COSMA – A European Approach on Aircraft Noise Annoyance Research

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ABSTRACT

COSMA - Community Orientated Solutions to Minimize Aircraft Noise Annoyance - was a European approach within the 7th Framework Programme of the European Commission.

Aircraft noise engineering is focused more or less on the reduction of the noise emission for single aircraft components, and separately treating the noise abatement procedures during take-off and landing. COSMA's aim was to combine both under the aspect of noise annoyance: To develop basic engineering criteria for an annoyance friendly aircraft design and managing flight operation routines in order to reduce the noise related annoyance within airport communities. The project had to create the link between the aircraft/sound engineering domain, and the noise effects domain. To achieve this goal, extensive field studies around European airports, combined with psychometric studies in laboratories have built the basis for describing the optimal aircraft sound characteristics which anticipates a lower annoyance. Specific sound synthesis methods, combined with the optimization of procedures for flight operations were used to create low noise annoyance practices, including future aircraft concepts.

The authors give an overview about the final status of the project's achievements in the major project areas: Annoyance related examinations, sound engineering, and optimization.

Keywords: Aircraft noise, noise annoyance, community noise
I-INCE Classification of Subjects Number(s): 13.1, 52.2

1. INTRODUCTION

COSMA was a project under the 7th Framework Programme of the European Commission, which run from 2009 to 2013. The project should contribute to the understanding of aircraft noise effects in the communities which are surrounding airports [1-4]. COSMA should help to develop the necessary techniques for the modelling of noise impact from aircraft. Supported by a set of tools, created and validated during the project's runtime, engineering guidelines and methods should be developed for the implementation of suitable design and operating practices, aiming together for the minimization of the aircraft noise annoyance. This has been one of the central objectives of COSMA, closely related to the following questions which should be answered after the project's end:

- What is annoying in a single aircraft noise event, considering typical aircraft noise signatures (spectral characteristics)?
- What characteristics should then have a Community Friendly Aircraft?
- What is annoying in a series of aircraft noise events, considering aircraft signatures and

frequency of events?
- What characteristics should then have Community Friendly Operations?
- What are the additional chronic annoyance factors to be considered in a community context?

21 partners from 9 European countries have been contributing to COSMA, performing an upstream research activity for an improved understanding of the effects and impacts of aircraft noise in the airports' communities and providing techniques for modeling of aircraft noise around airports. It was bringing together aircraft noise engineers, sound designers and noise effects experts, ensuring that the work clearly targeted to improve aircraft design and operations under the aspect of the ultimate goal: The reduction of aircraft noise annoyance.

2. COSMA – PROJECT AND CONCEPT

The scientific concept of COSMA is addressing the aspects regarding community noise reduction which are defined in ACARE 2020 and will have a significant strategic impact in reinforcing the competitiveness of the European industry while addressing the long term environmental goals. The basic COSMA concept is shown in Figure 1 below and is explained in detail in [5]. It indicates the principle work flow of the project and the highly interacting disciplines of noise impact research (WP2, WP4), sound engineering (WP3) and aircraft design (WP5), which are represented by the different work packages.

