Applied Acoustics 138 (2018) 101–114

Contents lists available at ScienceDirect

Applied Acoustics

journal homepage: www.elsevier.com/locate/apacoust

A study of the performance of a generalized exceedance algorithm for detecting noise events caused by road traffic

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ARTICLE INFO

Keywords:
Noise event
Detection algorithm
Indicator
Road traffic

ABSTRACT

A key question for road traffic noise management is whether prediction of human response to road traffic noise could be improved by accounting for noise events instead of, or in addition to, energy equivalent or percentile measures of noise exposure. However, there is a critical prior question: how should noise events in road traffic be measured? Even at moderate traffic flow rates, detecting and counting noise events caused by road traffic is not a trivial exercise, and as yet there is no generally accepted noise event detection algorithm. This paper investigates the performance of a generalized exceedance algorithm for detecting noise events, constructed on the basis of the literature on noise events caused by road traffic. For this purpose, a microscopic traffic simulation model, coupled to an emission model that accounts for distributions of sound power levels of individual vehicles, is used to simulate one-hour time histories of the noise level in the proximity of a roadway, for an exhaustive set of traffic flow/composition and propagation distance conditions in unshielded locations. The validity and reliability of the number of noise events detected by the generalized algorithm in these one-hour time histories is then evaluated for a range of algorithm parameter sets. By discarding parameter sets that do not result in an algorithm that returns valid or reliable counts, and by examining redundancy in the remaining ones, a small number of representative parameter sets is identified, which may prove useful in the construction of event-based indicators supplementary to energy-equivalent measures of road traffic noise.

1. Introduction

A *noise event* in the sound from a stream of road traffic is a discrete component of the sound signal that stands out, or emerges, from the rest of the signal generated by the traffic stream. It is most often the result of the passage of an individual loud vehicle, or succession of vehicles, or even the passage of a not particularly loud vehicle heard against a quieter background in situations of low traffic flow. The term *noise event* has been used extensively across road, rail and air transport modes (e.g. [1–5]). Synonyms for noise events, and other related terms describing event concepts, are: *maxima* [6], *emergences* [7,8], *noise peaks* [8], *peak* or *max dB(A) levels* [9], or *peak noise/sound levels* [10–14]. Also used is the non-acoustic term *vehicle passby* [15]. In the literature of noise events, reference to peaks in road traffic noise signals (as in [13,16]) are to noise events as described above, not to the peak sound pressure. A related concept, but defined instead as an instant of attention focus by an individual on the physical occurrence of a noise event, is the concept of *notice events* [17,18]. Noise events in traffic noise streams have also been described in inverse, using terms such as *lulls* [19], *noise-free intervals* or *windows* [20].

Noise events in transport noise signals are of interest because of the role they may play in human response to the noise, including disturbance to sleep, annoyance, interference with activities, cardiac responses, and effect on children in schools. Brown [21] has provided an overview of the scattered, but persistent, evidence regarding the effects of noise events in road traffic streams on human response. The presence of events is postulated to result in effects beyond those attributed to the level of road traffic noise exposure itself—the latter measured through conventional indicators such as L_{Aeq} and L_{A10}. The Environmental Noise Directive [22] notes the potential use of noise events as *supplementary* to the standardized energy-based indicators of noise exposure, though there appears to be limited application of such supplementary indicators to date. The WHO [23] suggests that events be measured by a combination of number of events and their level, but also noted that as yet there was no generally accepted way to count the number of events. For aircraft noise, measurement of noise events from overflights is standardized (e.g. [24]) and counts of events, or measures such as SEL, are relatively straightforward because of the time separation between

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https://doi.org/10.1016/j.apacoust.2018.03.031
Received 16 October 2017; Received in revised form 3 March 2018; Accepted 27 March 2018
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successive overflights. However, road traffic can have much shorter vehicle headways, resulting in problematic event detection and counting, even at moderate traffic flow rates [25–27]. Apart from their role in potentially explaining human response to certain traffic noise conditions, there is also an interest in road traffic noise events as an intermediate step in the estimation of energy measures of the whole traffic flow noise signal, or in the estimation of uncertainty measures due to the variability of the acoustic sources in time (as in [28]). The latter applications are not considered further in this paper.

This study applies a rigorous approach to the exploratory definition and measurement of noise events from road traffic—something essential given the largely ad-hoc approaches to event measurement in road traffic noise streams to date. In Section 2 we compile and categorize different formulations of event-based indicators relevant for road traffic noise that have appeared in the literature; formalize a general conceptualization of road traffic noise events based on these; systematically extend the set of event indicators to cover all relevant and realistic exceedance dimensions; and develop a formal approach to the detection of these events in time histories of road traffic noise. We then examine, through a modelling study, the behavior of this generalized event detection algorithm across acoustic conditions generated from a wide range of traffic parameter and propagation distance conditions found near roadways. The conditions we utilize are, effectively, the population of acoustic conditions that can exist near roadways where there is direct propagation of sound from traffic sources to receivers (that is, excluding only situations with roadside barriers or shielding by urban infrastructure). We also examine the limits on the likely repeatability of measurement of different noise event measures in practice, and the sensitivity of counts of noise events to the parameters of the event detection algorithms that define them. Finally, the wide range of parameter value combinations of the generalized noise event detection algorithm, based on exceedance, is narrowed to a smaller, hence more manageable in future work, valid, reliable set.

