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TREBALL DE FI DE CARRERA

Títol: Modelització de les molèsties sonores causades pel tràfic aeri mitjançant lògica difusa

Autor: Míriam Sánchez Franco

Director: Xavier Prats Menéndez

Data: 17 de novembre de 2008

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Resum

L'objectiu principal d'aquest treball tracta de la modelització i l'estudi de la molèstia sonora causada pel soroll aeri mitjançant la lògica difusa.

De la mateixa manera que molts altres problemes ambientals, el soroll del trànsit aeri continua creixent i ha arribat a convertir-se en un greu problema en molts països. Milions de persones que viuen o treballen al voltant de zones aeroportuàries poden patir els efectes d'exposició al soroll com, per exemple, la pèrdua d'audició, interferència en la comunicació, estrès, alteracions del son, efectes psicològics, així com una reducció general en la qualitat de vida i la tranquil·litat.

No obstant això, la molèstia sonora és un tema difícil d'avaluar ja que està oberta a les reaccions subjectives de les persones. La lògica difusa és l'eina perfecta per analitzar i avaluar tot tipus de conceptes imprecíssos que contràriament a moltes altres conceptes, com l'edat, la distància o el temps, no es pot mesurar tan fàcilment.

En aquest projecte s'ha desenvolupat una funció difusa per quantificar la molèstia que el soroll del tràfic aeri provoca sobre les persones que resideixen o treballen en zones pròximes a aeroports. Els paràmetres que entren en joc en aquesta funció són el nivell de soroll, el moment del dia, el nombre d'esdeveniments per hora i per últim, si es tracta d'una zona residencial o industrial.

Finalment, després del desenvolupament de la funció difusa, s'han obtingut els gràfics que mostren els nivells de molèstia causada pel soroll.

Title: Modeling noise annoyance caused by air traffic using fuzzy logic

Author: Míriam Sánchez Franco

Director: Xavier Prats Menéndez

Date: 17th November 2008

Overview

The main goal of this project is the study and modeling of the noise annoyance caused by air traffic by using the fuzzy logic theory.

Like many other environmental problems, air traffic noise, continues to grow and has become a serious problem in many countries. Millions of people living or working around airport areas can suffer from noise exposure effects as for instance hearing loss, interference with communication, stress, sleep disturbance, psychological effects as well as a general reduction in quality of life and tranquillity.

However, noise annoyance is a difficult issue to evaluate as it is open to subjective reactions. Fuzzy logic theory is the perfect tool to analyse and evaluate all that vague and imprecise concepts that contrary to many other concepts, like age, distance or time, can not be measured as easily.

In this project, a fuzzy function has been developed to quantify the annoyance level that people living or working in areas near airports are suffering. The parameters that come into play in this feature are the noise level, time of day, the number of events per hour, and finally, if it is a residential or an industrial area.

Finally, the results of the fuzzy system have been represented on graphics that show the levels of nuisance caused by aircraft noise in each of the situations according the variables of the fuzzy function.

A Silvia, mi hermana.

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CHAPTER 1. INTRODUCTION

Noise caused by traffic, factories and other activities is one of the main environmental problems in Europe. The major sources of environmental noise come from roads, rail and air traffic, factories, construction and so on. As opposed to many other environmental problems, noise pollution continues to grow, accompanied by an increasing number of complaints.

In terms of aviation, aircraft noise can be a much greater disturbance than other noises. Aircraft noise began to be a major problem with the great surge in air transportation that followed World War II. The introduction of jet airplanes led to a second revolution in aviation, as well as to an escalation of the noise level from aircrafts. Although piston engine aircrafts made noise, it was not until the use of jet engines that aircraft noise started to become a major problem for airports. Since then, annoyance to people living near airports caused by the noise of airplanes' take-offs and landings has become a social and economic problem.

In 1952, James Lighthill provided a formula to calculate the sound generation in moving fluids and proved that the sound emitted was proportional to the eighth power of the air flow speed. This meant that since the jet engine gets it thrust from accelerating large masses of air, the thrust can be kept constant but the noise can be reduced by simply increasing the jet diameter.

Fig.1 shows the aero acoustical evolution from 1955 to 2000.

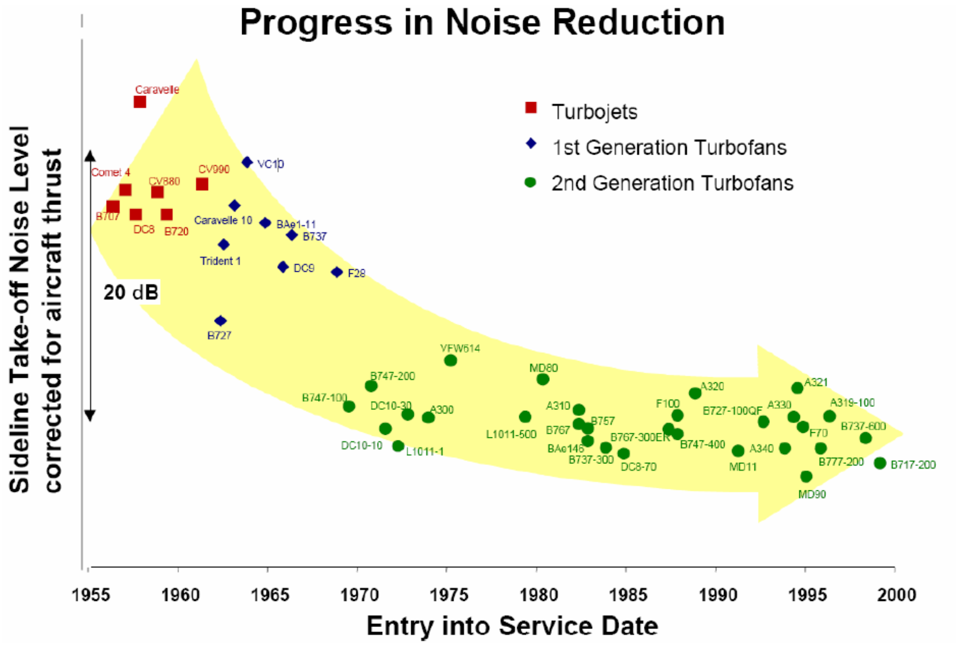


Fig. 1.1 Aero acoustical evolution thanks to engineering progress

As above Fig. 1.1 shows, thanks to the engineering and industrial progress, the aviation industry has seen the introduction of quieter engines and more modern aircrafts that can operate more efficiently. However, the new technology and the innovation progress will not be able to manage the rate of forecast traffic growth and it is estimated that the number of complaints will increase over the next twenty years.

The list below highlights some key points to better understand the problem and the current situation [1]:

- Around 20 percent of the European Union's population suffers from noise levels that scientists and health experts consider to be unacceptable.
- 170 million citizens are living in so-called "grey areas" where the noise levels are such to cause serious annoyance during the daytime.
- World Health Organization published that a human being requires less than 30 dB (A) for good quality sleep at nigh time, and less than 35 dB(A) in classrooms to allow good teaching and learning conditions.
- According to the World Health Organization:
    - About 40% of the population in the European Union (EU) countries is exposed to road traffic noise at levels exceeding 55 dB (A),.
    - 20% of population in EU countries is exposed to levels exceeding 65 dB(A) during daytime.
    - More than 30% of population in EU countries is exposed to levels exceeding 55 dB(A) during night time.

After a basic introduction to acoustic theory in chapter 2, chapter 3 contains the state of the art in noise annoyance modeling. This chapter is a bibliographical research about studies and papers talking about the problematic of aircraft noise and the different methods used to calculate the level of annoyance.

Following to this chapter, the fuzzy logic concept is introduced. Finally, chapter 5 is the main chapter of this project as it includes the development of the fuzzy system and the model for air traffic noise annoyance. The visual outputs obtained are also included in chapter 5. The general conclusions of the project are contained after chapter 5.

CHAPTER 2. BASIC BACKGROUND IN ACOUSTICS

This chapter introduces the basic concept of noise and the consequences that people could suffer from when they are exposed to noise events. It contains also an introduction to noise metrics showing the different units that can be used to measure noise level.

2.1. Aircraft noise

Aircraft noise is defined as “sound produced by any aircraft or its components, during various phases of a flight, on the ground while parked such as auxiliary power units, while taxiing, on run-up from propeller and jet exhaust, during take off, underneath and lateral to departure and arrival paths, over-flying while en route or during landing” [2].

Aircraft noise is generated by the engine (fan an exhaust) and the airframe (wings, flaps, landing gear). On departure, high levels of thrust are used and so most of the noise is from an aircraft engine during the take off. On arrivals, aircraft use much less thrust, but because they are using flaps and landing gear. Although arriving aircraft are less noisy than on departure, they descend towards the runway on a shallow “glide slope” of typically 3 degrees (ICAO standard) and so they are close to the ground for a much greater distance from the airport. Aircraft also create noise on the ground, when taxiing, testing engines, and when using the APU (auxiliary power unit).

Noise is the major problem for most communities living around airports and under flight paths, especially at night. Aircraft noise has been an discussion issue since the introduction of the first jet aircraft. The progressive technological improvements have tended to be offset by the introduction of larger aircraft, more frequent movements, and more operation during all daytime and also some ranges during nigh time.

2.2. Effects of aircraft noise exposition

Aircraft noise disturbs the normal activities of airport neighbours, like their conversation, sleep time and relaxation. In other words, aircraft noise degrades their quality of life. Noise can lead in people feeling stressed and it may interfere with conversations and any kind of activity, at work or at home. Noise may also affect education, health services and other public activities. Apart from these social effects, noise exposure can also cause health problems like hearing loss, hypertension, and it can affects to the immune system.

Although noise can cause social and physic harms, aircraft noise is predominantly an annoyance problem. One of the primary effects of aircraft noise is its tendency to interrupt speech, making it difficult to carry on a normal conversation. Another effect of aviation noise is the sleep disturbance. The effect of aviation noise on sleep is a long recognized impact of noise on people. As it will be shown in chapter 2, lots of research studios about sleep disturbance due to air traffic have been carried out around the world starting more than 30 years ago. Besides of these effects, there has been much attention focused recently on the issue of the effects of aviation noise on children and their learning. There are effects in the areas of reading, motivation, language and speech, and memory.

Clearly, the majority of people exposed to serious level of noise will suffer any of the above mentioned noise effects. Noises affect everybody in everyday life at home, at leisure, during sleep, when travelling, and at work.

2.3. Introduction to noise metrics

A noise metric refers to the unit or quantity that measures the effect of noise on the environment. During this project, different units and ways of measuring sound will be given. For this reason, it is necessary to make a short introduction to acoustic measurement.

2.3.1. Decibel (dB)

The decibel is a ratio that compares the sound pressure of the sound source to a reference pressure. Because the range of sound pressures is very large, logarithms are used to simplify the expression to a smaller range, and express the resulting value in decibels (dB).

The dB scale is then a logarithmic scale that increases by 10, meaning that 10 dB has 10 times greater energy than 1 dB, 20 dB has one hundred times more energy than 1 dB and 30 dB is a thousand times greater. See table 2.1.:

Table 2.1. Decibel scale

	Value compared to 1 dB
1 dB	Reference value
20 dB	100 times greater
30 dB	1,000 times greater

2.3.2. A-Weighted Decibel (dBA)

Frequency is an important characteristic of sound. The human hearing does not response in the same way to different frequencies. The following graph (Fig. 2.1) shows the relation between the frequency and the sound level in dB. It shows how the sound level line varies with the frequency:

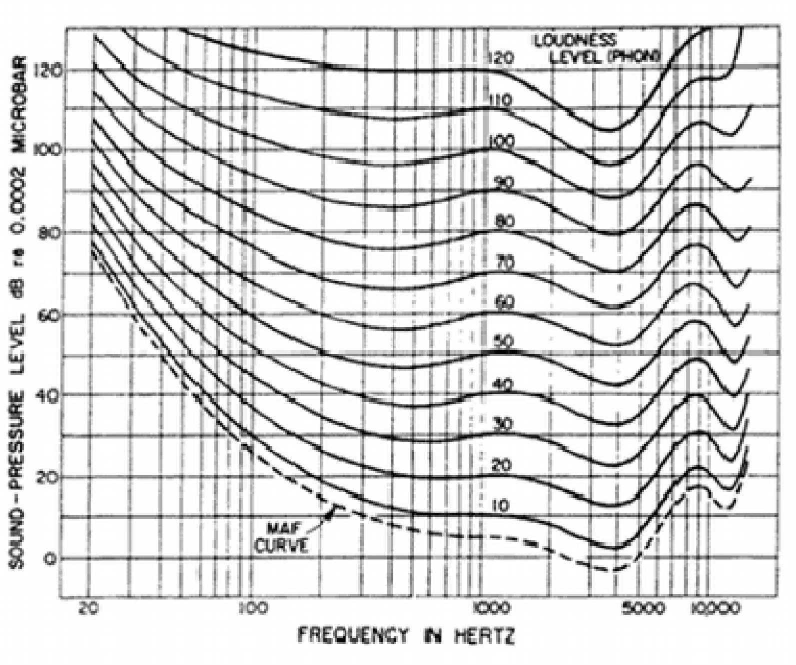


Fig. 2.1 Relation between frequency and sound level in dB

Pain and audibility thresholds in accordance with frequency level for the human ear are shown in Fig. 2.2:

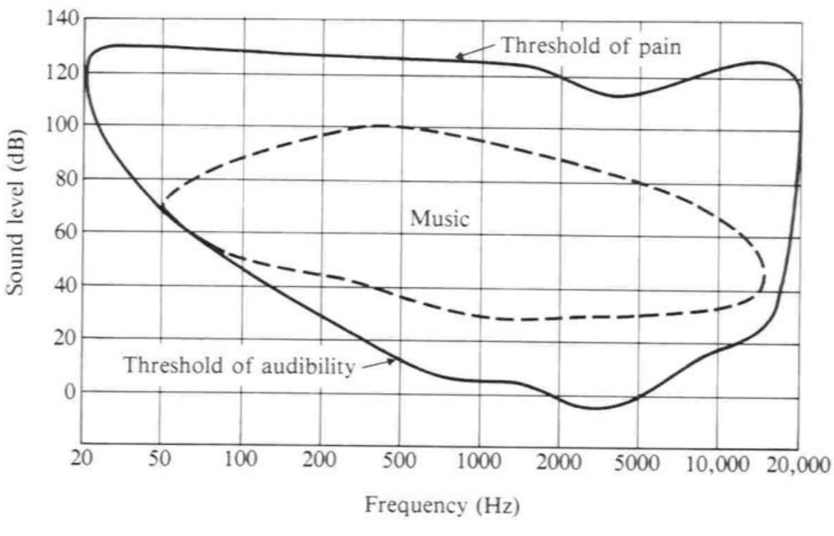


Fig. 2.2 Audibility thresholds in dB

Most people hear from about 20 Hz to about 15,000 to 20,000 Hz. People respond to sound most readily when the predominant frequency is in the range of normal conversation, around 1,000 to 2,000 Hz.

Acousticians have developed "filters" to judge the relative loudness of sounds made up of different frequencies. Sound pressure levels measured through this filter are referred to as A-weighted levels (dBA). A-weighting significantly de-emphasizes noise at low and high frequencies (below about 500 Hz and above about 10,000 Hz).

The A-weighted level has been adopted as the basic measure of environmental noise by the U.S. Environmental Protection Agency (EPA) and by nearly every other federal and state agency concerned with community noise.

The following graph (Fig. 2.3) shows the frequency response of the A-weighted filter:

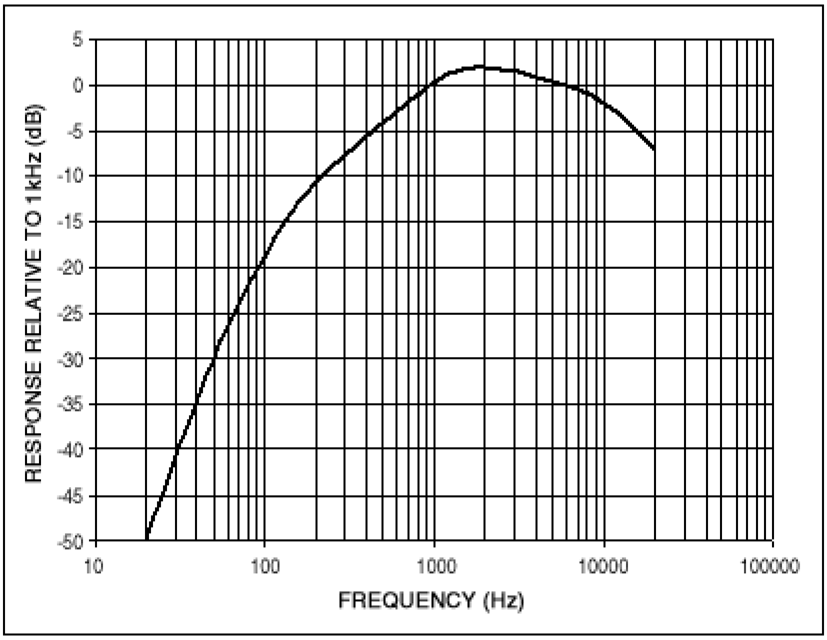


Fig. 2.3 Frequency response of the A-weighted filter

2.3.3. Basic noise metrics (Leq, Lmax, Lden)

There are several ways to quantify noise and give an objective noise value. For example, if we deal with sound levels which vary with time, we can define the noise equivalent continuous level (Leq). This metric indicates the average sound level over a particular time period which is usually taken as a 24h period. For example: a Leq 24h of 57dB(A) indicates that the sound energy produced by a given noise source (or sum of noise sources and events in a 24h period) is equivalent to a constant sound of 57dB(A) during 24 hours.

Other measures of noise that relate to different measurement periods are also available, such as the instantaneous maximum noise level (Lmax), or the average over certain periods, such as evening or night (Lden).

2.3.4. Day-Night Average Sound Level (DNL)

The Day-Night Average Sound Level (DNL) measures noise over a 24 hours period. Note that noise events occurring at night time are fined with 10 dB of penalty, the reason for this being that noise events at night are perceived to be more annoying.

Yearly day-night average sound level must be computed in accordance with the following formula:

$$L_{dn} = 10 \log_{10} \frac{1}{365} \sum_{i=1}^{365} 10^{L_{dni}/10} \tag{2.1}$$

where L_{dni} is the day-night average sound level for the i-th day out of one year.

2.3.5. Sound Exposure Level (SEL)

Sound exposure level abbreviated as SEL and/or L_{AE}, is the total noise energy produced from a single noise event. The Sound Exposure Level is a metric used to describe the amount of noise from an event such as an individual aircraft flyover. It is computed from measured dBA sound levels. The Sound Exposure Level is the integration of all the acoustic energy contained within the event.

$$L_{AE} = 10 \log_{10} \left[\sum_{k=t_1}^{t_2} 10^{L_{Ak}/10} \right] \tag{2.2}$$

Where L_{Ak} is the A-weighted sound pressure level in dB(A).

In words, SEL is the sum of the sound energy over the duration of a noise event, which is normalized to one second. Figure 2.4 shows that portion of the sound energy during 1 second.

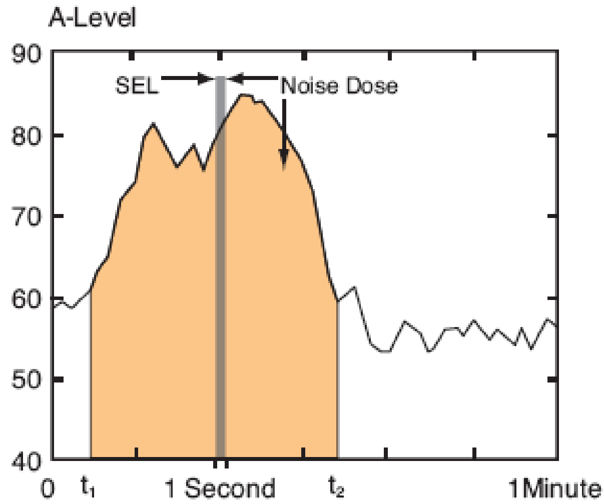


Fig 2.4. Sound Exposure Level. Source: [16].

