On seeking methodology to "measure" a soundscape

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1. BACKGROUND

Soundscape is just beginning to emerge as an evaluation method that could change the paradigm for evaluating the sonic environment, and improve the quality of life for all. The first ISO standard that defines soundscape, context, and other relevant material, was just approved, so now soundscape can start to grow and mature. With the definitions in the standard, there is now a shared understanding of what a soundscape is. Until now, “soundscape” has moved in many different directions without ever running towards a goal. Now is the time to begin to understand what soundscape can be and what it cannot be, and what it will become.

It has been stated that one cannot attach a measure to soundscape, that one cannot even say context A is better than context B. It is difficult to imagine any planning director or municipal official who will accept and use soundscape if they have no ability to compare two soundscapes and say which one is better; they will insist on answers to these questions before soundscape can come into widespread use. At a minimum, one has to be able to compare two contexts and be able to say definitively that context A will improve the quality of life more than context B. The natural follow-up question is, “How much better is context A than context B?” Here, one does not have to have exact numbers, but one must be able to say at least something like "no better," "a little better," "significantly better," or "a lot better," using some kind of scale. We cannot think of one situation involving planning or land use where soundscape could be used to an advantage without being able to compare alternatives. In fact, the basic goal of soundscapes, to improve the quality of life, implies that you can tell that the quality has improved-A is better than B. If one cannot measure the change, at least one must be able to say "A is better than B," or else how do we know there has been an improvement to the quality of life?

2. DISCUSSION

2.1 CONTEXTS DIVIDED INTO 2 BROAD CATERGORIES

This paper, based on Schomer *et al.* (2013) presents the proposition that contexts in which noise is evaluated can be divided into two broad categories: (1) contexts that affect the community, and (2) contexts that affect the individual. Examples of *community-wide* contexts include: cultural differences, such as the common meal times, or when "late" is, residential setting--urban, suburban, or rural--pervasiveness of traffic noise, as in the ambient level of traffic or highway noise as a function of population, and experience with the given noise source, or what Miedema and Vos (1999) term "use." On the other hand, examples of *individual* contexts include: preferences for windows or doors being opened or closed, preferences for electronics, such as computers or televisions being kept on or turned off, and choosing a place of residence that has or does not have a quiet side, or is close to or far from a main road. Schomer *et al.* (2012) show that in most situations the totality of the community contexts along with acoustic factors that are not incorporated in A-weighting can be represented by a single number that has units of DENL (or DNL). Fidell *et al.* (2011) and Schomer *et al.* go back to the worldwide body of attitudinal noise surveys and examine them based on a theoretical model for how a neighborhood or community should respond as a function of changing sound level. The results show that if the survey was conducted within a community (e.g. town, city, area) in contrast to a multi-city or country-wide survey, then the data generally fit this model very well, but if the survey was conducted in multiple cities, then the data become more cloud-like, and less aligned with the model; an example of this is shown in Figure 1 and Figures 2A through 2F. Figure 1 shows the model fit to a 6-city railroad noise survey in Sweden. The 6 cities are a cloud of points. Figures 2A through 2F show the model fit to each of the 6 cities separately. In this case the measured data fit the theoretical curve quite well. Community noise assessment needs to focus on a community to assess and should not use some hypothetical average community response to asses it.

