# Protocol to manage construction noise in urban areas: practical case in Bilbao municipality

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**Summary**

Measures to control construction noise should go beyond measuring the impact and reacting to it. Identification of potential problems before they occur is the optimal approach. At the same time, proposed methodologies and protocols should be realistic and practical, since they will be implemented in a very tight framework, both in terms of limitation of budget and time constraints. Therefore, practical testing of them is more than welcome.

This paper presents a procedure to define acoustic requirements to urban construction works and a methodology to answer to those requirements when executing the works. Both were defined as result of the collaboration between Tecnalia and a construction company in a real work developed in the city of Bilbao. Therefore, it considers the needs, capabilities and constraints expressed by a public local authority and a private construction company.

The procedure includes an integral approach that considers: the prediction of the noise impacts, proposing abatement measures and analyzing their efficiency in real time during the timeline of the construction works.

As result of the working process some criteria to adapt the requirements asked to different works are obtained. These criteria are related to: the type of works, classifying them in terms of how noisy they are; and the acoustic conditions of the area, the sensitivity to noise impact and existing environmental noise levels (consulting noise maps, developed by the city).

The methodology can be applied when planning and executing construction works in an urban area. The methodology faces two key challenges: being accepted by authorities leading the works, so not interfering too much in the timing and costs of the works, and being applicable by the construction companies as part of their environmental control.

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## 1. Introduction

This paper presents a procedure to control noise originated by construction works outdoors in our cities. The goal is to reduce annoyance caused by the activities developed during the works, making compatible the need of improving the city and its infrastructures and the wellbeing of its residents. Bilbao municipality looks for the improvement of the quality of life of its inhabitants. Construction noise is a source of annoyance and there is a need of defining what controls and measures are suitable to this noise sources in the city. The best way of learning is doing it from practice, so it was decided to apply possible measures and tools to manage construction noise in a specific work selected as case study. Tecnalia not only proposed measures and tools to be checked, but also leaded the experimental application of them. The case study was the work to renovate the square and streets surrounding La Alhondiga building, at the city centre. It took approximately 3 months.

A key point is to identify and overcome any potential difficulty to implement the procedure developing an experimental application of the protocol in a specific work carried out during 3 months in the city centre. The construction company subcontracted to do the works, played a key role in the project, giving data, applying the different tools of the protocol and helping on the assessment of its applicability. Tecnalia was involved in the development of the works to define best methodologies, to know the barriers found and to check how the tools were understood and apply by the construction company.

In fact, the initial intention was to transfer to the construction company during the project the

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responsibility of integrating noise control measures in their working process.

## 2. Protocol to manage construction noise in urban areas

As result of this practical study a complete protocol was defined with 6tools. Following paragraphs will explain each of them and present some results of their application into the case study.

1. Analysis of the official information regarding acoustic emission of the machinery that is planned to be used in the construction works.
2. Measurement of noise levels generated by each specific activity on site. A database of real noise levels will complement the official information about acoustic emission of point 1.
3. Measurement of noise levels caused in sensitivity points (mainly buildings nearby) by the global activity carried out during the construction work. Comparison of noise levels with a proposed threshold value allows assessing the actual impact produced.
4. Review of the planning of the works (weekly). A tool was developed to assess the potential acoustic impact of the activities planned for the next period, according to the planning. An index is proposed to quantify and summarize the impact expected and a threshold value is defined to decide when action should be taken. The application of the tool implies that the acoustic control of the work is included on the agenda of the periodic control meeting (weekly) between Bilbao municipality and the construction company.
5. Measures to be integrated in the planning of the works to reduce acoustic impact in the next period when the thresholds are not met.
6. Inspection controls of the fulfillment of the decisions adopted in the periodic meeting: activities and measures included in the planning of the works.

### 2.1 Analysis of the official information regarding acoustic emission of the machinery

The noise emissions from machines for outdoor use are regulated by the European Outdoor Machinery Directive 2000/14/EC. This sets out minimum requirements on machines for use outdoors (such as noise marking or noise emission limits) which have to be met if a product is to be placed on the European market.

