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NOISE MAP OF PAMPLONA, SPAIN. MAIN RESULTS.

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Abstract
According to the requirements of the European Noise Directive, *END*, as well as to the date of the Spanish Noise Law, the noise map of the Agglomeration of Pamplona has been carried out. The calculation area was 127 km^2 with a total population of 280,200 people. Receiver points were located on the corners of a grid 10x10 meters size.

With regard to people affected by noise, some doubts remain in relation to the method of calculation. From the method used in this work-noise level at the nearest grid point from the façade- 9% of people bear an Ld equal or greater than 65 dBA and 13% people bear an Ln equal or greater than 55 dBA. According to the limits stated in the new Spanish Law-RD 1367_2007, 60 dBA for Ld and 50 dBA for Ln- those percentages increase up to 37% and 44%, respectively.

Keywords: Noise mapping, END, prediction, GIS, nuisance.

1 Introduction

The European Directive 2002/49/EC (*Environmental Noise Directive* [1], henceforth END) states common assessment methods for environmental noise and a definition for 'limit values', in terms of harmonised indicators for the determination of noise levels. It is obvious that the Treaty objectives of achieving a high level of protection of the environment and of health will be better reached by complementing the action of the Member States with a Community action achieving a common understanding of the noise problem. Data about environmental noise levels should therefore be collected, collated or reported in accordance with comparable criteria. This implies the use of harmonised indicators and evaluation methods, as well as criteria for the grid sizes in noise-mapping. According to END definitions, an 'agglomeration' means part of a territory, delimited by the Member State, having a population in excess of 100,000 persons and a population density such that the Member State considers it to be an urbanised area. According to Article 7 of END, Member States shall ensure that no later than 30 June 2007 strategic noise maps showing the situation in the preceding calendar year have to be made and, where relevant, approved by the competent authorities, for all agglomerations with more than 250,000 inhabitants.

The agglomeration of the region of Pamplona takes up an area of 127 km^2 with a total population of 280,200. The official denomination for this agglomeration is 19_C_PAMPLONA. Figure 1 shows the location of Navarre in Spain as well as the location of the region of Pamplona within Navarre.

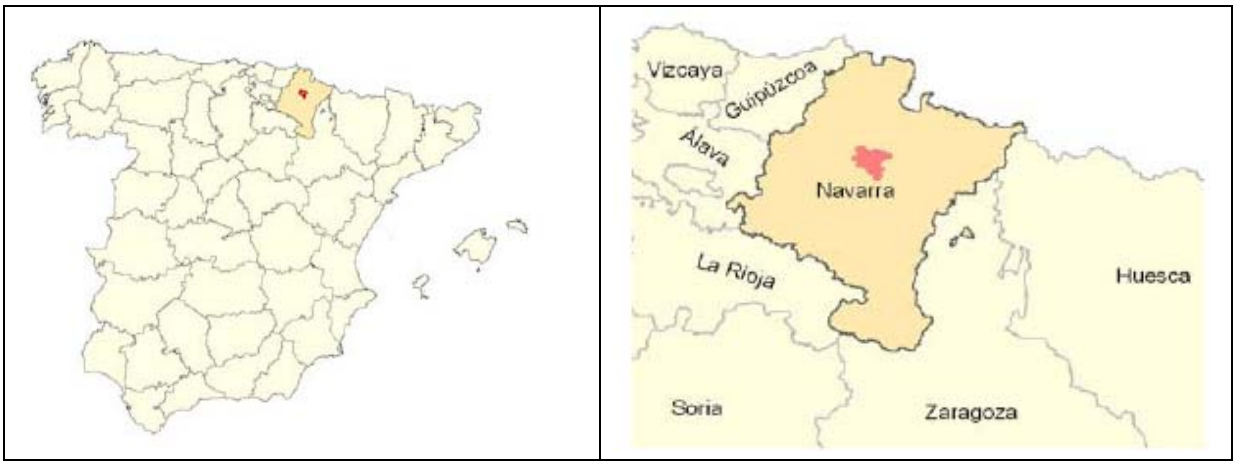

Figure 1 – Location of the agglomeration of Pamplona in Navarre, Spain.

Besides the city, the agglomeration of Pamplona includes a total of nineteen villages in their surroundings. Figure 2 shows villages surrounding the city and their area, in km^2. The external red line covers the calculation area.

