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NOISE MAPPING – WHAT FOR AND HOW TO BE MORE EFFECTIVE?

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Abstract

In the last decade, noise mapping has been applied to an increasing number of cities in different parts of the world utilizing recent advancement in noise prediction and GIS technologies. This paper reviews the noise mapping projects that have been undertaken and examines the extent to which the stated objectives have been achieved, technical problems overcome and how they can become more effective in facilitating public participation, project planning and formulation of noise action plans and policies. It has been observed that some noise mapping projects are data-rich but information-poor. To address current urban noise problems, the paper suggests that future noise mapping exercises should be focused on human responses and policy-oriented. The noise mapping tools should also be adapted for strategic planning and assessment. Current practices should be enhanced to make noise mapping a useful informational tool, an interactive planning tool as well as an effective policy assessment instrument.

1. INTRODUCTION

Driven by the EU Directive, noise mapping has been applied to an increasing number of European cities. There have also been reports of its application in other geographical areas such as Hong Kong, Japan and Korea. Considering that noise mapping incurs a large amount of time, efforts and resources, it is high time to review the objectives and effectiveness of this laborious exercise.

Noise mapping was originally conceived to be an instrument to inform noise policies and action plans. While many have accepted that it is potentially a useful tool, very few noise mapping projects have been undertaken with the objectives clearly spelled out. A cursory reading of the reports available reveals noise mapping are undertaken for a variety of objectives as follows:

- To determine noise exposure levels of the population
- To inform the public
- To provide the baseline for future reference

- To facilitate formulation of noise policies
- To assist formulation of action plans
- To facilitate project planning
- To facilitate public consultation and engagement

It can be seen that while noise mapping has been widely heralded to be an instrument to inform the public and policy-makers, there has been few attempts to critically examine if these objectives have been attained and how effective they have been. This paper attempts to address these important, albeit often neglected, issues.

Considering that noise mapping was initially developed in Europe where the cityscape is very different from that of densely populated cities in Asia, this paper also focuses on the potential benefits and technical constraints of noise mapping in compact high-rise cities.

2. RECENT TRENDS IN NOISE MAPPING

Early noise maps were made to depict, the incident day-time road traffic noise representative of the average conditions at an elevation of 4 m in the city region using noise intervals of 5 dB [1]. The EU Directive also requires noise maps be updated once every 5 years. In recent years, there is a trend that noise mapping has been undertaken to:

- Portray not only road traffic noise but also other noise sources emanating from the rail and air traffic separately
- Depict noise exposure not only during day-time, but also during evening and night-time [2]
- Identify and protect quiet areas rather than to abate existing noise pollution hotspots
- Be more oriented toward the impact of noise on annoyance reactions and human health
- Incorporate other population and socio-economic data to assess possible health and economic impacts [3, 4]

These developments signify a shift from the conventional curative to a proactive approach to noise issues in cities, and an increasing emphasis placed on the protection of human health rather than the mere reduction of noise. These changes have been augmented by repeated calls to re-examine the noise indicators used in mapping [5] and to undertake mapping for delineation and protection of quiet areas in cities.

The impetus to noise mapping has also been paralleled in the Asia Pacific region where cities are typically dense and compact and buildings are tall. The unique urban form poses a host of technical and methodological problems, such as:

- Elevated roadways stacked up at several levels
- Noise barriers and screening of a variety of forms and configurations
- Complex urban forms and building morphologies
- Multiple reflections in street canyons and confined urban spaces
- Propagation path in excess of the validity range of the prediction models

These problems are confounded by other technicalities. For instance, the upper floors of high-rise buildings in compact cities are often in line of sight with, and hence exposed to, many noise sources, both near and afar. Unlike the situation in the low-rise cities in which the noise of a dwelling is largely determined by the traffic on the adjacent road, the noise exposure of a dwelling in a high-rise building is determined by a multitude of sources emanating from a wide

acoustic horizon.

The greatest challenge of noise mapping for a high-rise city lies in the presentation of the results. The conventional 2-D noise contour map is grossly inadequate to portray the incident noise at various parts of a tall building. Significant advances have recently been made in Hong Kong to present the noise exposure on the façade of high-rise buildings for easy visualization in a 3-D virtual environment (Fig. 1) and browsing on the web [6].

