Strategic Noise Mapping of Herakleion: The Aircraft Noise Impact as a factor of the Int. Airport relocation

Abstract: In the framework of the European Directive 2002/49/EC, the city of Herakleion in Crete Island (Greece) recently completed (2013) its Strategic Noise Map (SNM) and relevant Noise Action Plan (NAP). Strategic noise mapping and action plans are important tools to define the main strategies to reduce noise exposure of residents and introduce and preserve "quite zones". Within this framework and as a part of the Herakleion city Strategic Noise Mapping general a specific analysis was introduced in the urban area of Alikarnassos (east part of the city) adjacent to the International Airport “Nikos Kazantzakis”. The 2nd biggest airport in Greece, airport is proposed to be relocated in Kastelli area (some 37 km south of the Herakleion city centre, far away from dense populated areas), within the next decade but in the mean time, air traffic (take off, taxi and landing procedures, especially during the extended spring and summer period), are affecting the city. This paper analyzes the extended acoustic measurement monitoring program and the modelling of environmental noise levels within the city’s SNM introducing – state of the art - qualitative surveys on the sound perception and noise annoyance by the residents as well as in depth analysis of the urban and architectural tissue. All these results have been transcribed in several maps introducing a very comprehensive evaluation tool towards an efficient noise action plan leading to the eventual relocation of the airport. This paper presents the main results of this research aiming to the evaluation of the influence at the inhabitants’ sonic comfort from aircraft operation.

Keywords: airport noise, strategic noise map, European Directive 2002/49/EC, qualitative sound maps, noise action plan

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1 Introduction

Environmental Noise annoyance - especially from airports operation - is widely accepted as an end-point of environmental noise that can be taken as a basis for evaluating the impact of noise on the exposed population. People annoyed by airport noise may experience a variety of negative responses, such as anger, disappointment, dissatisfaction, withdrawal, helplessness, depression, anxiety, distraction, agitation or exhaustion [1, 2]. Noise pollution is a growing concern in Europe. Of particular importance is noise from transport and industrial sources, which are addressed by Directive 2002/49/EC relating to the assessment and management of environmental noise, otherwise known as the Environmental Noise Directive (END) [3]. In the framework of the European Directive 2002/49/EC, the
city of Herakleion in Crete Island (Greece) recently completed (2013) its Strategic Noise Map (SNM) and the relevant Noise Action Plan (NAP). Within this framework, and as a part of the Herakleion city SNM, a specific analysis was introduced in the urban area of Alikarnassos (east part of the city) adjacent to the International Airport “Nikos Kazantzakis” [4].

The 2nd biggest airport in Greece is proposed to be relocated in Kastelli area (some 37 km south of the Herakleion city centre, far away from dense populated areas), within the next decade but in the mean time, air traffic (take off, taxi and landing procedures, especially during the extended spring and summer period), are affecting the city. In the framework of the environmental noise mapping of Herakleion, for the road traffic noise, the national French method “NMPB-Routes-96 (SETERA-CERTU-LPC-CSTB)” was taken into consideration, as it is presented in the “Article du 5 mai 1995 relatif au bruit des infrastructures routières, Journal Officiel du 10 mai 1995, Article 6” and in the French standard “XPS 31-133”. For aircraft noise, it was taken into consideration the methodology “ECAC.CEAC Doc. 29 / Report on Standard Method of Computing Noise Contours around Civil Airports, 1997”. This paper analyzes the extended acoustic measurement monitoring program and the modelling of environmental noise levels within the city’s SNM introducing – state of the art - qualitative surveys on the sound perception and noise annoyance by the residents as well as in depth analysis of the urban and architectural tissue.

All these results have been transcribed in several maps introducing a very comprehensive evaluation tool towards an efficient noise action plan leading to the eventual relocation of the airport. This paper presents the main results of this research aiming to the evaluation of the influence at the inhabitants’ sonic comfort from aircraft operation. The study area of Alikarnassos is adjacent to the west side of the International Airport “Nikos Kazantzakis” of Herakleion city. The study area, is included in the Herakleion city boundaries since the regional re-organization of 2008, covering a surface of some 0,51 km² and it can be described as an urban district that gathers mainly residential buildings, educational uses, shops, civil services (both public and private), some small crafts shops, etc. The study area is presented in Figure 1 on two levels, (a) as part of the greater urban agglomeration and (b) on the scale of the airport runway. Urban tissue follows a typical orthogonal grid with main streets from south to north towards the sea side. Road traffic is present in every street level as well also as parking spaces on both sides the road network (especially in main axes but also on some secondary urban road network). Architectural typology is quite simple with mainly 2 stores buildings – max height due to the proximity of the airport (as per specific safety building regulation).

Residential buildings are mainly one-floor houses with some small private balconies on the road façade and, sometimes, with internal small private gardens or atriums. The area has also several points of interests as described in the European Directive such as playgrounds, elementary schools, higher education schools, churches, and some small public places in the centre. All these urban elements are shown in Fig. 2.

