Estimation procedure of the descriptor $L_{Aeq,T}$ from the stabilization time of the sound pressure level value

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Abstract

Temporal structure of sound pressure level is a key aspect at the time of characterizing urban sound environments. In urban agglomerations, environmental noise levels fluctuate over a large range as a result of the great complexity of these settings, with considerable temporal and spatial heterogeneity. Furthermore, the domain in urban environments of noise sources, such as road traffic, commercial or leisure activities, construction works, etc., together with the occurrence of sudden sound-level maxima events (bells, sirens, vehicles at high traffic speed, honking horns...), which are quite frequent in urban agglomerations, generate the appearance of very high values of the impulsiveness of sound pressure level. This aspect causes a great influence on the time necessary for environmental noise levels to become stabilized, which is a key aspect for the accurate measurement, interpretation and guarantee of a statistically representative sample of a given urban sound environment. Therefore, the goal pursued in this work is to put forth a procedure for the calculation of a value of $L_{Aeq,T}$, representative of a certain urban location in a short-term time period, from the utilization of the value of the stabilization time of the sound pressure level.

Keywords: Temporal Structure; Environmental Noise; Temporal Variability; Road Traffic; Measurement Time.

1. Introduction

A major difficulty encountered in the description of an urban area from an acoustic perspective is the variability of environmental noise in time [1-3]. It is well known that road traffic noise levels vary highly over time and space [4]. Short-term variations due to individual vehicles' pass-by or fluctuations set by traffic cycles are quite common [5]. Moreover, urban environments often involve short time events that introduce a large amount of sound pressure. In this work, such phenomena are known as impulsive sound events. They include, in the urban context, ambulances, vehicles moving at high speeds, honking horns, banging or crashing sounds, shouting voices, etc., but also church bells, sirens of a school, etc. The occurrence of these impulsive sound events largely affects the temporal structure of urban sound ambient [6].

It has been widely asserted that noise variability should be taken into account in environmental noise research [4]. For example, Botteldooren et al. [7] maintain that the temporal structure of the environmental noise level should be considered in order to correctly characterize an urban sound environment. In fact, the timeframe (e.g. how long the measurement should be) must be considered [8], with the aim of ensuring that the results are representative of the real conditions [9-11]. Within this same context, Gonzalez et al. [12] establish that urban noise measurements must extend over a long enough period of time to be stable and reliable, but not extremely long in order not to increase field work expense beyond aceptable levels. A parameter which can inform about the time required to obtain a sound pressure level representative of the evaluated urban sound ambient is the stabilization time of the sound pressure level [6].

Accordingly, this work aims to propose a procedure to estimate a value of $L_{Aeq,T}$, representative of a given urban localization in a short-term time period, from the utilization of the value of the stabilization time of the sound pressure level. For it, the behavior of the stabilization time against both the road traffic intensity and the appearance of

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deterministic impulsive sound events have been studied.

In the following section we focus on the parameter "stabilization time of the sound pressure level" (Section 2). In Section 3.1, the definition of an impulsive sound event is provided, along with brief methodology for its detection. Section 3.2 describes the methodology used to obtain the data. Finally, in Section 4 the results of the work are presented and discussed.

2. Stabilization time of the sound pressure level

The continuous equivalent sound pressure level (L_{Aeq}) can be defined as a constant noise level whose sound energy value is equal to an averaged energy of the noise level fluctuation over a total measurement time interval [13]. When an environmental noise measurement is taken, the L_{Aeq} descriptor changes as time passes, according to the sound pressure level prevailing in the ambient. Over time, the sound pressure level accumulates, and the values of this sound pressure level fluctuate until its stabilization takes place. Due to L_{Aeq} being a parameter with "many inertia", there comes a point at which great variations in the instantaneous levels are necessary in order that fluctuations in the value of L_{Aeq} appear [6].

