DELIVERABLE 2.1.1[1]

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2.1	**Preliminary noise score rating model for the outdoors**
Written by	**Sabine A. Janssen and Erik Salomons**
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Project Co-Ordinator	Acoustic Control	ACL	SE
Partners	Accon	ACC	DE
	Alfa Products & Technologies	APT	BE
	Goodyear	GOOD	LU
	Head Acoustics	HAC	DE
	Royal Institute of Technology	KTH	SE
	NCC Roads	NCC	SE
	Stockholm Environmental & Health Administration	SEP	SE
	Netherlands Organisation for Applied Scientific Research	TNO	NL
	Trafikkontoret Göteborg	TRAF	SE
	TT&E Consultants	TTE	GR
	University of Cambridge	UCAM	UK
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PP	Restricted to other programme participants (including the Commission Services)	
RE	Restrictec to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for the members of the consortium (including the Commission Services)	

Nature of Deliverable

R	Report	✓
P	Prototype	
D	Demonstrator	
O	Other	

SEVENTH FRAMEWORK PROGRAMME

[1] see List of Deliverables, DoW … (document 233655_CITYHUSH … er)

This deliverable has been quality checked and approved by CityHush Coordinator *Nils-Åke Nilsson*

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0 EXECUTIVE SUMMARY

0.1 OBJECTIVE OF THE DELIVERABLE

Identification of hot spots in noise maps is currently based on façade levels at residents' home and does not include possible beneficial effects of nearby quiet areas. However, a quiet outdoor environment may be very important since people live, work or recreate outdoors during many hours of the day. In order to develop a noise score rating model that enables an evaluation of the outdoor environment as perceived by pedestrians on the streets and visitors to parks, information is needed on the impact of noise in different urban and recreational areas. Knowledge on the effects of noise in the outdoor environment is limited and pertains to very specific situations (e.g. national parks in the USA, aircraft overflights) so that it cannot be applied directly to the impact of predominantly road traffic related noise in the urban outdoor environment. The objective of the present deliverable is to develop a preliminary noise score rating model for outdoor noise based on current knowledge.

0.2 DESCRIPTION OF THE WORK PERFORMED SINCE THE BEGINNING OF THE PROJECT

As a starting point, an overview is made of information on the effects of noise in the outdoor environment. Based on this information and an analysis of the effects to be expected in urban (street, park) areas, a tentative noise score rating model for pedestrians and visitors of parks is designed. Furthermore, preparations have been made for a field study intended to gain more information on the effect of noise in the outdoor environment.

0.3 EXPECTED FINAL RESULTS

In the next stage within the project, the model will be further tested by investigating the effect of noise in the outdoor urban environment in subjects residing and walking in a realistic situation, both in an urban non-natural environment (streets) and in an urban natural environment (parks). For each type of location, both noisy and relatively quiet locations will be included in the study. Measures will involve self-report measures such as annoyance, mood state and perceived restoration, which will be strengthened by accompanying physiological measures such as heart rate and autonomic nervous system activity. Also, noise exposure will be individually assessed to enable the establishment of both instantaneous and aggregated relationships between exposure and human (annoyance) response. On the basis of these relationships, the above mentioned tentative environmental noise rating model for pedestrians and visitors of parks will be evaluated and improved.

0.4 POTENTIAL IMPACT AND USE[2]

In the context of the EU Environmental Noise Directive, it is important to be able to assess the impact of environmental noise in the outdoor situation on residents. The END promotes the

2 *including the socio-economic impact and the wider societal implications of the project so far*

preservation and creation of quiet areas, both in urban and in rural areas, and stresses the need for supplementary noise indicators for quiet areas. So far, the assessment of the impact of noise on residents is based solely on façade levels of dwellings as obtained from the noise maps. Therefore, measures directed towards a more quiet outdoor situation, in so far as they are not reflected in façade levels, will not show up in health assessment indicators. Using the intended noise score rating model for the outdoors, the expected effect of urban quiet areas on residents and visitors of parks may be quantified.