2 Methodology

In order to assess the noise impact and the relevant annoyance impact, we had developed a multidisciplinary methodology taking into account simultaneously real time acoustic measurements and SNM software predictions results with the outcome from interviews executed in situ, with inhabitants on the theme of acoustic comfort and sonic identities [5]. The methodology is pointed out in the following steps:

2.1 24h noise measurements campaign & Model simulation

Strategic noise maps were produced for the whole city using “CadnaA” acoustic prediction software including both airport and road traffic noise sources. A detailed 3D model of the Herakleion area including the International Airport based on the latest and most accurate cadastre and town planning data was implemented. In order to calibrate the model and achieve the best correlation between measured and calculated noise values a full 24 h noise measurements monitoring program was executed in the same period with the questionnaires survey. 24 hrs acoustic measurements were executed by using class 1 statistical noise analyzers, on special designed masts securing the European directive guidelines. The measurement results were compared with the theoretical results from the CadnaA including 4 different sensitive points of interests in Alikarnassos area e.g.: the 3rd / 6th elementary schools (location 33), the old Alikarnassos town hall (location 34), the area’s high school (point n° 35), and the location 32 at the Technical Chamber of Greece building (see locations in Fig. 7). The acoustic measurements were used to evaluate the noise impact of the airport operations (both take off & landing) by a coding software (dBTrait32 from 01dB-
ACOEM) for the triggering level of LAeq1s > 75 dB(A). The relevant air traffic volumes are described in the Table 1 for the base year 2012 in aircraft mix classes as per AzB96 [6] (see Table 2).

Fig. 3 shows a typical take off noise signature.

Some 30 take off events were identified, producing excessive noise, by more than 40 dB(A), higher to the relevant background noise levels. This fact introduces a severe annoyance to the exposed population. A full SNM analysis was elaborated for the whole city of Herakleion and especially for the immediate airport area for 2012 and both indices Lden & Lnight. The relevant SNM’s and exposure to noise population data are presented in Fig. 4 and 5 [4].

2.2 Questionnaires

A semi-directive questionnaire was launched in the local population proposing some 20 distinct questions based in previous studies in urban centres of Greece [5, 7, 8]. The interviews were executed providing no limitation to the interviewees to express themselves, on noises and annoyance issues, but inviting them to open up and to express their views on all types of sound that can be perceived in situ e.g.: natural sounds, sounds from human activities especially from the airport, pleasant or unpleasant sounds, annoying sounds, neighbourhood characteristic sounds, etc. The interviews were recorded in real time basis on a tape recorder and then transcribed and coded by investigation team in the office. The questionnaire was designed to capture the global impression and analyze further the main aspects, therefore:

- the interview was starting with questions related to the global evaluation of the area by the inhabitants or workers (regarding various issues as security property, acoustic environment etc.),
- a second group of questions was focused on the assessment of the sound environment using introducing a comparison method e.g. city vs nature, dynamic en-
Table 1. Annual average daily aircraft movements (TOffs & landings) - 2012.

| Flugzeuggruppe | Kategorie                                                        | ICAO Annex 16 | Typenbeispiele                          |
|----------------|-----------------------------------------------------------------|---------------|-----------------------------------------|
| RW 09 P1       | Ultraleichtflugzeuge                                            |               |                                        |
| RW 27 P1       | Motorsegler                                                     |               |                                        |
| RW 09 P2.1     | Propellerflugzeuge mit MTOM bis 5.7 t                          | 3/10          | DHC-7/-8, F-50, ATR 42                  |
| RW 09 P2.2     | Propellerflugzeuge mit MTOM über 2 t bis 5.7 t                  | -(3/10)       | F-27, HS748                             |
| RW 09 S1.0     | Strahlflugzeuge mit MTOM bis 34 t                             | 2             | Learjet 23-25, Sabreliner                |
| RW 09 S1.1     | Strahlflugzeuge mit MTOM von 34 bis 100 t                       | 2             | DC-9, Tu134, B737-200                  |
| RW 09 S1.2     | B737                                                            | 2             |                                        |
| RW 09 S1.3     | B727                                                            | 2             |                                        |
| RW 09 S2       | Strahlflugzeuge mit MTOM bis 100 t                             | -             | B727-100, B737-100                      |
| RW 09 S3.1     | 2/3-motorige Strahlflugzeuge mit MTOM über 100 t                | 2             | DC10 alterer Bauart                     |
| RW 09 S3.2     | 4-motorige Strahlflugzeuge mit MTOM über 100 t                  | 2             | ältereB747, IL 62M                      |
| RW 09 S4       | Strahlflugzeuge mit MTOM über 100 t                            | -             | B707, DC-8, IL 62                       |
| RW 09 S5.1     | Strahlflugzeuge mit MTOM bis 50 t                              | 3             | BAE 146, ARJ, CJR                       |
| RW 09 S5.2     | Strahlflugzeuge mit MTOM bis 120 t und Nebenstromverhältnis über 3 | 3             | A319, A320, A321, B757 B737-300...-800  |
| RW 09 S5.3     | Strahlflugzeuge mit MTOM bis 120 t und Nebenstromverhältnis bis 3 | 3             | MD-8x, B737/B727 mit Hush-Kit           |
| RW 09 S6.1     | 2-motorige Strahlflugzeuge mit MTOM über 120 t                  | 3             | A300, A310, A330, B767, B777            |
| RW 09 S6.2     | 3/4-motorige Strahlflugzeuge mit MTOM von 120 t bis 300 t       | 3             | DC-10, MD-11, DC-8-70                   |
| RW 09 S6.3     | A 340                                                           | 3             |                                        |
| RW 09 S7       | 3/4-motorige Strahlflugzeuge mit MTOM über 300 t                | 3             | B747                                    |

