

Institution: University College London (UCL)
Unit of Assessment: 10 – Mathematical Sciences
Title of case study: Enhancing civil and public understanding of environmental noise propagation
<p>1. Summary of the impact</p> <p>Research carried out in UCL’s Department of Mathematics addresses the accurate coupling of acoustic source fields to noise propagation models, for the determination of far-field environmental noise exposure. The work has increased understanding of issues related to noise propagation from infrastructure including roads and wind turbines, in the UK and internationally. For example, it has led to changes in thinking about freeway noise mitigation strategies at Arizona Department of Transportation (ADOT), discussion of concerns about the UK’s assessment of noise propagation from wind turbines by the Institute of Acoustics, and improved understanding of sound-related issues associated with a gas compressor station in the southwestern US that are of interest to local Indian tribes. The research also stimulated interest and discourse by groups and individuals including the Acoustic Ecology Institute in the US, a community group in Germany, Washington State Department of Transportation, the US Federal Aviation Administration, and an artist based in Berlin.</p>
<p>2. Underpinning research</p> <p>Assessing the impact of noise mitigation strategies on communities residing in the vicinity of freeways, airports and wind turbine farms requires accurate determination of the often highly localised sound sources in combination with efficient modelling of the transmission of that noise over great distances. Nick Ovenden, a researcher in UCL’s Department of Mathematics (Lecturer 2005-2012; Senior Lecturer 2012-present), has worked with international collaborators to tackle such issues in the case of urban freeway noise, in order to enable urban planners to assess efficiently how modifications or mitigation strategies implemented at or near the source affect the far-field noise characteristics.</p> <p>From 2006 to 2009, Ovenden worked with Professor Harindra Fernando at Arizona State University (ASU) in a combined experimental and theoretical investigation for ADOT [1, 2], to study the effect of local meteorological conditions on the propagation of freeway noise. The research was funded by ADOT as part of their ten-year Quiet Pavement Pilot Programme (QPPP), approved by the Federal Highways Administration (FHWA) in June 2003. Sound data and experimental measurements of vertical wind and temperature gradients were collected simultaneously at two freeway sites and input into a theoretical noise propagation model to predict the noise levels far from the freeway. The theoretical modelling was carried out by Ovenden, who also participated in the field experiments led by Fernando's team at ASU. The acoustic field close to the source was constructed using an extended Green’s function formulation for several virtual line sources, where the height and strength of each line source were determined via a least-squares minimisation to replicate accurately the sound measurements made in the field. This Green’s function near-source model was then coupled to a parabolic equation model for sound propagation out to 600 metres from the freeway. The research demonstrated that measured meteorological conditions, such as temperature inversions and wind shear, could create sound-focusing phenomena over a third of a mile from the freeway, potentially into residential areas, and that this sound could exceed state guidelines on acceptable noise levels. In addition, the research questioned the effectiveness of noise barriers, particularly those of reduced height as they do not block sound emitted at higher angles of incidence that can still be refracted back downwards towards residential areas.</p> <p>Between 2009 and 2012, Ovenden and Fernando extended their technique to incorporate terrain effects and also to enable vertically refined local meteorological data derived from the National Center for Atmospheric Research’s Weather Research and Forecasting model to be used in predicting long-range noise propagation [3]. The findings from the work on freeway noise are also applicable to wind turbine noise; indeed, in 2012 Ovenden and Fernando (now at the University of Notre Dame, USA) began a two-year project funded by the Royal Society to examine noise propagation from wind turbines in complex environmental and topographical conditions. In this latest project, the theoretical model from the earlier work [1] is being developed further with (i)</p>

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more focus on accurately determining the behaviour of the ducted part of the sound field close to the ground, and (ii) incorporation of the shear effects from the wake of a single wind turbine or a line of wind turbines. Furthermore, field measurements from wind turbines based at the University of Notre Dame and meteorological measurements taken in mountainous terrain are currently being analysed for input into the modified sound propagation model.