0.5 PARTNERS INVOLVED AND THEIR CONTRIBUTION

TNO is involved in reviewing the literature on the impact of outdoor noise on residents and visitors of parks and in developing the tentative outdoor noise score rating model. Also, TNO will subsequently validate the outdoor noise score rating model based on the results of a field study to be performed. ACL is responsible for feeding the model with factors that are important from the viewpoint of the CityHush case studies, while ACCON is responsible for the integration of the final validated noise score model in the noise mapping software.

0.6 CONCLUSIONS

Based on current knowledge, a tentative noise score rating model for pedestrians and visitors of parks is designed. In this rating model, indicators for outdoor noise are combined with information about the function of the area and the number of people making use of the area at a given time to predict the overall annoyance response, i.e. the percentage and number of visitors that will be expected to be annoyed by noise in a given area.

1 PRELIMINARY NOISE SCORE RATING MODEL FOR THE OUTDOORS

In order to build a noise score rating model for the outdoors, information is needed on people's evaluation of noise in specific outdoor situations. However, in comparison to knowledge on the community response to noise at the dwelling, relatively little is known about the response to noise in outdoor situations. Unlike the noise score rating model for dwellings, which takes into account the expected long-term annoyance response to noise at a given yearly average exposure to noise at the façade of the dwelling, the noise score rating model for the outdoors should reflect the direct expected annoyance response to noise in outdoor situations. In addition, factors influencing the expected annoyance response other than the noise level should be incorporated in the model. A summary of the available information is given below, on the basis of which a preliminary noise score rating model for the outdoors is constructed. Also, several other parameters than the noise level are tentatively incorporated given their supposed influence on the annoyance response.

1.1 CURRENT KNOWLEDGE ON THE EFFECTS OF NOISE IN THE OUTDOOR ENVIRONMENT

Aircraft noise in wilderness areas

The evaluation of noise in the outdoor environment is only addressed in few studies, most of which investigated the impact of aircraft noise in natural areas. Tarrant et al. (1995) reported that, apart from inducing annoyance, aircraft noise in natural areas disturbed feelings of solitude and tranquility. Fidell et al. (1996) found that the occurrence of (but not the number of noticed) high noise level overflights predicted annoyance among visitors of US wilderness parks, but that it did not affect their enjoyment of visits nor their intention to return. Mainly due to the uncertainty of the actual noise exposure and the number of overflights, it was not possible on the basis of these data to derive a relationship between the degree of annoyance and the maximum sound level of overflights or cumulative noise exposure. Anderson et al. (1993), based on data from three US national parks, derived relationships between the percentage of time aircraft can be heard and two effect measures: the percentage of visitors reporting annoyance (moderate to extreme), and the percentage of visitors reporting interference with natural quiet (moderate to extreme). For instance, on short-hike sites with aircraft being heard 30% of the time, about 26% of the visitors are expected to report annoyance, and 50% of the visitors are expected to report interference with natural quiet. These exposure-response curves may be adjusted for the percentage of first-time visitors and for the percentage of the visitors regarding natural quiet as important (both with default values of 50%). Furthermore, exposure-response relationships have been derived for aircraft LAeq during the visit, indicating that for instance at levels of 40 dB(A) 35% of the visitors are expected to be annoyed and 65% of the visitors are expected to report interference with natural quiet.

Aircraft noise in local recreational areas

In a partially controlled field study in a local recreational area near the airport in Oslo, Norway, Aasvang & Engdahl (2004) found a significant relationship between the total annoyance response of a particular visitor and the number of aircraft noise events judged as "not acceptable" by this visitor. The percentage of events judged as "not acceptable" could be described as a function of the sound exposure level of single noise events, with a sound exposure level of approximately 65 dB(A) corresponding to 10% "not acceptable" ratings, and a level of 90 dB(A) corresponding to 60% " not acceptable" ratings. In a related field study in two local recreational areas near Oslo airport before and after the relocation of the airport (Krog & Engdahl, 2004), it was found that LAeq and the percentage of time aircraft were audible were both significant predictors of annoyance (in separate analyses). No or only slight annoyance was reported below an LAeq of 40 dB(A), while an LAeq between 40-50 dB(A) corresponded to about 20% (rather or very) annoyed visitors in the area where noise had increased, but hardly any annoyance in the area where noise had decreased. An LAeq of 50-55 dB(A) corresponded to about 30% annoyed visitors in both areas, increasing to about 55% with an LAeq of 65-70 dB(A) and to 70% with an LAeq of 70 dB(A) or higher. Also, it was found that several contextual factors, such as the survey being before or after a change in levels due to the relocation, the duration of the visit, the reason for visiting (i.e. the acoustic nature experience and mental relaxation), and the area being the visitor's primary recreational area, highly influenced the degree of annoyance experienced at a given exposure level.

