Institution: University of Sheffield

Unit of Assessment: 16 - Architecture, Built Environment and Planning

Title of case study: Developing tools and products for designing better urban sound environments

1. Summary of the impact

Theoretical and experimental research on urban sound environments has been carried out by Professor Kang and his team at the University of Sheffield since 1999. This includes acoustic theories and models for urban sound propagation, soundscape theory and framework, and acoustic theories for sustainable building elements. Consequently, they have developed design guides/ tools that have become common standards in professional practice; invented sustainable low-noise products that have led to commercial outputs; organised networks and workshops that have set up the practice agenda for designing better urban sound environments; and delivered keynote presentations to international audiences of planning professionals and government policy-making organisations.

2. Underpinning research

The economic cost of problems caused by environmental noise is 0.4-2% of GDP in the EU [*soundscape-cost.org*]. European Parliament Directive 2002/49/EC demanded that from 2012 there must be regularly updated noise maps for all cities with more than 250,000 inhabitants, and quiet areas must be identified and protected. Since he joined the University of Sheffield in 1999, Professor Jian Kang has developed sound propagation theories, pioneered soundscape approaches, and established a theoretical basis for a range of green acoustic products.

Professor Kang leads a research group of 15-20 associates, PhD researchers and visiting researchers from 8 countries including France, Germany, Italy, Sweden, China, Korea, Brazil and Australia. Since 1999, 32 of his projects have received total funding of over £4m, from European Commission, EPSRC, AHRC, Royal Society, British Academy, British Council, China Natural Science Foundation, and from industry including BP, Samsung and Kingspan. The research has generated 428 publications, including 86 journal publications, 3 monograph books, 36 keynote speeches, and 5 design guides/tools now adopted as standard references by planning and design practitioners.

Professor Kang's research since 1999 at Sheffield can be divided in to three main areas:

Sound propagation

Professor Kang has been researching fundamental acoustic theories and models for urban sound propagation. Through theoretical analytic work, developing algorithms and codes for computer simulation, physical scale modelling and in-situ measurements, Professor Kang's research discovered a series of fundamental phenomena in long spaces, such as the variation of reverberation along their length and the non-linearity of the decay process. From these results he developed formulae to calculate reverberation in long spaces, as well as the radiosity model to simulate sound fields formed by diffuse boundaries. With its high accuracy, of 2dB, the radiosity model provided the basis for micro-scale urban area sound map computation [R1], and this has been integrated into practical noise-mapping techniques. His research at Sheffield on the acoustics of long spaces, including underground stations and urban streets, was published in a monograph book [R2].

Soundscape

Professor Kang pioneered soundscape research at Sheffield that examines a constructive and holistic approach to noise control in the built environment, closely related to the EU policy on identifying and protecting quiet areas. Rather than focusing on noise reduction alone, this considers environmental acoustics in a broader context that includes perspectives from psychology, sociology, anthropology and medicine. Together with his team, Professor Kang used

analyses of sound fields in urban spaces and subjective evaluation of soundscapes, to generate the world's largest soundscape database [R3]. This revealed direct relationships between the subjective evaluation of acoustic comfort and objective measures of sound fields within the urban context. The database has also been used to develop prediction models, based on neural network techniques, from which soundscape quality maps can be generated. This has led to the development of a set of design tools for planners and architects [R4] and the publication of a soundscape design framework [R5].

Green acoustics

This research area focuses on reducing noise in a sustainable manner. Since 1999 Professor Kang has established basic acoustic theories for a number of green building elements, including natural ventilation window systems [R6], low-noise ventilators, low-height noise barriers, green roofs and non-fibrous micro-perforated membrane sound absorbers. Correspondingly, a series of field and laboratory experimental studies were carried out, to validate the theories.

3. References to the research

R1. Kang, J. (2001) Sound propagation in interconnected urban streets: a parametric study. *Environment and Planning B: Planning and Design*, 28, 281-294.

R2. Kang, J. (2002) *Acoustics of Long spaces: Theory and Design Guidance*. Thomas Telford Publishing, London.

