ICSV14
Cairns • Australia
9-12 July, 2007

14th International Congress on Sound & Vibration

TECHNOLOGY DRIVEN SOLUTIONS FOR THE QUANTIFICATION OF URBAN ROAD NOISE

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Abstract

Road noise is widespread in urban and suburban Asia and commonly the predominant source of ambient noise during both daytime and night-time. Prolonged excessive exposure to road noise can cause adverse effects on health and well being through sleep disturbance and stress. The challenge to government agencies throughout the region to predict and quantify noise exposure to populations has led to a number of noise prediction and mapping initiatives. These typically aim to express noise exposure problems in terms that can be compared with existing and emerging guidelines that seek to address acute and adverse noise-related social impacts. Understanding the potential problems facilitates informed decision making in development and political promotion of strategies for reducing noise and promoting sustainable urban living. This is highly pertinent to the Asian nations whom promote the successive regeneration of the urban environment and, as economies prosper, the development of sustainable new towns to accommodate population growth.

Computerised noise exposure prediction technology is now widely accepted as an effective way to help quantify noise exposure to support decision-making on transport policy, development density and at source noise control measures. Most European Union member states, Canada, USA, developed Asian nations and Australia already have programs in place utilising such systems for the staged process of reducing noise exposure in large cities and suburban areas. Recently, improved system integration technologies have allowed organisations to make noise mapping tools more widely available, allowing use of these systems by both generalists and specialists alike. The technology offers enhanced interaction and offers a transparency to a highly technical process, which promotes a greater level of stakeholder participation.

This paper discusses noise mapping progress and provides an introduction to the types of technologies being employed as well as suggestions on the ground-truthing of technical models.

1. INTRODUCTION

Urban intensification and new town development in the present and last generation has supported economic and social growth in many of the developed nations. Success within the newly emerging economic powers in developing countries such as China bears witness to similar socio-economic trends. Economic stability broadens our aspirations for quality of life and the environment we live in and appreciate. The investment communities have made in efficient transportation has commonly been rewarded as businesses and families thrive, often attracting utilisation that far exceeds expectation.

Since the early 1960's, the growing exposure of the population to increasing noise has been a concern. Publication of The Wilson Report [1] brought increased recognition to the issue of rail, aircraft and, especially, road noise as the predominant source of annoyance: Lord Wilson concluded that, for London, no other single source of noise is of comparable importance. Around the same time, Mr G E Moore [2] (Moore's Law) predicted the rapidly continuing advancement in computing power: the power of computers doubling roughly every two years and so providing increasingly good value for money.

In the environment field, subsequent legislation provided for remedial measures to tackle existing problems and, for quantifying eligibility for retroactive action, methodologies were developed based upon field measurements of noise emission, propagation and reception at the receiver. Later, as we emerged from the 1980's, environmental impact assessments became increasingly integrated within the planning and design of new development and infrastructure [3], which provided for better protection of the living environment as well as conservation. In Hong Kong, formalisation of environmental impact assessment for certain new development and infrastructure occurred in 1997 [4] and environment planning standards have existed since the 1980s.

Today, we commonly witness the utility of road infrastructure exceeding forecasted expectation and so, with continued social attraction to the urban area, our aural environment is just as commonly dominated by road transport noise as Lord Wilson observed and reported to the British public over four decades ago. Indeed, in Hong Kong, the density of the urban fabric is among the highest in the world: its rapid development over the last several decades has provided safe housing and supported social integration, economic prosperity and founded stability for the future.

The World Health Organisation [5] guides us further in the modern day to the potential health effects of community noise, which can lead to social handicap, reduced productivity, decreased performance in learning, absenteeism in the workplace and school, increased drug use and accidents.

Increased public participation in environment matters and responsible governance has led to many historic and modern cities such as Hong Kong to take action to tackle the problem of road traffic noise. Enabling the swift implementation of noise management policy is the modern day computer technology, which has indeed evolved just as Mr Moore envisioned four decades ago.