Because the SEL is normalized to one second, it will almost always be larger in magnitude than Lmax for an event. In fact, for most aircraft events, SEL is about 7 to 12 dBA higher than Lmax. Note that as SEL is a cumulative measure, it means that a higher SEL can result from either a louder or longer event, or the combination of these two variables.

CHAPTER 3. STATE OF THE ART IN NOISE ANNOYANCE

Before embarking on the annoyance modeling by using fuzzy logic, it has been considered necessary to understand the real problem and to answer to the following questions:

- Why is aircraft noise such an annoyance for people living close to airport areas? What are the consequences of noise exposure for human beings, animals and wilderness areas?
- What kind of research studies have been carried out with a focus on aircraft noise by professionals around all over the world?
- Which methods have been used to calculate noise annoyance levels?
- Which factors influence most in the development of noise?

A bibliographical study has been carried out in order to see if the literature has already answers for the questions listed above and to understand the problem of noise annoyance due to the growth of air traffic in recent years.

3.2. Studies and research on aircraft noise

One of the results of the bibliographical research confirms the availability of huge amounts of information on the internet and libraries that refer to aircraft noise issue, proof of which is the number of links that “Google” found under the search “aircraft noise annoyance” (a total of 402,000 links).

The following pages contain the summary of those articles and research studies which have been considered most interesting and useful. Although many of those articles share the same goal (evaluate the noise pollution level in a specific area), the evaluation and calculation of the noise annoyance level has been developed using different methods. The selected articles consider different influence factors and, what is really interesting, they are also written from different points of view.

Aircraft Noise Modeling for Environmental Assessment Around Airports

Oleksancer I. et al. [3]

The authors of this article have designed improved both empirical and analytical methods to assess the noise level due to the aircraft operations in airport areas.

This article presents different methods about how to study the noise impact considering different factors of influence. For instance, the method titled “The noise radius approach for aircraft noise impact assessment” points out the distance between the noise factor and the listener as the main factor of influence. On the other hand, the flight path parameters or the sound propagation and attenuation effects are the main factors taken into account in the method titled as “basic trajectory model for aircraft noise assessment”.

To conclude, aircraft noise assessment is a complex task due to the variety of data that can be considered such as flight path, route parameters, type of aircraft and engines, noise attenuation, noise duration, atmospheric pressure, noise frequency and so on. Therefore, there is not a unique way to assess the noise impact since it can be studied depending of many different factors of influence.

Why do aircraft noise value estimates differ? A meta-analysis

Youdi Schipper et al. [4]

This article has been extracted from the Air Transport Management journal. It talks about the rapid growth of the air transport and its environmental impact.

“Hedonic Price Method“ is the tool used in this study to evaluate the environmental improvement or degradation. As Youdy Schipper comments in this report, “the HP (Hedonic Price) function P_h represents the market equilibrium, and the slope of the function with respect to each of its arguments is an estimate of the marginal willingness to pay for the particular characteristic”.

In this article, 19 hedonic price aircraft noise studies were developed. The results and conclusions from these 19 different studies were combined to obtain a pooled estimation in order to find the most exact solution. Nowadays and thanks to these studies, we are able to use the method suggested by Youdi Schipper to evaluate the future monetary cost of aircraft noise pollution.

Assessment of noise annoyance.

Paul Schomer [5]

Paul Schomer's article starts talking about the high number of people around the world that is exposed to noise pollution and that are exposed to the risk of suffering serious consequences due to noise annoyance.
In the United States, over 40% of the people are exposed to transport noise level exceeding 55 dB (A); in Japan this percentage is even higher. This paper shows that most of the international organizations consider the value of 55 dB (A) as the limit when defining noise impact in residential areas.

The purpose of this paper is to tabulate the minimum criteria values for the DNL metric in various types of communities. For instance, the United States method is explained step by step in the article. In this particular case, some of the factors of influence that are taken into account are:

- Noise frequency
- Noise duration
- Loudness and energy
- Time period (daytime, night time)
- Aircraft type (B-727-200, B-737-800)
- Number of noise events
- Residential area

A review of the Effects of A/C Noise on Wildlife and Humans, Current Control Mechanisms, and the Need for Further Study

Author: Christopher B. Pepper et al. [6]

Noise pollution is defined as the exposure of people or animals to levels of sound that are annoying, stressful, or damaging to the ”Noise annoyance has been defined as a feeling of resentment, displeasure, and discomfort when noise interferes with a person’s thoughts, feelings or actual activities” (Passchier-Vermmer and Passchier 2000).

Not all noises are perceived equally by different people as there are many factors that can influence this; the perception of noise depends not only on physical factors such as the distance or the actual noise level, but it also depends on subjective factors such as emotional moods, education level or the habits of that person.
Some people can be more susceptible to aircraft noise annoyance than others and it can depend of many factors, either quantitative (aircraft type, flight phase, proximity) or qualitative (irritability, ethnic background, education level and socio-economic level).

The relationship between civil aircraft and community annoyance in Korea

Author: C. Lim et al. [7]

This article analyses the levels of annoyance in communities caused by civil aircraft noise in Korea. To carry out this study, several field studies, surveys and questionnaires were undertaken in eighteen different areas (urban and rural) around two airports in Korea.

Although the surveys took place in nearby villages under the same noise level exposure and same noise sources, the results were quite different. This is because annoyance responses are affected by different factors: different cultures, different languages, different climatic conditions and so on. Given this, some human factors needed to be considered while analysing the results of the questionnaires, such as the age (younger than 20 years old, 20-40 years old, 40-60 years old and more than 60 years old), sex (male or female), married or single, occupation category, and etcetera.

Appendix A of this report offers a list including “factors affecting comparisons of annoyance by noise level relationships in residential areas”. Some of the most relevant factors which are listed in this work are:

1. Time period – hours of day, day of week, season of year.
2. Timing of noise events – day, evening, night.
3. History of noise exposure and experience with noise source.
4. Noise events – constant arbitrary level, detectable effect on noise levels, audible.

A survey on health effects due to aircraft noise on residents living around Kadena Air base in the Ryukyus

Author: K. Hiramatsu et al. [8]

The purpose of this article is to assess the health effects due to aircraft noise. One single model of questionnaire named “Today Health Index” and developed by the workers of the University of Tokyo were carried out in Chatan.

The metric used to evaluate the noise level of exposure included the equation below: WECPLN (weighted equivalent continuous perceived noise level).

$$WECPNL = La + 10\log N - 27 \qquad \textbf{(1.1)}$$

where La is the energy of all peak levels during one day, and N is the value obtained from:

$$N = N2 + 3N3 + 10(N1 + N4) \qquad \textbf{(1.2)}$$

where N2 is the number of aircrafts between 00:00 and 07:00 hours, N2 the number of aircraft between 10:00 and 12:00, N3 the number of aircrafts between 19:00 and 22:00, N4 the number of aircrafts between 22:00 and 24:00 hours.

The results showed that the exposed people suffered psychological disorders due to the noise exposure, especially to military aircraft.

The relationship between civil aircraft and community annoyance in Korea

Author: K. Hiramatsu et al. [9]

Aircraft noise measurements were recorded at residential areas of Kadena Air Base, Okinazwa at the time of the Vietnam War.

The Defense Facilities Administration Agency of Japan (DFAA) installed monitoring stations at Yara and at Sunabe (areas exposed to aircraft noise) which recorded the sound level every 5 seconds during 5 months, from November 1972 to March 1973. Statistics of noise indexes at Sunabe and Yara are shown in this article.

With spectrum information that was recorded from November 1972 to March 1973, the Temporary Threshold Shift (TTS) was calculated as a function of time and level change.

This article demonstrates that noise exposure caused hearing loss to people living around the areas of Kadena Air Base, Okinazwa.

Noise emitted from road, rail and air traffic and their effects on sleep

Author: B. Griefahn et al. [10]

The aim of this article is to compare the effects of road, rail and aircraft noise and the evaluation of sleep disturbances.

During the study, 16 women and 16 men from 19 to 28 years old slept during three weeks in a laboratory and were exposed to different kinds of noises. The results show that aircraft, rail and road noise caused similar effects. However, physiological sleep parameters were most affected by rail noise.

Annoyance by aircraft noise around small airports

Author: R. Rylander et al. [11]

The aim of this article is to study the level of annoyance in nine different areas located around three small and medium size Swedish airports.

To achieve its purpose, the first step was to measure and register the Maximum Noise Levels (MNL or Lmax) during two weeks thanks to special equipment located in the middle of each area.
Secondly, a total of 726 people living in the areas with ages ranging from 18 to 75 years old received a questionnaire at their houses to evaluate the noise annoyance levels; available responses were “not annoyed”, “a little annoyed”, “rather annoyed” or “very annoyed”.
Thirdly, apart from the MNL registration and questionnaire, the author needed the number of take offs and landings which were obtained from air traffic control.
Finally, with all this information, the authors of this article were able to obtain reliable results showing the correlation between the measured MNL values and the survey results.
Results highlighted that 5 to 48% of the people reported that they were “rather or very annoyed”.

Physiological aspects of noise-induced stress and annoyance

Author: R. Rylander et al. [12]

The aim of this research is to analyze the relation between environmental noise exposure and physiological stress reactions.

It is demonstrated that noise exposure has bad consequences for human being’s health, especially when the noise exposure is during a long period. “There are increases in skeletal muscle tension and pulse rate and slower breathing, preparing the organism for physical action”.

Evaluation of aircraft noise: effects of number of flyovers

Author: S. Kuwano et al. [13]

Noise annoyance can not be studied only by the noise level exposure as there are some other important factors as the number of noisy events, their duration, their temporal and also their frequency characteristics.

As the authors of this research point out, the number of noise repetitions and their duration are the most important factors that must be studied together with the noise level in order to get correct conclusions and results regarding noise annoyance. The level of background noise is also considered as an important influence factor.

The authors have developed a method called “the method of continuous judgment by category” [11] to evaluate the sound that varies with time. This method is described in depth in this article.

Daily sleep changes in a noisy environment assessed by subjective and polygraph sleep parameters

Author: T. Kawada et al. [14]

The authors of this article investigated the habituation of people while sleeping under repetitive and constant noisy events. Twelve students between 19 and 21 years old were exposed to noisy events from 45 to 60 dB every 15 minutes during night time.

The results of this research detected that a slight habituation to the noisy events was suffered by the students.

Complaints caused by aircraft operations: an assessment of annoyance by noise level and time of day
Author: K. Hume et al. [15]
The authors of this research use both airport data on complaints and noise monitoring to evaluate two important factors of influence on the annoyance due to aircraft noise: time of the day and noise level. The main aim of this article is to study the relationship between the noise level, the time of the day and the complaints generated. After that study, the authors of this article demonstrated that “the complaints generated not only depend on the noise level but also the time of the day that the noise occurred”.

3.2. Conclusions

Predicting the effect of noise on people and environment is an extremely difficult task due to the influence of a multitude of factors that vary from context to context and from person to person.

The main objective of this bibliographical research has been to gain understanding on the problem of noise nuisance and also to study which factors of influence are considered when assessing the noise nuisance, and of those, which are the most relevant and affecting ones.

In a first step a list of the factors of influence mentioned in each article is given. Secondly, once the factors are listed, they should be grouped in two main different categories: quantitative and qualitative factors. As Christopher B. Pepper says on his article [6] which has already been mentioned above, “*Some people can be more susceptible to aircraft noise annoyance than others and it can depend of many factors, either quantitative (aircraft type, flight phase, proximity) or qualitative (irritability, ethnic background, education level and socio-economic level)”*.

Therefore, the list of all factors of influence derived from the previous articles is summarised in table 3.1

Table 3.1 Factors influencing noise annoyance

GROUPS	FACTORS OF INFLUENCE
QUANTITATIVE FACTORS	Noise Level
	Noise Duration
	Noise Frequency
	Noise attenuation
	Noise constancy
	Number of events
	Time period: hours, days, season
	Type of area: urban, residential
	Noise distance
	Type of aircraft
	Flight path, flight phase
	Atmospheric pressure
	Weather conditions
QUALITATIVE FACTORS	Education level
	Habits
	Ethnic background
	Socio-economic level
	Culture
	Language
	Occupation category
	Age, sex, married or single
	Previous experience

A total of 22 factors of influence have been identified in table 3.1. This table is an excellent tool to get a general overview about which factors must be considered when evaluating noise nuisance. However, not all these factors have the same level of influence or incidence and not all of them are easy to be mathematically modelled.

Finally, after the analysis of more than 10 researches about noise annoyance, it can be concluded that the main variables and factors of influence when assessing noise annoyances are:

- Noise Level and duration (by using SEL metric for example).
- Time period: hours of day, days of week, season.
- Type of area: urban, residential, school area, hospital area, country area.
- Number and duration of the events.

These main factors of influence will be used to define the fuzzy logic model that will be carried out in this project to assess noise annoyance.

CHAPTER 4. BACKGROUND IN FUZZY LOGIC

In this project, noise annoyance is addressed as an inherent vague concept. It is a feeling that results from the perception of noise, which cannot be expressed using numbers. However, this feeling can be communicated with natural language. If someone says that he's "somewhat annoyed", it will be known more or less how that person feels, although the term has no exact numerical meaning.

Furthermore, noise annoyance is subjective and context-dependent. An annoyance term can have a slightly different meaning to different people, and in different contexts, such as the modeling of noise versus annoyance caused by odour or light. Vague concepts that are subjective and context-dependent are perfect candidates to be modelled as linguistic variables in the framework of fuzzy logic theory.

4.1 Introduction to Fuzzy Logic

Until mid of 20th century, the classic logic used in computer science came from Aristotelian logic [20] which offered only two possible solutions: truth (1) or false (0). Binary logic is based on the idea that everything is either A or not-A.

Aristoteles (384 BC-322 BC) created the foundations of binary logic as the universal laws of thought. Aristoteles was often considered the father of logic, or more precisely binary logic.

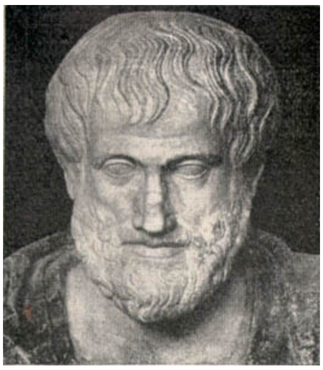


Fig. 4.1 . Aristoteles (384 BC – 322 BC)

For some applications, binary logic works very well. For instance, if a school class is asked to answer to the question "Who is wearing glasses in the class"? All the children wearing glasses will put up their hands giving a clear answer, since everyone is either wearing glasses or not wearing glasses.

However, if the question changes to “how much you like the school?” some children will answer that they love the school, others will answer that they like school, other will say that they do not like it, or that they hate it. In this case, a different kind of logic is needed to note the answers accurately; this logic needs to be able to consider more than two possible answers (yes or no).

In 1920, the Polish logician and philosopher Jan Łukasiewicz (1878-1956, Poland) [18] introduced the notion of a multi-valued logic by proposing a third additional truth value. This third value was “possibly true or false” and belonged somewhere between true and false. Later on, he also explored a four-valued and five-valued logic.

Fig. 4.2 . Jan Łukasiewicz (1878–1956)

But it was Lotfi Zadeh (born in 1921) [19] who developed the Fuzzy Logic and its mathematical framework in 1965. Lotfi A.Zadeh is a professor at the University of California at Berkley. In addition, he is also holding the role of Director of BISC (Berkeley Initiative in Soft Computing). Lotfi A.Zadeh not only developed the theory of fuzzy sets in 1965 but he recently also developed other interesting theories about computation and natural languages for computing.

Fig. 4.3 . Lotfi A.Zadeh (2000)

Due to insufficient computer capability available before the 70’s, the Fuzzy Logic (FL) theory could not be developed and applied until that time. Although the FL theory started in California, the theory has developed extensively in Europe and Japan where a lot of technology products have been built using FL basis. Nowadays, FL is becoming a growth subject and it is starting to be present in most of the automatic and auto-control systems. Some examples where FL circuits are implemented are air conditioners, cameras, digital image processing, elevators, dishwashers, video games, and so on.

4.1.1 What is Fuzzy Logic?

“Fuzzy Logic is a problem-solving control system methodology that lends itself to implementation in systems ranging from simple, small, embedded micro-controllers to large, networked, multi-channel PC or workstation-based data acquisition and control systems. It can be implemented in hardware, software, or a combination of both. FL provides a simple way to arrive at a definite conclusion based upon vague, ambiguous, imprecise, noisy, or missing input information. FL's approach to control problems mimics how a person would make decisions, only much faster” [21].

As it has been previously mentioned, as and alternative to the binary logic aristotelic, new theories were developed during the last century. One example of this could be as for instance the Jan Lukasiewicz’s theory (1878-1956, Poland) [18], that introduced the multi-valued logic, adding the medium truth or medium false (0.5) value to the classic one. Based on this, the first impulse is to continue creating new values; for instance if something is quite likely to be truth the value 0.75 could be assigned to it. This is exactly what the Fuzzy Logic theory demonstrates.

The previous explanation can be easily understood by observing the following figure. The value “0” is entirely touching the false area; on the other hand, value “1” reaches the last point of the arrow, what means that forms part of the truth area. However, there are some figures between 0 and 1 which are not considered entirely false or true.

Fig. 4.4 Multi valued Logic

In other words, the Fuzzy Logic theory describes a type of logic that recognizes more than simple true or false values. Using FL rules, computing propositions can be represented with degrees of truthfulness and/or falsehood. For example, the statement, *today is sunny,* might be 100% true if there are no clouds, 80% true if there are a few clouds, 50% true if it's hazy and 0% true if it rains all day.

4.1.2 Fuzzy Logic progress and applications

Although it emerged in the 60's, the fuzzy logic passed through an investigation and development phase in the following two decades. The first commercial applications began to appear in the early 80s in Japan. Although the FL was invented in the United States, Japan has been since the first moment the centre of the fuzzy logic investigation and research. However, the rapid growth of this technology has now reached USA and also Europe.

One of the first important applications of the fuzzy logic was the control of subway in Senday (Japan) in 1987. The fuzzy system controls breaking, acceleration, and deceleration of the subway. The fuzzy logic systems can be so precise that it has made possible for passengers in the subway not to noticing when the train is changing its velocity: *"The Nanboku Line was the world's first public train to use fuzzy logic to control its speed, and is often used as an example in university courses on the subject of neural networks. This system accounts for the relative smoothness of the starts and stops when compared to other trains, and is 10% more energy efficient than human-controlled acceleration"* [22].

After the success of the first applications of the FL, Japanese industries got more interested on the subject and started to use the FL in any area of intelligent control: photo and video cameras, vehicles cruise control, air conditioners, elevators, dish washers, video games using artificial intelligence and in general, in all the process that not depend of a "yes" or a "no". Japan exported in 1994 products using fuzzy logic at a total of $35 billion [23].

In the early 1990s, Europe started to deliver numerous electronic gadgets using the FL and after that, USA gained interest in fuzzy logic. Nowadays, FL is considered as the engineering key technology in all over the world.

4.2 Fuzzy Logic implementation

Which are the steps to follow to create a fuzzy logic system? Fuzzy technique involves in general two operations:

1. Fuzzyfication process, which includes linguistic variables definition, fuzzy sets and fuzzy rules definition.

2. Defuzzyfication process.

However, besides these two main parts of a fuzzy logic system implementation, there are other matters that must be considered as for instance the problem identification, the inputs that will be used in the system, and for sure the results or outputs and conclusions.

All this process is explained below giving an easy example to better understand each step of the system implementation.

