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An indicator for rating environmental quality of urban parks

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ABSTRACT

There are various noise limits for different sources that are well based on numerous studies and aim to protect inhabitants from the negative effects of noise, such as annoyance or sleep disturbance. However, regarding noise regulation for nature areas, city parks or other outdoor public spaces, in most countries there is no legal noise limit or standard approach on how to define the overall acoustic or environmental quality in relation to the surroundings. In defining an indicator that rates the quality of such areas, not only the noise levels within the area are important, but also non-acoustical aspects, such as the nature esthetics and the availability of the areas for residents. Travel time and the number of dwellings that are located within acceptable range of these areas should also be taken into account when trying to establish a suitable indicator. In this paper we present an empiric model for rating public green urban areas and propose an indicator (G_q) for rating both their acoustical and environmental quality.

1. INTRODUCTION

In the Netherlands, noise legislation since the seventies has mainly aimed on the reduction or limitation of noise levels on the facade of dwellings. The National noise Act defines L_{den} limit values for road traffic noise, railway noise and industrial noise. For aviation noise, limits are set in the Aviation Act for the number of dwellings that are exposed to Lden levels over 58 dB(A). Although many dwellings still exceed the limit values, the general feeling is that noise policy in many cases has led to improvement of the livability in the most exposed areas. In particular, noise barriers along busy motorways and railways have effectually reduced the number of 'hot spots' along these sources. In addition, in the framework of noise insulation program from 1986 onwards, many Dutch dwellings were provided with improved noise insulation in situations where barriers were not feasible. Regarding appropriate noise limits to protect citizens from negative effects of noise, such as annoyance or sleep disturbance, there exist various noise limits in the Netherlands for different sources that are well based on numerous studies. Notwithstanding the intensive noise abatement efforts that have been undertaken in the past decades, noise is still a problem in the Netherlands, particularly in dense urban agglomerations, due to busy local roads, airport traffic and freight trains. It is estimated from RIVM noise maps that 215.800 and 19.000 dwellings are exposed to high noise levels of 65 dB(A) or more, from road traffic and railways respectively. This jointly comes down to approximately 3.3 % of Dutch dwellings. This relatively modest percentage seems to indicate that our legislation and noise policy, despite strong traffic growth over the past decades, has been effective in keeping the number of highly exposed dwellings limited. The problem is that the threshold for a good noise quality is much lower than 65 dB(A) and lies around L_{den} 50 dB(A). Although the number of dwellings highly exposed by noise seems to have been kept relatively low, many dwellings are still exposed in the range 55-65 dB(A) and experience a far from good noise environment, particularly outdoors. The classic approach of trying reduce all noise levels on the façade below 60 dB(A) or even 55 dB(A) will be infeasible, simply because the costs of measures would turn out to be unacceptable for society. The Dutch government spent 2.8 billion guilders (app 1.3 billion euro) on noise abatement between 1979 and 1993, but the percentage of citizens who complain has hardly decreased at all, due to growing mobility and population (Bijsterveld 2008). This raises the question whether there are other additional (effective) noise policies available to improve the outdoor environment in urban areas. An alternative policy, that has been considered some time is to strengthen the classical approach by creating public outdoor spaces in urban areas with a high acoustic quality. The idea is that when its infeasible to create such areas in the direct vicinity of every dwelling, it may be possible to create 'reservoirs' of undisturbed nature that are within acceptable travel range for the majority of the citizens and can offer compensation. Studies suggest that spending time in 'green' areas with relatively low levels of mechanical noise is beneficial for our health and well-being (HCN 2006), (Alvarsson 1995), (Kaplan 1995). Noise policy is for quiet areas is now mentioned in Article 8 (Action Plans) of the European Noise Directive (END 2002) that states: *'Action plans shall also aim to protect quiet areas against an increase in noise'*. However, as we look at noise regulation for nature areas, city parks or other outdoor public spaces, there is no general agreement as to what should be an acceptable noise level nor what exactly is meant by a 'quiet area'. According to END: *'Quiet area in an agglomeration', shall mean an area delimited by the competent authority, for instance which is not exposed to a value of L_{den} or of another appropriate noise indicator greater than a certain value set by the Member State, from any noise source'*. This still leaves the regulation to the member states and does not tell us how a certain noise limit in public green areas relates to effects on the urban population. In defining an indicator that rates the environmental quality in 'quiet' public areas, not only the noise levels within the area should be taken into account, but also non-acoustical aspects, such as the nature esthetics and, in addition, the availability of the areas for residents. For example, a quiet area that is situated too far away from a residential area will have less benefits for its inhabitants. Travel time and the number of dwellings that are located within acceptable range of a quiet area also determine the restorative value of such areas. It is important to take these aspects into account when trying to establish an indicator for the restorative quality of a quiet area in relation to the populated surroundings. In this paper we propose an empiric model for rating the combined acoustical and other beneficial properties of outdoor public city areas, that incorporates the aforementioned aspects. The study is part of TASTE (Towards Acoustic SusTainable Environments), a research project currently running at RIVM.