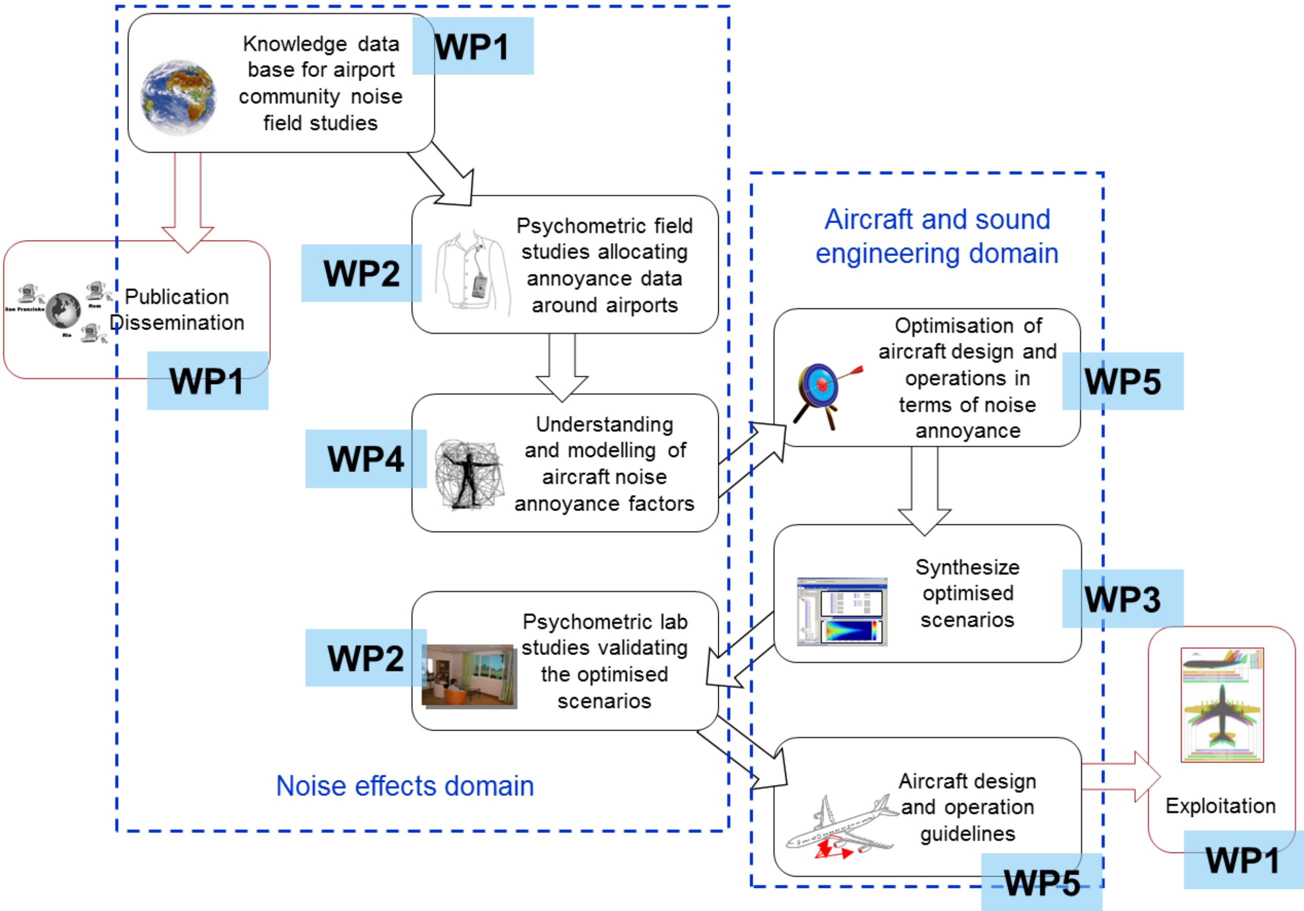

Figure 1 – COSMA scientific concept and project workflow

3. MAIN PROJECT RESULTS

3.1 Annoyance Examinations

Part of the annoyance examinations of COSMA were telephone and field studies at three different European airports, which were supported by the extensive literature study. In parallel, an extended analysis of original data of the Frankfurt Noise Annoyance Study 2005 FRA-S [6] has been made at the beginning of the project in order to identify the important acoustical and non-acoustical factors for the prediction of long-term and short-term (hourly) aircraft noise annoyance, which could be considered in the methodology for the telephone and field studies, and served as a first database input for the Virtual Resident (VRes) model development.

Besides reducing the sound pressure level (SPL) one possible way to reduce annoyance around airports is to improve the sound quality of future single aircraft, especially during overflights. An interactive Sound Synthesis Machine (SSM) was developed and test persons (subjects) had the task to create their own preferred sounds. Different aircraft noise sources were allocated to faders, assigned to attenuate or amplify those sources, which are explained with the SSM in section 3.2.1.

In order to analyze their potential regarding annoyance reduction in the community of airports, future airport scenarios were also investigated, i.e. improved aircraft sounds - so-called target sounds - were examined in three comprehensive laboratory studies in a living-room atmosphere.

3.1.1 Telephone and Field Studies

The field studies were mainly aiming to determine the

- Acoustic indicators that predict best acute annoyance.
- Non-acoustic variables that influence long-term annoyance overall and at night.

To achieve those goals, several studies around airports in the past found revealed not more than one third of the variance in the annoyance judgments could be explained only by acoustical features. A broad number of non-acoustical factors which might vary from airport to airport became more and more important. This suggests that there is not only one global exposure-response curve for annoyance that fits for all airports.

The extensive telephone and field study examinations of COSMA were carried out around three European airports: London-Heathrow as a main hub, Cologne/Bonn as an airport with many operations during night and Stockholm-Arlanda as a main Scandinavian hub in a non-densely populated area. Aim of the 1,200 telephone interviews with more than 40 questions at each airport (scopes: residential area, noise annoyance, coping measures, attitudes, demographic data) was to map the status quo of current aircraft noise annoyance situation as well as to provide information about the most important non-acoustical variables explaining the variance in the annoyance judgments. Furthermore, the results of the telephone interviews served as the basis to identify the areas where the field study subjects were recruited. In the field study at every airport 50 subjects were examined for six days whereas for four days and nights the exterior sound pressure level was continuously measured, damping parameters were determined and the acute annoyance during daytime has been quantified by means of brief hourly questionnaires. Comprehensive opening and conclusion questionnaires were applied as well as sound quality judgment sessions at the subjects' residence.