Imagine that the problem is a museum room where the temperature must be always controlled because the good preservation of the works of art. Then, an air conditioning machine is installed in the room to control the temperature. This means that the input of this system will be the temperature (ºC) and the output of this system will be the action of the installed air conditioning machine.

4.2.1 Fuzzyfication

After having understood the system and identified the inputs and desired output of the fuzzy system, the first step is the "fuzzyfication", which is the translation from real world values to fuzzy values. Membership functions are used to translate linguistic values to figures.

The only input in the FL system that it is being created to control the temperature of a museum room is the temperature.

A Linguistic Variable is simply a collection containing several Fuzzy Sets. The **linguistic variables** to control the temperature will be:

- VERY COLD which will be identified with the linguistic variables "VC".
- COLD this will be identified with the linguistic variables "CO".
- NORMAL which will be identified with the linguistic variables "NO".
- HOT this will be identified with the linguistic variables "HO".

The next step is to define the **fuzzy sets**. The fuzzy subset theory says that:

"Fuzzy sets are sets whose elements have degrees of membership. Fuzzy sets have been introduced by Lotfi A. Zadeh (1965) as an extension of the classical notion of set. In classical set theory, the membership of elements in a set is assessed in binary terms according to a bivalent condition, an element either belongs or does not belong to the set. By contrast, fuzzy set theory permits the gradual assessment of the membership of elements in a set; this is described with the aid of a membership function valued in the real unit interval [0, 1]. Fuzzy sets generalize classical sets, since the indicator functions of classical sets are special cases of the membership functions of fuzzy sets, if the latter only take values 0 or 1" [26].

A fuzzy set is a pair (R, t) where R is a set and

$$t: R \rightarrow [0,1]. \qquad \textbf{(4.1)}$$

For each t(x) is the grade of membership of

$$x \in (R,t) \leftrightarrow x \in R \wedge t(x) \neq 0 \qquad \textbf{(4.2)}$$

If $R = \{x_1,...,x_n\}$ the fuzzy set (R,t) can be denoted $\{t(z_1) / z_1,...,t(z_n) / z_n\}$.

Simplifying the above theory, in a universe of discourse X, a fuzzy subset A of X is a set defined by a membership function fA(x) representing a mapping which maps each element x in X to a real number in the closed interval [0, 1]. The value of fA(x) for the fuzzy set A is called the membership value or the grade of the membership of x in X. The membership value represents the degree of x belonging to the fuzzy set A.

Applying fuzzy set theory, the temperature ranges of this example will be:

Table 4.1. Linguistic variables and fuzzy sets

Linguistic Variable	Absolute values (in ºC)	Partial membership (in ºC)
VC	< 8	8-10
CO	10 – 16	8-10 and 16-18
NO	18 – 24	16-18 and 24-26
HO	> 26	24-26

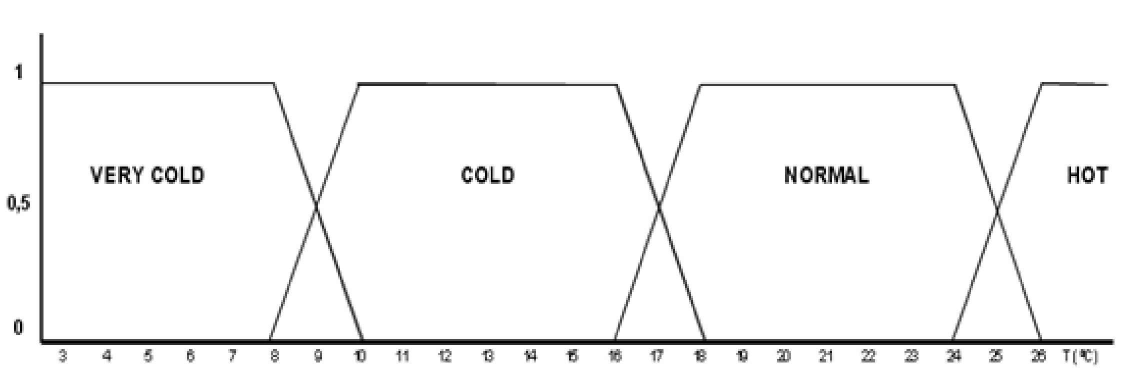


Fig. 4.5 Membership function for the temperature

A T= 12ºC is part of the category COLD. However, a T= 9ºC is 50% VC and 50% CO. The same situation happens with T=25ºC which is 50% NO and 50% HOT. If T=9.5ºC, it corresponds to 25% VC and 75% to CO. This last value will be used to continue with the example. T=9.5ºC.

Marking this value in the membership function:

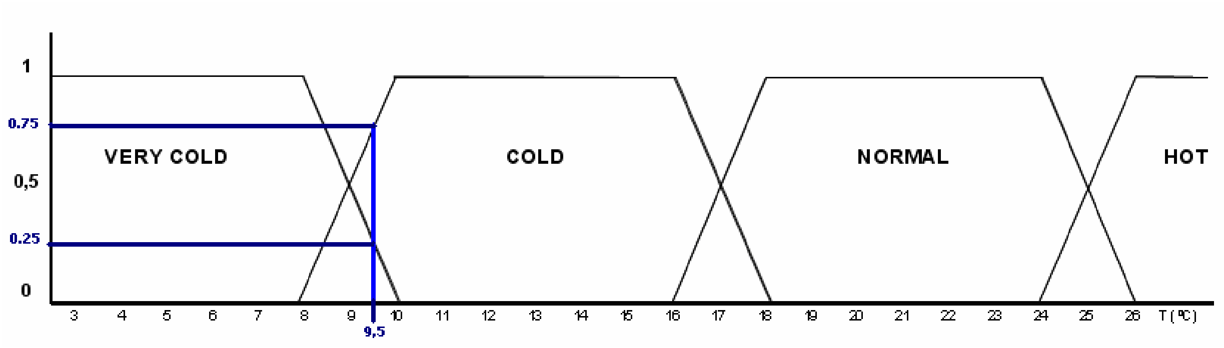


Fig. 4.6 Example of a membership value computation for a given temperature

T=9.5ºC has the following membership degrees:

- 0.25 to the fuzzy set VC (very cold)
- 0.75 to the fuzzy set CO (cold)

The actions of the outputs must be translated to numeric values that can be used to control the system. In this case, it will be used a simple one dimension model instead of real fuzzy membership functions. The one dimension output function for the fan of the air conditioning machine is a constant value that defines the power to be sent to the fan motor:

Table 4.2. Linguistic variables and absolute values

Ling. Variable	Absolute values
Fan off	0 Watt
Fan slow	20 Watt
Fan normal power	50 Watt
Fan full power	100 Watt

The next step is to describe the cause and effect action of the system with fuzzy rules:

R1. IF temperature is VC THEN air conditioning fan off
R2. IF temperature is CO THEN air conditioning fan slow
R3. IF temperature is NO THEN air conditioning fan normal power
R4. IF temperature is HO THEN air conditioning fan full power

As it has been demonstrated above, FL is not based only on mathematical formulas. Fuzzy rules are linguistic constructions that have the general form "IF A THEN B". It is very helpful also to write those rules in a based rule table format, as it is more visually descriptive. Using FL as many rules as considered can be used to approximate any continuous function to any degree of precision. Rules are much simpler to implement and much easier to debug than classic programming techniques.

4.2.2 Defuzzyfication

After computing the fuzzy rules and evaluate the fuzzy variables, the next and last process is the defuzzyfication which translates the results back to the real world and give a visual solution.

Defuzzyfication is the key step in many fuzzy systems applications and it is the reverse process of fuzzyfication. Fuzzy control engineers have many different ways of defuzzyfying. However, the most used method is the linear function described by:

$$Z = \frac{\sum_{i=1}^{N} z_i * S_i}{\sum_{i=1}^{N} z_i} \tag{4.3}$$

Where Z is the final result, z are the membership contributions, and S are the constant outputs values.

Applying this formula and following the example of the museum room, the defuzzyfication process will be as follows:

Z = (0,25x0W + 0,75x20W + 0x50W + 0x100W) / (0,25 + 0,75 + 0 + 0) = 15 W

That single rule has accomplished the defuzzyfication. In conclusion, with T=9,5ºC, the output of the system, which is the fan of the air conditioning machine, will work at 15 Watts of power.

CHAPTER 5. MODELING NOISE ANNOYANCE

After the previous pages of introduction to the Fuzzy Logic, it is time to go into the real aim of this project: make use of the fuzzy logic methodology to study the noise annoyance due to the air traffic.

This chapter applies all the previous theory learnt about FL for a real example. To carry out the FL system, the following tasks must be performed:

2. Inputs and outputs definition.
3. Fuzzyfication process.
4. Defuzzyfication process.

Before addressing these points, it is essential to become aware of how and why the FL basis has been selected to assess the noise annoyance.

5.1. Noise Annoyance Model

Annoyance measurement is highly subjective and, as a consequence, it is very difficult to measure. Contrary to many quantities encountered in everyday life, such as distance or time, there is no universally accepted scale for noise annoyance.
“Noise annoyance” is an inherently vague concept that can not be expressed using numbers but they can be approached using linguistic terms as “high annoyance” or “low annoyance”. These kinds of concepts are perfect candidates to be modelled using the FL theory.

Thanks to the FL theory, everything can be approached using a verbal scale. For instance and, referring to the previous example, the temperature verbal scale for an air conditioning machine could be: “very cold, cold, normal, and hot”. However, it is necessary to remark that behind each linguistic expression there is a range of figures; in this particular case, the only input of the system is a temperature value, so each verbal expression corresponds to a range of temperatures measured in Celsius. For instance, “very cold” could correspond to all responses from 0ºC to 5ºC, “cold” from 6ºC to 14ºC and so on. The accuracy of the system depends on the number of linguistics labels that compose the verbal scale.

When talking about assessing the noise annoyance level, the first thing that occurs to somebody is to think on sound level. However, as it has been previously studied in the first phase of this project, the noise nuisance level does not depend only on the sound level, but also on a lot of other factors of influence as the type of area of exposure, the time of the day, the social situation, and etcetera. These factors of influence will be the inputs of the fuzzy logic system which are explained in detail in the following section.

5.2. Inputs

Noise annoyance is a subjective term which can be affected by hundreds of different factors. A noise term usually has different meanings to different people and in different contexts, such as a typical smell or flavour. For instance, for a man working every day next to a digger, the most probable is that his response to an aircraft over flying is only a small annoyance. However, for a person living in the countryside the same sound could be extremely painful and uncomfortable.

Consequently, the first problem it is necessary to deal with is to take a correct decision regarding which factors of influence must be considered. Note that the factors of influence will be the inputs of the FL system, and therefore, they will play the main role on the results and outputs of the system.

To make the most accurate possible decision regarding factors of influence definition, a bibliographical researched was done in the first chapter of this project. Referring to chapter 3 and as it was concluded after analyzing several noise annoyance articles, the main factors of influence in the generation of noise annoyance due to the air traffic are:

- Noise Level exposure and duration of the noise events
- Time period of noise exposure (hours of day)
- Number of noise events per interval of time
- Type of area of noise exposure (urban, residential, school area, hospital area, country area).

Data from surveys in which people are asked to judge their experience of total annoyance and annoyance caused by several types of sources separately, have been used to minimize the error measure.

As a conclusion, the fuzzy logic system proposed is represented in the following blocks:

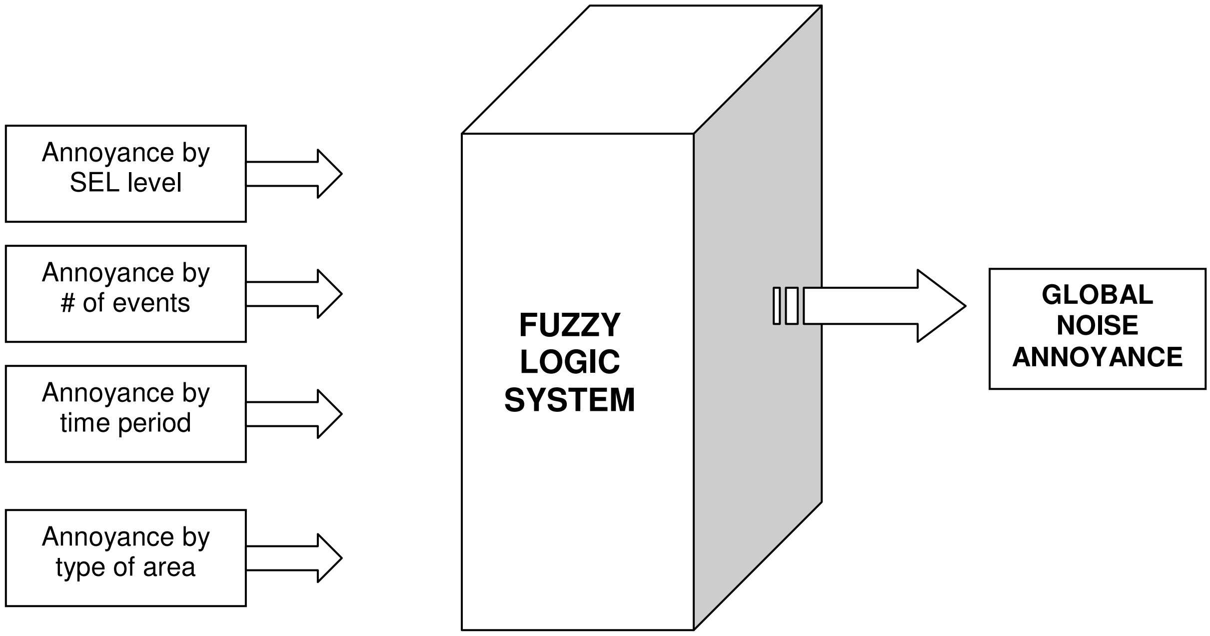


Fig 5.1. Proposed FL System to model noise annoyance

5.2.1. Measuring noise level and duration of the event

Both, the amount of noise and the length of time that someone is exposed to the noise determine the annoyance level.

As it was described on chapter 2, the Sound Exposure Level metric is the sum of the sound energy over the duration of a noise event, which means that both time and sound level are accounted in the same value. So, SEL will be the metric used to count both noise level and duration of the event.

Once the unit of measure has been selected, the next step is to evaluate the limits of the SEL values that correspond to the following linguistic values. This will be done in the Fuzzyfication process.

5.2.2. Measuring time period, number of events and type of area

Apart from noise level and duration of the event, other factors of influence must be taken into account. They are:

- Time Period
- Number of events per day (period of t between 2 events)
- Area of exposure

Time period will be divided up in three categories: morning, afternoon and night time.

Time period is one of the most important inputs of this system. Noise annoyance is directly linked to the time of exposure. The same noise can be painful or in the other hand, not very annoyance depending on the time period of its exposure. During night time, both urban and countryside areas use to be quiet and it is at that moment when a not very high noise could result in a very annoyance event due to the fact that it is time to relax, to sleep and that no other sources of noise are activated. *"The main effect of noise on sleep was sudden awakening; the repetition of sudden awakenings throughout the night might lead to chronic sleep loss with its usual consequences such as chronic fatigue, sleepiness during daytime, and an overall poor quality of life."*[24]

The number of events is just as important as the nose level. Number of events refers to both aircraft arrival and departure at a specific airport. It is necessary to define an interval of time to evaluate if the number of events is high, medium or low and it will always depend of a unit of time, in that particular case it has decided to use the hours.

Finally, the linguistic variables used to define the type of area of the noise exposure are:

- Residential area
- Industrial area

5.3. Fuzzyfication process

The first thing one must do before even starting to consider modeling a concept is to devise a suitable representation for it. As this work is concerned with the modeling of noise annoyance, it is needed a way to represent the concept of noise annoyance.

An important aspect of representation is the underlying scale. Contrary to many quantities encountered in every day life, such as length and weight, there is no universally accepted scale for noise annoyance.

So, a first step in the fuzzyfication process consists in finding the most appropriate scale of values that will be used to evaluate each input of the fuzzy system. In order to use correct numbers, it is important first to investigate, to look for any legal publication, any official document or law in which the scale of values can be based. The next step is to translate from figures to linguistic terms. The linguistics terms will be firstly represented as fuzzy sets on a linguistic variable table and secondly, they will adopt the curves constructed based in the previous linguistic variable definition. All this process has been carried out in the following subchapter for each input of the system.

5.3.1. SEL fuzzyfication process

With the aim of defining a range of SEL and fuzzy sets as much approximate and consistent as possible, a search on Spanish laws which mark the permeated noise levels have been carried out. Unfortunately, no Spanish regulation has been found as at the present time there is no national legislation on noise exposure in Spain. However, in January 1997, the Environment Ministry of Spain began to work on a new law and it has been reported that a draft noise pollution law is planned in the near future.

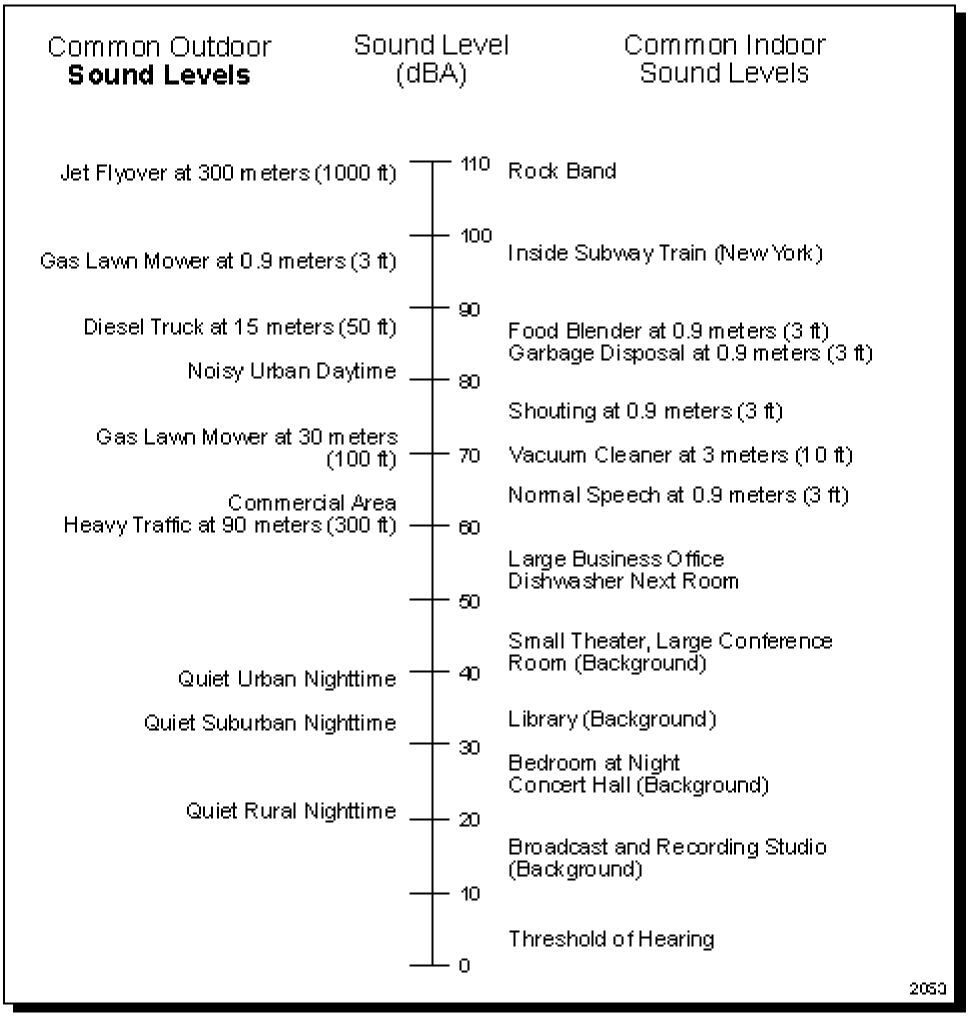
On the other hand, the WHO (World Health Organization) published the following recommended maximum values which serve as a guide for countries and researchers on noise:

Table 5.1. World Health Organization publication

Environment	Critical health effect	dB(A)	Hours
Outdoor living areas	Annoyance	50 - 55	16
Indoor welling	Speech intelligibility	35	16
Bedrooms	Sleep disturbance	30	8
School classrooms	Disturbance of communication	35	During class
Industrial, commercial and traffic areas	Hearing impairment	70	24
Music through earphones	Hearing impairment	85	1
Ceremonies and entertainment	Hearing impairment	100	4

In addition to above recommended maximum noise levels published by the World Health Organization, the following table shows some of the more typical values that can occur daily in our society:

Table 5.2. World Health Organization publication



Values shown in table 5.2. are values given by the World Health Organization and they have been taken as a basis and reference for defining the fuzzy sets. Of all of the boards, agencies and internationals organizations, one should consider the World Health Organization as the primary authority on acceptable levels of pollutants. It is charged with developing this type of scientific position.