There are many different environmental noise sources so the first step to elaborate a noise map is to differentiate such sources. Four types of sources were analyzed; road, railroad, industry and aircraft. The way followed was to elaborate individual noise maps by each one of the sources. Introduction of every road-which their corresponding traffic density, average speed, percentage of heavy vehicles, etc.- became tedious. A total of 7,441 roads were introduced in the model. Once individual noise maps were calculated, an energetic sum of the four maps was done in order to get the total noise map of the agglomeration.

2 Methodology

2.1 Equipment and Digital Terrain Model

The environmental prediction software Cadna/A V. 3.6.118 from Datakustik© [2] was used to calculate the noise map of the agglomeration of Pamplona. At the present time it is one of the most popular noise prediction software. Several measurements were carried out in order to compare actual noise levels with predicted noise levels, obviously under consideration of equal values for the variables: traffic density, average speed, etc. For that, two Sound Level Meters B&K type 2260 with modules BZ 7203, and two environmental stations of 01 dB type Oper@ EX+ GSM GPRS #20181 were used in the measurements.

Figure 2 – Municipalities inside the calculation area

In order to carry out the calculation, the first step is to import the needed objects to build the 3D model of the calculation area. In this case, 22,903 contour lines (iso-lines), 12,703 curve lines (different height at each point) and 39,930 elevation points were used to build the Digital Terrain Model (DTM), in which 22,272 buildings, 7,441 roads, 538 industrial sources and a railroad were placed. The z-coordinates of points ranged from 380 to 750 meters. Because the grid size chosen was 10 x 10 meters (combining precision and time) the number of points calculated was-approximately- $1{,}26 \cdot 10^6$.

2.2 Calculation parameters

The configuration of the main calculation parameters is shown in table 1. The *Raster Factor* was established in 0.5, as it is the maximum value allowed by ISO 9613-2 [3] and provides a very good time-accuracy ratio. The most critical parameter is the reflection order. In general, the chosen value (1) implies enough precision although for severely screened receiver points as well as for very narrow streets with high buildings-*canyon* configuration- differences can be large [4].

Table 1 – Configuration of the parameters.

Parameter	Value
Discretization of the sources	Raster factor = 0.5
Maximum search radius	2000 m
Lateral diffraction allowed	No
Tolerance (maximum error)	0
Grid interpolation	No
Calculate points inside buildings	No
Building absorption	0.21 (=1 dB)
Ground absorption	0.4 (mean value)
Correction limit by diffraction	25 dB
Reflection order	1
Reflection depth	Infinite – Not available
Max. search radius of reflecting surfaces	100 m
Minimum distance receiver-reflector and interpolation (for reflection)	1 m. Interpolation to 1 m.
Max. distance source-receiver and interpolation (for reflection)	1000 m. Interpolation from 1000 m.

2.3 Noise sources

2.3.1 Traffic lines

Traffic data used for the highways surrounding Pamplona (PA-30 and PA-15) were obtained from the Transport Department of the Government of Navarre. With respect to the main roads inside the agglomeration, a public sector company supported by the Pamplona City Council provided data. These were based both in measurements and predictions. Data also included both average speed and traffic composition.

For the rest of roads several criteria were implemented. One of them was to extrapolate figures obtained from measurements to other similar roads. Another criterion was to evaluate the traffic density in function on the density of population to which the road is serving. In some cases great deviations were found but a pragmatic decision was finally taken and acceptable correlations with measurements were found. Average values of Hourly Average Intensity (HAI) for the six types of roads were as follows:

Type 1. Outlying roads. Only serving to neighbours: HAI (day) = 10 v/h.

Type 2. Residential (very quiet areas). HAI (day) = 50 v/h.

Type 3. Residential. HAI (day) = 100 v/h.

Type 4. Residential-Commercial. HAI (day) = 200 v/h.

Type 5- Commercial. HAI (day) = 350 v/h.

Type 6- Industrial. HAI (day) = 200 v/h.