In these extensive acoustic datasets the single aircraft events had to be identified by means of flight schedules and flight route maps. More than 40 acoustic parameters have been calculated and the results of these acoustical data were used for the final statistical analysis of field data:

<u>Acoustic predictors for noise annoyance</u>

The acoustic stress that causes annoyance is a complex variable, where not only the sound pressure level but the temporal and spectral composition plays a decisive role. Noise stress is usually indicated by a single number, but this number can be composed and calculated by differently weighted acoustic parameters. For the present study, noise stress was expressed during the day and for each hour by a selection of overall 33 indicators. 27 of them are based on outdoor measurements and 6 are person related indicators that consider the actual position of the participants, i.e. if they are involved in indoor or outdoor activities. Considerable differences between the three airports could be demonstrated. The most important variable that determines hourly annoyance at the airports Cologne/Bonn and Stockholm is obviously the total number of aircraft as well as the number of aircraft above 55, 60, 65 and 70 dB(A), and the time an aircraft is perceived.

Time-of-day

The analysis of the most annoying times-of-day obtained from the opening questionnaire, revealed that overall annoyance and the annoyance at night are higher for those persons who feel particularly annoyed on weekdays and on weekend days in the early morning from 06:00 to 07:00 and/or in the evening between 20:00 and 24:00. For weekend days, annoyance from 13:00 to 14:00 was again decisive for the evaluation of long-term annoyance.

It was, however, disadvantageous that the participants revealed a very low annoyance rate during the four days where the hourly degree of annoyance from 7:00 to 22:00 has been rated. 80% of the answers indicated that the participants were ‘not at all’ or ‘slightly’ annoyed. This rather low rate prevented e.g. the statistical analysis of annoyance, related to their activities.

Summary of non-acoustic variables that enhance annoyance

Long-term annoyance is determined by a large number of non-acoustical factors, some of them are listed as examples below and can provide a rough survey of those, most important non-acoustical factors for the long-term annoyance and for the annoyance at night:

- Overall annoyance over 24 hours:
  For all three airports the stepwise selection of variables identified the following factors with a significant higher risk of being highly annoyed:
  - ¬ being disturbed at mental work and relaxing indoors
  - ¬ being disturbed at relaxing outdoors
  - ¬ being disturbed at falling asleep, at sleep in the 2nd half, having a reduced sleep quality
  - ¬ using coping strategies
  - ¬ being less satisfied with noise insulation
  - ¬ thinking that aircraft noise is bad for health for the individual and for the residents in general
  - ¬ being noise sensitive
  - ¬ not having influence over results of airport decision processes
  - ¬ not feeling fairly treated concerning aircraft noise

- Annoyance at night:
  For all three airports the stepwise selection of variables identified the following factors, with a significant higher risk of being highly annoyed at night:
  - ¬ being disturbed at relaxing indoors or outdoors
  - ¬ being disturbed at falling asleep, at sleep in the 2nd half, having a reduced sleep quality
  - ¬ having shorter occupancy
  - ¬ using coping strategies
  - ¬ being less satisfied with noise insulation
  - ¬ thinking individually and globally that aircraft noise is bad for health
  - ¬ not agreeing with the opinion that the airport is important for the economic system
  - ¬ being noise sensitive
  - ¬ not feeling fairly treated concerning aircraft noise.

Based on the odds ratios for the non-acoustical factors the influences on annoyance can be summarized as in Figure 2. It shows that disturbances and resulting annoyance at night, disturbances of relaxation, negative attitudes against the airport, particularly the fear that air traffic is a health hazard and the necessity to apply coping measures enhance annoyance. In contrast, satisfaction with the area the respondents live in, the conviction that they get used to aircraft noise in the future and the feeling to be fairly treated by the airport authorities reduce the chance to be annoyed by aircraft noise.

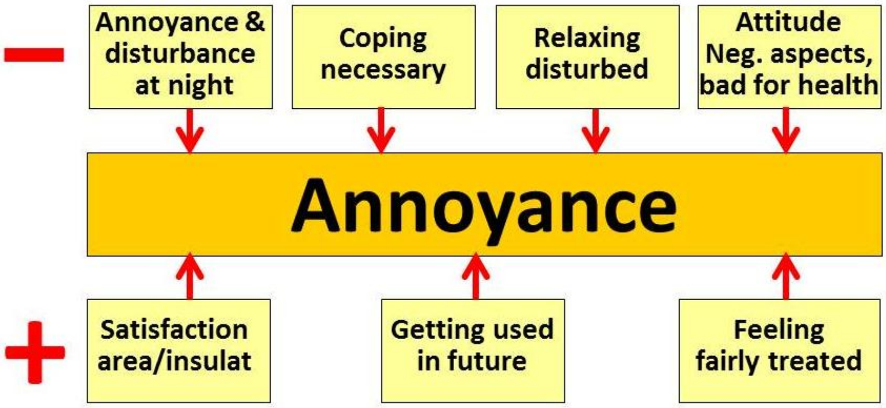

Figure 2 – Summary of non-acoustical factors influencing long-term annoyance

3.1.2 Laboratory Studies

Laboratory studies were required for the evaluation of optimized/improved future airport noise scenarios vs. current airport scenarios, as they allow the variation of the acoustic stimuli (number of sound events, noise levels, sound quality, etc.) while keeping constant other environmental factors. Participants, placed under laboratory conditions close to the "real world situations" (from point of view for noise exposure and host conditions) were exposed to air traffic sounds reproducing different noise situations. During this time, they had to perform various “like-at-home” activities as well as a cognitive performance task.