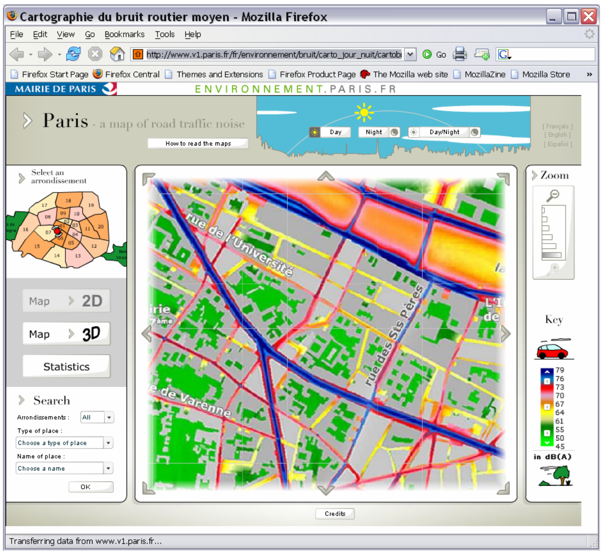
Recent commitments by European member state countries to map and take action to reduce noise problems has led to the initiative being taken by software development specialists such as Stapelfeldt to provide affordable noise calculation platforms integrated with geographical information systems. The use of such platforms is common place today. Recent enhancements of these by the authors further simplifies their use, while providing greater user interaction to query possible noise management measures, while gaining spatial appreciation of the urban setting from the desk top. We are pleased to present in this paper the recent further technological enhancement of these integrated platforms in Hong Kong and role they play in the public's participation in environmental quality.

2. GEOGRAPHICAL APPRECIATION

Whilst noise mapping initiatives are underway in most developed nations of the world, differences in urban geography have resulted in different approaches to computerised noise prediction initiatives.

In general, the Western nations have lower population densities with built urban environment characterised by low-rise to medium rise development. In contrast, the Asian nations tend to have high population densities within cities characterised by high-rise with some medium rise development. Therefore the types of noise mapping products required to assess problems differ. With lower density cities, emphasis is on the horizontal distribution of noise with less on its vertical distribution. In high density Asian cities, the focus is very much on the vertical distribution as the majority of the population in these cities live in high-rise buildings.

Typical low-rise Parisian street



2D grid of noise levels in Paris

Typical residential development in Hong Kong

Calculated 3D façade noise levels in Hong Kong

Figure 1. Comparison of built environment in low and high density cities.

Data collection exercises are necessary for the generation of noise inventory databases to account for these differing needs. In the Hong Kong case, much effort has been put into assembling sufficient height data for elevated structures, buildings, podiums and topography. This is necessary in order to accurately estimate noise exposure to the population and can be a costly activity. In less dense cities where height data is perhaps less important, large areas may be mapped for lower costs.

3. INITIATIVES TO TACKLE URBAN NOISE PROBLEMS

In the European Union (EU), many initiatives designed to tackle noise problems have been undertaken or are currently underway. The EU Directive 2002/49/EC[6], adopted on 25th June 2002, for the management and assessment of environmental noise (END) has provided the driving force for noise mapping and noise action planning within the European Community over the past four years.

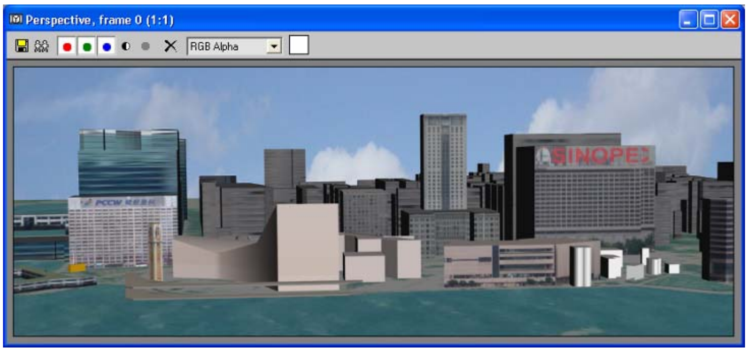
The END provides a common approach across the European Union to avoid, prevent and reduce on a prioritised basis the harmful effects, including annoyance, due to exposure to environmental noise. The END has prompted the standardisation of noise indicators through the development of models such as HARMONOISE[7], strategic noise mapping activities by EU member states, and production of action plans to manage and reduce environmental noise where necessary and to preserve environmental noise quality where it is good.