Table 2. Aircraft categorisation as per AzB96
environment vs “dead” environment, vivid vs disturbing qualities,
• a third group of questions was focused on the several sound sources that inhabitants can hear and remember such as road traffic, aircrafts, PTW (power 2wheelers) traffic, neighbourhood sounds, domestic animals, etc.). The conditions under such sounds are heard where requested to be identified by the interviewed residents (e.g. where? when? frequency?, etc.)
• the sounds that can be considered as representative or unique for the urban district were, then, identified,
• the interview was concluded by a discussion on the specific noise from the aircrafts operations. Local residents were asked to express their personal level of discomfort (if any) on a 7 evaluation points assessment scale. Interviewed people were asked to express their opinion on the relocation of the airport to be introduced in the next years.

2.3 Crossed analysis

The analysis of the interviews follows the protocols used in similar research in the field of urban sociology and the perception of the environment [9–12]. The purpose was to synthesize population input data in a proper form for the analysis, grouping them by the redundancy point of view of their individual expressions. Actually, the interviews transcriptions were checked and categorized on the redundancy of singular semantic expressions. Each location where the interview took place was marked on the area’s detailed map, ensuring the possibility to re-contextualize the input of the inhabitants inside the district and there-
fore allowing to partly explaining why various sound phenomena were described accordingly. This synthesis allows to update two types of results are thus re-transcribe them in the form of relative maps for each case study area.

2.4 Sound signals and sound marks map

The sound signals and/or the sound events are mentioned mainly by the local residents. These are sounds that are related to the district representative activities, which -even though- were produced mainly beyond the boundaries of the district but can be clearly perceived in the study area (i.e. airport activities). All these sounds are audible indications of the sound identity of the Alikarnassos study area. Sometimes, some of them can only be heard within the area, since they are typical and they describe the area, in a certain clear way, therefore when one is listening to these sounds – actually sound marks - understands that “this is home”. It is important to underline that the map in Fig. 6 shows what people hear and describe accordingly. In all the sounds, one can hear in a day, in a week, in a year, some particular sounds are the most memorable, marking, therefore, consists the basic ordinary perception of the local population. They are pleasant or unpleasant; but they mark people’s minds, as both signs and markers of the sound identity of the district.

2.5 Sound Identity Map

The compilation of all interviews can bring out parts of the study area rather homogeneous in terms of how sounds are produced and heard by the local residents. These are the identities describing - on an average level - in this specific urban area, how the people perceives and produces sounds. For each identity, a name is allocated, characterizing the urban sound environment. An evocative title was chosen to summarize what the interviews have described (see map in Fig. 6).

3 Results

3.1 Acoustic characterization of Airport operation inside the study area

The acoustic measurements executed and coded in order to evaluate the impact of the aircraft noise traffic on the study area for the most representative sensitive locations are presented in Table 3 along with the relevant results of the acoustic measurement campaign.

One may conclude that:

- the daily traffic of planes coded in the measurement session is similar with the statistical data introduced in the model (as presented above)
- take off & landing procedures create obviously a very significant emergence of noise (approx. some 40 dB(A) above the background noise)
Fig. 6. Study area of Alikarnassos: (a) Sound signals and sound marks map and (b) Sound Identity Map.

Table 3. 24h measurement at Alikarnassos study area.

