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Assessing impacts of interventions: acoustics and perceptions of low noise road pavement

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ABSTRACT

Various interventions are applied in cities with the aim to improve living and acoustic environments, and thereby well-being and health of citizens. Low noise road pavement is a common noise abatement measure which can locally reduce noise emission levels with approximately 3 dB at municipal roads. Additional costs, compared with normal asphalt types, weigh well up regarding the health benefits. Although abundant studies are available on the acoustic and physical characteristics of low noise pavement, very limited research has addressed the effects on perception of well-being, acoustic and/or environmental quality. In order to examine health and other benefits of this and other road traffic noise abatement measure, Rotterdam recently initiated two studies.

In 2013 and 2014 the effects of low noise road pavement on the perception of well-being, health and soundscape will be evaluated at citizens' home environment and when visiting a relatively quiet area (cf. END). Although both studies are set up within different frameworks (ROAM resp. LIFE+ QUADMAP project) methodologies and approaches are aligned where feasible and possible. In short, noise calculations, in situ noise measurements and field surveys will be carried out, both before and after low noise pavement has been applied.

Keywords: Noise, Annoyance, Health, Well-being, Perception, Intervention

1. INTRODUCTION

Abundant academic research is available proving detrimental health effects of long term exposure to – even relatively low – noise levels [1, 2]. In 2011 approximately 40% of the Dutch population stated to be (sometimes) annoyed by noise due to traffic (air, road and railway) and/or industrial activities [3]. This is in line with WHO reports stating that 40% of the European population is regularly exposed to sound levels from road traffic that are considered harmful [4, 5].

As noise (annoyance) significantly influences the city's quality of life and the health of citizens, Rotterdam, part of an agglomeration according to the Environmental Noise Directive (END) [6], implemented ambitious noise policy and action plans during recent years. Currently, a new noise action plan 2013-2018 is drafted building on the pillars defined in the previous noise action plan (2009) and the Rotterdam Approach for Noise Annoyance (in Dutch RAG, 2010).

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In addition, the Rotterdam Council set a policy target in 2010, stating "At the end of the year 2013 15.000 Rotterdam citizens will have – at least – 3 dB lower noise exposure levels in their dwellings".

The main noise abatement policy instrument employed in the implementation of the action plan(s) and in achieving this ambitious policy target, is the application of low noise road pavement (thin layer asphalt). This noise abatement measure is a (cost-)effective instrument that is most frequently applied in cities, as noise barriers or tunnels are physically difficult to construct and are expensive. Nevertheless, various challenges remain such as (discussions on) technical and acoustical performance of these road surfaces, budget restrictions due to costly maintenance, and limited and/or fragmented insights on the (health and perception) effects of this measure. Therefore DCMR Environmental Protection Agency prepared a societal cost-benefit analysis as part of the noise action plan 2013-2018.

In this societal cost-benefit analysis (additional) costs, compared to traditional road maintenance works and road surfaces, are weighed against the benefits in terms of health and well-being. These benefits are monetarised using DALYs (disability adjusted life years) expressing the reduction of numbers of highly annoyed and severely sleep disturbed citizens. The value for one DALY is, based upon earlier studies [e.g. 7 and 8], approximately 75.000 EUR. The Rotterdam study revealed that low noise road surfaces are a cost-effective noise abatement measure and as such indispensable in municipal noise policy and action planning.

The key parameter in the societal cost-benefit analysis, and future monitoring and reporting of the outcomes achieved, is the number of annoyed citizens. The underlying assumption is the expectation that the population response to noise abatement measures and subsequent changes in noise exposure is in line with dose-response relations for annoyance and sleep disturbance used in calculating the (health) effects in the cost-benefit analysis [9]. The use of these relations in changing noise exposure situations was recently assessed and nuanced by Brown and Van Kamp [10]. More specifically, these authors' overview regarding so-called change studies revealed that in specific change situations different changes in annoyance are found; of which in some cases a so-called change effect either positively or negatively affected the predicted annoyance outcomes as one might expect from the exposure-response relations. Furthermore, "for changes resulting from noise mitigation measures, [such as the application of low noise road surfaces], the evidence for a change effect is not clear" (p. 3028). In the latter case the assumptions applied in the societal cost-benefit analysis in Rotterdam might be correct; though today limited research is available to establish firm conclusions.

