon preschool children's health and also their learning abilities. Moreover the aim was to find out which acoustical parameters are of importance for a good sound environment. What was uncovered formed a guide for how to create a satisfactory sound environment in a preschool.

The process during this thesis has included a literary review to find out the consequences upon children who reside in a dissatisfactory sound environment. Furthermore a case study was performed which investigated the sound environment in two preschools. Interviews were performed with personnel and the design of the preschool was inspected. From the findings uncovered through the processes of interview and inspection, acoustical improvements were considered. Calculations to compare the values of acoustical parameters of the current and altered design in the schools were thereafter performed using CATT-Acoustic modelling software. Further information from the literary review, opinions from interviews and results from calculations were compared so as to outline a method of practical acoustical improvements for preschools.

Measurements of sound pressure levels in preschools has shown that a daily exposure during 8 hours, $L_{eq,8h}$, is approximately 75 dBA. According to Swedish Environment Work Authority a daily exposure limit of $L_{eq,8h}$=80 dBA is regarded as having an impact upon hearing. Sound levels in this range seem not to be unusual in preschools and are even more remarkable as children's auditory organs are more sensitive to damage. In general studies have shown that children are exposed to higher sound levels than the personnel since they are nearer the activities that generate the sounds. However hearing defects is not the only negative impact of noise. Effects such as increased blood pressure level, sleeping disorders,

decreased learning abilities and increased stress can emerge at significantly lower sound pressure levels than $L_{eq,8h}$=80 dBA. The extent of the effects may also depend upon the individual's experience of the sound; as the definition of noise is individual.

An environment that is suitable for learning is of course of importance when considering preschools. Children are going to develop their knowledge and moreover their speech is going to be developed to consist of a good vocabulary and fundamental grammar during the years they spend at preschool. Children are also going to develop their abilities to communicate with each other during these years. To ensure that these abilities can be developed it is of great importance that speech can be perceived clearly with good intelligibility.

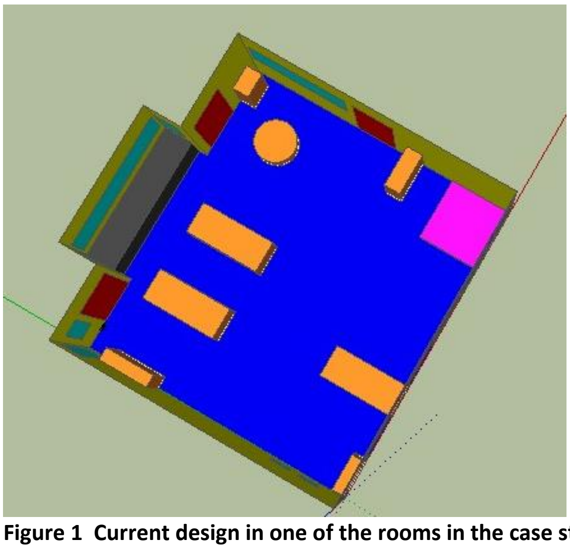
From interviews in the case studies it was found that high sound levels were experienced as the main problem when considering the sound environment. It was also found that it is of importance for personnel to be able to get an overview of the room/rooms and also to have the opportunity to divide the children into small groups.

According to the purpose of preschools and the experience of the sound environment that was mentioned was following acoustical parameters evaluated through this thesis;

- Sound strength- the experience of sound depending of the rooms impact of the generated sound (dB)
- Reverberation time- the time it takes for the sound level to decrease 60 dB after the sound source has been switched of (s)
- Speech Clarity, the relation of early and late reflections of the sound (dB)
- Speech transmission index, the intelligibility of speech (%)

Evaluation of the parameters was performed trough CATT-Acoustic software.

Differences in altered design were low walls, covered with sound absorption also wall absorption of some walls. Example of one room as current and altered design is showed in figure below.



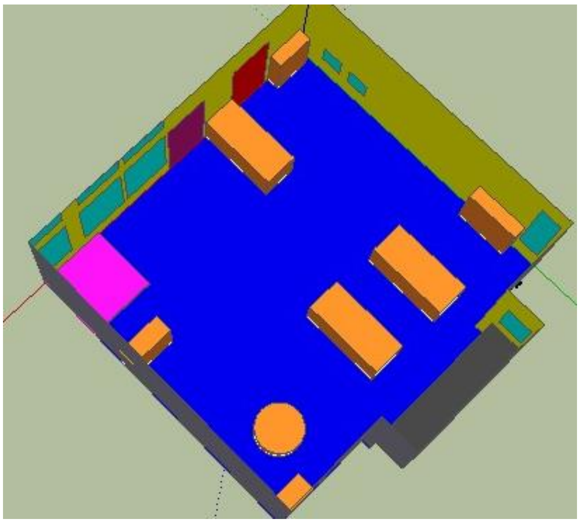


Figure 1 Current design in one of the rooms in the case study.

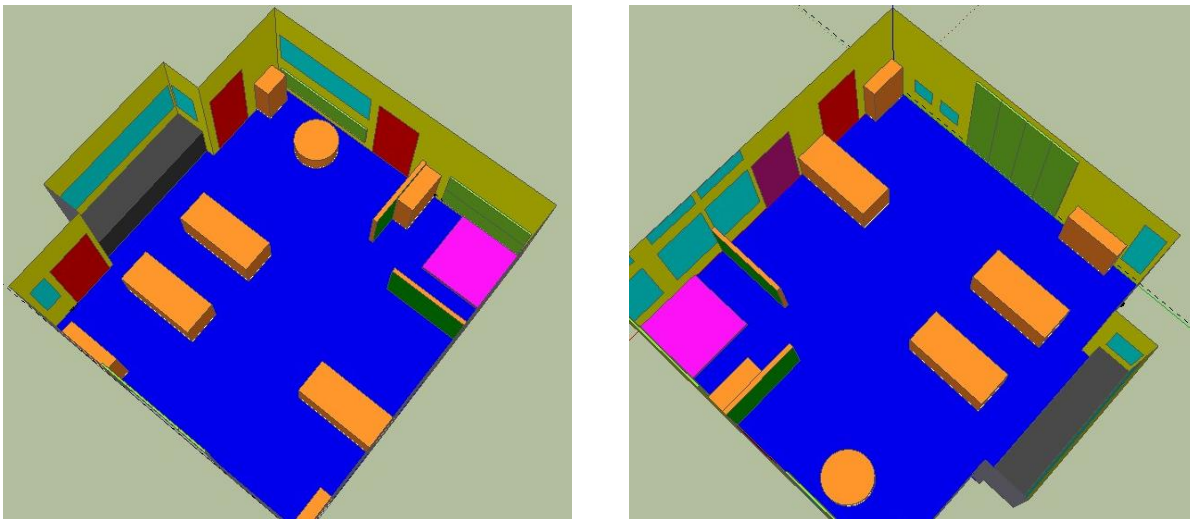


Figure 2 Altered design in one of the rooms in the case study.

The calculations showed significant improvements of the evaluated parameters. The sound levels in altered design would be experienced as almost the half strength. The clarity of speech would increase; positive for perceiving spoken messages. Even the parameter speech transmission index increased; the speech intelligibility increased. The reverberation time in the rooms decreased significantly; the feeling of the sound environment will become much more confident since the reflections of the sound waves have decreased.

Knowledge and results found during the study was collaborated to so as to state the most important aspects to consider when design a preschool with a satisfactory sound environment, these aspects are seen below;

- Consider the environment from an acoustical view from the very beginning of the building process.
- Involve representatives from the preschools from the very beginning of the building process. Make sure that their experience of the sound environment is considered.
- Create the design from the perspective of the activities undertaken in preschools.
- Consider how people are moving inside the building.
- Let huge room as playhalls or dining rooms be easy to divide into smaller parts where personnel still are able to get an overview.
- Consider different acoustical parameters depending of the use of the specific room.

Sammanfattning

En icke tillfredställande ljudmiljö kan orsaka flera olika konsekvenser så som ökat blodtryck, hörselnedsättning, röstproblem, sömnproblem och nedsatt inlärningsförmåga. Vad gäller ljudmiljö i förskolor är detta en av de miljöer från vilken Arbetsmiljöverket får in stort antal klagomål.

Förskolan ska, enligt läroplanen, vara en trivsam plats där barn får möjlighet att utveckla sin kunskap, sitt språk och färdigheter vad gäller kommunikation och beteende gentemot sina medmänniskor.

Ovanstående fakta gör det uppenbart att en god ljudmiljö i förskolor bör prioriteras och är bakgrunden för detta examensarbete med följande frågeställningar:

- Vilka konskevenser kan en icke tillfredställande ljudmiljö i en förskola orsaka barnen med avseende på hälsa, välbefinnande och inlärningsförmåga?
- Hur kan en förskola utformas för att minimera riskerna för negativa konsekvenser orsakade av ljudmiljön?

Syftet var att undersöka vilka konskevenser en icke tillfredställande ljudmiljö i en förskola kan ha på förskolebarnen. Vidare undersöktes vilka akustiska parametrar som är viktiga för att skapa en god ljudmiljö i förskolor. Syftet var att utifrån resultat från dessa undersökningar skapa en metod för hur förskolor kan utformas för att ljusmiljön i förskolan ska vara tillfredställande.

Genom en litteraturstudie undersöktes konsekvenserna av en icke tillfredställande ljudmiljö. Därefter utfördes en fallstudie. Personal på två förskolor intervjuades och utformningen av dessa skolor studerades. Utifrån vad som framkom i dessa processer togs förslag fram för hur ljudmiljön skulle kunna förbättras. Genom beräkningar med CATT-Acoustic jämfördes olika akustiska parametrar för rum med ursprunglig respektive förändrad utformning. Sammanställning av litteratur- och fallstudie lade grunden till en metod för hur en förskola kan utfromas.

Mätningar av ljudtrycksnivåer i förskolor har visat på att den dagliga exponeringen under åtta timmar, $L_{eq,8h}$, är omkring 75 dBA. Enligt Arbetsmiljöverket ska den dagliga exponeringen understiga 80 dBA, detta utifrån risken för hörselskador. Ljudnivåer på $L_{eq,8h}$=80 dBA är inte ovanliga i förskolor. I en förskola är barn vanligtvis utsatta för högre nivåer än vuxna då de är närmre den aktivitet som orsakar de höga ljudnivåera i förskolan. Samtidigt är barns hörselorgan känsligare än vuxnas. Andra negativa konsekvenser förutom defekter på hörseln kan uppstå vid betydligt lägre ljudnivåer än $L_{eq,8h}$=80 dBA. Sådana effekter är ökat blodtryck, sömnsvårigheter, försämrad inlärningsförmåga och ökad stress. Dessa effekter kan yttra sig olika mycket hos olika personer bland annat beroende på den individuella upplevelsen av ljudmiljön.

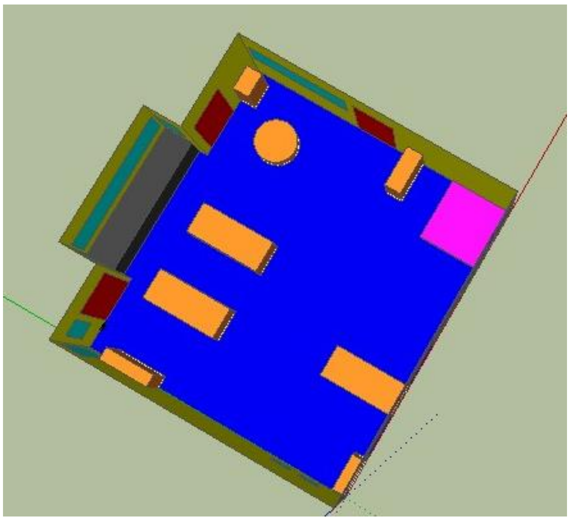
Det är av stor vikt att förkolans miljö innebär de förutsättningar som krävs för att barnen ska kunna utveckla sin kunskap och sitt språk som under förskoleåren utvecklas till att innehålla

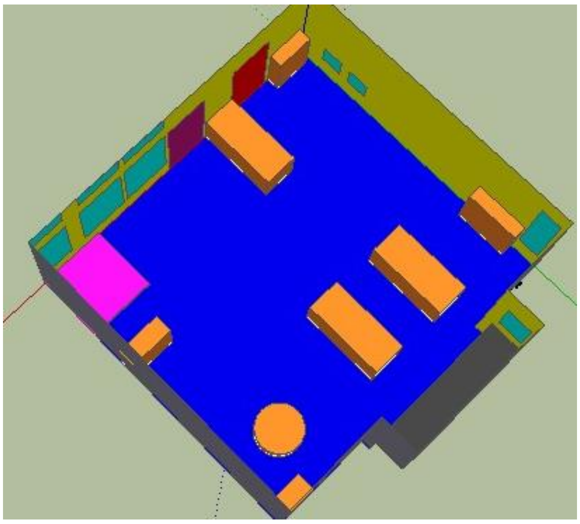
en stor vokabulär samt en fundamental grammatik. Barnen ska också utveckal sin förmåga att kommunicera med varandra. För att garantera dessa förutsättningar är det viktigt att tal kan bli korrekt uppfattat.
Höga ljudnivåer var det problem avseende ljudmiljön som personalen i intervjuerna upplevde som mest besvärligt. Det framkom också att en viktig aspekt vid planering av förskolan var att personalen måste ha möjlighet att få god överblick över lokalerna samt att de måste kunna dela upp barnen i mindre grupper.

Vid sammanställning av litteratur- och fallstudie kunde slutsats om att följande akustiska parametrar är viktiga att studera för en god ljudmiljö i en förskola. Dessa parametrar är de som utvärderades i denna studie vilket utfördes med programvaran CATT-Acoustic.

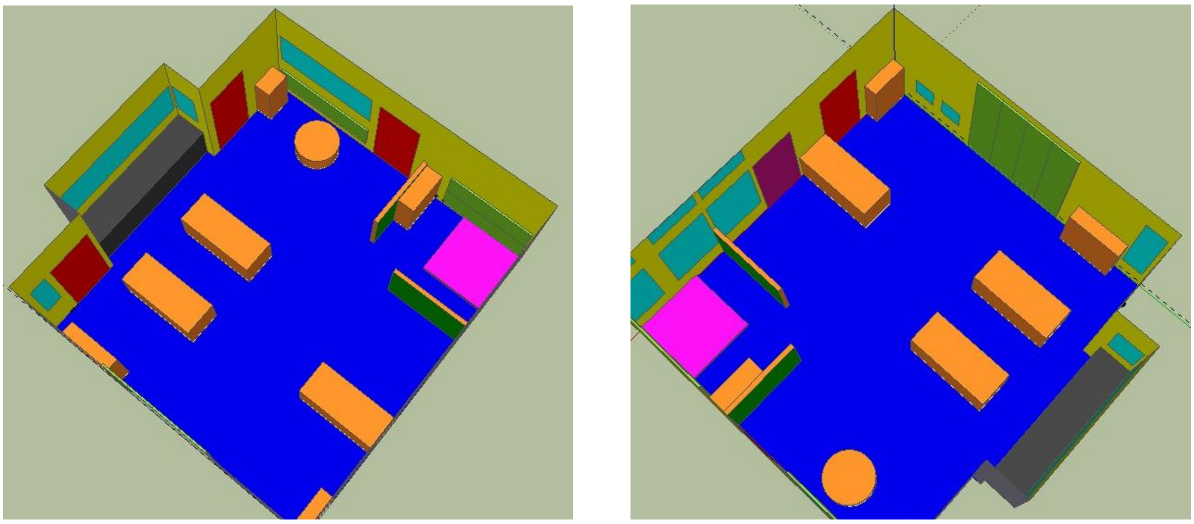
- Sound strength- ljudstyrkan i rummet, beskriver hur rummets egenskaper påverkar ljudstyrkan (dB).
- Efterklangstid- den tid det tar för ljud nivån att sjunka 60 dB efter att ljudkällan har stängs av (s).
- Speech clarity, taluppfattbarheten i rummet (dB).
- Speech transmission index, talets tydlighet i rummet (%).

Förändringarna i rummet bestod i att skärmar, klädda med absorbenter installerades. Även vissa väggpartier kläddes med absorbenter. Följande figurer beskriver rummen i ursprungligt respektive förändrat utförande.





Figur 3 Ursprungligt utförande i ett av rummen i fallstudien.



Figur 4 Förändrat utförande i ett av rummen i fallstudien.

Beräkningarna visade på stora skillnader för de utvärderade paramterararna. Vad gällde ljudstyrkan visade resultaten på att upplevelsen av ljudet styrka nästintill halverades. Taluppfattbarheten ökade också betydligt och taltydligheten ökade med 3-4 %. Efterklangstiden minskade signifikant vilket kommer innebära en behagligare upplevelse av ljudmiljön i rummet då ljudet reflekteras i mindre utrstäckning.

Sammanställning av litteratur studie, intervjuer och beräkningar gav att följande punkter är av stor betydelse och bör studeras för att skapa en bra ljudmiljö I en förskola.

- Begrunda akustiken redan vid starten av byggprocessen.
- Involvera representanter från förskolor från början av processen, ta till vara på dessa personers upplevelser och erfarenheter av ljudmiljön i förskolor.
- Utforma förskolans design utifrån den verksamhet som ska bedrivas i lokalerna.
- Planera/studera hur människor kommer att röra sig i byggnaden.
- Gör det möjligt att dela in stora rum i mindre avdelningar, föredömesvis med låga skärmar som gör att personal fortfaranade kan få en överblick.
- Studera olika akustiska parameterar beroende på syftet med respektive rum.

Acknowledgement

This thesis constitutes the final part of the master program in Civil Engineering at the University of Lund. The thesis has been performed within the division of Engineering Acoustics at Lunds institute of technology in collaboration with Lundafastigheter, the facility manager in the community of Lund.

I would like to express my outmost appreciation to my supervisor Delphine Bard. Thank you for all your support and your honest and encouraging remarks.

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Emma Arvidsson

Table of contents

1 Introduction

This chapter consists of the background of the problem which forms the thesis questionnaires, also presented in this chapter. Even the purpose and restrictions of the thesis are explained.

1.1 Background

Preschools, according to Swedish Environment Work Authority, are one of the workplaces which have the greatest problem with high sound pressure levels (SPL) and significant amount of complaints are apportioned to the sound environment. The daily sound exposure over eight hours, $L_{eq,8h}$, the addition of higher and lower sound levels during a day, in a preschool is in general 75-80 dBA (Persson Waye, 2009). Letter “A” in previous unit means that the sound pressure is filtered through an A-filter which corresponds to the auditory organs perception abilities.

A daily exposure $L_{eq,8h}$<80 dBA may not have any impacts on hearing losses for an adult but children’s auditory organs is more sensitive to getting injured (Broms, 2013). Important to consider is also that a sound level defined in terms of $L_{eq,8h}$ may be influenced of momently high levels, peaks, that can cause direct injury of the hearing organs (Arlinger, 2006).

It is not only the high levels of the sounds that can cause negative impacts. When a sound is experienced as disturbing it is defined as noise. Noise can cause decreased learning abilities (Hygge, 2007) sleep disorders, stress (Sjödin, 2012) and increased blood pressure level as well as increased heart rate (Hygge, 2007).

Schools and leisure centres located in Sweden are regulated by the Swedish Education Act (Education Act, 2010). Guidelines to this act are described by curriculums such as “Curriculum for the Preschool, Lpfö 98” (Lpfö, 1998), published by the Swedish National Agency for Education (Skolverket, 2013). According to this document preschools should give all children the opportunity to obtain and develop knowledge and also develop their ability for speech and communication. This should be done in an environment that is enjoyable; a place where fantasy and games is a part of the learning process. The preschool should also be a place where the children learn how to integrate with each other (Lpfö, 1998).

In October 2011, according to Official statistics of Sweden, Swedish preschools had 98 532 workers and 470 200 children registered (Skolverket Statistik, 2013). Personnel in an average Swedish preschool have responsibility for 5.4 children while the average preschool-teacher has responsibility for 10.1 children (Skolverket Statistik, 2013). By personnel means al personnel who works with the children, calculated as yearly workers (Skolverket Statistik, 2013).

The huge number of children that are registered in the Swedish preschools, the fact that children are exposed to high sound levels during their activities and that the aim of the preschools is jeopardised because of noise makes surveys of how to improve the sound environment in preschool a topic of importance that should be critical considered.

1.1.1 Demander

This thesis is undertaken in cooperation with Lundafastigheter. Lundafastigheter are a section of Lund's municipality which handles the facility management of the community's preschools.

In 2005 an investigation into the sound environment of preschools in the community of Lund was undertaken. Questionnaires were sent to all personnel at all preschools in Lund, which at that time comprised of 373 persons at 29 different preschools. When the questionnaires were evaluated five preschools were deemed to have the worst sound environment. Thereafter an investigation into the sound environment was undertaken by these five preschools. The acoustic parameters measured included sound pressure level (SPL) and reverberation time (RT) which is the time it takes for sound to decrease 60 dB after the sound source has been switched off.

The SPL was measured by stationary equipment during two workdays. Results showed SPL of 68-79 dBA in play areas and 67-72 dBA in dining rooms. After installing absorbents upon wall and ceiling surfaces the same measurements where undertaken and this resulted in decreased sound pressure levels. In play areas the SPL decreased in the range of 2-6 dB and in dining areas in range of 0-3 dB. Reverberation time prior to the remedial actions was between 0.4-0.7 seconds in playareas and 0.3-0.5 seconds in dining rooms. Post acoustic absorption action the RT decreased to 0.3-0.4 seconds and 0.2-0.3 seconds respectively.

1.1.2 Acoustical requirements through the building process

Acoustical requirements for preschools in Sweden are defined in the national building regulations (BBR) (Boverket, 2012). Guidelines to fulfil these requirements are published by the Swedish Standards Institute. Through these documents the recommended values and sound parameter are outlined, the values can be seen in chapter “Case Studies”.

In recent years further requirements have been placed upon acoustical parameters due to the integration of environmental certification schemes for buildings such as Miljöbyggprogram SYD (Miljöbyggprogram Syd, 2012). This program is based upon the Swedish standards but sets higher requirements related to the control and contribution of acoustics throughout the building process in deliver a sustainable environment. Lundafastigheter uses Miljöbyggprogram SYD beyond the requirements set by BBR.

Still persist problems with regards to sound in Lundafastigheter's preschools and no specific method is used through the building process so as to improve the sound environment. A guide of how to consider the acoustical design when building new schools is therefore requested.

1.2 Purpose

The purpose of this thesis is to investigate the consequences of a dissatisfactory sound environment and the implications upon preschool children's health and also their learning abilities.

The aim is also to find out how to design a preschool to achieve a better sound environment. Moreover how this is influenced by regulations and policies and how these correlate to the experience of the sound environment was investigated.

Furthermore the optimal design of a preschool, from a sound environment perspective, will be considered to find out a method of how Lundafastigheter could implement actions so as to improve the sound environment in their preschools.

1.3 Thesis questionnaires

A satisfactory sound environment in preschools is essential so as to foster an appropriate teaching and learning environment. The negative consequences of a poor sound environment in preschools are such that the health and wellbeing of both personnel and children can be jeopardised.

As alluded to previously in this chapter appropriate sound environment is of great importance for children's health and development. These facts in combination of the ambitions Lundafastigheter has regarding to build preschools with a good sound environment and the problems they found through the building process form the basis for this thesis. The following questions will be posed and discussed in this document;

- What consequences does a dissatisfactory sound environment have upon the health, wellbeing and learning abilities of preschool children?
- What method of preschool design minimizes the negative consequences of the sound environment?

1.4 Restrictions

This thesis will only focus upon the sound environment in preschools which implies children with a maximum age of six. The consequences for preschool personnel will not be directly investigated in this thesis. However there is a likely correlation that a good sound environment for the children will probably have a positive impact upon the teacher's experience of the sound environment. Only the internal environment will be taken into account.

Only room acoustical actions and consequences upon preschool environment will be assessed during this thesis. The discussion and conclusions will consider actions that can be improved by Lundafastigheter. The preschools organisation and their pedagogical method will not be considered.

1.5 Dissertation contents

Chapter 1- This chapter consists of the background of the problem which forms the thesis questionnaires, also presented in this chapter. Even the purpose and restrictions of the thesis are explained.
Chapter 2- By this chapter is the method of the thesis presented. The choice of method is explained followed by the method of the different parts. Further is validity and reliability of the thesis discussed.
Chapter 3- Acoustical terms and definitions that are used during the thesis are explained in this chapter.
Chapter 4- In this chapter is the concept of sound environment according to this thesis explained.
Chapter 5- In this chapter is a short presentation of speech presented followed by the section "children´s speech development". Also the function of the human auditory organ is presented in this chapter.
Chapter 6- In this chapter is the concept of noise presented and the typical sound environment in a preschool is discussed.
Chapter 7- Effects of noise on people are presented by this chapter. Medical and physical effects as well as cognitive skills and wellbeing are discussed.
Chapter 8- This chapter consists of the case studies which include a presentation of the preschools and their requirements of building phase. It also includes collaboration of the investigation. Furthermore are preventive measures of the preschools explained and results of calculations are outlined.
Chapter 9- In this chapter is a discussion of the thesis presented. Literary review and case studies are discussed and forms guidelines of practical design for a good sound environment in preschools.
Chapter 10- This chapter consists of the conclusion and also a suggestion of continuing work of for even better sound environments in preschools.