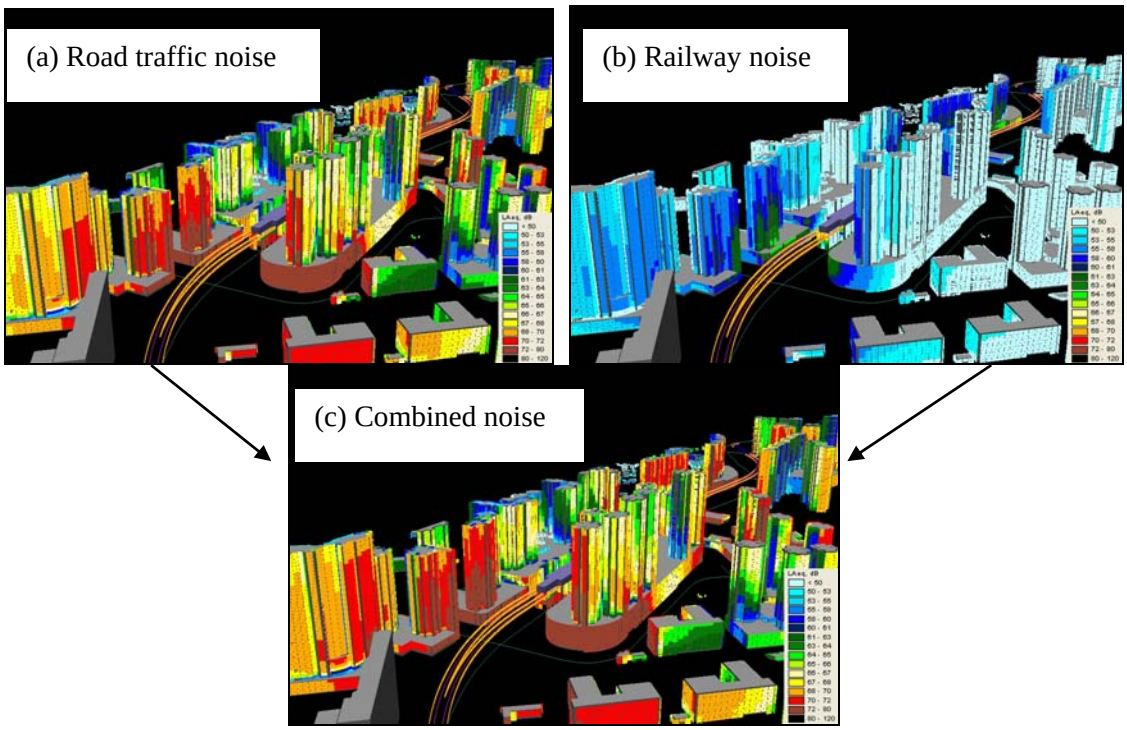

Figure 1. 3-D Noise Mapping of (a) road traffic, (b) railway and (c) combined noises in Hong Kong

3. HUMAN RESPONSE-ORIENTED NOISE MAPPING

Whether noise mapping is an effective tool depends on the extent noise mapping results can actually influence noise policies and action plans. Such influence will only occur if the noise map is not just a representation of noise contours, but a measure of human response in terms of annoyance reactions and adverse health effects. The emphasis on the link to human response has been underscored in several EU papers on environmental noise [2, 3].

This shift in focus has been given impetus by recent advances in the understanding of annoyance reactions, noise induced health impacts and sleep disturbances. It is now generally accepted that annoyance is not directly determined by noise exposure levels, but by a host of other factors such as the sensitivity to noise at different times of the day; type of noise source, sudden change in noise exposure, acoustic environment in the neighbourhood [7, 8] and whether there is quiet facade in the dwelling. The recognition of these factors has precipitated the adoption, in EU countries, of noise indicators depicting noise exposure at day-time, evening and night-time [1, 5].

However, there is as yet few noise mapping projects which directly link noise exposure to annoyance reactions or health effects. This probably reflects that policy makers are still primarily concern with compliance with simple noise criteria which are not related to the well-being and health prospect of the urban population. As a consequence, most noise mapping projects were set out to identify noise pollution hotspots and to identify noise reduction

measures.

4. FUNCTIONS OF NOISE MAPPING

Noise mapping can serve several functions. It can be an information tool to inform the public, a planning tool to assist project designers, and more importantly, an instrument to assist policy-makers to evaluate policy options and development strategies. Whilst noise mapping has rarely been undertaken to serve a single purpose, different functions may require different steps and procedures. Different users of the noise maps may also have different expectations. For example, the general public would be interested to know the acoustic environment of the city in general and their dwelling places in particular. In addition to providing such information, environmental authorities would be interested to use the tool to enhance the public's intuitive understanding of the behaviour of noise in a city. Project proponents are keen to use the tool to engage the public and solicit their feedbacks on projects with the aim of enhancing public acceptance and lessening resistance.