In the majority of cases the construction company does not own the equipment and it rents the machinery to a second company during the works.
In addition, sound power data reported by the manufacturer are measured under conditions of operation of machinery which may be substantially different from the conditions under which it is used in the work.
Nevertheless, these data do provide a good source of information to compare machinery and promote selecting low-noise outdoor equipment and machinery. In that sense, the use of quieter machines could provide a competitive advantage in the market, reinforcing the benefits of their use.
The experience of applying this protocol in the pilot case derives in the following conclusions:

- The documentation provided was irregular in its content. In some cases only the type of equipment is known. In others, the machinery model is known, as well as its compliance with the National legislation about Noise emission limits.
- An additional difficulty in analyzing such information is the inhomogeneity of how these data are presented by the manufacturers. This difficult to interpret and compare. There are different acoustic variables used to report the acoustic power ($L_{Aw}$ or emission level $L_{Aeq}$); different types of documents containing information related to the acoustic power (marketing factsheets of the machine, technical sheet, or nowhere, so it should be requested to the manufacturer). In general, it is unknown the type of test performed to get the emission values and there is no certificate or technical responsible of the testing.

### 2.2 Measurement of noise levels generated by each specific activity on site

These measurements aim to determine the level of noise associated with a specific activity of the work and the use of specific machinery (including its brand). The results also serve as to contrast the official noise emission marking of machinery.
The measurements were carried out under a simple and standardized procedure, which is described in terms of practical instructions.
In the pilot case the noise caused by each activity and each specific machine was measured. These results constitute the first version of a database of sound power levels of activities of the work (associated with specific machinery).
This database can be completed if this information would be collected in future works. It also reports, when needed, comments related to specific needs

of checking the status of maintenance of each machinery, in order not to increase its noise emission.
Having a database of construction machinery measures is useful to:
- Know the noise levels generated by each activity using each particular machine and analyze the degree of correspondence of these data with the noise emission information provided by the manufacturer.
- Make comparisons between noise levels generated by different models and types of machines performing the same type of activity in the work.
This information would allow the City Hall at midterm implementing the following actions on machinery to reduce the noise impact of construction works
- Be able to rule out the use of outdated or poorly maintained equipment, because it generates noise levels much higher than those for the same new or in good condition equipment.
- Establish guidelines about the type of machinery to be used for certain activities, promoting the use of machines of low-noise equipment available at the market for the same type of activity. This means an increase in the market force.
During the pilot case the construction company carried out some measurements of noise levels generated by specific activities on site following the instructions written by Tecnalia. The results differed by more than 3 dB to those obtained by Tecnalia in the same conditions. Therefore, the need for training in the sector is strengthened.

### 2.3 Measurement of noise levels caused by the global activity during works in sensitivity points

These measurements aim to determine the overall impact generated by all activities that occur in the work at any given time. This impact is assessed at specific sensitive receptors, such as the façade of a residential building near the work. The results serve to globally assess the impact of the work by applying a threshold value.
During the case study Tecnalia developed a measurement campaign at selected receiver points in the vicinity of the work by recording the overall contribution of the overall activity of the work at each point.
The selection criteria of points is to represent the impact caused in sensitive areas close to the work, so receiver points were located in the proximity of the residential buildings close to the work sites.

Figure 1. Receiver points used in the measurement campaign of noise levels caused by the global activity.

The measurements were carried out under a simple and standardized procedure, which is described in terms of practical instructions. In all cases the measurement time corresponds to 30 minutes.

Table I. Measured levels during the case study

| P | Activities | $L_{Aeq}$ | $L_{AmaxF}$ |
|---|---|---|---|
| 1 | Compact excavator caterpillar biting and collecting material | 81 | 93 |
| 2 | Compact excavator caterpillar biting and collecting material and truck unloading | 79 | 94 |
| 3 | Cutting wood and radial. | 73 | 89 |
| 4 | Compact excavator caterpillar collecting material | 74 | 94 |
| 5 | Caterpillar, radial and hammer hand. | 69 | 85 |
| 6 | Hammer hand, radial and washer asphalt | 87 | 102 |
| 7 | Shapers | 76 | 88 |
| 8 | Shapers | 83 | 92 |

Having made these measurements in the case study, we conclude that when $L_{Aeq}$ noise levels obtained for 30 minutes are higher than 80 dBA, it implies that working activities are having a high noise impact.
Therefore, it is proposed that the results of noise measurements of the general activity of the work are evaluated against a $L_{Aeq}$ threshold value of 80 dBA. Thus, the protocol defines that the construction company must propose corrective measures where any measure exceeds this value.

### 2.4 Review of the planning of the works (weekly)

Since the final goal is to anticipate situations that can generate impact and act to minimize it, the protocol reviews the planning of the works in advance.

Tecnalia has developed a tool that predicts the noise impact of the work and quantifies it with an index, the prediction index of acoustic discomfort due to construction noise (IECO). This index applies the concept of dose of noise (combination of noise levels and their duration) that is obtained by adding (using the unit dBA) all doses of noise generated by all the activities that are planned along a week's work.

This is a numeric value (in dBA) that is not representative of noise generated by the activities of the work, or the actual dose of noise received by citizens affected by the work.