Finally, the linguistic variables used to define the SEL fuzzy sets are: "very loud" (VL), "loud" (LO), "medium" (ME), "high" (HI) and "very high" (VH). Fuzzy sets are described in the following table 5.3. and figure 5.2:

Table 5.3. Linguistic variables and memberships of SEL

Linguistic variables	Absolute values (dBA)	Partial membership (dBA)
VL	< 40 dBA	40-50 dBA
LO	-	40 – 70 dBA
ME	-	50 – 90 dBA
HI	-	70 – 100 dBA
VH	> 90 dBA	90-100 dBA

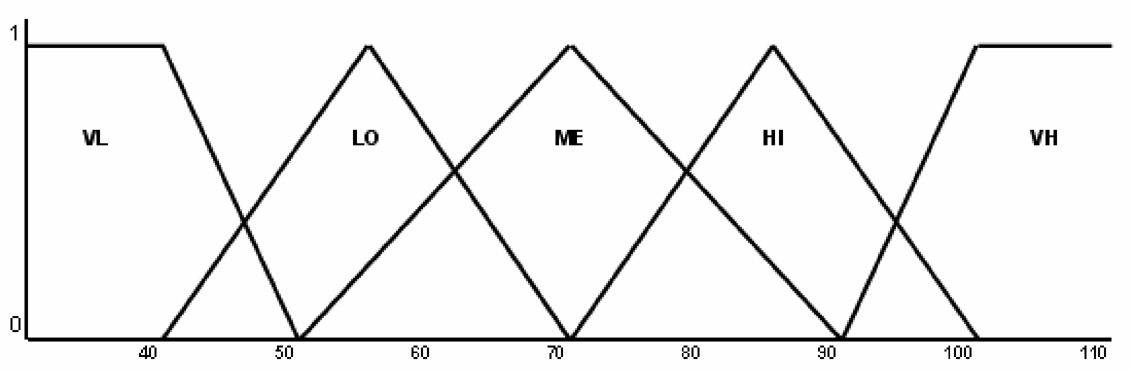


Fig 5.2. SEL fuzzy membership functions

5.3.2. Time period fuzzyfication process

During the bibliographical research carried out in chapter “state of the art in noise annoyance” it was noticed that each researcher distributes the hours of day, afternoon and night based on the customs and normal human activity of the country that was being studied. For instance, reference [7] assigns the daytime from 7h to 22h and night-time from 22h to 7h. Contrary to that, reference [15] assigns the daytime from 6h to 23h and night-time from 23h to 6h.

While Irish people usually get up at 5 or 6am, Spanish population uses to get up around 7 or 8. Also, the schedule of meals changes with respect to other countries. This argument justifies that the timetable ranges have been chosen based on the Spanish habits.

So, the linguistic variables to evaluate the time period are “morning” (MOR), “afternoon” (AFT) and “night” (NIG). They are considered as crisp sets with absolute membership variables described in the following table 5.4. (see also figure 5.3):

Table 5.4. Linguistic variables and memberships of time period

Linguistic variables	Absolute values
MOR	8am – 14pm
AFT	15pm - 20pm
NIG	21pm – 7am

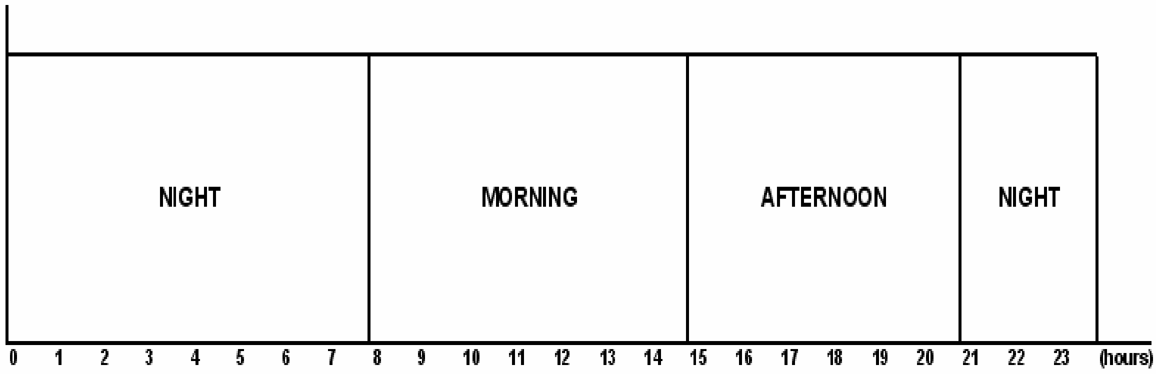


Fig 5.3. Time fuzzy membership functions

5.3.3. Number of events fuzzyfication process

The following table show the number of operations (arrival and departures) performed in the Spanish airports from the 1st to 31st of March 2008. This information has been taken out from the Spanish air navigation services provider (AENA) website [25]. However, AENA only supplied the total number of operations. The last column of the table below shows the number of events per hour. To carry out this calculation the following formula has been used as a first approximation:

$$\text{Events per hour} = \text{Operations} / 31 \text{ days} / 24 \text{ hours} \quad \textbf{(5.1)}$$

Table 5.5. Total of events at the Spanish airports (Source of first three columns: [25].)

AIRPORTS	Total	% Inc 2008 s/2007	Events / Hour
MADRID-BARAJAS	40.961	0,2%	55,1
BARCELONA	27.491	-5,8%	37,0
PALMA DE MALLORCA	12.262	-0,3%	16,5
GRAN CANARIA	10.917	5,7%	14,7
MALAGA	9.517	-2,8%	12,8
VALENCIA	8.167	4,0%	11,0
ALICANTE	6.518	15,1%	8,8
TENERIFE SUR	6.394	4,6%	8,6
SEVILLA	6.042	7,1%	8,1
TENERIFE NORTE	5.882	4,6%	7,9
MADRID-CUATRO VIENTOS	5.628	-17,9%	7,6
BILBAO	5.237	6,4%	7,0
SABADELL	4.934	-8,4%	6,6

LANZAROTE	4.897	10,7%	6,6
JEREZ DE LA FRONTERA	4.697	20,9%	6,3
GIRONA	4.225	30,0%	5,7
FUERTEVENTURA	4.016	7,4%	5,4
IBIZA	2.578	10,3%	3,5
SANTIAGO	1.948	-6,2%	2,6
MENORCA	1.815	7,1%	2,4
FGL GRANADA-JAEN	1.796	-12,8%	2,4
LA PALMA	1.776	-1,0%	2,4
MURCIA-SAN JAVIER	1.516	1,1%	2,0
VIGO	1.516	-5,3%	2,0
ASTURIAS	1.496	-9,6%	2,0
ALMERIA	1.484	-4,6%	2,0
SANTANDER	1.450	18,6%	1,9
A CORUÑA	1.438	-3,7%	1,9
REUS	1.388	-17,8%	1,9
HUESCA-PIRINEOS	1.318	178,6%	1,8
ZARAGOZA	1.301	8,1%	1,7
MADRID-TORREJON	1.296	-15,9%	1,7
SON BONET	1.185	4,6%	1,6
CORDOBA	1.098	6,4%	1,5
VALLADOLID	1.057	-19,4%	1,4
PAMPLONA	1.017	-4,3%	1,4
SAN SEBASTIAN	920	-19,2%	1,2
MELILLA	906	-2,2%	1,2
VITORIA	758	-23,9%	1,0
SALAMANCA	734	-22,2%	1,0
LEON	509	-21,3%	0,7
EL HIERRO	444	11,0%	0,6
LA GOMERA	298	11,2%	0,4
BADAJOZ	287	-15,1%	0,4
LOGROÑO	244	-19,2%	0,3
CEUTA /HELIPUERTO	224	-4,3%	0,3
ALBACETE	185	37,0%	0,2

As can be seen in table 5.5., there is a big difference in flying events between airports. For example, in Salamanca airport there is only 1 event per hour while in Barcelona airport there are 37 events per hour. As the table shows, there are some big jumps between some airports and others. For that reason, it makes no sense to define more than 3 linguistic variables.

The linguistic variables to evaluate the number of events are “High number of events” (HE), “medium number of events” (ME) and “low number of events” (LE).

Table 5.6. Linguistic variables and membership of number of events per hour

Linguistic variables	Absolute values	Partial membership
LE	<4	4-7
ME	7-11	4-7 and 11-14
HE	>14	11-14

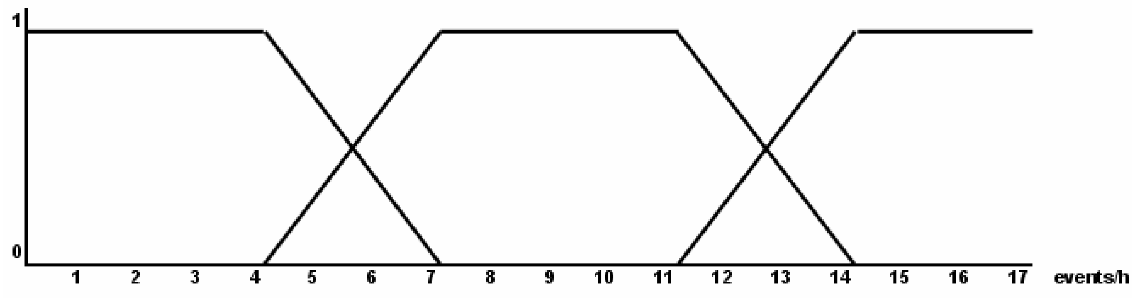


Fig 5.4. Events fuzzy membership functions

5.3.4. Type of area fuzzyfication process

Barcelona airport is situated in the region of Catalonia, in El Prat de Llobregat located 10km away from the centre of Barcelona. In the vicinity of the airport, there are three villages or residential areas (Gavá, Viladecans and El Prat) and a large industrial area located in the north of the airport (Zona Franca). Typically, the areas surrounding airports tend to be industrial or residential areas, as occurs in the airport of Barcelona.
The image below is an aerial photograph taken from the “Google Earth” and it shows the residential and industrial areas around Barcelona’s airport.

Fig 5.5. El Prat de Llobregat and peripheries. Source: Google Earth.

The following pictures are some images from different industrial and residential areas surrounding the airport in Barcelona.

Fig 5.6. Industrial area Zona Franca

Fig 5.7. Industrial area Zona Franca

Fig 5.8. Residential area of Sant Cosme, El Prat de Llobregat.

Fig 5.9. Residential area of Gavà Mar.

Finally, and based on the example of Barcelona's airport, the linguistic variables to evaluate the type of area are "residential area" (RES) and "industrial area" (IND).

Table 5.7. Linguistic variables and membership of number of type of area

Type of area	Linguistic variables
Residential area	RES
Industrial area	IND

5.3.5. Noise annoyance fuzzy rule base

In this part of the FL system definition, a rule base is fixed to evaluate the noise annoyance level depending on the factors of influence.

In the rule based implementation the linguistics variables used to evaluate the noise annoyance are: "extremely annoying noise" (EA), "very annoying noise" (VA), "medium annoying noise" (MA), "low annoying noise" (LA), "very low annoying noise" (NA).

Table 5.8. Set of fuzzy rules

	RESIDENTIAL														
	MORNING					AFTERNOON					NIGHT				
SEL/ EVE	VL	LO	ME	HI	VH	VL	LO	ME	HI	VH	VL	LO	ME	HI	VH
LE	NA	NA	LA	MA	VA	NA	LA	MA	VA	EA	LA	MA	VA	EA	EA
ME	NA	LA	MA	VA	EA	LA	MA	VA	EA	EA	MA	VA	EA	EA	EA
HE	LA	MA	VA	EA	EA	MA	VA	EA	EA	EA	VA	EA	EA	EA	EA
	INDUSTRIAL														
	MORNING					AFTERNOON					NIGHT				
SEL/ EVE	VL	LO	ME	HI	VH	VL	LO	ME	HI	VH	VL	LO	ME	HI	VH
LE	NA	NA	LA	MA	VA	NA	NA	NA	LA	MA	NA	NA	NA	NA	LA
ME	NA	LA	MA	VA	EA	NA	NA	LA	MA	VA	NA	NA	NA	LA	MA
HE	LA	MA	VA	EA	EA	NA	LA	MA	VA	EA	NA	NA	LA	MA	VA

An example is given just to understand the philosophy of above fuzzy rule table: if the noise is produced during night, in a residential area, its SEL level is medium (ME) and the number of event is low (LE), the level of annoyance will be very annoying (VA).

5.4. Defuzzyfication process

As it has been introduced in chapter 3.2.2, defuzzyfication is the process of producing a quantifiable result in fuzzy logic. Typically, a fuzzy system will have a number of rules that transform a number of variables into a fuzzy result. Defuzzification would transform this result into a single number.

The most popular method of the defuzzyfication is the calculation of the centre of gravity (cog) which returns the centre of the area under the curve:

$$cog = \frac{\int f(z) \bullet z \bullet dz}{\int f(z) \bullet dz} \qquad \textbf{(5.2)}$$

where cog is the final result, $f(z)$ are the fuzzy membership function, and z are the outputs values.

In a continuous basis, the formula is:

$$cog = \frac{\sum_{i=0}^{n} \mu(z)_i \bullet z_i}{\sum_{i=0}^{n} \mu(z)_i} \qquad \textbf{(5.3)}$$

where cog is the final result, $\mu(z)_i$ are the membership contributions, and z_i are the constant outputs values.

This formula has been developed in an excel file which can be consulted in APENDIX A. There are several software that are essential set of tools for creating, modifying and visualizing fuzzy sets and fuzzy logic-based system. However, to develop a fuzzy system it is not imperative to use special software designed only to compute fuzzy system.

The fuzzy system carried out in this project has been done by using Microsoft Office Excel. As it has been previously mentioned, the fuzzy and defuzzyfication process are based in simple formula that can be applied by using standard mathematical software. The final numerical values of this mathematical process have been copied and pasted from the excel file and are available in appendix A.

The following pages show the final solutions of the fuzzy system. These graphs represent the noise discomfort level from 0 to 1. There are in total 6 graphs:

1. Noise annoyance in a residential area during morning
2. Noise annoyance in a residential area during afternoon
3. Noise annoyance in a residential area during night
4. Noise annoyance in a industrial area during morning
5. Noise annoyance in a industrial area during afternoon
6. Noise annoyance in a industrial area during night

5.5. Graph solution and conclusions

The charts below shows the level of noise nuisance suffered by residents of a residential area exposed to noise from aircraft over flying the area. The three figures refer to the same residential area but at different times of day: morning, afternoon and evening.

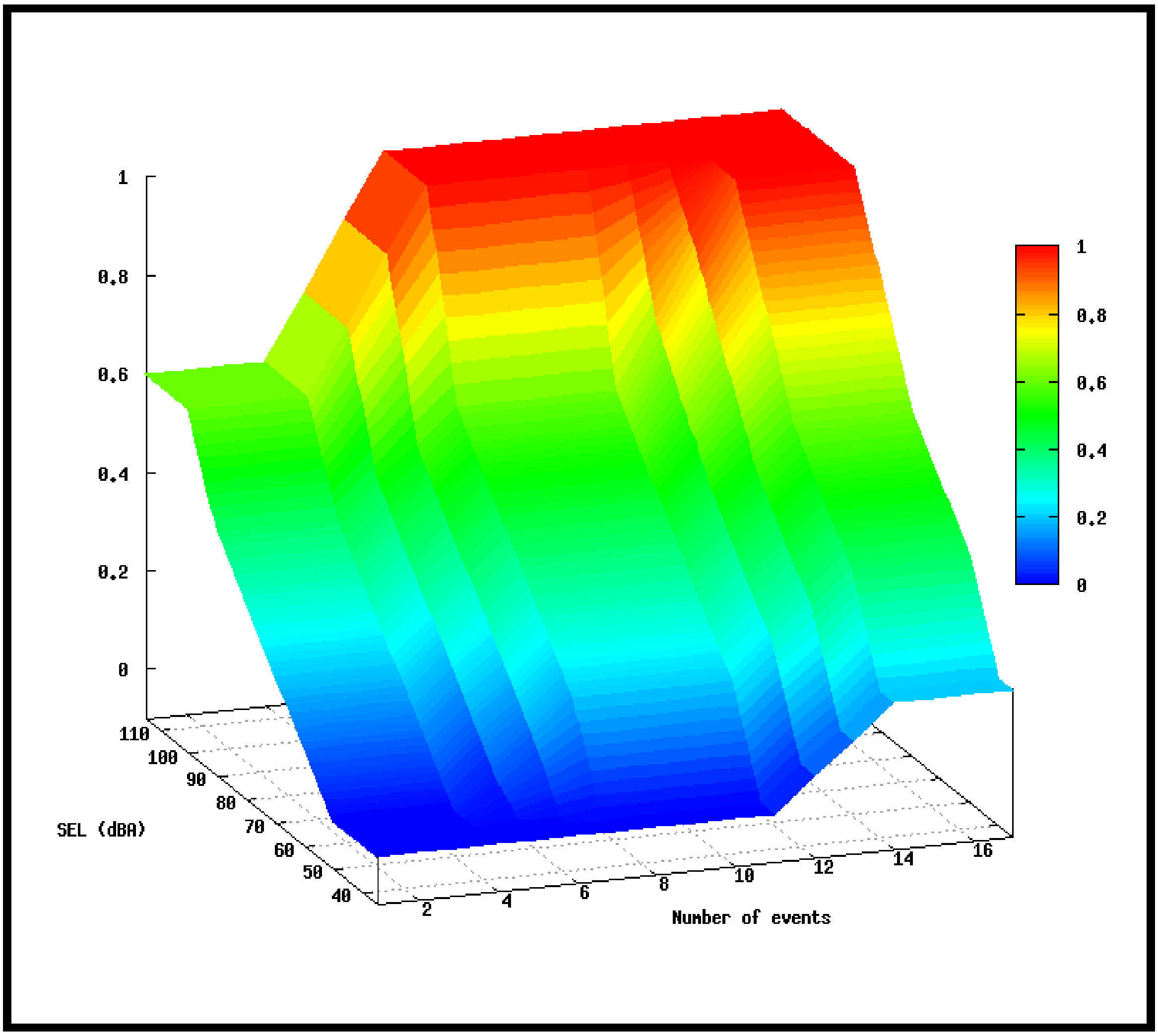


Fig 5.10. Residential morning

Fig 5.10 shows the noise nuisance in a residential area exposed to the sound of air planes over flying the area during morning time. As shown in the graph, the area of maximum discomfort occupies approximately 25% of the total surface area of the curve, that is, from 100dBA and especially as of 6 events per hour. For what, it can be concluded that people in a residential area close to an airport, for instance Sabadell (6.6 events / tour), is exposed to a high level of noise annoyance given that the aircraft that operate from this airport are often private planes and jets with a high level of noise pollution. On the other hand, if the example is Palma de Mallorca (16 events / hour) the level of discomfort is unbearable from a SEL of 70dBA. The number of events is, like the SEL, a determining factor in the level of nuisance.