R3. Kang, J and Zhang, M. (2010). Semantic differential analysis of the soundscape in urban open public spaces. *Building and Environment*, 45, 150-157. doi: 10.1016/j.buildenv.2009.05.014 [REF submission]

R4. Yu, L and Kang, J. (2009). Modelling subjective evaluation of soundscape quality in urban open spaces – An artificial neural network approach. *Journal of the Acoustical Society of America*, 126, 1163-1174. doi: 10.1121/1.3183377 [REF submission]

R5. Kang, J. (2007) *Urban Sound Environment*. Taylor & Francis incorporating Spon, London. *[First book specifically in the field of urban acoustics - it has been positively reviewed in 7 acoustics and engineering journals including the Journal of the Acoustical Society of America. Chinese version published in 2011 by the China Science Press]*

R6. Kang, J. and Brocklesby, M. W. (2005) Feasibility of applying micro-perforated absorbers in acoustic window systems. *Applied Acoustics*, 66, 669-689. doi: 10.1016/j.apacoust.2004.06.011 *[One of the most cited articles in Applied Acoustics]*.

4. Details of the impact

Development of design guides/ tools that have advanced professional practice

The design guides/tools developed by Professor Kang, based on his research in sound propagation and soundscape, have been adopted by built environment and industry professionals worldwide. These include:

1) Noise abatement best-practice guide, requested and initially used by BP in 2001 and since adopted worldwide by acoustic consultants for use on large-scale noise-mapping projects, including, within this REF period, urban noise-mapping projects in Taipei and Wuhan, and industrial noise-mapping projects for BP Shanghai and BP Grangemouth. The consultants for these projects, Acoustic Modules Ltd, assessed it as a "comprehensive guidance" [S1];

2) A design guide for soundscape in urban open public spaces published by the EU in 2004, and correspondingly, a neural network model for predicting perception of soundscapes. Both are now used worldwide as benchmark guidance for planners, architects and urban designers, such as in 5 urban soundscape projects since 2008, in Harbin and Dalian (China), Valdera (Italy), Assen (The Netherlands), and Antwerpen (Belgium) [S2];

3) Design guide for long spaces, requested and initially used by Hong Kong Mass Transit Railway Cooperation, and finalised in 2002. Its applications since 2008 by consultants and

planning authorities include underground projects in Buenos Aires, Delhi, Hyderabad, Chennai, Tianjin, Guangzhou, Harbin, and road tunnels/motorway enclosure projects in New Zealand and Australia. For example, the use of these design tools in underground station projects has led to improved speech intelligibility of public address systems [S3], which has been strictly regulated since the King's Cross fire in 1987. Conversely, 2012 documents from DLA Piper [S4] demonstrated that employing Professor Kang's long space design tools over conventional acoustic design theories would have saved multi-million A$ worth of remedial work on a railway tunnel project.

Invented sustainable low-noise products that have led to commercial outputs and environmental improvements.

Based on his acoustic theories for building elements, Professor Kang has invented and, together with industrial partners below, successfully commercialised a series of construction products for sustainable environmental noise abatement that satisfy the requirement of Planning Policy Guidance: 24 (Planning and Noise). These include low noise domestic ventilation systems manufactured by Greenwood and Titon; acoustic green-roof systems developed by Kingspan; and road noise barriers manufactured by Acoustic Modules Ltd. In particular, since 2011 a novel acoustic window system, designed by Professor Kang, has made significant contributions to overall built environment sustainability in six major projects led by the Hong Kong Housing Department [S5]. The system reduces external noise while allowing effective day-lighting and natural ventilation, with a typical saving of £60k per year per building over the use of standard air-conditioning systems.