The information collected to calculate the index is as follows:

1- Information associated with the activities to be developed during the next week according to the planning and the machine that will be used on it. An estimation of the duration in hours of each activity is needed. The description of the activities is referred to different spatial units of execution of the work (in urban area is considered to be the area of 50 $m^2$ or, in the cases of streets, 50 m length). This information also includes the result of the verification of the compliance, in terms of acoustic emission values, with the European Outdoor Machinery Directive 2000/14/EC and its transposition into national legislation.

During the case study developed in the site of La Alhondiga in Bilbao, the construction company gave to Tecnalia their estimation of the hours of operation of each of the activities or operations of work.

2- Acoustic levels associated to each activity extracted from the database built in the step 2 of sound power levels of activities of the work (associated with specific machinery). The tool also includes comments related to specific needs of checking the status of maintenance of the machinery to be used, in order to emit measured noise levels.

With this information, the tool calculates the prediction index of acoustic discomfort due to construction noise (IECO).

In the work of La Alhondiga a total of 70 IECO values were calculated and compared, based on the workweek planning provided by the construction company: 5 different units of work during 14 weeks.

After analyzing those results, a threshold value for the IECO index is proposed. This value represents the balance between: the annoyance caused to citizen, the need of executing of the work (within and a reasonable budget and time) and the possibilities for action.

In case of exceeding this threshold value it will be necessary to identify the activities related thereto and to define the appropriate corrective measures.

Finally, Tecnalia has identified the construction work activities that, by themselves, could exceed the threshold; other activities that if happen simultaneously could lead to exceeding the threshold; and activities that generally do not significantly contribute to the IECO and would not require corrective action.

The weekly application of this tool in the works of La Alhóndiga area has allowed us identifying its strengths and weaknesses as a tool to be used in the protocol for control of the construction noise in Bilbao.

Strengths:

- It allows the municipality monitoring the activities that will be developed in the work on a weekly basis, placing them spatially and determining the duration of each of them.
- It identifies in space and in time the noisy activities (every week) and detects the need of corrective measures in each case.
- It requires that the construction company considers noise as part of its responsibility and it should take the initiative in proposing corrective measures weekly.
- It facilitates the work of verification or control of the implementation of corrective measures by the municipality, so they know previously which specific activities should be treated and where are located.

Weaknesses:

- Its application requires the construction company having a person who knows the tool.
- It is necessary a clear chain of transmission of information on the construction company, so that the conclusions of the protocol have real effectiveness in the execution of work.
- It should be complemented with municipal inspections, regular visits to the works (step 6).

Given all these considerations, it is concluded that the application of the tool is appropriate only in those cases when it is considered that the work (or any of its phases) will have a high acoustic impact.

### 2.5 Abatement measures to be integrated in the planning of the works

During the case study Tecnalia identified the main lines of action to reduce the impact of construction noise.
- Measures at the source (machinery). The aim is reducing the acoustic power of a particular activity to generate noise. Measures such as the following: selection of low-noise outdoor equipment and machinery; placement of the activity away from sensitive uses and / or covered by a closed structure; analysis of actions to improve the machinery; good practice deployment of operators; proper maintenance of its elements. Possible inconveniences of their application: it may affect the timing of the works.
- Measures at the propagation path: It implies the placement of temporary noise barriers.
Possible inconvenience is the limitation of their use: installing temporary noise barriers requires a good relationship between the operating time of the activity to be shielded and the time required for putting in pace the barrier (at least a 2: 1). It also requires a distance receiver-barrier at least double that the source-barrier one.

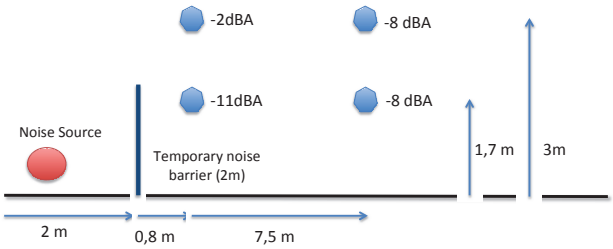


Figure 2. Efficiency of the temporary noise barrier. Measurements made in the case study.

- Measures at the receiver: The aim is to lower the dose of noise (noise level versus time of exposure to it) at sensitive receptors living close to the works. Measures such as the following: fixing the hours of operation to less sensitive times of the day, and avoiding high-impact activities happening simultaneously in one area. Possible inconvenience is that they can lead to reduced performance in the work due to having to reduce the operating time to minimize the exposure dose.
These actions require that the work manager of the company knows which activities may require corrective action and also knows how to apply them.

