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DECISION-MAKING TOOLS FOR ACTION PLANS BASED ON GIS: A CASE STUDY OF A SPANISH AGGLOMERATION

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Abstract

Among the diagnosis offered by the strategic noise maps at macro-scale level and the final implementation of the measures against noise, there are some processes within the Action Plans which have not always received adequate attention by different Spanish authorities. These processes are responsible for managing the project at micro-scale level which aims to characterize hot spots correctly, quantify the impact of every noise source in such spots and provide the best noise solutions for every case. To do so, different criteria from the action plan against noise such as urgency, feasibility, effectiveness, unwanted side effects, cost, etc., is taken into account. Considering that fighting against environmental noise can involve large investments from public funds, this multi-criteria approach can be judged as one of the keys for the project's success.

In order to systematize, this set of criteria can be integrated into a platform that assists decision-makers using relevant information. This kind of platforms can be based on GIS, integrating databases, expertise knowledge, and the stakeholders' requirements translated into logical rules, technical procedures and algorithms; this whole set is widely known as Decision Support Systems or DSS. This paper will focus on the designing of some of the tools that are part of DSS platform for road traffic noise. Finally, it includes a case study concerning a traffic management solution applied to the city of Santa Cruz de Tenerife.

Keywords: Action Plans, DSS, GIS.

1 Introduction

The adoption of the Directive 2002/49/EC [1] gives European governments the responsibility to act against environmental noise. The first step entails the diagnosis of the current environmental situation in every country. This means the development of the, so-called, Strategic Noise Maps, with a special interest in estimating the population exposed to different levels of noise. We may consider these Maps, and the noise legislative framework transposed to every country, the point of departure for tackling environmental noise. This legislative framework includes not only the noise limits criteria, but also the definition of zoning, within which these limits must be maintained.

The second part covered by the Directive concerns the designing and developing of action plans against environmental noise. We should not forget that the main objective of Noise Directive is to improve the citizens' environmental quality of life and preserve environmental noise quality wherever it is good. In this context, authorities have the responsibility to deal with noise problems, but taking into account efficiency and cost criteria. Obviously, public funds are not unlimited and it is necessary to carefully schedule a plan to obtain the best solutions for the largest number of population and in the shortest period of time. But the Action Plan Project is a dynamic process that manages to assess the consequences of established preventive and corrective measures and tries to detect future trends. It is a control system that feedbacks all the steps of the Project and requires its own indicators and alert warnings.

Every administration has tried to comply with the Noise Directive's demands, but finally, the quality of the results has been extraordinarily variable between maps. There is a direct relationship between the quality of maps and the confidence on the action plans' effectiveness based on those maps. Besides, strategic maps are created to assess the noise situation at macro scale level, while sometimes action plans are designed to solve problems detected at micro scale level.

Roughly speaking, three steps are needed to carry action plans through. We will focus on the technical phases.

1. Detecting and ranking hot spots and quiet areas.
2. Identifying and analysing the impact in such hot spots and quiet areas of the source of current and future noise problems.
3. Designing and introducing the corrective and preventive measures against noise in the short and long term.

Of course, the appropriate way to guarantee the success of the process is not straightforward. A set of tools should be created to help consultants estimate what is the best way to achieve these three steps. This set of tools creates a Decision System to assist those responsible to make decisions using a relevant data.

These structures, and other local requirements, influence the design of 2009-2010 Noise Action Plan promoted by the Canary Island Regional Government through its Environmental Agency. And this paper is intended to evaluate the pros and cons of development and application of these Decision Systems to agglomeration and major roads in Canary Island.

The Action Plan project is still running.

2 GIS-based Decision Making tools

Noise Action Plans [2] [3] [4] require a system that helps environmental consultants to analyse a great amount of spatial data, allowing a close cooperation with stakeholders in the process of decision-making. Geographic Information System or GIS is the perfect centralized platform to support this kind of projects. This platform consists of a combination of GIS functionalities, such as geo-processing tools and geo-database management, with expertise knowledge and the requirements of stakeholders translated into procedures and algorithms; this whole set is widely known as Decision Support Systems or DSS [5] [6] [7]. Simulations models are usually linked to DSS to achieve key information for the project. For Noise DSS, this relevant information is provided by noise prediction and traffic models, especially for recalculating the current situation with updated data and then assessing and validating possible short- and long-term strategies. We should not forget that, for urban planners, noise is one of the variables in urban environmental planning, among others like sustainable mobility, land-use planning and urban environmental assessment.