Organised networks and workshops that have helped define the regulatory agenda

Based on his research in sound propagation, soundscape, and green acoustic components, Professor Kang has set up and chaired three professional networks to propagate research and best practice and inform the development of relevant regulations:

1) European Cooperation in Science and Technology (COST) [S6] Network on Soundscape of European Cities and Landscapes (2009-2013, €500k), which created an international network of 83 participating organisations from 22 COST countries and 7 partner organisations outside Europe;
2) EPSRC Noise-Futures network [S6] (2006-2009, £100k, Professor Kang is joint Chair), with 52 participating organisations including policy makers, consultants and researchers;
3) Worldwide University Network on Environmental Acoustics (2004-) with major world-leading acoustic centres.

32 workshops have been hosted by these networks across the EU, attended by over 2000 people, to discuss and define environmental acoustic practice and policy. Sonic installations following COST workshops in Brighton, in 2011, demonstrated a ground breaking soundscape implementation that enhances public safety and improves crowd behaviour [S7]. The workshop outputs also formed the foundation of the first ISO Standard for soundscapes: ISO/TC 43/SC 1/WG 54: Perceptual Assessment of Soundscape Quality - a key standard for designers, planners and policy makers. Part 1 of this standard was published in 2012 [S8].

Influenced development and adoption of international policies on environmental noise

A major impact of Professor Kang's research is that urban planning now takes better account of environmental noise. Professor Kang's soundscape research has been delivered to policy makers through invited keynote lectures at international and national conferences and workshops organised by local authorities and government policy-making organisations. In 2009 Professor Kang delivered a keynote speech to 150 practitioners and policymakers at the *Tranquil Spaces* conference, organised by the Greater London Authority [S9]. Ten similar presentations have been delivered since 2008 in London, Brighton, China, India, Malta and Sweden, with a total audience of

over 500. As a consequence, Professor Kang's research is now included in the recent DEFRA benchmarking report [S10] on soundscape and creation of quiet areas, following the strict requirements by the EU Directive 2002/49/EC.

The impact of his research on international policy is evidenced by Professor Kang being appointed as Chief Environmental Acoustics Adviser to the Planning Department of four major Chinese cities, Dalian, Harbin, Huludao, and Taiyuan. In this role he is able to apply his research to guiding planning policy to integrate environmental noise and soundscape issues with a fast urbanisation process. The dissemination of Professor Kang's research and its adoption as part of national and local planning policy has been encouraged by media coverage of his work on urban sound environment, including BBC, Times, Radio New Zealand National, and China Changsha TV.

5. Sources to corroborate the impact

S1. Letter from a Senior Consultant at Acoustics Modules Ltd. corroborates the impact of the application of the design guide.

S2. The screening plan-Mer-plicht, RUP Nieuw Zurenborg, VERZOEK TOT RAADPLEGING corroborates the claims of the application of soundscape design guide www.lne.be/merdatabank/uploads/nthnvq1443.pdf. [See page 100]

S3. A letter from Kandaswamy Acoustics in India corroborates the application of the design guide.

S4. A letter from DLA Piper Australia and attached reports from acoustic consultants corroborate the claim that employing the research would have saved multi-million A$ worth of remedial work on a railway tunnel project.

S5. Contract between Professor Kang and the Housing Department of the Hong Kong Government through ENVIRON corroborates the application of the window system.

S6. Websites for two of the networks established by Professor Kang corroborate the activities with impact on regulatory agenda: http://www.soundscape-cost.org/ and http://www.noisefutures.org/.

S7. Report of the project on the UK Noise Abatement Society web site corroborates the impact of the soundscape research and workshop: http://tinyurl.com/lg69bbq

S8. ISO/TC 43/SC 1/WG 54: Perceptual Assessment of Soundscape Quality. Part 1: Definition and Conceptual Framework, 2012.

S9. Kang research impact is corroborated by this invited keynote in this practice-led bench marking event: *TRANQUIL SPACES - from understanding perceptions to practical protection*. A one-day conference organised by the Greater London Authority, London, UK, 2009.

S10. The DEFRA report corroborates the claim that it was underpinned by Professor Kang's research. Research into the Practical and Policy Applications of Soundscape Concepts and Techniques in Urban Areas (NANR 200). DEFRA, October 2009. (Page12,13,14,16,21,22,23,24,38,46,53,55,71,72,73,74,75,76,77)