The hourly distribution of traffic for day, evening and night periods were obtained from data continuously recorded at 66 measurement stations. The percentages of heavy vehicles for the different types of roads were obtained from real measurements in several roads and subsequent extrapolation to similar types of roads. Several noise measurements were carried out with the aim to configure the calculation parameters according to NMPB 96 [5], mainly to adjust the type of asphalts. Correlation between predicted and measured values was quite high (differences lower than 1 dB for receiver points near to emission lines). Nevertheless, differences increased with distance.

2.3.2 Railroad

Information about timetables-leaving and arrivals- as well as about the different types of trains operating in Pamplona was given by Spanish Train Network (RENFE). Four different types of trains were introduced: Regional, Talgo, Altaria and freight trains. Railroad was divided in three segments in order to take into account different conditions of operation-accelerated, decelerated and constant speed. Several measurements were carried out with the aim of correlating measurement results with the sound power data file of the model SRM II. Results were also very satisfactory in this case.

2.3.3 Industry

Following END recommendations ISO 9613 was used, taken into account favorable conditions for the propagation model. 0, 1 and 2 values were selected, respectively, for day, evening and night periods. In order to model noise sources, both point and line sources were used. Several measurements were carried out to adjust acoustic power of sources. It was decided to assign the level L_{Aeq} in broadband for the acoustic power of the point and line sources according to the reliability of the measurement method, also influenced by limitations in time and resources.

2.3.4 Aircraft

Due to the impossibility to access to reliable data about flights information (timetables, type of planes, flight paths, etc.) the solution adopted was to convert AENA's acoustic map in pdf format to vectorial and raster format in order to integrate the aircraft noise map with the other types of sources (road, railroad and industrial). From measurements carried out along one week-continuous recording- at two receiver points, predictions satisfactorily agree with measurement results.

3 Affected people

With regard to people affected by noise previous research works relating to noise disturbance in the community [6] and noise mapping [7] were carried out. Nevertheless, such works were focused on the correlation between annoyance-data obtained from surveys- and noise level index Ldn-data obtained from in situ measurements. Now, affection of noise on population is evaluated from predictions.

According to END, the noise level at the most exposed façade of a building- 4m above the ground- is assigned to all dwellings that belong to such building. That is to say, all people living in a building are theoretically exposed to the same noise level. This procedure can actually be valid for detached or semidetached urban configuration but it could introduce errors in urban areas with high and large buildings. This is the reason why another method to evaluate affected people has been followed in this work. It consists on calculating a grid map-4 m above the ground- and assign to each dwelling of the building the level of the nearest receiver point of the grid. Results by different sources are shown in table 2 for the index Ln.

Table 2 – Number of people affected by noise in 5 dB ranges (Ln).

Range (dB)	Aircraft	Railroad	Industry	Road
<50	0	6,489	842	160,074
50 - 55	75	579	0	84,183
55 - 60	0	62	0	32,326
60 - 65	0	3	0	3,400
65 - 70	0	0	0	132
>70	0	0	0	3

It is noticeable that almost the totality of affected people is due to noise generated by road traffic. This result is clear from the noise maps showed in Figures 3 to 6.