Road traffic noise in recreational areas

While the above relationships are based on studies investigating the response to aircraft noise, a survey that was done in three natural recreational areas in the Netherlands (Goossen et al., 2001) looked at the relation between manmade noise in general (mainly road traffic noise) and visitors' evaluation of the acoustic situation. It was found that among several noise indicators (LAeq, LA95, LA5, number of manmade noise events), LAeq showed the highest correlation with the evaluation of the acoustic situation, although at one of the sites LA95 (as an indicator of background noise) was a better predictor. It was concluded that an LAeq level of 40 dB(A) or lower is evaluated by most visitors as sufficiently quiet, whereas levels above 50 dB(A) strongly reduce their positive evaluation. A similar conclusion was reached by Nilsson & Berglund (2006), who found that the Swedish criterion that 80% of the park visitors should perceive the sound environment as good was only met when the traffic noise exposure (LAeq, 15 min) in suburban and city parks during daytime was below 50 dB(A). However, a field study in 3 Italian urban parks showed that the majority of visitors liked the parks very much, despite LAeq levels over 50 dB(A), stressing the role of other environmental factors or the contrast with noisier surroundings (Brambilla & Maffei, 2006). Nilsson et al. (2007) showed that while LAeq predicted the perceived soundscape quality and annoyance due to road traffic noise in 16 city parks, the explained variance was raised a little when LA50 was used as a predictor instead. Over and above the effect of the overall sound level, an indicator for the average spectrum (LCeq-LAeq), as well as the identification of technological and of nature sounds contributed (in opposite ways) to the perceived soundscape quality and annoyance. This is in line with other indications that, next to the loudness of specific sounds, also the physical characteristics and the perceived appropriateness of sounds in outdoor recreational environments are factors that influence their evaluation (Kariel, 1990).

1.2 CHOICE OF THE APPROPRIATE NOISE INDICATOR FOR OUTDOOR NOISE

In the studies cited above, several noise indicators were used to predict annoyance or the perceived soundscape quality as primary indicators. Apart from LAeq measures, the percentage of time noise events are heard, as well as the background noise level (LA95) and the level exceeded 50% of the time (LA50), have been shown to be relevant predictors of annoyance or the evaluation of the acoustic situation, and it is currently not clear what is the best predictor. For instance, in the aircraft noise study in the wilderness areas on which the D-R relation is based (Anderson et al., 1993), the LAeq measures proved to be closely related to the peak levels of events, making it hard to select the best noise indicator to predict annoyance. However, since the LAeq level was the indicator that most consistently correlated with annoyance, and because of the consistency with environmental noise policy and the exposure-response relationships for annoyance at the dwelling, LAeq (during daytime) is chosen as the primary noise indicator in the noise score rating model for the outdoors. In addition, an indicator of the low frequency components of the noise (LCeq-LAeq) is proposed, which was found to be associated with a slight increase in annoyance (Nilsson et al., 2007). Furthermore, because of the evidence for an influence of the temporal distribution of noise (such as the amount of time that noise events may be heard or the number of events that are judged as "not acceptable"), an additional indicator is proposed of the difference between peak and background noise levels (LA5-LA95). The influence of these more specific noise characteristics will have to be based primarily on extrapolation of their observed influence on indoor annoyance or on the evaluation of noise in laboratory listening tests.