4.1 As a Tool to Inform the Public

As an information tool, noise maps can serve different purposes as follows:

4.1.1 Information Dissemination

There is hardly any dispute that the outputs of noise mapping are superior to conventional figures and tables in portraying the acoustic environment of a city. A map, either in 2-D or 3-D format, can readily be understood by the general public. There is also a trend to provide such information to the public on the web as in the case of Hong Kong [9] and London. Significant advancements have been made, for example in Hong Kong, to presenting the results in an interactive virtual environment in which members of the public can walk or fly through the 3-D space [6]. This can facilitate the user to relate readily to one's own neighbourhood and quickly immerse into the virtual environment. There is also recent breakthrough in incorporating auralization capability to emulate a near-real virtual environment. Notwithstanding these advances, much more effort is needed to overcome technical bottlenecks caused by computational and internet download speed.

4.1.2 Public Engagement

In response to the call for public participation, some noise maps can present results in a 3-D virtual environment such that members of the public can readily comprehend the project details and can envisage the acoustic consequences of selecting different options in siting, alignment, and design and mitigation measure.

Project proponents can also use noise maps, as in Fig. 2, to identify areas where the impacts are the greatest and people who are likely to be highly annoyed caused either by the a sudden change in noise exposure or noise source [10]. Such a tool can be employed by project proponents to anticipate and manage public reactions to new projects and hence to overcome public opposition.

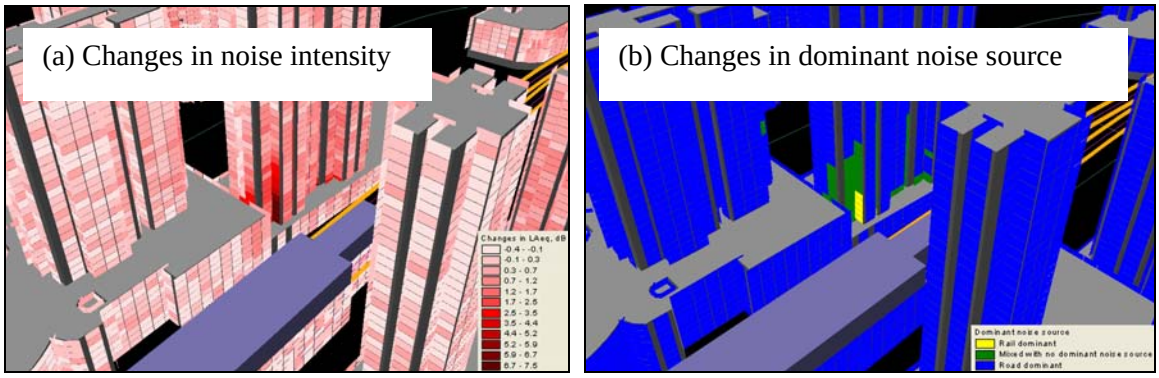

Figure 2. Changes in (a) noise intensity and (b) dominant noise source after the operation of a new railway line in Hong Kong

4.2 As a Tool for Project Planning

Noise mapping can also be applied to assess the acoustic impact of specific projects. Unlike conventional noise prediction tools which are good for a small area, a noise map can portray acoustic changes over a large area in the city. This is particularly suited for transport infrastructure, such as a railway or a road network, which may cover large areas in a city.

4.2.1 Facilitating Interactions between the Proponent, Designer and Authority

Compared to conventional noise assessment methods, noise maps are superior in presenting assessment findings because of the visualization advantage. They can hence facilitate dialogs between the key players in project planning. It has been shown that such dialogs can allow environmental problems to be identified, considered and taken into account early in the project cycle. Such dialogs can pre-empt problems, reduce conflicts and minimize project delay [11].

4.2.2 Facilitating Evaluation of Options and Design

Further development is needed to provide an interactive immersive environment so that the acoustic outcome of different design can be readily visualized. Because of the visualization capability, advanced noise mapping systems can greatly facilitate the evaluation of siting, alignment and design options. The potential use of noise mapping as a project planning tool has sometimes been criticized for not spelling out the error and uncertainty associated with the mapping outputs. There is however no reason to believe that the error of noise mapping is significantly greater than that of conventional noise prediction methods. This is not to say that the accuracy and resolution of noise maps need not be further improved and refined.

4.3 As a Tool to Inform Policy Making

Noise mapping was initially advanced as a tool to inform policy making and to formulation of noise abatement plans. To be helpful to policy makers, noise mapping must be capable of informing decision makers the costs and benefits of different options, and the risks, political as well as health, of doing nothing. There are two particular areas in which further advances in noise mapping can be made to assist policy makers.