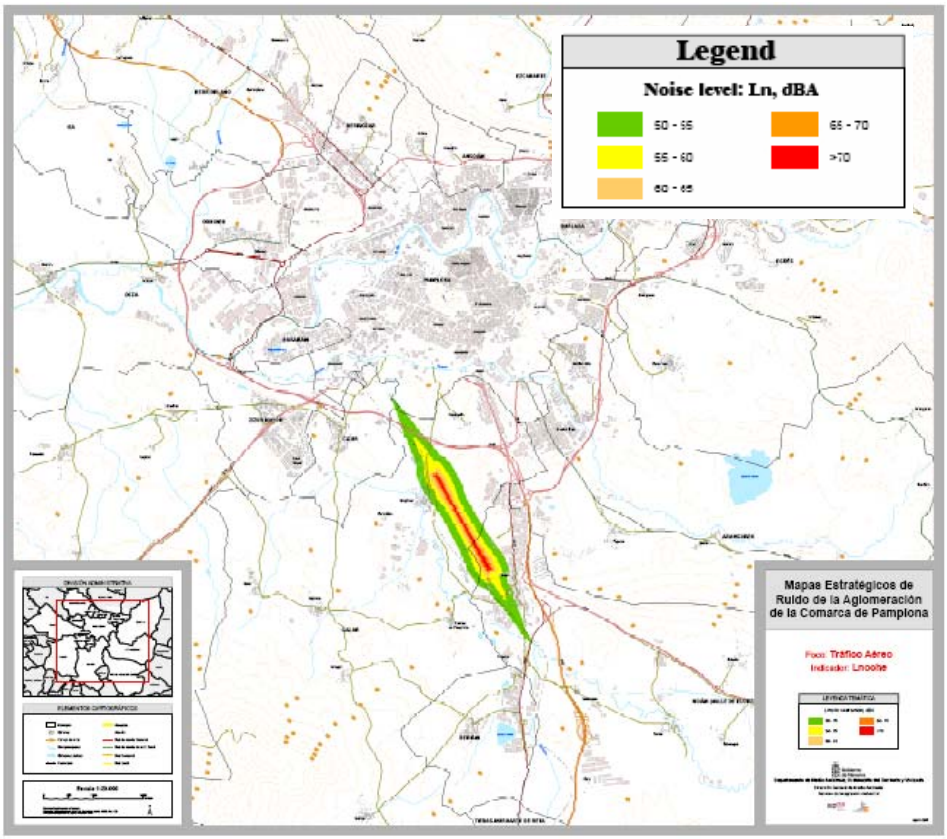

Figure 3 – Aircraft noise map

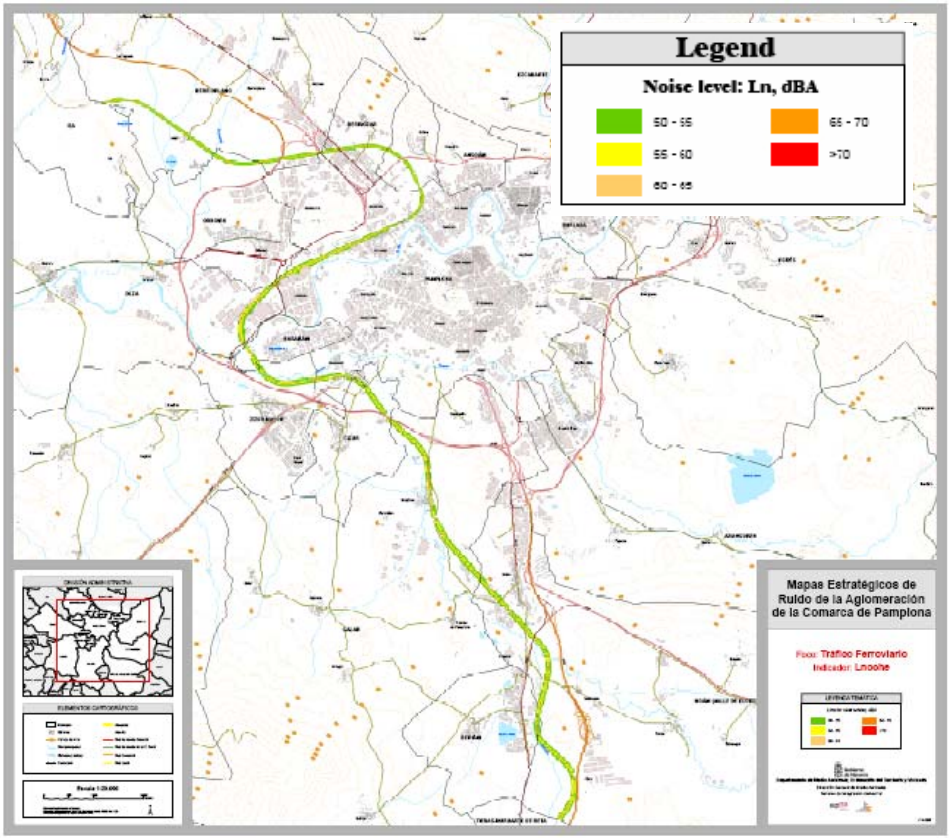

Figure 4 – Railroad noise map

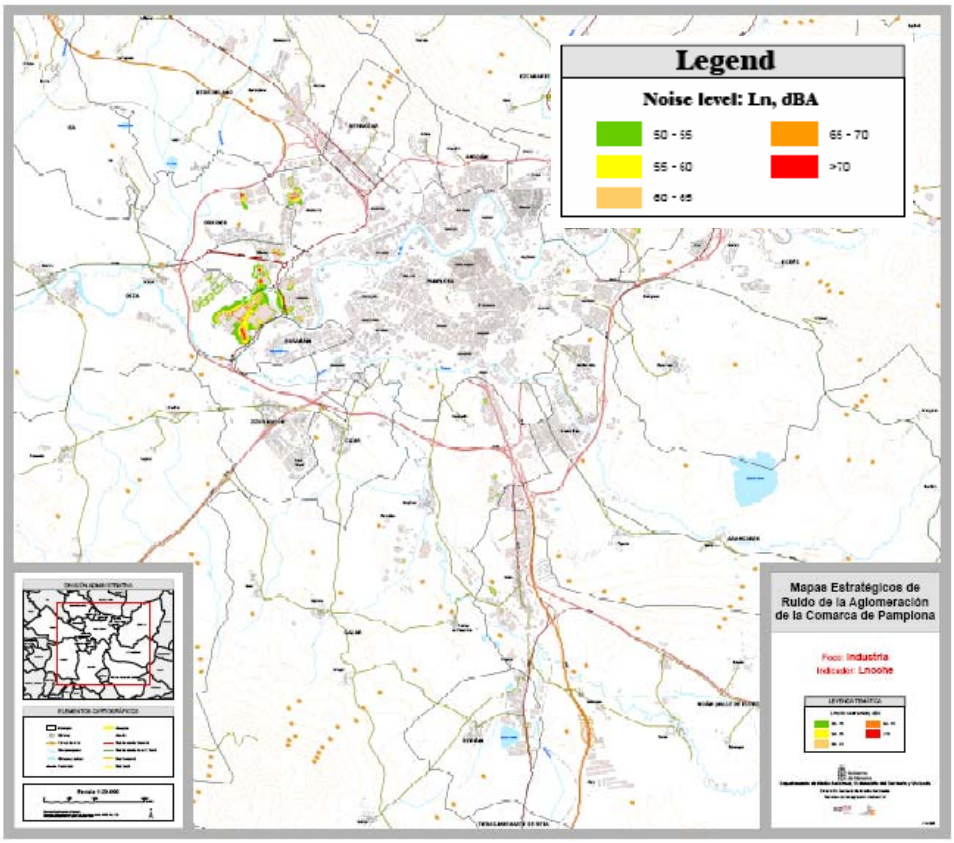

Figure 5 – Industry noise map

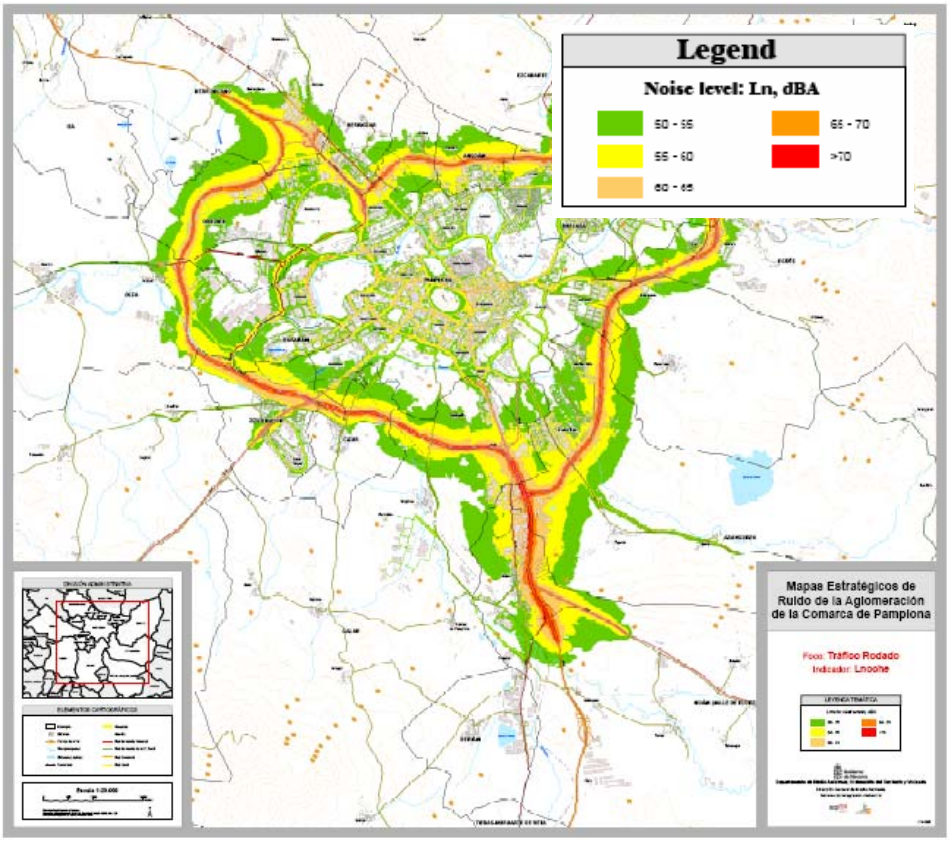

Figure 6 – Road traffic noise map

Table 3 shows the number of people affected by noise for every municipality, including Pamplona.

Table 3 – Number of people affected by noise (in 5 dB ranges) for all municipalities (Ln).

Range	1	2	3	4	5	6	7	8	9
50 - 55	768	2,392	7,007	64	3,095	7,482	104	758	4
55 - 60	78	1,010	1,195	21	1,421	1,105	11	259	
60 - 65	5	64		6	232	364		81	
65 - 70		15		1	46			6	
>70									
TOTAL	**1,305**	**5,738**	**22,123**	**340**	**8,122**	**18,123**	**576**	**3,399**	**6**

Range	10	11	12	13	14	15	Pamplona	17	18
50 - 55	40	49	899	1,460	23	315	55,974	2,967	2,186
55 - 60	34	23	288	1,376	8	21	24,752	860	358
60 - 65	6	1	24	323	1	2	2,229	14	93
65 - 70			10				48		6
>70			2				1		
TOTAL	**168**	**246**	**3,931**	**4,016**	**204**	**1,982**	**186,964**	**9,907**	**13,026**