The evaluation and the comparison of these scenarios were carried out on the basis of the following criteria:

- Short term effects: overall annoyance - activity disturbance - cognitive performances
- Perception of single overflights (sound quality)

An experimental protocol was applied to four comparisons, involving 288 participants: 72 per comparison and 96 per laboratory. The first and the second comparisons focused on the number of aircraft sound events, respectively at takeoff and landing. The baseline sequence was composed from 22 events (5 different types of aircraft) and has been compared to 11 aircraft (2 different types of aircraft among the 5 of the baseline sequence). All sequences were supposed to keep the number of passengers constant at about 4000. For these two comparisons with about the same equivalent sound level (within ±1 dB accuracy), and the same peak levels, the number of aircraft had a significant influence on global annoyance, which can be summarized by higher scores of annoyance for 22 aircraft than for 11 aircraft. There was an interaction between the sequences and the order of the listening. The annoyance was rated in the median of the scale whatever the number of aircraft, but the difference between the 22 and the 11 event sequences was clearly noticed at the second listening.

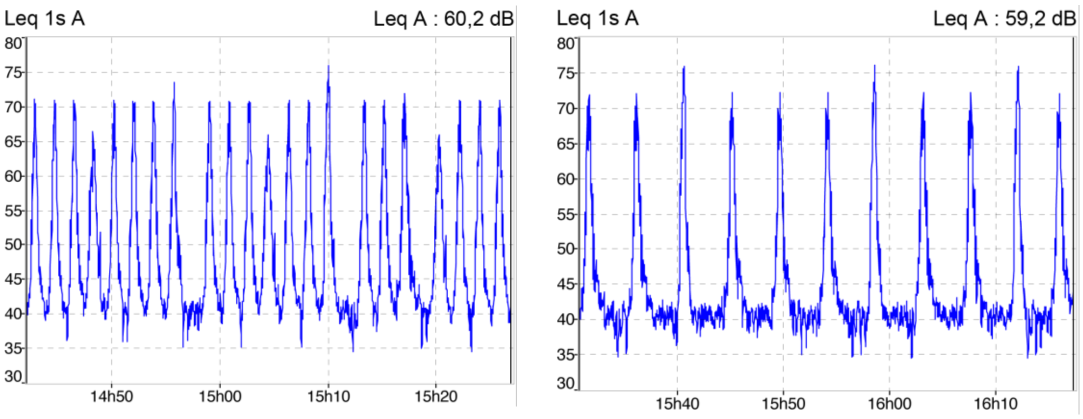

Figure 3 – Example of the sound level evolutions for the 22 and 11 events at take-off

The memory task - which has been judged as the most difficult activity - was the activity most disturbed by aircraft noise. The rating of the global annoyance was similar to this activity disturbance. The global annoyance was also correlated to the reading task, which lasted 30 minutes over the 45 minute duration of the listened sequence. Performance scores were not influenced by the noise sequences.

Further the role of proposed optimizations regarding sound quality and new approach procedures has been investigated during the laboratory experiments. During these comparisons, the baseline sound sequence was composed by 22 aircraft (5 different types of aircraft for sound quality and 3 different types of aircraft for new approach procedure). For the comparisons each overflight has been optimized. For the sound quality optimization, the sounds which have been created by the participants at the sound machine have been used instead of the original aircraft sounds. For a new approach procedure, each original overflight has been substituted by synthesized sounds with an optimized trajectory. In both cases, the annoyance is not significantly reduced by the optimization. This is not to say that there is no influence of the sound quality or of the approach procedure, but the number of subjects was too small to reveal such a subtle effect, due to the large variance between the participants.

3.2 Sound Engineering

3.2.1 Sound Machine

The SOUND MACHINE tool was developed for the target sound design investigations in the annoyance studies using the main identified noise sources with a complex interrelation affecting the sound quality perception (see Table 1) [7].