| Location | Description                        | Period       | Results |
|----------|------------------------------------|--------------|---------|
|          |                                    |              | Source  | Leq source dB | Leq (partial) dB | L_min dB | L_max dB | L_95 dB | L_5 dB |
| 32       | National Technical Chamber of Greece | 10 to 11/06/13 | Aircraft | 77.6          | 69.9           | 29.5     | 103.1    | 40.4    | 82.2    |
|          |                                    |              | Background noise | 59.4       | 58.6           | 27.7     | 97.0     | 35.6    | 57.5    |
|          |                                    |              | Global 32 | 70.2          | 70.2           | 27.7     | 103.1    | 36.0    | 61.8    |
| 33       | 3rd / 6th Elementary School         | 10 to 11/06/13 | Aircraft | 78.7          | 68.6           | 36.6     | 97.5     | 43.5    | 84.1    |
|          |                                    |              | Background noise | 64.2       | 63.7           | 33.9     | 92.9     | 38.2    | 68.0    |
|          |                                    |              | Global 33 | 69.8          | 69.8           | 33.9     | 97.5     | 38.4    | 69.7    |
| 34       | Alikarnassos Town Hall              | 07 to 10/06/13 | Aircraft | 75.7          | 68.4           | 41.3     | 100.1    | 46.6    | 80.4    |
|          |                                    |              | Background noise | 60.4       | 59.5           | 39.1     | 93.8     | 42.7    | 62.7    |
|          |                                    |              | Global 34 | 69.0          | 69.0           | 39.1     | 100.1    | 43.0    | 64.8    |
| 35       | High School                         | 07 to 08/06/13 | Aircraft | 79.7          | 69.9           | 43.7     | 97.1     | 47.5    | 87.4    |
|          |                                    |              | Background noise | 57.6       | 57.2           | 39.3     | 85.0     | 43.8    | 61.1    |
|          |                                    |              | Global 35 | 70.1          | 70.1           | 39.3     | 97.1     | 44.0    | 65.5    |

– each measurement location is considered as a relatively quiet place when no airport activity is present: \( L_{Aeq} \) values for the residual environmental noise varies around 60 dB(A) and \( L_{Aeq} \) values from airport operations are higher than 20 – 25 dB(A) compared to the residual noise.

– the frequency analysis level take off procedures - as per the spectrogram in figure 8 - suggests a large spectral range noise (in the area from 50 to 8000 Hz).

Thus, acoustic measurements, in terms of noise levels and in terms of frequencies, show that the passage of an aircraft is a sound mask on all the neighbourhood activities.

3.2 Simulation results

An acoustic model has been set up under “CadnaA” software calibrated with the 24h measurement realized in situ. As stated above, a full Strategic Noise map of the whole city of Herakleion and also the Alikarnassos study area for both \( L_{den} \) and \( L_{night} \) noise indices for the 2012 scenario was executed. The relevant simulations of measured vs calculated values with high \( R^2 \) values in the area of 0.975 absolutely confirm the accuracy of the calculated values (see relevant analysis in Fig. 8).

The entire Alikarnassos area is exposed to high noise levels during the day and during the night: 70 dB (A) \(< L_{den} \)< 75 dB (A)), and it can be very high (> a 75 dB (A)) for buildings located near the airport. In the north part of the area,
The values of $L_{den}$ is lower from a in noise level class (a minus 5 dB(A), $65 \text{ dB (A)} < L_{den} < 70 \text{ dB (A)}$). These values are high and comparable with noise levels due to intense road traffic (not typical for the area). The relatively lower noise level in this section are due to the slope toward the sea and to the fact that aircraft’s flight paths are already away (higher initiating a turn), therefore the buildings are less exposed to aircraft noise during departures (see Fig. 9 and 10).

### 3.3 Subjective perception of the aircraft operation inside the area of study

#### 3.3.1 Quantitative results from interview

The interviews executed in the area, cover an important part of the inhabitants, reporting, as much as possible, noise annoyance incidents. Some 201 interviews were finally executed from 10\textsuperscript{th} to 14\textsuperscript{th} of June 2013, mainly during morning and noon hours (until 15:00), a day period when is easier to catch inhabitant’s attention. If we consider that one interview can represent one acoustic situation (average assessment of the noise exposure for the whole building), it means that we have covered approximately a 14\% of the building in use in the study area as per Table 4.

The survey population was composed by 52\% women and 48\% men. There are various ages from 18 years old to aged and retired people. They were all active, retired or unemployed and residents and/or workers in the area. A large panel of professional situations e.g. residents, traders, teachers, engineers, people from the municipality, free lance workers, shop’s owner, coffee place’s owner, hotel owner, social workers, butchers, bakers, grocers, etc. were met. The goal was to cover the maximum of “residential situations” gathering the largest panel of impressions regarding noise, sounds and in general the prevailing characteristics of the existing acoustic environment. The results for the general evaluation of the neighbourhood are presented in the relevant diagrams in Fig. 11. The large majority, of the residents or the people that work in the area think that their neighbour is not safe, but dirty and very noisy.

It’s obvious that the continuous operation of aircrafts degrades substantially the perceived quality of the district’s acoustic environment. However measured data and the relevant simulations indicate that the sound environment of the neighbourhood is actually quiet and peaceful when no aircraft operation (especially TO) are present. The aircraft pass byes over the district introduce an important effect in the perceived soundscape (see Fig. 12).

It means that a significant part of the interviewed population appreciates their neighbourhood. Indeed, when people were asked to describe the sounds that they like to hear, a lot of sources are mentioned as a part of the sound identity of the place. Interviewers were also asked to qualify their sound environment e.g. if in general, they have the feeling to live in a noisy area with a few moments of silence, or quite the opposite, and also if they think they live in a quiet area disturbed by aircraft noise.

