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Miguel Arana*, Ricardo San Martin, and Juan C. Salinas

People exposed to traffic noise in european agglomerations from noise maps. A critical review

Abstract: Two of the main objectives of the European Directive on environmental noise are, firstly, to unify acoustic indices for assessing environmental noise and, secondly, to standardize assessment methodologies. The ultimate goal is to objectively and comparably manage the impact and evolution of environmental noise caused both by urban agglomerations and by traffic infrastructures (roads, rails and airports). The use of common indices and methodologies (together with five-year plan assessment required by the authorities in charge) should show how noise pollution levels are evolving plus the effectiveness of corrective measures implemented in the action plans. In this paper, available results from numerous European agglomerations (with particular emphasis on Spanish agglomerations) are compared and analysed. The impact and its evolution are based on the percentage of people exposed to noise. More specifically, it demonstrates the impact caused by road traffic, which proves to be the main noise source in all agglomerations. In many cases, the results are extremely remarkable. In some case, the results are illogical. For such cases, it can be concluded that either assessment methodologies have been significantly amended or the input variables to the calculation programs have been remarkably changed. The uncertainty associated with the results is such that, in our opinion, no conclusions can be drawn concerning the effectiveness of remedial measures designed within the action plans after the Directive's first implementation Phase.

Keywords: Traffic noise; Noise map; Exposed population; European agglomerations.

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***Corresponding Author: Miguel Arana:** Acoustics Laboratory, Physics Dept, Public University of Navarre, Campus de Arrosadia, 31006 Pamplona, Navarre, Spain, E-mail: marana@unavarra.es; Tel.: +34 948169568; Fax: +34 948169565
Ricardo San Martin, Juan C. Salinas: Acoustics Laboratory, Physics Dept, Public University of Navarre, Campus de Arrosadia, 31006 Pamplona, Navarre, Spain

1 Introduction

The European Parliament and the Council of the European Union adopted the Directive 2002/49 [1] relating to the assessment and management of environmental noise. On a prioritised basis, the Directive aims at providing a common approach to avoid, prevent or reduce the harmful effects, including annoyance, due to exposure to environmental noise. The Directive introduces the noise indices L_{den}, L_{day}, $L_{evening}$ and L_{night}(L_{den}, L_d, L_e and L_n); the concepts of *agglomeration*, *major road, railway and airport*; as well as *noise mapping* and *action plan*. The Directive articulates the assessment methods and their timing for the purpose of strategic noise mapping and their corresponding action plans. This implies the use of harmonised indicators and evaluation methods, as well as criteria for noise-mapping alignment.

The Directive has been transposed to the law in each European country. In the case of Spain, it is referred to as the Law 37/2003, or the Noise Law [2]. The Royal Decree 1513/2005 [3] was the first implementation of the Noise Law. It regulates drawing up strategic noise maps and adopting action plans to prevent and reduce environmental noise. Royal Decree 1367/2007 [4] completed the development of the Noise Law. It outlines the noise and vibration indices, establishing the different types of acoustic areas and easements as defined in the Noise Law. It also defines the objectives of acoustic quality for each acoustic area and, finally, the procedures and assessment methods concerning noise and vibration. In the case of Italy, the national Decree n.194/2005 [5] transposed the END Directive. Italy, however, had a very detailed national legislative structure, based on Framework Law n.447/1995 [6] and their corresponding implementation decrees.

The Directive provides a timetable for delivering phases and publishing results. The production of the strategic noise maps involved two stages. The deadline for results submission was December 2007 for Phase I (Data Flow 4), and December 2012 for Phase II (Data Flow 8). Some Member States have completed the Phase II data delivery while others have not yet completed. Results and analyses presented in this work were based on information available in August 2013. Data were collected from three main sources: the European Environment Information and Observation Network (EIONET) [7], the Communication and Information Resource Centre for Administrations, Businesses and Citizens (CIRCABC) [8], and the Information System on the Acoustic Pollution in Spain (SICA) [9]. Despite beginning the administrative procedures, there are still a great number of agglomerations that will not complete their acoustic maps before 2015. In the case of Spain, 38 of the 60 agglomerations have not completed their acoustic maps by August 2013.