According Fig. 5.10 noise annoyance is maxim (1) when the sound level arrives to 100dBA since 6 events per hour until 12 events per hour. When the events per hour are higher than 12, the maxim annoyance (1) starts around 90dBA.

Figure below shows the noise annoyance level in the same area and during afternoon.

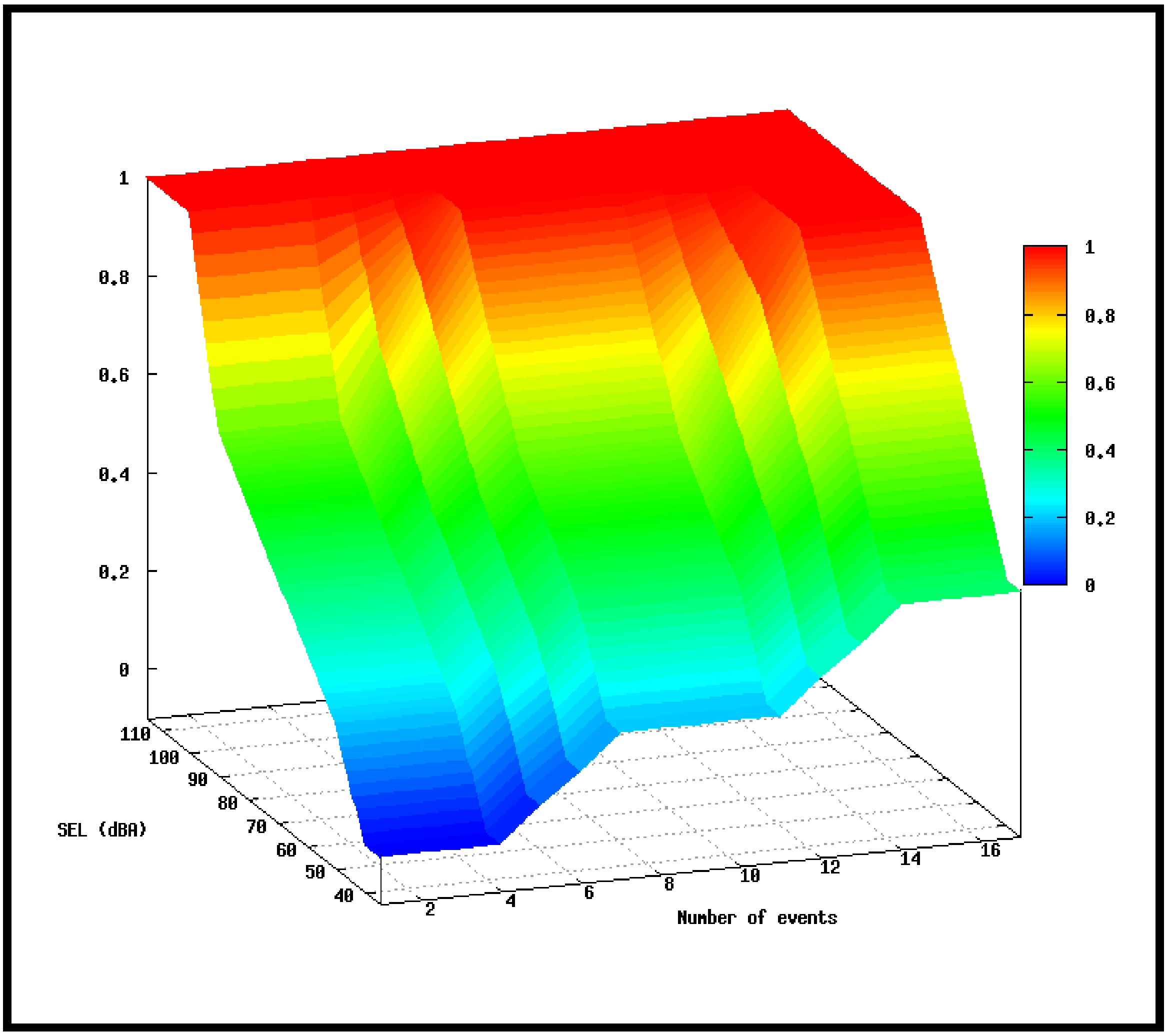


Fig 5.11. Residential afternoon

Figure 5.11 shows respect to the Fig 5.10 a larger surface area of orange-red colour, which indicates that during the afternoon, the inhabitants of the residential area are more influenced by the noise annoyance, and this may be due to several reasons such as that during afternoon human activity grows in the residential area. In this case, the sound can be unbearable from 2 events per hour with a SEL of 100dB.

According to the graph 5.11, in a residential area during afternoon and in a ME range of events (medium number of events in absolute values which goes from 7 to 11 events per hour), for example, 8 events per hour, the annoyance level is 0 below 60dBA, 0.5 between 60 and 80dBA and 0.8 above 90dBA.

Finally, Figure 5.12 shows the noise nuisance at night.

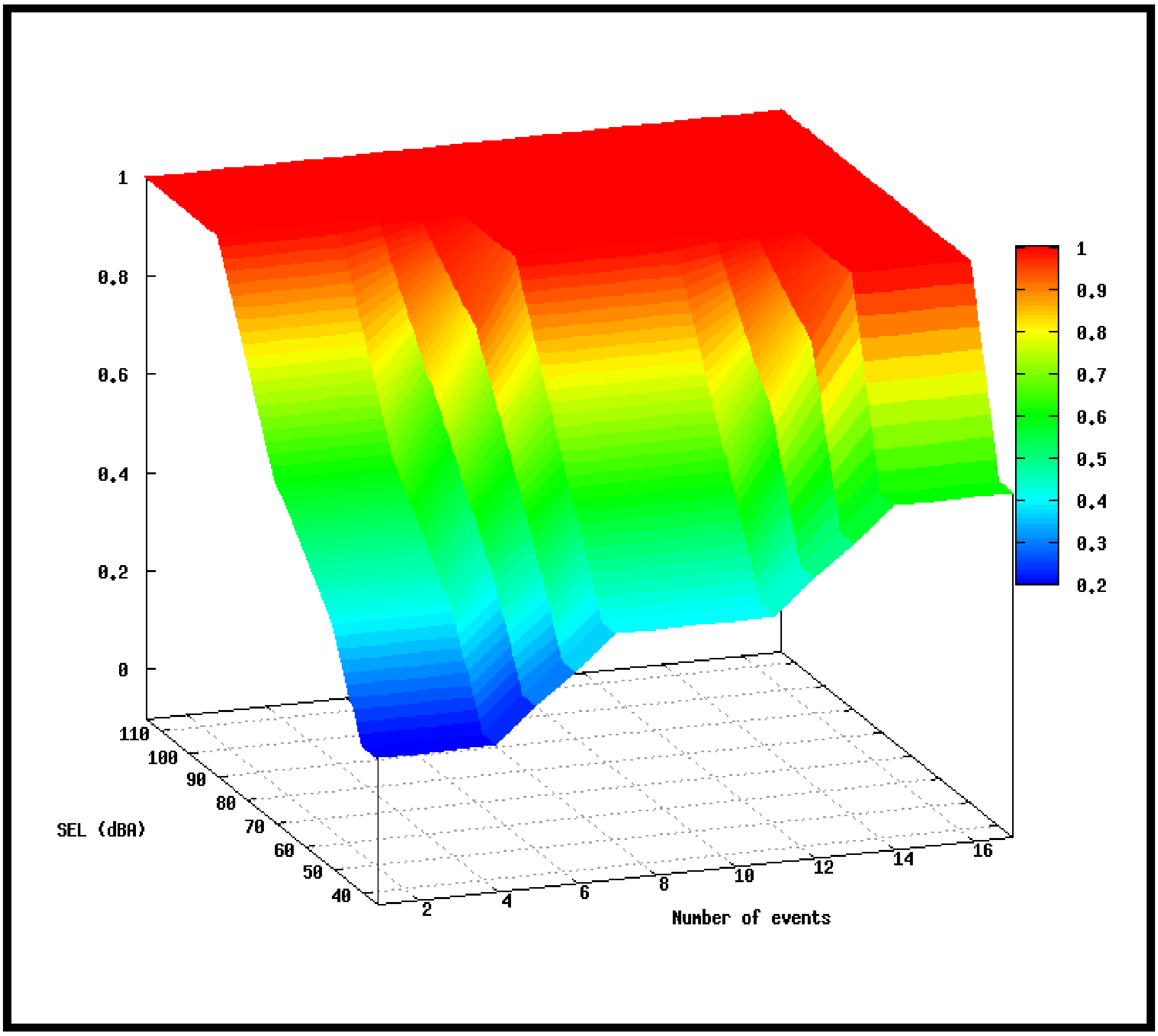


Fig 5.12. Residential night

Logically, this is the time where the level of discomfort grows with respect to other graphics. In this image, the unbearable nuisance zone covers almost more than 50% of the entire surface. This leads to conclude that during the night, an event from 70dBA can be irritatingly annoying.

According to the graph 5.12, in a residential area during night and on a range of HE events (high number of events which start in absolute value at 13 events per hour), for instance, 15 events per hour, the level of nuisance unable to assert 0 never, and the minimum sound starts at 40dBA. This is because during the night, residential areas are often in absolute silence as well as being the period of rest and relaxation. For both reasons, it is time for more sensitivity to noise and greater annoyance.

The charts below shows the level of nuisance noise experienced by workers in an industrial area exposed to airborne noise from aircraft over flying the area close to an airport. The three figures refer to the same industrial zone but at different times of day: morning, afternoon and evening.

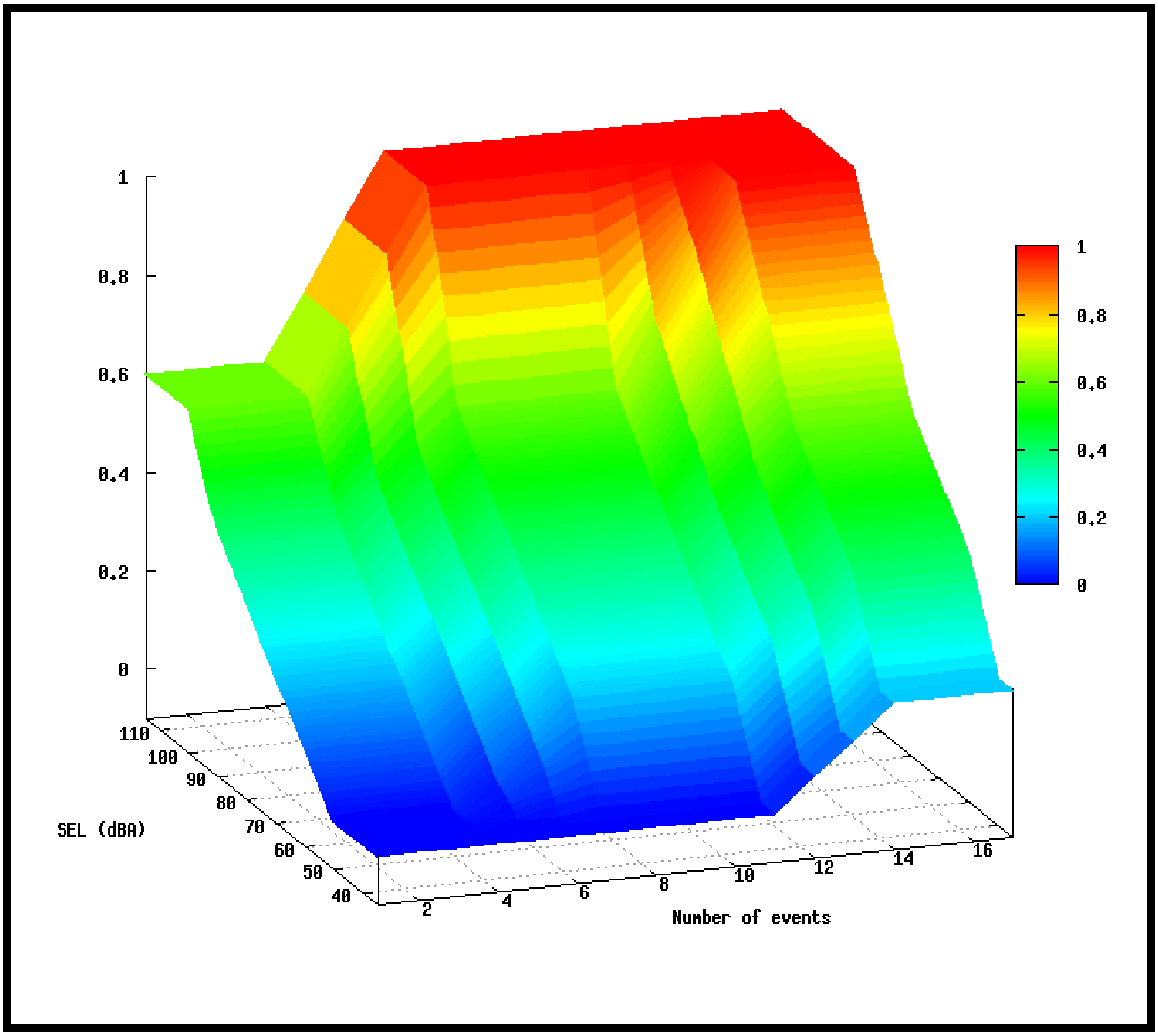


Fig 5.13. Industrial morning

Fig 5.13 shows the noise annoyance level to which the workers of an industrial zone working in morning shift are exposed. As shown above, the discomfort cranky area is, compared to the residential area graphs, much less extensive. This is because workers are already involved in industrial and other noises are also not in time for relaxation but on the contrary, they are working in industries which most of the time do not require silence to do their jobs.

In the industrial zone morning graph becomes irritating aircraft sound from the 5 events per hour and from 90dBA. On the other hand, a worker exposed to 70dBA does not suffer a high level of annoyance in any case.

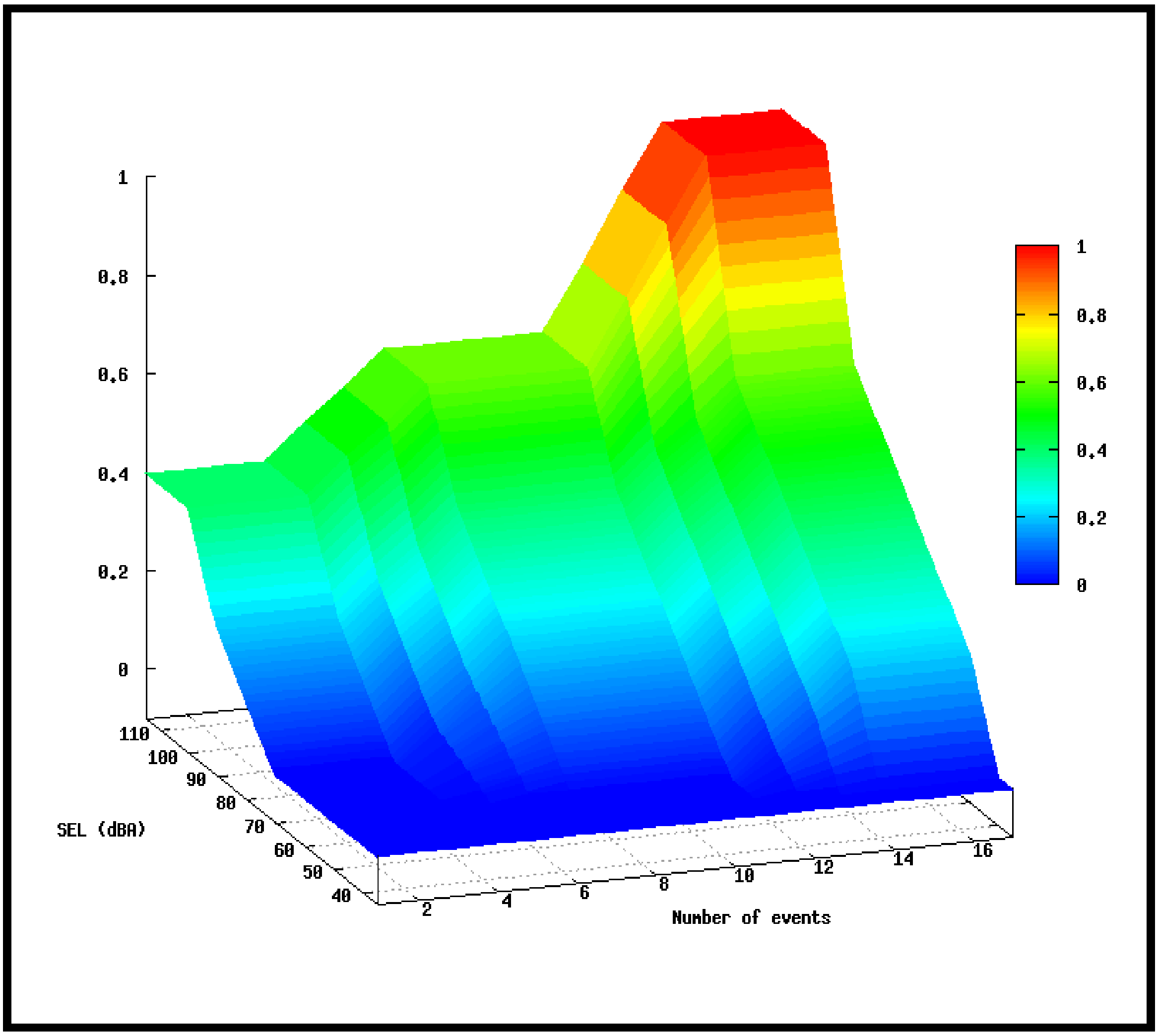


Fig 5.14. Industrial afternoon

Comparing Fig 5.14 with Fig 5.13 is easy to realize that the surface of red high level of discomfort decreases. In the afternoon, aircraft noise is less annoying unlike in the residential area, the trouble was compounded with less SEL and number of events. In this image dominates the blue and green.

When comparing the two graphs in the period of night, in an industrial zone and the other in a residential area, there is a big difference. During the afternoon in an industrial area, a large proportion of workers leave their jobs to go to rest at home, the residential area. In addition, residential area will always be more susceptible to annoyance because it tends to be at home when people rest and relax, so that a noise they cause more annoyance.