The stabilization time of the sound pressure level is defined as the required measurement time (t_i) in order that the measured continuous equivalent sound pressure level $L_{Aeq,ti}$ differs from the overall continuous equivalent sound pressure level $L_{Aeq,T}$ in less than ε.

$$\left|L_{Aeq,T} - L_{Aeq,ti}\right| \leq \varepsilon, \tag{1}$$

where ε is the accuracy claimed for the measurement [6]. The value of ε used in this work is ±1 dBA (the value of ε was chosen from a deep analysis of the works [14-16], as well as of a preceding investigation [17]). Therefore, stabilization time is calculated by comparing the overall L_{Aeq} of a given location with the L_{Aeq} of the first second of measurement, of the first two accumulated seconds, of the first three accumulated seconds, etc. (L_{Aeq1}, L_{Aeq1+2}, $L_{Aeq1+2+3}$, etc.). It is established that n is the stabilization time when, from the second n of measurement onward, the accumulated L_{Aeq} and the overall L_{Aeq} of the location differ less than the given ε.

This parameter informs us about the time required for measuring in a given localization in order to obtain a value of $L_{Aeq,T}$ representative of the considered urban sound ambient. In other words, to attain a reliable short-term characterization of the sound climate of a certain urban location, one must measure during at least a period equal to the stabilization time. Nonetheless, it should be mentioned that this parameter is very sensitive to high emerging noise, called impulsive sound events in this research. Although these sound events are mostly not representative of the analyzed environment, in certain cases, appear deterministic impulsive sound events, which are representative of a given urban soundscape, since, these emerging sound events are an essential part of the sound ambient (e.g. church bell, siren of a school, etc.). Because the latter, the behavior of the stabilization time against the occurrence of a deterministic impulsive sound event is a key issue examined in this research.

3. Methodology

3.1. Identification of impulsive sound events

An impulsive sound event (hereafter ISE) can be defined as an acoustic occurrence which generates an increase of 1 dB in the foreground continuous equivalent sound pressure level L_{Aeq} (for more detail see [6]).

Following the procedure established in Torija et al. [6], to detect an ISE, the evolution in time of the parameter $L_{Aeq,foreground}$ is analyzed. To obtain the parameter $L_{Aeq,foreground}$, from each of the instantaneous sound pressure levesl ($L_{p,i}$) the overall background noise level (L_{A90}) was logarithmically subtracted, thus obtaining the foreground instantaneous sound pressure levels ($L_{p,foreground,i}$) and then from $L_{p,foreground,i}$ values $L_{Aeq,foreground}$ descriptor is calculated. Thus, if a great emerging sound event appears in time t_i, this event will be considered as an impulsive sound event whenever the foreground continuous equivalent sound pressure level in time t_i is at least 1 dB higher than the foreground continuous equivalent sound pressure level in time t_{i-1}.

3.2. Data sampling

A number of 80 measurement locations of the city of Granada (Spain) were selected to be as generically representative as possible of the wide range of urban settings. In this sample were included locations where the main noise source was road traffic, but also some locations affected by other sources of environmental noise. It should be mentioned that 35% of the selected localizations were affected directly by noise sources from commercial/leisure activities and 17.5% of the locations were not directly impacted by road traffic. In this case, the main noise sources were those proceeding from natural (water fountains, birds, etc.) and social (people walking, talking, etc) activities.

In each of 80 selected locations a measurement of the sound pressure level A-weighted every second ($L_{Aeq,1sec}$) was performed, with a total duration of 60 minutes. Therefore, the measurement campaign consisted of a sample of 80 1-hour records. Measurements were carried out following the ISO 1996-2:2007 guidelines [18], using a 2260 Brüel & Kjaer type-I sound-level meter, with tripod and windshield, placed at a height of 4 m above local ground level as well as 2 m away from the nearest vertical surface. Before carrying out the measurement a calibration of the sound-level meter was performed using a 4231 Brüel & Kjaer calibrator. Moreover, a manually count of road traffic was done simultaneously and, other relevant information, such as noise sources and meteorological conditions, was also noted.

It is necessary to indicate that the methodology established in this work refers to a 60-min period. Nevertheless, this methodology could be extrapolated to any short-term time period.

4. Results and discussion

4.1. Stabilization time vs. road traffic intensity

The behavior of stabilization time of sound pressure level against different road traffic intensities and the occurrence of an impulsive sound event is investigated in the next two sections.