2 Method

By this chapter is the method of the thesis presented. The choice of method is explained followed by the method of the different parts. Further is validity and reliability of the thesis discussed.

The structure the researcher follows during the study is called "the design of the research" (Yin, 2006). It describes the way of how the different parts of the study are collaborated (Yin, 2006). In figure 5 below is an overview of the design of this research. In following sections of this chapter each part is further explained.

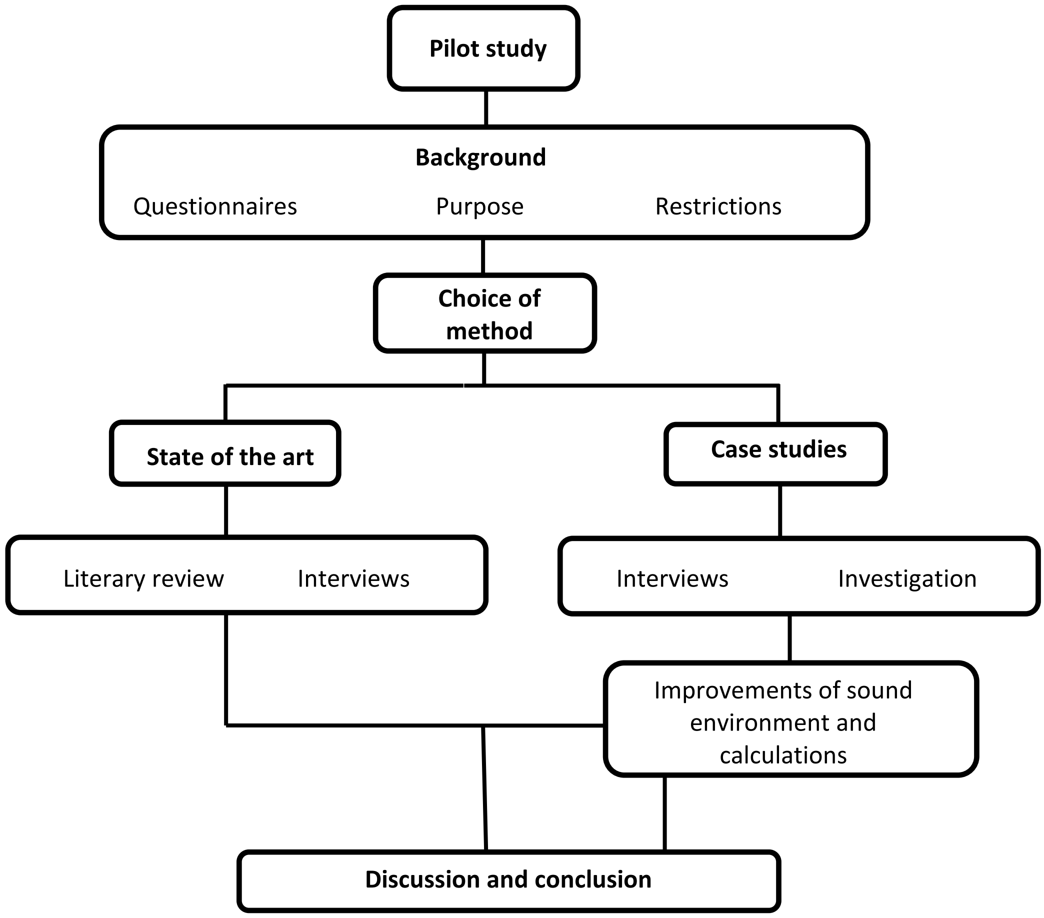


Figure 5 Design of the research.

2.1 Pilot study

Through a simple internet research was the first fundamental and basic information found in this topic which lays the foundation of the ideas of the thesis construction. Further were discussions with project managers at Lundafastigheter and also with acoustical consultants performed. Through these discussions were the basis of the thesis questionnaires, purpose and restrictions established.

2.2 Choice of method

Different research methods can be used for the data collection. Choice of research depends of the topic and the purpose of the thesis and also the availability that is required (Naoum, 2007).

2.2.1 Qualitative research

Significant for a qualitative research is that the investigated subject not is measurable and opinions and perception puts the basis of the research (Naoum, 2007).

The qualitative research is typical none structured with high flexibility (Andersen, 1994). The data of a qualitative study is “rich and deep” and the relationship between researcher and subject is close (Naoum, 2007).

A qualitative research is used when several qualities, which not are measurable, have impacts of the subject that are investigated (Naoum, 2007).

2.2.2 Quantitative research

The quantitative research is an objective method (Naoum, 2007). The investigated object is measurable and the result is numerical presented (Andersen, 1994). The object is investigated with regards to different parameters that are rated in an interval (Andersen, 1994).

A hypothesis constitutes the basis of the research which is statistical tested during the research (Naoum, 2007). The quantitative study has a high extent of structure and low flexibility (Andersen, 1994).

The quantitative study is used when relationships between facts are studied or facts of a concept or an attribute are investigated (Naoum, 2007). Facts and data are “hard and reliable” (Naoum, 2007).

Acoustics is a combination of physics, measurable parameters, and individual perception, non-measurable parameters. To guarantee the trustworthiness and sustainability of the results validity of the research, with regards to the purpose and questionnaires, has a combination of the two main research methods previous presented been chosen.

Performing an environment where the experience of sound is appreciated can only be done when the subjective experience are known, qualitative methods was used to perform this part of the study. The purpose of the study was also to find acoustical improvements which were done with regards to measurable parameters as in accordance with a quantitative method.

2.3 State of the art

With regards to a literary review the consequences of a dissatisfactory sound environment was investigated. This study took heed of medical, psychological and mental health and also the impact upon learning abilities and pedagogic work of the sound environment in preschools. The function of the auditory organ and speech was also studied during this part of the thesis.

The information for this part was obtained by databases via Lund's University libraries. Even articles from journals like "Noise and Health" and "Journal of Voice" was investigated. Reports published by Sound Environment Centre at Lund University were considered as well as articles in newspapers. The literary review also included interviews for an auditory doctor and a speech pedagogic.

Studies of acoustical terms and definitions were also performed during this part of the thesis. Information regarding this part was found through library literature and also from producers of acoustical materials.

2.4 Case studies

The sound environment within two preschools was investigated. The preschools selected were determined by Lundafastigheter and the author. The selection criteria included that preschools should be recently built so as to reflect the building process that Lundafastigheter uses. It was also desired that the person who had been project manager through the building process still worked at Lundafastigheter so decisions and actions undertaken during the design and building process could be explained.

The first step of the chapter entitled "case studies" was to perform interviews with the preschool's personnel to find out their opinion regarding the sound environment. This involves questioning regarding specific activities and/or places within these schools with a view to understanding their acoustic climate. Moreover the design of these spaces and the impact upon children was questioned during these interviews. The interviews was performed as non-standardized which means that the formulations and series of questions could vary so as to suit the situation (Andersen, 1994).The questions during the interviews was askes as open questions to let the participants may have different answers depending of their experience and opinions (Andersen, 1994).

The results of the interviews and literary study was connected so as to determine appropriate acoustical modelling and calculation processes to objectively measure the sound environment with the schools under investigation. This was done both from current design of the preschools and with acoustical measures in one representative room at each school.

Through discussion and meeting with project managers at Lundafastigheter was their way to work and which requirements they uses through the building process clarified.

2.4.1 Measurements

Measurements of reverberation time were performed onsite in the preschools in accordance with “SS-EN ISO 3382-2:2009- Measurement of room acoustic parameters- Part 2: Reverberation time in ordinary rooms” (SS-EN ISO 3382-2, 2009). The measurements were used for calibration of CATT-models, described in next section.

Interrupted noise method was used during the measurements which mean that a source has generated sound and the measurement starts when the sound was switched off. Two different source positions were used, one generated noise at a time. The source generated broadband random noise at a level at a level of 90 dBA to ensure the generated noise was at least 45 dB over the level of background noise for each frequency band.

Three microphone positions were used for each source position, which means six microphone positions in each room. The microphone positions were placed at least 1.0 m above the floor so as to reduce the risk of influence of standing waves. The receivers were placed 1.0 m from reflecting surfaces.

The measurement equipment, Norsonic140, was calibrated before and after the measurements (Norsonic, 2013).

Every measurement was recorded for six seconds to ensure that the recorded time was sufficiently long to enable determination of background noise.

To archive a steady state in the room the noise was generated for a least five seconds before the measurement was done, i. e. before the noise was switched off.

The measurements were transferred and evaluated through software NorXfer and NorBuild (Norsonic, 2013). This evaluation was done in accordance with SS-EN ISO 3382-2:2008.

2.4.1.1 Uncertainly of measurement

The number of measurement affects the uncertainly (SS-EN ISO 3382-2:2008). Standard deviation of the measurements of reverberation time was calculated as in (1) according to SS-EN ISO 3382-2:2008.

$$\sigma(T_{30}) = 0{,}55T_{30}\sqrt{\frac{1+\frac{1.52}{n}}{NBT_{30}}} \qquad (1)$$

B=bandwith in Hertz calculated as $B=0{,}71f_c$
f_c=mid band frequency
n=number of decays measured in each position
N=number of independent measurement positions
T_{30}=reverberation time in seconds

Results of calculations above showed results as viewed in table for respectively frequency band.

Table 1 Results of measurements and its uncertainly at the Preschools Kattfoten and Orkesterparken.

Frequency (Hz)	Kattfoten T_{30} (s)	Kattfoten $\sigma(T_{30})$	Orkesterparken T_{30} (s)	Orkesterparken $\sigma(T_{30})$
125	0.55	0.03	0.49	0.03
250	0.42	0.02	0.38	0.02
500	0.45	0.01	0.32	0.01
1000	0.47	0.01	0.39	0.01
2000	0.54	0.01	0.47	0.01
4000	0.56	0.01	0.55	0.01

Results of measurements and uncertainly shown in the table indicates high accuracy of the measurements. Since these measurements were used for calibration of the CATT-models high accuracy of those calculations could be expected.

2.4.2 SU^{2}CATT

The rooms have been drawn in SketchUp (SketchUp, 2013). Through the interface SU^{2}CATT (Rahe-Kraft, 2013), has the models been converted to CATT-Acoustic described in next section.

Template “Acoustic Modeling- Meters” has been used in SketchUp since “The Templates are still optimized for modeling with the plugin” (Rahe-Kraft, 2013). The accuracy of point overwritten to CATT-Acoustic was chosen to seven as recommended from ”Rahe-Kraft” (Rahe-Kraft, 2013).

Each material and/or furniture was assigned in SketchUp with a specific name and colour. The name of each material and/or furniture is overwritten to CATT-Acoustic to be further defined in means of acoustical properties.

2.4.3 CATT-Acoustic

CATT-Acoustic, a room acoustic prediction program (CATT-A, Introduction Manual, 2012), has been used for control of the acoustical improvements. CATT-Acoustics includes CATT- A where the geometry of the models has been handled while the prediction of the acoustical parameters has been done through the “standalone” TUCT- The Universal Cone-Tracer (TUCT, 2011).

The geometry of the models has been simply drawn, details is not included. Frequency dependent scattering coefficient, in octave bands, 125-4000 Hz, has been used for each material and/or furniture. Even absorption coefficient was defined for each material and/or furniture in the same octave bands.

Information about the materials in walls, ceilings and floor was provided by Lundafastigheter. From documentation as pictures from the visits at the preschools were the furnishing defined. Acoustical properties of the materials and also furnishing were collected from acoustical handbooks and from specific material producers if these where known.

Prediction of models was performed through TUCT. The prediction can be done by addition of energies or by addition of pressures, impulse response (CATT-A, Introduction Manual, 2012), last mentioned has been used through this thesis.
The model was calibrated against the measurements, described above.

The function “debug” was used. Through this function are the geometry of the model checked (CATT-A, User’s Manual, 2011). Following was checked through the debug:

- Single-connected plane corners
- Plane edges cutting/touching other planes
- Planes with (potentially) reversed normals
- Inaccurate plane corners
- Coinciding/overlapping planes

All errors that were found through the “debug-function” were eliminated in the results that are represented.

In small rooms, as in this case, is sensitive for phase reflection. The absorption coefficient cannot truly describe the phase reflection (TUCT, 2011). Through comparison between the energy based result and the impulse response will an indication of the uncertainly in low frequencies be identified (CATT-A, Introduction Manual, 2012). Typical will differs be seen in frequency of 125 Hz, 250 Hz and also a bit for 500 Hz (TUCT, 2011). This comparison has been done for the calculated results in this thesis.

In the paper “Engineering principles and techniques in room acoustics problem” has the author Bengt-Inge Dalenbäck, creator of CATT-Acoustic, written “One misunderstanding is that if a sufficient detailed model is made and if a high number of rays are used, the result will always be accurate” (Dalenbäck, 2010). In the same paper can also following be read “Software like this can, for many reasons never be “highly accurate” and that software this is “a qualified discussion partner”. This is the reason of why the drawings have been done without details.

2.5 Discussion and conclusion

Through discussion and conclusion was a basis of how to design a preschool assessed. The facts studied through the state of the art and information and opinions from interviews with preschool personnel and the calculations results was collaborated to find out how to create a good sound environment. These discussions formed guidelines for practical design of preschools. The guidelines were discussed with professionals with experience of building preschools; project managers at Lundafastigheter and acoustical consultants, to ensure that the resulting document are applicable.

2.6 Thesis validity and reliability

To ensure validity of concepts, the warrant of correct use of concepts (Yin, 2006), have different references been used to explain the concepts through the literary study. Neither were acoustical, medical or psychical definitions defined during interviews, therefore has experience and opinions mentioned during interviews not been evaluated as concepts or definitions to warrant concept validity. One exception is the concept of sound environment which is defined specific for this thesis and further is explained in chapter "Acoustical terms and definitions".

The internal validity describes the extent of property of the study and its conclusion (Yin, 2006). An internal validity is guaranteed when all parameters that can have an impact of each other are discussed and evaluated (Yin, 2006). A good sound environment does not only depend of acoustical properties. Therefore have parameters as behaviour and concentration been considered through the thesis. Even organisation and learning method in the preschool have impacts of the experience of the sound environment. These parameters are not considered since it not reformed by acoustical improvements.

Extend of external validity describes weather the results of the thesis can be applicable in other studies (Yin, 2006). The results of this thesis have been discussed with project managers which has built several preschools and also with acoustical consultants with work experience of acoustics in preschools. These discussions give the thesis external validity and declare that the guidelines could be applicable even for other facility managers than Lundafastigheter. The suggested acoustical improvements in the discussion and results are reinforced by acoustical empirics that strengthen the external validity.

The extent of reliability describes weather someone else can do the same study in the same way and get the same results (Yin, 2006). To ensure the thesis reliability is each step during the thesis explained.

3 Acoustical terms and definition

Acoustical terms and definitions that are used during the thesis are explained in this chapter.

3.1 Definition of sound

Sound is a mechanical wave, a movement where the particles oscillates around its equilibrium (Nilsson, et al., 2008). An oscillation is the variation of magnitude of a measurable quantity, dependent of the time (Vigram, 2008). In air these oscillations variants along the atmospheric pressure which results in audible sound (Vigram, 2008) that we experience with our auditory organs (Nilsson, et al., 2008).

3.2 Sound Pressure Level

The strength of the sound wave are described by a root mean square, rms, $\tilde{p}$, *(Pa)* (Nilsson, et al., 2008), viewed in figure 6 and calculated as in formula (2).

$$\tilde{p} = \sqrt{\frac{1}{\Delta t}\int_{t_0}^{t_0+t_0} p^2\,(t)dt} \qquad (2)$$

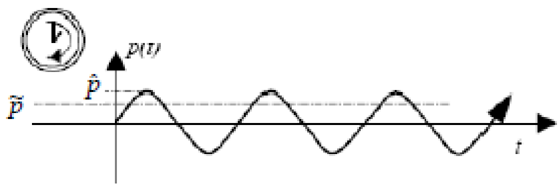


Figure 6 Root mean square, $\tilde{p}$, and period time *(Nilsson, et al., 2013).*

The sound pressure level, SPL, which has the unit decibel, dB, is then evaluated from the rms-value as in (3) and described with L_p (Nilsson, et al., 2008).

$$L_p = 20 * \log\left(\frac{\tilde{p}}{p_{ref}}\right) \qquad (3)$$

Figure 7 describes typical SPL of some common activities; frequency is seen at x-axis and sound pressure level at y-axis.

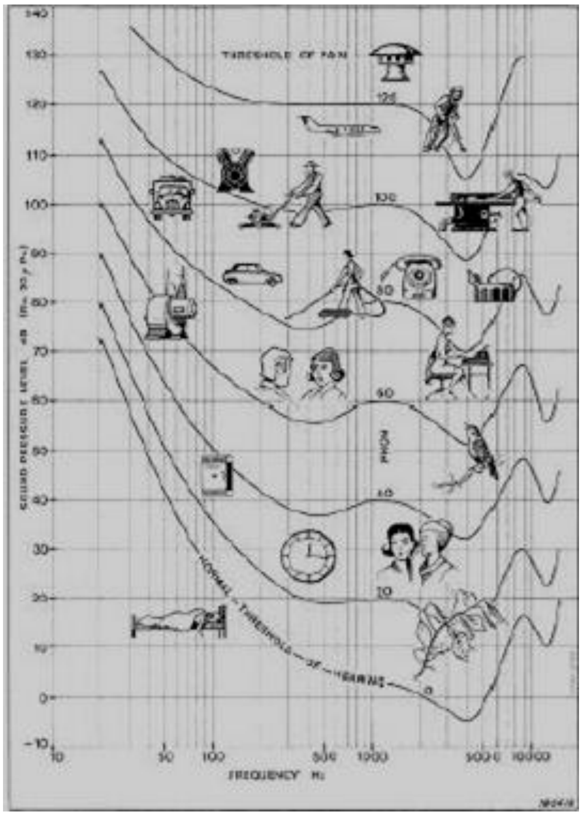


Figure 7 Sound pressure level of some common activities *(Nilsson, et al., 2013).*

In the guidelines for community noise published by World Health Organization, WHO, is equivalent, described in the next section, SPL in a preschool, indoors, recommended to be below 35 dBA, during class (Berglund, et al., 1999). In rooms prepared for sleeping recommends the same organization equivalent SPL of 30 dBA during sleeping time (Berglund, et al., 1999). The highest sound that toys should generate is 120 dBpeak (Berglund, et al., 1999), means an impulse sound (Nilsson, et al., 2013).

3.3 Loudness

Loudness is the subjective impression of sound (Rossing, 2007). A standard to compare the subjective experience with measured sound pressure level has been evaluated (SS-ISO 226:2004, 2004). This comparison is performed through equal-loudness-curves which are dependent of frequency since the auditory organs sensitivity differs with frequency (Rossing, 2007).

A phon contour represents how loud the sound is perceived at each frequency, seen at x-axis while the numerical SPL can be seen on the y-axis. Reference sound is a pure tone at 1000 Hz (SS-ISO 226:2004, 2004). Dotted lines of phon 10 and 100 indicate a lack of experimental data/information (SS-ISO 226:2004, 2004).

The dashed line in figure 8 describes the hearing threshold which is the sound level where "a person gives 50 % of correct detection responses on repeated trials" (SS-ISO 226:2004, 2004).

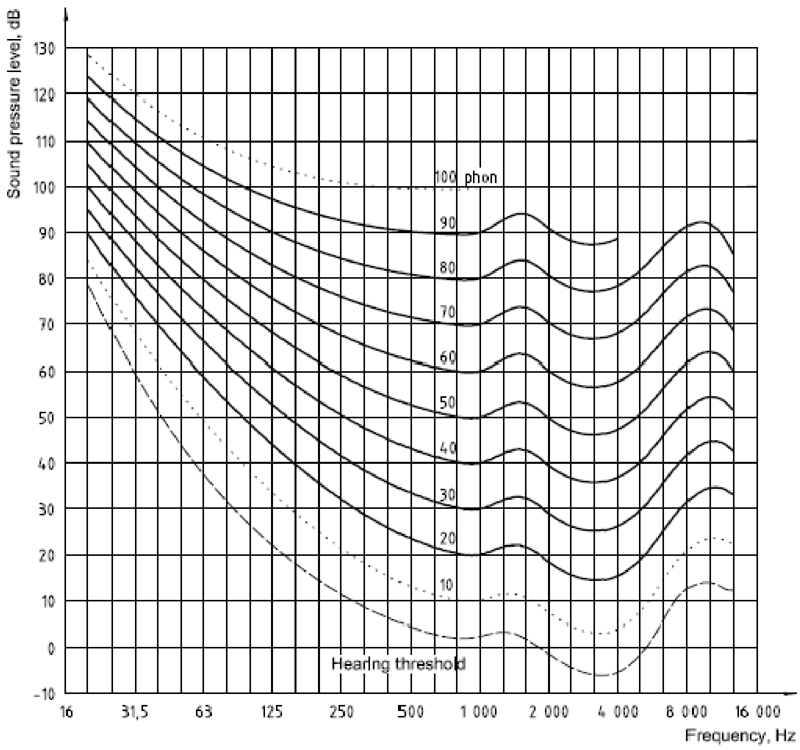


Figure 8 Equal-loudness-level contours and hearing threshold, indicated by dashed line *(SS-ISO 226:2004, 2004).*

The threshold of pain is reached at a SPL of 120 dB (Nilsson, et al., 2008) but a level of discomfort is reached by SPL of 100-110 dB (Ljung, 2010).

3.4 Wavelength period and frequency

Sound waves can be described as a function of sine or cosine (Nilsson, et al., 2008). The length from one point to the next point of the same value of the function is one wavelength, λ (m) (Nilsson, et al., 2008). The time it takes for the wave to travel one wavelength is named one period, *T (*s) (Nilsson, et al., 2008), viewed in the figure below.

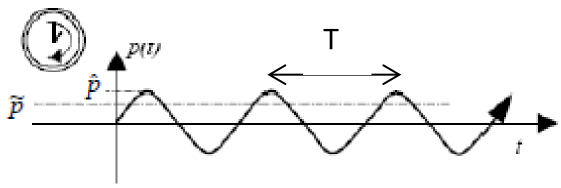


Figure 9 The period time T of a wave. Original figure *(Nilsson, et al., 2008), processed by the researcher.*

The number of wavelengths over 1 second determines the wave's frequency, f, (Hz) (Nilsson, et al., 2008). High frequency means that the wavelength is short.

Sound is often composed of several different frequencies otherwise it is just one tone (Nilsson, et al., 2008). To describe L_p for each frequency is pretty unpractical, therefore filters are used. In building acoustics octave or one third octave filters are common (Nilsson, et al., 2008). In each subsequent octave the frequency is double but covers for all frequencies and is defined by a middle frequency (Nilsson, et al., 2008) which can be seen in table 2.

Table 2 Frequencies of one third octave and octave.