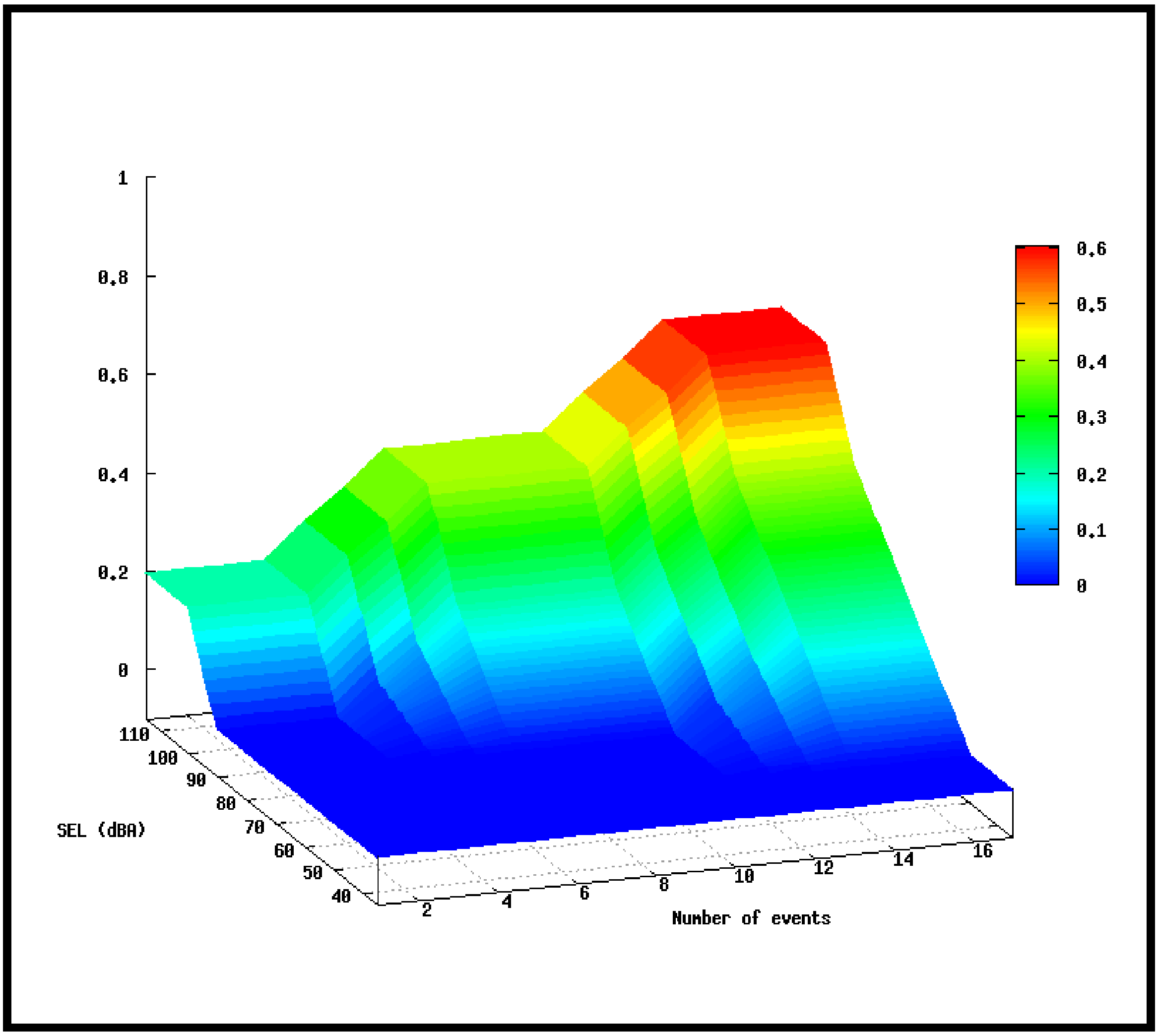


Fig 5.15. Industrial night

Finally, this above figure 5.15 has less red in all surfaces, which leads to the conclusion that in an industrial zone and at night, the noise nuisance is not very annoying despite suffering a high number of events per hour.

According to the graph, in an industrial zone and by night, the maximum noise nuisance (1) starts to occur at 12 events per hour and from 90dBA. Rather, the annoyance goes from 0 to 0,2 from 80dBA for any number of events per hour.

CONCLUSIONS

Like many other environmental problems, air traffic noise, continues to grow and has become a serious problem in many countries. Millions of people living or working around airport areas can suffer from noise exposure effects as for instance interference with communication, sleep disturbance, cardiovascular or psychological effects. However, the most common effect of aircraft noise exposure is annoyance, which is considered an adverse health effect by the World Health Organization.

Annoyance is a difficult concept to evaluate as it is open to subjective reactions and it is and imprecise and vague concept. In this project, the noise annoyance concept has been thoroughly analyzed. Annoyance has been approached as an inherent vague concept that is modelled with the use of fuzzy logic theory being the perfect tool to analyse and evaluate all that concepts that contrary to many other concepts, like age, distance or time, can not be measured as easily.

Obviously, the degree of annoyance will largely depend on the characteristics of the noise exposition, like the sound level, the number of events, the time of the day or the type of area. However, this has not been a problem to calculate the noise annoyance level as fuzzy logic theory permits to combine as much inputs as desired to obtain a personalized output.

The visual results obtained with the development of the fuzzy system, show how annoying can result one, two or ten noise events per hour at a certain sound level, in a residential or industrial area, and at a chosen period of time. As the graph shows, it is demonstrated that people working or living around a main airport are exposed to suffer a high level of annoyance.

The graphs obtained can be used as a perfect tool to evaluate the level of annoyance at which people working or living around airports are exposed to. Select the type of area, select the period of the day, select the number of events per hour, and finally select the sound level of the events and you will obtain a figure that will give you the noise annoyance level from 0 to 1, being 0 the minimum noise annoyance level and 1 the maximum.

A thermometer is used to measure temperature, a balance is used to measure the weight, and a clock to measure the time, and finally, the visual solutions developed in this project could be used to know how annoying a sound event can be.

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APPENDIX A: NUMERICAL VALUES OF ANNOYANCE

	DEFUZZYFICATION VALUES, AREA: RESIDENTIAL, TIME: MORNING																
SEL (dBA) / Events per hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
35	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,07	0,13	0,20	0,20	0,20	0,20
36	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,07	0,13	0,20	0,20	0,20	0,20
37	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,07	0,13	0,20	0,20	0,20	0,20
38	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,07	0,13	0,20	0,20	0,20	0,20
39	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,07	0,13	0,20	0,20	0,20	0,20
40	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,07	0,13	0,20	0,20	0,20	0,20
41	0,00	0,00	0,00	0,00	0,01	0,01	0,02	0,02	0,02	0,02	0,02	0,09	0,15	0,22	0,22	0,22	0,22
42	0,00	0,00	0,00	0,00	0,01	0,03	0,04	0,04	0,04	0,04	0,04	0,11	0,17	0,24	0,24	0,24	0,24
43	0,00	0,00	0,00	0,00	0,02	0,04	0,06	0,06	0,06	0,06	0,06	0,13	0,19	0,26	0,26	0,26	0,26
44	0,00	0,00	0,00	0,00	0,03	0,05	0,08	0,08	0,08	0,08	0,08	0,15	0,21	0,28	0,28	0,28	0,28
45	0,00	0,00	0,00	0,00	0,03	0,07	0,10	0,10	0,10	0,10	0,10	0,17	0,23	0,30	0,30	0,30	0,30
46	0,00	0,00	0,00	0,00	0,04	0,08	0,12	0,12	0,12	0,12	0,12	0,19	0,25	0,32	0,32	0,32	0,32
47	0,00	0,00	0,00	0,00	0,05	0,09	0,14	0,14	0,14	0,14	0,14	0,21	0,27	0,34	0,34	0,34	0,34
48	0,00	0,00	0,00	0,00	0,05	0,11	0,16	0,16	0,16	0,16	0,16	0,23	0,29	0,36	0,36	0,36	0,36
49	0,00	0,00	0,00	0,00	0,06	0,12	0,18	0,18	0,18	0,18	0,18	0,25	0,31	0,38	0,38	0,38	0,38
50	0,00	0,00	0,00	0,00	0,07	0,13	0,20	0,20	0,20	0,20	0,20	0,27	0,33	0,40	0,40	0,40	0,40
51	0,01	0,01	0,01	0,01	0,08	0,14	0,21	0,21	0,21	0,21	0,21	0,28	0,34	0,41	0,41	0,41	0,41
52	0,02	0,02	0,02	0,02	0,09	0,15	0,22	0,22	0,22	0,22	0,22	0,29	0,35	0,42	0,42	0,42	0,42
53	0,03	0,03	0,03	0,03	0,10	0,16	0,23	0,23	0,23	0,23	0,23	0,30	0,36	0,43	0,43	0,43	0,43
54	0,04	0,04	0,04	0,04	0,11	0,17	0,24	0,24	0,24	0,24	0,24	0,31	0,37	0,44	0,44	0,44	0,44
55	0,05	0,05	0,05	0,05	0,12	0,18	0,25	0,25	0,25	0,25	0,25	0,32	0,38	0,45	0,45	0,45	0,45
56	0,06	0,06	0,06	0,06	0,13	0,19	0,26	0,26	0,26	0,26	0,26	0,33	0,39	0,46	0,46	0,46	0,46
57	0,07	0,07	0,07	0,07	0,14	0,20	0,27	0,27	0,27	0,27	0,27	0,34	0,40	0,47	0,47	0,47	0,47
58	0,08	0,08	0,08	0,08	0,15	0,21	0,28	0,28	0,28	0,28	0,28	0,35	0,41	0,48	0,48	0,48	0,48
59	0,09	0,09	0,09	0,09	0,16	0,22	0,29	0,29	0,29	0,29	0,29	0,36	0,42	0,49	0,49	0,49	0,49
60	0,10	0,10	0,10	0,10	0,17	0,23	0,30	0,30	0,30	0,30	0,30	0,37	0,43	0,50	0,50	0,50	0,50
61	0,11	0,11	0,11	0,11	0,18	0,24	0,31	0,31	0,31	0,31	0,31	0,38	0,44	0,51	0,51	0,51	0,51
62	0,12	0,12	0,12	0,12	0,19	0,25	0,32	0,32	0,32	0,32	0,32	0,39	0,45	0,52	0,52	0,52	0,52
63	0,13	0,13	0,13	0,13	0,20	0,26	0,33	0,33	0,33	0,33	0,33	0,40	0,46	0,53	0,53	0,53	0,53
64	0,14	0,14	0,14	0,14	0,21	0,27	0,34	0,34	0,34	0,34	0,34	0,41	0,47	0,54	0,54	0,54	0,54
65	0,15	0,15	0,15	0,15	0,22	0,28	0,35	0,35	0,35	0,35	0,35	0,42	0,48	0,55	0,55	0,55	0,55
66	0,16	0,16	0,16	0,16	0,23	0,29	0,36	0,36	0,36	0,36	0,36	0,43	0,49	0,56	0,56	0,56	0,56
67	0,17	0,17	0,17	0,17	0,24	0,30	0,37	0,37	0,37	0,37	0,37	0,44	0,50	0,57	0,57	0,57	0,57
68	0,18	0,18	0,18	0,18	0,25	0,31	0,38	0,38	0,38	0,38	0,38	0,45	0,51	0,58	0,58	0,58	0,58
69	0,19	0,19	0,19	0,19	0,26	0,32	0,39	0,39	0,39	0,39	0,39	0,46	0,52	0,59	0,59	0,59	0,59
70	0,20	0,20	0,20	0,20	0,27	0,33	0,40	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60
71	0,21	0,21	0,21	0,21	0,28	0,34	0,41	0,41	0,41	0,41	0,41	0,48	0,55	0,62	0,62	0,62	0,62
72	0,22	0,22	0,22	0,22	0,29	0,35	0,42	0,42	0,42	0,42	0,42	0,49	0,57	0,64	0,64	0,64	0,64
73	0,23	0,23	0,23	0,23	0,30	0,36	0,43	0,43	0,43	0,43	0,43	0,51	0,58	0,66	0,66	0,66	0,66
74	0,24	0,24	0,24	0,24	0,31	0,37	0,44	0,44	0,44	0,44	0,44	0,52	0,60	0,68	0,68	0,68	0,68
75	0,25	0,25	0,25	0,25	0,32	0,38	0,45	0,45	0,45	0,45	0,45	0,53	0,62	0,70	0,70	0,70	0,70

76	0,26	0,26	0,26	0,26	0,33	0,39	0,46	0,46	0,46	0,46	0,46	0,55	0,63	0,72	0,72	0,72	0,72
77	0,27	0,27	0,27	0,27	0,34	0,40	0,47	0,47	0,47	0,47	0,47	0,56	0,65	0,74	0,74	0,74	0,74
78	0,28	0,28	0,28	0,28	0,35	0,41	0,48	0,48	0,48	0,48	0,48	0,57	0,67	0,76	0,76	0,76	0,76
79	0,29	0,29	0,29	0,29	0,36	0,42	0,49	0,49	0,49	0,49	0,49	0,59	0,68	0,78	0,78	0,78	0,78
80	0,30	0,30	0,30	0,30	0,37	0,43	0,50	0,50	0,50	0,50	0,50	0,60	0,70	0,80	0,80	0,80	0,80
81	0,31	0,31	0,31	0,31	0,38	0,44	0,51	0,51	0,51	0,51	0,51	0,61	0,72	0,82	0,82	0,82	0,82
82	0,32	0,32	0,32	0,32	0,39	0,45	0,52	0,52	0,52	0,52	0,52	0,63	0,73	0,84	0,84	0,84	0,84
83	0,33	0,33	0,33	0,33	0,40	0,46	0,53	0,53	0,53	0,53	0,53	0,64	0,75	0,86	0,86	0,86	0,86
84	0,34	0,34	0,34	0,34	0,41	0,47	0,54	0,54	0,54	0,54	0,54	0,65	0,77	0,88	0,88	0,88	0,88
85	0,35	0,35	0,35	0,35	0,42	0,48	0,55	0,55	0,55	0,55	0,55	0,67	0,78	0,90	0,90	0,90	0,90
86	0,36	0,36	0,36	0,36	0,43	0,49	0,56	0,56	0,56	0,56	0,56	0,68	0,80	0,92	0,92	0,92	0,92
87	0,37	0,37	0,37	0,37	0,44	0,50	0,57	0,57	0,57	0,57	0,57	0,69	0,82	0,94	0,94	0,94	0,94
88	0,38	0,38	0,38	0,38	0,45	0,51	0,58	0,58	0,58	0,58	0,58	0,71	0,83	0,96	0,96	0,96	0,96
89	0,39	0,39	0,39	0,39	0,46	0,52	0,59	0,59	0,59	0,59	0,59	0,72	0,85	0,98	0,98	0,98	0,98
90	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00
91	0,42	0,42	0,42	0,42	0,49	0,57	0,64	0,64	0,64	0,64	0,64	0,76	0,88	1,00	1,00	1,00	1,00
92	0,44	0,44	0,44	0,44	0,52	0,60	0,68	0,68	0,68	0,68	0,68	0,79	0,89	1,00	1,00	1,00	1,00
93	0,46	0,46	0,46	0,46	0,55	0,63	0,72	0,72	0,72	0,72	0,72	0,81	0,91	1,00	1,00	1,00	1,00
94	0,48	0,48	0,48	0,48	0,57	0,67	0,76	0,76	0,76	0,76	0,76	0,84	0,92	1,00	1,00	1,00	1,00
95	0,50	0,50	0,50	0,50	0,60	0,70	0,80	0,80	0,80	0,80	0,80	0,87	0,93	1,00	1,00	1,00	1,00
96	0,52	0,52	0,52	0,52	0,63	0,73	0,84	0,84	0,84	0,84	0,84	0,89	0,95	1,00	1,00	1,00	1,00
97	0,54	0,54	0,54	0,54	0,65	0,77	0,88	0,88	0,88	0,88	0,88	0,92	0,96	1,00	1,00	1,00	1,00
98	0,56	0,56	0,56	0,56	0,68	0,80	0,92	0,92	0,92	0,92	0,92	0,95	0,97	1,00	1,00	1,00	1,00
99	0,58	0,58	0,58	0,58	0,71	0,83	0,96	0,96	0,96	0,96	0,96	0,97	0,99	1,00	1,00	1,00	1,00
100	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
101	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
102	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
103	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
104	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
105	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
106	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
107	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
108	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
109	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
110	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
111	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
112	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
113	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
114	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
115	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00

SEL (dBA) / Events per hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	DEFUZZYFICATION VALUES, AREA: RESIDENTIAL, TIME: AFTERNOON																
35	0,00	0,00	0,00	0,00	0,07	0,13	0,20	0,20	0,20	0,20	0,20	0,27	0,33	0,40	0,40	0,40	0,40
36	0,00	0,00	0,00	0,00	0,07	0,13	0,20	0,20	0,20	0,20	0,20	0,27	0,33	0,40	0,40	0,40	0,40
37	0,00	0,00	0,00	0,00	0,07	0,13	0,20	0,20	0,20	0,20	0,20	0,27	0,33	0,40	0,40	0,40	0,40
38	0,00	0,00	0,00	0,00	0,07	0,13	0,20	0,20	0,20	0,20	0,20	0,27	0,33	0,40	0,40	0,40	0,40
39	0,00	0,00	0,00	0,00	0,07	0,13	0,20	0,20	0,20	0,20	0,20	0,27	0,33	0,40	0,40	0,40	0,40
40	0,00	0,00	0,00	0,00	0,07	0,13	0,20	0,20	0,20	0,20	0,20	0,27	0,33	0,40	0,40	0,40	0,40
41	0,02	0,02	0,02	0,02	0,09	0,15	0,22	0,22	0,22	0,22	0,22	0,29	0,35	0,42	0,42	0,42	0,42
42	0,04	0,04	0,04	0,04	0,11	0,17	0,24	0,24	0,24	0,24	0,24	0,31	0,37	0,44	0,44	0,44	0,44
43	0,06	0,06	0,06	0,06	0,13	0,19	0,26	0,26	0,26	0,26	0,26	0,33	0,39	0,46	0,46	0,46	0,46
44	0,08	0,08	0,08	0,08	0,15	0,21	0,28	0,28	0,28	0,28	0,28	0,35	0,41	0,48	0,48	0,48	0,48
45	0,10	0,10	0,10	0,10	0,17	0,23	0,30	0,30	0,30	0,30	0,30	0,37	0,43	0,50	0,50	0,50	0,50
46	0,12	0,12	0,12	0,12	0,19	0,25	0,32	0,32	0,32	0,32	0,32	0,39	0,45	0,52	0,52	0,52	0,52
47	0,14	0,14	0,14	0,14	0,21	0,27	0,34	0,34	0,34	0,34	0,34	0,41	0,47	0,54	0,54	0,54	0,54
48	0,16	0,16	0,16	0,16	0,23	0,29	0,36	0,36	0,36	0,36	0,36	0,43	0,49	0,56	0,56	0,56	0,56
49	0,18	0,18	0,18	0,18	0,25	0,31	0,38	0,38	0,38	0,38	0,38	0,45	0,51	0,58	0,58	0,58	0,58
50	0,20	0,20	0,20	0,20	0,27	0,33	0,40	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60
51	0,21	0,21	0,21	0,21	0,28	0,34	0,41	0,41	0,41	0,41	0,41	0,48	0,55	0,62	0,62	0,62	0,62
52	0,22	0,22	0,22	0,22	0,29	0,35	0,42	0,42	0,42	0,42	0,42	0,49	0,57	0,64	0,64	0,64	0,64
53	0,23	0,23	0,23	0,23	0,30	0,36	0,43	0,43	0,43	0,43	0,43	0,51	0,58	0,66	0,66	0,66	0,66
54	0,24	0,24	0,24	0,24	0,31	0,37	0,44	0,44	0,44	0,44	0,44	0,52	0,60	0,68	0,68	0,68	0,68
55	0,25	0,25	0,25	0,25	0,32	0,38	0,45	0,45	0,45	0,45	0,45	0,53	0,62	0,70	0,70	0,70	0,70
56	0,26	0,26	0,26	0,26	0,33	0,39	0,46	0,46	0,46	0,46	0,46	0,55	0,63	0,72	0,72	0,72	0,72
57	0,27	0,27	0,27	0,27	0,34	0,40	0,47	0,47	0,47	0,47	0,47	0,56	0,65	0,74	0,74	0,74	0,74
58	0,28	0,28	0,28	0,28	0,35	0,41	0,48	0,48	0,48	0,48	0,48	0,57	0,67	0,76	0,76	0,76	0,76
59	0,29	0,29	0,29	0,29	0,36	0,42	0,49	0,49	0,49	0,49	0,49	0,59	0,68	0,78	0,78	0,78	0,78
60	0,30	0,30	0,30	0,30	0,37	0,43	0,50	0,50	0,50	0,50	0,50	0,60	0,70	0,80	0,80	0,80	0,80
61	0,31	0,31	0,31	0,31	0,38	0,44	0,51	0,51	0,51	0,51	0,51	0,61	0,72	0,82	0,82	0,82	0,82
62	0,32	0,32	0,32	0,32	0,39	0,45	0,52	0,52	0,52	0,52	0,52	0,63	0,73	0,84	0,84	0,84	0,84
63	0,33	0,33	0,33	0,33	0,40	0,46	0,53	0,53	0,53	0,53	0,53	0,64	0,75	0,86	0,86	0,86	0,86
64	0,34	0,34	0,34	0,34	0,41	0,47	0,54	0,54	0,54	0,54	0,54	0,65	0,77	0,88	0,88	0,88	0,88
65	0,35	0,35	0,35	0,35	0,42	0,48	0,55	0,55	0,55	0,55	0,55	0,67	0,78	0,90	0,90	0,90	0,90
66	0,36	0,36	0,36	0,36	0,43	0,49	0,56	0,56	0,56	0,56	0,56	0,68	0,80	0,92	0,92	0,92	0,92
67	0,37	0,37	0,37	0,37	0,44	0,50	0,57	0,57	0,57	0,57	0,57	0,69	0,82	0,94	0,94	0,94	0,94
68	0,38	0,38	0,38	0,38	0,45	0,51	0,58	0,58	0,58	0,58	0,58	0,71	0,83	0,96	0,96	0,96	0,96
69	0,39	0,39	0,39	0,39	0,46	0,52	0,59	0,59	0,59	0,59	0,59	0,72	0,85	0,98	0,98	0,98	0,98
70	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00
71	0,41	0,41	0,41	0,41	0,48	0,55	0,62	0,62	0,62	0,62	0,62	0,75	0,87	1,00	1,00	1,00	1,00
72	0,42	0,42	0,42	0,42	0,49	0,57	0,64	0,64	0,64	0,64	0,64	0,76	0,88	1,00	1,00	1,00	1,00
73	0,43	0,43	0,43	0,43	0,51	0,58	0,66	0,66	0,66	0,66	0,66	0,77	0,89	1,00	1,00	1,00	1,00
74	0,44	0,44	0,44	0,44	0,52	0,60	0,68	0,68	0,68	0,68	0,68	0,79	0,89	1,00	1,00	1,00	1,00
75	0,45	0,45	0,45	0,45	0,53	0,62	0,70	0,70	0,70	0,70	0,70	0,80	0,90	1,00	1,00	1,00	1,00