As it shown in Fig. 13, the opinion of the population is clearly divided between two distinct points of view: the half thinks that the area is very noisy and the pauses of
silence are rare while the other half thought otherwise. Objectively, the measurements show very well this dual aspect of the neighbourhood and the relevant results indicate, according to sociological criteria, if this nuisance is considered acceptable or not. In this sense however the following results are also interesting. The interviewers were also asked to describe their sound environment considering on two criteria, especially if apart from aircraft operation, how they hear the sounds and if those sounds express some dynamism or rather are simply indicative of a neighbourhood that looks acoustically "dead" (see Fig. 14).

It seems that everybody agreed that all the sounds that they hear in the district reflect its dynamism and the people appreciate this point. The most important sounds that express this dynamism, often quoted by residents, are:

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**Fig. 8.** Herakleion SNM 2012 Measured vs calculated values $R^2$: (a) Noise index $L_{den}$ (b) Noise index $L_{night}$.

**Fig. 9.** Strategic Noise Maps 2012 for noise indices $L_{den}$ (a) and $L_{night}$ (b) for the Alikarnassos study area with airport operation.

**Table 4.** Statistic coverage of Alikarnassos study area - Questionnaires.

| District Name       | No of building in use | No of interviews | Coverage |
|---------------------|-----------------------|------------------|----------|
| Alikarnassos @ Herakleion | 1402                 | 201              | 14.3%    |

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road traffic both cars and PTW (2 wheelers), sounds linked to various activities such as schoolyards, and also sounds from the neighbours (music, TV, voices).

3.3.2 Qualitative results from interview

A sound signal as well as a sound mark of this neighbourhood is the continuous operation of aircrafts. Indeed, due to the direction of prevailing winds, practically all aircraft take offs from the international airport passes is take place over the study area. Thus, depending on the season, the frequent take offs of aircrafts (even less than 10 minutes apart) mark the sonic environment. Air traffic is continuous all day until late at night and is much more intense in the spring and especially during summer months. Even though the plane take off lasts only some 20-30s, the generated noise covers even the loudest sound activity (speak on the phone, watch TV, listen to radio, chatting etc.). People complain for the aircraft noise and the claim that they experienced psychological fatigue related to sleep disorders. This is even more true when we refer to children, babies and also elderly people. Some parents say that their children are afraid of the loud noise of the aircraft operation and cry at every aircraft passing. In addition, teachers in schools express vividly the difficulties to conduct properly their courses due to aircraft noise experiencing, lack of concentration of students, difficulties to push them to participate in class activities. Furthermore and particularly in schools adjacent to the airport, the insecurity and safety factor of a potential accident due to an aircraft crash during take off dominates the population. The feeling of insecurity becomes their obsession and very often it is mentioned by interviewers characterizing their particular relationship with the airport. In addition, many residents are worried about their health – and they think that some forms of cancer - that their friends or “known people in the district” experienced - may be correlated with the air pollution emissions from the aircraft operations. It is therefore obvious that the aircraft’s operation is a powerful sonic & social landmark for the neighbourhood and rightfully, is
a significant discomfort for the majority of the residential population. However, it should be noted that a part of the population seems to be accustomed to aircraft noise and did not agree with a possible relocation of the airport. For some of them, the aircraft noise seems not so annoying due to its non-continuous character with rather long periods of pause and silence. Of course, when no aircraft operations are present, ones can hear all the sound richness of this neighbourhood:

- in the north-west side of the district, some residents have underlined pleasant sounds of the harbour (audio announcement of ships arrivals and ships departures) and also the sounds of the sea (waves crashing on the rocks, seagulls, wind, etc.)
- in the southern area of the district, the sonic identity is characterized by commercial activities and the road traffic. Apart from periods when aircrafts are over passing the district, the neighbourhood is sounding with the rhythms of the commercial activities expressing the true life of the district.
- it emerges also, from the interviews, some other pleasant sounds such as those of children playing on playgrounds and courtyards of schools, and similar activities sounds like the traditional school bell. Particularly residents living near schools and playgrounds characterize these sounds as pleasant.
- in some areas, residents are partially "appropriating" existing public urban spaces (for example by placing chairs on sidewalks), forming spaces designated as special areas of socialization. The sounds that we can hear are talks, laughs, music and they are more often commented pleasantly and therefore this environment is rarely considered as a nuisance.