The above stresses the necessity to establish further research into the effects (in noise and health perception) of (road) traffic noise abatement; two research projects in Rotterdam addressing this topic are introduced in this paper (section 3) after a short reflection is provided on the current academic theoretical and methodological discussions (section 2).

2. Assessing outcomes of noise abatement measures

2.1 Interventions and acoustical and perceptional outcomes

In their updated paper Brown and Van Kamp [11] describe two different mechanisms regarding changes in noise exposure and change effects. A short summary of the authors meta analysis, of specific interest for our paper, is the following:

- *A step, or abrupt, change in noise exposure may occur through three different mechanisms. Type 1 changes result from a new or eliminated source, or change in intensity of the source [..]. Type 2 changes result from some mitigation intervention, usually in the propagation path, [..]. Another possible Type 3 change is where an individual may relocate from one dwelling to another that has a different noise exposure.*
- *Dimensions of the change in exposure include the direction of the change – increment or decrement; the magnitude of the change; and whether the change is a step change or gradual; and if gradual, the rate of change.*
- *There is evidence that human response to changed transport noise exposure includes both an exposure effect and a change effect. The change effect is manifest as an excess response to the new noise exposure over that predicted from steady-state exposure-response curves (which predict the exposure effect).*

- *Excess response was found, unambiguously, for changes in road traffic noise, in noise annoyance responses though not in activity interference responses, where the change in exposure resulted from an increment or decrement in source levels (Type 1 changes) rather than from the insertion of barriers or other path mitigation interventions ((Type 2 changes).*

Our Rotterdam studies can be characterized as so called type 2 changes, resulting "from some mitigation intervention, usually in the propagation path [in our case the application of low noise road surfaces], without changes in the transport flow rates or source noise emissions, just in exposure of the respondents".

A nuance to this typology could be to consider not only effects resulting from changes in noise exposure levels), but also perceptional effects. Psychoacoustic research illustrated that perception of sound sources is influenced not only by absolute or relative changes in noise levels, the noise source, the location of the source and more, but spectral, roughness, sharpness and other factors as well [e.g 12]. From the meta-analysis of Brown and Van Kamp the possible impact of such psychoacoustic factors is not clear. In addition, the question arises whether (exposure and/or change) effects differ in situations where absolute exposure levels are relatively high or fairly low. Secondly, differences might occur as well concerning the relative noise exposure change. Preliminary results of studies on the effects of quiet facades on noise annoyance reveal that absolute as well as relative noise exposure levels are explanatory for the annoyance response. As De Kluizenaar et al. [13] stated "the difference in response between groups, seemed to increase with increasing difference (Q) between exposure at the most and least exposed façade and with increasing Lden at the most exposed façade".

The above reflections illustrate that absolute as well as relative exposure levels (changes) might be explanatory for perception of changes. Regarding change effect, though, data is still limitedly available for statistical significant conclusions. As such we aim to add to future research in this subdomain.

2.2 Methodological and research challenges

In order to gain more insight into responses to changing noise exposures following noise mitigation measures, concerning noise from road traffic in homes as well as in parks, we designed a methodology based on current knowledge and research practice from annoyance, sleep disturbance, health perception and soundscape studies. Relevant information on change effects are expected to become available through the field surveys; the questionnaires thus addressing variables explanatory for the change effect such as noise sensitivity; valuation and perception of various sound sources; noise annoyance due to various noise sources (ISO standard); stakeholder involvement and valuation and perception of the (living and park) environment.

Both Rotterdam studies, finally, aim to address the call from Brown and Van Kamp to study excess effects in outcomes such as restoration, enjoyment, recreation and enhanced quality. These 'new' soundscape topics gained increasingly more attention since the END requirements on quiet (urban) areas, and the search for preservation and improvement of these acoustic environments.

