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Smartphone-based noise mapping: Integrating sound level meter app data into the strategic noise mapping process

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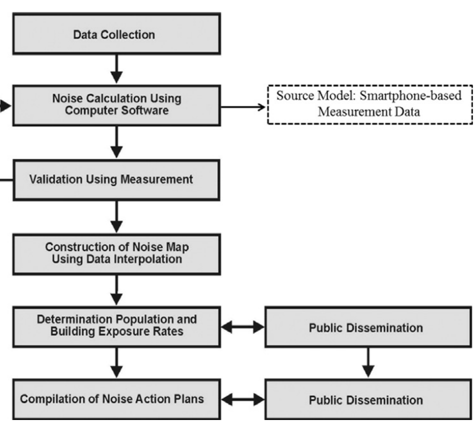
HIGHLIGHTS

- We investigate the use of smartphone apps for noise mapping.
- We integrate smartphone-based noise data into the strategic noise mapping process.
- The results for smartphone and traditional noise mapping are presented.
- Smartphone-based noise mapping has potential for the future.

GRAPHICAL ABSTRACT



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ABSTRACT

The strategic noise mapping process of the EU has now been ongoing for more than ten years. However, despite the fact that a significant volume of research has been conducted on the process and related issues there has been little change or innovation in how relevant authorities and policymakers are conducting the process since its inception. This paper reports on research undertaken to assess the possibility for smartphone-based noise mapping data to be integrated into the traditional strategic noise mapping process. We compare maps generated using the traditional approach with those generated using smartphone-based measurement data. The advantage of the latter approach is that it has the potential to remove the need for exhaustive input data into the source calculation model for noise prediction. In addition, the study also tests the accuracy of smartphone-based measurements against simultaneous measurements taken using traditional sound level meters in the field.

1. Introduction: Strategic noise mapping and smartphones

Smartphones have the potential to act as useful monitoring devices for a wide range of environmental and public health issues. In developed nations, smartphone use is now very widespread with recent assessments suggesting that 64% of US adults own some form of

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smartphone (Pew Research Center, 2014). The corresponding figure for 2011 was 35% (Smith, 2015) which highlights that the rise in the use of smartphones has been very rapid indeed. Moreover, the rise in use of smartphones is not confined to developed economies: Puoshter (2016) has noted more than 25 percentage point increases in many emerging economies since 2013. At the international level, estimates suggest that 80% of internet users own a smartphone; 54% of those use the Android operating system, 15% the iOS while the remainder are a mixture of alternative operating systems (GlobalWebIndex, 2015).

Recent studies have demonstrated that smartphone apps can be useful for monitoring individual health as well as for assessing overall environmental quality (see Milošević et al., 2011; Aram et al., 2012; Sagawe et al., 2016). They are not of course without their problems with significant concerns being raised about their accuracy over traditional monitoring approaches (see Kardous and Shaw, 2014). Despite their use being sparse, they nevertheless have also been utilised to some extent for measuring environmental noise. For example, Kanjo (2010) utilised sound level meter apps to develop a mobile phone platform for measuring environmental noise in cities; this work outlined the potential use of smartphones for the future monitoring of environmental noise while also demonstrating their limitations. Since then, however, smartphones and their apps have become more sophisticated which suggests that more widespread use of such applications for measuring environmental noise could be adopted. In this regard, D'hondt et al. (2013) investigated the possibility of a specific smartphone app – Noise Tube – to be used by ordinary citizens as a form of crowd sourced noise mapping and monitoring. Their work shows that if smartphone-based noise mapping is implemented properly it can achieve noise maps with error margins that compare favourably with modelling-based noise maps.