2. PROPOSED MODEL

In this paper we will use the word 'park' as a synonym of 'public green' or quiet area with the restriction that we only consider relatively large city areas that are open to the public. Our model does not incorporate acoustic (non-public) benefits from a 'quiet' backyard which were studied elsewhere, e.g see results of the EU- City Hush project (Janssen 2011).

As outlined in the introduction, an indicator for the acoustic value of a quiet area should be able to incorporate multiple environmental aspects:
a) average noise levels caused by mechanical sources (cars, trains, airplanes etc)
b) the accessibility of the area for nearby inhabitants
c) the presence of pleasant sounds that could enhance the perceived acoustic quality, such as birds, trees, waterfall etc. These aspects are related to soundscape theory.
d) non-acoustical factors, both positive and negative: nature, 'beauty' of the area, safety, sufficient lighting, cleanliness, visual variety, fit of context etc
From a) to d), rating these factors will become increasingly subjective, but merely considering a) seems inadequate for the overall assessments of environmental quality. One would like to take all of these factors somehow into account. From a practical view, preferably by a simple, easy to apply indicator, e.g. a number classifying the accumulated value of the factors a) to d), that allows a mutual comparison of different areas. To this aim we defined an indicator (G_q) as follows:

$$G_q = L_{ref} + 10\log\left(\sum_j \sum_i \frac{Q_i \cdot s_i}{r_{ij}^{\,b}} \cdot 10^{\frac{-L_{den,i}}{10}}\right) \qquad (1)$$

in which,
L_{ref} : reference level [dB(A)] above which no benefits from the outdoor areas are assumed
i : summation index over al sub regions of an public outdoor area
s_i : surface of the area (i) [m^2]
$L_{den,i}$: noise level inside the area (i) [dBA]
r_{ij} : distance from the outdoor area (i) to dwelling receiving benefits (j) [m]
b : power of reducing benefits with increasing distance
Q_i : quality factor (0-100), taking into account soundscape and non-acoustical aspects [-]
j : summation index over all dwellings in the neighborhood of the public area
G_q : resulting 'group quality level' of homes surrounding the considered area [dBA]

This model is further explained in eq. 2. The group quality level (G_q) contains both acoustic and broader environmental aspects. The latter are taken into account by the quality factor Q. In addition, this factor can also be used to incorporate insights from soundscape theory. For example, Q can be based on the nature richness of the considered area ('beauty') and also on the presence of natural sounds, pedestrian facilities, etc. Although this factor introduces a considerable degree of ambiguity and subjectivity into our model, it's a necessary element of the rating, as many studies show (e.g. Jackson, 2008) that for the perception of environmental quality, both non-acoustical factors and soundscape (Brown, 2010) play an important role.

3. Application to Dutch Parks

The application of eq. 1 to Dutch urban parks required to identify public green areas, determine the (effective) noise levels and assess non-acoustical qualities. We made an inventory of parks based on internet maps and aerial photos. Public green could partly be identified using the 'park' icon in Google Maps. In this way, 353 parks and green areas were inventoried in fourteen of the largest Dutch municipalities (based on number of inhabitants) in the Netherlands, which involves approximately one fourth of the total Dutch population. The noise levels were estimated using the STAMINA noise model for noise mapping, developed at RIVM (Schreurs 2008).

The attractiveness ('beauty') of a park is an important factor that assumingly influences how often people will visit the park and how long they will stay relaxing, recovering, chatting, playing and so on. This aspect is highly subjective and therefore difficult to assess objectively. Van Herzele and Wiedemann (Herzele 2004) give a short history of the meaning of parks in city planning. They also provide a list of features that determine the attractiveness of parks. We will follow their approach hereafter. In early city planning, the surface area of a park and its distance to the surrounding neighborhood were mainly considered as significant factors. Later, research into perception was used to explain why some parks appeared to be more attractive than others. Important factors appeared to be a large range of possibilities for use (facilities), the accessibility, size and safety. Sometimes not the features of the park itself, but its coherency with other parks in the area is important. In any case, the presence of different themes with large variety within a park is important for quality: different facilities, variety in visual aspects and landscape elements. An overview of important qualities is listed in Table 1.