Middle frequency (Hz)	One third octave (Hz)	Octave (Hz)	Middle frequency (Hz)	One third octave (Hz)	Octave (Hz)
50	44,7-56,2		800	708-891	
63	56,2-70,8	44,7-89,1	**1000**	891-1120	708-1410
80	70,8-89,1		1250	1120-1410	
100	89,1-112		1600	1410-1780	
125	112-141	89,1-178	**2000**	1780-2240	1410-2820
160	141-178		2500	2240-2820	
200	178-224		3150	2820-3550	
250	224-282	178-355	**4000**	3550-4470	2820-5620
315	282-355		5000	4470-5620	
400	355-447		6300	5620-7080	
500	447-562	355-708	**8000**	7080-8910	5620-11200
630	562-708		10000	8910-11200	

3.5 Weighting

It is the common to weight the octave values through filters. A-filter is the most common and is meant to represent the human hearing, the experience as by our auditory organs (Nilsson, et al., 2008). Weighting calculations are done as formula (4) and weighting values are seen in figure 10.

$$L_{Weighting} = 10\,log\left(\sum 10^{(L_n + weighting)/10}\right) \qquad (4)$$

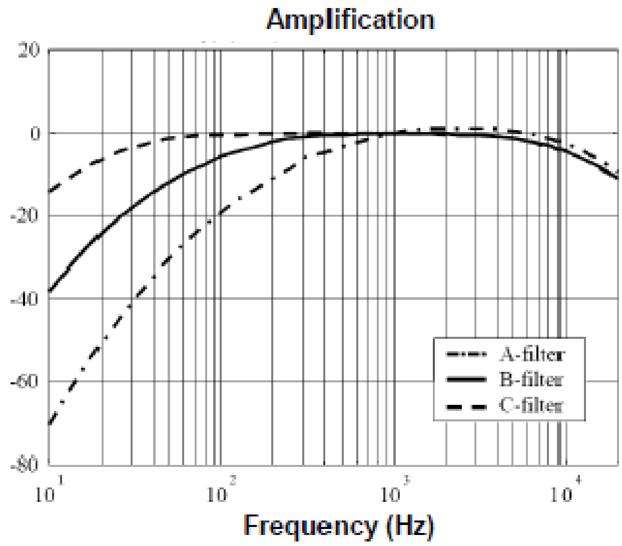


Figure 10 Reducing values of different frequencies for A-, B- and C filters *(Nilsson, et al., 2008).*

3.6 Equivalent sound pressure level

To get a value of SPL over time (T) the equivalent SPL, $L_{eq,T}$, are calculated (Nilsson, et al., 2008) as in (5).

$$L_{eq,T} = 10\,log\left(\frac{1}{T}\int_0^T \frac{p^2}{p_{ref}^2}dt\right) = 10\log\left(\frac{1}{T}\int_0^T 10^{L_p(t)/10}\,dt\right) \qquad (5)$$

Since SPL are correlated to a logarithmic scale it cannot be linearly added through addition of sound. Therefore the following holds (Nilsson, et al., 2008).

$$L_{p,total} = 10\,log\left(\sum_{n=1}^{n} 10^{(L_{p,n})/10}\right) \qquad (6)$$

This means that when a sound source is added with another sound source of the same SPL, L_p increases by 3 dB.

3.7 Absorption

Through absorption is the sound energy converted into heat energy which means that the sound level will be reduced (Rossing, 2007).

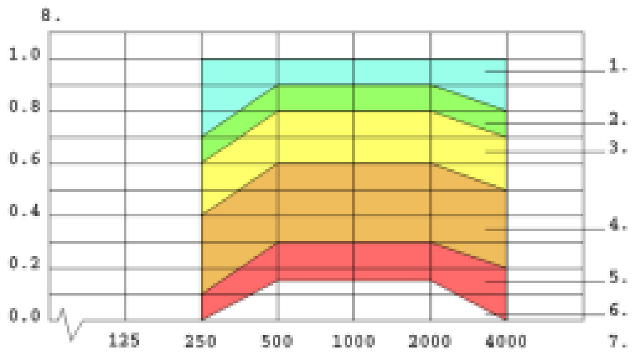
A materials ability to absorb the sound energy varies with frequency (Rossing, 2007) and is described by the absorption coefficient, α. This coefficient can vary between zero and one. If α=0 is no sound energy is absorbed, if α=1 are all incoming sound energy absorbed by the material (Nilsson, et al., 2008).

Absorption coefficients of common materials and objects in preschools are described in table 3 below. Values in the table are collect from “acoustical handbook”.

Table 3 Absorption coefficients of material and objects that are common in a preschool.

	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Curtains, light weight	0,03	0,12	0,15	0,27	0,37	0,42
Heavy curtains	0,06	0,1	0,38	0,63	0,7	0,73
Window glass	0,35	0,25	0,18	0,12	0,07	0,04
13 mm gypsum of 25 mm beams and mineral wool	0,26	0,20	0,10	0,07	0,04	0,07
Linoleum floor	0,02	0,02	0,03	0,03	0,04	0,04
1.0 person/m2	0,16	0,29	0,55	0,80	0,92	0,90
Chair made of tree	0,02	0,02	0,02	0,04	0,04	0,03
Chair made of tree, clothed	0,09	0,13	0,15	0,15	0,11	0,07

To evaluate the absorption coefficient of material made for absorbing sound energy is “EN ISO 11654” used. Absorption of class A is the class which has highest absorption value; figure 11 describes absorption class dependent of the practical absorption coefficient, α_p. α_p is based of measurements in one third octave.



1. Absorption class A
2. Absorption class B
3. Absorption class C
4. Absorption class D
5. Absorption class E
6. Unclassified
7. Frequency Hz
8. αp Practical absorption coefficient

Figure 11 Practical absorption coefficient for classification of absorption material according to EN ISO 11654 ***(Ecophon, 2013:3).***

3.8 Sound insulation

A walls ability to reduce sound is described by the term sound reduction, R_w, (Nilsson, et al., 2008). The index describes that the value is weighted according to a reference curve according to SS ISO 170/1. Value of R_w that are measured in a real room is defined by R'_w. R'_w includes sound transmitted through leakage as slots (Nilsson, et al., 2008). The higher values of R'_w the more sound are reduced through the wall. In following table is some example of how different reduction values are perceived. The information in table is collected from the document “Ljudlig miljö” (Lewin, 2011)

Table 4 The effect of different values of R’w.

R'_w (dB)	Effect of the sound reduction
30	A normal conversation will be heard and the message will be perceived correct.
35	A normal conversation will be heard but the message will not be perceived correct.
40	A normal conversation will be lightly perceived, loud conversations will be perceived correct. Office machines will be heard lightly.
44	A normal conversation will not be heard, loud conversations will be lightly perceived and office machines will not be a distraction.
48	Loud conversations will not be heard but screaming will be heard as well as music.
52	Screaming will be perceived lightly, music will be heard.
55	Screaming will not be heard, but music will, especially low frequency.
60	Music will be heard lightly; low frequency will still be heard.

3.9 Impact sound

Sound waves that are generated because of an excitation against a building element are named impact noise (Nilsson, et al., 2008). The Swedish requirements and recommendations of impact sound is outlined as L'_{nTw}, weighted standardised impact sound pressure level (SS-EN 25268:2007). The standardised level describes how the measurements should be performed. The weighting is done according to reference curves defined in SS ISO 170/1.

The highest value of L'_{nTw} level in a classroom, according to minimum requirements in Sweden is 56 dB if the impact sound is generated in room where a lot of impact noise are generated. In a room made for rest with the same conditions as in previous example is the highest value 68 dB.

3.10 Background noise

Background noise is the sound from ventilation and traffic but also speech, movement of furniture, falling toys or sounds from other rooms or corridors (Ecophon, 2013:5). Impacts of acoustical parameters regarding to background noise are described in following sections in this chapter.

3.11 Masking

Masking means that a sound is lost because of another sound like background noise (Nilsson, E. et al., 2008). This masking-effect can cause default of information and misunderstanding (Sjödin, 2012). Acoustical phenomena as reverberation can explain the masking, reverberation time is described in following section.

3.12 Reverberation time

The reverberant nature of a room, the resound because of sounds reflections against surfaces, has great influence upon how sound is experienced (Rossing, 2007). One common and traditional parameter to describe reverberation is reverberation time, T_{60} (Rossing, 2007). T_{60} is defined as the time it takes for the SPL to decrease 60 dB in an enclosure after a sound source has been switched off (Vigram, 2008). T_{60} is evaluated from the decay of range 20-30 dB (Rossing, 2007). Reverberation time and measuring range are explained in figure 12. Even in figure 8 of content "clarity" can the reverberant phenomena described.

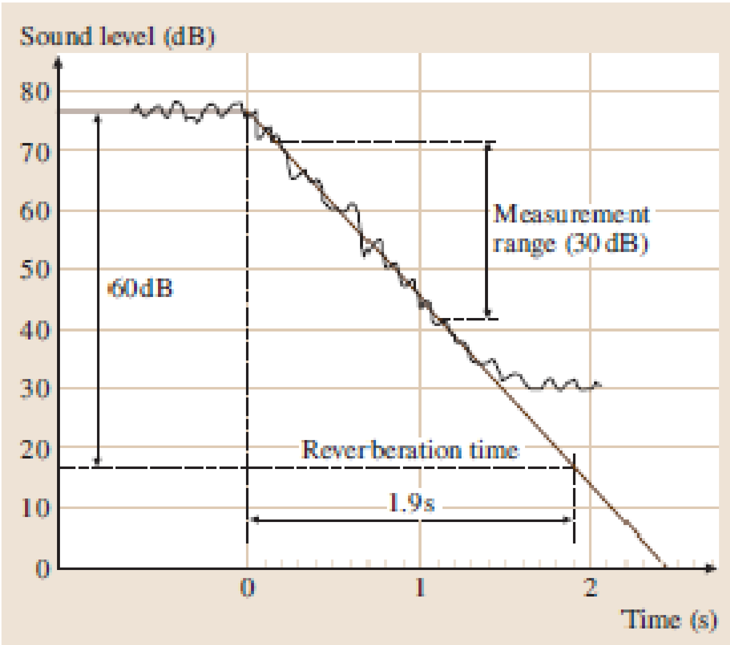


Figure 12 Description of reverberation time and measurement range *(Rossing, 2007).*

A long reverberation time means that the sound is reflected by different surfaces, as in figure 13, instead of being absorbed (Ljung, 2010). The optimal value of reverberation time depends upon the type of environment; a church may have a reverberation time of 3.0 s so as to amplify the sound throughout a large space (Rossing, 2007). According to Swedish standard should the reverberation time in a playroom be 0.5 s (SS-EN 25268:2007, 2007) to fulfil requirement of BBR. In places as classroom and also at preschools where understanding speech is of importance can long reverberation time make the speech indistinguishable and increase effort are required to understand the message (Ljung, 2010). This intelligibility problem occur since the louder vowels of low frequencies resists longer and masks the informative consonants, generated in higher frequencies that easier are absorbed (Rossing, 2007). Further explanation of generation of speech is explained in the chapter “Speech and auditory organs” below.

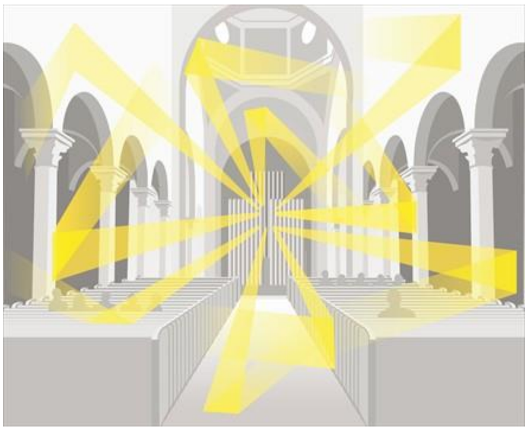


Figure 13 Sound reflected of the surfaces *(Ecophon 2013).*

3.13 Clarity

Clarity is a description of how well speech is transferred from the source to the listener (Ecophon 2013:1).

Reflected sounds that reaches the ear within 50-80 ms after the direct sound, the first sound that reaches the listener (Ecophon 2013:1) will be added to the direct sound energy which strengthens the sound, the amplitude increases and the sound is perceived as clear (Rossing, 2007). In figure 14 are the terms of direct sound and reflected sound visual described.

Figure 14 Direct sound, black arrow, and reflected sound, grey arrows, that reaches the ear *(Ecophon 2013:1).*

With regards to clarity it is those early reflections that are considered, see figure 15. The clarity is the relation between sound energy that reaches the ear within the 50-80 ms, described by the C_{te} where the index ‘te’ are set to 50 or 80 milliseconds (Rossing, 2007). Unit of speech clarity is dB.

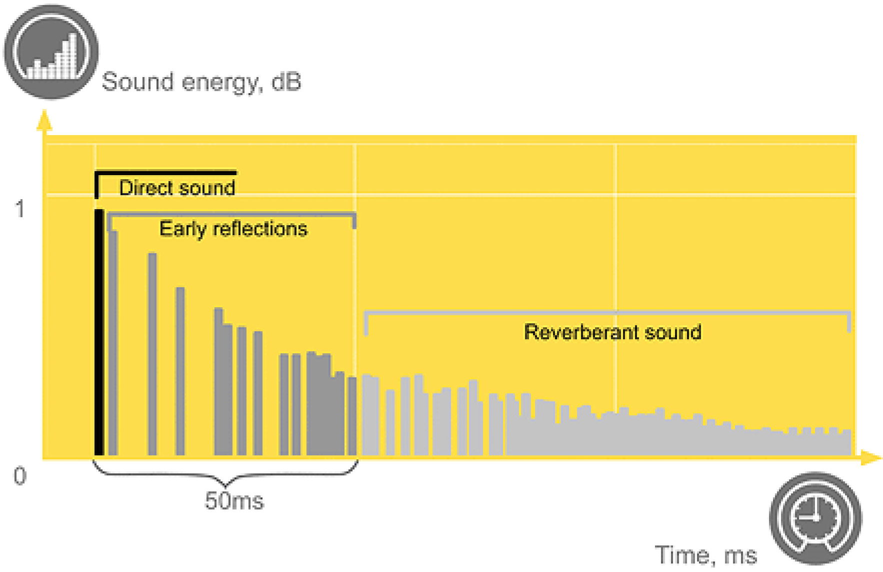


Figure 15 Direct sound, early reflections and reverberant sound *(Ecophon 2013:1).*

A high value of C_{te} means that significant part of the total energy has been perceived within the time of ‘te’ and the sound are perceived as clear (Rossing, 2007), the higher value of C_{te}, the clearer are the perceived sound (Ecophon 2013:1). Further understanding of clarity can be undertaken by studying the explanation in figure 12.

According to this parameter is 1.0 dB a noticeable difference (SS-EN ISO 3382-1, 2009). The opportunity to perceive sound clear is of importance especially for children since they process the information of the speech while learning (Ecophon 2013:4). The author of “Springer Acoustics” has written “Clarity is to a large extent a property complementary to reverberance” (Rossing, 2007).

3.14 Speech transmission index

Another common parameter that is used in accordance with building acoustics is speech transmission index, STI. STI describes the intelligibility of speech (Rossing, 2007). The concept of intelligibility is the quality of speech transfer that describes how much of the spoken information that is perceived and correct understood (Ecophon, 2013:4). As previous mentioned do children have to process the information of the speech which means that it is of importance to create opportunities to proper speech intelligibility in environments as preschools.

STI varies between 0-1 where 0 means bad/very poor intelligibility and 1 means that the speech transmission is perfect (Ecophon, 2013:4). The relation between values of STI and the perceived speech quality is explained in following table. STI in a normal classroom should be >0.75 (Ecophon, 2013:1).

Table 5 Quality of speech transmission depending of STI value. The table is processed by information given by "Springer acoustics" (Rossing, 2007).

Bad	Poor	Fair	Good	Excellent
<0,30	0.30-0.45	0.45-0.60	0.60-0.75	>0.75

Background noise and also much reverberance can disturb the sounds transmission which reduces its intelligibility (Rossing, 2007) and increased effort are needed to understand the message.

3.15 Sound strength

SPL is not always correlated with the subjective experience of the sound level. To get a better insight between the measured values and the perceived loudness of sound the parameter sound strength, G, is used (Rossing, 2007). Sound strength describes the impact of sound that the properties of the room cause, a room with high reverberation does strengthen the sound generated (Ecophon, 2013:2).

Sound strength is defined as the difference of dB in a "real" room and an "anechoic" room when the same sound source generates the same sound (Rossing, 2007). This situation is described in figure 16 below. The left part represents the "real" room and the right part represents an anechoic room, no sound is reflected at the surfaces. The properties of the "real" room causes 10 dB higher SPL than in the anechoic room which then is the value of the sound strength in the specific microphone position in the "real room".

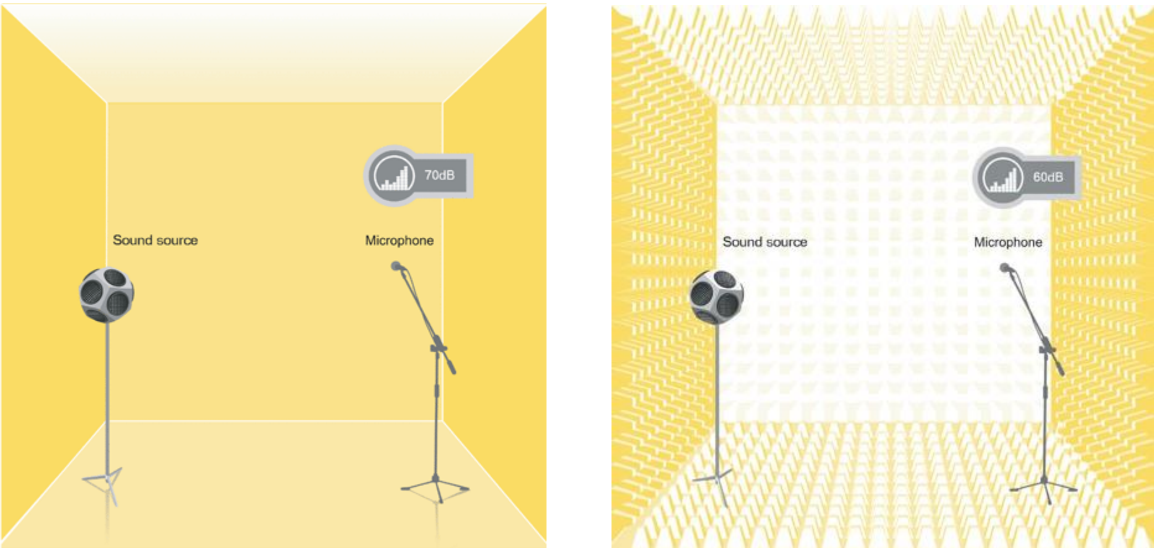


Figure 16 A "real" room and an "anechoic room where sound pressure level are measured.

In an unoccupied performance place of around 2500 m^3 with 300 seats is sound strength of 10 dB a suggested value (Rossing, 2007). A difference of 1.0 dB is a noticeable difference according to this parameter (SS-EN ISO 3382-1, 2009).

4 Sound Environment

In this chapter is the concept of sound environment according to this thesis explained.

The concept of sound environment is common during this thesis. No specific definition are declined in general of what the concept sound environment includes, thus is an explanation of what the concept of sound environment regards to through this thesis explained underneath.

The concept of sound environment consists of several parameters which can be measured, objective parameters. Weather the sound environment will be experienced as good or bad will be judged subjective. The subjective perspective will depend of individual demands and feelings but also the aim of the room. In the figure below are examples of the objective parameters described in the circle and example of subjective experience are described in the ellipsis. The arrows in the figure describes that the objective parameters have impacts of the subjective parameters. The arrows will also describe that it is the experience of the subjective parameters that put's the demands of the objective parameters.

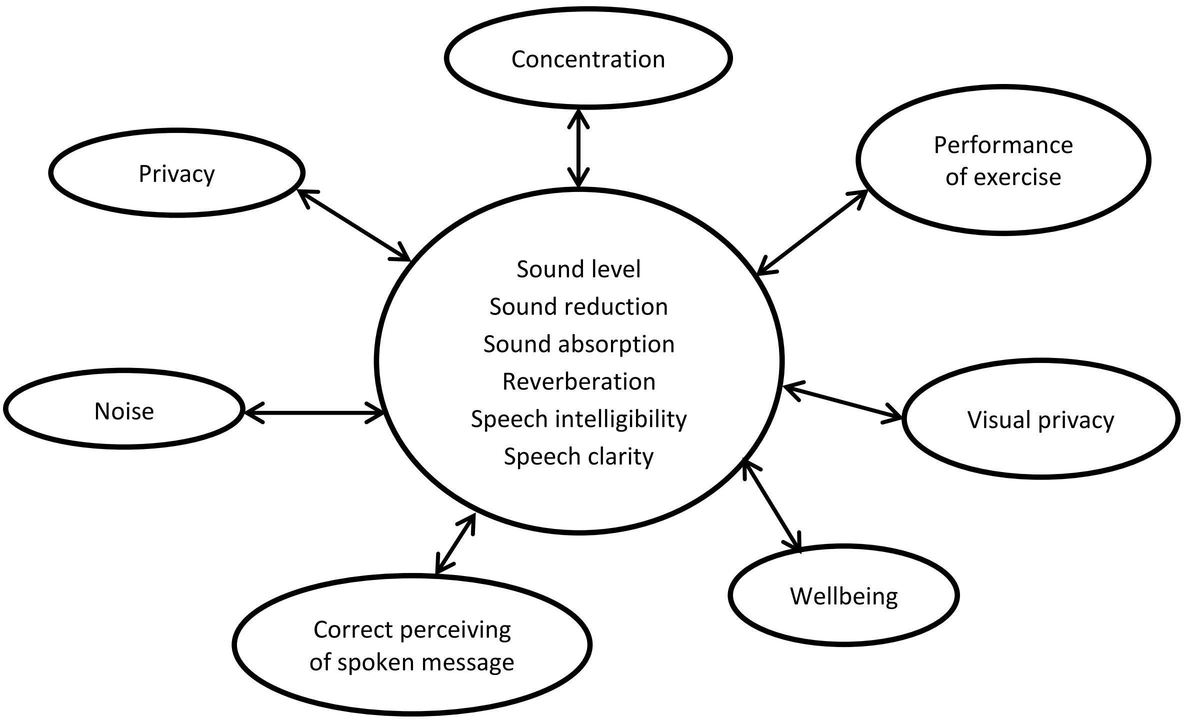


Figure 17 Examples of objective parameters and subjective experience of the sound environment.

Weather the sound environment is experience as satisfactory will depend of the extent of quality of each parameter and the aim of the room. The experience of a good sound environment may be fulfilled even if all parameters not are satisfying. On the other hand can one dissatisfactory parameter reduce the total experience so as the complete experience of the sound environment is jeopardised, depending of what's important for the specific room and the people in the room.

Through considering the acoustical design improvements of both objective parameters and the subjective experience can be performed. The type of acoustical design of the specific room that is needed depends of the aim of the room and which demands that are required.

Sound environment is then the relation between objective parameters and subjective experience, which have impacts of health and wellbeing. Thus rooms can be improved through considering the acoustical design. The relations can be viewed in following figure.

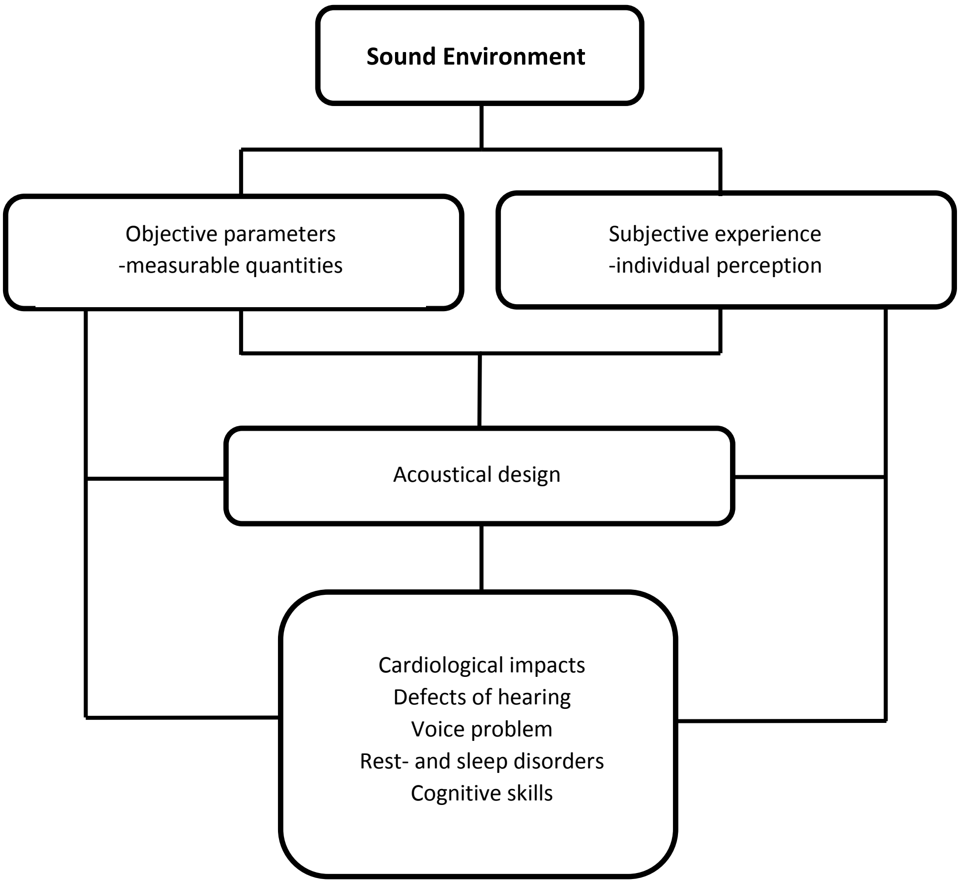


Figure 18 Relations of the concept sound environment.

5 Speech and auditory organs

In this chapter is a short presentation of speech presented followed by the section “children´s speech development”. Also the function of the human auditory organ is presented in this chapter.