3. RESEARCH OUTLINES: ROAM and QUADMAP

3.1 ROAM: an introduction

The ROAM study (Dutch acronym for 'Rotterdam-Amsterdam: Spatial research for better advise regarding environment and health') is conducted in Amsterdam and Rotterdam by the respective GGD Public Health Services, in cooperation with the Erasmus University Rotterdam, Utrecht University (IRAS), DCMR Environmental Protection Agency, RIVM Dutch Institute for Public Health and Environment, and NIVEL. This research is supported by ZonMw, The Netherlands Organisation for Health Research and Development, as part of the Academic Collaborative Centre Environment & Health. The aim of the ROAM study is to gain more insight into the relation between (interventions in) the living environment and health, or more specific, the effect of spatial and acoustical interventions on self-reported health and well-being of residents.

3.2 ROAM: methodology

In a radius of 500 metres around the intervention area (the road section that will be layered with low noise pavement), the expected noise exposure at dwellings - before and after the intervention – is calculated. All addresses with an expected noise exposure reduction of at least 2,5 dB are selected for the so-called 'intervention group'. A similar number of dwellings without an expected noise exposure reduction is selected as 'control group'.

As personal data from the municipal basis administration can be matched with the selected addresses in both the intervention and the control group, respondents are addressed personally. The selected residents will receive a questionnaire before the application of the new low noise pavement takes place. The questionnaire includes questions on health (such as perceived health, health complaints), annoyance, sleep disturbance, soundscape, noise sensitivity, appreciation and satisfaction of the living environment, use of green areas, concern about environmental stressors, dwelling characteristics, life style, social-economic status and demographic characteristics. Residents can fill in the questionnaire on paper as well as through the Internet. After one year, the respondents will receive a comparable questionnaire.

In parallel with the survey, noise exposure levels are measured and traffic flows are assessed during 3 to 4 weeks, both nearby the road section where the intervention(s) take place and a location outside the impact area of the intervention (control).

3.3 ROAM: description of the study area and noise abatement intervention

In December 2012/January 2013 a pre-measurement has been conducted in the borough Hilligersberg-Schiebroek (north east in the city of Rotterdam). The noise abatement measure, the intervention, concerned a change of road surface into asphalt; originally the selected road section (Wilgenplaslaan) was paved with bricks. In total 628 respondents were asked to fill in the questionnaire; the response rate was 30%. Noise measurements and traffic counts have been conducted at both selected roads, i.e. Wilgenplaslaan and Teldersweg. The latter is considered as a control, which is located outside the impact area of the intervention, see figure 1. Currently, data stemming from the noise measurements, the noise exposure calculations and the surveys are triangulated and analysed.