The DSS was designed following five principles, which guarantee the confidence in its results.

1. GIS-based, interactive and functional. Once the routines have been programmed, everyone with minimum GIS knowledge could interact with the platform obtaining information. The selection of Input data variables and calculation parameters and the presentation of outcomes are performed in an easy to understand way, for example using a noise impact indicators scientifically contrasted. Our DSS is not fully automated, but the platform systematizes some complex and iterative processes offering a multi-criteria approximation. Besides, GIS format assures the transparency and accessibility of the information generated in every step of the project for the technical responsible team of the administration.
2. Adaptive, flexible and scalable. DSS try to anticipate the casuistic integrating all possible contingences. Depending on the context identify the relevant variables to work with. Plan and demand the search for new updated information when it is not available. Always ask for information not provided to the system. Furthermore, the system is able to take into account local singularities and governments' requirements. Finally, it can address different spatial and temporal scales.
3. Robust. The system minimizes the negative impact of errors and data gaps and tries to guarantee the selection of the best solutions as possible. In spite of this, in case of a lack of valuable data, warning signals alert over the weakness of the situation. Strategic Maps is considered as the minimum information unit to develop an Action Plan, but even when a lack of data is detected the system goes ahead.
4. Continuously checkable. A Feedback loop could be customized in every stage of the project.
5. Systematically applied. Once adopted and approved, procedures that estimate objectively every stage of Action Plan process must be applied systematically. The converse means using a comprehensive approach based on experience. This non-systematic approach does not guarantee the best solutions, neither in efficiency terms, cost terms and the area's suitability.

3 Case Study: Canary Island Action Plan

The scope of Canary Island Action Plans coincides with those features previously analysed by the 2006-2007 Strategic Noise Maps, which include:

- The Islands' major roads that comply with the criteria of more than 6 millions passing-bys per year.
- The agglomeration composed by the municipalities of Santa Cruz de Tenerife and San Cristobal de La Laguna.

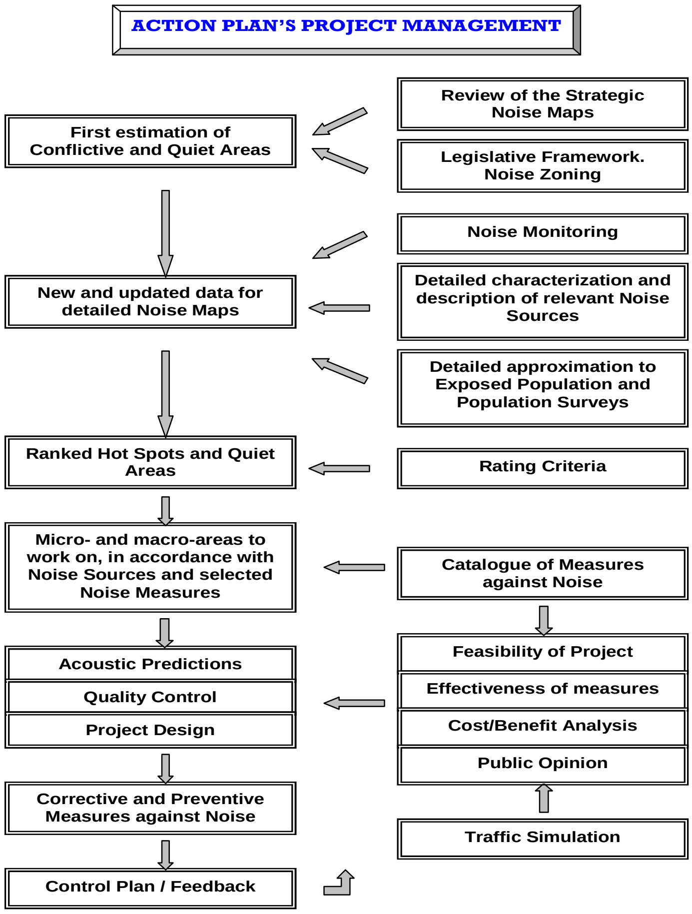


Figure 1 – Tasks planned for Action Plan Projects inside built-up areas.