5.1 Speech

Our speech consists of vowels and consonants. The speech is generally in the range of 100 Hz to 8000 Hz (Ljung, 2010). Vowels generally consist of low frequencies while consonants are in the higher frequencies (Konradsson, 2011). Vowels are generally louder which depends of the way it is generated; a greater flow of air goes through the windpipe since its open when the vowels are generated (Konradsson, 2011). The lower sound strength of the consonants is the reason of why constants easier gets disturb in noisy environments (Konradsson, 2011). Acoustical parameters as background noise and reverberation time can therefore have a huge influence of the communication (Ljung, 2010).

5.2 Children’s speech development

Following part refer to an interview with Christina Dravins, speech therapist at Hearing department, children and youth, Skåne University Hospital.

Children’s communication abilities start directly when they are born. Children have an inborn ability to communicate. As new born the mouth is configured for eating. A gradual change on the anatomy allows the infant to explore sound by babbling and at the age of around six months they are able to produce complex babbling as syllables. At the age of three years the mouth is fully developed for its double function eating and speaking. One year later the typically developed child has a good vocabulary, know all sorts of sounds and know fundamental grammar. At six years the sound structure of the mother tongue is often completely establish. At the age of one year children are playing side by side but not together. Between three to six years they are playing by roles, i.e. playing mother, father, baby, together. Their games are based on verbal communication which typically is egocentrically based. Already at this age it is of importance to be able to use language and speech so as to further develop the language and speech and social behaviour. By the age of four the speech has become even more important for their communication and they are using it in different social situations, not only games but also for discussion and to resolve conflicts.

5.3 Auditory organs

The components of a human's ear can be viewed in figure 19 below. Following is a description of the components functions.

The variations of pressure, sound, are caught by the pinna and then transferred to the auditory canal where sounds, of frequencies 2000-5000 Hz, are strengthening according to the resonance phenomena (Konradsson, 2011). Through the auditory canal can the sound be six till eight times stronger (Konradsson, 2011). Adults auditory canal is between two and three cm but is shorter for a child (Konradsson, 2011). Therefore are higher frequencies strengthening through a child's auditory canal, frequencies about 5000 Hz which makes them more sensitive for environments consisting of high frequencies (Broms, 2013).

The auditory canal ends at eardrum which transmits the vibrations to the auditory ossicles; hammer, anvil, and stirrup in the middle ear (Konradsson, 2011). Beyond the auditory ossicles contains the middle ear of air. A difference in pressure can appear over the eardrum which impairs the vibration abilities of the eardrum. This pressure difference is equated by the auditory tube, connected to the throat (Konradsson, 2011).

The ossicles are connected through the hammer muscle which strengthen the sound of two till three times and the stirrup muscle which are compromises when exposed to high sound levels and is therefore an important protection (Konradsson, 2011). Thus can the stirrup muscle be worn out when exposed to noisy environments for long time (Konradsson, 2011).

The vibrations are transferred to the cochlea in the inner ear. In cochlea are the vibrations converted through receptors too electrical signals. Thereafter are the signals send through the hearing nerve to the brain to be perceived (Konradsson, 2011).

In the inner ear is also the balance organ placed, the semi-circular canals and the vestibular nerve in the figure below belong to this organ.

The hair cells are sensitive for different frequencies. Hair cells that perceive high frequencies are those that are first reached in the inner ear and therefore most sensitive to get injured (Broms, 2013).

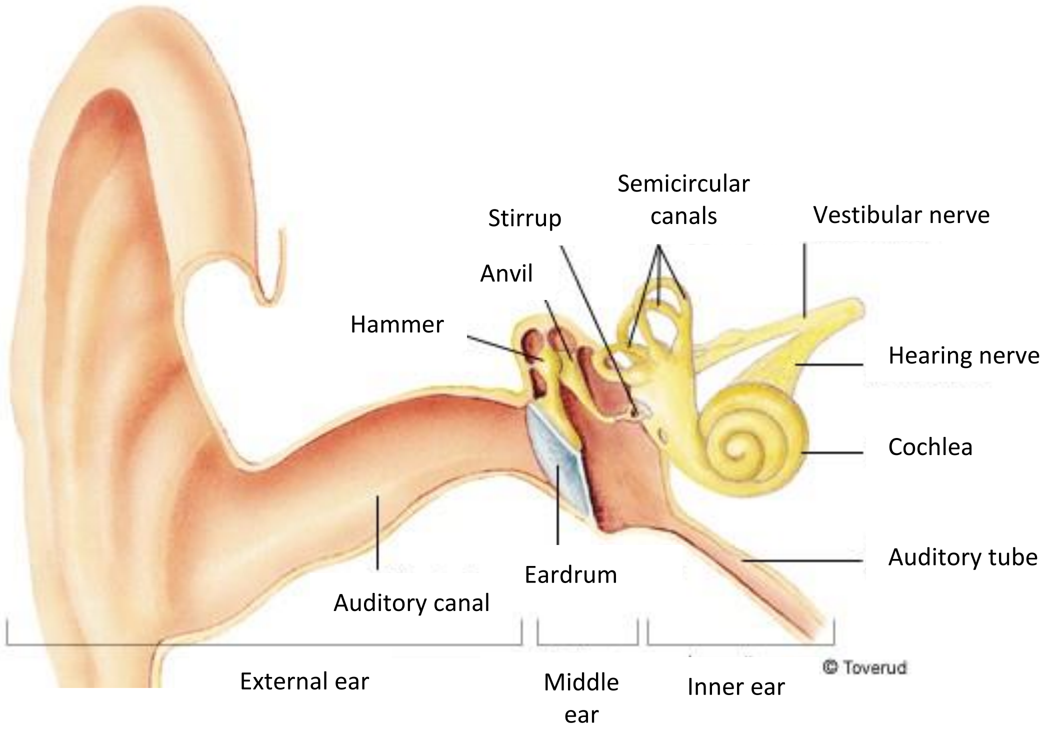


Figure 19 The components of the external-, middle- and inner ear of a human *(Sjukvårdupplysning, 2013).*

6 Noise

In this chapter is the concept of noise presented and the typical sound environment in a preschool is discussed.

6.1 The concept of noise

Noise is those kinds of sounds that we experience as disturbing (Watson, et al., 2007). Those sounds that actually are noise cannot be defined since the experience is individual (Sjödin, 2012). This means that one type of sound can be favourable for one person and unfavourable for another (Watson, et al., 2007) depending upon earlier experiences, situations, mood etc.

Sound can typically become noise when it is not expected, is experienced as unnecessary or interferes with an activity (Pershagen, et al., 2012). An example is music that has been transmitted from one room to another as it is not intended to be heard somewhere else than in the space where it is generated (Watson, et al., 2007). When complaints regarding noise are not taken seriously then noise tends to be even more disturbing (Nilsson, 2013).

Individual sensitivity to sound also affects how sound is experienced as noise (Sjödin, 2012). Noise sensitivity means sensitivity to stimuli of sound but also the ability to exclude distraction sounds (Pershagen, et al., 2012). Noise sensitivity can be divided into sensibility for SPL and sensitivity for different kinds of sound (Soames Job, 1999). An individual's noise sensitivity depends upon our genetic makeup and psychological conditions (Pershagen, et al., 2012).

Sound qualities like frequency spectrum, composition of frequencies, duration, variety and SPL also affects whether a sound becomes noise and how noisy it is perceived by the individual (Landström, 1999).

Noise can cause several negative effects, described in the chapter" Noise effects of people". As to how the individual experience of the sound actually affects these consequences is not totally clarified, but it is known that a high SPL:s is more likely to result in hearing losses and increase stress levels, even if the sound is perceived as positive (Pershagen, et al., 2012).

6.2 Sound and noise in preschools

Sound sources in preschools primarily consist of the children and their activities; talking, screaming, crying and playing, which may include a falling chair and a toy being thrown (Sjödin, 2012). Other common sound sources are ventilation, drying cabinets, kitchen equipment etc. These are sounds that probably can be perceived as irrelevant, annoying and therefore become noise (Sjödin, 2012).

The generation of sound is a part of the learning process where children develop their speech, language and social behaviour. To be able to speak and listen is a requirement for a functional and healthy preschool, for both children and personnel (Sjödin, 2012). Compared to sound sources in places such as factories there is the possibility of isolating the sound. This has generally reduced noise levels in factories over the last 50 years while it has increased in schools and after-school activities (Hygge, 1999). According to the Swedish Environment Work Authority preschools are one of the workplaces which have most problems with high SPL (Sjödin, 2012).

In the Report “Sound, mind and emotion” Persson-Waye writes that typical values of SPL in preschools are in the range of 75-80 dBA, equivalent for 8 h (Persson Waye, 2009). Children are generally exposed to higher SPL than personnel (Persson Waye, 2009). In a study made in Mölndal measurements showed that personnel were exposed to L_{eq8h}=78 dBA when children were exposed to levels of about 7 dB higher (Persson Waye, 2009).

Measurements of SPL in preschools was published in 2005 report entitled “Barn i bullerbyn”. This report included 165 measurements in preschools ninety nine dosimeter measurements and sixty six stationary sound level meter measurement. All measurements were undertaken in different preschools or preschool departments. The mean value performed using stationary equipment, was L_{eq8h} =74 dBA. Measurements performed using dosimeters showed a mean value of L_{eq8h} =78 dBA. The lowest results found by stationary equipment were L_{eq8h} =62 dBA and highest value were L_{eq8h} =83 dBA. Lowest value measured by dosimeters was L_{eq8h} =64 dBA and highest L_{eq8h} =87 dBA. (Dahlberg, et al., 2005). The value of 110 dBA was exceeded on 31 occasions and 115 dBA was exceeded on 19 occasions. These maximum values were all measured by dosimeters (Dahlberg, et al., 2005). The value of 110 dBA was not exceeded any time by stationary equipment (Dahlberg, et al., 2005).

In the 2012 doctoral thesis” Noise in the preschool”, measurements by stationery equipment and personnel dosimeters were performed in 17 different preschools. Stationery measurements where done in play halls and dining rooms and resulted in an average value of L_{eq8h}=63 dBA . Average value from dosimeters were LA, L_{eq8h} =71 dBA (Sjödin, et al., 2012;2). In figure 20 results from each preschool can be found.

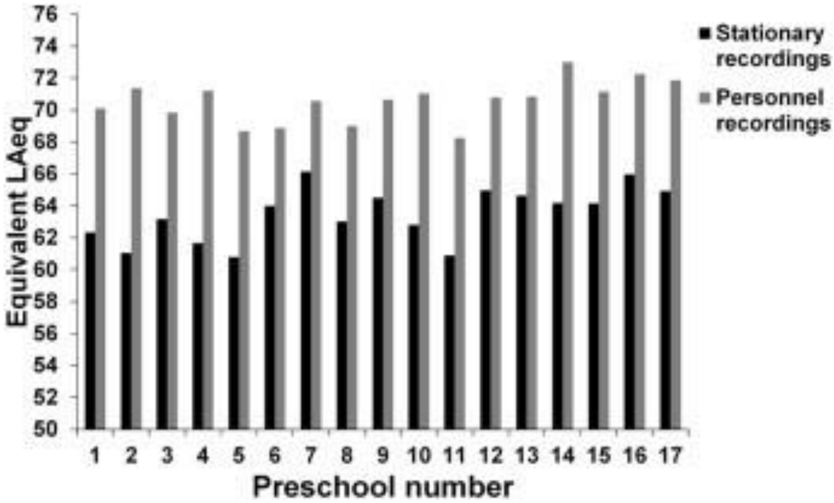


Figure 20 Equivalent SPL, dBA, measured by stationery equipment and personnel dosimeters in 17 different preschools *(Sjödin, et al., 2012;2).*

In the study" Noise in the preschools" the number of occasions where the SPL exceeded 85 dBA was observed and described in figure 21. Measurements in excess of this limit could mostly be seen correlated with morning and afternoon meal times, average of exceeds was 66/hour. Results were relatively consistent across measurements in the various preschools (Sjödin, et al., 2012;2).

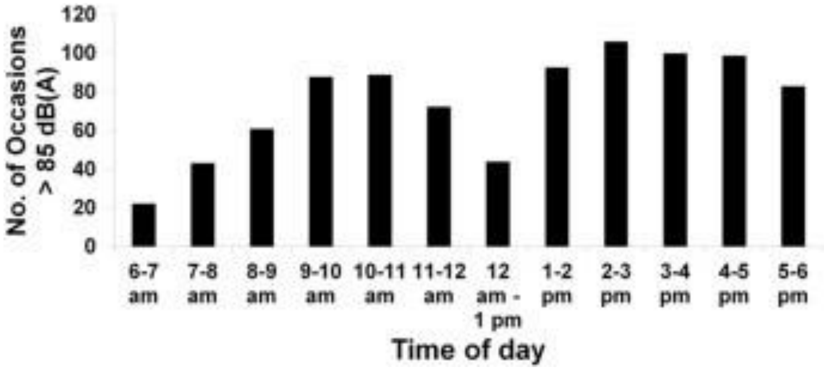


Figure 21 Number of occasions exceeding 85 dBA each hour during the work day *(Sjödin, et al., 2012;2).*

In the article" Noise exposure and auditory effect on preschool personnel", associated with the thesis "Noise in the preschool", a correlation between high SPL and frequency spectrum was seen. High SPL was mostly contributed by sound in frequencies around 1000-4000 Hz where children's voices are active (Sjödin, et al., 2012;2). In figure 22 the typical spectrum of a children's voice is shown. This figure shows that the highest SPL from a typical child's voice is centred on the high frequencies. The comparisons with phon curves show that the highest SPL from children's voices are in the same area that phon curves have the lowest value. This means that SPL at these frequencies are typically experienced as higher SPL than they actually are.

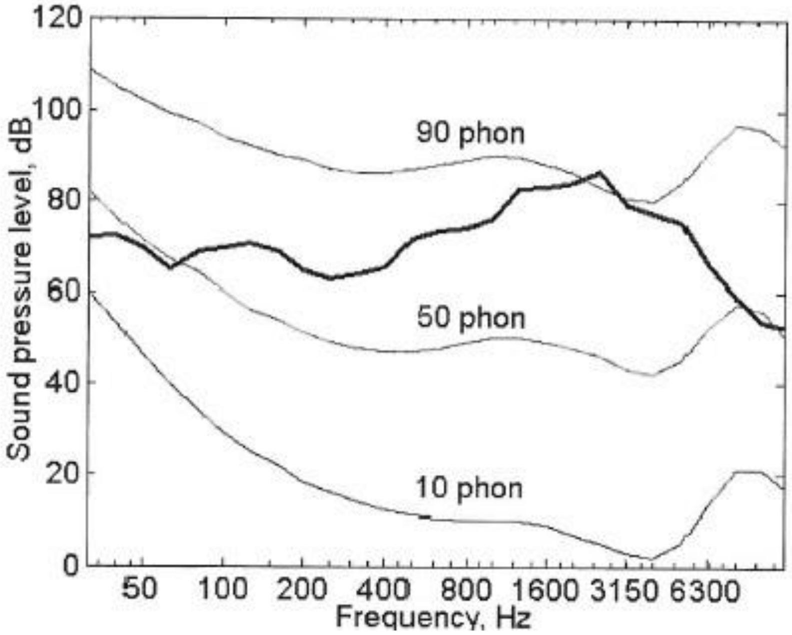


Figure 22 Typical frequency spectrum of a children voice compared with phoncurves *(Nilsson, et al., 2005).*

In the thesis ”Noise in the preschool” Sjödin found a strong connection between high SPL and fluctuations related to huge groups of children (Sjödin, et al., 2012;2). Sjödin writes in his report that this relation probably appoints to a behavioural problem. With an increased number of children the generated noise from each child increases, it is not only increasing number voices and summarized SPL (Sjödin, et al., 2012;2).

7 Noise effects on people

Effects of noise on people are presented by this chapter. Medical and physical effects as well as cognitive skills and wellbeing are discussed.

7.1 Cardiological impacts

An investigation into the health effects of aircraft noise upon children at schools nearby the old and new Munich airports was undertaken. The condition of these children’s health was controlled against a group of children who weren’t exposed to aircraft noise (Hygge, 2007). Children that went to the school nearby the new airport had not been exposed to aircraft noise before (Hygge, 2007).

The external SPL at schools nearby an airport was 60 dBA. Schools which were not located near an airport had an external SPL of 55 dBA (Hygge, 2007). All children were 9-10 years old and came from similar background. One parameter that was studied was blood pressure which increased in those children who were in schools located near to the new airport (Hygge, 2007).

A Polish study which investigated blood pressure of children in the age group of 11-12 years. They were exposed to a tone of 80 dBA over the hearing threshold in the 2000 Hz frequency. Results showed increasing diastolic blood pressure and also increasing heart rate (Paunovic, 2013). The systolic blood pressure was decreased and so was the amplitude of the pulse. The study also showed that the affects were greater amongst the youngest children (Paunovic, 2013).

In Slovakia a study of blood pressure effects of children of preschool-age was undertaken. The children’s preschools and homes were investigated and classified as quiet if SPL <60 dBA, noisy meant SPL 61-69 dBA or very noisy SPL >70 dBA (Paunovic, 2013). Results of the study, which included 1500 children, showed that children attending noisy and very noisy preschools, compared to children attending quiet preschools, had an increased blood pressure of 4-5 mmHg of both diastolic and systolic (Paunovic, 2013). The impact of blood pressure depending of sound environment in homes was smaller, but still significant; 1-2 mmHg higher diastolic as well as systolic blood pressure was seen by children living in noisy and very noisy homes compared to children in quiet homes (Paunovic, 2013). An unsuspected observation in this study was a higher heart rate for children living in quiet residences and attending quiet preschools (Paunovic, 2013).

7.2 Defects of hearing

Hearing impairment is caused by an overload of the auditory organs (Arlinger, 2006) and can be proved in different ways, usual impacts is decreased sensitivity and increased hearing threshold (Arlinger, 2006). Other disorders are diplacusis, hyperacusis, audio fatigue and tinnitus.

Diplacusis is a defect of the perception process and usually affects people who already have hearing losses (Sjödin, 2012). Two different types of diplacusis exist, binaural diplacusis and monaural diplacusis (Arlinger, 2006). The former means that that the perceived tone isn't correct while the latter means that one tone is perceived as two different (Sjödin, 2012). Audio fatigue means that the energy to listen is lost, a consequence of being in noisy environments for too long (Sjödin, 2012).

Hearing that is experienced without the presence of physical sound means that one is suffering from tinnitus (Arlinger, 2006). Tinnitus could be permanent or temporary (Arlinger, 2006). The impairment is often seen in relation to high SPL but it is also more common for older people (Arlinger, 2006). Even people who are deaf can suffer from tinnitus; however the consequences can be even more severe since there's no noise masking. No cures for long term tinnitus have been found nevertheless psychological treatments can be helpful in reducing the condition (Arlinger, 2006).

Arlinger writes in "Störande ljud" that sound levels below 80 dBA generally do not have any impact of hearing losses (Arlinger, 2006). According to Swedish Work Environment Authority an employer who is exposed to $L_{eq,8h}$=80 dBA should have access to hearing protection. In a work environment where employees are exposed to $L_{eq,8h}$=85 dBA immediate interventions should be undertaken. If immediate interventions are not possible then an action plan should be drawn up. that is not possibly a plan of interventions should be done (Arbetsmiljöverket, 2005).The graph below shows the increasing noise-induced hearing loss, NIHL, defects as SPL increases and with regard to the hearing loss for 10 % of a group that are exposed to each SPL for 8 h each day during ten years.

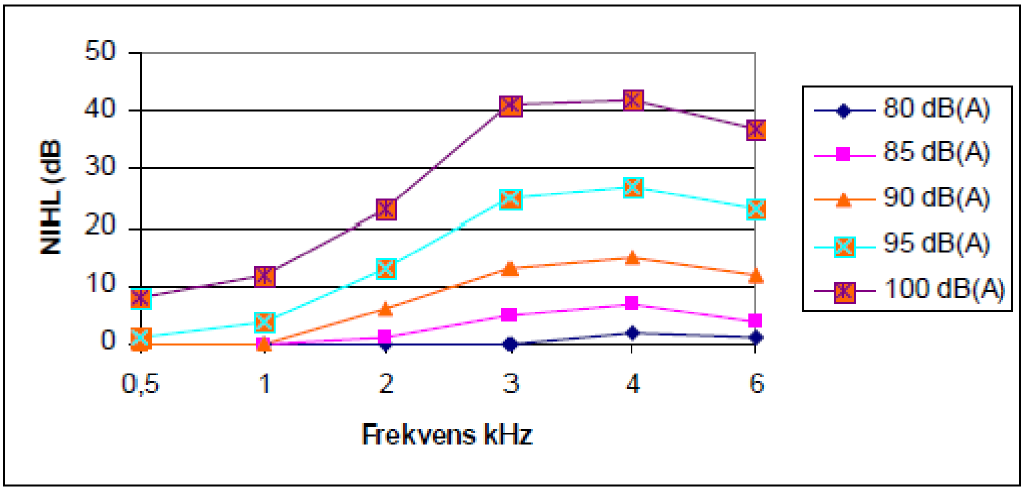


Figure 23 Noise impact hearing losses depending upon frequency and SPL *(Arlinger, 2006).*

The duration of noise exposure has an influence upon hearing losses (Arlinger, 2006). As the duration decreases by half the SPL permits 3 dB higher for the same hearing impact. This means that the same defects are caused by 88 dBA over 4 hour duration as 85 dBA over an 8 hour period (Arlinger, 2006).

A study including 301 children between the ages of 10-12 years was made in Czech Republic. 124 of these children went to a school determined as noisy; external SPL outside the school was above 75 dBA (Paunovic, 2013). The school was located near a highway (Paunovic, 2013). 177 children went to a school determined as quiet; an external SPL below 60 dBA (Paunovic, 2013). The children's hearing ability was tested for all of the children in the schools and the researchers found that 6,19 % of children from the noisy school had some degree of hearing loss while only 1.3 % of the children from the quiet school had the same impairment (Paunovic, 2013). It was also found that 43.5 % of the children in noisy school suffered from otitis media which is an inflammation of the middle ear. This disorder was found in 28.3 % children in the quiet school (Paunovic, 2013). A tuning-fork test was also performed in this study. This test outlines sound perception of each ear. No impacts were shown for children from the quiet school but 13 % of the children in the noisy school showed auditory impairment of this kind (Paunovic, 2013).

A Polish study considering hearing threshold has been undertaken. Children between the ages of 11-12 years old participated in the study. The study considered the relationship between sound environments at home and in school in relation to hearing threshold (Paunovic, 2013). The environments were divided into noisy, SPL between 76 and 85 dBA, or quiet, SPL between 42 and 57 dBA. The children were exposed to a sound of 80 dBA above the hearing threshold, at 2000 Hz during 4 minutes (Paunovic, 2013). The noisy zone included 79 pupils and the quiet zone 80 pupils. All participants showed an increased hearing threshold momentarily after the testing sound had been turned off. However the recovery time was significantly shorter for children from the quiet zone than those in the noisy zone a difference of recovery time was seen already after seen after two minutes (Paunovic, 2013).

The threshold of hearing for children was also studied in 24 Primary-schools in Slovakia. The value of hearing threshold was observed in the beginning of the first lesson of the day, at the end of the second lesson, in the beginning of the third and at the end of the day, and these values shown to increase over the duration of the day and increase significantly after longer breaks (Paunovic, 2013). A correlation could also be seen between hearing fatigue and increasing hearing threshold (Paunovic, 2013).

Sjödin writes in his report "Noise in the Preschool" that the typical preschool environment causes a lot of impairments, considering hearing (Sjödin, et al., 2012;2). His thesis, performed in Sweden, observed that 31 % of the preschool personnel that participated were suffering from tinnitus; the normal value within Swedish population is between 15-20 % (Sjödin, 2012). Persson Waye writes in the report "Sound, mind and emotion" that there is a great risk that children spending time in environments with high SPL can suffer from hearing loss, of various different kinds, which present themselves with age (Persson Waye, 2009).

Researchers have also emphasise that it is of importance to take action to create a better sound environment in schools, not only acoustically speaking, but also to educate personnel and children in the physics of the auditory organs and the impairments that a noisy environment can cause (Eysel-Gosepath, et al., 2012).

7.3 Voice problems

The definition of voice problems includes subjective symptoms such as problems with phonation, impaired voice quality, physical problems and also problems regarding voice endurance (Lyberg Åhlander, 2011). Voice problems are caused by too short voice recovery time; dissatisfactory acoustical design and high background noise (Lyberg Åhlander, 2011). Age, physical and psychological wellbeing, stress and gender can determine the grade of voice problem (Lyberg Åhlander, 2011).