Table 1 – Aircraft noise sources used for the SSM tests

Tonal noise sources	• fan • turbine • buzz-saw noise • airframe
Broadband noise sources	• jet • airframe • combustor • fan

Faders of the SOUND MACHINE tool (see Figure 4) were assigned to the individual sound components from above to allow the online changing of the composition of the sound during playback in the listening laboratory and compose target sound which is more preferred by the test person. The tool is running an inner algorithm that compensates the loudness to a constant level, no matter how the faders are being changed. The software is controlled by an external hardware device equipped with a touch screen, presenting the most important control elements and information, such as faders, start/stop, etc., to the user.

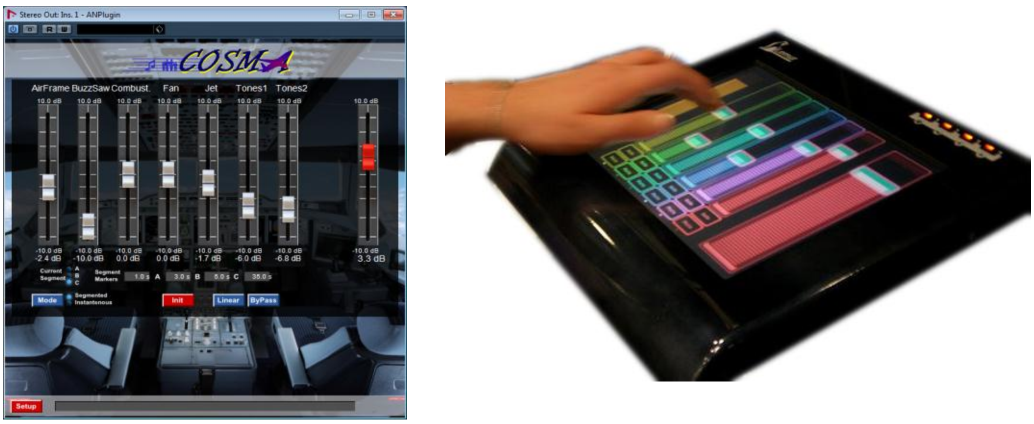

Figure 4 – SOUND MACHINE with faders. Implemented as software (left) and hardware (right)

The fader input sound components were generated for several aircraft types in take-off and approach conditions. A dedicated sound decomposition algorithm was used to extract the harmonics and broadband noise components for the use in the sound machine from real aircraft noise recordings. Technical constraints of future noise reduction potentials were considered while the overall-loudness of the aircraft sound always remained unchanged.

3.2.2 Airport Noise Climate Synthesizer

Another important tool, developed in COSMA, is the so-called AIRPORT NOISE CLIMATE SYNTHESIZER (ANCS). The ANCS allows the reproduction of the noise environment at any location in an airport community, additionally with the capability to consider the effect of novel aircraft technologies and noise optimized procedures, which makes the ANCS a powerful sound engineering tool, using source component spectra and appropriate noise propagation models for the noise synthesis.

The ANCS is a further development of a tool already established in the FP6 project SEFA [8]. The main improvements were:

- Source component modification capabilities are provided, allowing impact assessment of technology increments and novel aircraft technologies.
- Improved noise propagation models are integrated, covering turbulences, wind effects and complex terrain effects.
- Complex airport scenarios can be synthesized including multiple events.
- Sound quality post-processing algorithms allow computing noise annoyance maps for airport communities.

A 3-dimesional sound reproduction system was developed and interfaced to the ANCS tool to enhance the degree of authenticity of the synthesized sounds [9]. The sound system combines a conventional surround setup with four line array speakers mounted above the listener. Digital sound control is done in multi-channel mode. The 3D method successfully simulates a spatial sound environment which is more effective than one generated by stereo or mono sound reproduction.

A case study was conducted to test and validate the complete ANCS chain, including the modeling of the aircraft noise sources and their propagation to the ground as well as the synthesis of audio signals and their comparison to noise recordings. Public domain source prediction models were developed for airframe noise, fan/compressor noise and jet noise. The noise signatures of the simulations showed a good correspondence with the recordings, comparing the signal vs. time and the spectral characteristics. The synthesized sounds have been judged as realistic in terms of perception, confirming the validity of the tool.

3.2.3 Synthesis of Airport Noise Scenarios

The five airport noise scenarios described below have been synthesized [10] for a whole aircraft family (small/medium/long range):

Table 2 – Airport scenarios and main parameters regarding a/c and noise sources

Szenario	**Aircraft**	**Aircraft noise**
S1 (Baseline)	different existing aircraft types	existing a/c noise data
S2	different existing aircraft types	a/c sounds from S1 replaced by target sounds from SSM
S3	different existing aircraft types	optimized flight procedures
S4	design optimized aircraft (wing geometry)	approach and take-off sounds were synthesized
S5	novel aircraft concepts	synthesized for novel low noise technologies and a/c (in cooperation with FP7 project OPENAIR [11])

3.3 Virtual Resident - VRes

3.3.1 Task of the VRes Tool

One main goal of COSMA was to develop a so-called Virtual Resident (VRes) tool [12], capable for simulating people's perception of aircraft noise. Human response should be predicted with respect to i) single aircraft sounds, i) hourly aircraft noise exposure as well as iii) the long-term annoyance of airport residents who are regularly exposed to multiple events. The VRes tool has been developed as a standalone application, an executable program and has been extensively tested and validated.