### 3.4 Sound identity of the area

As per the analysis above in conjunction with simulations and the acoustic measurements within the district, it is clear that aircraft operation mask practically all sound activities throughout the neighbourhood. What is the study area's perceived acoustic climate when no aircraft operations are present? Are there any sound qualities that need to be protected and enhanced in the future? Actually, different sound identities seem to be identifying from the interviews analysis:

- The **seaside zone** includes the coastal zone of the park where the acoustic environment is characterized by the background noise of road traffic and the sounds of the sea, the harbour and human activities (sound markers). It is a quiet place, where one can enjoy both the visual and the sonic landscape.
- The **shopping area** and the **industrial zone** on the east where the sound environment of these places are linked with the rhythms of the commercial activities.
- The **residential zone** is present throughout the study area. It is a zone of calm (except during aircraft operation) with a minimum of sound signals and general audio events. Road traffic is rather moderate. However, residents are living mainly on the behind façade of their building with or away of open spaces - while the courtyard area in front of the street serves primarily as a parking. It is a uniform zone, both from architectural and acoustic point of view.
- Two particular sections with acoustic similarities have been observed inside the study area. These are the areas around the two central meeting places for residents. The presence of several dynamic activities (such as coffee shops, parks, playgrounds, schools etc.) within an "open air" dominant characteristic, creates all kind off sounds, diffused to adjacent streets and spaces creating a particular “sonic” atmosphere. These areas behave, from the sound point of view, like two urban squares that are pleasantly disturbing the tranquillity of the surrounding residential areas. It creates, the perception, to the inhabitants, of an urban centre, where all the ‘sounds’ can create socializing areas and providing the opportunity to fully use these public spaces with private furniture as chairs installed on the sidewalks.
- The western and north-eastern area, a vibrant neighbourhood of the district, is characterized by a different sound "color", and can be described as an area where the residents create themselves their proper sonic identity. The sound marks are mostly human sounds of conversations, children playing, screams, laughs, tears, brawls and music TVs or neighbours. Only the noise from aircraft operation disturbs this "sound bubble".

### 4 Noise Action plan: Relocation of Herakleion Int. Airport

A new tender for the construction and management of a new airport on Crete in the area of Kastelli at Herakleion (see Fig. 15), is expected to launch within 2014 [13]. According to Greek Minister of Infrastructure, Transport and Networks, the aim is for a bidder to be selected by the end of the year. The new airport is scheduled to replace the ex-
isting “Nikos Kazantzakis” Int. Airport at Herakleion and will feature a runway length of 3.2 km. The construction of the new airport in Kastelli, is considered as an “imperative need” because the existing airport “Nikos Kazantzakis” has reached its operational limits serving over six million passengers a year, creating as well a significant annoyance.

![Fig. 15. Proposed location of the new airport of Herakleion at Kastelli.](image)

Apart from the new airport’s construction works, the roads linking the new airport with key roads of Crete will be significantly upgraded. The ultimate goal for the new airport to relocate at Kastelli is to operate in five years and the expected air traffic is estimated as follows.

The expected aircraft noise impact (target year 2025) of the new relocated airport at Kastelli indicates rather no significant level due also to the non dense urban agglomerations in the area. Simulations for the 2025 air traffic estimations, for the new location, as per Table 5, were executed in order to access the new relocated expected airport impact in the communities in its vicinity. The relevant strategic noise maps for the study area for both $L_{den}$ and $L_{night}$ indices are displayed in Fig. 16 [14].

Simulations show very clearly the positive impact of the existing Herakleion Int airport relocation to Kastelli.

In the Alikarnassos study area with the existing Airport operation there is not a single spot where you can be protected from the aircraft noise. Due to the aircraft operation, the sound level ($L_{den}$) is very high, above 70 dB (A) even 75 dB(A) as analysed above.

Without the aircraft operations (see Fig. 17), the relevant acoustic model simulations indicate sound levels similar to those from a “classical” residential area in Greece. Noise levels are higher during the day in the vicinity of the road network and fall sharply at night with commercial activities to emerge.

Meanwhile, the existing open areas in the backside of the properties are now protected from the road traffic noise introducing - by their urban form - interesting quiet islets, presenting very low noise levels of both indices: $L_{den}$ and $L_{night}$ varies at levels less than 40 dB (A). Therefore the proposed relocation will introduce to the neighbourhood a new enhanced sound environment with many quiet periods that will positively affect the rest and relaxation of the residents. To further improve sound qualities of the environment, the noise action plan proposes also several additional actions aiming to upgrade the sound environment to a better and more suitable form in the future.

The "relocation" noise action plan, is based on people’s perception of the soundscape, aiming to preserve the sound identity of the given neighbourhood in a major urban agglomeration such as Herakleion. It is unfolded on three distinct levels:

- an environmental dimension level describing all physical, emission and propagation characteristics for all types of environmental sound sources including e.g. noise barriers and various propagation obstacles, road surface characteristics, urban soil media, shape and use of buildings, etc. These actions - even though rather predictable - are permitting to evaluate with high exactitude the quantity aspect in resulting noise reduction.
- a “milieu” dimension level (social practices), aiming to identify all land uses already available within the area, acting on a major land use redesign level, that welcomes or discourages some distinct uses, such us public open or “intra muros” spaces, restaurants, coffee shops, bars, public gathering places, schools, playgrounds, markets, allowing multiple events, etc. This level of action is not fully predictable or accurate, but the possibility of choosing to implement or to avoid and exclude even, certain activities, is expected affect positively the global acoustic environment.
- a soundscape dimension level, characterizing the most aesthetic and symbolic links that residents establish with the particular sounds of their neighbourhood, highly valued by their aesthetic characteristics, such as some natural sounds, city sounds e.g. church bells, markets, schoolyards, etc. This level is rather difficult to fully be predicted but it consists an important factor, for the success of a broader noise action plan [5].