### 2.6 Inspection controls during works

Those inspection controls could have different goals:
- To analyze the status of maintenance of machinery, since a bad maintenance could derive in an increase of acoustic emission.
- To verify that the planning of the works weekly is being fulfilled. It would mean that the input values to calculate the IECO index are correct. During the visit the deployment of the abatement measures is also checked.

## 3. Criteria to apply the protocol to manage construction noise in future works

Tecnalia proposed to Bilbao municipality to adapt the application of the protocol to the risk of each work of doing impact to inhabitants. Therefore the protocol to manage construction noise in urban areas will depend on the typology of works or the typology of activities to be developed in its phases.
As it is known the acoustic impact caused by a specific activity in its surrounding is determine by three variables: Noise levels generated or acoustic power of the activity; Time the activity lasts and distance to sensitivity buildings or potential receivers.
Therefore those variables constitute the criteria to assess the capacity of a construction work to generate acoustic impact and to adjust the requirement of applying the protocol to manage construction noise in the city.
Considering those variables as criteria, Tecnalia has developed a matrix that classifies the types of construction works according to their potential acoustic impact. Two levels are defined: high impact (red color) and medium impact (orange color).

| TYPE OF WORK OR PHASE | POTENTIAL NOISE IMPACT | |
|---|---|---|
| Works to build/renovate sidewalks or road | >4 Months / < 50 m | >2 Months / < 100 m |
| Works to build/renovate parks | >4 Months / < 50 m | >2 Months / < 100 m |
| Works to build new buildings | >4 Months / < 50 m | >2 Months / < 100 m |
| Works at sewerage and lighting network | >4 Months / < 50 m | >2 Months / < 100 m |

Figure 3. Matrix to classify construction works according to their potential acoustic impact.

The potential acoustic impact is classified according to three variables:
- Noise levels generated or acoustic power of the activity: in the matrix this variable has been converted into the type of construction work or

activity developed. This proposal is based on the experience gained during the pilot case and it was checked by the responsible of public works of the municipality of Bilbao.
- Time the activity lasts. In the matrix this variable distinguishes two ranges: duration longer than 4 months or longer than 2 months.
- Distance to sensitivity buildings or potential receivers. In the matrix this variable defines two types of works: distance up to 50 meters, and distance up to 100 meters.
- Other types of construction works not mentioned on the matrix are considered as low potential acoustic impact. On those types of works only some elements of the protocol are required or even only some general requirements to be fulfilled by the construction company.

Besides the characterization of the potential acoustical impact of the works, also the acoustic conditions of the area could be considered to determine the level of requirements included in the public tender, in terms of elements of the protocol. Those conditions refer to the sensitivity of the area to noise impact and existing environmental noise levels. Noise maps developed by the city are a source of information for this complementary approach.

## 4. Requirements to offers answering to public tenders

The public tender of construction works in Bilbao contains requirements to control and prevent the acoustic impact nearby. Tenderers should include in their offer the following items:
- The machinery and equipment that will be used in the works should be listed and the official documents of the acoustic emission marking (European Outdoor Machinery Directive 2000/14/EC) should be annexed. It is valuated positively the commitment to use low-noise outdoor equipment, already identified and technically justified (Step 1 of the protocol).
- A measurement campaign of noise levels should be defined to be done during the works. Its goal is to determine if the impact caused in sensitivity points by the global activity carried out during the construction work does not imply an exceedance of the threshold value (step 3 of the protocol). It is valuated positively to justify the selection of the simple periods to measure noise levels, so that the activities with highest potential impact are analyzed.
- The municipality of Bilbao has started applying the threshold of 80 dBA for $L_{Aeq}$ 30 minutes in other public works, since it is considered as a minimum criterion of protection.

## 5. Conclusions

Applying the procedure to control noise originated by construction works outdoors in our cities implies a change in the way of developing the works, so that noise becomes a variable that could condition the execution of the works.
The identification of potential acoustic impact caused by the planned activities will derive in conditions to the periodic planning of the works.
The case study carried out in the works to renovate the area of La Alhondiga building in Bilbao, showed the need of doing activities of awareness and training among construction companies. The goal is that they could apply by themselves the procedure to control noise and play an active role on it.
The thresholds proposed in the protocol are considered as a preliminary approach, since they were defined based on its application in the case study in Bilbao, on the acoustical analysis of its results, besides the expertise of Tecnalia and the study of other legal and technical references.
In order to define more conclusive thresholds it is necessary to study the perception of annoyance associated to noise caused by construction works analysis.
It is also interesting to share this experience with other European cities in order to contrast its outputs and to enrich protocol to control noise caused by construction works in urban sites.

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