Colloque international
international symposium

10-12 septembre 2008
auditorium du musée

Grenoble (France)

creating an atmosphere
faire une ambiance

Title of the paper
REDESIGN OF ONE ATMOSPHERE – WHAT DO YOU WANT TO HEAR?

Authors
Björn Hellström (main author)
PhD, Architect, Acoustic designer. bjorn.hellstrom@konstfack.se, www.acousticdesign.se
Ongoing Work: Visiting Professor and researcher (50%) at the University College of Arts,
Crafts and Design (Konstfack), Stockholm. Acoustic Designer (50%) at the acoustic
consultancy company ÅF-Ingemansson.
Ongoing research activities: Delegate of the Management Committee of the COST Action
ICO601 / Sonic Interaction Design (SID), www.cost-sid.org/. Involved in three research
projects – main topics: development of acoustic design artifacts and methods / art based
musical, architectonic and acoustic investigations of urban space / aurailization.

Bengt Johansson (co-author)
Acoustician and senior consultant at the acoustic consultancy company ÅF-Ingemansson,
Stockholm. bengt.johansson@afconsult.com

Philip Zalyaletdinov (co-author)
Acoustician and consultant at the acoustic consultancy company ÅF-Ingemansson,
Stockholm. philip.zalyaletdinov@afconsult.com

Abstract
In an ongoing research project the design of acoustical atmospheres in large indoor spaces are
investigated. The research question is: “How to redesign one sonic atmosphere into a
variation of sub-atmospheres in large indoor spaces?” This question is especially valid for
spaces such as semi-public commercial spaces (e.g. shopping malls), libraries, airports and
communication spaces. The sonic atmosphere in these collective spaces is often loud, blurred
and confusing, with little correspondence between visual and aural perception, and with weak
articulations of spatial dimension, distance, borders and orientation. Together the different
sound sources within these spaces generate a sonic hubbub. Even though such spaces
comprise of several types of activities, the sonic atmosphere is the same all over the place.

Hence, this research project focuses on design of sonic variations of the atmosphere;
i.e., site specific sounds that deal with qualities such as communication, comfort, orientation,
identity and privacy. The objective is to develop and test an interdisciplinary design
methodology, which comprises a number of co-related methods; e.g. acoustic measurements,
arhitectural site analysis, as well as virtual modeling and representation (visual and acoustic)
of the space. The main part of the project is the virtual modeling and representation. It
connects software that handles architectural 3D-modelling (SketchUp) with the Catt-Acoustic
software, used for prediction and aurailization.

The research project also includes a case-study, which comprises proposals for redesign
of a congress centre (Scandic Infra City), situated north of Stockholm. The proposals –
consisting of architectural elements, sound installations (additions of sounds) as well as
acoustical measures – will be demonstrated in a virtual model. The presumed effect is a
differentiation in terms of a variety of sonic sub-atmospheres within the congress centre. The
methodology developed in the project is intended to function as a tool for design measures of
large indoor spaces. It is an interdisciplinary tool in that it supports acousticians as well as
architects. The case-study may serve as a pilot model for future applications of redesign of the
sonic atmosphere in large indoor spaces.

This paper is a result of a research project, executed by the acoustic consultancy
company ÅF-Ingemansson and the University College of Arts, Crafts & Design (Konstfack),
Stockholm. The project has funding from the White´s Foundation for research and ARKUS, a
Swedish foundation for the improvement of qualifications within architecture.
INTRODUCTION

Generally, today our greatest acoustic efforts are concentrated on defensive strategies for protecting people from noise disturbances. Without getting sidelined by these issues, it is time for offensive strategies that aim at exposing the acoustic space; to develop constructive and creative relations within an architectural context. Such strategies involve critical discussions on the development of interdisciplinary methodologies that connect acoustics and architecture, and also to some extent psychology, sociology, anthropology, et al. What are asked for are qualitative aspects of the architectural space in constructing and innovative perspectives, with regard to dynamic time-space-based design as well as to human interaction.