Table 1: Translated from Van Herzele and Wiedemann (2003).

Green Qualities	*Main Variables*	*Raising Quality*	*Detracting Quality*
Space	- Low degree of fragmentation (1) - Harmonious and/or functional blending of parks in urban environment	- Attractive visual variation and context - demarcation (if appropriate with regional features)	- Disturbing visual elements -Little visual variety
Nature	- Natural character - Diversity of vegetation - Sustainability	-Presence of bushes/lakes -Close pattern of varying landscapes -Elements of uncultivated (wild) nature	
Culture History	-Relicts of landscape history -Degree of cultivation/ -Age of parks	-Close pattern of characteristic relicts -Harmonious context	-Poor maintenance -Vandalism -elements disturbing context
Sound quality	-Presence of roads/railways/airports -Noise levels and statistics	-Attractive and contextual soundscape (presence of pleasurable, 'wanted'sounds e.g. birds, water, wind)	-Unnatural sounds from sources that are out of context
Facilities	-Accessibility, entries and paths	-Facitities, benches, playing yards toilets, supply of survices, terraces etc	-Unsafe poorly maintained facilities -Excess of facilities

Some of these features can roughly be evaluated from aerial photos or street view pictures. Other aspects however, like culture and history, are much more difficult to assess. Only few qualities can be expressed objectively into a number. This applies for example to degree of fragmentation (a narrow long stretch of park is less attractive than a circular park of the same area). Of course, also noise or sound indicators can be quantified, though it is not certain which noise measure (LAeq, L10, L95, peak levels) are most important for the perception of acoustic quality.

As a first attempt to assess a non-acoustical quality factor Q, we use only the following features that are visible on aerial photos: visual variation, possibilities for recreation, degree of fragmentation and the fraction of green area. Optimum rating was set at 100% and worst rating at 50% We define the non-acoustical quality factor Q (range 0-100) as the multiplication of the ratings of the above features. This way, the Kralingse Bos in Rotterdam received a high score of 90, while the result for the Prinsenmolenpark was only 24.

So far we have not yet tried to rate and incorporate soundscape properties of parks into the quality factor Q in eq. (1). Research indicates that the (natural) soundscape of a park can have a large influence on perception and the feeling of enjoying nature (Brown 2010). However, unlike noise from roads, airports or railways, the development of indicators and objective tools for assessing natural soundscapes are still undeveloped. Perhaps the most promising methods consist of well-designed questionnaires where visitors are specifically asked to their perception of natural sounds. Apart from the lack of objective tools for rating soundscapes, it can be expected that their perception and possible environmental benefits are highly related to the time behavior of noise exposure from mechanical non-nature source. For now we have relied upon Lden (yearly average) noise levels, but possibly background noise levels are far more important. High background noise levels will continuously mask natural soundscapes and do not allow for alternating periods in which the natural soundscape of a park can be observed and enjoyed. This will be studied further in the TASTE project (see Chapter 5 ‘Ongoing research’).

In eq. 1 we assume that parks can be seen as a (fictitious) ‘source of silence’, when the noise exposure is below a reference threshold value. As a next bold step, we assume a geometrical attenuation of a ‘quality level’, L_q with distance.

$$L_{qj} = L_{ref,i} - L_{den,i} + 10\log(Q_i \cdot s_i) - 10\log(r_i) \quad (2)$$

The source strength consists of the first three terms in eq. 2 and depends on the product of the non-acoustical quality factor Q times the ‘emitting’ area (s_i) and the effective degree of silence experienced in the park expressed by the difference L_{ref} - L_{den}. The more the L_{den} exposure lies below the reference level, the more a park is expected to attract visitors that are looking to enjoy its nature and natural soundscape. Equation (1) is just the accumulation of eq. (2) over all parts of the park (summation index i) and over all surrounding dwellings (summation index j), which results in a single aggregated indicator G_q. We are aware of the high degree of pragmatism in defining G_q, but this indicator has a number of advantages:

- G_q contains most of the factors that are known to influence the perceived environmental quality
- Setting an urban policy to increase G_q will steer in the right direction (as far as environmental quality is the issue), in the sense that urban policymakers are urged to improve one or several mutually non-contradictory factors (i.e improving nature, lowering mechanical noise, improving natural soundscapes, increasing the size or the number of parks etc)
- With this definition of G_q, ‘acoustic summation’ of contributions from different parks is allowed (e.g. 10 parks each with G_q =100 dB, will give a total of 100+10log(10)=110 dB). In realizing a policy to improve the total (joint) quality urban parks, this will give local policymakers more flexibility to fit design and targets within other interests.