3.1 Hong Kong Initiatives

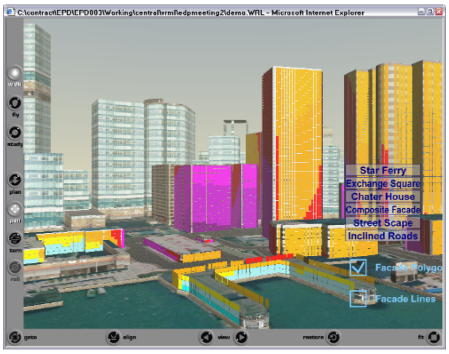
The Environmental Protection Department (EPD) of the Government of Hong Kong SAR has also been actively developing a programme for tackling problems including noise mapping studies for some ten years. The motivation behind this programme is to facilitate a better understanding of the acoustic environment within the Territory.

The first large scale mapping exercise was commissioned by the EPD in the year 2000 and titled *Review of the Acoustical Environment due to Infrastructure Projects in Hong Kong*. The Study produced a territory wide noise inventory and grid-based model results which were used to produce estimates of noise exposure to population.

In the year 2004, a subsequent study was commissioned to produce an updated model for the core urban areas within Territory. The aim of the assignment was to extend the previous study to produce building façade calculations of traffic noise for all urban buildings in the vicinity of the harbour and to prepare photorealistic 3D models in both 3DS Max and VRML which included these facades. The study allowed, for the first time, a large scale comprehensive representation of the vertical noise environment in Hong Kong. Lima, 3DSMAX and VRML models were employed to execute the project.



Tsim Sha Tsui harbour front in 3DS Max



Facade noise levels in VRML

Figure 2. Noise model results in 3DS Max and VRML formats.

In the year 2006, a full update of the model was commissioned with the aim of improving the accuracy. Key tasks being conducted include:

- Conducting a territory-wide update of certain important GIS elements of the noise propagation model inventory to year 2005 currency;
- Updating territory-wide noise emission levels of road traffic to the year 2005; and
- Computing the spatial distribution of road traffic noise problems in Hong Kong

This project, being executed jointly by the authors of this paper for EPD, represents an opportunity to update the previous system and outputs and to improve upon them.

4. GROUND TRUTHING

Computerised noise exposure prediction technology is now widely accepted as a cost effective way to assist the understanding of noise exposure problems and support decision making on transport policy, development density and at source noise control measures. The development of robust noise calculation methodologies over the past several decades twinned with modern geographical information systems has enabled the widespread quantification of noise exposure for low cost. The quick pace of urban development and renewal apparently overtakes traditional quantification by noise measurement surveys alone.

The use of established prediction methods such as Calculation of Road Traffic Noise [8] currently used in Hong Kong (and similar national standards by other countries and regions) strongly supports noise control policy. These calculated forecasts are usefully supplemented by noise measurements[5], especially in regions where source emissions, topography and the character of the built environment differ from the situations surveyed for the formulation and assembly of the prediction models. For example, the high rise character of Hong Kong sets it apart from many urban and suburban situations typical of overseas countries.

The publication of noise exposure maps helps to raise public awareness and the action Governments and authorities take to tackle adverse situations. In Hong Kong, the public has asked about noise measurements to support the computer generated exposure maps. The surveys conducted have helped to monitor the accuracy of the computer generated maps and make incremental improvements while providing further transparency throughout the process. The Hong Kong public’s participation in environment matters has helped to raise awareness and encourage environmental improvement from the “bottom-up”. For example, the greater use of public transportation and the quality of the living environment in urban regeneration and the development of new towns.

5. TECHNOLOGICAL TREND

Over the last decade, new approaches to software integration and development combined with ever-increasing performance improvement of hardware and communication technology have allowed for the development of systems that were previously only conceptually possible.