One basic issue concerning qualities of sounds is the listening perception itself. Sounds bring information regarding aspects of place characteristics (a place has a certain sonic identity), spatial criteria (we orientate in regards to sounds), social criteria (who/what produces the sound and what is my relation to it?) and communication (we act and respond to sonic information).

In the research project, we want to explore the use of modern acoustic design tools in the design of acoustical atmospheres in large indoor spaces such as shopping malls, libraries, airports and communication spaces. These tools can, besides calculating a number of acoustic parameters, also provide possibilities for auralization, which means listening to recorded sounds that have passed through the simulation model. The methods used today considering large indoor spaces are primarily focused on noise control. This implies that the only acoustic parameter of interest is the noise level. The quality of the sound in these spaces is not taken into consideration. With auralization, it is possible to decide which acoustic qualities that is preferred from a listening perspective, thereby including aspects of design.

The main part of the project concerns virtual modeling and representation. The University College of Arts, Crafts & Design (Konstfack) in Stockholm possesses an advanced sound design lab. This lab is specialized in surround techniques, especially auralization. The lab is unique in that ten people can share the same listening, which means that the lab also has a pedagogic and social function in that people can discuss about what they hear, contrary to e.g., headphone listening. This means that the sound design lab is an open platform where people from different disciplines – acousticians, architects, building contractors, artists, musicians, sociologists and others – can work together in the design of acoustic spaces. Another advantage of using sound design lab instead of headphones is that the listener can turn her head to experience the acoustic environment.

PROJECT DESCRIPTION

Objective

The objective is to develop and evaluate a design methodology for acoustic design, applied to one case study of one specific type of indoor space; namely large indoor spaces that comprises different activities. The main part of the project deals with virtual modeling and representation. It connects software that handles architectural 3D-modelling (SketchUp) with the Catt-Acoustic software, used for prediction and auralization. The project comprises the following activities:

1. To create and validate an acoustic design methodology where acoustic simulation tools are integrated into the design process.
2. To provide a case-study example of acoustic improvements in a large indoor space, comprising different activities.
3. To evaluate the suggested acoustic improvements in a sound design lab – using a 5-channel listen simulation system – and determine the potential of the design methodology for providing an acoustic atmosphere that strengthens the spatial qualities as well as the social interaction in the investigated area.
Acoustic Simulation – Auralization
A number of commercial computer programs exist today where acoustic parameters are calculated directly from a 3D-model, containing the geometry and the acoustic properties of all boundaries for the space under evaluation. These programs also provide tools for auralization, which allows the user to listen to a recorded sound as it has passed through the simulation model. Auralization is a validated tool for indoor acoustic design and is now used extensively by acoustic designers. Catt-Acoustic is a computer program used for prediction and auralization, created by Catt - Bengt-Inge Dalenbäck. Based on CAD data for a specific room, Catt-Acoustic can produce a number of parameters that are useful in the acoustic design process. Auralization was invented by the Room Acoustic Group at Chalmers in Göteborg. The word "auralization" means listening to sounds as they have passed through (a model of) a specific room. The auralization technology has been refined by Catt and is now a powerful tool in the prediction and design of acoustic spaces.

RESEARCH ACTIVITIES – CASE STUDY

Architectural and acoustical site analysis
The primary assignment of the case-study was to select a built, large indoor space that comprises different activities. A congress centre located 30 km north of Stockholm was selected (Scandic Infra City in Upplands Väsby). The congress centre comprises a variety of activities such as a restaurant, an information desk and a large lobby connected to a congress hall.
The site analysis rests on a comparative study of visual–architectural representation and audible–acoustic representation of the congress centre. The following main criteria were scrutinized:

- what distinguishing visual and audible qualities are connected to the congress centre from a spatial, temporal and social point of view (qualities such as communication, comfort, orientation, identity and privacy)?
- what constitutes the interaction between the architectural and acoustical qualities?