1.3 EXPOSURE-RESPONSE RELATIONSHIP

In the absence of exposure-response relationships for outdoor noise based on meta-analyses, the preliminary CityHush outdoor noise score rating model can only be based on the scarce data reviewed above. So far, the only exposure-response relationship derived between noise exposure and outdoor annoyance is the relationship observed by Anderson et al. (1993). Comparison of the relationship between aircraft LAeq and the expected percentage outdoor annoyance by Anderson et al. (1993) with the EU-endorsed indoor annoyance curve for aircraft noise at the dwelling (Miedema and Oudshoorn, 2001) suggests that the outdoor curve is much less steep. While at higher LAeq levels (over 60 dB(A)) the percentages of expected annoyance are similar, annoyance is much higher at the lower end of the LAeq levels (e.g. 40 dB(A)). One possible reason for this may be that individual aircraft noise events at these lower levels will not be heard in an indoor situation due to the insulation of the façade, or that they are masked by background noise in urban settings. Furthermore, it has to be kept in mind that the relationship above is derived from data gathered in a wilderness area, in which the expectation of people regarding quietness will probably be much higher than in the urban living environment or in urban recreational areas. Therefore, the exposure-response curve of Anderson et al. (1993) may not be applicable to urban recreational areas, which is confirmed by the findings of Krog & Engdahl (2004) showing that visitors of local recreational areas hardly report aircraft noise annoyance below levels of 40dB(A). In fact, the pattern found by Krog and Engdahl (2004) strongly resembles the EU-curve for aircraft noise at the dwelling (Miedema & Oudshoorn, 2001), except for a -5dB shift in the LAeq levels corresponding to specific annoyance percentages (see Figure 1 for the corrected aircraft noise curve and observed values by Krog and Engdahl).

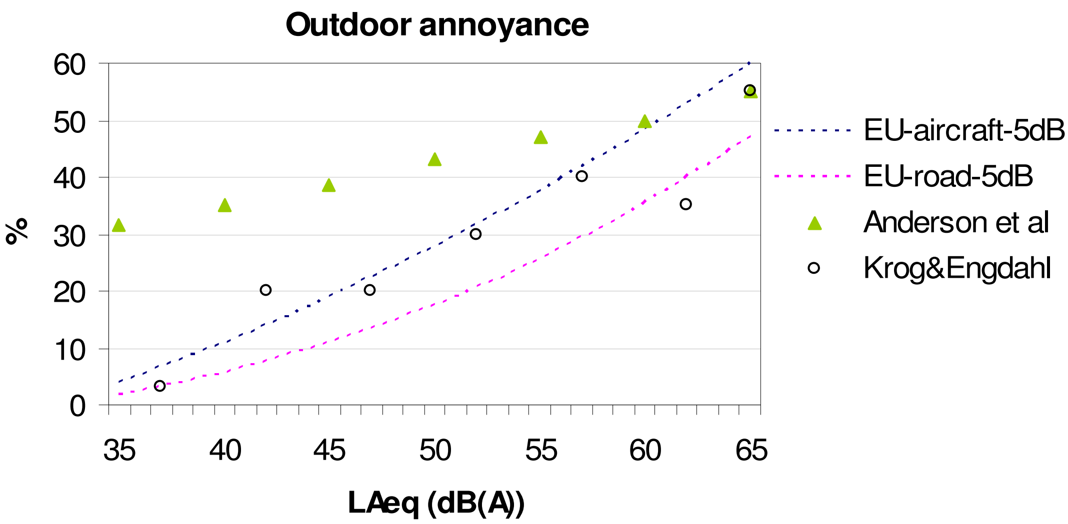

Figure 1 Tentative relationships between noise (LAeq) from road traffic noise and aircraft noise in outdoor recreational areas and % annoyance expected

However, the model is intended for use in urban recreational areas with road traffic as the main noise source, and road traffic noise is known to induce less annoyance than aircraft noise at a given exposure level at the dwelling. Therefore, the -5 dB correction was also applied to the EU-curve for road traffic noise at the dwelling (Miedema & Oudshoorn, 2001), resulting in the tentative relationship for outdoor road traffic noise annoyance (Figure 1). With this relationship, the expected percentage and number of annoyed visitors in a given area may be calculated.