Noise prediction systems have been extended from catering for small scale projects to full-featured applications capable of mapping entire cities. The drive for transparency and access by general environmental practitioners as well as specialists has spurred the evolution of systems integrated with GIS and web-based applications. In Hong Kong, the EPD has been active in developing several systems to make available assessment and visualisation systems to non-specialists. One such system is that developed under the *Service for Reviewing the Technical Feasibility of Retrofitting Barriers on Existing Road Sections and Developing 3D Model for Assessing Road Traffic Noise and for Visualising and Presenting Noise Assessment Results*. The service is comprised of three main tasks: (a) conducting the technical feasibility of retrofitting barriers for existing road sections in response to ad hoc requests from the public and elected representatives; (b) construction of an interactive web-based retrofitting noise measure assessment software (iRMAS); and, (c) construction of a 3D model server (3DMOS).

The iRMAS and 3DMOS are used for presenting the existing traffic noise impacts and assessing the possible methods to tackle traffic noise thus enabling the effectiveness of retroactive mitigation measures on problematic road sections to be quickly evaluated.

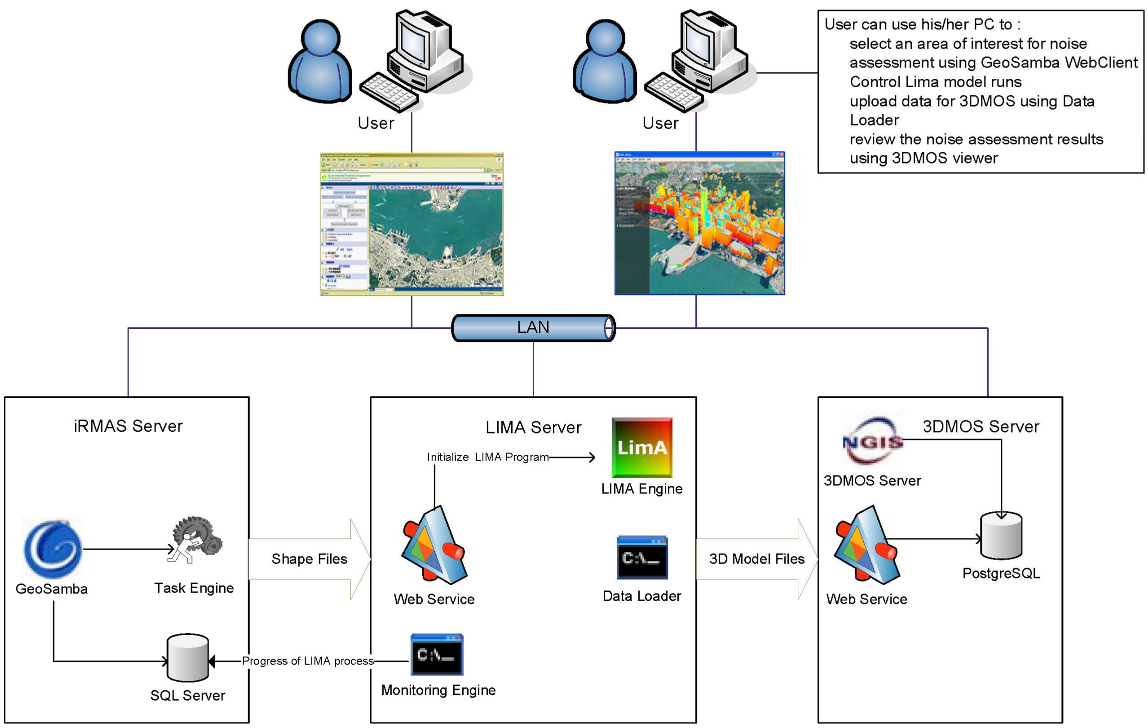


Figure 3. Integrated iRMAS, LIMA, 3DMOS noise assessment system.