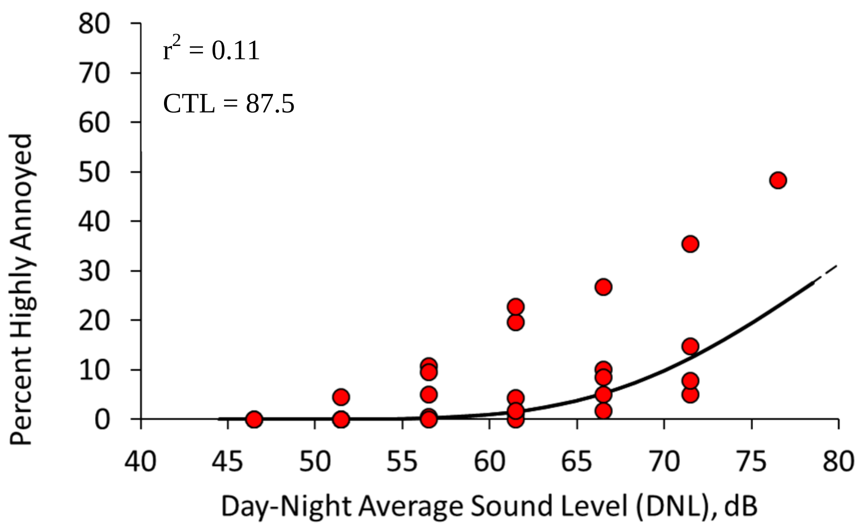
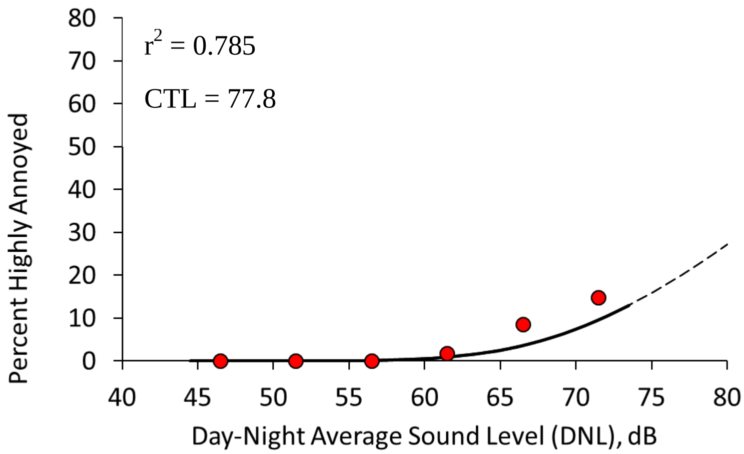


Figure 1. An amalgamation of the data from the six Swedish cities form a cloud of data, and the corresponding correlation coefficient (r^2) and CTL.

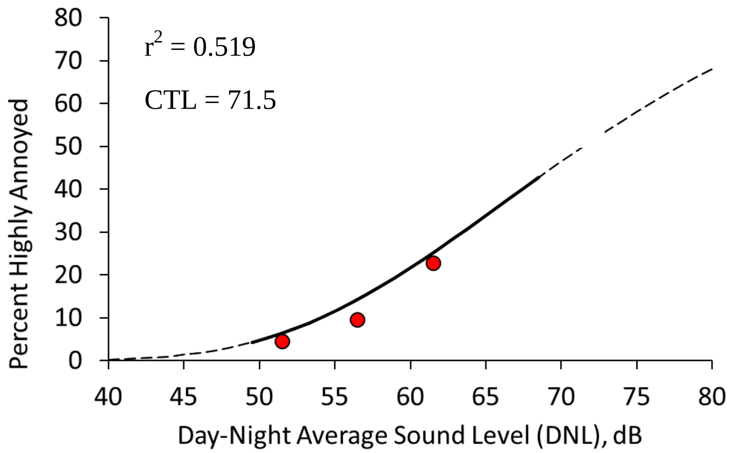
2.2 COMMUNITY TOLERANCE LEVEL (CTL)

Development of the model, given mathematically as Equation 1, makes two theoretical hypotheses: (1) annoyance is basically a loudness type of function and annoyance grows as DENL^0.3, and (2) the basic relation takes the form of the simplest transition function, $e^{(-1/x)}$. To find the CTL value for a community, one does a least squares fit of the community noise survey data to predictions made by the model by varying the CTL variable, L_{ct}, to find the least squares fit. That value of L_{ct} is designated the CTL for that survey. By definition, when the DNL for that community (or any community) equals *its own* CTL, then the percentage predicted by equation 1 is 50%. The "proof" that the CTL theory is viable is that the explained variance goes from about 45% to 70%.