Results of research of voice problems of children vary significantly, prevalence from 1-80 % between different studies (Nygren, et al., 2012). A reason for this can be differences in the definition of voice problems and also differences in research methods (Hartelius, et al., 2009). The most common voice problem is dysphonia, i.e. hoarseness (Hartelius, et al., 2009). Studies have shown that dysphonia is more common for children who live in big cities. A study performed in Sweden showed that 21-24 % of children, at an age of ten, who lived in big cities suffer from dysphonia (Hartelius, et al., 2009). It was also found that boys are more likely to suffer from this disorder (Nygren, et al., 2012). Also personality seems to affect the risk of dysphonia, talkative, outwardly, energetic and loud children more often suffering from dysphonia compered to children with a calm personality. Usually dysphonia is caused by a cold and is then defined as acute dysphonia. Even a temporary extreme use of the voice can cause acute dysphonia (Hartelius, et al., 2009). There's also chronic dysphonia which seems to be more common when spending more time in day care centres or after school care environments (Nygren, et al., 2012). In a survey conducted in 2012 measurements to compare differences in voice use of boys and girls was performed. Participants of the study included 30 children between the ages of 4-5 years (Nygren, et al., 2012). No significant differences because of gender could be seen (Nygren, et al., 2012).

High voice load, which implies speaking with high intensity, to be heard, for a long time can also cause changes in vocal tissues and so called vocal fold nodules (Hartelius, et al., 2009). Boys tend to suffer more from this disorder (Nygren, et al., 2012), as do outwardly and talkative children (Hartelius, et al., 2009). Zangger

Edema of glottis is another disease caused by high voice load, usually in combination with infection, injury or inhalation (Zangger, 2012). The disorder appears as a fluid accumulation, at vocal cords in an attempt to protect themselves (Hartelius, et al., 2009). Children seem to be predisposed to have this disorder since their vocal cords are not completely developed (Hartelius, et al., 2009).

7.4 Rest, sleep disorders, stress and wellbeing

Studies of preschool personnel's wellbeing shows that these people often suffer from fatigue, energy losses and stress (Sjödin, et al., 2012;1) which are parameters that could be correlated to high SPL and noisy environments (Persson Waye, 2009). Whether the symptoms described above also could affect children in preschools is not fully understood but there is nothing that says that it won't, writes Persson Waye in the report, "Sound, mind and emotion" (Persson Waye, 2009).

In the survey, carried out in Czech Republic, previously mentioned, were even psychological effects of noise and outlined and significant differences were observed. Children from the noisy school more often had decreased school performance, concentration problems, were more tired and also were more likely to be irritated more often compared to children in quiet school (Paunovic, 2013).

A study of children's health due to aircraft noise in preschools described earlier in this chapter, also measured levels of adrenaline and noradrenaline. Children who were exposed to aircraft noise had higher values of these hormones (Hygge, 2007). When recovery time is sufficiently long then temporary stress is not hazardous, but long-time stress can cause fatigue, sleeping disturbance, depression, headache, burn-out and pain in the neck and shoulders (Sjödin, et al., 2012;1).

In the article ”Noise and stress effects on preschool personnel" the author writes that noise can cause stress because noisy environments are uncomfortable but also because it can be difficult to correctly observe information and instructions and to perform tasks (Sjödin, et al., 2012;1). From this study a significant observation was found between subjective experience of noise and typical stress symptoms (Sjödin, et al., 2012;1). It was also found that preschool personnel, who reported that they were suffering because of the noisy environment, were more likely to report of symptoms that are typical of a burnout state. If those symptoms are consequences of a noisy environments or if the one's sensitivity to noise increases in a burnout state is not totally understood (Sjödin, et al., 2012;1). Objective measurements of sound did not correlate with burnout symptoms as it did when the subjective experience of the sound environment was described, which the author perceives could depend upon the low variety of measurements (Sjödin, et al., 2012;1). Moreover the relation between sleeping quality and SPL found that decreasing sleep quality was caused with increasing time in environments where SPL was above 85 dBA (Sjödin, et al., 2012;1). When more fluctuations were seen in the measurements a correlation with symptoms of depression was seen (Sjödin, et al., 2012).

Sounds can be connected to memories; feelings and is also a part of social interaction and hearing losses which could therefore be significant for social wellbeing (Wikström, 2008). It is typical that people with hearing loss avoid social happenings or get a feeling of being outside in social situations since it is hard to be a part of the discussions due to perceived problems or an increased sensitivity to noisy surroundings (Arlinger, 2006). People with hearing loss often need to see where sound comes from (Dravins, 2013). Children who have hearing loss often get rowdy and loud or on the contrary become quiet (Dravins, 2013). Already at the age of two and a half year it is important to be able to use speech to be a part of a game and for further development of social behaviour (Dravins, 2013).

Hearing impairment can also cause an increased risk of misunderstanding or misperception of instructions or warnings (Arlinger, 2006). It is common that people with hearing loss have a higher prevalence for psychiatric problems and decreased wellbeing (Dravins, 2013).

7.5 Cognitive skills

In the report ”Ljud och inlärning” Hygge writes that memory and learning abilities decrease when exposed to noise, both temporary as well as long-lasting noise (Hygge, 2007). However long-lasting noise affects the learning abilities even more according to several parameters such as perseverance, motivation, attention and helplessness (Hygge, 1999). However noise does not have any impact upon short term memory, speech abilities and the performance of easy exercises, according to Hygge and the report “Ljud och inlärning” (Hygge, 2007).

In the Czech Republic study previously discussed, children between 11 and 14 years old in the nosier school showed a lower level of academic performance (Paunovic, 2013).

In the survey made in Munich, described in the section “Cardiological impacts” in this chapter, which investigated children’s ability of perception, cognition, motivation, life quality and psychophysiology (Hygge, 2007), Children who went to the school were the old airport was located showed a decreased performance according to vocabulary and memory of texts compared to children in control group. Eighteen months after the airport had been moved from its original location the results showed that the children in the old school now achieved comparable results with those children in control group. When the same test was performed for children near the new airport the results showed that eighteen months after the new airport had opened these children had a decreased performance regarding vocabulary and memory tests (Hygge, 2007).

Another survey, by Evans and Maxwell, also evaluated the impact of aircraft noise upon children’s ability, in this case of speech and sound perception (Hygge, 1999). The children involved were in first or second grade and had been exposed to aircraft noise that gave a SPL Leq of 65 dBA. All tests were performed in silence. The results showed decreased speech perception, but no changes in sound perception (Hygge, 1999).

A further study named the classroom experiment included students of Swedish grade 7, means an age of 13-14 years. These children were exposed to different sources of noise, over a period of 15 minutes (Hygge, 2007). All type of sources were used, such as traffic noise, aircraft noise, noise from trains and verbal noise, which had an $L_{eq,8h}$=66 dBA (Hygge, 2007). The participant’s abilities of learning and memory of texts were investigated. Results showed that aircraft noise had an influence upon these parameters but the other sources did not affect these kinds of abilities (Hygge, 2007).

The effect of background noise and reverberation time on learning was investigated by Ljung in the thesis “Room acoustics and cognitive load when listening to speech”. Tests were conducted on participants, which tested recollection of a wordlist and recognition of sentences. These tests were performed in different rooms with varied background noise and reverberation times (Ljung, 2010). Even work memory was taken into account in this survey.

When performing a task there is a limit to the capacity of the working memory (Kjellberg, 2004). The working memory is used for process the phonological but also to process the sounds information (Kjellberg, 2004). When decreasing memory capacity is needed the capacity for evaluating the information increases (Kjellberg, 2004). Ljung's survey showed that background noise had the effect that the participants weren't able to recall as much words as when there was no background noise. Background noise seems to have no influence upon the ability to recognize sentences. When the influence of long reverberation time was investigated a significant difference could be seen in rooms with longer reverberation times, both in terms of fewer words recalled and less sensitivity with regards to the recognition of sentences. This survey also found that background noise and long reverberation time affects the pupil's memory of a spoken lecture, even if the pupils are able to hear what was said. The author's conclusion is that background noise and long reverberation time does not always result in impaired memory but that it can hinder learning (Ljung, 2010).

Research regarding the noise impact of memory has shown that episodic memory will be affected but not semantic memory. Episodic memory means the recollection of information by the process of remembering facts while semantic memory is more generally knowledge such as Stockholm is the capital of Sweden (Hygge, 2007). This theory was also found to hold true in the survey "Cognitive skills and restoration", where the performance seemed to be affected more if episodic memory and rehearsal was needed which means that the level of impact by noise depends upon which cognitive process is used (Jahncke, 2012).

To learn superficial facts or perform skills that are already known and ingrained is usually not disturbed by noise. Noise becomes a problem when learning new knowledge and when information has to be processed and/ or analysed (Hygge, 1999). In this situation the sensitivity to becoming disturbed increases and it is usually noise that includes words that are meaningful but irrelevant that is the most disturbing (Hygge, 1999). Irrelevant speech seems to be disturbing even when SPL are at low levels such as 50 dBA. The grade of disturbance by noise tends to increase when the difficulty of the exercise increase (Hygge, 1999).

In a survey by Christie and Glickman in 1980 it was shown that there was a difference between girls and boys performance in noisy environments (Hygge, 1999).The children assessed were between 7 and 12 years and the noise recorded classroom was over SPL 70 dBA in the noisy environment and 40 dBA in the quiet environment (Hygge, 1999). Boys tended to perform better in a noisy environment while girls had better results in the quiet environment (Hygge, 1999).

A survey, by Johansson 1980, showed that children with high performance could easily solve multiplication while children with lower performance got an even worse score in the noisy environment (Hygge, 1999).

In a newly published survey in "Noise and heath" adolescent's experience of their schools environment was investigated. A questionnaire was answered by adolescents between the ages of 11-16 years (Connolly, et al., 2013). The survey showed that older pupils were more sensitive and affected more by the acoustics than younger pupils. It also showed that an open plan design more often was experienced as a bad environment in comparison to cellular classrooms.

The surveys and findings described above have been applied primarily to older children as opposed to those of preschool age but Persson Waye says in ”Sound, mind and emotion” that surveys of this kind are not that common for children of preschool-age. However she also says that there’s nothing that says that young children acknowledge sound in the same fashion (Persson Waye, 2009). It should also be mentioned that other surveys have shown that older children are more affected than younger children (Hygge, 1999). Persson Waye observes that a satisfying sound environment is a requirement for the development of good language comprehension and that noisy environments in preschools can cause problems with reading and writing when the children become older (Persson Waye, 2009).

It is common that children with hearing loss have difficulties at school since their conditions related to speech and language development are decreased. They often have a decreased vocabulary, do not uptake information to develop knowledge and their abilities for communication are impacted (Dravins, 2013).

8 Case studies

This chapter consists of the case studies which include a presentation of the preschools and their requirements of building phase. It also includes collaboration of the investigation. Furthermore are preventive measures of the preschools explained and results of calculations are outlined.

8.1 Presentation of the cases

Two preschools, Kattfoten and Orkesterparken, were investigated during the period of January until June 2013.

The preschool Kattfoten is located in Dalby in southern Sweden. The design for this school started 2008 and the building was ready for occupation in June 2010. Preschool Orkesterparken is located in the city of Lund and was designed in 2010 and the building was finished and handed over for occupation by March 2012. An overview of the layout of the preschools can be seen in appendix I, preschool Kattfotens and appendix II, preschool Orkesterparken.

Acoustic requirement was outlined for both schools in the same way, following was stated;

Standards require are fulfilled by using sound class C in Swedish Standard SS 25268:2007. According to sound absorption and room acoustics has sound class B, Swedish Standard SS 25268:2007 been used in this document (translated from 2008-12-12 *Förfrågningsunderlag Handling 06.2.12* and 2010-06-22 *Förfrågningsunderlag Handling 06.2.9).*

As previous mentioned is sound class C used to fulfil the minimum requirement in BBR (SS 25268:2007). When a better sound environment is prioritized should sound class B be used (SS 25268:2007).

In the tables below are the values of the parameters that are outlined in SS 25268:2007. Table 6 showes the lowest weighted value of sound reduction, R'w. Table 7 shows Highest Standardized impact noise, $L'_{nT,w}$. Table 8 shows highest reverberation time $T_{20,}$ table 9 shows the highest A and C-weighted sound level from installations and table 10 shows sound levels from traffic and outside sources.

Table 6 The lowest weighted value of sound reduction, R'w in differnet types of rooms according to SS 25268:2007 *(SS 25268:2007, 2007).*

Tabell 15 – Lägsta vägda reduktionstal i byggnad, R'_w, för undervisningslokaler: skolor, förskolor och fritidshem

	Från annat utrymme R'_w dB				*Från korridor* R'_w dB			
	Ljudklass				Ljudklass			
Typ av utrymme	A	B	C	D	A	B	C	D
15a Till utrymmen för gemensam undervisning *exempelvis klassrum, lektionssalar*	48	44	44	40	44	40	40	30
15b – dock till utrymmen för undervisning eller elev-arbete i mindre grupper *exempelvis grupprum, hemvist*	44[a]	44[a]	44[a]	40[a]	40[b]	40[b]	40[b]	30
15c – dock mellan stora utrymmen för undervisning i grupper *exempelvis utbildningslandskap*	40	35	35	30	–	–	–	–
15d Till utrymmen för enskilt arbete eller samtal *exempelvis expedition, bibliotek*	40	35	35	–	35	30	30	–
15e – dock till utrymmen med krav på måttlig sekretess eller avskildhet *exempelvis yrkesvägledare, personalrum, konferens-rum*	48	44	44	40	40[b]	35[b]	35[b]	30
15f – dock till utrymmen med krav på hög sekretess *exempelvis rektor, studierektor, talklinik, kurator, psyko-log, skolhälsovård*	52	52	48	48	44	44	40	40
15g Till utrymmen för lek eller samvaro i förskola *exempelvis lekrum, snickarrum*	48	44	44	40	35	30	30	–
15h Till hygienutrymmen och eller utrymmen för vila *exempelvis wc, vilrum, duschrum*	44	44	44	40	35	30	30	–
15i – dock mellan hygienutrymmen	35	35	35	–	–	–	–	–

[a] För skiljekonstruktion med dörr från annat utrymme för undervisning godtas 5 dB lägre värden.

[b] För skiljekonstruktion med större glasparti bredvid dörr som ger god uppsikt om vad som sker utanför godtas 5 dB lägre värden.

Table 7 The Highest standardized impact noise, L'nT,w in differnet types of rooms according to SS 25268:2007 *(SS 25268:2007, 2007).*

Tabell 16 – Högsta vägd standardiserad stegljudsnivå, $L'_{nT,w}$, för undervisningslokaler: skolor, förskolor och fritidshem

	Från utrymme med låg stegljudsbelastning $L'_{nT,w}$ dB				*Från utrymme med hög stegljudsbelastning* $L'_{nT,w}$ dB			
	Ljudklass				Ljudklass			
Typ av utrymme	A	B	C	D	A	B	C	D
16a Utrymmen för gemensamma samlingar, mer än 50 personer[a] *exempelvis aula*	48	48	52	–	40	44	48	56
16b Utrymmen för gemensam undervisning[a] *exempelvis utbildningslandskap, klassrum, lektionssal, musiksal*	56	56	60	–	52	52	56	60
16c Övriga utrymmen för undervisning *exempelvis hemvist, grupprum, slöjdsal, undervisnings-kök*	60	60	64	–	56	56	60	64
16d Övriga utrymmen där människor vistas mer än tillfälligt *Exempelvis vilrum, lärarrum, personalrum, kontor, expedition, studierum, bibliotek, mediatek, kurator, psykolog, talklinik, skolhälsovård, musikövningsrum, matsal, uppehållsrum*	68	–	–	–	64	64	68	–

[a] För ljudklass A och B skall även $L'_{nT,w} + C_{I,50\text{-}2500}$ uppfylla ställda kravvärden.

Table 8 The highest reverberation time T_{20} in differnet types of rooms according to SS 25268:2007 *(SS 25268:2007, 2007).*

Tabell 17 – Längsta efterklangstid i rum, T_{20}, för undervisningslokaler: skolor, förskolor och fritidshem

	T_{20} s			
	Ljudklass			
Typ av utrymme	A	B	C	D
17a Utrymmen för gemensam undervisning *exempelvis klassrum, lektionssalar*	0,5	0,5	0,5	0,8
17b Utrymmen för undervisning eller elevarbete i mindre grupper *exempelvis grupprum, hemvist, konferensrum, lekrum*	0,4	0,5	0,5	0,6
17c Utrymmen för undervisning i musik *exempelvis musiksal, musikövningsrum*	0,6	0,6	0,6	0,8
17d Stora utrymmen för idrott *exempelvis gymnastiksal, idrottshall, simhall*	1,0	1,2	1,2	2,0
17e Utrymme för samvaro eller matservering större än 100 m² samt utrymme för matlagning *exempelvis uppehållsrum, matsal, cafeteria, storköksutrymme*	0,4	0,5	0,5	0,6
17f Övriga utrymmen där människor vistas mer än tillfälligt *exempelvis rum för vila, lärare, personal, kontor, expedition, studierum, bibliotek, mediatek*	0,5	0,6	0,6	–
17g Utrymmen där människor vistas tillfälligt *exempelvis korridorer, entréer, kopieringsutrymmen, omklädningsrum*	0,5	0,5	0,5	0,8
17h – dock i trapphus	0,8	0,8	0,8	1,0

Table 9 Highest A and C-weighted sound level from installations in differnet types of rooms according to SS 25268:2007 ***(SS 25268:2007, 2007).***

Tabell 18 – Högsta A- och C-vägd ljudnivå från installationer, för undervisningslokaler: skolor, förskolor och fritidshem

Lägsta tillåtna sammanvägda ljudisolering skall fastställas genom beräkning utifrån dimensionerande ljudtrycksnivåer utomhus så att tabellens värden på ljudtrycksnivåer inte överskrids i följande utrymmen:	L_{pA} dB				L_{pC} dB			
	Ljudklass				Ljudklass			
Typ av utrymme	A	B	C	D	A	B	C	D
18a Utrymmen för gemensamma samlingar, mer än 50 personer *exempelvis aula*	26	26	30	30	45	45	50	50
18b Utrymmen för undervisning, upp till 50 personer *exempelvis klassrum, musiksal, grupprum, slöjdsal*	26	30	30	30[a]	45	50	50	50
18c Utrymmen för hälsovård, vila, enskilt arbete, enskild undervisning, lek, samtal *exempelvis vilrum, talklinik, kurator, psykolog, skolhälsovård, lärarrum, personal, kontor, expedition, konferensrum, studierum, bibliotek, mediatek, musikövning, lek, snickarrum*	30	35	35	40	50	55	55	55
18d Utrymme för beredning av mat och därtill hörande utrymmen *exempelvis storkök*	50	50	55	–	65	–	–	–
18e Övriga utrymmen där människor vistas mer än tillfälligt *exempelvis uppehållsrum, matsal, cafeteria, gymnastiksal*	35	35	40	40	55	55	–	–
18f Utrymmen där människor vistas tillfälligt *exempelvis korridor, entréhall, trapphus, kapprum, WC, omklädningsrum*	40	40	–	–	60	–	–	–

[a] I utrymme för gruppvis undervisning i utrymmen med många installationer, exempelvis slöjdsal trä/metall, teknikundervisning, undervisningskök, kan i undantagsfall 5 dB högre värden godtas (avser grundflöde hos ventilation, etc.)

Table 10 shows sound levels from traffic and outside sources in differnet types of rooms according to SS 25268:2007 *(SS 25268:2007, 2007).*

Tabell 19 – Dimensionerande ljudnivå från trafik och andra yttre ljudkällor, för undervisningslokaler: skolor, förskolor och fritidshem

Lägsta tillåtna sammanvägda ljudisolering skall fastställas genom beräkning utifrån dimensionerande ljudtrycksnivåer utomhus så att tabellens värden på ljudtrycksnivåer inte överskrids i följande utrymmen:	$L_{pA,eq}$ dB				L_{pAFmax} dB			
	Ljudklass				Ljudklass			
Typ av utrymme	A	B	C	D	A	B	C	D
19a Utrymmen för gemensamma samlingar, mer än 50 personer *exempelvis aula*	26	26	30	30	35	40	45	50
19b Utrymmen för undervisning, upp till 50 personer *exempelvis klassrum, lektionssal, musiksal, grupprum*	26	30	30	30	41	45	45	50
19c Utrymmen för hälsovård, vila, enskilt arbete, enskild undervisning, lek, samtal, idrott *exempelvis rum för vila, talklinik, kurator, psykolog, skolhälsovård, lärare, personal, kontor, expedition, konferenser, studierum, bibliotek, mediatek, musikövning, lek, snickarrum, slöjdsal, undervisningskök*	30	35	35	40	45	50	50	60
19d Övriga utrymmen där människor vistas mer än tillfälligt *exempelvis uppehållsrum, matsal, cafeteria, storköksutrymme*	35	35	40	45	55	–	–	–
19e Utrymmen där människor vistas tillfälligt *exempelvis korridor, entréhall, trapphus, kapprum, WC, omklädningsrum*	40	45	–	–	–	–	–	–

8.2 Acoustical requirements

Lundafastigheter usually use the recommendations outlined by Swedish Standard SS 25268:2007, sound class B is generally used.

Even requirements according to Miljöbyggprogram SYD are used. Miljöbyggprogram SYD is an environmental policy which is used when building on lands that are owned by the municipality of Lund or Malmö. The aim of this policy is to put higher requirements when building, for a sustainable environment and reduce the impact on the environment and resources (Miljöbyggprogram SYD, 2012).

With regards to building acoustics and traffic noise requirements the values are the same as in SS 25268:2007. Environmental classification C is the lowest, and classification A the highest. The differences between these classifications are the values of the acoustical terms. Beyond these values requirements an acoustician has to be involved throughout the building process; from the first planning until control measurements are conducted on the finished building. An acoustician are responsible for documentation of decision and choice that are done according to the sound environment (Miljöbyggprogram SYD, 2012).

The ambition of Lundafastigheter preschools representative from the preschool should be involved through the building process. Even trade unions are involved through the process. Thus did project managers at Lundafastigheter that it is uncommon that opinions according to sound environment were explained by these representatives.

8.3 Investigation of the preschools

Personnel were interviewed in both preschools. The acoustical parameters which were then evaluated in the schools were based upon reflections and conclusions drawn from interviews with personnel.

Both preschools have six different sections. Three sections at Kattfoten and four sections at Orkesterparken are reserved for the youngest children who usually are up till 2.5 years. Each section houses between 13-14 children. The other three sections are for children between 2.5-6 years of age. These sections house older groups of approximately 18 children. Every section usually has two till three personnel.

Questions performed during the interviews are seen in appendix III.

8.3.1 Interviews with personnel at Kattfoten

Five personnel were interviewed and both ”young” and “old” sections were represented. The participants were both women and man and their age varied from between 20 and 39 years. They had been working in preschools for between 3-15 years.

8.3.1.1 Sound levels and health consequences

All participants expressed that they experienced very high sound levels. Some of the personnel were using earplugs. They all concurred that it is the children’s activities that generate the noise. Noise from other sources such as ventilation, kitchen, drying cabinets etc. was not observed as significant by any of the participants.

The participants experienced varying levels of sound throughout the working day. For sections housing the younger children the participants experienced highest sound levels just before lunch and late in the afternoon which was explained by children’s tiredness at these times. In the sections housing older children the highest sound levels were experienced just before lunch and just after lunch. This point to the fact that older children do not have any sleeping time as opposed to those in the younger sections.

The ability to be outdoors during the school days was deemed to make a huge difference in reducing sound related symptoms while days with bad weather and long cold winter days really makes the symptoms caused by a bad sound environment worse.

All of the participants reported that they suffered from hearing fatigue at the end of the day. One participant, who had worked in preschools for two years, fulltime, mentioned howling in her ears upon coming home. All of the participants emphasised that they made every effort to have a quiet environment after coming home from a day at work. It was also found that noise was a reason that they did not work full time. None of them experience that they have to increase their voices to be heard. One participant said that she almost every day had a headache and was really tired when she got home: symptoms which she thought arose due to high sound levels.

8.3.1.2 Children's experience

The participants thought that the children also suffer from the sound environment, however may not get as mentally tired as the personnel since the sounds is a part of their activity. Sometimes children are seen to be holding their ears. Crying or screaming children can upset their fellow classmates. Participants also thought that the children sometimes scream just to get heard but different children are more vocal/ nosier that other which the participants thought mostly depended upon a child's personality. Restless children and those who find it harder to concentrate tend to be louder. They thought that children who are calm themselves suffers more than those children who generate the most noise. Sometimes it is hard to communicate with the children because of high sounds levels, they "cutting off".

The fact that children feel comfortable within their routines and activities does mean that they are not as loud as they could be. However when routines and activities are changed, due to for example sickness or meeting, then noise levels generally do increase.