Observing the results shown in Table 1, we can assert that urban sound environments with direct impact of road traffic have higher stabilization time values than those without road traffic in the proximities. Furthermore, in Torija et al. [6] it is found that the greatest values of stabilization time are obtained in urban localizations with low road traffic intensity and intermittent traffic flow dynamics. Because of this, the relationship

Table 1. Average stabilization time value in urban locations with/without road traffic and impulsive sound events.

		Stabilization time [min]
Road Traffic	With	23.31
	Without	4.15
Impulsive Sound Events	With	24.84
	Without	2.81

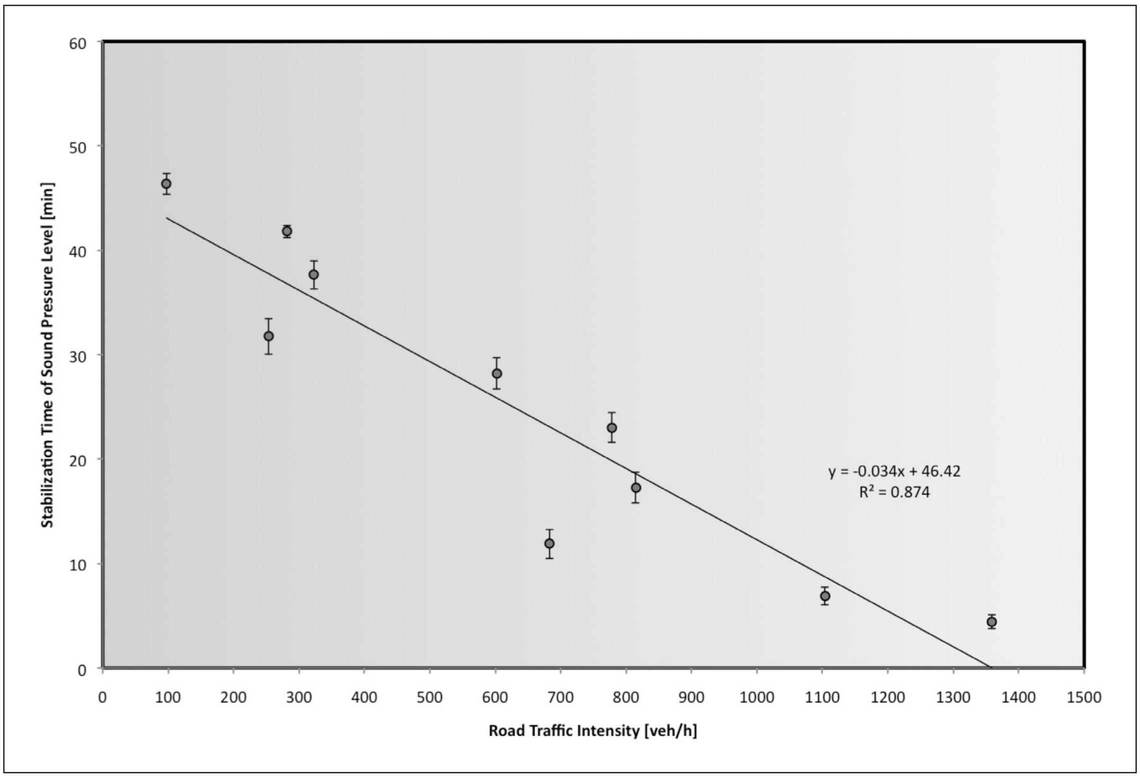

Figure 1. Relationship between road traffic intensity and the stabilization time of the sound pressure level [6].

between stabilization time and road traffic intensity is analyzed (Figure 1).

According to Figure 1, an inversely proportional linear relationship between stabilization time of sound pressure level and road traffic intensity is observed ($R^2 = 0.87$). Low road traffic intensities correspond to intermittent traffic flow dynamics, so the short-term temporal fluctuation is higher, and therefore stabilization time has high values. In contrast, great road traffic intensities imply moderately stable sound levels, because of the saturation and accumulation of noise sources. Under these circumstances short-term temporal fluctuation is smaller, and the stabilization time is quite low. Therefore, under lower road traffic intensity, stabilization time value increases [6].