3. References to the research

[1] Impact of meteorological conditions on noise propagation from freeway corridors, N.C. Ovenden, S.R. Shaffer and H.J.S. Fernando, *J. Acoust. Soc. Am.*, 126(1), 25-35 (2009) doi:[10/b7rr7d](https://doi.org/10/b7rr7d)

[2] Investigations of environmental effects on freeway acoustics, H.J.S. Fernando, N.C. Ovenden and S.R. Shaffer, *Arizona Dept. of Transportation Research Reports SPR-605(1)* (2010) http://bounced.azdot.gov/TPD/ATRC/publications/project_reports/PDF/AZ605-1.pdf

[3] Investigations of environmental effects on freeway acoustics, S.R. Shaffer, H.J.S. Fernando and N.C. Ovenden, *Arizona Dept. of Transportation Research Reports SPR-605(2)* (2013) [http://www.azdot.gov/adotlibrary/publications/project_reports/PDF/AZ605\(2\).pdf](http://www.azdot.gov/adotlibrary/publications/project_reports/PDF/AZ605(2).pdf)

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4. Details of the impact

UCL research findings on long-range noise propagation have led to improved understanding and changes in thinking about highway noise mitigation at ADOT. The findings have also had an impact on a variety of other organisations and individuals worldwide, informing their understanding and stimulating discourse about the assessment of noise propagation, not only from roads, but also from wind turbines, and additionally from a gas compressor station and various sources in its vicinity, including a railway line.

Impact on thinking about traffic noise mitigation at ADOT: The principal goal of ADOT's ten-year QPPP is to assess the effectiveness of rubberised asphalt at reducing environmental noise from urban freeways, in comparison with other noise mitigation strategies, such as noise barriers. In addition to the public health benefits arising from a reduction of freeway noise in residential areas, using alternative noise mitigation strategies may also be cost effective, as the typical concrete noise barriers used in Arizona are very expensive and cost approximately \$1 million per mile to construct. Since the UCL research was funded by ADOT as part of the QPPP, major policy changes will not occur until the project's field trials have been completed in 2015; however, UCL research findings have already impacted upon thinking about noise mitigation at ADOT, causing the department to consider more carefully the effectiveness of costly noise barriers and how they invest in noise mitigation strategies [A].

ADOT currently makes use of the widely used FHWA Traffic Noise Model (TNM) v2.5 for assessing the environmental noise impact of new and existing freeways. The UCL research findings suggest, however, that the noise barriers used throughout Arizona and elsewhere may not be as effective at reducing noise as the FHWA-TNM might indicate; this difference occurs because TNM does not incorporate local meteorological effects whereas the model in reference [1] above does. Indeed, references [1] and [2] above strongly suggest that typical meteorological conditions can readily defeat noise barriers that are erected based simply on blocking the line-of-sight to residential areas of concern. These research findings helped convince ADOT that investigation into better noise barrier technology is required. In October 2012, this realisation led ADOT to announce a call for a follow-on three-year project entitled "Materials Properties and Optimum Geometries for the Design of Noise Walls" [text removed for publication] [A]. The project entails inviting noise barrier manufacturers to present novel noise barrier designs to a panel of project researchers, with selected designs subsequently being tested using the combined experimental/theoretical approach developed in references [1], [2] and [3] above, incorporating both measured and simulated meteorological data.

Raised awareness at the Institute of Acoustics (IoA): In May 2013, Ovenden was contacted by a community campaigner in the UK who was interested in the relevance of the findings of reference [1] above to the assessment of noise propagation from wind turbines. In particular, the campaigner was concerned that the “Good Practice Guide for Wind Turbine Noise”, being launched at that time by the IoA at the request of the Department of Energy and Climate Change, recommended a propagation model (ISO9613-2) that did not sufficiently include wind shear and therefore did not account for some of the enhanced effects that had been predicted using the model in [1] above. This interest stimulated a detailed discussion between Ovenden and the campaigner about the science and the issues [B], and led to Ovenden writing to the UK’s Chief Scientific Adviser and to the President of the IoA raising his concerns about the use of ISO9613-2 – a method originally designed for near-ground noise sources – in assessing the environmental impact of high-altitude noise sources such as wind turbine facilities, with the results of [1] used as evidence of this concern. The President of the IoA reported back that Ovenden’s “concern in relation to the use of ISO9613-2 as the method of propagation was discussed at length by the GPG [Good Practice Guide] working group” [C] at the IoA’s council meeting in June, and that, while changes will not be made at this point, they recognise “that many arguments are made for a different approach to the assessment of wind farm noise.” [C]

Improved understanding of sound-related issues in AZ tribal areas: In October 2010, Ovenden was contacted by a co-founder of a consultancy firm called EN3 Professionals in Flagstaff AZ, which specialises in engineering, environmental and energy-related matters, with some questions about the research findings in reference [1] above in relation to one of the firm’s current projects. After continued discussion and a meeting in April 2013, the co-founder invited Ovenden to offer his opinion (based on his work with ADOT) on an environmental baseline sound level report for a groundwater remediation project in the vicinity of a gas compressor station near Topock, AZ. The project is of interest to local tribes, including the Hualapai, Cocopah, Fort Mojave, Chemehuevi and Colorado River Indian tribes, as the area is of great cultural significance to these communities. Ovenden’s contribution led to improved understanding of the project’s sound-related issues; EN3’s co-founder said: “Dr. Ovenden’s review of and comment on the baseline sound studies completed to date at Topock was vital for identifying how the studies can be improved to better address tribal issues.” [D]