Therefore for both Alikarnassos study area and the global Herakleion urban agglomeration as well, a comprehensive
Table 5. Annual average daily aircraft movements (TOffs & landings) at the new Kastelli airport - 2025.

| Time        | RW 02 | P1 | P 2.1 | P 2.2 | S 5.1 | S 5.2 | S 5.3 | S 6.1 | S 6.2 | S 6.3 | S 7 |
|-------------|-------|----|-------|-------|-------|-------|-------|-------|-------|-------|-----|
| 07:00-19:00 | 8     | 3  | 59    | 4     |
| 19:00-23:00 | 5     | 1  | 16    | 1     |
| 23:00-07:00 | 2     | 1  | 19    | 14    |

| Time        | RW 20 | P1 | P 2.1 | P 2.2 | S 5.1 | S 5.2 | S 5.3 | S 6.1 | S 6.2 | S 6.3 | S 7 |
|-------------|-------|----|-------|-------|-------|-------|-------|-------|-------|-------|-----|
| 07:00-19:00 | 2     | 1  | 15    | 1     |
| 19:00-23:00 | 1     | 4  | 1     | 1     |
| 23:00-07:00 | 1     | 1  | 5     | 3     |

Fig. 16. New Kastelli Int. Airport-SNM 2025-Expected noise indices $L_{den}$ & $L_{night}$. 
noise action plan was proposed based on the sound analysis identities aiming:
1. to preserve the qualities that are identified by residents for the study area through a full airport relocation plan, allowing to enhance certain qualities already observed in the field,
2. to manage activities on the area ensuring land use mixture establishing however their distinction, and
3. to create sound aesthetic dimensions in order to promote soundscape listening.

The overall strategy within these multi-level noise action plan aims:
- to remain unaffected by the commercial activities in the urban road arteries,
- to reinforce commercial and cultural activities,
- to introduce pedestrian axes, particularly around education buildings and public services (town hall, social security building, churches, etc.) and the ocean front, facilitating browsing through the neighbourhood and the seaside,
- to create bike paths inside and around the district: along the seaside, along the airport, and finally
- to introduce actions on the abandoned sites upgrading them as new relaxation areas such as parks, playgrounds etc.

Especially based on the analysis of the existing situation in the Alikarnassos study area, five zones with different sonic identities (when not the dominant aircraft operation is present) were accessed.

Table 6 shows for each zone, actions intended to maintain and enhance existing environmental sound qualities.

5 Discussion

A comprehensive comparison of the Strategic Noise Map 2012 vs the proposed Noise Action Plan introducing the major "Int airport relocation" action indicates a high positive effect to the acoustic environment as presented hereafter: In Table 7 and Fig. 18, the expected values for $L_{\text{night}}$, show a significantly reduction of the proportion of the population exposed to noise levels in ranges 60 – 65 and 65 – 70 dB (A).

On January 2014 [15] the Council and European Parliament agreed on updated rules for the introduction of noise-related operating restrictions at EU airports. The member states’ permanent representatives endorsed the compromise reached between the Council and the European Parliament concerning a regulation which harmonizes and strengthens rules on how authorities, take decisions to set operating restrictions at EU airports to limit
Table 6. Qualitative noise actions plan.

| Places / Sonic Identities | Environment                                                                                      | Milieu (social practices)                                                                 | Soundscape                                                                 |
|----------------------------|--------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|----------------------------------------------------------------------------|
| The seaside               | Construction of noise barriers in the northern part of the port area for noise protection of housing in the west sub-region. | - transformation of urban public spaces in shaded relaxation areas (playgrounds, small parks, benches) | - proposal of various points of view and hearing of the landscape along the beachfront. |
| The commercial zone       | - manage the flow of traffic through the reconstruction of the road network (widening of sidewalks, bus lanes and creating temporary parking) | - preservation of existing activities                                                      |                                                                            |
| The residential zone      | - widening of sidewalks and allowing parking only on one side of the road, make pedestrian some transversal street. | - create cycle paths linking landmarks of the neighborhood, public services and the seaside |                                                                            |
| Urban squares and the vibrant neighbourhoods | - conservation of urban built typology, promoting the reconstruction of some important buildings and their connection | - back as possible of public space (sidewalks) to pedestrians, encouraging ownership by residents | - planting footpaths and squares introducing new sounds of nature such as rustling, birds singing etc. |

Fig. 18. Alikarnassos study area: Comparison SNM 2012 - NAP Population exposure to noise indices $L_{den}$ & $L_{night}$.

nuisance from aircraft noise. The Hellenic Presidency of the EU continues the relevant work for the best possible progress in favour of the European citizens especially regarding noise is a significant issue for the people living in the vicinity of airports. It is therefore important that a European agreement needs to be reached on this sensitive file by having better and more harmonized rules concerning the decision making process on noise-restriction measures.