4. Preliminary results

We have applied the model for rating G_q as outlined above for 16 parks in the city of Rotterdam. The reference level was set at L_{ref} = 60 dB(A) and we assumed a 10log(r) attenuation of quietness levels L_q (i.e the parameter b in eq. 1 was set to 1). The parks are shown in Figure 1. They display significant differences in their range of attraction. The colored dots correspond with parks of the same color and indicate the homes of people, who in the COS enquiry of 2011

(Weber2011) indicated that they regularly visit a particular park. Some parks show a relatively large range of attraction, especially the larger ones. For example, this is the case for the 'Kralingse Bos' and the 'Zuiderpark' in Rotterdam. It is also notable that the 'Zuidelijke Randpark', which is located nearby the A15 highway, hardly attracts visitors. This may have to do with the fact that the area is experiencing a relatively high noise exposure because of road traffic on the A15. Table 2 gives the calculated values of G_q. The last column is based on the COS enquiry of 2013 and gives the percentage of people that mention the park as the one that they visit most. For the 'Prinsenpark' the highest value of G_q was found, mainly because the average L_{den} exposure level was estimated rather low in this park. Despite the high value of G_q, its range of attraction seems to be rather poor. Obviously a high value of G_q does not necessarily mean that a park will have a large range of attraction. Here also the presence of the nearby 'Kralingse bos' may be of influence and maybe the underlying factors in the model need better assessment for this park. (e.g. the park is grazing next to a cemetery). For 'The park' (nr 12), the Q-factor may have been underestimated. This park is located beautifully on the Meuse, an extra bonus particularly in the summer. This also holds for the 'Oude Plantage' (nr. 13) but this park may be too small and is also located nearby the 'Kralingse bos'.