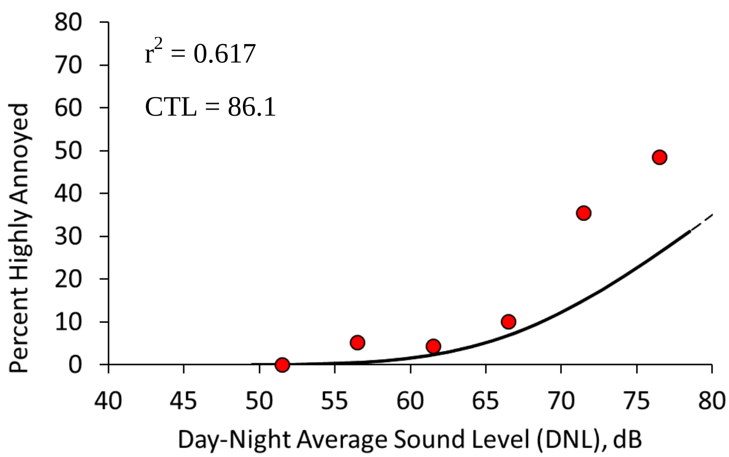
$$P_{HA} = 100 * e^{-\left(\frac{1}{10^{(L_{dn}-L_{ct}+5.3/10)}}\right)^{0.3}} \qquad \text{eq. 1}$$