Over the last few decades, many research projects had been conducted on different aspects of noise pollution. Many agglomerations ran measurement campaigns to quantify their noise pollution levels [10–12]. Some studies revealed a decrease in the urban noise pollution levels [13, 14]. In addition, the literature provided much evidence [15–19] on the harmful effects of noise on human, both physiological and psychological (e.g., annoyance, sleep disturbance, stress). More specifically, the connection between environmental noise and cardiovascular disease have become clear [20, 21]. The effect of noise on health depends not only mainly on the long-term exposure to sound pressure levels, but also the types of noise source. Annoyance studies have shown that aircraft noise is perceived as more annoying than road traffic noise of the same average noise level [22, 23]. The noise exposure levels in many urban areas seem to be considerably greater, both during the daytime and at night-time, than the limits recommended by the World Health Organisation [24]. These limits are regarded as the levels above which exposure to noise is detrimental to human health. The majority of people in the European Union, the United States, and elsewhere in the world are typically exposed to environmental noise (L_{den}) of between 50 and 60 dB [25]. For instance, it was found that 90.2 % of the central Dublin residents were exposed to night-time noise levels of over 45 dBA [26]. In a study carried out in Fulton County, Georgia in USA [27], it was concluded that 28 % of the residents were exposed to daytime noise levels over 55 dBA and 32 % were exposed to night-time noise levels over 50 dBA. As a final example, it was found that a 13 % of the population in the agglomeration of Pamplona, Spain, were exposed to night-time noise levels over 55 dBA and 15.1 % were exposed to L_{den} noise levels over 65 dBA [28]. In all the aforementioned studies, the main noise source was road traffic noise.

2 Material and methods

The agglomerations that have produced a strategic noise map (Phase II) in Spain are listed with demographics in Table 1. Alicante, Bilbao, Málaga, Murcia, Pamplona, and Valencia also produced maps in Phase I. More than 5.5 million people have been evaluated, representing 12 % of the entire Spanish population.

The municipal government was the authority in charge in 20 agglomerations while in two cases, this fell into the Autonomous Community government. The delimitation of the agglomeration was carried out in line with the criteria established under the Spanish law [3]. Pursuant to the requirements to produce noise maps, only the total number of inhabitants living in the agglomeration (based on the last population census) would be taken into account. To identify sectors in the territory of concern, at least the following criteria about proximity and population density should be applied: a) sectors of the territory with a population density of 3,000 inhabitants or more per square kilometer, b) residential areas far away from one another equal to or lower than 500 m. It should be noted that bystander population could be taken into account, if there were important seasonal variations. However, none of the Spanish agglomerations had considered this option.

From the total number of agglomerations listed in Table 1, engineering companies produced the maps in 15 of the cases. In four of the cases, maps were created by university research groups. In three of the cases, maps were drawn up by in-house experts from the municipal government. The commercial software used was Cadna (10), SoundPlan (6), or Predictor (3); in the three remaining cases, the software used was not reported. As a general practice, the simulation parameter figures (e.g., reflection order, type of pavement, size of the grid) used to calculate the maps were not specified in details in the reports. As exceptions to this general practice, Albacete, Almería, Badajoz and Pamplona reported using a reflection order of 1, while Bilbao and Leganés used an order equal to 2. The reflection order was not mentioned in the report from the other agglomerations. For grid size, only Albacete, Almería, Badajoz, Elche, Leganés, and Pamplona used a grid size of 10×10 m, while Bilbao and Cartagena used 5×5 m. The grid size was not indicated in the rest.

The reports did not provide detailed descriptions of the methods used to calculate the percentage of people exposed to noise. Only one case (Pamplona) pointed out that the evaluation was carried out through a facade map. The remaining agglomerations reported either vaguely on the method of calculation or nothing at all. It was plausible to

Table 1: Strategic noise maps in Spain (Agglomerations). Phase II.

Agglomeration	Size (km^2)	Population	EU code
A Coruña	36.83	247,482	ES_a_ag_45
Albacete	29.00	165,443	ES_a_ag_44
Alcobendas	27.70	111,882	ES_a_ag_36
Alicante	46.60	328,441	ES_a_ag_1
Almería	25.25	165,612	ES_a_ag_30
Badajoz	20.90	126,177	ES_a_ag_49
Bilbao	40.65	352,402	ES_a_ag_5
Burgos	55.40	180,561	ES_a_ag_21
Cádiz	4.40	124,530	ES_a_ag_26
Cartagena	22.70	122,796	ES_a_ag_43
Castellón	107.00	181,243	ES_a_ag_33
Elche	29.40	215,290	ES_a_ag_50
Leganés	43.09	186,066	ES_a_ag_40
León	39.00	132,744	ES_a_ag_22
Móstoles	45.36	206,031	ES_a_ag_41
Málaga	46.00	575,322	ES_a_ag_9
Murcia	886.00	442,064	ES_a_ag_10
Pamplona	134.12	317,142	ES_a_ag_19
Salamanca	27.42	158,823	ES_a_ag_23
San Sebastián	60.73	185,512	ES_a_ag_47
Valencia	134.65	799,188	ES_a_ag_15
Vitoria	276.80	240,900	ES_a_ag_48

infer from the reports that the evaluation was carried out using only data from grid maps (at the height of 4 m). None seem to have followed the Working Group recommendations [29] for implementing the Directive with regard to this issue.