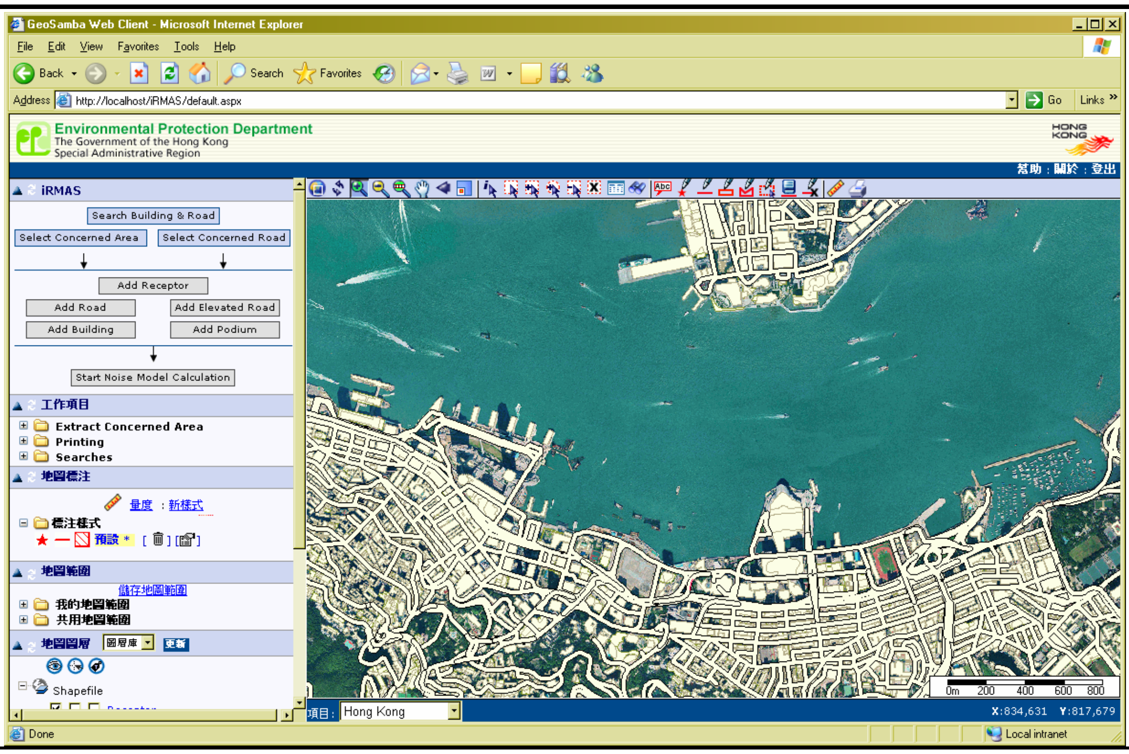


Figure 4. The iRMAS interface.

The system allows users to operate a simple-to-use web-based interface in which proposed mitigation measures can be digitised and other model elements created and edited. The system also provides control over Lima model runs and production of option comparison spreadsheets to assist with selection of the most cost-effective noise reduction measures. Flexibility within the Lima suite allows further interrogation with optional noise calculation methodologies.

The outputs from the system are available for 3D visualisation through the 3DMOS as described below. The system is extremely useful as it enables generalists to carry out sophisticated assessments in a matter of minutes rather than weeks.

6. VISUALISATION

3D visualisation technologies are now being used to help non-specialists and the public understand noise exposure and mitigation employed to tackle problem areas. As with noise prediction systems, the technology has matured and improved incrementally with time to the present landmark. File size limitations encountered when using file formats such VRML have now been overcome by recent advances in software technology. 3D technology is now being innovatively applied to work alongside internet technology to deliver massive amounts of data from server systems to smart client systems such as 3DSee. In the future, these systems may be made available to the public.

The 3D Model Server (3DMOS) is one such 3D streaming server product being developed as part of the same study as iRMAS described above. The 3DMOS allows the interactive presentation of the outputs from the iRMAS assessments, so that users can see just what proposed mitigation measures look like and their effectiveness.