A. Säffle

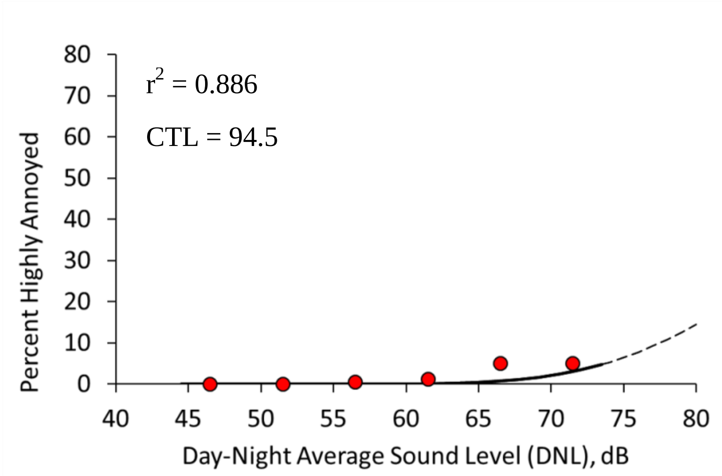


B. Kungsbacka

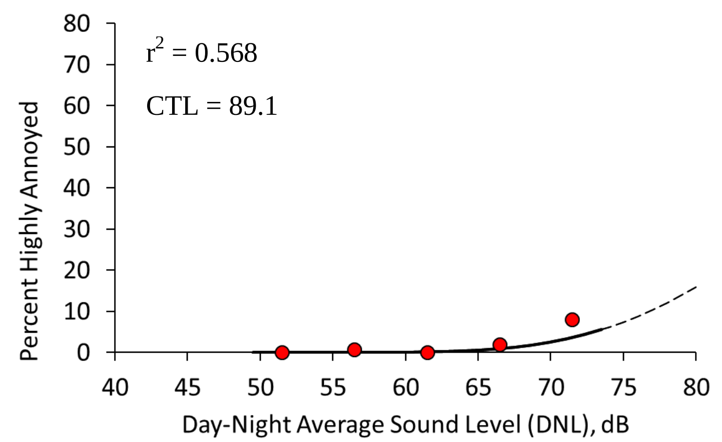


C. Partille

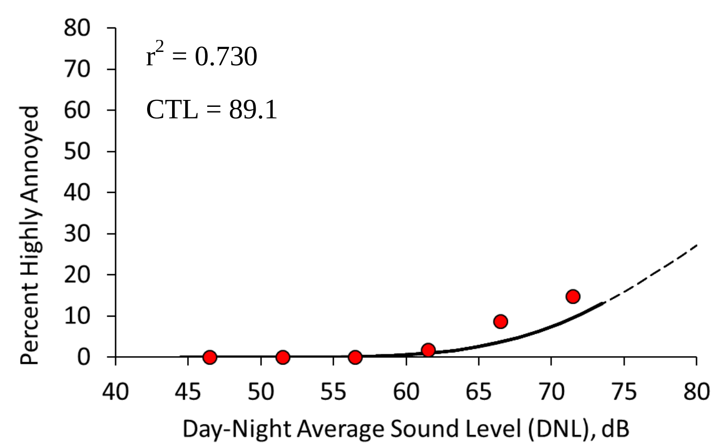
Figure 2. Percent Highly Annoyed versus DNL for each of the six Swedish cities (2A-2F). The correlation coefficients for these figures are mostly much higher than the coefficient in Figure 1; the smallest is 0.519. This high correlation is reflected in how closely the data for an individual community fit the theoretical curve.



D. Hässleholm



E. Huskvarna



F. Lund

Figure 2. Percent Highly Annoyed versus DNL for each of the six Swedish cities (2A-2F). The correlation coefficients for these figures are mostly much higher than the coefficient in Figure 1; the smallest is 0.519. This high correlation is reflected in how closely the data for an individual community fit the theoretical curve.

This single number, CTL, incorporates all the non-acoustic variables and all the non-A-weighted acoustic factors not included in A-weighting or DENL. The latter are the well-known group: impulsive noise, tonal noise, very low frequency noise that induces rattle[1], etc. The non-acoustic variables are what we concentrate on now. These have been around for many years and have been suggested by various authors, notably Job (1988) and Job *et al.* (2001), and their observations that sensitivity to noise was a more important factor in reducing variance than was the noise level. So what has been presented so far is that CTL works because it reduces the unexplained variance a large amount, and it is quantifying what people have always said, i.e., that there are non-acoustic and non-A-weighted acoustic factors that affect the community responses; that is not new. What is new is that we can quantify all these effects with one simple parameter--CTL.

2.3 Relationship between CTL and soundscape

Now we show how CTL relates to soundscape on a community-wide basis. We make the observation that all attitudinal noise surveys are soundscape surveys and not just acoustic noise surveys. We say this because every respondent in an attitudinal survey must be responding within their context. So it becomes clear that every attitudinal survey is a soundscape study and there exists a large body of data with respect to human response within various transportation-related soundscapes. This is the second of three factors that link soundscape and CTL together.

So far we have the following: the non-acoustic community response can be characterized by one number, CTL, and the non-acoustic factors are things like sensitivity to noise, urban vs. rural setting, familiarity with the sound source, etc. The third observation is that these non-acoustic characteristics, and probably many others unnamed, result in the community response measured and quantified by the single number CTL. The contexts of soundscape must be these non-acoustic factors that have been discussed over the decades and soundscape, at least in part, is a formal manifestation of what, for decades, has been called, "non-acoustic variables." So the result is not just that CTL and soundscape are linked, but that in many to most situations soundscape and CTL are different manifestations of the same thing. So the fact that CTL represents the total response of all the non-acoustic variables suggests that soundscape can be represented by one number. This suggests that all the singular contexts somehow add up to CTL, which further suggests that when we understand it better we will be able to say that context A along with contexts B and C give a certain benefit; we just have to learn how all of these come together to form the total. I believe that this must be the goal; it has been demonstrated that it is possible, but we do not know how it works. That is the direction; that is the challenge.

3. Steps towards quantifications of contexts

In this section, we look at several of the traditional non-acoustic factors and offer thoughts as to their magnitude and range, and what is needed to give these estimates greater validity.

3.1 Sensitivity to noise

Sensitivity to noise has long been recognized as an important factor in an individual's response to their sonic environment. We can turn this into a community context by reviewing estimates of the percent of communities that are noise sensitive. Reviewing authors such as Miedema and Vos (1999), Fields (1993), Langdon (1976),

[1] Schomer and Averbuch (1989) find in a study of human response to large weapon noise (artillery, armor, demolitions) that the sensitivity increases by more than 13 dB for nearly identical sound conditions with rattle present versus conditions where rattles are not present; the only differences in level between the two cases—rattle and no rattle—was a C-weighted difference of a few tenths of a dB.