Results from many other European agglomerations have also been analysed, particularly in 149 cities from 18 countries. The list of agglomerations is shown in Table 2.

Finally, a comparative study of the results between Phases I and II was carried out. In accordance with the Directive, strategic noise maps produced by the agglomerations in Phase I must be updated every five years. A comparison between the two phases has been carried out for the 31 agglomerations where data were available.

3 Results

3.1 Spanish agglomerations

The percentages of people exposed to traffic noise in the Spanish agglomerations are shown in Figures 1 and 2, for the L_{den} and L_n indices respectively. The agglomerations are listed in the order from lowest to highest percentage of population affected by noise level > 60 dBA for L_{den} and > 50 dBA for L_n. Great variability can be observed among agglomerations in the results. For extreme cases, neither the urban morphology nor traffic volumes were able to explain such great differences.

Contradictions were found after detailed data analysis. The L_{den} index is calculated using expression 1. Even imposing that L_d and L_e levels are equal to zero, a minimum ratio between L_{den} and L_n is obtained, shown in expression 2. Expression 2 not only indicates that the L_{den} index is always above L_n; but it also indicates that if a percentage of people is above a certain level of L_n, the same percentage should at least be at the level marked by the L_n plus 5 dBA at the L_{den}.

$$L_{den} = 10 \times Log \frac{1}{24}(12 \times 10^{\frac{Ld}{10}} + 4 \times 10^{\frac{Le+5}{10}} + 8 \times 10^{\frac{Ln+10}{10}})\,(dBA) \quad (1)$$

$$L_{den} \geq Ln + 5\,(dBA) \quad (2)$$

A ratio has been calculated relating the percentage of the affected people above 55 dBA in L_{den} and above 50 dBA

Table 2: European agglomerations. Phase II.

Country [No. of aggl.]	Agglomerations
Austria (AT) [1-3]	Graz, Linz, Innsbruck
Belgium (B) [4]	Brugge
Bulgaria (BG) [5-7]	Burgas, Ruse, Pleven
Denmark (DK) [8-11]	Kobenhavnsomradet, Arhus, Odense, Aalborg
Estonia (EE) [12-13]	Tallinn, Tartu
Finland (FI) [14-21]	Helsinki, Espoo, Tampere, Vantaa, Turku, Oulu, Lahti, Kauniainen
France (FR) [22-31]	Angers, Besancon, Dijon, La Rochelle, Poitiers, Reims, Thionville, Troyes, Fort de France, Montbeliard
Germany (DE) [32-67]	Stuttgart, Mannheim, Karlsruhe, Freiburg, Heidelberg, Heilbronn, Ulm, Pforzheim, Reutlingen, Berlin, Potsdam (Kerngebiet), Hansestadt-Rostock, Hannover, Braunschweig, Osnabrück, Oldenburg, Göttingen, Hildesheim, Düsseldorf, Moers, Bonn, Aachen, Bergisch-Gladbach, Bottrop, Gelsenkirchen, Recklinghausen, Leverkusen, Münster, Saarbrücken, Dresden, Leipzig, Chemnitz, Halle (Saale), Magdeburg, Kiel, Lübeck
Iceland (IS) [68]	Reykjavik
Ireland (IE) [69-70]	Dublin, Cork
Lithuania (LT) [71-75]	Vilnius, Kaunas, Klaipeda, Siauliai, Panevezys
Luxembourg (LU) [76]	Luxembourg
Malta (MT) [77]	Malta
Norway (NO) [78-82]	Oslo, Bergen, Trondheim, Stavanger, Fredrikstad
Poland (PL) [83-114]	Bydgoszcz, Gdańsk, Kraków, Warszawa, Łódź, Lublin, Bielsko-Biala, Bytom, Chorzów, Częstochowa, Dąbrowa- Górnicza, Elbląg, Gdynia, Gliwice, Gorzów-Wielkopolski, Koszalin, Legnica, Olsztyn, Opole, Płock, Ruda-Śląska, Rybnik, Rzeszów, Sosnowiec, Toruń, Włoclawek, Zabrze, Zielona-Góra, Poznań, Kalisz, Kielce, Tychy
Romania (RO) [115-116]	Oradea, Galati
Spain (ES) [117-138]	A Coruña, Albacete, Alcobendas, Alicante, Almería, Badajoz, Bilbao, Burgos, Cádiz, Cartagena, Castellón, Elche, Leganés, León, Málaga, Móstoles, Murcia, Pamplona, Salamanca, San Sebastián, Valencia, Vitoria
Switzerland (CH) [139-149]	Winterthur, Zurich, Bern, Olten-Zofingen, Baden-Brugg, Lausanne, Geneva, Lucerne, Basel, St. Gallen, Lugano