Participants all reported that they felt uneasy about limiting children's noise levels as it can inhibits their fantasy and playfulness and consequently affect the learning performance. Participants experienced it is harder to get younger children to understand the problem of high sound levels and also how to reduce the noise. Dividing children into smaller groups has the best effect for decreasing sounds levels.

8.3.1.3 Sound and pedagogic work

The participants reported that they were always aware of sound levels when they were planning activities, but they also said that many exercises have to be done in smaller groups and that sound environments do not present themselves to the learning activities. If they do not think of the sound levels when planning activities it gets to loud and it is not possible to carry out the activity. They also experienced that a good cooperation between the personnel, even among different sections, works well in terms of them performing their work.

8.3.1.4 Preschool design

By using an open design the personnel are able to get an overview of all children and their activities. However it is hard for the children to concentrate on playing only one game or doing one exercise since they see the range of what all the other kids are doing. The open design also makes it impossible leave an area when the sound levels get too high, for example when someone is crying or screaming.

A problem encountered in sections housing the younger children was that it was difficult to use different rooms. Since there are only two employees per section taking care of 13 children, it is hard to get an oversight of children when they are playing in the smaller adjoining rooms. In the section with the youngest children one of the personnel is often busy with only one child, which means that the other staff member has to look after all of the other children. This is not possible if they are playing in different rooms. Nor can personnel close the doors to other rooms because then they won't be able to see the children.

In the sections housing older children all rooms can be used which also means that there is a means of escaping the unbearable noise levels.

Other opportunities to use divide children into smaller groups can help to decrease sound levels i.e. the use of music rooms, libraries, and gymnastic halls.. However it is not possible for all six sections in the school to share these rooms all of the time.

All of the participants thought that the open design is the reason why the sound levels become too high. All participants have previous experience working in other preschools which all had several small rooms and therefore they haven't experienced these high sound levels at these preschools.

One participant said that "it would be great if they had asked us who work in these kinds of places when planning the design". It was also mentioned that personnel's knowledge of how to create a good sound environments significantly.

8.3.2 Interviews with personnel at Orkesterparken

Six personnel were interviewed and every section was represented. The participants were all women between the age of 24 and 39. Their working experience in preschools was between 3-16 years.

8.3.2.1 Sound levels and health consequences

Some of the participant experienced high sound levels every day but also commented that some days could be worse than others. Most of the participants did not experience that the sound levels was a problem but it was stated that "many children and personnel in the same room do create high sound levels". Some of the personnel did have symptoms such as tinnitus when coming home after a day at work and all of them noted hearing fatigue after a day at work and required recuperation in a quiet environment.

Some of them said that they had more problems with the high sound levels when they started to work at preschools but had got used to it after a while. There were also participants who said that the personnel earlier had discussed that they won't be able work in preschool all their working life because of the sound and that their sensitivity of sound has increased since they first started to work in preschools.

Participants from sections for the eldest children tend to experience a worse sound environment than participants that represented sections for younger children.

8.3.2.2 Children's experience

None of t participants observed that the children complained about the sound levels, just occasionally when someone had yelled or had been crying for a long time. However it was recognized that the children seem to be more tired after a noisier day than a general day. It was observed that different children generates different sounds and different levels and they all stated that quiet children seem to suffer more from high sound levels than noisy children. Also it was stated that personnel also generally suffer more than noisy children. Children with poor self-confidence tend to be quiet and withdraw further in noisy environments. They had observed that the children also get sadder and easily become angry and irritated on a noisy day. Larger groups of children also have an impact upon the length of a conversation. One participant stated that they are concerned for the children's health and development due to all the different noises they have to decipher and process. This often differs depending upon the size of the group of children but also dependent upon the degree of sound reflection via the walls and distribution of sound via the floor.

Participants mentioned that different children have different ability to concentrate which has an influence on how sensitivity they are to a noisy environment and how their games can be disturbed by noise. Also how interesting they found an activity has an influence upon the degree to which they are disturbed or otherwise.

8.3.2.3 Sound and pedagogic work

The participants stated that they consider the sound levels when planning the activities but that the risk of high sound levels does not stop them from performing an activity that would be of benefit for the children's development. Instead of cancelling a loud activity they divide the children into smaller groups which they done not just due to high sound level but also because the dynamic and size of the group can stimulate a healthy environment. Some sections had structured activities where they were allowed to use their voice at high levels. This meant that it is hard to tell those children to be quiet since it can interrupt their playfulness and creativity. Participants also stated that they try to be outside as often as they can, however this means that they suffer more from high sound levels in the winter.

8.3.2.4 Preschool design

Each section had two small rooms and one large room, which made it possible to divide the children into smaller groups where they could concentrate on their own game. A problem, with regards to the design was the fact that both airborne and impact sound was easily transmitted between different rooms. The integration of glass as a part of the wall between the small rooms and also in the doors was appreciated since personnel have good oversight between the rooms without clearly hearing the conversation.

Most of the participants experienced echo in all rooms, especially in the kitchen and in the small rooms. The echo in the kitchen was the reason that they did not sit in the kitchen for meals, instead they were divided into small group sitting in different rooms while eating. During the spring and summer when the weather allows dining is usually done outside. Almost all of the participants had noted that the sound did not stay in the room where it was generated, which becomes a disturbing factor especially when children are going to rest and sleep.

8.4 Evaluation of room acoustics

High sound levels were a common problem that was mentioned during the interviews. A lot of measurements of SPL has been undertaken in earlier surveys and has showed that sound levels are high in preschools. However due to the nature of preschool activities, sound is to be expected and is an important part of children's development. The actual SPL is not of most importance as it is mainly an indicator of how loud an activity is. Instead evaluating parameters such as sound strength, G, to uncover information regarding the room properties impact of the sound. This parameter has been undertaken in the case studies as outlined in this section.

Another problem revealed during the interviews was echo which becomes a disturbing factor and can lead to problems regarding concentration. Reverberation time, T_{60}, gives a value in seconds of the decay of sound and was therefore evaluated. However the value of reverberation time is not a complete description of the sensation of reverberation. Since speech clarity, C_{50}, can be a good complement and the fact that high quality of spoken message is of importance in preschools was even this parameter evaluated. Speech intelligibility is also of importance as speech development is a primary activity in preschools. Therefore were also speech transmission index, STI, evaluated. These parameters were evaluated from simulations through CATT-Acoustic software. Reverberation time was also measured in the preschools; these measurements were used for calibration of the models. Further description of the method of measurements and calculations are described in the chapter "Method".

The four parameters described above were evaluated from simulations for one playroom in each preschool. These rooms were chosen since they are representative and common in all six sections, at each school, and were also outlined as those spaces with the worst sound environment situation.

The rooms that were investigated are described by green lines in following figures.

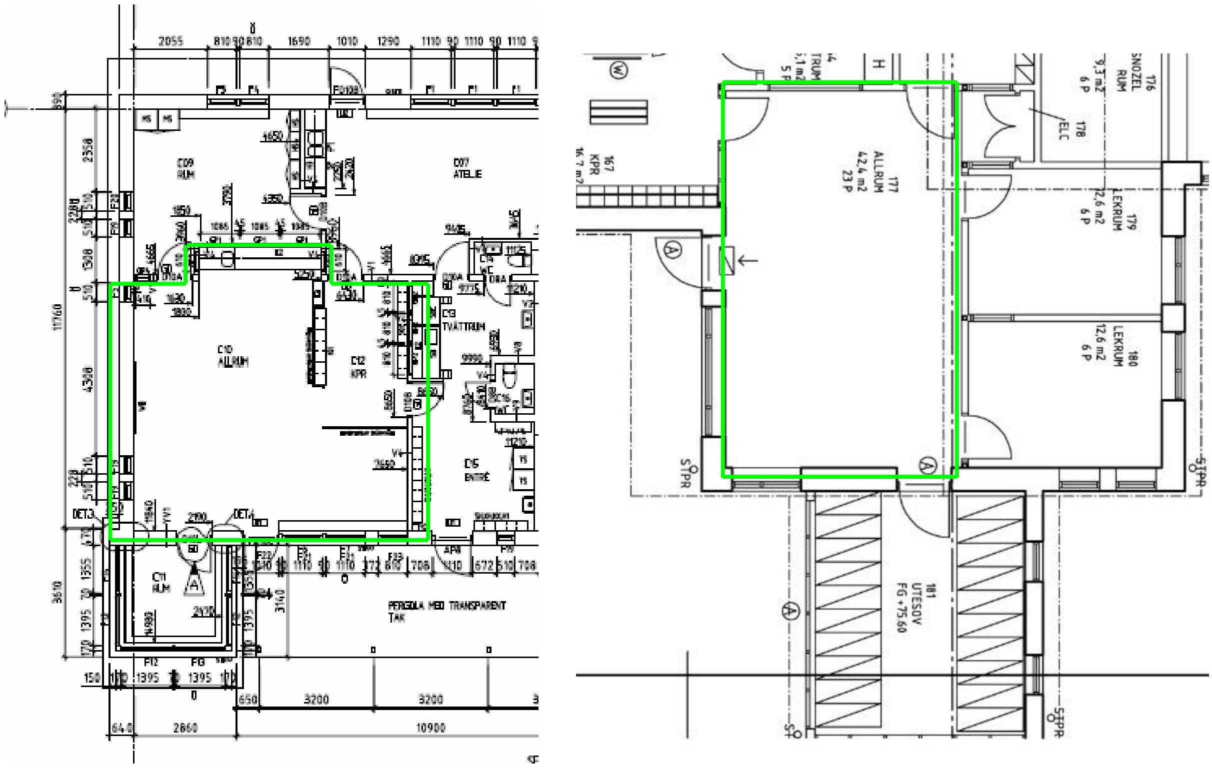


Figure 24 Investigated playrooms at preschool Kattfoten to the left and preschool Orkesterparken to the right

Figure of number 25-28 describes the playroom as current design and with design so as to improve the sound environment. The screens in altered design are 1.2 meter high and covered with absorption of class A. Even wall absorption is of absorption class A.

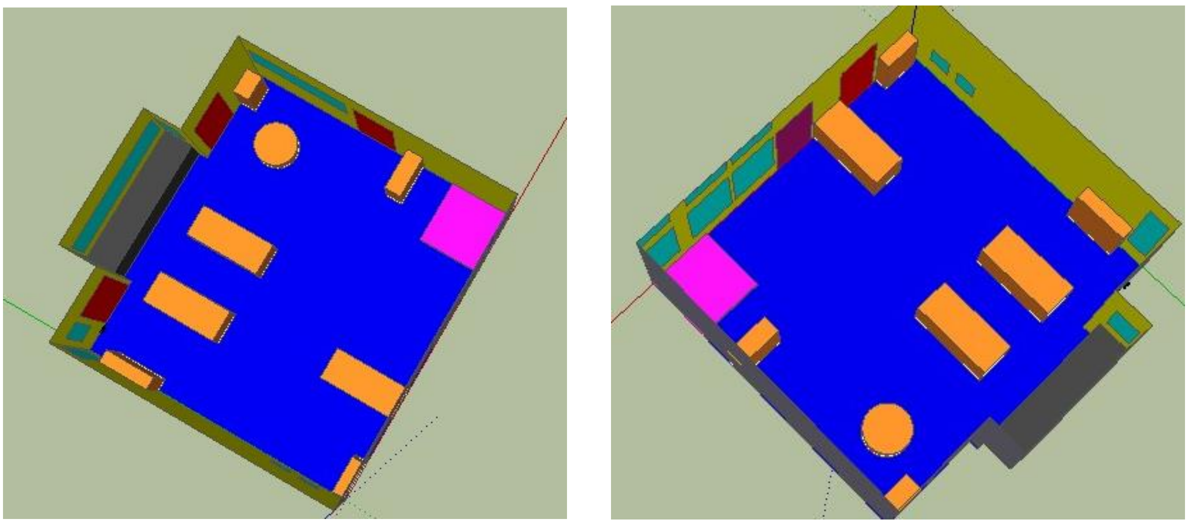


Figure 25 Current design of Kattfoten's playroom.

The green section below the window consists of 1.44 m^2 of absorption panel and in the new playcorner do 2.40 m^2 absorption cover the wall. The green section at the wall in the right figure below consists of 6.24 m^2 absorption panels. Length of the new walls can be seen in the figure below.

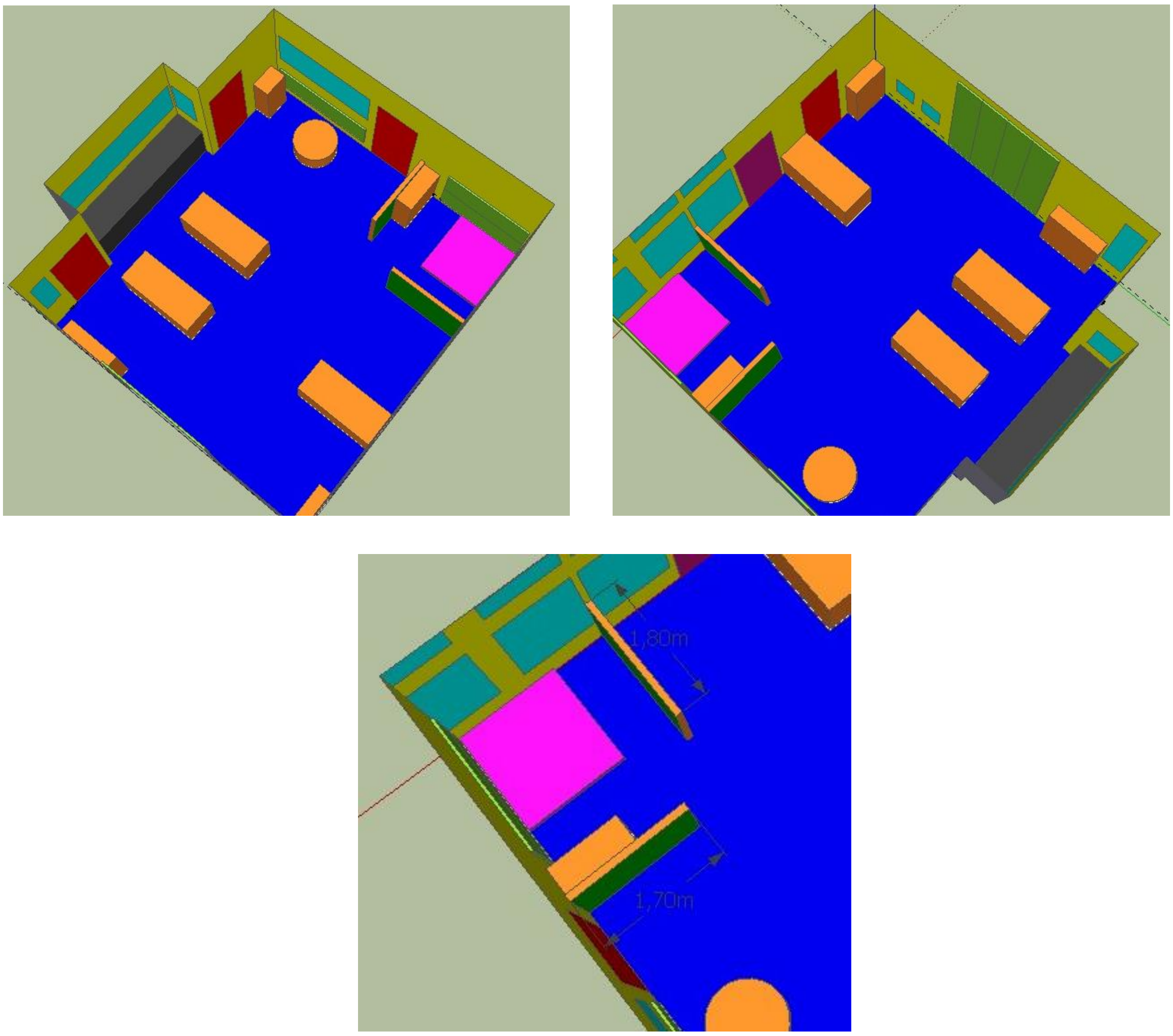


Figure 26 Altered design of Kattfoten's playroom.

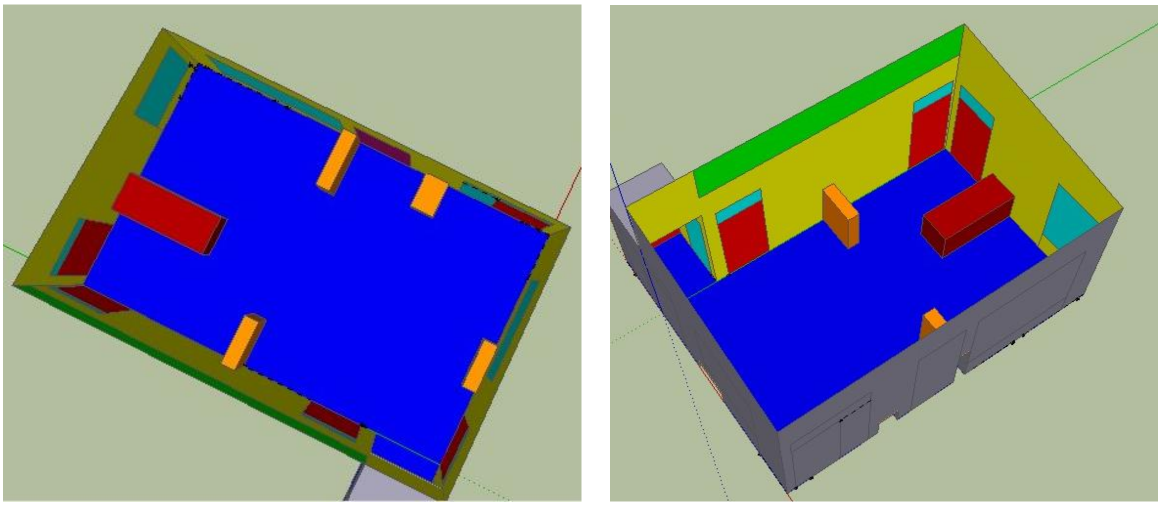


Figure 27 Current design of Orkesterparken's playroom.

The green section in current design consists of perforated plasterboard. Green section below plasterboard consists of 5.52 m^2 absorption panel. Length of the new walls can be seen in the figure below.

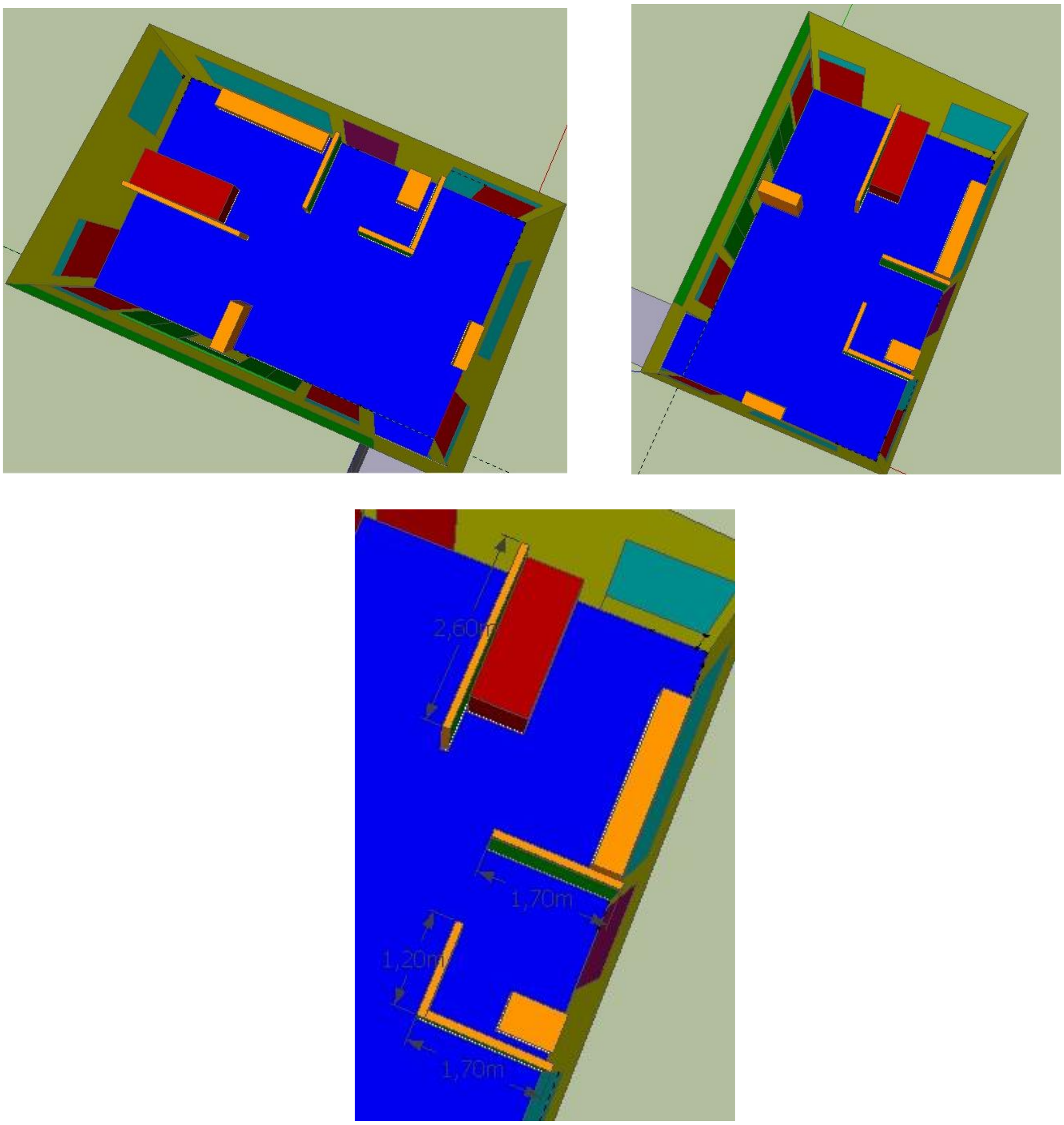


Figure 28 Altered design of Orkesterparken's playroom.

8.4.1 Result

The following tables present the difference from current form and post remedial acoustic works of the two representative rooms. For each playroom are results of each receiver position presented for all parameters without reverberation time since it regards to the rooms reverberation. Even results for each frequency are presented. All results from both rooms are presented in appendix IV.

8.4.1.1 Result preschool Katttfoten

In following figure can the receiver positions in Kattfoten's playroom be seen.

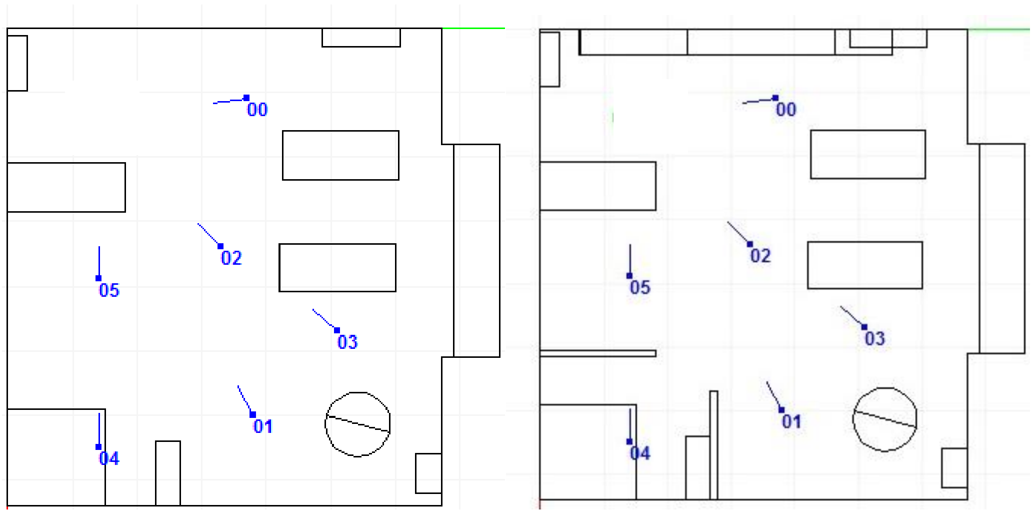


Figure 29 Receiver positions, Kattfoten's playroom.

Reverberation time decreased for 0.08 s, numerical average in the playroom of Kattfoten.

Table 11 The difference, as average values, with regards to the logarithmic scale for sound strength and speech clarity, in each receiver position, Kattfoten's playroom.

Receiver	Sound strength (dB)	Speech clarity (dB)	Speech transmission index (%)	Reverberation Time (s)
0	8,70	10,40	4	0.09
1	8,37	10,91	5	0.06
2	8,52	9,77	3	0.06
3	9,53	9,03	4	0.07
4	9,78	9,72	2	0.11
5	8,86	10,50	4	0.06

Table 12 Difference as average values, with regards to the logarithmic scale for sound strength and speech clarity, in each frequency, Kattfoten's playroom.