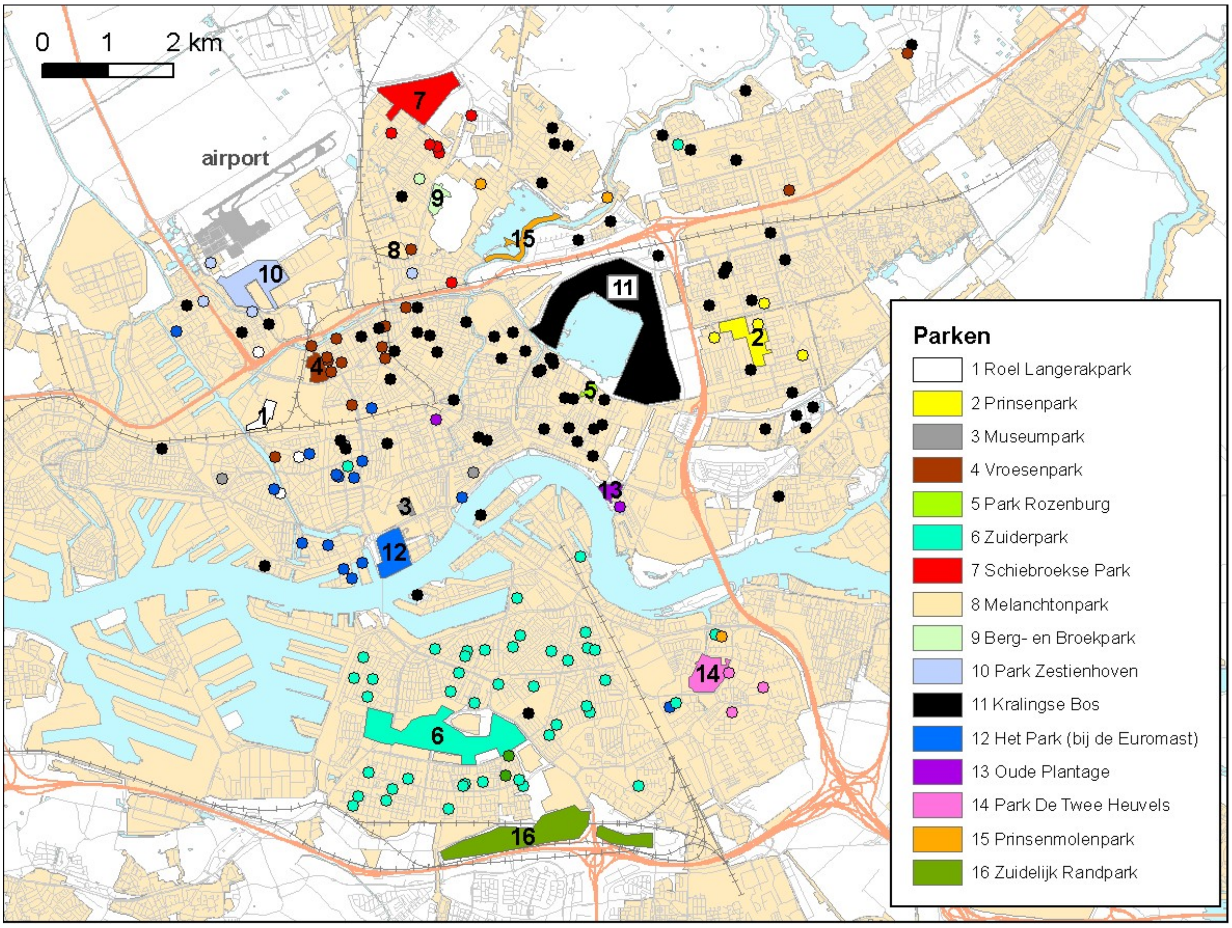

Figure 1: Map of parks in the city of Rotterdam

Table 2: Model parameters and G_q for the parks in Fig 2

park	%green	%fragm	Area [10.000m^2]	Q	Lden	G_q	Most visits[%] (COS 2013)
2 Prinsenpark	70	56	24	56	48	117	2
6 Zuiderpark	70	49	100	63	54	116	10
11 Kralingse bos	100	53	190	90	54	115	26
10 Zestienhoven	100	56	42	80	48	115	2
14 Twee Heuvels	70	79	25	56	52	112	2
12 Het park	100	85	26	80	58	109	8
8 Melanchton	70	78	7	49	49	109	1
9 Berg&Broek	70	63	19	44	50	109	1
5 Rozenburg	100	69	4	80	49	109	1
7 Schiebroek	50	71	53	45	55	108	1
3 Museumpark	70	80	5	39	51	107	3
16 Zuidlk randpark	100	46	92	80	64	105	1
4 Vroesenpark	100	81	10	90	61	104	4
13 Oude plantage	70	74	6	49	58	102	0
1 Roel Langerak	70	69	9	63	62	102	1
15 Prinsenmolen	70	33	14	24	54	99	1

5. Ongoing research

Ongoing research in the TASTE project is focused on the extent where public parks are experienced as a clear improvement of the urban environment. To this end within the TASTE project several enquiries are carried out. In 2011 in cooperation with the EPA Rotterdam (DCMR) and the Rotterdam Centre for Research and Statistics (COS) a questionnaire was set out in the city of Rotterdam among approximately 3600 inhabitants (Weber 2011). The survey response rate was 35%, i.e. 1.263 citizens aged between 16 and 85 years answered the questions on noise annoyance and (quiet) urban parks. As these results only cover the city of Rotterdam other additional questionnaires with a larger scope were designed. In July 2012 a (pilot) questionnaire was launched using a noise application on RIVM's website (RIVM 2012). People who live near a park and visit the site are requested to fill in a questionnaire and report the experienced quality within a particular park and how often they visit the park. During the past half year this so far has led to a moderate number of 200 responses. In February 2013 the COS-questionnaire was repeated and results are now ready for further analysis. Finally, in March of 2013 an extensive broader survey has started within 31 neighborhoods distributed in Amsterdam, Rotterdam and Arnhem among more than 10.000 inhabitants. In this survey, questions not only focus on the environmental quality of parks, but on the acoustic quality of urban neighborhoods in general, with particular attention for the role of soundscapes and a further understanding of non-acoustical factors that are important for environmental quality.

6. Summary

This paper describes a pragmatic model that can be used as a tool for rating the environmental quality of urban parks. The model is able to incorporate both acoustical and non-acoustical aspects and takes into account the distance that visitors have to travel to visit the park. A first application for 16 parks in the city of Rotterdam shows that the parks display a large range in the calculated value of G_q. Some parks with a high group quality level G_q show a large region from where visitors are attracted, particularly the parks that have large size. For some other parks the correlation is still rather poor. To improve the predictive value of the proposed method, survey data concerning perceived environmental quality from ongoing enquiries will need to be further analyzed and correlated with quality indicators. This will be taken up in the TASTE project in 2013 and 2014.

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