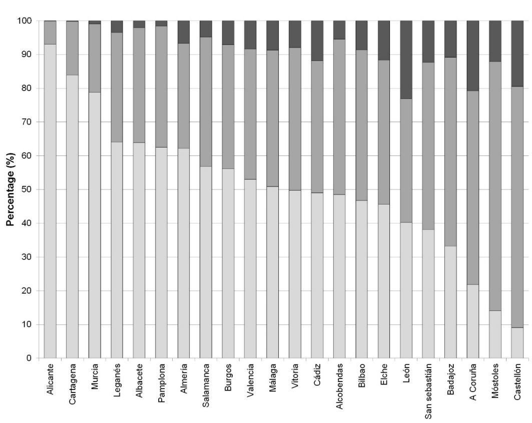

Figure 1: Percentage of people affected by traffic noise (L_{den}) in the Spanish agglomerations, arranged in ascending order of proportion of people affected by Lden > 60 dBA.

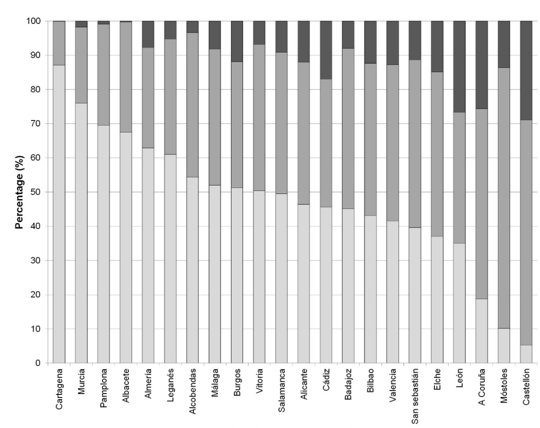

Figure 2: Percentage of people affected by traffic noise (L_n) in the Spanish agglomerations, arranged in ascending order of proportion of people affected by L_n > 50 dBA.

in L_n, as shown in Figure 3, to all Spanish agglomerations. One of the agglomerations has a ratio of less than 1, suggesting that the percentage of exposure for L_{den} and L_n are incompatible since the ratio must always be greater than unity.

3.2 European agglomerations

As seen in Figure 4, the average percentages of the population (only for countries where two or more strategic noise maps had been created) affected by traffic noise in

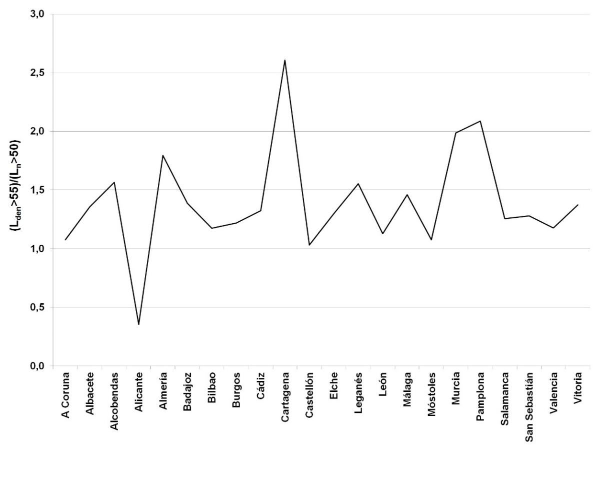

Figure 3: The $(L_{den} > 55)/(L_n > 50)$ ratio for all Spanish agglomerations.

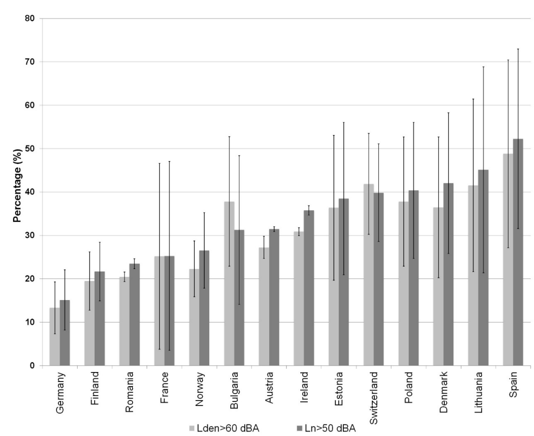

Figure 4: Percentage of the population exposed to traffic noise (L_{den} > 60 dBA and L_n > 50 dBA) in European countries (agglomerations). Error bars show the standard deviation among cities within the country.