The research methodology of the modelling study is outlined in Section 3, and the results are analyzed in Sections 4 and 5. The intent of this paper is to rigorously and comprehensively report counts of noise events arising from different possible algorithm definitions for detecting noise events in road traffic, the interrelationships between these alternatives, and any practical limitations on their use. Our focus is on alternative ways in which noise events in road traffic noise might be measured, and on the sensitivity of the number of noise events to different traffic and distance conditions for the different formulations of a noise event. Increasing the rigour and the understanding of the occurrence and measurement of road traffic noise events in this way is a prerequisite to future studies that may seek to develop relationships between the level and number of noise events in road traffic streams, and human responses to events in terms of annoyance and sleep disturbance—and to attempts to limit or manage exposure to events.

2. Noise events

Estimation of noise event metrics in the sound level signal caused by traffic noise requires a two-step procedure. Firstly, individual events in the time history of the traffic noise signal have to be identified using a detection algorithm based on a set of criteria, for example the instantaneous sound level exceeding a predefined threshold. Secondly, once individual events are identified, summary indicators can be calculated, such as the total number or total duration of all noise events over the period of interest. Sections 2.1 and 2.2 focus on the first stage of identifying noise events based on detection algorithms used in literature over the past decades. These are reviewed, and a generalized noise event detection algorithm is proposed. With events detected by a specific algorithm, noise event metrics for the period of interest can then be calculated. Section 2.3 summarizes different noise event metrics that have been proposed in the same body of literature—though in this paper, the focus is primarily on the number of noise events.

2.1. Noise event detection in literature

A wide range of algorithms, protocols, or criteria, have been reported in the literature for identifying noise events within a time series of A-weighted sound levels—usually from road, rail or aircraft sources. These algorithms have been built into noise measurement equipment systems (e.g. [29]), used in experimentation or field studies (e.g. [30]), or sometimes just postulated as possible approaches to event detection. To date, there is no agreement regarding the appropriate algorithm for event detection in road traffic noise streams. This study makes no *a priori* assumptions regarding identification of a noise event. Although noise event detection algorithms have typically been constructed *ad hoc*, a general commonality among algorithms is that they utilize exceedance of some threshold of the instantaneous sound level of the traffic noise signal. Three main categories of algorithms can be identified, which differ in how this threshold is constructed.

In the first category of algorithms, the *threshold* for noise event detection is set to a predefined, fixed, value. Typical values for this threshold range from 45 dB(A) for identifying events in indoor situations with closed windows [31] to 80 dB(A) for detecting events in outdoor situations [8,32]. Some authors [1,30,33] have adopted variable thresholds, even within the same study, depending on vehicle flow rates (higher thresholds being used with higher flow rates). In the second category of algorithms, events are detected when the instantaneous sound level *emerges* by a specified amount above a predefined background level [26,34,35]. The first category of algorithms can be seen as a subset of the second category, in which the emergence is set to zero. In the third category, events are detected when the instantaneous sound level emerges by a specified amount, typically 3–15 dB(A), above another conventional traffic noise indicator, such as L_{Aeq} [36,37], L_{A50} [7,38] or L_{A90} [25,39], this way used as an *adaptive* threshold.

In their suggested event algorithms, most authors have implemented additional decision rules as to whether to retain or reject exceedances above the threshold as noise events. A first criterion commonly encountered is based on the duration of the exceedance. For example, events may have to last for at least 2–3 s, before they are counted [1,25,33,38]. In [31], a much longer minimum event duration of 30 s is used, but their detection algorithm is mainly directed towards air and railway traffic noise events. In [29,25], in addition, a maximum duration is set on the length of an event. Another criterion is based on the time between events. A minimum time gap between noise events can be set to implement an elementary hysteresis effect into the detection algorithm [25,29,39]. This overcomes the problem of multiple event registrations of a single event with irregular rise or decay pattern, and it responds to the (untested) notion that multiple events in short sequence are likely to be perceived as a single event, or that the disturbances caused by multiple events might be experienced as one disturbance.

Table 1 summarizes the parameters for a number of transportation noise event detection algorithms found in literature. This table is not meant to be comprehensive, but gives an idea of the ranges of parameters that have been used in literature, and this has guided the research methodology that will be presented in Section 3 below. For each reference, Table 1 indicates the type of noise source that the algorithm has been designed for, and the situation in which it has been applied (noise events detected indoor or outdoor). Typically, the instantaneous A-weighted sound level envelope of the noise signal is used as the time series, but various time weighting (S/F) and sampling rates can be found (see [27]). Often not all details were reported as to the basis on which noise events were detected. Note that here, only detection algorithms that are based solely on (the time history of) the sound signal are discussed. There are other approaches, such as those in which event time periods are set *a priori* based on data from an external database, e.g. for airplane overflights, those in which there is human intervention in selecting events, or those that apply more general pattern recognition

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