The core of the action plan is a predefined flow diagram in which the sequence of activities and data management is expressed. As we claimed previously, some of these steps are programmed in GIS. Although it is a generic diagram, ultimately there are some slight differences between the configuration of tasks for major roads and for agglomerations.

The following examples involve residential buildings only. Outdoor noise limits are only applicable to those buildings inside residential noise zones. In Spain, limits for day and evening are 65dBs and 55dBs for nights. This criterion is tensed until 60/50 pair for new developments and it is expected to be the objective for all residential areas in the long-term [8].

3.1 Major Roads

Firstly, we are going to summarize the work scenario regarding highways action plans and, afterwards, we are going to establish a comparative framework with the action plan's design for the principal network inside the agglomeration. There are more automated phases included in DSS in the first case than in the second one. The measures solutions are restricted to noise barriers, porous asphalt, reduction of speed during night time and insulation. Then the conflict areas are selected following the criteria of exposed population density per road length. DSS can provide reliable decisions for these repetitive situations, but cannot respond creatively and with common sense to unusual circumstances, open situations or in complex scenarios how is demanded by agglomerations.

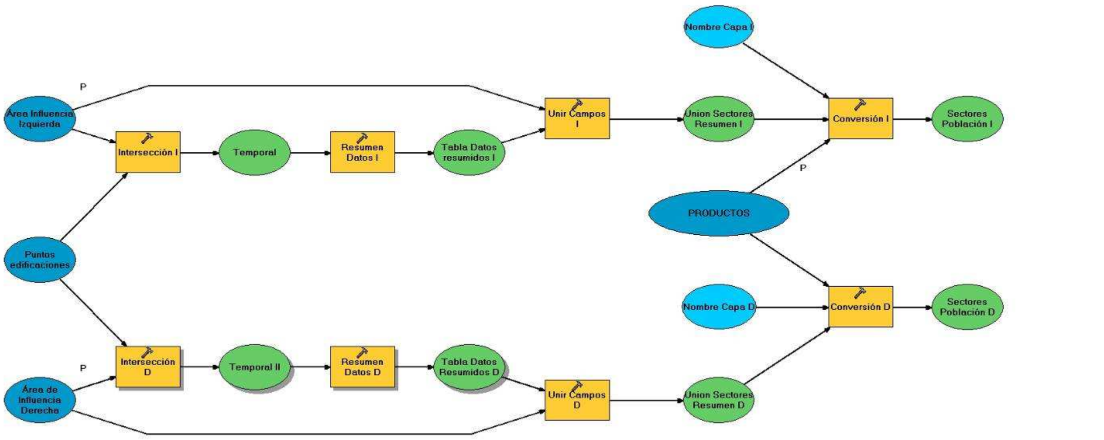
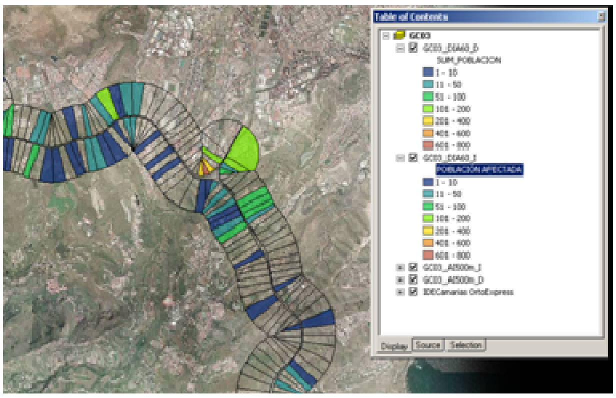


Figure 2 – GIS model to estimate the total number of people per noise level per segment of the road.