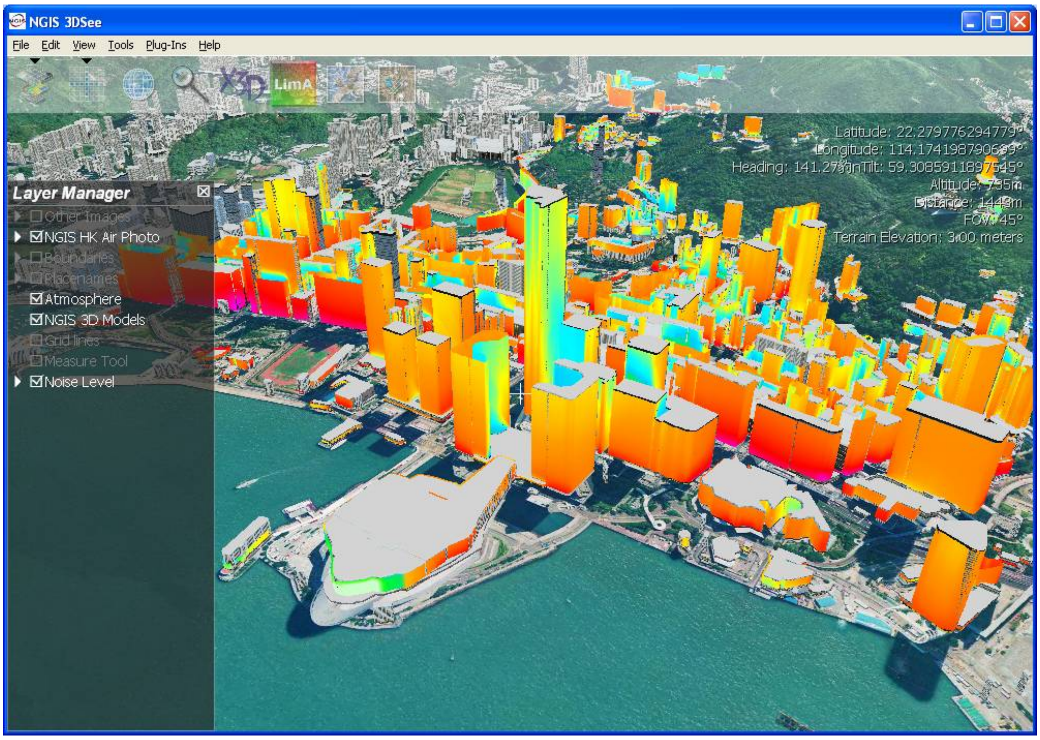


Figure 5. 3D Model Server (3DMOS) for Streaming Noise Model Data.

We are likely to see the trend towards realism continue as technology continues to advance exponentially, much as Mr Moore predicted in the 1960's. We are beginning to see 3D visualisations that utilise more of our senses at the desk top. Soundscapes in which audio playback is introduced to the visualisation are already being produced. Emerging 'Haptic' technology in which our sense of touch may also be used in the future to allow us to interact within a virtual simulation of the environment. There are many interesting opportunities for development within reasonable bounds of cost.

7. CONCLUSIONS

Technology is now mature enough to assist authorities in cost effectively addressing community noise problems. Systems such as those described in this paper extend noise mapping initiatives beyond the basic but required exercises in quantification by providing tools that address all aspects of the process of community noise reduction. Simple easy-to-use applications that allow the rapid assessment, evaluation and visualisation of changes to our acoustic environments can assist in communicating issues to the public. In this way, authorities can ensure that community views are captured and incorporated into the urban planning process.

The challenge for spatial information professionals and environmental scientists alike is to work together so that the possibilities provided by ever improving technology can be harnessed to further improve community-based decision making.

REFERENCES

[1] A. Wilson, "Noise: Final Report", Her Majesty's Stationery Office (London), 1963.

[2] G. E. Moore, "Cramming More Components onto Integrated Circuits", *Electronics Magazine*, 1965

[3] European Economic Community, "Council Directive of 27 June 1985 on the Assessment of the Effects of Certain Public and Private Projects on the Environment", (85/337/EEC)., 1985. *Official Journal* NO. **L 175** , 05/07/1985 P. 0040 - 0048

[4] *Environmental Impact Assessment Ordinance*, Cap. 499, Hong Kong SAR Government, 1997

[5] World Health Organisation, Edited by B. Berglund , T. Lindvall, D. H. Schwela, "Guidelines for Community Noise" (1999)

[6] European Economic Community, "Directive 2002/49/Ec of the European Parliament and of The Council of 25 June 2002 relating to the Assessment and Management of Environmental Noise", *Official Journal of the European Communities* NO. **L 189/12**, 18/07/2002.

[7] Dr R Jones et al, "Imagine", http://www.imagine-project.org, 2007

[8] Department of Transport, Welsh Office, "Calculation of Road Traffic Noise", Her Majesty's Stationery Office (London), 1988.