From Figure 1 and, knowing the road traffic flow of a given urban localization, the minimum required time to measuring to undertake a short-term sound characterization (calculation of $L_{Aeq,T}$) of this urban location can be obtained.

4.2. Stabilization time vs. impulsive sound event occurrence

As stated previously, in urban environments the occurrence of impulsive sound events is very common [19]. In Table 1 it can be seen that in urban locations with impulsive sound events appearance, stabilization time value is greater than in the urban settings without this kind of sound events.

In this section, the behaviour of the stabilization time of the sound pressure level against the occurrence of one impulsive sound event is examined. The incidence of the time position and magnitude of the impulsive sound event on the stabilization time value is thoroughly analyzed.

To evaluate the influence of impulsive sound event time-position on the value of stabilization time, in a sample measurement with a relatively low short-term temporal fluctuation (stabilization time equal to 11.92 min) an impulsive sound event with 30 dBA more than the sampled measurement (with no impulsive sound event) L_{Aeq} is introduced. When this event is introduced the stabilization time increases to 41.33 min (Figures 2b-c). This event is added in minute 20 (Figure 2b) and 41.33 (Figure 2c), obtaining that the stabilization time value is the same in both cases. Indeed, the value of the stabilization time if an impulsive sound event is added inside the stabilization time period, in the sampled measurement, can be said to be independent of its position. However, when this impulsive sound event is introduced at time above 41.33 min, as in figure 2(d) where the impulsive sound event appears in minute

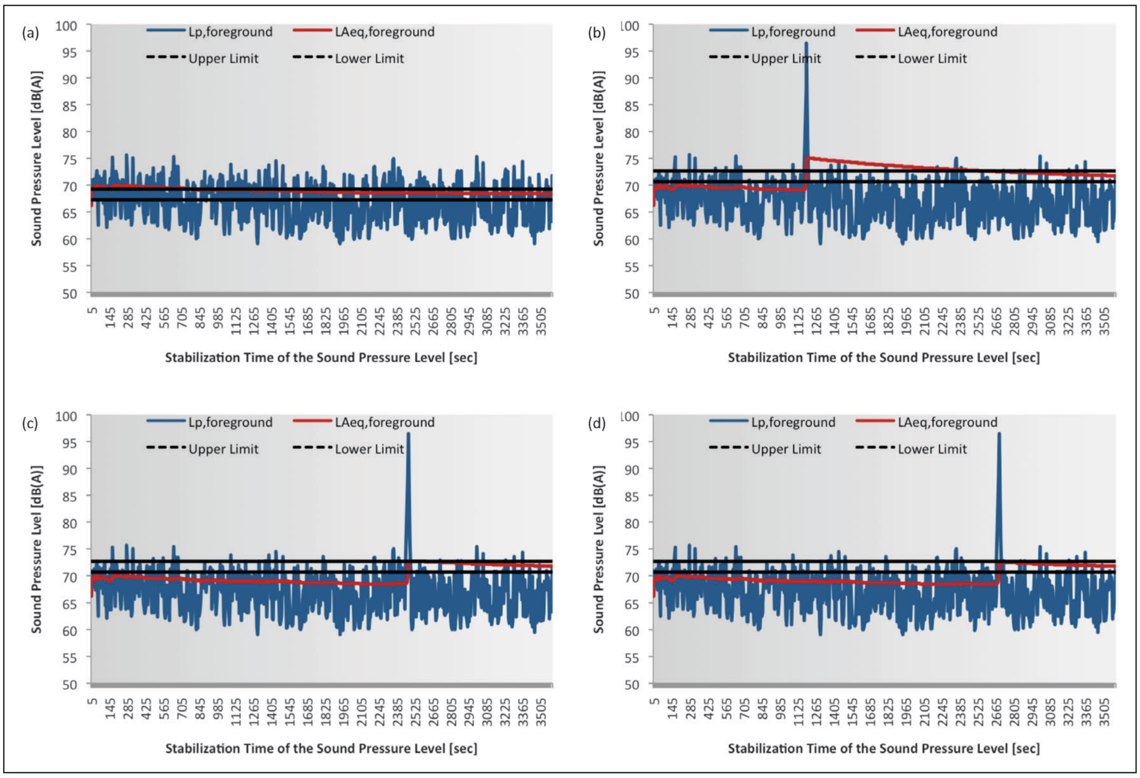

Figure 2. Evolution of the stabilization time according to the location of impulsive sound event. (a) Without impulsive sound event, (b) in minute 20, (c) in minute 41.33 and (d) in minute 45 [6].