1.4 The influence of function of the area and other contextual factors

Main motives reported for visiting green urban natural areas are to relax, to escape from the city and to observe and listen to nature (Chiesura, 2004). Still, the function of urban green areas may differ from that of the natural recreational areas in some of the previous studies, which will have implications for the expected annoyance by noise. Furthermore, while this preliminary model concerns the expected effect of noise on annoyance in green areas, there is even less data on the effects of noise on pedestrians in a built environment. Since the potential restorative effects and the expectation regarding quietness will probably be larger in a green area than in a built environment (i.e. Hartig et al., 2003; Bodin and Hartig, 2003), the disturbing effect at a given noise level is expected to be smaller for pedestrians in a built environment. Other contextual factors that need more exploration are the duration of the visit (+), the perceived appropriateness of sounds (-), the percentage of first-time visitors (-), the percentage of visitors regarding natural quiet as important (+), and the area being the visitor's primary recreational area (+)(+ denotes that factor is associated with an increase in annoyance, - denotes a decrease in annoyance).

2 LINK TO THE NOISE SCORE RATING MODEL FOR DWELLINGS

Many studies have found evidence for restorative effects of a natural environment versus an urban built environment (Ulrich et al., 1991, Kaplan, 1995; Hartig et al., 2003). Although the role of noise is hardly addressed in these studies, noise may lead to disturbance of restoration in a natural area. The potential effects of quiet urban areas may be twofold (Netherlands Health Council, 2006):

1) General restorative effects of being in an urban green environment may be disturbed by noise (or increased by quietness)

2) Quiet (natural?) areas nearby may compensate for negative effects of noise in the living environment by offering opportunities for restoration

While the information in chapter 1 mainly concerned the perceived interference effects of noise in the potential restorative effect of natural areas (1), there are also indications that urban green areas near the dwelling may compensate for negative effects of noise in the living environment (at or near the dwelling) by offering opportunities for restoration (2). While some studies investigating the effect of nearby green areas on residential noise annoyance found no clear beneficial effects (Klaeboe, 2007), a study by Gidlöf-Gunnarson and Öhrström (2007) showed that the mean annoyance reported by residents, either at the dwelling or outdoors near the dwelling, was lower for those with better (perceived) access to green areas than those with poorer access, despite similar exposure levels at the dwelling. The effect of perceived access to a nearby green areas was similar to or even larger than the effect of having a quiet façade to the dwelling Furthermore, a lower percentage regarded noise as a problem in the neigbourhood, their desire to stay outdoors was less frequently disturbed by noise, and they had lower prevalence of stress-related psychosocial symptoms. A precondition for the annoyance reduction at home and restorative effects of nearby green areas is presumed to be that these areas are perceived as quiet. These results are important in linking the restorative effects of quiet areas to the residents living nearby.

2.1 THE ROLE OF DISTANCE AND ACCESSIBILITY OF THE AREA

The distance of the green area from the dwelling of an inhabitant may be crucial for its relevance to residents, with previous studies indicating that urban green areas within a maximum distance of 400 m (5 minute walk) from the home encourage outdoor recreation and health-promoting activities (Kaplan, 1985; Takano et al., 2002; Humpel et al., 2004; Jim and Chen, 2006). On the other hand, van den Berg et al. (2010) found that the amount of green space in a 3 km radius, but not in a 1 km radius, moderated the relationship between stressful life events and number of health complaints. However, the 3 km radius may include larger non-urban green spaces, with potentially more profound restorative qualities, whereas the present model is concerned with urban green spaces. Therefore, for the present purpose, a radius of 400 m around the dwelling may be chosen.

2.2 Relation to the Qcity approach

The approach used within Qcity (Miedema & Borst, 2007) for assessing the influence of ambient noise may be extended to include the influence of green areas. In Qcity, ambient noise was tentatively defined as the lowest 25th percentile of the outdoor levels within a radius of 200 m around the dwelling. This radius may be increased to 400 m around the dwelling. Furthermore, given that the effect of perceived access to nearby green areas was similar to or even larger than the effect of having a quiet façade to the dwelling, the effect of ambient noise seems to have been underestimated in the Qcity approach, which assumed the effect to be about 25% of the potential effect of having a quiet façade. Tentatively, based on the information in chapter 1, an LAeq value during the daytime of 50 dB(A) or lower may be chosen as required for these effects to occur. This corresponds well to the Qcity parameter for non-quiet area (AREA50), i.e. the percentage of area with Lden > 50 dB(A).

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