GIS-DSS is programmed to consider a 100 meters length segment longitudinally to the centre reservation of the highway. These segments marks the areas buffered on the right and on the left of the road obtaining a choropleth map. These maps provide an easy way to visualize how the density of highly annoyed inhabitants (or another noise score index) [9] [10] [11] varies from left to right along the road. Much care must be taken with this method when applied to road segments within sharp curves The DSS compares all index profiles on the right and on the left, looking for maximum index peaks when the solution is noise barriers. When barriers are not considered as a suitable solution, then, renewal of old asphalt and reduction of traffic speed are considered as the main option. This require, first, reunify the entire population on the right and on the left of road, and second, generate a sliding window of 500 meters shifted in steps of 100 meters that help to find the largest accumulated population highly annoyed over large sections of road.



POBLACIÓN AFECTADA GC-03									
LADO DERECHO					LADO IZQUIERDO				
Sector	Num Edificios	Población	Sup. Edificio	Sup. Edificio x Plantas	Sector	Num Edificios	Población	Sup. Edificio	Sup. Edificio x Plantas
GC03_D102	2	5,35	146,59	419,68	GC03_I101	1	0,290	12,606	25,212
GC03_D103	4	12,10	508,36	948,61	GC03_I103	4	146,940	3475,050	7915,460
GC03_D104	3	57,21	2332,36	4486,32	GC03_I104	1	4,700	126,544	253,089
GC03_D105	2	91,75	3597,21	7194,43	GC03_I106	1	1,750	33,669	67,339
GC03_D108	3	47,00	1248,98	2497,96	GC03_I110	4	83,900	1886,150	4905,735
GC03_D109	2	14,24	378,38	756,77	GC03_I112	1	1,770	99,186	198,373
GC03_D115	1	2,39	63,45	126,89	GC03_I113	1	1,880	105,799	211,598
GC03_D117	1	14,01	372,34	744,67	GC03_I115	1	1,120	62,894	125,788
GC03_D121	5	151,76	2741,75	5483,49	GC03_I116	1	4,010	225,571	451,142
GC03_D122	1	7,90	142,72	285,44	GC03_I118	5	12,010	754,575	1350,256
GC03_D123	5	13,48	358,43	716,86	GC03_I119	6	11,310	738,887	1272,260
GC03_D124	2	38,31	1337,32	2674,63	GC03_I120	1	3,090	346,874	346,874
GC03_D134	1	6,47	211,75	423,49	GC03_I121	2	1,570	88,359	176,718
GC03_D136	1	160,85	2377,01	4754,03	GC03_I122	1	0,170	9,609	19,218
GC03_D138	2	104,39	927,11	3251,88	GC03_I124	9	23,030	856,012	1607,409
GC03_D139	2	11,15	192,50	385,00	GC03_I125	2	17,470	409,541	819,082
GC03_D140	1	139,17	1601,71	4805,14	GC03_I132	1	3,560	143,606	287,213
GC03_D40	1	3,04	148,81	297,63	GC03_I4	4	7,690	147,987	295,973
GC03_D41	1	49,96	1633,05	4899,15	GC03_I5	1	1,240	50,220	100,441
GC03_D44	1	21,51	1054,78	2109,56	GC03_I59	1	2,240	120,308	240,616
GC03_D63	2	5,85	262,92	518,16	GC03_I66	1	1,760	77,857	155,713

Figure 3 – Choropleth Map with density of population per sector and the table with the calculated population highly annoyed assigned to every sector. Complementary data as number of buildings, habitable surface, length of exposed façade, number of floors, etc. are also included.

Normally we recreate this process in two phases. The first one is exclusively done with the information provided by Strategic Noise Map. Next, with the government's involvement, a number of candidates are proposed for the first cut. In these areas, a deeper approach to the real situation is carried out. In this phase, several detailed noise maps are developed taken into account variables usually not considered for Strategic Noise Maps. The data was updated when the situation is relevant in noise terms: new infrastructure, new residential developments, important changes in traffic [12], etc. There is some information gathered on the site: how are the exposed facades, what is the real population living in an area, corrections of errors on the assignation of use of a building, surveys, etc. Noise measurements could give us new information, for example: Lmax during night hours.

Only a review of the candidates finally grades the urgency of situations. However, until we analyse viability, effectiveness, cost/benefit and public opinion variables we cannot establish the sequence of intervention in the short and long-term in relation to the funds available.