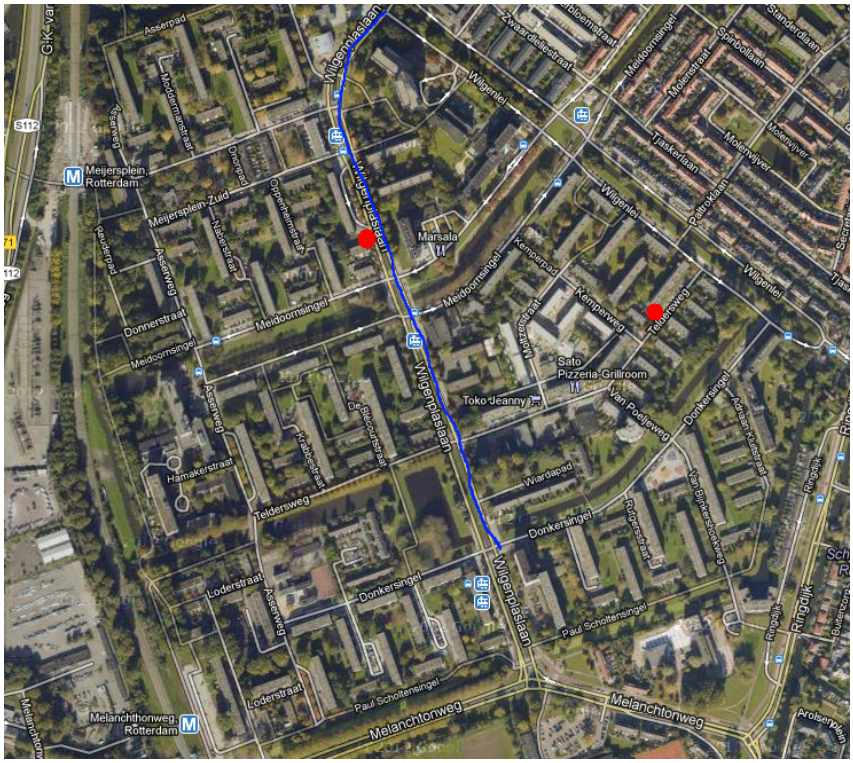

Figure 1: Locations for noise measurements along the Wilgenplaslaan and Teldersweg in Rotterdam. The blue marked road will be repaved with reduced noise layer.

3.4 QUADMAP: an introduction

Since end 2011 the LIFE+ 2010 co-financed QUADMAP project (QUiet Areas Definition and Management in Action Plans) focuses on the development of a harmonized methodology for selection, assessment (combining quantitative and qualitative parameters) and management (noise mitigation) of quiet urban areas, according to the END. The main task in the project is to develop and test methods for the definition, characterisation and assessment of quiet urban areas, and to identify the key parameters for local experts to be used in their daily work regarding noise policy, physical planning and maintenance, for example. In 2012 based upon literature studies, assessment of best practices in several EU Member States, and interviews with key experts at national and local level, a methodology has been proposed. In 2013 this approach will be tested in pilot studies in Bilbao, Florence and Rotterdam. This paper focuses on the latter pilot, in which two parks will be assessed in combination with the use of low noise road surfaces.

The QUADMAP partners are the following: University of Florence, VIE EN.RO.SE Florence, municipality of Firenze, DCMR Environmental Protection Agency, municipality of Bilbao, Tecnalia and BruitParif.

3.5 QUADMAP: methodology

The proposed methodology of the QUADMAP project consists of the following data collection steps: (i) noise mapping of the area and its surroundings, including cumulated environmental noise sources in Lden (or rather, in soundscape terminology 'mechanical sounds' [14]) using the END strategic noise maps, (ii) noise measurements, both long term unmanned measurements and short term in-situ measurements during the surveys; and (iii) surveys of park visitors. These three data flows facilitate falsification, reduction of bias, through triangulation of the data. All three data collection methods have been employed in earlier studies, for example [15, 16 and 17], and in Rotterdam study in 2011 [18]. As such the three methods have been improved during recent years and illustrated their added value. The challenge though lies in the further simplification and standardisation of research methods and the correlation of (statistically significant) variables, in order to improve and increase research in quiet (urban) areas.

In the Rotterdam pilot for QUADMAP we aim to gain insight on the effects of noise abatement measures as well; in order to inform and advice the municipal board and politicians on future steps in protection and management of quiet areas in line with the END requirements. The subsequent aim of the pilots thus is to assess whether visitors of these parks perceive changes due to the use of low noise road surface and/or evaluate the soundscape and environmental characteristics of the selected parks more positively after the low noise pavement has been applied. In order to identify possible effects and assess the (seize and impact of the) effect the above presented steps will be repeated at the end of this year, after the road surfaces have been changed.

3.6 QUADMAP: description of the study area and noise abatement intervention

In March 2013 two parks have been selected for the pilot study on (soundscape and change effect) perception located in the southern part of Rotterdam. The parks were selected mainly based upon practical reasons, that is the maintenance planning of the infrastructure department. As mentioned above, Rotterdam has implemented a rather ambitious noise abatement programme as part of the noise action plan, in which annually tens of kilometres municipal roads are selected for applying low noise pavement. This year, amongst others, the Groene Kruisweg and the Spinozaweg, will have new road surfaces; both are situated in respectively parallel to a park (see figure 2).