45, then the stabilization time correspond to the time in which the high emerging noise appears [6].

On the other hand, a sound event with 20 dBA (Figure 3a), 25 dBA (Figure 3b) and 30 dBA (Figure 3c) more than the sampled measurement (with no impulsive sound event) L_{Aeq} is introduced to evaluate the influence of magnitude of the impulsive sound event on stabilization time. As expected, if the sound pressure level added by the sound event is higher, the stabilization time value (26.16 min, 34.42 min and 41.85 min, respectively) increases. From this results can be deduced that, the required time for the sound pressure increase to become steady depends on its magnitude: the greater the generated sound pressure increase above the mean sound pressure level (without sound event), the higher the time necessary for stabilization to take place [6].

If the appearance of an impulsive sound event takes place, stabilization of the sound pressure incorporated by the impulsive sound event can be produced according to the following function:

$$L_{eq}(t) = 10 \cdot Log_{10} \frac{1}{T}\left[\left(T - t_{ISE,i}\right) \cdot 10^{SPL_{mean}/10} + t_{ISE,i} \cdot 10^{SPL_{ISE,i}/10}\right] \quad (2)$$

where $L_{eq}(t)$ is the energy-equivalent sound pressure level; T is the total time; $T_{ISE,i}$ is the time corresponding to the appearance of the impulsive sound event; SPL_{mean} is the mean sound pressure level without the appearance of impulsive sound events; and $SPL_{ISE,i}$ is the sound pressure level introduced by the appearance of the impulsive sound event [6].

In turn, when at the beginning of a sound pressure level sample with a constant value events with 1 to 50 dBA of sound pressure more than this constant L_{Aeq} (Figure 4) are introduced, can be checked that the stabilization time increased, according to a logistic function (R^2 = 0.99), when the sound event magnitude was higher. According to Figure 4, for increases below 10 dB and above 30 dB, stabilization time increases slightly. However, if the sound augment is comprised between 10 and 30 dB, an increase in the stabilization time value appears close to the linear function.

4.3. Calculation of $L_{Aeq,T}$ from the stabilization time value

A general procedure to $L_{Aeq,T}$ descriptor estimation from the value of the stabilization time of the sound pressure level is put forth in this section. The presented procedure contemplates two ways of calculation.

On the one hand, to obtain the minimum required time for measuring in a given urban