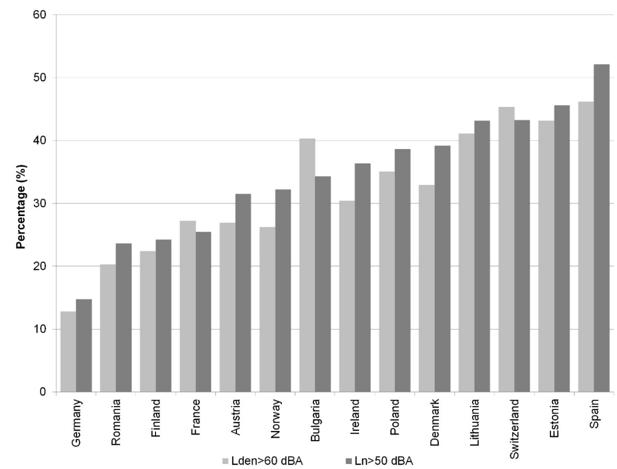

Figure 5: Percentage of the population (considering the total population of the agglomerations where strategic noise maps were realized) exposed to traffic noise in European countries.

European agglomerations, by agglomeration, vary among cities within the same country. The remarkable aspect of this graph is the level of dispersion for some countries. Countries such as Spain, France and Poland show high variability, while Germany has low variability. The average percentages of the exposed population (considering the total population of the agglomerations where strategic noise maps had been carried out) each country are shown in Figure 5, which provides a more realistic average exposure than the data shown in Figure 4. It can be clearly seen that Germany, on average, has the lowest exposure levels, while Spain is one of the countries with the highest exposure levels.

As previously shown, the ratio of $(L_{den} > 55)/(L_n > 50)$ should be greater than unity. This ratio was used to identify potential inconsistencies in the results. Another ratio of interest is the percent population exposed to day-evening-night levels (L_{den}) above 65 dBA compared to the percent exposed to night-time levels (L_n) above 55 dBA. This difference of 10 dB is assumed by the Lden index as a penalty for night levels compared to daytime levels. The daytime traffic volumes in European agglomerations is often ten times higher than that of the night-time. Moreover, in the absence of data on hourly traffic distributions, the most widely used prediction programs (i.e., Cadna and SoundPlan) provide an hourly distribution similar to this ratio. Therefore, the ratio will be defined (Eq. 3) as

$$R_{L_{den},L_n} = \frac{\%\text{population affected by } L_{den} > 65dBA}{\%\text{population affected by } L_n > 55dBA} \quad (3)$$

Values close to unity indicate that the noise levels approximately follow the pattern suggested by the L_{den} index, where L_n is 10 dB less than L_d. Values much greater than unity (e.g., > 1.5) indicate that discomfort is most noticeable during daytime. Similarly, small ratios (e.g., < 0.5) suggest that annoyances are more remarkable during night-time. Although leisure activities may contribute to increasing traffic noise levels in nightlife areas, it is not appropriate to compare R_{L_{den},L_n} against the ratio calculated using the leisure night-time noise levels since road traffic is the only noise source of concern.

The ratios of $(L_d > 65)/(L_n > 55)$ for the Spanish agglomerations are illustrated in Figure 6. Although not required by the Directive, the exposed population was calculated for the day and evening periods in the reports by the Spanish agglomerations. In general, reports from agglomerations in other European countries only evaluated data for the L_{den} and L_n indices. High values (above 1.5) indicate

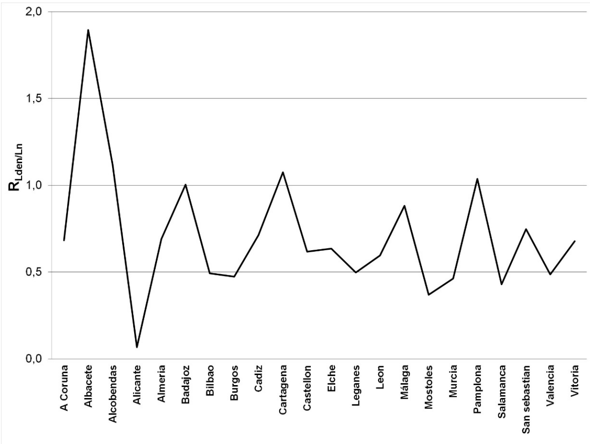

Figure 6: The $R_{Lden/Ln}$ = $(L_d > 65)/(L_n > 55)$ ratio for each Spanish agglomeration.