In brief, the outcome of the analysis of the congress centre confirmed the initial hypothesis in that it is a prime example of a place with little correspondence between visual and aural perception, and with weak articulations of spatial dimension, distance, borders and orientation; i.e., the sonic atmosphere is the same all over the place.

**Redesign of the atmosphere**

The next step dealt with redesign of the sonic atmosphere of the congress centre. The basic idea was to differentiate the atmosphere by using four different types of acoustic design tools: screening, addition, absorption and diffusion. The main purpose with these acoustic design tools is to distillate and strengthening the sound generating activities and elements in the congress centre. Thus, these tools aim at bringing qualities to the congress centre. The project focuses on three types of activities in the congress centre: a restaurant, an information desk and a lobby.

Regarding the restaurant the objective was to install a sound-absorbing screen in order to isolate the sounds connected to the different activities that are located outside the restaurant. By separating the sounds of the restaurant from the surrounding activities, the assumed effect was to strengthen the sonic atmosphere in the restaurant, as well as to improve the acoustical comfort.

Regarding the information desk the objective was to install a sound-masking system in order to reduce distractions. The sound-masking system, consisting of pink noise, is an effective solution for “spot treatment” of situations where one individual is being distracted by voices and other noises around them. Hence, the assumed effect was to improve the speech privacy at the information desk, as well as to improve the acoustical comfort.

Regarding the lobby the objective was to install sound absorber panels in the ceiling, and also wall mounted diffusers. The sonic atmosphere can be very noisy in the lobby when people get together in connection with conferences. The lobby also serves as a mingle area; therefore it is important to install ceiling absorbents in order to reduce the noise level. The wall-panel diffusers are designed to scatter sound waves, and thereby reducing higher frequency standing waves and echoes and creating better listening environment.

Summing up, the purpose with the acoustic design was to articulate the spatial, temporal and social dimensions in the congress centre, and, thus, to improve the relation between visual and aural perception.

**Acoustic measurements**

Reverberation time and several other room-acoustic parameters were measured for evaluation of the acoustic qualities of the studied spaces and later on to make comparisons with predictions carried out with room acoustic modelling software. An omni-directional loudspeaker was used during the measurements. The speaker was placed at four different positions at the ground floor of the building; six different microphone positions were used for each loudspeaker position, all measurements were made with WinMLS2004 software.
Virtual – visual – modelling and representation
The architect’s 2D Cad-drawings were brought into the SketchUp, software for creating 3D-models. By placing the 2D-drawings of the different floors on its accurate level, the 3D-model could be created. Also vertical section planes were brought into SketchUp, acting as a base for the modelling. All planes were represented by a material. The material name was chosen to comply with the material data-base of the coming Catt-model.

The transformation from the SketchUp model to the Catt-model was performed using a plug-in for SketchUp, SU2Catt, from the German company Rahe-Kraft. The plug-in automatically produces a Catt-model from a SketchUp model. However, the SketchUp model must be created with Catt in mind. Since SketchUp is a visual software you cannot really see if planes or lines are created several times. This will obviously cause errors in Catt. You also have to make sure that the model does not have leaks, which would cause ray-loss in Catt. The Catt model was made of about 1000 planes.

Acoustic calculations and auralization
Each face in the imported 3-D model was given an appropriate absorption coefficient, approximately matching the real materials of the studied acoustical space. Virtual loudspeakers and microphones were placed at approximately the same positions as during the real-life measurements. Several room-acoustic parameters were calculated and evaluated, the main focus stayed on the reverberation times of the room. The results of the calculations were compared with the real measurements. Some fine-tuning of the scattering coefficients was needed to be made to better match the sound field of the real room. After the adjustments the
correlation between the measurements and calculations showed to be rather high for such a complex model.