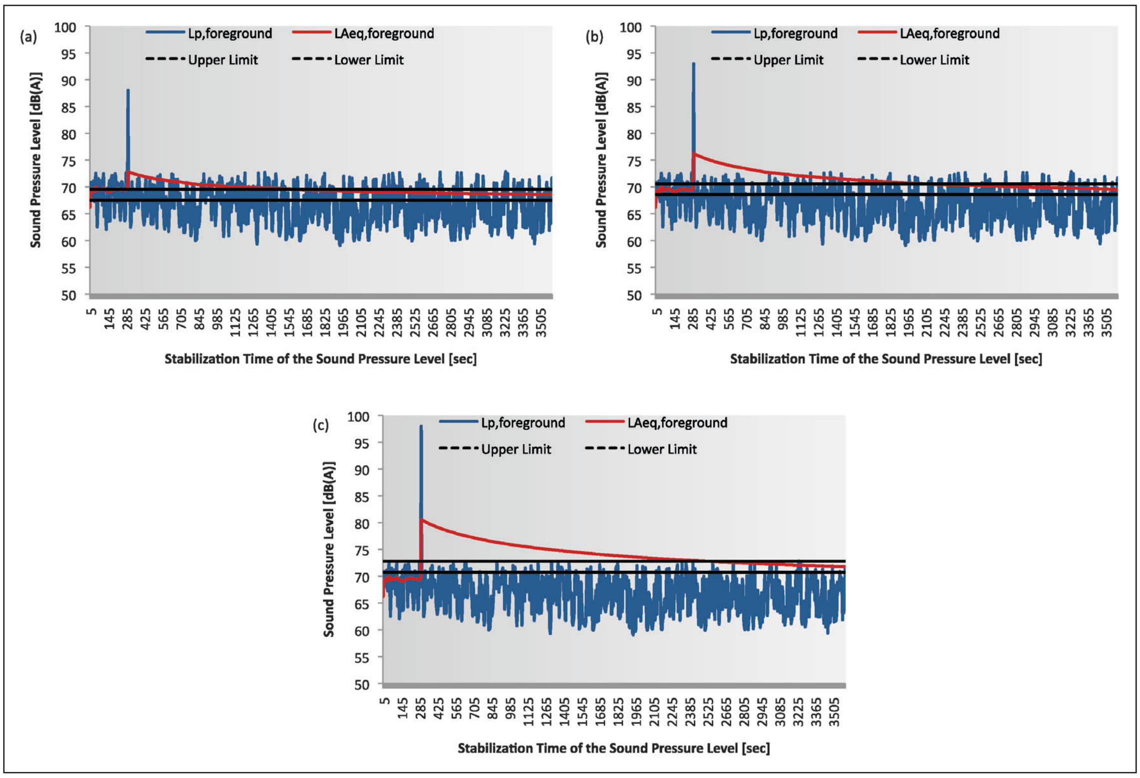

Figure 3. Evolution of the stabilization time according to the sound pressure introduced by the impulsive sound event, 20 dB(A) (a), 25 dB(A) (b) and 30 dB(A) (c) [6].