3.3.2 The COSMA Virtual Resident software

The software can be divided into two main tasks:

- Pre-processing of the data, i.e. bringing various kinds of data to the required input format, extracting/selecting relevant information / reducing the input data set.
- Running the Virtual Resident's core algorithm on the pre-processed data: parameterizing the model (i.e. "teaching") and then predicting annoyance unknown data.

Pre-processing of the data

In COSMA three different kinds of data have been collected during the field studies:

- Long-term annoyance through telephone interviews
- Computed acoustical data, hourly-annoyance through in-situ SPL-log measurements
- Hourly based participants' ratings and single overflight sound preference through in-situ noise recordings and participants' ratings

The core algorithm, which later has to be applied on those three data sets, will always be the same, so only a suitable pre-processing is needed to bring these data into the same format. It is of key importance that the input data are condensed enough. This requires a very strong data reduction for tests which are producing huge amount of data.

The input data from telephone interviews regarding long-term annoyance are already very condensed, in fact from the point of view of acoustics they are not detailed enough. So for the telephone interview data there is no input data pre-processing necessary.

During the hourly annoyance tests of the field studies, SPL-logs have been recorded at participants' home. Making use of actual airport flight schedule data, from the SPL logs aircraft overflights are identified and then acoustical data is computed for the hours, which have been rated by the participants. For this kind of data requirements to the format of the various input data are exactly specified. The pre-processor reads these files and computes hourly-acoustical data from them.

The pre-processing itself consists of the different phases

- Detecting a flight by suitable algorithm
- Finding events by advanced peak-picking with constraints
- Assigning corresponding flight events from the flight schedule, if provided

After identifying the overflights in the SPL log, aircraft specific acoustical parameters were computed, e.g. number of aircraft, duration of overflight events, aircraft related L_{Aeq}, aircraft level ratio to background noise level. Knowing the location of the participant during the hours of analysis and the status of the windows (open/closed/tilted), a sort of personal acoustical level can be computed, which is approx. the level to which the person has been exposed (ignoring indoor noise sources, i.e. focusing only on the external noises). Together with regular acoustical parameters, the module computes a total of 39 parameters.

Core Algorithm

For the actual data processing two kinds of models have been developed: a Categorical and Regression Tree- and a multi-step Neural Network based model.

- Categorical and Regression Tree modeling (CART):
  This modeling works by recursively sub-dividing the data into smaller parts. Normally the model is constructed as a binary tree where each node of the tree is a simple yes/no question and the answer guides us to next node until we reach a leaf and the predicted value. An example of a prediction tree model can be seen in Figure C. The nodes closer to the root of the tree contain the questions that will maximize the information about the predicted values at the leaf. The raw output from a CART analysis is a decision tree, which can be quite large to use for model purposes. Therefore a process called pruning is commonly used to reduce the size of the tree. This procedure can be performed in several steps to reduce important variables that have been discovered and consequently to reveal other parameters that might predict the annoyance.

- Neural Networks:
  The Neural Network based core algorithm uses a function approximation approach to predict annoyance for acoustical events (both short- and long-term). Function approximation means that an unknown mapping from measured parameters onto annoyance is supposed and it is aimed to learned by Radial Basis Function Neural Network (RBF). Hence, input parameters are supposed to be of numerical types (categorical descriptors cannot be handled). The network has to undergo certain "training" procedure that consists of three steps but which are not further explained here. After the training predictions can be computed by feeding unknown data (test set) into the model. For each element of the test set (i.e. each acoustical event) the expected annoyance can be predicted by the optimized RBF. The performance can be determined by different metrics such as correlation or mean squared error.

3.3.3 Evaluation of COSMA field study data

Performance of prediction models with the VRes tool

After building and fine tuning the VRes tool it has been extensively tested. The accuracy of the models is reasonable, the correlation between predictions and actual ratings is approx. 0.7-0.8 for all three kinds of the above described input data. Taking into account the high uncertainty of human ratings and the relatively small data set collected in COSMA, the models can be judged to be fairly good and they are worth to be applied on larger, future field study data.

An additional result of the VRes tool is the possibility to determine the importance of parameters from the fine-tuned models, i.e. to be able to identify the most important parameters that are determining the annoyance. As the results for the collected data cannot be generalized and the data-sets even don't represent fully the examined three airports, the extracted parameter importance is not presented here.