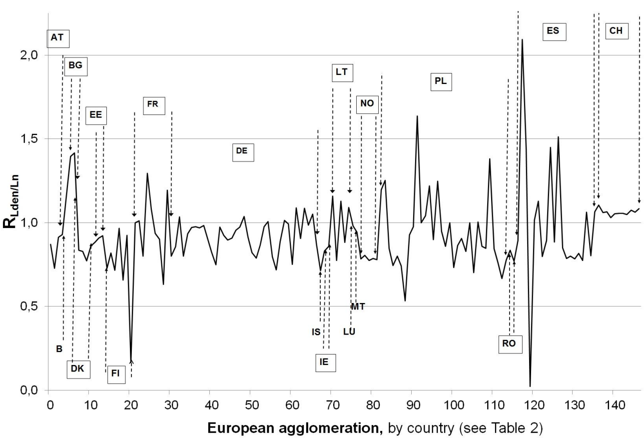

Figure 7: The $R_{Lden/Ln}$ = $(L_{den} > 65)/(L_n > 55)$ ratio for European agglomerations (by country).

that annoyance occurs mainly during the daytime period (both day and evening), whereas low values (below 0.5) suggest that annoyance occur mainly at night. This can be checked by looking at the outlier cases in Figures 1, 2 and 3. The $(L_{den} > 65)/(L_n > 55)$ ratios for all other European agglomerations analysed are demonstrated in Figure 7, as sorted by country. It outlines variability among the values of the $(L_{den} > 65)/(L_n > 55)$ ratios for the Spanish, Polish and, to a lesser extent, French cities. On the other hand, such values are very close to one for all the Swiss cities. For the Swiss agglomerations, lower annoyance during the night-time period can be identified.

The difference in the variability of the $R_{Lden/Ln}$ ratios between the German and Spanish agglomerations has led to more detailed analysis on the percent population exposed to traffic noise. The percentages of the population exposed to traffic noise have been evaluated, grouped by increments of 5 dB in L_{den} in Figure 8, for both German

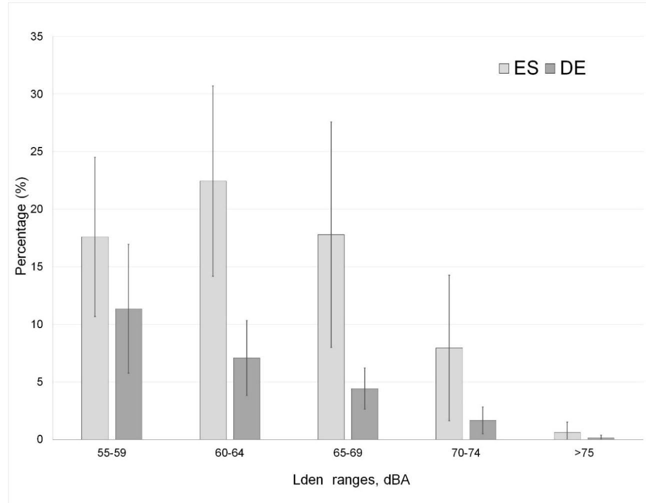

Figure 8: Comparison of the average percent population exposed to traffic noise, by L_{den} ranges, in the Spanish (ES) and German (DE) agglomerations. Error bars indicate one standard deviation.

and Spanish. It is already shown in Figure 5 that annoyance due to traffic noise is much higher in the Spanish cities. However, as seen in Figure 8, the majority of the German agglomerations follow a similar trend while this does not happen in Spanish cities, where the trend presented is more than a little odd. This behaviour can be explained as follows. The German data were based on the national method of population distribution [30]. In most Spanish agglomerations, the exposed population percentage had been evaluated from the grid map at a height of 4 m. The term "most exposed façade" was interpreted as building instead of dwelling. Subsequently, the most exposed façade level is assigned to all dwellings in the building. As stated in the WG-AEN Position Paper (Toolkit 21), when the position of the dwellings within a residential building is unknown and the levels calculated at grid points around the buildings are used (assigning the highest overall level at any façade of the building to each dwelling within the building as its “most exposed façade” level), both the complexity and the cost of the calculation is low but, in contrast, the inaccuracy is high, greater than 3 dB [31]. Several studies [32–34] have shown that considerable differences are observed on the number of people exposed to different noise levels ranges, depending on the assessment methodology.