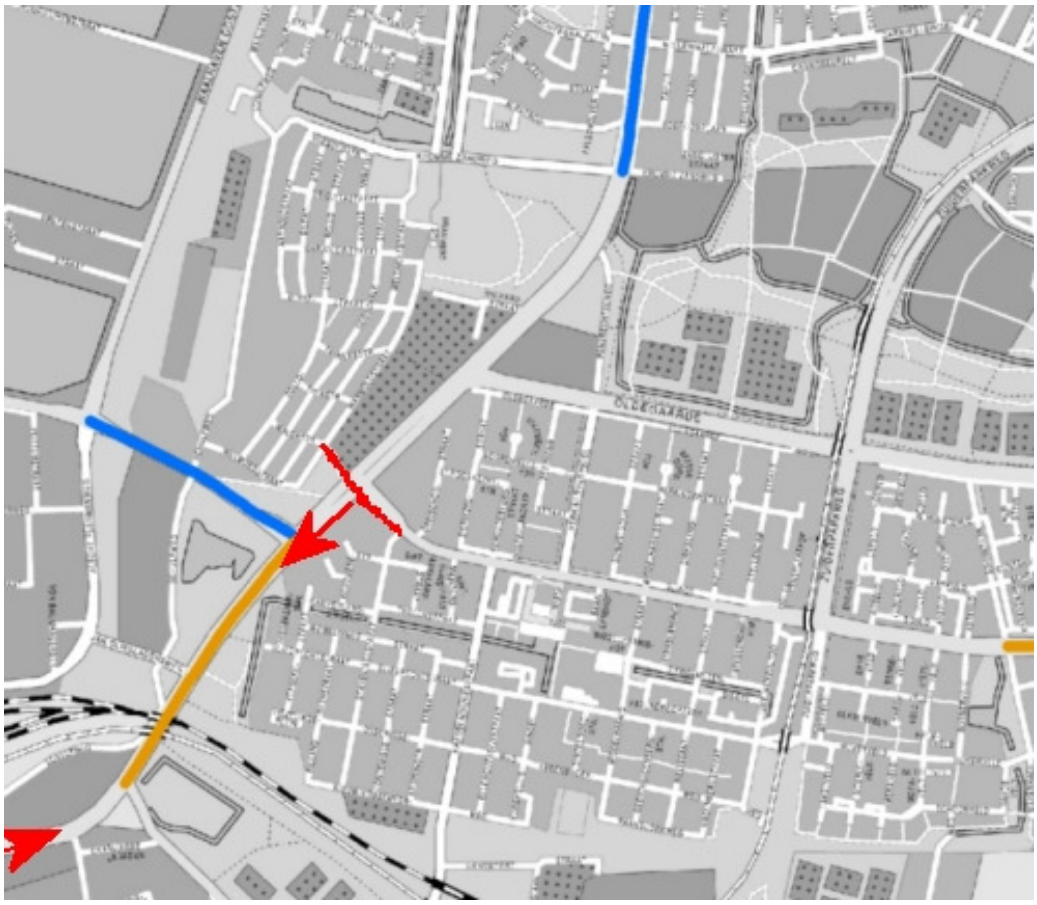

Figure 2: QUADMAP pilot area Groene Kruisweg; blue marked road will have low noise pavement in 2013 and orange marked roads were repaved in 2011 and 2012

In the period May until July the so-called status-quo situation will be assessed based upon noise measurements and surveys. We aim at questioning approximately 100 respondents per park on their perception of sound(scape), visual aspects, and environmental appreciation of the area. The questionnaire developed in the QUADMAP project is largely based upon the questionnaire employed in the 2011 study in Rotterdam; some additional information though is sought regarding noise annoyance and acoustic quality in the residential area the respondent is living in. In combination with information on postal address, the distance between home and the park, and the acoustic perceptions in the park as well at home, interesting correlations might be found.

4. CONCLUDING REMARKS

The research results and products from both ROAM and QUADMAP are expected by the end of 2014; this paper focuses on - preliminary - methodological discussions and observations. During the next months and year, though, information will be made available through conference proceedings, peer reviewed articles and, as concerns QUADMAP, the website (www.quadmap.eu).

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