For auralization three different listening positions were chosen, one in the restaurant area, one behind the information desk and one in the lobby area. Each listening position was surrounded by four nearby sound sources, with the aim to simulate a fairly realistic sound environment. The impulse response of the room was calculated at each listening position and from each source, (it is possible to hear all sound-sources in the room from each listening position). Each sound source represents a site-specific sound, (people talking, telephone ringing, sounds of tableware, turning of the newspaper, ventilation noise etc). With five-channel loudspeaker system in mind a B-Format was chosen as an appropriate receiver model in CATT-A. The calculated impulse responses were convolved with the anechoic wav-files in MultiVolver software, for each of the B-Format channels, (W, X, Y). Every wav-file’s sound level was adjusted with regards to each other for each channel-set. Level adjusted W, X, and Y channels were Ambisonic-decoded for the speaker rig in our sound design lab. Finally the Ambisonic decoded files were encoded into five discrete DTS channels, which made it possible to listen to the files with a regular DVD-player hooked up to a multichannel DTS-compatible surround receiver. After aural evaluation of the sound files in the sound design lab, acoustic measures were modelled in CATT-A.

A 1.6 m high sound absorbing barrier was modelled at the back of the restaurant area. A high directivity loudspeaker, driven by a pink-noise signal was modelled above the surface of the information desk. The surfaces of the walls in the lobby area were given high scattering coefficients to simulate highly diffusive elements; the ceiling surface of the lobby area was given high absorption coefficients corresponding to a high quality, porous, broadband sound-absorber.

A new set of room impulse responses was calculated and ran through the above described auralization process, which made it possible to evaluate the effect of the introduced acoustic measures. The introduction of the sound absorbing barrier made it possible to reduce the sound pressure level emitted from the sound sources in the restaurant area with over 5dB at the information-desk receiver point. The incoming sound was also masked with a low level (about 38 dB) pink noise signal, emitted from the loudspeaker-array, installed above the information desk. The sound environment in the lobby area was experienced as much more speech-friendly, after the introduction of highly absorptive ceiling and sound diffusing walls. STI (Speech Transmission Index) was calculated at five different positions in the lobby area. The mean value went from 0.68 to 0.75 after the introduction of the acoustic measures in the room. The STI calculation was done with the default NCB 28 (35.8 dBA) background noise level in both cases.

![Calculated reverberation time T-30, mean values of four virtual loudspeaker positions](image1)

![Calculated reverberation time T-15, mean values of four virtual loudspeaker positions](image2)
SUMMARY & EVALUATION
The presented research project deals with development and evaluation of a design methodology for acoustic design, applied to large indoor spaces that comprise different activities. The objective has been to redesign one sonic atmosphere into a variation of sub-atmospheres in large indoor spaces. The acoustic proposals have been designed in a virtual model, using a computer program for prediction and auralization. The auralization technology makes it possible to simulate acoustic spaces, and is a powerful tool for indoor acoustic design. The virtual model has been tested and evaluated in a sound design lab, using a 5.1-channel speaker system.

When listening to the virtual model in the sound design lab it becomes clear that the proposed acoustic design tools (screening, addition, absorption and diffusion) have an obvious effect in order to improve the sonic atmosphere in the congress centre. The impact of the sound absorbing screen in the restaurant is obvious; the sounds connected to the different activities that are located outside the restaurant are screened off, as well as the sonic atmosphere is more distinct with regard to spatial qualities. The sound masking system – consisting of pink noise – has an apparent effect in that it masks the surrounding sounds and also improves the speech privacy. The absorber and diffuser panels that are installed in the lobby-area have also a great impact on the acoustic climate, especially regarding the reverberation time and the background noise level.

In conclusion, the proposed acoustic design methodology has proved to work out well. However, since this project only comprises of one case-study, the next step is to apply the methodology on other cases, in order to swell the number of relevant design cases as reference examples.

REFERENCES
Arkus, www.arkus.se
Konstfack (University College of Arts, Crafts & Design), www.konstfack.se
ÅF-Ingemansson, Swe. www.ingemansson.se / Eng. www.ingemansson.se/?sid=702