Matsumura and Rylander (1991), and Heinonen-Guzejev *et al.* (2000) gives the indication that the percent of the population that is noise sensitive ranges from 22% to 38%, with 25% or so being a good average (weighted by number of subjects).

Miedema and Vos (1999) provide decibel estimates of various non-acoustic variables, including noise sensitivity, and come up with the following numbers for the decibel difference in annoyance for the change from low sensitivity[2] to medium sensitivity, there is an increase of 4.6 dB, and from low to high sensitivity, there is an increase of 11.2 dBWhat is needed is a greater confidence to these percentages and especially the decibel levels.

3.2 Fear related to noise

Fear is the non-acoustic factor found by Miedema and Vos with the largest effects on human response. From low to medium fear, they find an 11.4 dB increase, and from low to high fear, they find a 19.5 dB increase. As with sensitivity, one would need to turn this individual context into a community context by understanding the percentages of people in these different categories.

3.3 Other individual factors that can be treated on a community basis

Miedema and Vos (1999) discuss several other non-acoustic variables that provide small decibel changes. Some of these are amenable to being placed on a community basis given the statistical relations. We choose two of the designations, household size and home ownership, as these two are independent of what member of the family is being focused on. Other factors appear to be more individual factors, such as age, highest educational level, occupation, dependent or not, and familiarity with the noise source. All of these factors could be used as contexts, but home ownership and household size seem to be the easiest to implement as they apply to the whole household and not just to one member.

3.4 Expectations as a context in which soundscapes are developed

Like sensitivity to noise, expectations are known to be a modulator of a person's perceptions of the noise environment, i.e. the soundscape. One particular expectation known to exist and documented is that rural, urban, and suburban dwellers all expect rural areas to have more peace and quiet than urban areas. For this reason ISO 1996-1 and ANSI S12.9 Part 4 both currently incorporate a 10 dB adjustment to the criteria levels for quiet rural areas. Again, more research is needed to obtain more precision in the decibel adjustment.

3.5 Attitudes towards the sound maker

Attitudes towards the sound maker is another factor that has been in the literature since the early 1970s or earlier. This is the first indication that there can be positive contexts compared to the average. If the attitude towards the sound maker is positive, then there can be a bonus of up to 10 dB, and conversely if the attitude towards the noise maker is negative, there can be a penalty of up to 10 dB.

[2] The definitions of these three categories, low, medium, and high sensitivity, are not given. We interpret low to include total non-sensitive people, and high to include the most sensitive people. Low sensitivity is clearer as it is being compared to, high sensitivity is not as clear.

In summary, it is clear that virtually all of these factors that have been talked about in the past are clearly contexts within which the judgments on surveys and indeed public reaction has been based. In looking at these numbers it is clear that it is easy to shift from a 10 dB bonus to CTL to a 10 dB penalty. Thus, it is not surprising that the standard deviation is so large. Just consider a quiet rural area with a bus terminal and imagine the impact in this rural area versus downtown New York.

4. Conclusions and research directions

4.1 Conclusions

1) Virtually every attitudinal noise survey that has been done is a soundscape study as the respondents had to answer within their context.

2) All of the factors discussed over the past 50 years dealing with non-acoustic variables are applicable to soundscapes. Because virtually every survey was a "noise annoyance" survey, the response was in a negative scale. So it is more difficult to know what the positive factors might look like other than positive attitudes towards the noise source.

3) CTL provides a one-number descriptor for the soundscape. This is clearly true when the factors are negative, and would seem to imply that at least a subset of soundscapes can be quantified with one decibel value.

4.2 Research directions

The larger problem facing us is to find all of the contexts that are applicable and relevant to the soundscape, find methods to quantify, in some fashion, each of these contexts, and then find the means to combine these together into a measureable description of the soundscape.

In the short term, immediate work that can commence is to develop data and methods to quantify with higher certainty the decibel values for the various contexts, and the means to take a percent of the population at a certain level and to combine that into one indicator of that context, and then test if the indicators for the various sources can add together using decibels, as this text might indicate.

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