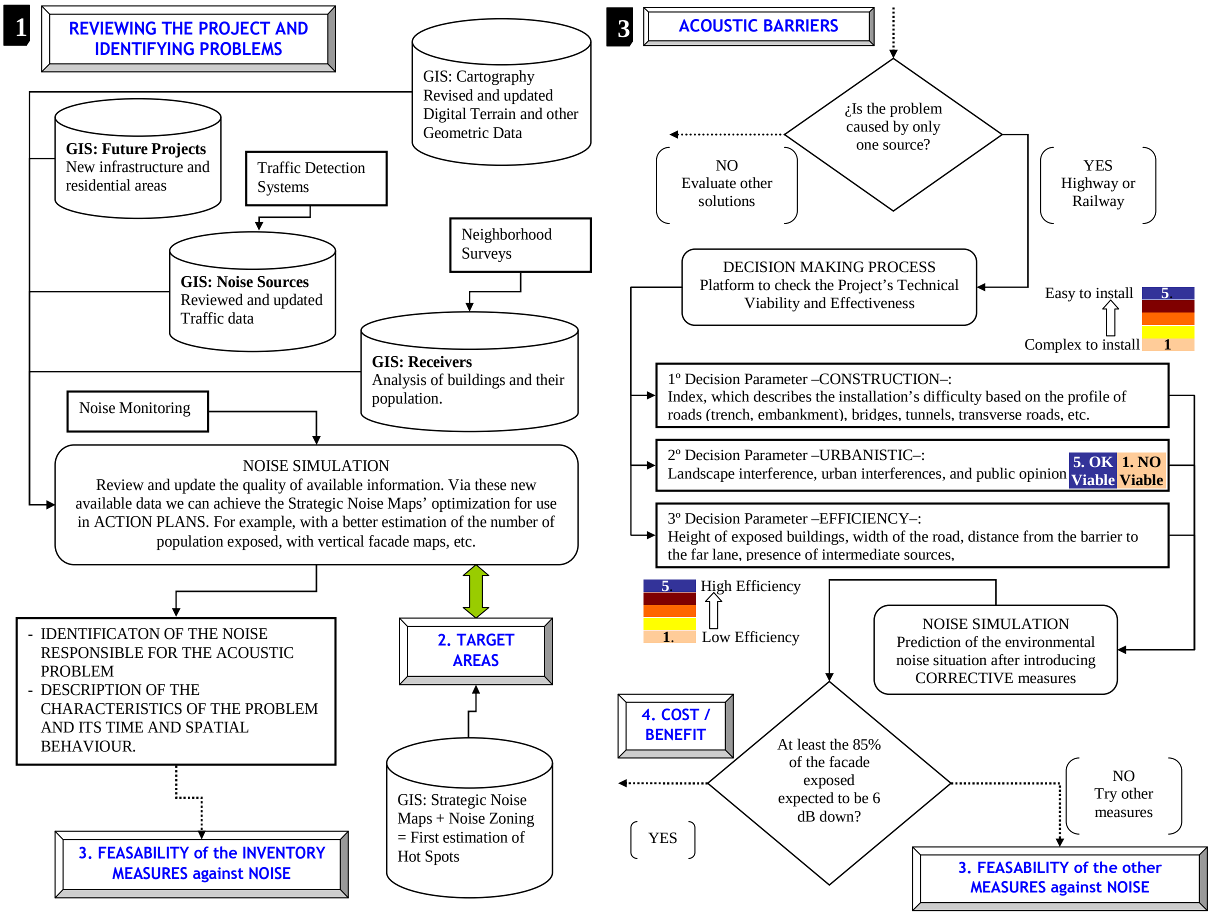


Figure 4 – Logic structure of examples of automated task programmed in GIS. These diagrams help consultants to clarify tasks with the authorities.