3.4 Optimization of Airport Noise Scenarios

COSMA's optimization work has dealt with all the aspects more strictly related to the aeronautical engineering domain. In this respect, two main functions can be identified: On one hand, the support to the other work packages in providing all the technical information and data required to accomplish their tasks; on the other hand, the definition of the final engineering recommendations, design directions and operational constraints to eventually achieve a community friendly aviation system, with a level of annoyance as lowest as possible. As a consequence, all the results and foregrounds achieved in this part of the project should be contextualized within this framework, in order to properly understand the technological and cultural advancements. In doing this, it must be kept clear in mind that the two mentioned functions have been always carried out in a deeply interconnected fashion, to comply with the basic requirements of a continuous multidisciplinary interaction between the project's work packages.

The main results can be summarized as follows:

- A database of 2D noise optimized procedures, including the noise spectra at specified positions on the ground, as well as a database of sequences of take-off and landing events, optimized with respect to objectives related to the number and/or the type of the aircraft involved. A tool for the generation of the sequences sound files out of a database of recordings or simulations.
- A large database of multi-objective, multidisciplinary optimizations of 3D procedures,

including the complete sets of operational settings of the aircraft, ready to be used in the synthesis of sound files.

- A database of spectra, describing the effect of the low noise technologies on the most energetic aircraft noise sources, as well as a database of directivity filters, to take into account the effect of an unconventional engines installation in the synthesis of noise tracks.

All these results are directly related to the mentioned function of support to the other work packages. One of the fundamental needs of the annoyance studies and the sound engineering tasks was the possibility to have access to a complete, detailed description of the operational procedures, including the time history of all the settings of the aircraft, such as the engines operation point, the high-lift-device setting, and the angle of attack. Indeed, the descriptions of the take-off and landing procedures available in the literature (or through the use of commercial software) are typically limited to the basic features of the aircraft operation, such as the trajectory and the instantaneous speed. Furthermore, they are limited to standard, certified procedures. Figure 5 depicts one example of the set of parameters made available for each procedure analyzed.

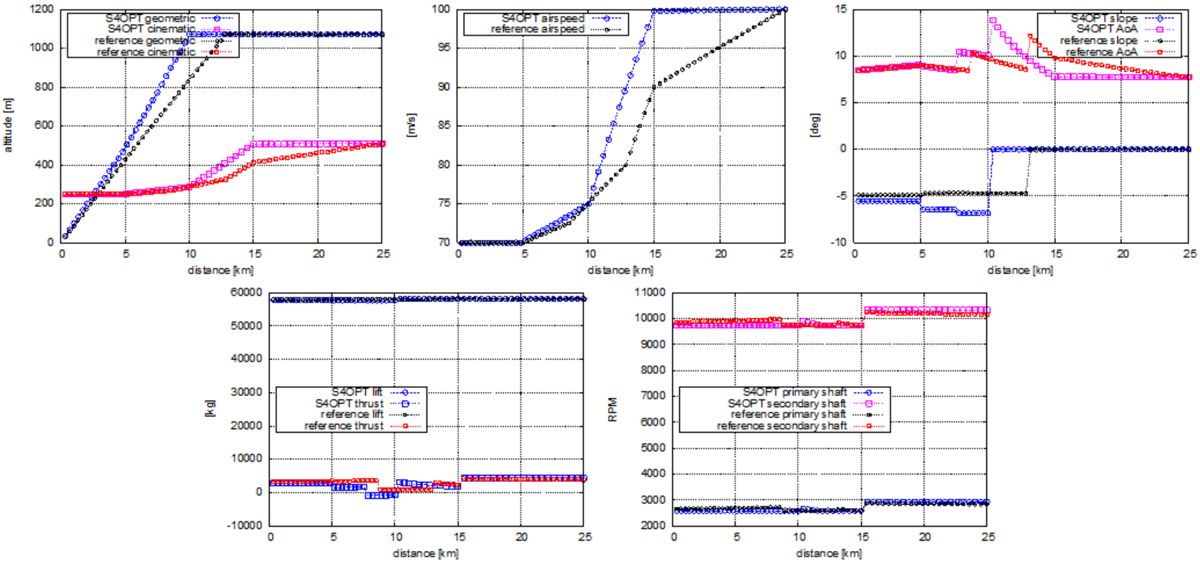

Figure 5 – Example for an optimized procedure and its detailed operational description, e.g. concerning altitude, AoA, and airspeed

In order to analyze the effect of complete airport scenarios, a number of sequences of events, described in five different technological scenarios, were introduced to support a proper definition of the laboratory studies (see Table 2). Using the different scenarios, it has been possible to take into account not only the technologies currently available, but also those expected to be operative in the next two decades.

Moving to a larger scale, to consider the effects of approach and departure procedures on a wider area, the multi-objective optimization of procedures for noise and fuel consumption has been completed using state-of-the-art evolutionary algorithms. The results, achieved in the form of bi-objective Pareto fronts (see Figure 6), established the basis to implement an innovative decision-making approach, which is one of the major foregrounds achieved in this area of COSMA.