While the foregoing research has investigated the use of sound level meter apps for monitoring and mapping noise in cities there has also been a related body of work which investigates the accuracy of smartphone apps in a laboratory environment. Kardous and Shaw (2014) tested the accuracy of a selection of iOS and Android apps as well as one tablet for measuring environmental noise in occupational settings. The results of their experiments showed that the iOS app SoundMeter had the best agreement in A-weighted terms with reference sound levels. They also found that three other apps measured to within ±2 dB(A) of reference values. On the basis of their results the authors concluded that iOS apps had the potential to be utilised in occupational settings but that Android apps did not. The latter conclusion was due to the more volatile nature of the Android-based apps for measuring noise compared to those for the iOS given their utilisation of a wide range of manufacturer and hardware components while those for the iOS are standardised. In related work, Nast et al. (2014) tested five sound level meter apps on one iPhone in the laboratory. The outcome of their tests showed that the results varied widely from reference values for all apps tested. This led the authors to conclude that with the exception of one app – SoundMeter – sound level meter apps are not accurate enough to be used as a substitute for traditional sound level meters. The most recent and most comprehensive work on the issue has been conducted by Murphy and King (2016). They tested 100 smartphones (totalling in 1472 tests) and several leading apps on both the iOS and Android platforms in a laboratory environment. Their tests concluded that apps written for the iOS platform are superior to those for the Android platform. Indeed, one of the apps tested for the iOS – SLA Lite – was accurate to within ±1 dB of true sound levels across a range of reference values while another iOS app SPLnFFT performed strongly. Their work concluded that sound level meter apps had considerable potential to be used as SLMs in the future. While the foregoing studies have demonstrated the possibility and limitations of smartphone noise apps for measuring environmental noise none of them have assessed specifically how smartphone apps could be integrated into the current strategic noise mapping process of the European Union (see Murphy and King, 2010). This paper is concerned with exactly that task.

The EU Environmental Noise Directive was signed into European law in 2002. Its overall objective is to identify a common EU approach aimed at avoiding, preventing or reducing the negative and harmful effects caused by environmental noise. The EU strategic noise mapping process has a number of aims but the two key ones are: (1) to produce strategic noise maps for agglomerations in the EU with a population in excess of 100,000; and (2) to estimate population/building exposure to environmental noise pollution in pre-defined decibel cohorts. In relation to (1) the Directive recommends that strategic noise maps are produced using noise prediction models which rely heavily on the input of accurate traffic flow data, with related assumptions around the composition and speed of the traffic, to calculate noise levels. Almost fifteen years on from its signing into law, it is widely recognised among experts (see Murphy and King, 2014) that the European Noise Directive has been important for stimulating noise pollution research internationally which had been scarce until then. Particular areas of research focus have included noise calculation and mapping approaches, methods of assessing population exposure as well as different approaches for noise mitigation through noise action planning. More broadly, however, the END has had a significant impact in terms of policy transfer throughout the world with not only scholars but administrative authorities in countries beyond the EU applying strategic noise mapping approaches to examine the extent of noise pollution in their territories.

While not mandated in the United States (US), some academic studies have nevertheless applied the EU strategic noise mapping process to US locations. A number of European-based commercial noise mapping software vendors offer the option to implement the Federal Highway Administration's (FHWA) Traffic Noise Model (TNM) even though it has not been officially 'approved' by the FWHA; others have simply applied the EU calculation approaches to locations in the US which has allowed a number of strategic noise mapping studies to be undertaken. To take some examples, researchers recently created strategic noise maps for roadways in Chittenden County, Vermont (Kaliski et al., 2007). Their research found that 30% of residents were exposed to road traffic noise levels above 45 dB(A) L_{eq}. More recently, Seong et al. (2011) undertook road noise mapping for Fulton County, Georgia including noise mapping of downtown Atlanta. After constructing noise maps, they estimated that 48% of the resident population were exposed to noise levels above 55 dB(A) or higher during daytime with 32% exposed to 50 dB(A) or higher during night-time. More recently, King et al. (2014) created a noise map of the city of Hartford, CT. This work demonstrates the possibility of utilising the EU approach for undertaking strategic noise mapping in US cities.

Bearing the foregoing context in mind, this paper has two core objectives. The first is to provide proof of concept for integrating smartphone-based sound level meter data into the existing strategic noise mapping process. In this regard, we detail how smartphone-based noise measurement data can be manually input and substituted for traffic data to compile information necessary for the calculation of the source model in the strategic noise mapping process. The second objective is to add to the existing body of evidence that has tested the accuracy and reliability of noise apps in the laboratory. However, our contribution here is to test sound level meter apps in the field. Until now, all of the testing of sound level meter apps has been in a laboratory environment where noise levels and frequency has been tightly controlled. Thus, we examined the performance of sound level meter apps for measuring environmental noise in a more realistic and varied sound environment.

2. Methods

The study area for the current piece of research is a one square kilometre area in the centre of West Hartford, CT. The town is located on the northern suburbs of the city of Hartford. It encompasses 22.2 mile^2 and has a population of 62,000. In terms of its scale, West Hartford is a low rise town with only a small number of buildings