3.2 Agglomeration

Agglomeration Action Plans cover the same phases as the ones for roads, but with some peculiarities that increase the project's complexity. The case study contemplated here puts the focus on one of these particularities of decision system that appears when traffic management measures are contemplated. Being mobility the city planners' main worry, it is necessary to manage noise solutions with care. What is considered an environmental quality improvement in one part of the city could be considered a negative one in another. As environmental strategies involving the main network inside towns are complicated and expensive, usually plans are programmed in the long term. These plans comprise more environmental variables than noise. Nevertheless, in the short term there are some things we can do to mitigate the most adverse situations. That is why this case concerns the environmental impact over the population during night time. This impact causes harmful effects such sleep disturbance, and other health problems described in the literature [11].

Figure 5 – The left map shows the pattern of spatial distribution of exposed population to night noise in residential buildings. Dense population areas affected by high levels of noise at night hours are highlighted in yellow. The map on the right seeks for a link between the exposed facades of that building regards the main road network.

3.2.1 Case Study: Evaluation of the viability of the noise measures based on traffic management using traffic models

La Rambla Boulevard is one of the city network's most important streets, traversing Santa Cruz de Tenerife from East to West. La Rambla connects and feeds traffic from the downtown and commercial district to TF-1 and TF-5, which are the highways linking Santa Cruz with the rest of the island. The boulevard supports a great flow of vehicles during day and night. The fleet is composed mainly by cars, motorcycles, mopeds, buses and two axles' delivery vehicles. The leisure area downtown is a gravitational pole during the night and especially at weekends. Along the boulevard there are residential buildings with different configurations: from detached houses to multi-storey buildings. La Rambla arise as a macro-area after analysing the main streets traffic parameters and merges eight micro-areas identified in the first approximation. One of these micro-areas is situated around the bullfight arena with more than five thousand inhabitants exposed to more than 65 dBs during night period. In this point the vehicle flow is close to 38.000 vehicles per 24 hours (with approximately 5.000 pass-bys from 23 pm to 07 am). A great percentage of the road is uphill, but gradient of slope never exceeds 5%. At the same time, the pavement is not in good condition in many stretches of La Rambla. The speed limit is 50 Km/h and junctions are regulated by traffic lights. But drivers usually do not obey this speed limitation throughout night period.

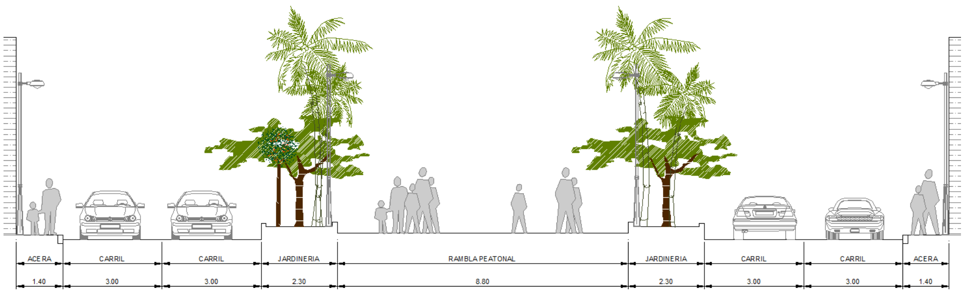


Figure 6 – Cross section of La Rambla.

In short, a new night noise map of the macro-area has been developed trying to reproduce and evaluate everyday situation in a most realistic way. We are now ready to analyse proposals that have to comply with the requirement to not affect mobility during daytime. To evaluate the measures' viability, one of the tools employed was a traffic microsimulation model [13] [14]. In this case, the software package Aimsun version 6.0.5 was used. The process of automatic exchange of data between GIS, traffic simulation model and noise prediction software is not completely solved [14]. The model was constructed using data provided by the municipality. It consists of 56 traffic count spots distributed along the city's main network and updated to 2008. Traffic light phases are contemplated in the model taking into account the current program for day and night. We managed an Origin-Destination matrix which also included intra-agglomeration travels. Finally, the traffic model was calibrated and validated. Normally, this type of model is developed for rush hours, although in this case, our interest focused on night hours.

The set of measures proposed to mitigate night noise for this area was selected regarding the prevention of uneven driver behaviour and trying to calm traffic by night. A steady traffic flow without accelerations and decelerations helps reduce noise by traffic management.