76	0,46	0,46	0,46	0,46	0,55	0,63	0,72	0,72	0,72	0,72	0,72	0,81	0,91	1,00	1,00	1,00	1,00
77	0,47	0,47	0,47	0,47	0,56	0,65	0,74	0,74	0,74	0,74	0,74	0,83	0,91	1,00	1,00	1,00	1,00
78	0,48	0,48	0,48	0,48	0,57	0,67	0,76	0,76	0,76	0,76	0,76	0,84	0,92	1,00	1,00	1,00	1,00
79	0,49	0,49	0,49	0,49	0,59	0,68	0,78	0,78	0,78	0,78	0,78	0,85	0,93	1,00	1,00	1,00	1,00
80	0,50	0,50	0,50	0,50	0,60	0,70	0,80	0,80	0,80	0,80	0,80	0,87	0,93	1,00	1,00	1,00	1,00
81	0,51	0,51	0,51	0,51	0,61	0,72	0,82	0,82	0,82	0,82	0,82	0,88	0,94	1,00	1,00	1,00	1,00
82	0,52	0,52	0,52	0,52	0,63	0,73	0,84	0,84	0,84	0,84	0,84	0,89	0,95	1,00	1,00	1,00	1,00
83	0,53	0,53	0,53	0,53	0,64	0,75	0,86	0,86	0,86	0,86	0,86	0,91	0,95	1,00	1,00	1,00	1,00
84	0,54	0,54	0,54	0,54	0,65	0,77	0,88	0,88	0,88	0,88	0,88	0,92	0,96	1,00	1,00	1,00	1,00
85	0,55	0,55	0,55	0,55	0,67	0,78	0,90	0,90	0,90	0,90	0,90	0,93	0,97	1,00	1,00	1,00	1,00
86	0,56	0,56	0,56	0,56	0,68	0,80	0,92	0,92	0,92	0,92	0,92	0,95	0,97	1,00	1,00	1,00	1,00
87	0,57	0,57	0,57	0,57	0,69	0,82	0,94	0,94	0,94	0,94	0,94	0,96	0,98	1,00	1,00	1,00	1,00
88	0,58	0,58	0,58	0,58	0,71	0,83	0,96	0,96	0,96	0,96	0,96	0,97	0,99	1,00	1,00	1,00	1,00
89	0,59	0,59	0,59	0,59	0,72	0,85	0,98	0,98	0,98	0,98	0,98	0,99	0,99	1,00	1,00	1,00	1,00
90	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
91	0,64	0,64	0,64	0,64	0,76	0,88	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
92	0,68	0,68	0,68	0,68	0,79	0,89	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
93	0,72	0,72	0,72	0,72	0,81	0,91	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
94	0,76	0,76	0,76	0,76	0,84	0,92	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
95	0,80	0,80	0,80	0,80	0,87	0,93	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
96	0,84	0,84	0,84	0,84	0,89	0,95	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
97	0,88	0,88	0,88	0,88	0,92	0,96	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
98	0,92	0,92	0,92	0,92	0,95	0,97	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
99	0,96	0,96	0,96	0,96	0,97	0,99	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
100	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
101	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
102	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
103	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
104	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
105	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
106	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
107	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
108	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
109	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
110	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
111	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
112	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
113	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
114	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
115	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00

SEL (dBA) / Events per hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	DEFUZZYFICATION VALUES, AREA: RESIDENTIAL, TIME: NIGHT																
35	0,20	0,20	0,20	0,20	0,27	0,33	0,40	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60
36	0,20	0,20	0,20	0,20	0,27	0,33	0,40	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60
37	0,20	0,20	0,20	0,20	0,27	0,33	0,40	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60
38	0,20	0,20	0,20	0,20	0,27	0,33	0,40	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60
39	0,20	0,20	0,20	0,20	0,27	0,33	0,40	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60
40	0,20	0,20	0,20	0,20	0,27	0,33	0,40	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60
41	0,22	0,22	0,22	0,22	0,29	0,35	0,42	0,42	0,42	0,42	0,42	0,49	0,57	0,64	0,64	0,64	0,64
42	0,24	0,24	0,24	0,24	0,31	0,37	0,44	0,44	0,44	0,44	0,44	0,52	0,60	0,68	0,68	0,68	0,68
43	0,26	0,26	0,26	0,26	0,33	0,39	0,46	0,46	0,46	0,46	0,46	0,55	0,63	0,72	0,72	0,72	0,72
44	0,28	0,28	0,28	0,28	0,35	0,41	0,48	0,48	0,48	0,48	0,48	0,57	0,67	0,76	0,76	0,76	0,76
45	0,30	0,30	0,30	0,30	0,37	0,43	0,50	0,50	0,50	0,50	0,50	0,60	0,70	0,80	0,80	0,80	0,80
46	0,32	0,32	0,32	0,32	0,39	0,45	0,52	0,52	0,52	0,52	0,52	0,63	0,73	0,84	0,84	0,84	0,84
47	0,34	0,34	0,34	0,34	0,41	0,47	0,54	0,54	0,54	0,54	0,54	0,65	0,77	0,88	0,88	0,88	0,88
48	0,36	0,36	0,36	0,36	0,43	0,49	0,56	0,56	0,56	0,56	0,56	0,68	0,80	0,92	0,92	0,92	0,92
49	0,38	0,38	0,38	0,38	0,45	0,51	0,58	0,58	0,58	0,58	0,58	0,71	0,83	0,96	0,96	0,96	0,96
50	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00
51	0,41	0,41	0,41	0,41	0,48	0,55	0,62	0,62	0,62	0,62	0,62	0,75	0,87	1,00	1,00	1,00	1,00
52	0,42	0,42	0,42	0,42	0,49	0,57	0,64	0,64	0,64	0,64	0,64	0,76	0,88	1,00	1,00	1,00	1,00
53	0,43	0,43	0,43	0,43	0,51	0,58	0,66	0,66	0,66	0,66	0,66	0,77	0,89	1,00	1,00	1,00	1,00
54	0,44	0,44	0,44	0,44	0,52	0,60	0,68	0,68	0,68	0,68	0,68	0,79	0,89	1,00	1,00	1,00	1,00
55	0,45	0,45	0,45	0,45	0,53	0,62	0,70	0,70	0,70	0,70	0,70	0,80	0,90	1,00	1,00	1,00	1,00
56	0,46	0,46	0,46	0,46	0,55	0,63	0,72	0,72	0,72	0,72	0,72	0,81	0,91	1,00	1,00	1,00	1,00
57	0,47	0,47	0,47	0,47	0,56	0,65	0,74	0,74	0,74	0,74	0,74	0,83	0,91	1,00	1,00	1,00	1,00
58	0,48	0,48	0,48	0,48	0,57	0,67	0,76	0,76	0,76	0,76	0,76	0,84	0,92	1,00	1,00	1,00	1,00
59	0,49	0,49	0,49	0,49	0,59	0,68	0,78	0,78	0,78	0,78	0,78	0,85	0,93	1,00	1,00	1,00	1,00
60	0,50	0,50	0,50	0,50	0,60	0,70	0,80	0,80	0,80	0,80	0,80	0,87	0,93	1,00	1,00	1,00	1,00
61	0,51	0,51	0,51	0,51	0,61	0,72	0,82	0,82	0,82	0,82	0,82	0,88	0,94	1,00	1,00	1,00	1,00
62	0,52	0,52	0,52	0,52	0,63	0,73	0,84	0,84	0,84	0,84	0,84	0,89	0,95	1,00	1,00	1,00	1,00
63	0,53	0,53	0,53	0,53	0,64	0,75	0,86	0,86	0,86	0,86	0,86	0,91	0,95	1,00	1,00	1,00	1,00
64	0,54	0,54	0,54	0,54	0,65	0,77	0,88	0,88	0,88	0,88	0,88	0,92	0,96	1,00	1,00	1,00	1,00
65	0,55	0,55	0,55	0,55	0,67	0,78	0,90	0,90	0,90	0,90	0,90	0,93	0,97	1,00	1,00	1,00	1,00
66	0,56	0,56	0,56	0,56	0,68	0,80	0,92	0,92	0,92	0,92	0,92	0,95	0,97	1,00	1,00	1,00	1,00
67	0,57	0,57	0,57	0,57	0,69	0,82	0,94	0,94	0,94	0,94	0,94	0,96	0,98	1,00	1,00	1,00	1,00
68	0,58	0,58	0,58	0,58	0,71	0,83	0,96	0,96	0,96	0,96	0,96	0,97	0,99	1,00	1,00	1,00	1,00
69	0,59	0,59	0,59	0,59	0,72	0,85	0,98	0,98	0,98	0,98	0,98	0,99	0,99	1,00	1,00	1,00	1,00
70	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
71	0,62	0,62	0,62	0,62	0,75	0,87	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
72	0,64	0,64	0,64	0,64	0,76	0,88	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
73	0,66	0,66	0,66	0,66	0,77	0,89	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
74	0,68	0,68	0,68	0,68	0,79	0,89	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
75	0,70	0,70	0,70	0,70	0,80	0,90	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00

76	0,72	0,72	0,72	0,72	0,81	0,91	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
77	0,74	0,74	0,74	0,74	0,83	0,91	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
78	0,76	0,76	0,76	0,76	0,84	0,92	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
79	0,78	0,78	0,78	0,78	0,85	0,93	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
80	0,80	0,80	0,80	0,80	0,87	0,93	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
81	0,82	0,82	0,82	0,82	0,88	0,94	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
82	0,84	0,84	0,84	0,84	0,89	0,95	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
83	0,86	0,86	0,86	0,86	0,91	0,95	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
84	0,88	0,88	0,88	0,88	0,92	0,96	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
85	0,90	0,90	0,90	0,90	0,93	0,97	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
86	0,92	0,92	0,92	0,92	0,95	0,97	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
87	0,94	0,94	0,94	0,94	0,96	0,98	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
88	0,96	0,96	0,96	0,96	0,97	0,99	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
89	0,98	0,98	0,98	0,98	0,99	0,99	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
90	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
91	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
92	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
93	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
94	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
95	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
96	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
97	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
98	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
99	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
100	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
101	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
102	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
103	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
104	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
105	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
106	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
107	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
108	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
109	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
110	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
111	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
112	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
113	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
114	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
115	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00

SEL (dBA) / Events per hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	DEFUZZYFICATION VALUES, AREA: INDUSTRIAL, TIME: MORNING																
35	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,07	0,13	0,20	0,20	0,20	0,20
36	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,07	0,13	0,20	0,20	0,20	0,20
37	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,07	0,13	0,20	0,20	0,20	0,20
38	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,07	0,13	0,20	0,20	0,20	0,20
39	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,07	0,13	0,20	0,20	0,20	0,20
40	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,07	0,13	0,20	0,20	0,20	0,20
41	0,00	0,00	0,00	0,00	0,01	0,01	0,02	0,02	0,02	0,02	0,02	0,09	0,15	0,22	0,22	0,22	0,22
42	0,00	0,00	0,00	0,00	0,01	0,03	0,04	0,04	0,04	0,04	0,04	0,11	0,17	0,24	0,24	0,24	0,24
43	0,00	0,00	0,00	0,00	0,02	0,04	0,06	0,06	0,06	0,06	0,06	0,13	0,19	0,26	0,26	0,26	0,26
44	0,00	0,00	0,00	0,00	0,03	0,05	0,08	0,08	0,08	0,08	0,08	0,15	0,21	0,28	0,28	0,28	0,28
45	0,00	0,00	0,00	0,00	0,03	0,07	0,10	0,10	0,10	0,10	0,10	0,17	0,23	0,30	0,30	0,30	0,30
46	0,00	0,00	0,00	0,00	0,04	0,08	0,12	0,12	0,12	0,12	0,12	0,19	0,25	0,32	0,32	0,32	0,32
47	0,00	0,00	0,00	0,00	0,05	0,09	0,14	0,14	0,14	0,14	0,14	0,21	0,27	0,34	0,34	0,34	0,34
48	0,00	0,00	0,00	0,00	0,05	0,11	0,16	0,16	0,16	0,16	0,16	0,23	0,29	0,36	0,36	0,36	0,36
49	0,00	0,00	0,00	0,00	0,06	0,12	0,18	0,18	0,18	0,18	0,18	0,25	0,31	0,38	0,38	0,38	0,38
50	0,00	0,00	0,00	0,00	0,07	0,13	0,20	0,20	0,20	0,20	0,20	0,27	0,33	0,40	0,40	0,40	0,40
51	0,01	0,01	0,01	0,01	0,08	0,14	0,21	0,21	0,21	0,21	0,21	0,28	0,34	0,41	0,41	0,41	0,41
52	0,02	0,02	0,02	0,02	0,09	0,15	0,22	0,22	0,22	0,22	0,22	0,29	0,35	0,42	0,42	0,42	0,42
53	0,03	0,03	0,03	0,03	0,10	0,16	0,23	0,23	0,23	0,23	0,23	0,30	0,36	0,43	0,43	0,43	0,43
54	0,04	0,04	0,04	0,04	0,11	0,17	0,24	0,24	0,24	0,24	0,24	0,31	0,37	0,44	0,44	0,44	0,44
55	0,05	0,05	0,05	0,05	0,12	0,18	0,25	0,25	0,25	0,25	0,25	0,32	0,38	0,45	0,45	0,45	0,45
56	0,06	0,06	0,06	0,06	0,13	0,19	0,26	0,26	0,26	0,26	0,26	0,33	0,39	0,46	0,46	0,46	0,46
57	0,07	0,07	0,07	0,07	0,14	0,20	0,27	0,27	0,27	0,27	0,27	0,34	0,40	0,47	0,47	0,47	0,47
58	0,08	0,08	0,08	0,08	0,15	0,21	0,28	0,28	0,28	0,28	0,28	0,35	0,41	0,48	0,48	0,48	0,48
59	0,09	0,09	0,09	0,09	0,16	0,22	0,29	0,29	0,29	0,29	0,29	0,36	0,42	0,49	0,49	0,49	0,49
60	0,10	0,10	0,10	0,10	0,17	0,23	0,30	0,30	0,30	0,30	0,30	0,37	0,43	0,50	0,50	0,50	0,50
61	0,11	0,11	0,11	0,11	0,18	0,24	0,31	0,31	0,31	0,31	0,31	0,38	0,44	0,51	0,51	0,51	0,51
62	0,12	0,12	0,12	0,12	0,19	0,25	0,32	0,32	0,32	0,32	0,32	0,39	0,45	0,52	0,52	0,52	0,52
63	0,13	0,13	0,13	0,13	0,20	0,26	0,33	0,33	0,33	0,33	0,33	0,40	0,46	0,53	0,53	0,53	0,53
64	0,14	0,14	0,14	0,14	0,21	0,27	0,34	0,34	0,34	0,34	0,34	0,41	0,47	0,54	0,54	0,54	0,54
65	0,15	0,15	0,15	0,15	0,22	0,28	0,35	0,35	0,35	0,35	0,35	0,42	0,48	0,55	0,55	0,55	0,55
66	0,16	0,16	0,16	0,16	0,23	0,29	0,36	0,36	0,36	0,36	0,36	0,43	0,49	0,56	0,56	0,56	0,56
67	0,17	0,17	0,17	0,17	0,24	0,30	0,37	0,37	0,37	0,37	0,37	0,44	0,50	0,57	0,57	0,57	0,57
68	0,18	0,18	0,18	0,18	0,25	0,31	0,38	0,38	0,38	0,38	0,38	0,45	0,51	0,58	0,58	0,58	0,58
69	0,19	0,19	0,19	0,19	0,26	0,32	0,39	0,39	0,39	0,39	0,39	0,46	0,52	0,59	0,59	0,59	0,59
70	0,20	0,20	0,20	0,20	0,27	0,33	0,40	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60
71	0,21	0,21	0,21	0,21	0,28	0,34	0,41	0,41	0,41	0,41	0,41	0,48	0,55	0,62	0,62	0,62	0,62
72	0,22	0,22	0,22	0,22	0,29	0,35	0,42	0,42	0,42	0,42	0,42	0,49	0,57	0,64	0,64	0,64	0,64
73	0,23	0,23	0,23	0,23	0,30	0,36	0,43	0,43	0,43	0,43	0,43	0,51	0,58	0,66	0,66	0,66	0,66
74	0,24	0,24	0,24	0,24	0,31	0,37	0,44	0,44	0,44	0,44	0,44	0,52	0,60	0,68	0,68	0,68	0,68
75	0,25	0,25	0,25	0,25	0,32	0,38	0,45	0,45	0,45	0,45	0,45	0,53	0,62	0,70	0,70	0,70	0,70