	Frequency (Hz)					
	125	**250**	**500**	**1000**	**2000**	**4000**
Sound strength (dB)	9,15	8,75	8,79	9,09	8,88	9,26
Reverberation time (s)	-0,01	0,02	0,09	0,09	0,15	0,41
Speech clarity (dB)	7,17	9,59	10,26	10,66	10,46	11,39
Speech transmission index (%)	0	2	2	4	6	7

8.4.1.2 *Result preschool Orkesterparken*

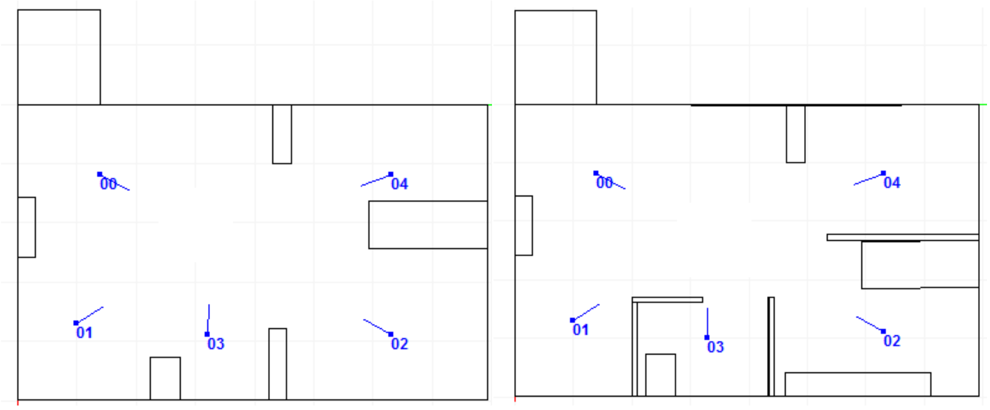


Figure 30 Receiver positions, Orkesterparken's playroom.

Reverberation time decreased for 0.10 s in the playroom of Orkesterparken.

Table 13 The difference, as average values, with regards to the logarithmic scale for sound strength and speech clarity, in each receiver position,Orkesterparken's playroom.

Receiver	Sound strength (dB)	Speech clarity (dB)	Speech transmission index (%)
0	8.48	10.23	5
1	8.97	8.91	4
2	7.98	11.93	8
3	10.09	12.22	10
4	8.59	10.53	7

Table 14 Difference as average values, with regards to the logarithmic scale for sound strength and speech clarity, in each frequency, Orkesterparkens playroom.

	Frequency (Hz)					
	125	**250**	**500**	**1000**	**2000**	**4000**
Sound strength, (dB)	7.63	8.96	9.38	8.68	8.43	9.02
Reverberation time (s)	0	0.08	0.14	0.12	0.14	0.09
Speech clarity (dB)	8.27	10.50	10.10	11.22	7.55	11.69
Speech transmission index (%)	16	4	4	12	11	7

9 Discussion

In this chapter is a discussion of the thesis presented. Literary review and case studies are discussed and forms guidelines of practical design for a good sound environment in preschools.

Few studies have been undertaken regarding the noise effects upon health and learning on children of preschool-age. However a lot of studies considering the effects upon older children have been undertaken. Moreover researchers' predict that young children probably are impacted in much the same way. It should also be stated that children of preschool-age are not able to recognize and express how they are affected by noise.

There is a risk that as children get older the impact of sound environments encountered at an early age can cause significant problems with their continued development. This is primarily due to the fact that during the early years child spend in the preschools their speech is completely developed. They will acquire different types of sounds, their vocabulary and a fundamental grammar and their speech are even from the age of three developed to the extent that it acts as the most important part of their communication.

9.1 The sounds effect on children as a literary review

Results of measurements performed in earlier surveys have shown that the typical SPL in preschools is in the range of 75 dBA. In Sjödins survey the average from static measurement instruments was $L_{eq,8h}$ =63 dBA while the dosimeters, placed on personnel at the same preschools showed $L_{eq,8h}$ =71 dBA. At the same preschools the number of occasions where the SPL exceeded 85 dBA was 66/hour, this fact should be taken in consideration when $L_{eq,8h}$ =63 dBA. It was also found that the highest sound levels were generated in frequencies of 1000-4000 Hz, which reflects the research that children's speech and activities are the primary sources of noise generated in preschools.

Results from the survey "Barn i Bullerbyn" showed higher average values of SPL than in Sjödins study. The average value showed, even in this case, a reduced difference between levels recorded by static measurement equipment (74 dBA) and dosimeters (78 dBA). There is an 11 dB difference between the levels recorded by static equipment between the two surveys. This is hugely significant as a difference of ten decibels is experienced by the human ear as a doubling of sound levels. Sjödins study was carried out in 17 different preschools and the static measurement equipment was placed in similar rooms in the different schools. The similar conditions make it possible to compare the different values of the 17 schools. On the other hand "Bullerbyn-survey" was performed in as many as 66 different preschools or departments and could therefore be considered in depth. The method of measurements used during this survey wasn't strictly set which makes it difficult to explain why the values are higher in this survey. It should also be considered that there was a difference of 21 dB between the highest and the lowest value measured in the "Bullerbyn-survey" measured by static measurement equipment. As to whether this large difference depends upon the different sound environments in the schools, different measurement methods or the number of preschools that were involved, it is difficult to definitively say.

In the study carried out in Mölndal the average from dosimeters placed at personnel showed a similar average sound level as outlined in the survey "Barn i Bullerbyn". Dosimeters were also placed at children, in the "Mölndal-survey". Results showed that the children were exposed to around 7 dB higher SPL than personnel. Since the children's dosimeters were placed nearer the activities this is likely to reflect the true value. Reflections from the floor can also have a significant influence on the results. However it should also be considered that the children with dosimeters may have interfered with them. On the other hand the dosimeter can have the opposite effect and make them more quiet and careful in their presence.

The measurements that earlier has been done at Lundafastigheter's preschools showed that SPL was between 67-79 dBA, which decreased by up to 6 dB after the installation of absorbents. These measurements were done by using static measurement equipment.

Measurements with static measurement equipment generally results in lower SPL compared with dosimeters. The dosimeters are placed near the ear and could therefore better reflect the actual sound level experienced by the subjects. However dosimeters do also register sounds caused by movements. The values from static measurement equipment therefore have a higher degree of certainty when compared with dosimeters.

The sound levels in preschools do typical not reach or exceed the limit that is set by the Swedish Environment Work Authorities in terms of exposure to noise at work. These regulations are set from a hearing impairment perspective.

Arlinger has mentioned that for sound levels lower than 80 dBA there is no impact as regards hearing loss, which correlates with the regulations as outlined by the Swedish Environment Work Authority. However these regulations do not consider children at preschools, since for them school is not a workplace. Beyond it is known that children are more sensitive to high sound levels and $L_{eq,8h}$ of 80 dBA is not uncommon in preschools. In relation to the impact of high sound levels on hearing, inflammations of the ear and increased hearing threshold can be caused. A common secondary effect of an increased hearing threshold is increased voice strength when talking which naturally results in higher sound levels. Children who have spent more time in environments like preschools do more often have disorders such as hoarseness. It is common that hearing impacts have negative impacts on these people's social life and wellbeing, the ability to perceive sounds correctly and to be a part of discussions and social happenings are affected.

Noise does also have cardiological impacts; increased blood pressure is one example. These types of consequences have been seen when L_{eq8h} has been in the range of 61-69 dBA, usual sound pressure level in a preschool. In the Munich study increased blood pressure can be seen to occur with an external SPL of 60 dBA. Even heart rate may be influenced by noise.

Noisy environments can also affect learning abilities. The performances of easy exercises or skills that are already ingrained are not affected by noise. Neither is the learning of superficial facts or short term memory. However when new information is going to be processed or analysed, as for children in preschools, then noise can have a negative impact. In a noisy environment a greater part of the working memory is used to process phonological sounds and less to process information. The consequences of noise increase when the exercises get harder. Acoustical parameters such as background noise and reverberation time do have an impact on the cognitive skills since the sound becomes unclear and masked. It is then of importance to consider the sound environment to guarantee children's development.

Noisy environment can even improve parameters like irritation, problems regarding concentration, tiredness, headache and stress. These different effects of noise can impact upon each other and makes emphasise the symptoms. It has also been seen that noise fluctuations, usual in preschools, do have a negative influence on psychological effects and for a person's recovery time is one parameter that can be prolonged by these negative effects. However different sounds can benefit different people in different ways, depending on memories, earlier experiences and also daily moods. It is therefore important that a preschool give the opportunity to children to experience different activities and sounds. According to wellbeing it is also of huge importance that the preschools give the opportunity for recovery in calm environments. Recovery is also a condition needed to develop knowledge and to consider experiences.

9.2 Case studies and sound environment

Participants from both schools in the case studies experienced high sound levels. Several of the personnel from both schools suffered from hearing fatigue after a day at work, headache due to the noise and some of the participants experienced howling sounds in their ears after a day at work. The personnel at preschool Orkesterparken seemed to have a more positive experience with the sound environment. This difference could not be explained when comparing the results of acoustical parameters but may be in part due to the timing/the season in which the interviews were conducted.

Interviews at preschool Kattfoten were undertaken during winter, which all participants from both schools experienced as the worst period as regards to the sound environment due to the fact that more activities and time were spent inside. Interviews at Orkesterparken were done during the spring. At this time of year lunch, another potentially noisy activity was eaten outside. Another potential reason for Orkesterparkens relatively positive outlook on noise could be that there was more collaborated work between different departments which gives personnel and children the opportunity to use several rooms.

The design of each department at Kattfoten may also have an impact upon the sound experience. The fact that the small rooms were placed in such a way so that personnel had difficulties in overseeing activities in both small rooms and the playroom at the same time was a main reason as to why the small rooms were rarely used in departments for the youngest children; older children can play more by themselves. The participants meant that they need to have opportunity to get an overview of several children, playing different games in different groups at the same time.

It was found by all participants that different children are more or less noisy and also more or less sensitive of noise. They also found that the loudness varied during different activities. Lunch could be one activity when very high sound levels were experienced. Even free activities tend to be loud since this can consist of many different activities and involves a lot of fantasy and imagination. Other times when it tended to be noisy were when children were hungry and/or tired.

From calculations, performed in CATT-Acoustic, it was seen that the sound strength decrease by about 9 dB, for each receiver position in preschool Kattfoten. For this parameter is 1 dB a just noticeable difference. It should also be mentioned that a reduction of 10 dB is experienced as half the sound level. By Orkesterparken sound strength decreased by 8-10 dB for each receiver position. In both cases the changes were almost the same for each frequency and receiver. Thus was the sound strength at Kattfoten of a better value from the beginning, in current design.

Since high sound levels are a common problem in preschools and it causes several negative effects as increased heart rate, blood pressure, hearing disorders and voice problems as well as impacts on rest and may also cause sleep disorders, sound strength is a parameter worth to consider. Decreased sound strength will also improve the conditions for concentration and thereby also the children's cognitive skills.

Likewise the reverberation time decreased in both preschools following the introduction of absorption measures. In lower frequencies (i.e. below 500 Hz) reverberation time decreased by about 0.05 s and in the higher frequencies (i.e. 500 Hz and above) it decreased by 0.1s. This indicates that there is a calmer acoustic environment post the installation of acoustic treatment. This calmer sound environment is achieved since more sound is absorbed faster, the sound waves will not be reflected as much as before which makes the sound level decrease. The reduced reverberation time could improve wellbeing, decrease stress and will makes it easier for the children to concentrate which means increased learning abilities.

The speech clarity increased by approximately 10-11 dB in each receiver position in both schools with increasing values as frequency increased. This changes means that more sound is received in the first 50 ms and strengthens the early sounds, the clarity, while less sound is reflected, the reflections that makes the spoken message unclear is thereby reduced. A difference of 10 dB means that the effective sound pressure is changed by three times. The increased speech clarity will improve the ability to perceive spoken message correct which is important for the preschool children's speech development. Increased speech clarity means that late reflections are reduced which indicates a calmer sound environment with the same improvements as mentioned in the section above, regarding reverberation time.

STI increased for both schools. At Kattfoten were the changes for about 2-5 % at each receiver. At Orkesterparken were the changes generally higher, 4-10 %. Even for this parameter were larger increases observed in the higher frequencies. The increased STI indicates that spoken messaged will be easier to perceive, important for the children's speech development but also for parameters as concentration and learning abilities.

In general larger differences could be seen at the higher frequencies, which are expected since the absorption coefficient of the installed materials is higher at those frequencies. Since the highest sound levels in preschools are often generated in high frequencies it is favorable to have efficient absorption in these frequencies so as to calm the acoustic environment. Thus one should remember that the speech information is delivered within the consonants which are generated in the high frequencies. Too much absorption in high frequencies could therefore have a negative impact of the perceiving of speech. In small areas, as in this case, where the speech just have to be transmitted a short distance the risk of negative effect like this are estimated. Thus it is of importance to reduce the sound level and the reflections even in low frequencies. To place furniture, books, boxes with toys etc can cause a more diffuse sound field since the sound wave will be crushed when it hit furniture, book etc.

Interesting to consider and remember is that small changes in the design can lead to great improvements for health and wellbeing as well as cognitive skills.

Regarding the trustworthiness of the results from the simulations were no differences or very small differences seen when comparison of energy based result and the impulse response. This indicates high certainly even in low frequencies. The measurements of which the models where calibrated against had high certainly, means that also the simulated calculations have a high certainly.

The variation in the results has to be considered; the software is a qualified discussion partner and the results should not be stated as totally correct. The result in each receiver varies which depends of its position in relation to absorption panels. Better results are naturally found when the receiver is placed nearer absorption panels which indicate the huge improvement of just small actions as installing sound absorbing panels.

9.3 Practical design for a good sound environment

Since many preschools have increasing numbers of children each personnel have to look after a lot of children. Open plan design can be preferable from that point of view but can jeopardise the sound environment. To divide these types of rooms into smaller part by fixed or flexible low walls is one solution that may save the open plan feeling and will let the personnel have an overview of the entire space.

Since the children's voices and activities often consists of sound in high frequencies, selecting sound absorption which is most efficient in these frequencies should be prioritized. This could be done by sound absorption panels which preferable could cover the walls/screens .When placing the walls/screens should children's activities and an acoustical view been taken in consideration. The walls/screens should be placed so that it blocks the view of sight into other playing locations and corridors. It should also be placed in a way so as it can absorb the sound from the activities. It is also of importance that the walls/screens are sealed to the floor. To not get reflections that increase the reverbrance should hard reflect surfaces be avoid. Absorption panels can be used at walls and especially in corners to avoid reflections that strengths the noise. It can also be used at parallel surfaces to avoid flutter echo and room modes. This should be taken in consideration even in small rooms.

Sound transmitted through walls and floors causes' unnecessary and unexpected noise that interferes activities. It is of importance to ensure that the building is established with high performance. Sound reduction can be jeopardise by slots, missing pug at doors, windows and walls and should not be accepted. The floor can be chosen so as to control the impact noise.

From a design perspective it is also important to consider how both children and personnel move within a building. The design should be such that children can play and concentrate on their games or exercises without getting disturbed by someone who uses their space as means of getting from one room to another. The design should ultimately be chosen from both the personnel's and the children's perspective.

The requirements according to The Swedish National Building Regulations (BBR) (Boverket, 2012) can be fulfilled adhering to Sound class C in the Swedish Standard SS25268:2007. Both preschools studied in this thesis were found to comply with the requirements but problems with the sound environment are still experienced. To ensure satisfying sound environment other room acoustical parameters can be required, for example those that have been discussed through this thesis namely sound strength, speech clarity and speech transmission index. The sound strength should be evaluated since high sound levels can cause several negative impacts of both children and personnel, impacts as decreased learning abilities, sleep disorders, increased blood pressure and of course even hearing impacts. To be able to understand spoken messages is of great importance for the children's speech development and also for their development of behaviour and abilities to integrate with each other. An environment where the speech intelligibility is good and the speech is clear is the risk for misunderstanding and reduced and also the risks for accidents.

By using Miljöbyggprogram SYD (Miljöbyggprogram SYD, 2012) the same requirements as in SS 25268:2007 are set but with added requirements upon the acousticians involvement throughout design and build process. This allows for the opportunity to focus on creating a satisfactory sound environment and influence the design throughout the project. The involvement of an acoustician throughout the design process could allow for modeling of such acoustic parameters in preschools and mean that other acoustic parameters can be investigated not just those related to requirements. This could include a thorough investigation of materials and furniture.

The definition of noise is individual and the experience of sound can be correlated with feelings and earlier experiences, therefore a preschool should include different small departments for different activities. Even aesthetics is of importance in creating a satisfactory sound environment. Absorption panels with colors, motives and alternative shapes can be used.

It is also of importance to discuss the environment early in the building process and the throughout the whole process, as required by Miljöbyggprogram syd. Discussions between preschool's personnel, architects and acousticians are one such way to ensure that all perspectives are considered in the sound design.

A practical guide document of how to create a satisfactory sound environment can be seen in appendix V.

10 Conclusion

This chapter consists of the conclusion and also a suggestion of continuing work of for even better sound environments in preschools.

A dissatisfactory sound environment in a preschool can cause children several negative consequences. Noise can cause medical side effects such as increased heart rate and blood pressure, even at sound levels between 61-69 dBA. Sound levels of 75 dBA are common in preschools. Voice problems are also more common in children that spend more time at preschools. Since children's vocal chords aren't totally developed they are more sensitive to high voice load. To be able to use and develop one's voice is of importance especially for a child in preschools. During these years that a child spends at the preschool their speech is developed from merely consisting of babble to a great vocabulary with fundamental grammar. This is another reason as to why a healthy voice is of importance.

Hearing impacts are another effect of spending time in noisy environments. Other than hearing losses noise can cause inflammations of ear, tinnitus and increased hearing threshold. Children are more sensitive to hearing loss since their auditory canal is shorter than adults which can increase pressure in the high frequencies according to resonance in the auditory channel.

Mental health can be affected by noise such as increased stress which can result in sleep disorders, problems with concentration and motivation as well as irritation. These parameters do affect learning abilities. Noise can even have an impact upon memory and the ability to learn new skills, which is a common element in a child's development in preschools.

The reduction of sound levels in preschool is an important acoustical parameter. From earlier surveys and as found in interviews during this thesis it was concluded that children's voices and activities are the primary sources of noise in preschools. Their speech and exercises are their way to develop their knowledge and learn how to interact with each other; ordering children to be quiet is not a sustainable solution. Instead the room acoustics should be considered. From calculations performed in two case studies during this thesis it found that even small improvement, such as absorption panels on walls and screens to divide open plan rooms into smaller parts, can have a great influence of the room acoustics. Parameters such as sound strength, reverberation time, speech clarity and speech transmission index were considered was and all parameters showed significant improved post acoustic improvements. By considering room acoustical parameters the sound environment can be improved so that children get the opportunity to perceive sound correct and develop their speech and knowledge. Through models and calculations of room acoustical parameters an assessment of how the sound is perceived can be understood which gives the opportunity to create a good sound environment.

Moreover a proper design of the rooms can improve the sound environment. By paying attention to the design of spaces and its materials and furnishings, the appropriate acoustical parameters can be considered for specific spaces. Acousticians, preschool personnel and architects should take action in and communicate sound requirements in accordance with design of the room.

It can then be concluded that it is of the utmost importance that facility managers, preschool personnel and parents give young children the possibility to learn and develop in sound environments which support their development, knowledge and social behaviour without becoming exposed to a sound environment which may have temporary or prolonged negative consequences. This can be undertaken through proper planning of the design of preschool spaces and by considering room acoustical parameters from the preschools' point of view.

10.1 Continuing work

Several measurements of sound pressure levels has been undertaken in preschools and the also several of studies considering noise impacts of health and learning has been undertaken. In environments for entertainment is the knowledge of room acoustical parameters adapted well. To improve the sound environment in preschools should those surveys, knowledge and experience be connected and utilized. Suggested as continuing work in this topic is a deeper insight of room acoustical parameters optimal values in preschools.

It is also of importance that knowledge and methods of how to improve the sound environment in preschools reaches builders, constructers, architects and acousticians. With better knowledge and practical examples of how to design preschools will the chance to create preschools with satisfactory sound environment increase. Suggested work is thereby acoustical handbooks adapted for preschools. Those should consist of how to design preschools, technical examples and values of room acoustical parameters.

It could of course be interesting to perform the preventive measures that are calculated in this thesis and thereafter do the interviews to see the response of the subjective experience of the sound environment.

In the future, maybe even other room acoustical parameters as those mentioned in this thesis will be put as requirements thus are further knowledge of their optimal values considered needed.

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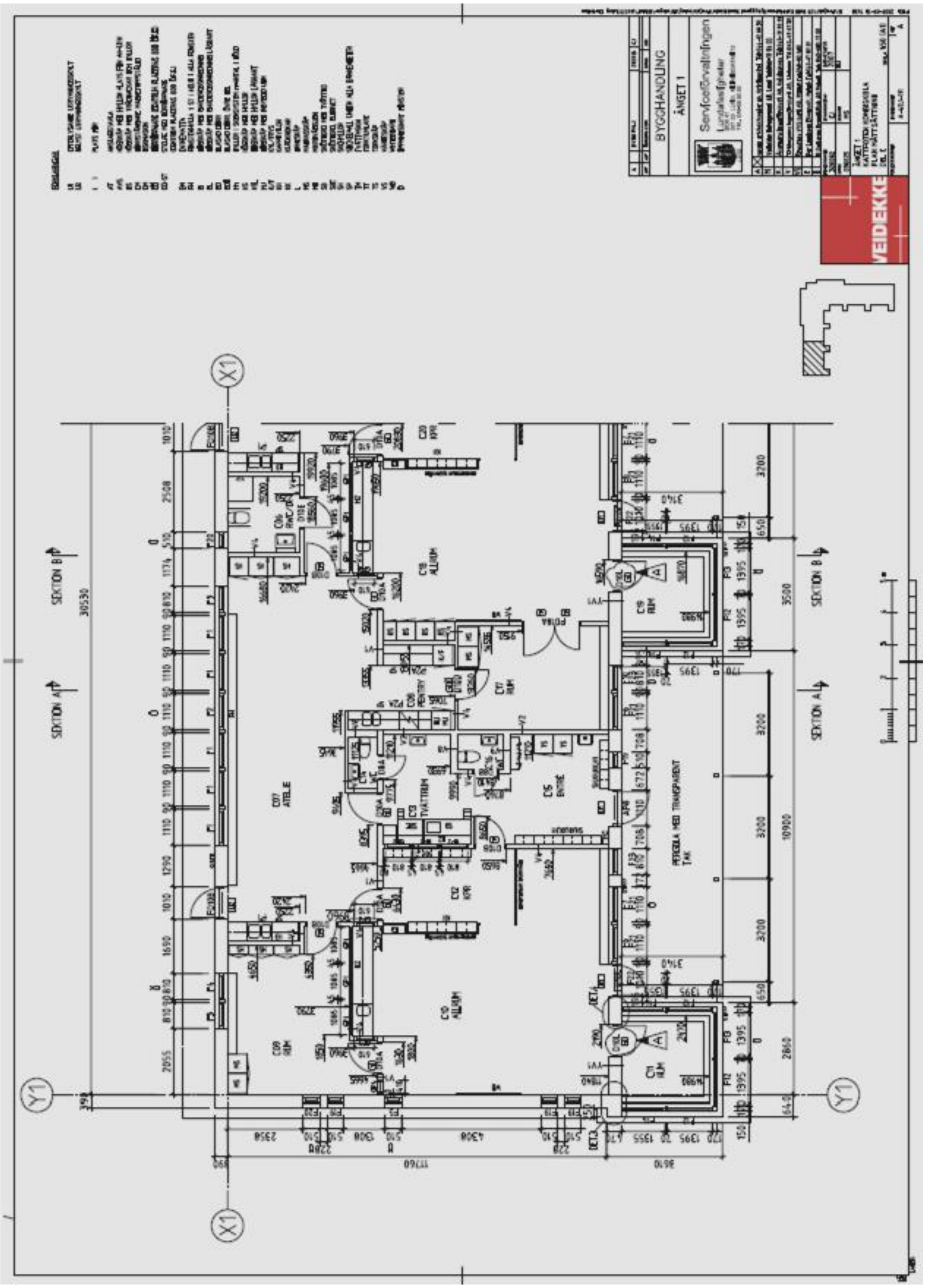
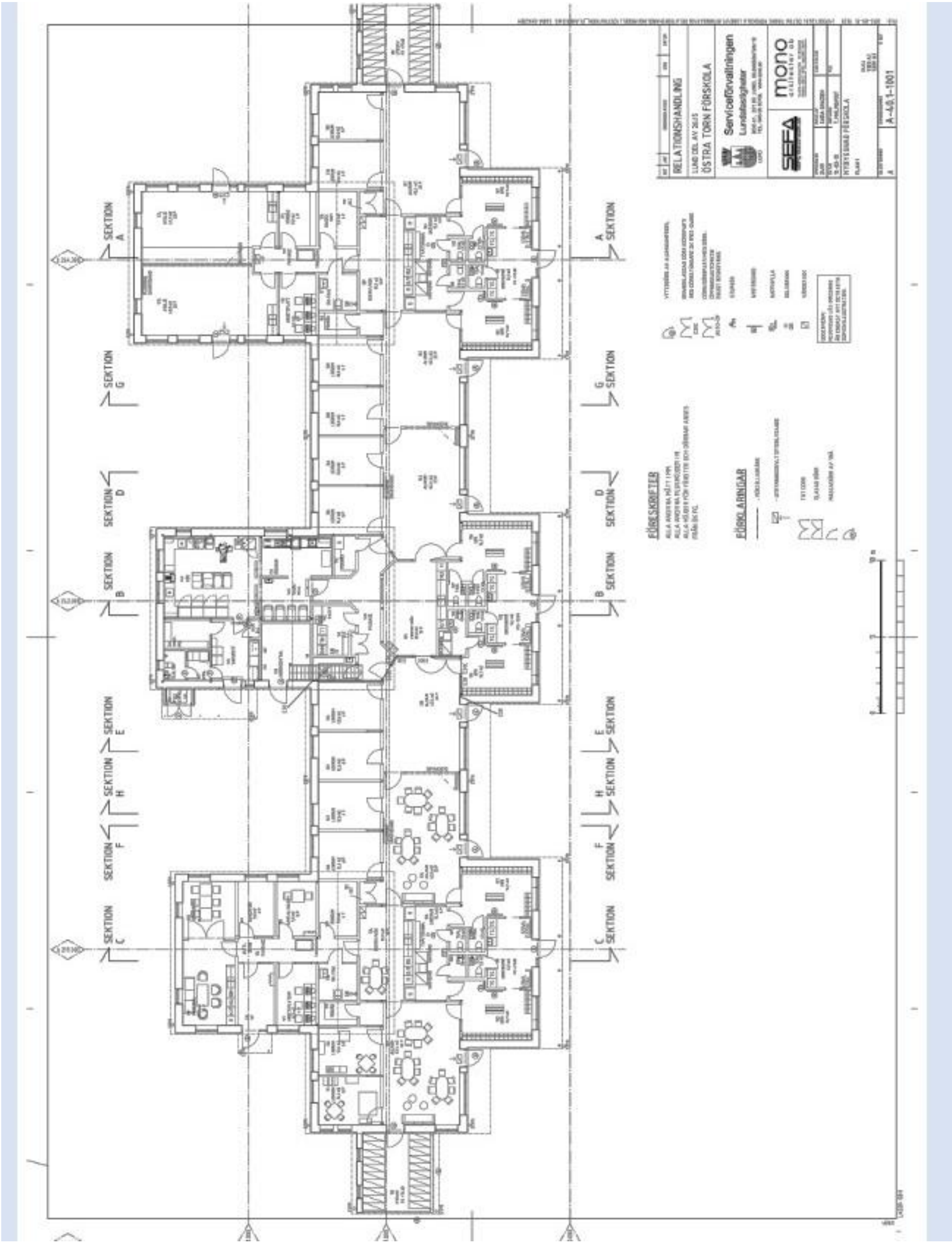
Appendix I Layout of preschool Kattfoten