- Only one lane per direction should remain available from 00h to 06 a.m. throughout La Rambla. Traffic information panels are being installed and it would be easy to inform which lane is open and which is closed. Cats' eyes (lane flashing reflectors glued to the pavement) will be installed to mark the separation between lanes.
- The traffic information panels should set night speed limits to 30-40 Km/h and traffic lights should be programmed with a green wave calculated for selected speed limit. The information panels will invite drivers to behave in an eco-friendly manner, driving smoothly and shifting quickly to the higher gears where the engine works more efficiently and uses less fuel. The synchronisation traffic lights for lanes in uphill situations should be reappraised in order to avoid acceleration noise.

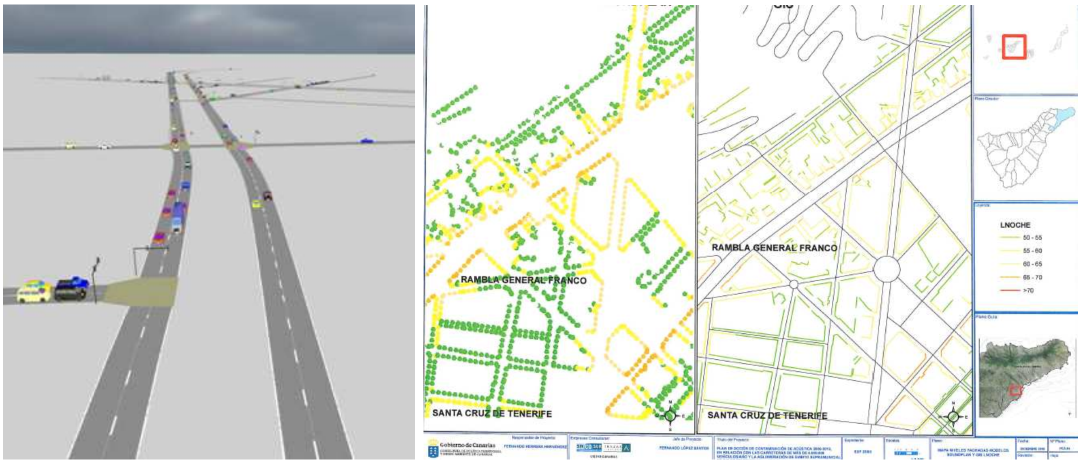


Figure 7 – Traffic microsimulation of La Rambla and surroundings during night hours. Current detailed noise exposed maps are developed based in the output of this traffic model.

Only with this set of measures we expect L_{Aeq} reductions from 3 to 7 dB depends on the stretch of La Rambla and a considerably higher reductions in L_{AFmax}. We rejected the installation of dissuading devices like radars and video cameras because their unpopularity. In the future, and in case of a lack of citizen collaboration, these devices should be taken into account, especially those activated by trigger signal supplied by noise monitoring stations. Now we are studying the pros and cons of resurfacing of the current deteriorated surface with new experimental acoustic asphalt. At least an Improvement of street maintenance is needed to prevent this type of noise source: bumps, potholes and other faults can cause needless noise

4 Conclusions

GIS-based DSS has been applied in Canary Island's Noise Action Plan. This system has proven to be a valuable tool for the set of task scheduled for this Action Plan’s Project. These tasks involve the identification and prioritization of conflict zones, the detection of the noise sources responsible for that harmful situation and the proposal of best measures regarding issues such as the best efficiency and cost.

GIS platform allows minimizing time and errors in repetitive geographical data processing. The system is continuously growing and is becoming more and more sophisticated. But what it makes so attractive, is the interactivity.

- DSS is designed to always ask for the necessary and updated information
- An interactive system should include friendly handling of the calculation parameters, total adaptability to local legislation and the flexibility to easily introduce stakeholder demands.

The case study presents the first results for the city of Santa Cruz de Tenerife. The work focused on a macro-area defined by La Rambla Boulevard where we found a large concentration of people highly annoyed by traffic noise at night. The starting requirements and the complexity of the situation lead us to explore the application of noise control solutions based on traffic management. The effects on noise and traffic on the area and the side effects on other areas of the proposed measures have to be evaluated using traffic microsimulation models and noise prediction software.

Acknowledgments

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