A suitable regulation is therefore needed to ensure consistent application of the Balanced Approach to noise management as per the International Civil Aviation Organization (ICAO), aiming to strike a balance between citizens' quality of life in terms of protection from aircraft noise, and the needs of air transport.

It is expected to make the noise assessment process more robust and put competent authorities in a better position to phase out the noisiest aircraft in the fleet. Incorporation of the international rules should also reduce the risk of international disputes in the event of third country carriers being affected by noise abatement measures. Furthermore, the relevant comparative analysis, confirms that residential neighbourhoods in vicinity of airports are rather quiet, with more or less vivid activities around the shopping areas during the day, but only when airport operation is interrupted or radically reduced. However due to aircraft
operation, the area’s sonic character is covered by excessive noise emissions. With no aircraft operation, the neighbourhood changes completely and can evolve on its own.

Improvements to the strategic noise maps in future will no doubt help to improve calculation of the disease burden, using data on a reliable exposure-response relationships based on large population studies compared to the outputs from the strategic noise modelling [16]. Several tools may be successfully used, such as noise mapping tools, GIS maps tools and qualitative maps tools allowing researchers and political deciders to improve their comprehension of the city problems. It is a fresh and useful evaluation methodology tool which, considering also with other decision parameters & interventions, can fully support decision-making processes and back up difficult choices, able to improve the acoustic comfort for citizens and reduce annoyance, even though these choices may be quite severe and decisive, introducing even an airport full relocation.

References

[1] WHO-JRC “Burden of disease from environmental noise- Quantification of healthy life years lost in Europe European Centre for Environment and Health & JRC EU, 2011

[2] K. E. Vogiatzis, “Assessment of Environmental Noise due to Aircraft Operation at the Athens International Airport according to the 2002/49/EC Directive and the new Greek National Legislation”, Applied Acoustics 84 (2014) 37–46

[3] Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise, Official Journal of the European Communities L 189/12 18.7.2002

[4] ADK S.A.- N. Koletitis, Environmental noise assessment for the urban agglomerations of Herakleion & Chania (Crete island) (according to 2002/49/EC & IMD 13586/724) - final report - Ministry of the Environment - November 2013.

[5] Vogiatzis K. and Remy N., From environmental noise abatement to soundscape creation through strategic noise mapping in medium urban agglomerations in South Europe, in Science of the Total Environment journal, Editor Elsevier, 482-483 (2016), 420-431.

[6] AzB-08 "Anleitung zur Berechnung von Lärmschutzbereichen nach dem Gesetz zum Schutz gegen Fluglärm" vom 19. November 2008 in: 1. Verordnung zur Durchführung des Gesetzes zum Schutz gegen Fluglärm (1. FlugLSV) vom 27.12.2008 (BGBl. I S.2980

[7] C. Vogiatzis, et al., Rehabilitation of the acoustic environment of the city of Rhodes- INTERNOISE 2000–Nice France – August 2000

[8] C. Vogiatzis, Noise Mapping in Greece and the Psychosocial Parameters of Mediterranean Countries - INTERNOISE 2000–Nice France – August 2000

[9] Thibaud J-P. and Grosjean M. L’espace urbain en méthodes, Editions Parentheses : Marseilles, 2001.

[10] Amphoux Pascal, L’identité sonore des villes Européennes - Guide Méthodologique, à l’usage des gestionnaires de la ville, des techniciens du son et des chercheurs en sciences sociales. Tome 1: Techniques d’enquêtes. Tome 2: Répertoire de concepts, rapport de recherche n°117. Grenoble & Lauzanne: Cresson & IREC, 1992.

[11] Amphoux, Pascal, L’identité sonore des villes Européennes, opus quoted.

[12] Augoyard Jean-François, L’objet sonore ou l’environnement suspendu. Oui, entendre, écouter, comprendre après Schaeffer. Paris: Ina-Buchet Chastel,1999, p. 103.

[13] http://news.gtp.gr/2014/04/07/new-tender-kasteli-airport-crete-launch/

[14] EIA study of the New Int. Airport at Kastelli - ENVECO S.A.-TT&E S.A. March 2009

[15] Council of the European Union Presse 41 Brussels, 29 January 2014, 5839/14

Table 7. Alikarnassos Study Area: Noise Action Plan vs Strategic Noise Map 2013 Comparative population noise exposure by environment noise classes.
[16] Ioannis Karipidis, Danielle Vienneau, Manuel Habermacher, Micha Köpfli, Mark Brink, Nicole Probst-Hensch, Martin Röösli, and Jean-Marc Wunderli, Reconstruction of historical noise exposure data for environmental epidemiology in Switzerland within the SIRENE project Noise Mapping (2014); 1, pp: 3–14 DOI 10.2478/noise-2014-0002