Raised awareness and understanding at Coconino County authorities: Also in April 2013, a meeting was held between Ovenden and the Head of Coconino County’s Community Development Department and a colleague to discuss noise concerns from wind farms. Their awareness and understanding of the issues were informed by the findings of reference [1] above, which were discussed at the meeting, and they expressed much interest in using such a methodology to see how local meteorology could be taken into account when assessing the noise impact of the county’s current and proposed wind energy sites.

Greater understanding at the Acoustic Ecology Institute (AEI): The AEI is a US non-profit organisation that aims to inform public debate about the environmental impact of noise. The institute’s Executive Director contacted Ovenden in early 2010 as he was very intrigued by the fact that the model in reference [1] above predicts in some cases increasing near-ground sound levels and sound focusing beyond 400-plus metres from the source. Subsequent correspondence with Ovenden resulted in greater understanding within the AEI about such work and how it might be used to assess the long-range propagation of noise from wind farms. This led to reference [1] being highlighted in the organisation’s newsletter in February 2010 [E], where it is noted that Ovenden’s model combines field recordings and new acoustic modelling, and demonstrates significant differences of 10-20dB in noise levels from those predicted by traditional sound models at 300 metres and beyond, thereby offering the possibility of regulatory limits being breached at much greater distances than perhaps previously considered.

Stimulation of public interest and discourse: The research in reference [1] above was highlighted by the Acoustical Society of America (ASA) in April 2011 as being of interest to the general public. The society asked Ovenden to prepare a lay language version of the paper to help disseminate information about acoustics to the general public and elevate awareness about topics

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in acoustics to a worldwide audience. Following this lay language version [F] and an invited talk at the 161st ASA meeting in May 2011, the research received significant media attention (including a news story on the NBC News website [G] and an interview on Deutschlandradio [H], both in May 2011), stimulating public discourse and interest internationally.

Examples include:

- In June 2011, Ovenden was contacted by a community group in Germany concerned about traffic noise from a neighbouring autobahn, where the local mountainous topography creates significant highway crosswinds. The group requested a copy of reference [1] above, as they believed the paper's results would be useful in the group's battle with their local authorities about what measures should be employed to reduce noise.
- At the ASA meeting in May 2011, Ovenden was approached by employees at Washington State Department of Transportation concerning noise complaints they received from residential areas located a mile or more from the apparent noise sources of concern (e.g. construction noise in particular). They indicated their strong interest in any further field tests validating the research findings.
- The US Federal Aviation Administration contacted the authors of reference [1] by email in June 2011 requesting a copy of the paper, as they also have an interest in using detailed weather information for the prediction of sound propagation.
- In March 2013, a Berlin-based artist requested to know more about the propagation mechanisms in the research [I]. The artist stated in her email: "Being myself a sonic artist living and working directly by the river Spree in Berlin, I recognize similarities in my experiences and observations with those of your article" [I]. She wishes to compare the research work with her own observations and ideas in producing sonic artwork.

5. Sources to corroborate the impact

[A] Supporting letter from QPPP Project Manager, ADOT – corroborates that the research has led to improved understanding and changes in thinking about noise mitigation at ADOT. Also corroborates the details of the follow-on project. Available on request.

[B] Email correspondence with community campaigner – corroborates that the research has informed understanding about the science and stimulated discourse. Available on request.

[C] Email correspondence with the President of the IoA – corroborates that Ovenden's concerns were discussed by the IoA's GPG working group. Available on request.

[D] Supporting letter from a co-founder of EN3 Professionals – corroborates that the research and further discussions with Ovenden have informed understanding of sound-related issues at EN3. Available on request.

[E] The AEI's February 2010 newsletter is available online: <http://bit.ly/18ppiMV> (the review of [1] is on page 17) – corroborates that understanding of the research and its potential use was informed.

[F] The lay language version of reference [1] is available online: <http://bit.ly/1hZmKGt>

[G] The news story about the research on NBC News can be seen at: <http://nbcnews.to/1cZ3j2l> – corroborates that the research stimulated media interest.

[H] A transcript of the broadcast about the research on Deutschlandradio can be seen at: <http://bit.ly/17oUxal> – corroborates that the research stimulated media interest.

[I] Email received from a Berlin-based artist – corroborates that the artist's creative interest was stimulated by the research. Available on request.