4.3.1 Decision Support

To assist policy makers to make appropriate decisions, noise mapping results should be integrated with population and socio-economic data on the GIS platform for the assessment of

the potential social and economic consequence of policy options. Furthermore, noise mapping results should also be integrated with economic and engineering data for the search for the optimal and most cost-effective designs [12].

4.3.2 Strategic Planning

EU has recently used the term strategic noise maps in her papers and directives. The term "strategic" underscores the need to be forward looking and future oriented. Hence, noise maps should not just disseminate information, but also to assist evaluation of strategic options. This is an area which little has been done and warrants more commitment and efforts. There are potentially many ways by which noise mapping can contribute to strategic planning and building a sustainable society as envisaged in the London study. A study along this line is the use of noise mapping as a tool to identify sustainable urban forms [13].

5. KEY ISSUES FOR FURTHER DEVELOPMENT

There are two issues which may constrain the further development and popularization of the noise mapping technology. Firstly, the start up cost of noise mapping is still very high. Secondly, the accuracy of, or uncertainty association with, noise mapping results are yet to be ascertained.

5.1 Cost-Effectiveness

To many small governments, the cost of undertaking noise mapping may be inhibitive. The high cost arises not merely from the resources needed to implement various mapping tasks, but also from the financial and resource commitments needed for starting up. Start-up costs include licensing, testing, commissioning and adaptation of the software, personnel training and capacity building, acquisition, checking and harmonization of the ancillary data for noise mapping. Noise mapping professionals are well aware of the pain-staking job of checking and validating and harmonizing of traffic and building data. Some of those are not yet in digital and standard format. It is often the lack of, or excessive cost of acquiring, those data that renders noise mapping unaffordable.

The only way to get around this problem is through cost-sharing. The more functions noise mapping can serve, the less is the unit cost of implementation. It is thus instrumental to ensure that the objectives of each exercise are well thought-out and the outputs of noise mapping aligned with such objectives. Similarly, the more accessible the findings of noise mapping are to the public, the more justified is the spending on starting up and implementation. Other avenues of cost reduction and sharing can be achieved through:

- Repeating the noise mapping exercise once every five years as recommended in the EU
- Harmonization of format and collection protocol of ancillary data
- Creation of a central clearing house for the acquisition, storage and archiving of ancillary data such as topography, roadways, building, traffic etc.
- Integration of noise mapping with other urban environment prediction models for air quality and day lighting

5.2 Modelling Accuracy and Uncertainty

The issue of noise mapping accuracy and uncertainty has received some attention in recent years [1]. While there has been a number of proposals on how modelling accuracy can be further improved, the question of how accurate noise mapping can be cannot be divorced from

the question of how noise mapping results are needed to be. This brings us to the fundamental question of what noise mapping is for.

Of the three major functions of noise mapping described in section (4), it can be argued that for at least two purposes, namely public consultation and policy making, the current uncertainty associated with the mapping outputs is probably fit for the objectives. As afore-mentioned, there is no ground to suggest that the model accuracy of noise mapping is greater than that of those outputs from project-based noise prediction tools.

It has been argued earlier that the greatest untapped benefit of noise mapping probably lies in its use as a strategic assessment tool. Given the nature and requirements of strategic environmental assessment, the modelling accuracy is already adequate for the purpose. What is badly needed is adaptation of the current noise mapping tool for the broad-brush assessment and screening of development options and plans.

6. CONCLUSIONS

The notion of undertaking noise mapping for urban agglomerations was conceived over a decade ago. We have witnessed how the technology has developed and matured over time. Noise mapping has evolved gradually from merely a map to a tool that can serve many functions such as public consultation, project planning and policy making. The changes that have taken place reflect the changing emphasis of environmental management, from mitigation to prevention, noise emission to imission, single source to multi-source and from presenting the results in visual to multi-media formats. All these changes have enabled noise mapping to assume an increasingly important role in engaging the public, facilitating dialogs between project team members and formulating noise policies and action plans.

At the moment, noise maps tend to be data-rich and information-poor. The utility of noise mapping can be significantly enhanced if the noise mapping results can be directly linked to human response and health effects and the noise mapping data can be integrated with socio-economic and engineering data for project optimization and policy evaluation. Unless one can fully capitalize on the potentiality of this multi-faceted tool, the huge cost of starting up and implementing noise mapping may not seem acceptable. A significant potential of noise mapping which has yet to be refined and developed is in the area of strategic planning and assessment.

Thanks to the efforts of the EU expert group on noise mapping, a number of technical issues have been identified and gradually resolved. The cost of implementation can be overcome by sharing of cost and ancillary data. What remains to be done is adaptation and refinement of noise mapping procedures to attain the enhanced goals afore-mentioned and for strategic assessment.

7. ACKNOWLEDGEMENT

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