76	0,26	0,26	0,26	0,26	0,33	0,39	0,46	0,46	0,46	0,46	0,46	0,55	0,63	0,72	0,72	0,72	0,72
77	0,27	0,27	0,27	0,27	0,34	0,40	0,47	0,47	0,47	0,47	0,47	0,56	0,65	0,74	0,74	0,74	0,74
78	0,28	0,28	0,28	0,28	0,35	0,41	0,48	0,48	0,48	0,48	0,48	0,57	0,67	0,76	0,76	0,76	0,76
79	0,29	0,29	0,29	0,29	0,36	0,42	0,49	0,49	0,49	0,49	0,49	0,59	0,68	0,78	0,78	0,78	0,78
80	0,30	0,30	0,30	0,30	0,37	0,43	0,50	0,50	0,50	0,50	0,50	0,60	0,70	0,80	0,80	0,80	0,80
81	0,31	0,31	0,31	0,31	0,38	0,44	0,51	0,51	0,51	0,51	0,51	0,61	0,72	0,82	0,82	0,82	0,82
82	0,32	0,32	0,32	0,32	0,39	0,45	0,52	0,52	0,52	0,52	0,52	0,63	0,73	0,84	0,84	0,84	0,84
83	0,33	0,33	0,33	0,33	0,40	0,46	0,53	0,53	0,53	0,53	0,53	0,64	0,75	0,86	0,86	0,86	0,86
84	0,34	0,34	0,34	0,34	0,41	0,47	0,54	0,54	0,54	0,54	0,54	0,65	0,77	0,88	0,88	0,88	0,88
85	0,35	0,35	0,35	0,35	0,42	0,48	0,55	0,55	0,55	0,55	0,55	0,67	0,78	0,90	0,90	0,90	0,90
86	0,36	0,36	0,36	0,36	0,43	0,49	0,56	0,56	0,56	0,56	0,56	0,68	0,80	0,92	0,92	0,92	0,92
87	0,37	0,37	0,37	0,37	0,44	0,50	0,57	0,57	0,57	0,57	0,57	0,69	0,82	0,94	0,94	0,94	0,94
88	0,38	0,38	0,38	0,38	0,45	0,51	0,58	0,58	0,58	0,58	0,58	0,71	0,83	0,96	0,96	0,96	0,96
89	0,39	0,39	0,39	0,39	0,46	0,52	0,59	0,59	0,59	0,59	0,59	0,72	0,85	0,98	0,98	0,98	0,98
90	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00
91	0,42	0,42	0,42	0,42	0,49	0,57	0,64	0,64	0,64	0,64	0,64	0,76	0,88	1,00	1,00	1,00	1,00
92	0,44	0,44	0,44	0,44	0,52	0,60	0,68	0,68	0,68	0,68	0,68	0,79	0,89	1,00	1,00	1,00	1,00
93	0,46	0,46	0,46	0,46	0,55	0,63	0,72	0,72	0,72	0,72	0,72	0,81	0,91	1,00	1,00	1,00	1,00
94	0,48	0,48	0,48	0,48	0,57	0,67	0,76	0,76	0,76	0,76	0,76	0,84	0,92	1,00	1,00	1,00	1,00
95	0,50	0,50	0,50	0,50	0,60	0,70	0,80	0,80	0,80	0,80	0,80	0,87	0,93	1,00	1,00	1,00	1,00
96	0,52	0,52	0,52	0,52	0,63	0,73	0,84	0,84	0,84	0,84	0,84	0,89	0,95	1,00	1,00	1,00	1,00
97	0,54	0,54	0,54	0,54	0,65	0,77	0,88	0,88	0,88	0,88	0,88	0,92	0,96	1,00	1,00	1,00	1,00
98	0,56	0,56	0,56	0,56	0,68	0,80	0,92	0,92	0,92	0,92	0,92	0,95	0,97	1,00	1,00	1,00	1,00
99	0,58	0,58	0,58	0,58	0,71	0,83	0,96	0,96	0,96	0,96	0,96	0,97	0,99	1,00	1,00	1,00	1,00
100	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
101	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
102	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
103	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
104	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
105	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
106	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
107	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
108	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
109	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
110	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
111	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
112	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
113	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
114	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
115	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00

SEL (dBA) / Events per hour	DEFUZZYFICATION VALUES, AREA: INDUSTRIAL, TIME: AFTERNOON																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
35	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
36	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
37	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
38	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
39	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
40	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
41	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,01	0,02	0,02	0,02	0,02
42	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,03	0,04	0,04	0,04	0,04
43	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02	0,04	0,06	0,06	0,06	0,06
44	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,03	0,05	0,08	0,08	0,08	0,08
45	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,03	0,07	0,10	0,10	0,10	0,10
46	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,04	0,08	0,12	0,12	0,12	0,12
47	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,05	0,09	0,14	0,14	0,14	0,14
48	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,05	0,11	0,16	0,16	0,16	0,16
49	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,06	0,12	0,18	0,18	0,18	0,18
50	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,07	0,13	0,20	0,20	0,20	0,20
51	0,00	0,00	0,00	0,00	0,00	0,01	0,01	0,01	0,01	0,01	0,01	0,08	0,14	0,21	0,21	0,21	0,21
52	0,00	0,00	0,00	0,00	0,01	0,01	0,02	0,02	0,02	0,02	0,02	0,09	0,15	0,22	0,22	0,22	0,22
53	0,00	0,00	0,00	0,00	0,01	0,02	0,03	0,03	0,03	0,03	0,03	0,10	0,16	0,23	0,23	0,23	0,23
54	0,00	0,00	0,00	0,00	0,01	0,03	0,04	0,04	0,04	0,04	0,04	0,11	0,17	0,24	0,24	0,24	0,24
55	0,00	0,00	0,00	0,00	0,02	0,03	0,05	0,05	0,05	0,05	0,05	0,12	0,18	0,25	0,25	0,25	0,25
56	0,00	0,00	0,00	0,00	0,02	0,04	0,06	0,06	0,06	0,06	0,06	0,13	0,19	0,26	0,26	0,26	0,26
57	0,00	0,00	0,00	0,00	0,02	0,05	0,07	0,07	0,07	0,07	0,07	0,14	0,20	0,27	0,27	0,27	0,27
58	0,00	0,00	0,00	0,00	0,03	0,05	0,08	0,08	0,08	0,08	0,08	0,15	0,21	0,28	0,28	0,28	0,28
59	0,00	0,00	0,00	0,00	0,03	0,06	0,09	0,09	0,09	0,09	0,09	0,16	0,22	0,29	0,29	0,29	0,29
60	0,00	0,00	0,00	0,00	0,03	0,07	0,10	0,10	0,10	0,10	0,10	0,17	0,23	0,30	0,30	0,30	0,30
61	0,00	0,00	0,00	0,00	0,04	0,07	0,11	0,11	0,11	0,11	0,11	0,18	0,24	0,31	0,31	0,31	0,31
62	0,00	0,00	0,00	0,00	0,04	0,08	0,12	0,12	0,12	0,12	0,12	0,19	0,25	0,32	0,32	0,32	0,32
63	0,00	0,00	0,00	0,00	0,04	0,09	0,13	0,13	0,13	0,13	0,13	0,20	0,26	0,33	0,33	0,33	0,33
64	0,00	0,00	0,00	0,00	0,05	0,09	0,14	0,14	0,14	0,14	0,14	0,21	0,27	0,34	0,34	0,34	0,34
65	0,00	0,00	0,00	0,00	0,05	0,10	0,15	0,15	0,15	0,15	0,15	0,22	0,28	0,35	0,35	0,35	0,35
66	0,00	0,00	0,00	0,00	0,05	0,11	0,16	0,16	0,16	0,16	0,16	0,23	0,29	0,36	0,36	0,36	0,36
67	0,00	0,00	0,00	0,00	0,06	0,11	0,17	0,17	0,17	0,17	0,17	0,24	0,30	0,37	0,37	0,37	0,37
68	0,00	0,00	0,00	0,00	0,06	0,12	0,18	0,18	0,18	0,18	0,18	0,25	0,31	0,38	0,38	0,38	0,38
69	0,00	0,00	0,00	0,00	0,06	0,13	0,19	0,19	0,19	0,19	0,19	0,26	0,32	0,39	0,39	0,39	0,39
70	0,00	0,00	0,00	0,00	0,07	0,13	0,20	0,20	0,20	0,20	0,20	0,27	0,33	0,40	0,40	0,40	0,40
71	0,01	0,01	0,01	0,01	0,08	0,14	0,21	0,21	0,21	0,21	0,21	0,28	0,34	0,41	0,41	0,41	0,41
72	0,02	0,02	0,02	0,02	0,09	0,15	0,22	0,22	0,22	0,22	0,22	0,29	0,35	0,42	0,42	0,42	0,42
73	0,03	0,03	0,03	0,03	0,10	0,16	0,23	0,23	0,23	0,23	0,23	0,30	0,36	0,43	0,43	0,43	0,43
74	0,04	0,04	0,04	0,04	0,11	0,17	0,24	0,24	0,24	0,24	0,24	0,31	0,37	0,44	0,44	0,44	0,44
75	0,05	0,05	0,05	0,05	0,12	0,18	0,25	0,25	0,25	0,25	0,25	0,32	0,38	0,45	0,45	0,45	0,45

76	0,06	0,06	0,06	0,06	0,13	0,19	0,26	0,26	0,26	0,26	0,26	0,33	0,39	0,46	0,46	0,46	0,46
77	0,07	0,07	0,07	0,07	0,14	0,20	0,27	0,27	0,27	0,27	0,27	0,34	0,40	0,47	0,47	0,47	0,47
78	0,08	0,08	0,08	0,08	0,15	0,21	0,28	0,28	0,28	0,28	0,28	0,35	0,41	0,48	0,48	0,48	0,48
79	0,09	0,09	0,09	0,09	0,16	0,22	0,29	0,29	0,29	0,29	0,29	0,36	0,42	0,49	0,49	0,49	0,49
80	0,10	0,10	0,10	0,10	0,17	0,23	0,30	0,30	0,30	0,30	0,30	0,37	0,43	0,50	0,50	0,50	0,50
81	0,11	0,11	0,11	0,11	0,18	0,24	0,31	0,31	0,31	0,31	0,31	0,38	0,44	0,51	0,51	0,51	0,51
82	0,12	0,12	0,12	0,12	0,19	0,25	0,32	0,32	0,32	0,32	0,32	0,39	0,45	0,52	0,52	0,52	0,52
83	0,13	0,13	0,13	0,13	0,20	0,26	0,33	0,33	0,33	0,33	0,33	0,40	0,46	0,53	0,53	0,53	0,53
84	0,14	0,14	0,14	0,14	0,21	0,27	0,34	0,34	0,34	0,34	0,34	0,41	0,47	0,54	0,54	0,54	0,54
85	0,15	0,15	0,15	0,15	0,22	0,28	0,35	0,35	0,35	0,35	0,35	0,42	0,48	0,55	0,55	0,55	0,55
86	0,16	0,16	0,16	0,16	0,23	0,29	0,36	0,36	0,36	0,36	0,36	0,43	0,49	0,56	0,56	0,56	0,56
87	0,17	0,17	0,17	0,17	0,24	0,30	0,37	0,37	0,37	0,37	0,37	0,44	0,50	0,57	0,57	0,57	0,57
88	0,18	0,18	0,18	0,18	0,25	0,31	0,38	0,38	0,38	0,38	0,38	0,45	0,51	0,58	0,58	0,58	0,58
89	0,19	0,19	0,19	0,19	0,26	0,32	0,39	0,39	0,39	0,39	0,39	0,46	0,52	0,59	0,59	0,59	0,59
90	0,20	0,20	0,20	0,20	0,27	0,33	0,40	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60
91	0,22	0,22	0,22	0,22	0,29	0,35	0,42	0,42	0,42	0,42	0,42	0,49	0,57	0,64	0,64	0,64	0,64
92	0,24	0,24	0,24	0,24	0,31	0,37	0,44	0,44	0,44	0,44	0,44	0,52	0,60	0,68	0,68	0,68	0,68
93	0,26	0,26	0,26	0,26	0,33	0,39	0,46	0,46	0,46	0,46	0,46	0,55	0,63	0,72	0,72	0,72	0,72
94	0,28	0,28	0,28	0,28	0,35	0,41	0,48	0,48	0,48	0,48	0,48	0,57	0,67	0,76	0,76	0,76	0,76
95	0,30	0,30	0,30	0,30	0,37	0,43	0,50	0,50	0,50	0,50	0,50	0,60	0,70	0,80	0,80	0,80	0,80
96	0,32	0,32	0,32	0,32	0,39	0,45	0,52	0,52	0,52	0,52	0,52	0,63	0,73	0,84	0,84	0,84	0,84
97	0,34	0,34	0,34	0,34	0,41	0,47	0,54	0,54	0,54	0,54	0,54	0,65	0,77	0,88	0,88	0,88	0,88
98	0,36	0,36	0,36	0,36	0,43	0,49	0,56	0,56	0,56	0,56	0,56	0,68	0,80	0,92	0,92	0,92	0,92
99	0,38	0,38	0,38	0,38	0,45	0,51	0,58	0,58	0,58	0,58	0,58	0,71	0,83	0,96	0,96	0,96	0,96
100	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00
101	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00
102	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00
103	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00
104	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00
105	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00
106	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00
107	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00
108	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00
109	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00
110	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00
111	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00
112	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00
113	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00
114	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00
115	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60	0,60	0,73	0,87	1,00	1,00	1,00	1,00

	DEFUZZYFICATION VALUES, AREA: INDUSTRIAL, TIME: NIGHT																
SEL (dBA) / Events per hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
35	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
36	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
37	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
38	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
39	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
40	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
41	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
42	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
43	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
44	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
45	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
46	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
47	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
48	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
49	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
50	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
51	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,01	0,01	0,01	0,01
52	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,01	0,02	0,02	0,02	0,02
53	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,02	0,03	0,03	0,03	0,03
54	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,03	0,04	0,04	0,04	0,04
55	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02	0,03	0,05	0,05	0,05	0,05
56	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02	0,04	0,06	0,06	0,06	0,06
57	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02	0,05	0,07	0,07	0,07	0,07
58	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,03	0,05	0,08	0,08	0,08	0,08
59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,03	0,06	0,09	0,09	0,09	0,09
60	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,03	0,07	0,10	0,10	0,10	0,10
61	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,04	0,07	0,11	0,11	0,11	0,11
62	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,04	0,08	0,12	0,12	0,12	0,12
63	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,04	0,09	0,13	0,13	0,13	0,13
64	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,05	0,09	0,14	0,14	0,14	0,14
65	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,05	0,10	0,15	0,15	0,15	0,15
66	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,05	0,11	0,16	0,16	0,16	0,16
67	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,06	0,11	0,17	0,17	0,17	0,17
68	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,06	0,12	0,18	0,18	0,18	0,18
69	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,06	0,13	0,19	0,19	0,19	0,19
70	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,07	0,13	0,20	0,20	0,20	0,20
71	0,00	0,00	0,00	0,00	0,00	0,01	0,01	0,01	0,01	0,01	0,01	0,08	0,14	0,21	0,21	0,21	0,21
72	0,00	0,00	0,00	0,00	0,01	0,01	0,02	0,02	0,02	0,02	0,02	0,09	0,15	0,22	0,22	0,22	0,22
73	0,00	0,00	0,00	0,00	0,01	0,02	0,03	0,03	0,03	0,03	0,03	0,10	0,16	0,23	0,23	0,23	0,23
74	0,00	0,00	0,00	0,00	0,01	0,03	0,04	0,04	0,04	0,04	0,04	0,11	0,17	0,24	0,24	0,24	0,24
75	0,00	0,00	0,00	0,00	0,02	0,03	0,05	0,05	0,05	0,05	0,05	0,12	0,18	0,25	0,25	0,25	0,25

76	0,00	0,00	0,00	0,00	0,02	0,04	0,06	0,06	0,06	0,06	0,06	0,13	0,19	0,26	0,26	0,26	0,26
77	0,00	0,00	0,00	0,00	0,02	0,05	0,07	0,07	0,07	0,07	0,07	0,14	0,20	0,27	0,27	0,27	0,27
78	0,00	0,00	0,00	0,00	0,03	0,05	0,08	0,08	0,08	0,08	0,08	0,15	0,21	0,28	0,28	0,28	0,28
79	0,00	0,00	0,00	0,00	0,03	0,06	0,09	0,09	0,09	0,09	0,09	0,16	0,22	0,29	0,29	0,29	0,29
80	0,00	0,00	0,00	0,00	0,03	0,07	0,10	0,10	0,10	0,10	0,10	0,17	0,23	0,30	0,30	0,30	0,30
81	0,00	0,00	0,00	0,00	0,04	0,07	0,11	0,11	0,11	0,11	0,11	0,18	0,24	0,31	0,31	0,31	0,31
82	0,00	0,00	0,00	0,00	0,04	0,08	0,12	0,12	0,12	0,12	0,12	0,19	0,25	0,32	0,32	0,32	0,32
83	0,00	0,00	0,00	0,00	0,04	0,09	0,13	0,13	0,13	0,13	0,13	0,20	0,26	0,33	0,33	0,33	0,33
84	0,00	0,00	0,00	0,00	0,05	0,09	0,14	0,14	0,14	0,14	0,14	0,21	0,27	0,34	0,34	0,34	0,34
85	0,00	0,00	0,00	0,00	0,05	0,10	0,15	0,15	0,15	0,15	0,15	0,22	0,28	0,35	0,35	0,35	0,35
86	0,00	0,00	0,00	0,00	0,05	0,11	0,16	0,16	0,16	0,16	0,16	0,23	0,29	0,36	0,36	0,36	0,36
87	0,00	0,00	0,00	0,00	0,06	0,11	0,17	0,17	0,17	0,17	0,17	0,24	0,30	0,37	0,37	0,37	0,37
88	0,00	0,00	0,00	0,00	0,06	0,12	0,18	0,18	0,18	0,18	0,18	0,25	0,31	0,38	0,38	0,38	0,38
89	0,00	0,00	0,00	0,00	0,06	0,13	0,19	0,19	0,19	0,19	0,19	0,26	0,32	0,39	0,39	0,39	0,39
90	0,00	0,00	0,00	0,00	0,07	0,13	0,20	0,20	0,20	0,20	0,20	0,27	0,33	0,40	0,40	0,40	0,40
91	0,02	0,02	0,02	0,02	0,09	0,15	0,22	0,22	0,22	0,22	0,22	0,29	0,35	0,42	0,42	0,42	0,42
92	0,04	0,04	0,04	0,04	0,11	0,17	0,24	0,24	0,24	0,24	0,24	0,31	0,37	0,44	0,44	0,44	0,44
93	0,06	0,06	0,06	0,06	0,13	0,19	0,26	0,26	0,26	0,26	0,26	0,33	0,39	0,46	0,46	0,46	0,46
94	0,08	0,08	0,08	0,08	0,15	0,21	0,28	0,28	0,28	0,28	0,28	0,35	0,41	0,48	0,48	0,48	0,48
95	0,10	0,10	0,10	0,10	0,17	0,23	0,30	0,30	0,30	0,30	0,30	0,37	0,43	0,50	0,50	0,50	0,50
96	0,12	0,12	0,12	0,12	0,19	0,25	0,32	0,32	0,32	0,32	0,32	0,39	0,45	0,52	0,52	0,52	0,52
97	0,14	0,14	0,14	0,14	0,21	0,27	0,34	0,34	0,34	0,34	0,34	0,41	0,47	0,54	0,54	0,54	0,54
98	0,16	0,16	0,16	0,16	0,23	0,29	0,36	0,36	0,36	0,36	0,36	0,43	0,49	0,56	0,56	0,56	0,56
99	0,18	0,18	0,18	0,18	0,25	0,31	0,38	0,38	0,38	0,38	0,38	0,45	0,51	0,58	0,58	0,58	0,58
100	0,20	0,20	0,20	0,20	0,27	0,33	0,40	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60
101	0,20	0,20	0,20	0,20	0,27	0,33	0,40	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60
102	0,20	0,20	0,20	0,20	0,27	0,33	0,40	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60
103	0,20	0,20	0,20	0,20	0,27	0,33	0,40	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60
104	0,20	0,20	0,20	0,20	0,27	0,33	0,40	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60
105	0,20	0,20	0,20	0,20	0,27	0,33	0,40	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60
106	0,20	0,20	0,20	0,20	0,27	0,33	0,40	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60
107	0,20	0,20	0,20	0,20	0,27	0,33	0,40	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60
108	0,20	0,20	0,20	0,20	0,27	0,33	0,40	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60
109	0,20	0,20	0,20	0,20	0,27	0,33	0,40	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60
110	0,20	0,20	0,20	0,20	0,27	0,33	0,40	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60
111	0,20	0,20	0,20	0,20	0,27	0,33	0,40	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60
112	0,20	0,20	0,20	0,20	0,27	0,33	0,40	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60
113	0,20	0,20	0,20	0,20	0,27	0,33	0,40	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60
114	0,20	0,20	0,20	0,20	0,27	0,33	0,40	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60
115	0,20	0,20	0,20	0,20	0,27	0,33	0,40	0,40	0,40	0,40	0,40	0,47	0,53	0,60	0,60	0,60	0,60