Table 4 shows the number of people affected by noise for the 14 districts of Pamplona. All sources are considered.

Table 4. Number of people affected by noise (in 5 dB ranges) for all districts of Pamplona (Ln)

Range	1	2	3	4	5	6	7
50 - 55	922	4,392	1,763	1,590	5,361	1,043	1,958
55 - 60	277	5,167	1,108	108	985	511	923
60 - 65	64	891	334	3	73	11	9
65 - 70		4	20		6		
>70					1		
TOTAL	**1,930**	**20,379**	**7,416**	**12,149**	**18,144**	**5,227**	**5,510**

Range	8	9	10	11	12	13	14
50 - 55	8,493	3,342	3,000	3,856	8,127	4,223	7,904
55 - 60	3,994	1,836	1,402	2,559	1,754	1,052	3,076
60 - 65	49	66	184	249	86	105	105
65 - 70			18				
>70							
TOTAL	**23,647**	**11,363**	**11,364**	**13,992**	**23,377**	**11,302**	**21,164**

Finally, table 5 shows the percentage of people affected by noise according to two limit figures. 65-55 dBA for Ld/Ln respectively (Autonomous legislation in Navarre) and 60-50 dBA for Ld/Ln respectively (new Spanish legislation for future urbanizations).

Table 5 – Percentage of people affected by noise (Agglomeration of Pamplona).

% Affected people	**Ld**	**Ln**
65-55 dBA	9%	13%
60-50 dBA	37%	44%

4 Conclusions

In this work, the noise map of the Agglomeration of Pamplona – according to the requirements of the European Noise Directive – has been carried out and the percentage of people affected by noise evaluated considering two different limits stated in both Autonomous and Spanish legislation.
The evaluation method consisted on calculating a grid map-4 m above the ground- and assign to each dwelling of the building the level of the nearest receiver point of the grid. This procedure is believed to be more accurate than that suggested in END, which assigns the noise level at the most exposed façade of a building- 4m above the ground- to all dwellings that belong to such building.
Four types of sources were analyzed; road, railroad, industry and aircraft, being the first one the most influent. The results showed that 9% of people bear an Ld equal or greater than 65 dBA and 13% people bear an Ln equal or greater than 55 dBA. According to the limits stated in the new Spanish Law - 60/50 dBA for Ld/Ln - those percentages increased up to 37% and 44%, respectively.

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