3.3 Comparison between Phases I and II

The percentages of population exposed to traffic noise, both for L_{den} and L_n, from the 31 European agglomerations for which data are available are compared in Table 3. In some cases, the differences between Phase I and II are so great that it may suggest considerable inconsistency either in the calculation methodologies or in input data from mainly traffic flows. In addition to the former, it is reasonable to conclude that such large divergences on the population affected by traffic noise between Phases I and II may be due to the different method used for the delimitation of the agglomerations. For example, some agglomerations have noticeable differences both in geographical size and in population between Phases I and II.

4 Discussion

Many factors can influence the quality of the results, and therefore good practices in the methodology are needed to improve the quality of output [35]. The major methodological differences in the process of developing strategic acoustic maps are summarized below.

- Quality and coverage of the noise source data: in many cases, the default data are often used instead of real-life scenario data (e.g., extrapolated traffic flows, speed limit for realistic averaged speed of vehicle fleet, standard flight tracks rather than radar based movements);
- Quality of geographical and topographical data: for example, mapping with 5 m accuracy in elevation is insufficient and may drastically change the evaluation of the percent population affected by traffic noise [36]. In order to achieve accuracy in acoustic simulations, a mapping accuracy of 0.5 m in elevation is desired and perfectly feasible with currently available techniques;
- Methods of assigning noise levels to buildings: the method selection to estimate noise exposure of inhabitants is crucial for planning actions of effective noise mitigation. The best approach to calculate the percent population exposed to traffic noise is through a facade map. The simple method to consider only the noise level at the grid point closest to the building may seem suitable and informative to the public, but it is not appropriate for epidemiological studies or definition of action plans [32, 34].

With regard to the definition of 'agglomeration', different criteria are used in the EU Member States to define and demarcate agglomerations. The criterion of the population density may range from 500 people/km^2 in the UK to 3,000 people/km^2 in Spain. The criterion of maximum distance between residential areas, aggregated as continuous "urban area" or agglomeration, may range from 200 m in the UK to 500 m in Spain. In accordance with the European Directive, each Member State can determine specific criteria for the definition of agglomeration. Based on the concern of standardizations, would it be desirable to establish certain minimum criteria that all Member States should make use in the determination of agglomerations? This question remains open. Moreover, is it unachievable to consider the entire population in the exposure to environmental noise? In a recent remarkable research study, noise exposures for the entire Swiss population (7.9 million inhabitants) from road, railway and air traffic was estimated separately through calculations at the facade points [37].

Despite different methodologies applied in European cities, a recent study [38] has shown that it is possible to rate noise pollution by using the revised G_{den} and G_{night} indicators, which appear strongly related to the highly annoyed population. In addition, they also allow comparisons among agglomerations that are heterogeneous in size. Some European projects working in the field of strategic noise maps are contributing to the implementation and revision of Environmental Noise Directive 2002/49/EC. For instance, the HUSH project (Harmonization of Urban Noise reduction Strategies for Homogeneous action plans [39]) has proposed a pattern of a homogeneous and harmonized action plan, integrated with the Italian noise management tools [40]. One of the goals of the NADIA project (Noise Abatement Demonstrative and Innovative Actions and Information to the public [41]) is to demonstrate the technical and economic feasibility and the effectiveness of best practices to reduce road traffic noise levels, using noise mapping activities. Different procedures used in the noise maps of eight important roads have allowed the creation of noise maps using different levels of input data [42]. As a last example, the main idea of the HARMONICA project (HARMOnised Noise Information for Citizens and Authorities [43]) is based on the fact that the general public finds it difficult to understand the standard acoustic indicators as expressed in decibels, hence limiting the suitability of the project. The partners in this project have been working on a proposal to create new indices that are closer to what the population perceive. Four proposals of indices have been developed, based on different approaches, but all integrating both the continuous and the sporadic nature of noise [44].

It is reasonable to expect that the common framework for noise assessment methods (CNOSSOS-EU [45]) will represent a harmonised and coherent approach to address and assess noise levels from the major sources (i.e., road traffic, railway traffic, aircraft, and industrial) across Eu-

Table 3: Comparison of percentages of the population exposed to traffic noise (L_n > 50 and L_{den} > 60 dBA) between Phases I and II in European agglomerations. Area in km^2.