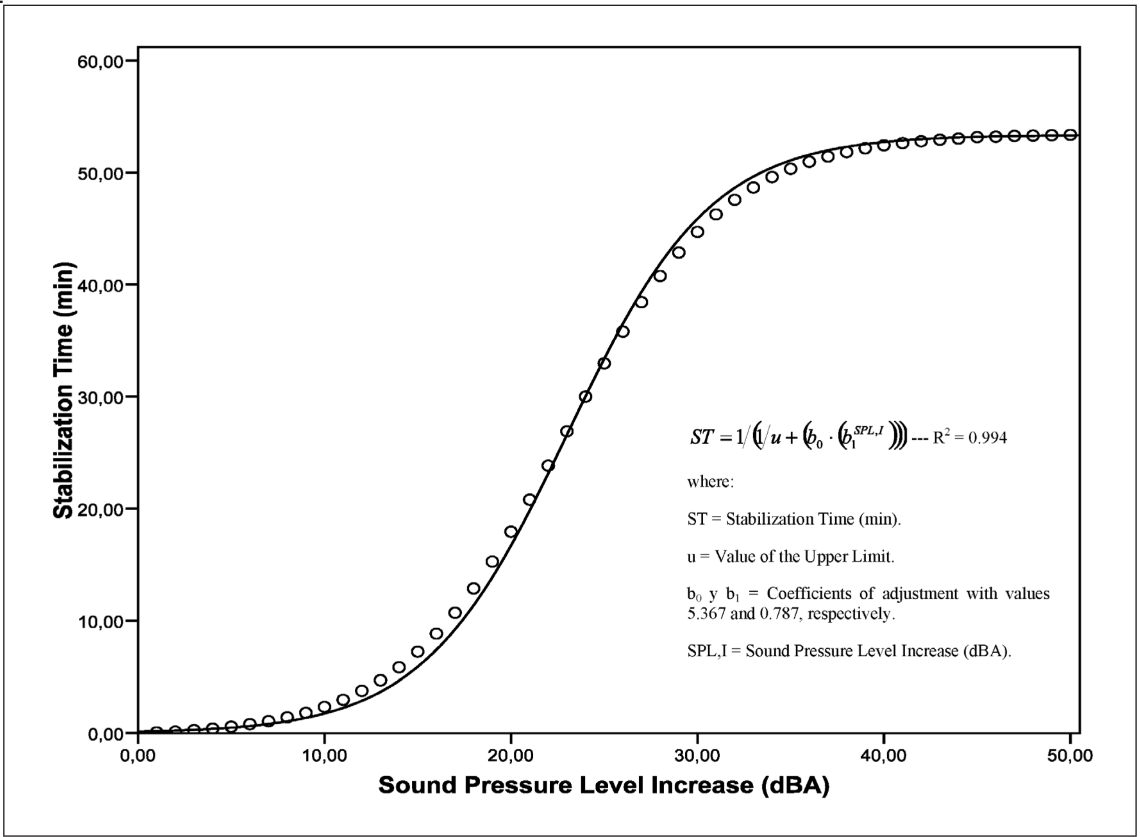

Figure 4. Relationship between the stabilization time of the sound pressure level and the sound pressure introduced by the impulsive sound events [6].

localization a representative value of $L_{Aeq,T}$ of the considered short-term time period, the stabilization time of the sound pressure level can be estimated from the road traffic intensity value (Figure 1).

On the other hand, if a deterministic impulsive sound event, which deeply marks the temporal structure, being a quite representative element of the ambient sound (e.g. siren of a school, church bell, etc.) appear in a given urban location, to take a representative environmental noise measurement of this localization we must measure up at least the necessary time, as obtained in Figure 4, in order that the sound pressure level introduced by this event be stabilized. However, if the stabilization time indicated by Figure 1 is higher, this one will be the minimum time to measuring.

It is suitable indicator that if the least measurement time indicates by the Figure 1 is over and yet the deterministic impulsive sound event (that we know appears once during the measurement period in this urban location) has not appeared, then it is necessary to extend the period of measurement at least until this event appears and the sound pressure level introduced become stabilized. In addition, if already the required time to the sound pressured level introduced become stabilized has passed, only until the event appears (Figure 2).

To conclude, this procedure will be valid if it is known that the deterministic impulsive sound event appears only once during the considered short-term time period. Moreover, this procedure is independent of the time when the measurement begins. Finally, if other impulsive sound events, which are not representative of the considered urban sound environment (e.g. ambulances, honking horns, vehicles circulating at high speeds, etc.) appear while the environmental noise measurement is taken, these sounds events have to be detected and removed to the estimation of the descriptor $L_{Aeq,T}$ (from the value of the stabilization time).

5. Conclusions

In this paper it is put forth a general procedure to estimate, from the value of the stabilization time of the sound pressure level, a representative value of the $L_{Aeq,T}$ descriptor in a short-term time period for a given environment. According to the introduced methodology, to obtain an appropriate short-term characterization of the ambient sound in a given urban localization it is necessary to measure at least a minimum period of time, which is provided by the parameter stabilization time. In this work, this methodology is applied to 60-min time period, nevertheless, this procedure could be extrapolated to any short-term time period.

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Smart, healthy travel in a single European transport area by 2020

To complete a safe, efficient, low-pollution single transport area the EU must set itself realistic but binding environmental and safety goals for 2020, says Parliament in a resolution in December. Pollution, noise and congestion costs should be included in the prices paid by users, MEPs said. The “roadmap to a single European transport area” with figures, as approved by Parliament, supplements the long-run view of a Commission white paper on the future of EU transport policy. “Co-modal efficiency encompasses economic, environmental and safety aspects and it includes decent working conditions”, said rapporteur Mathieu Grosch (EPP, BE), in the debate. “Parliament wishes to send a strong signal to Member States to accelerate the transposition of directives into national laws and abolish remaining ‘invisible frontiers’ so as to complete a single, co-modal and efficient transport area” he added. MEPs ask the Commission to table a proposal by 2014 for the “internalisation of external costs” for all modes of transport, with a view to including noise, pollution and congestion costs in the price paid by the user. Member States should use the revenue that this generates to fund sustainable mobility and transport infrastructure costs, says the resolution.