Appendix II- Layout of preschool Orkesterparken



Appendix III- Interview questions

Information of participant
Age______
Year of work experience in preschools______________________
Gender__________
Number of children at the section___________
Age of children___________
Opening hours of the preschool ___________

How do you experience the sound environment at your workplace?

- What's good?
- What's bad?
- Any difference in different locations of the building?
- Any difference depending of time of the day?

What is the children's experience of the sound environment?

- Have the mentioned any complaints according to sound?
- Different behaviour depending of noisy or quiet environment?
- Different behaviour during the day?

Do the children act differently depending of activity?

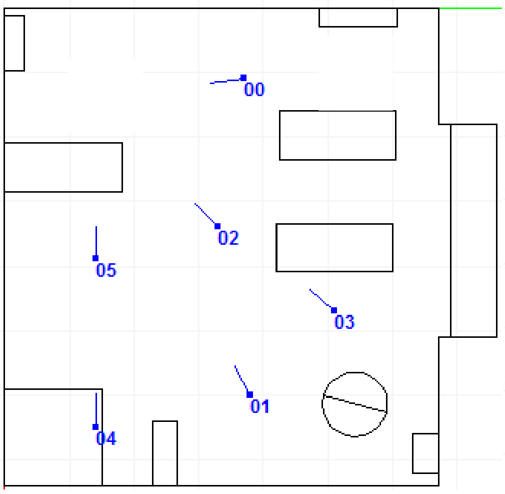
- Free activities?
- Outside?
- Inside?

Could the sound environment affect the pedagogic activities?

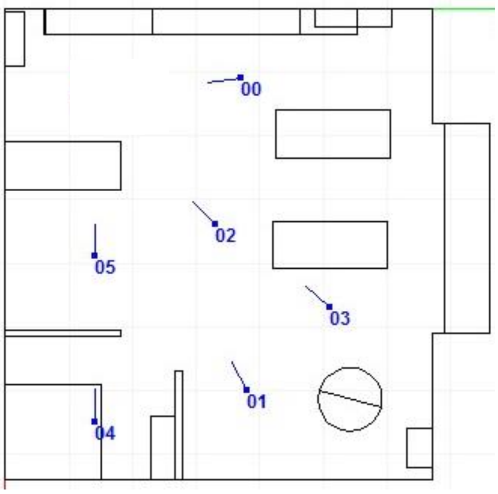
- Can the fact of noise have impact of which activities that are performed?
- Noise problem?
- Misunderstandings because of noise?

Appendix IV- Results from calculations

The following tables present the results from calculations of the playrooms in both their current form and post remedial acoustic works



Receiver positions in current design of Kattfoten's playroom.



Receiver positions in altered design of Kattfoten's playroom.

Sound strength Kattfoten's playroom, current design.

Current design	Sound strength, G, (dB)					
	125	250	500	1k	2k	4k
Receiver						
0	21.69	23.65	26.33	22.83	19.81	19.86
1	17.68	18.51	21.86	19.99	16.76	16.08
2	21.39	24.40	29.02	21.34	19.43	18.10
3	18.76	21.75	24.36	18.25	16.82	16.68
4	16.97	19.84	21.31	18.09	16.08	16.54
5	19.88	23.17	25.64	20.65	18.89	17.94

Sound strength Kattfoten's playroom, altered design.

Altered design	Sound strength, G, (dB)					
	125	250	500	1k	2k	4k
Receiver						
0	21.60	24.76	25.78	20.36	19.23	17.87
1	16.75	18.59	21.87	18.93	15.82	15.51
2	20.05	23.60	28.31	22.18	17.90	17.61
3	17.90	20.43	21.77	16.42	15.49	14.37
4	13.86	16.69	20.91	16.54	14.90	14.63
5	18.63	22.65	24.33	19.50	17.90	16.70

Reverberation time Kattfoten's playroom, current design.

Current design	Reverberation time, T30, (s)					
	125	250	500	1k	2k	4k
Receiver						
0	0.57	0.46	0.38	0.42	0.51	0.51
1	0.60	0.43	0.38	0.40	0.53	0.51
2	0.52	0.41	0.40	0.45	0.49	0.49
3	0.65	0.41	0.40	0.43	0.53	0.53
4	0.52	0.46	0.40	0.47	0.59	0.53
5	0.52	0.42	0.37	0.49	0.52	0.51
Total	0.56	0.43	0.39	0.44	0.53	0.51

Reverberation time Kattfoten's playroom, altered design.

Altered design	Reverberation time, T30, (s)					
	125	250	500	1k	2k	4k
Receiver						
0	0.46	0.39	0.30	0.34	0.43	0.37
1	0.65	0.41	0.28	0.32	0.38	0.44
2	0.58	0.40	0.32	0.36	0.33	0.41
3	0.58	0.44	0.33	0.35	0.42	0.40
4	0.52	0.39	0.28	0.35	0.35	0.45
5	0.62	0.41	0.31	0.40	0.37	0.38
average	0.57	0.41	0.30	0.35	0.38	0.41

Speech clarity Kattfoten's playroom, current design.

Current design	Speech clarity, C_{50}, (dB)					
	125	250	500	1k	2k	4k
Receiver						
0	8.53	14.05	16.5	12.27	9.34	8.85
1	6.10	11.69	13.47	10.45	7.09	5.29
2	10.6	16.47	22.76	11.77	8.19	7.51
3	7.43	13.83	14.59	7.80	8.23	7.09
4	6.86	12.40	12.26	9.19	6.47	5.90
5	9.68	12.77	15.09	11.59	8.31	7.43

Speech clarity Kattfoten's playroom altered design.

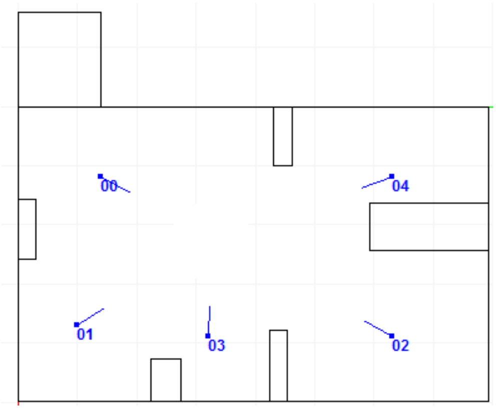
Altered design	Speech clarity, C_{50}, (dB)					
	125	250	500	1k	2k	4k
Receiver						
0	8.71	16.62	19.74	14.29	12.92	12.15
1	7.84	12.95	16.36	14.07	10.48	10.16
2	7.89	16.47	23.17	15.85	10.09	11.9
3	6.37	14.27	15.78	10.68	10.02	8.37
4	4.25	11.81	16.06	11.39	8.73	9.37
5	8.77	17.38	17.51	13.63	11.14	10.95

STI, Kattfoten's playroom, current design.

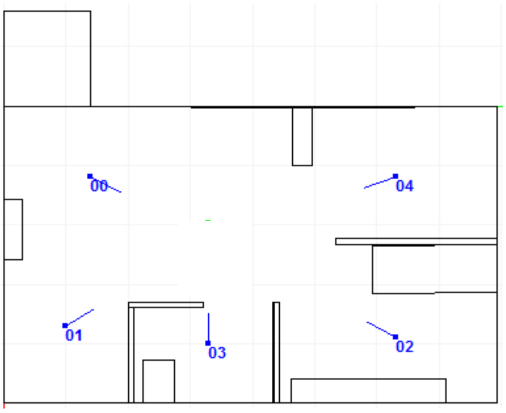
Current design	Speech transmission index, STI					
	125	250	500	1k	2k	4k
Receiver						
0	0.81	0.90	0.93	0.74	0.71	0.76
1	0.78	0.84	0.88	0.83	0.76	0.73
2	0.84	0.93	0.98	0.63	0.69	0.71
3	0.81	0.90	0.92	0.63	0.77	0.77
4	0.75	0.87	0.88	0.79	0.74	0.75
5	0.80	0.89	0.91	0.70	0.77	0.71

STI Kattfoten's playroom, altered design.

Altered design	Speech transmission index, STI					
	125	250	500	1k	2k	4k
Receiver						
0	0.83	0.94	0.95	0.71	0.87	0.76
1	0.81	0.89	0.92	0.87	0.81	0.82
2	0.80	0.92	0.98	0.69	0.69	0.85
3	0.79	0.91	0.92	0.78	0.82	0.80
4	0.70	0.87	0.92	0.79	0.80	0.80
5	0.81	0.93	0.94	0.71	0.83	0.81



Receiver positions in current design of Orkesterparken's playroom.



Receiver positions in altered design of Orkesterparken's playroom.

Sound strength, Oreksterparken's playroom, current design.

Current design	Sound strength , G, (dB)				
	125	250	500	1k	2k	4k
Receiver						
0	20,07	26,24	23,17	21,47	20,05	19,67
1	19,85	21,48	23,19	19,83	18,45	20,36
2	16,59	19,18	19,68	18,91	17,44	17,45
3	19,85	23,71	26,04	22,05	20,3	20,58
4	16,84	21,94	24,47	18,8	17,74	18,44

Sound strength, Oreksterparken's playroom, altered design.

Altered design	Sound strength, G, (dB)					
	125	250	500	1k	2k	4k
Receiver						
0	20.74	26.15	21.37	20.70	19.15	18.78
1	19.16	20.05	21.35	20.25	17.91	17.89
2	16.90	18.34	20.38	17.94	17.24	17.51
3	19.26	19.87	22.88	19.63	19.49	18.48
4	18.42	22.81	22.15	17.74	16.43	17.06

Reverberation time, Oreksterparken's playroom, current design.

Current design	Reverberation time, T30, (s)					
	125	250	500	1k	2k	4k
Receiver						
0	0,53	0,50	0,52	0,50	0,51	0,52
1	0,51	0,53	0,56	0,50	0,49	0,56
2	0,51	0,45	0,5	0,47	0,57	0,55
3	0,52	0,51	0,53	0,50	0,48	0,56
4	0,60	0,52	0,52	0,50	0,52	0,54
Average	0,53	0,50	0,52	0,49	0,52	0,54

Reverberation time, Oreksterparken's playroom, altered design.

Altered design	Reverberation time, T30, (s)					
	125	250	500	1k	2k	4k
Receiver						
0	0.51	0.44	0.40	0.37	0.37	0.42
1	0.48	0.39	0.38	0.38	0.40	0.46
2	0.53	0.40	0.36	0.38	0.35	0.45
3	0.63	0.42	0.36	0.35	0.39	0.47
4	0.51	0.43	0.39	0.36	0.40	0.47
Average	0.53	0.42	0.38	0.37	0.38	0.45

Speech clarity, Oreksterparken's playroom, current design.

Current design	Speech clarity, C50, (dB)					
	125	250	500	1k	2k	4k
Receiver						
0	8.16	14.88	9.01	8.58	11.49	5.62
1	7.69	9.26	11.78	7.97	10.90	8.48
2	2.24	5.88	7.01	5.99	9.88	5.31
3	6.38	10.17	13.24	9.87	13.99	7.81
4	5.57	11.13	12.29	8.25	10.06	6.27

Speech clarity, Oreksterparken's playroom, altered design.

Altered design	Speech clarity, C50 (dB)					
	125	250	500	1k	2k	4k
Receiver						
0	7.65	18.25	12.57	11.56	10.97	9.31
1	5.18	10.03	11.03	12.56	10.64	9.85
2	4.64	8.67	12.05	12.17	11.11	10.47
3	10.46	15.01	16.28	14.20	15.22	14.80
4	5.43	15.77	15.11	10.10	10.87	10.70

STI, Oreksterparken's playroom, current design.

Current design	Speech transmission index, STI					
	125	250	500	1k	2k	4k
Receiver						
0	0.78	0.93	0.79	0.79	0.72	0.69
1	0.78	0.82	0.85	0.75	0.75	0.76
2	0.68	0.77	0.77	0.76	0.75	0.72
3	0.77	0.85	0.88	0.70	0.71	0.74
4	0.72	0.86	0.86	0.64	0.76	0.75

STI, Oreksterparken's playroom, altered design.

Altered design	Speech transmission index, STI					
	125	250	500	1k	2k	4k
Receiver						
0	0.80	0.96	0.82	0.86	0.82	0.75
1	0.76	0.84	0.86	0.87	0.82	0.82
2	0.75	0.82	0.86	0.84	0.84	0.82
3	0.83	0.88	0.93	0.86	0.92	0.80
4	0.75	0.91	0.89	0.79	0.82	0.82

Appendix V -Guide to create a satisfactory sound environment

These guidelines consist of general suggestions for preschool design followed by suggestions for how specific rooms can be designed with regards to common problems in such room.

General

The first important step in creating a good sound environment in a preschool is to create a forum for communication between

- Preschool personnel
- Architects
- Acoustical consultants

Collaboration between these professionals is essential to create a design that is aimed to cater for the preschool environment. Suggestions and recommendations that follows should be considered as well as the views of each of the professional and stakeholders mentioned above.

Create the design from the child's and personnel's perspective; they need spaces for different activities and the personnel have to be able to get an overview of these activities. The design and choice of materials needs to be critically considered in relation to each space's function and the type of sound environment that they required.

Demands/ activities in the space can be

- Playing
- Sleeping
- Resting
- Dining
- Concentrating
- Several different activities?

When the functions for the rooms are defined consider which sound parameters that are of importance. Parameters of importance will depend of the aim of the room but also of which problems that could appear. Following can examples of parameters/problems to consider of each specific room be seen

- Speech clarity
- Speech intelligibility
- Risk for echo?
- Risk for high sound levels?

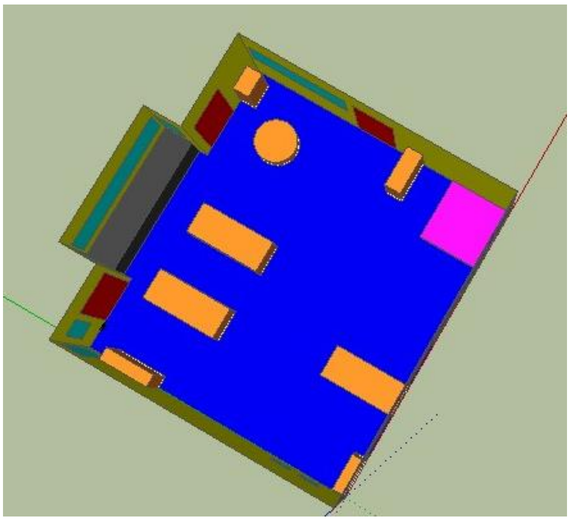
It is also of importance to consider how children and personnel are going to move inside the building. Location of different rooms should be places in a way so that corridors and/or passages not occur through rooms where preschool activities are performed.

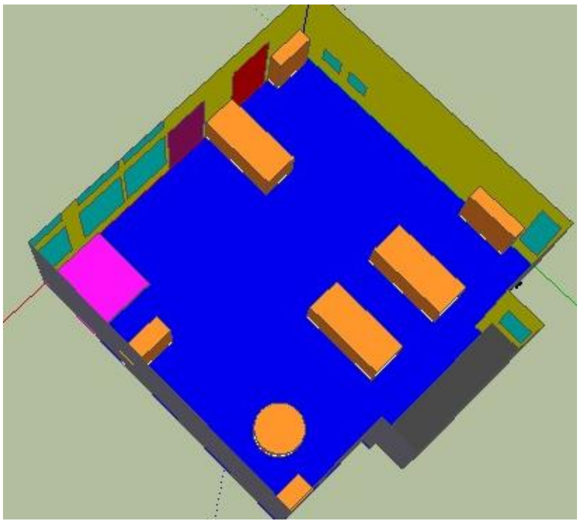
High sound levels are a huge problem in preschools. This problem can be helped through sound absorption panels and ceilings. Acoustic ceiling should always be used and it is preferable to install absorption panels at walls. During the planning of the preschool do consider the design so that it will be possible to put sound absorption panels at the walls. The wall absorption should be placed at the height of children's ears and mouth. It can also preferably be used in corners where sound waves risk being strengthened by means of reflection.

At least one wall in a small room with parallel walls should be covered in an absorbing treatment so as to avoid flutter echo.

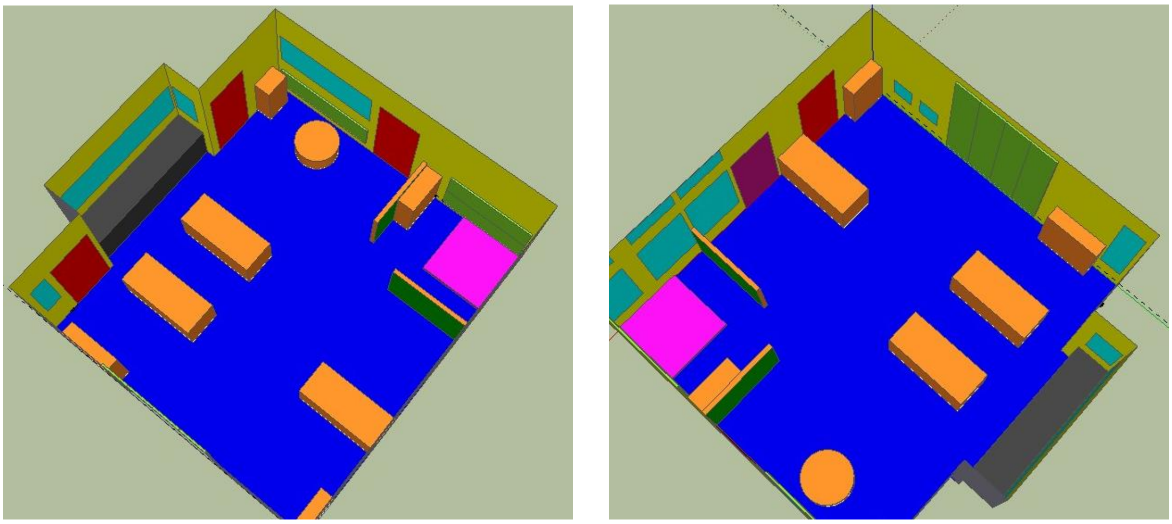
The ability to divide larger rooms into smaller sections, using screens for example, should be considered during the planning stage.

In the figure below is a room in its original design presented. In the next section of figures are the same room presented but in this case has acoustical treatments been performed. These treatments consist of screens of 1.20 m in height covered with absorption. Moreover wall absorption is installed. The green section below the window consists of 1.44 m^2 of absorption and in the new playcorner 2.4 m^2 of absorption covers the wall. The green section on the wall in the figure to the right consists of 6.24 m^2 of absorption panels.





Original design.



Design post acoustical improvements.

These improvements had significant effects on the sound environment and resulted in a reduction in sound strength of 9 dB throughout the room. This is significant as a reduction of 10 dB is perceived by the human ear as a halving of the level of noise.

Moreover the reverberation time decreased by 0.1 second within the space. The reverberation time describes the time it takes for sound to decay in a space. Speech clarity which describes how clear the sound is perceived increased by approximately 10 dB in the room which means that spoken message will be easier to understand since it will become clearer.

When choosing screens, consider how they are placed to ensure that their function is fulfilled. Screens should be placed based upon specific requirements such as;

- Privacy
- Visual privacy
- Speech intelligibility
- Sound reduction

Walls between different rooms should have glass sections to make it possible for the personnel to get an overview. Moreover the placement of such glass panels should be considered so as to limit the potential for visual disturbance of children looking between rooms.

Specific rooms

Sleeping rooms

These types of rooms should not be placed next to playgrounds or high trafficing roads.

A room defined as quiet, not intended for sleeping but for quiet activities, should exist within preschools.

Cloakroom
Windows between these rooms and playrooms/dining rooms are not recommended. Disturbing sound incidents can easily occur in cloakrooms and the combination of visual and audio disturbance can hinder children's concentration.

Consider the design so as to avoid queue in corridors of the cloakroom and to toilets etc.

Consider placement and/or isolation of drying cabinets so as to avoid potentially disturbing background noise in other rooms.

Open plan and dining rooms
Ensure that corridor or passages through these rooms are avoided. Large playrooms should not be placed next to sleeping rooms. The design of these rooms should allow for the spaces to be divided into smaller parts and absorption will preferably be installed at walls.

Beyond the measurement of reverberation time, consider and evaluate other relevant room acoustical parameters such as sound strength, speech clarity and also speech transmission index, STI, in these types of rooms.

Small playrooms
Consider the location of these rooms. Personnel need to be able to see the children inside the room. Sections of glass could preferably be used, theses glass sections should be placed from the personnel's viewpoint so as not to cause a visual distraction for children.

The door to these types of rooms is often open, therefore consider the placement of the door so as to minimise sounds transmission from other spaces.

Parallel walls in small rooms can cause flutter echoes. So as to avoid flutter echoes cover at least one of the parallel walls with sound absorption. Corners should preferably be covered with absorption panels since sounds are strengthened by means of reflection in these areas.

Beyond the measurement of reverberation time, consider and evaluate other relevant room acoustical parameters such as sound strength, speech clarity and also STI in these types of rooms.

Kitchen
If possible, kitchens should be placed in connection to dining rooms but not next to playrooms or other quiet rooms designed for activities such as sleeping. If such placement is needed, ensure sounds from machines, air born as well as impact sound, do not disturb.