The activity in support of the sound engineering and annoyance assessment work packages has been completed with the evaluation of the benefits, which will be achievable by using low-noise technologies and non-conventional aircraft configurations. Also in this case, the specific needs of COSMA required a dedicated approach to the problem. Indeed, the effect of technology advancement has been recast in form of spectral and directional filters, to allow the easy use of the simulations in the synthesis of sound.

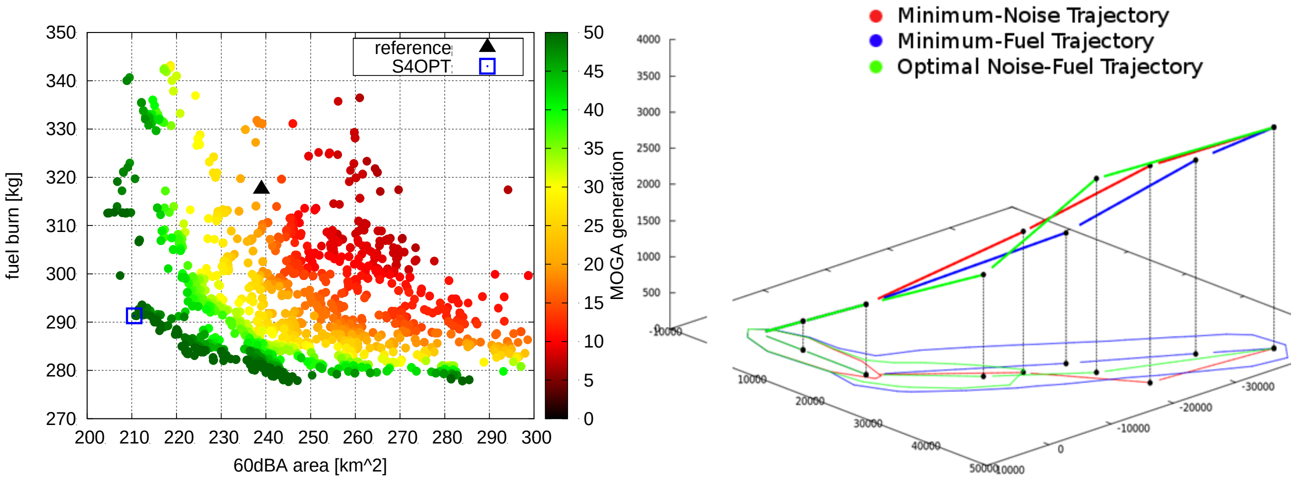

Figure 6 – Pareto set of multi-objective optimization for approach, and three selected solutions [13]

On the second front of activity, i.e. the identification of the design criteria and the operational constraints, capable to potentially accomplish the recommendations received from the annoyance studies, the achievements can be considered as the main foreground produced by the optimization task. The interactive loop implemented at the beginning of the project (see Figure 1) has revealed to be an effective approach to include annoyance-related considerations in the optimal design process.

Thanks to the continuous interchange of information, it has been possible to address the final task using two different approaches.

- The “annoyance-driven optimization,” where procedures and design concepts were optimized to minimize the influence of those noise sources which were considered as the more annoying during the Sound Machine tests.

- An innovative “decision-making” approach, aimed at the selection of the least annoying design and procedural solutions along the Pareto front obtained with the multi-objective optimization.

Both the approaches represent a novelty in the aircraft design community, and definitely deserve additional investigation and development to disclose their potential. The preliminary results obtained in COSMA are extremely promising.

4. CONCLUSIONS

The very detailed analysis of the COSMA field and laboratory studies shows that the understanding of the annoyance due to aircraft noise is a very complex issue. The variance in the annoyance judgment of airport residents cannot solely be explained by acoustics. Non-acoustic factors become more and more important and there is not only one exposure-response curve that is alone capable to describe the annoyance around all here investigated EU airports.

Indeed the ratio of acoustic factors explaining the variance in annoyance judgments becomes smaller. However, reducing the noise at the source will confidently reduce annoyance as well. Thus, further small improvements can be achieved by enhancing the sound quality, especially with respect to tonal components.

On the contrary, non-acoustical factors as they were identified and ranked in the COSMA studies, might vary from airport to airport and also in time. But, on the other hand, they provide the potential for airport managers and politics to clearly reduce annoyance around individual airports in short sight, whereas reducing aircraft noise at the source typically needs ten years and even more until a modernized aircraft fleet will be equipped with the “quieter” technology and is reaching a significant number in air traffic.

Reducing the annoyance around airports first requires a detailed analysis and description of the problem at the considered airport. Therefore, in the European Union it is inevitable to replace the current exposure-response curve by several curves for different kinds of airports, respecting the findings of COSMA. An open and trustful communication between airport/politics and residents is one main key point for a successful implementation of annoyance reducing procedures, and future annoyance studies necessarily should also tackle this issue.

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