		Phase I				Phase II			
Cou.	**Agglomeration**	**Pop.**	**Area**	**Ln>50**	**L_{den}> 60**	**Pop.**	**Area**	**Ln>50**	**L_{den}> 60**
DK	**Copenhagen**	1071714	400	45.7	32.0	1163000	670	39.0	32.3
EE	**Tallinn**	401140	159	9.0	7.4	406703	159	50.2	47.5
FI	**Helsinki**	560905	186	28.9	26.8	570578	215	32.4	30.7
DE	**Aachen**	256486	161	19.4	17.5	260454	161	36.7	31.3
	Berlin	3332249	889	15.7	12.9	3460725	892	13.4	11.3
	Bonn	311231	141	26.4	22.7	327913	141	15.1	12.1
	Dresden	456000	150	15.7	12.9	495800	186	15.4	12.7
	Düsseldorf	571150	217	19.9	18.7	592393	217	23.3	20.6
	Gelsenkirchen	271267	105	7.2	13.3	256652	105	20.6	16.4
	Hannover	555862	238	16.9	14.2	520000	204	16.1	14.4
	Karlsruhe	300134	173	13.7	11.4	288917	174	16.6	12.9
	Kiel	292933	189	8.2	7.1	253319	189	8.9	8.3
	Leipzig	350000	132	13.0	13.2	522882	297	9.7	9.8
	Stuttgart	600700	211	10.7	9.7	581858	207	13.1	11.3
IE	**Dublin**	1150000	1163	82.9	73.6	1273100	908	36.5	30.2
LT	**Kaunas**	378943	157	38.8	28.8	311148	157	65.0	56.9
	Vilnius	553904	400	35.1	22.4	554100	401	28.6	30.9
NO	**Oslo**	822800	-	29.4	25.8	906318	1003	40.0	31.6
PL	**Bydgoszcz**	355085	179	53.5	53.5	357650	176	38.7	44.9
	Gdańsk	459072	262	39.2	47.9	456591	262	29.3	33.0
	Gdynia	253193	135	55.3	55.3	247859	135	36.9	40.6
	Kraków	1410000	327	17.0	15.2	755000	327	24.6	21.3
	Łódź	764100	294	11.5	13.2	742387	293	53.6	44.5
	Lublin	353500	147	48.3	29.1	349440	148	45.7	38.7
	Poznań	564035	216	15.1	11.3	554221	262	58.9	51.2
	Warsaw	1700536	512	71.7	67.0	1714446	517	32.9	26.6
RO	**Galati**	298861	242	36.5	30.8	292898	246	24.3	19.7
ES	**Alicante**	320021	40	73.7	69.6	328441	47	53.6	6.9
	Murcia	436000	881	14.5	13.2	442064	886	24.0	21.2
	Pamplona	280199	127	42.8	45.6	317142	134	30.4	37.5
	Valencia	807396	135	79.2	73.8	799188	135	58.4	47.0
	TOTAL	**20239416**		**33.8**	**30.0**	**20103187**		**30.4**	**25.9**

rope. Based on the state-of-the-art knowledge, it will be the result from an intensive collaboration and the exchange of data and experiences through a formal process on both policy and scientific and technical levels [46].

5 Conclusions

A comprehensive analysis has been performed on the results concerning the percent population exposed to traffic noise from the Phase II strategic noise maps in European agglomerations, with particular emphasis on the Spanish agglomerations. Wide variability was observed in the percentages of the population exposed to traffic noise in the Spanish agglomerations. In one specific case, incompatibility was found between exposure levels for the L_{den} and L_n indices. Comparing across all European agglomerations with available data, Germany has the lowest exposure to traffic noise and Spain the highest.

More details should be given both on the input data and on calculation parameters in the reports of strategic noise maps, at least in the case of Spain. In the reports issued by Spanish agglomerations, it is necessary to emphasize the reflection order and the methodology used to evaluate the percentage of the population exposed to noise. For example, it would be desirable to use a higher reflection order, at least of the second order, in areas with high building density. Another issue is the important seasonal variations in the population, such as several towns on the Mediterranean coast in Spain. Some coastal towns in Spain regularly exceed 100,000 residents in the summer months, increasing the traffic density for several roads to be designated as major roads during the specific period. Nevertheless, none of the Spanish towns with such seasonal characteristics had created strategic noise maps, suggesting underestimation in the exposure to traffic noise.

Results from Phases I and II in the 31 European agglomerations examined in this study have also been compared. Some agglomerations experienced significant change in the exposure levels, either increased or decreased drastically. The large and controversial differences can only be explained by either a qualitative change in the map calculation methodology or the inconsistency of input data in the calculation programs. In our opinion, all the above results and discussions will contribute to the improvement and harmonization of procedures to estimate the noise exposure among the population.

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