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7
Mapping for sustainability: environmental noise and the city[1]

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Introduction

In the last decade or so, the term sustainability has become fashionable not only among scientists but also among the general public. While this undoubtedly demonstrates that public awareness of environmental issues is increasing, it is also the case that the meaning of the concept can be elusive for many. As has been highlighted earlier in this volume, the notion of sustainability is something of a contested term quite aside from the idea of environmental sustainability, which is a more specific component of the broader concept.

The concept of environmental sustainability is somewhat different to the general concept of sustainability alluded to earlier. To a large extent, environmental sustainability is defined differently to social and economic sustainability (see Goodland and Daly, 1996). Goodland's seminal paper (1995: 10) defines environmental sustainability as 'a set of constraints on the four major activities regulating the scale of the human economic subsystem: the use of renewable and non-renewable resources on the source side, and pollution and waste assimilation on the sink side'. He argues convincingly that the concept of environmental sustainability does not allow for economic growth, quite aside from the idea of sustainable economic growth. His rationale is that environmentally sustainable development 'implies sustainable levels of production (sources), and consumption (sinks), rather than sustained economic growth' (Goodland, 1995: 5). And he is not alone in this assertion; other scholars hold similar views (Meadows et al., 1972, 1992; Daly, 1993). Yet these views are certainly not adhered to in any practical manner, and while they are highly controversial, they deserve attention as a potential alternative and radical solution to our environmental problems. Nevertheless, there is no debating that environmental sustainability is fundamentally important for human well-being, because it allows for the maintenance of human life-support systems which are under considerable threat from the economic growth imperative.

The primary focus of this chapter is demonstrating the importance of mapping as a method for environmental sustainability, using the issue of noise pollution in cities as an illustrative example. The relationship between noise pollution and environmental sustainability is considerable. What is not quite as well-developed is the link between noise pollution and public health sustainability – this will be outlined later. However, numerous studies have demonstrated that preservation of a good sound environment is important for the maintenance of public health well-being and overall quality of life. Any serious threat to this environment is a threat to broader environmental sustainability. This is so because the continued

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deterioration of the sound quality of our cities directly affects the public health conditions of city inhabitants in a highly negative fashion.

The next section of this chapter focuses on highlighting the general importance of mapping as a sustainability tool in the social sciences and specifically for environmental sustainability. Then, section three details the role of noise mapping for future environmental and public health sustainability. In section four, the methodological approach used for noise mapping and population exposure estimation is presented together with results from a recent case study of Dublin, Ireland. Section five offers some limitations associated with the noise mapping approach before some critical concluding comments are offered in the final section.

Mapping as a sustainability tool

The role of mapping in sustainability is something that is given relatively little attention, despite the fact that maps are used very frequently for informing sustainability research and associated policy decisions. In fact, throughout history, maps have been used repeatedly to understand and represent the surrounding environment. As a discipline, cartography is primarily concerned with the making and use of maps, but it is also concerned heavily with the entire process of mapping 'from data collection, transformation and simplification through to symbolisation ... map reading, analysis and interpretation' (Visvalingam, 1989: 26). Lydon (2003: 133) suggests that 'all maps represent and reflect how an individual or society names and projects themselves onto nature, literally and symbolically'. Indeed, they can be regarded as a conduit for the understanding, recording and communication of spatial relationships and forms. In this regard, much environmental research is inherently spatial in nature and as a result the contribution of mapping to the display, analysis and interpretation of environmental data has become increasingly important in recent years, particularly in light of the enhanced interdisciplinary nature of environmental research.

The first known use of maps can be traced to the gold mines of ancient Egypt; it was the ancient Greeks who combined basic maps with the mathematics of space to develop the first coordinate system (Burrough and McDonnell, 1998) while, in more modern times, the first explorers used maps to document new coastlines and land masses (Bernhardsen, 1999). However, the first known utilisation of maps for informing public health issues was not until 1854 when Dr John Snow plotted the location of cholera outbreaks in Soho, London and was able to trace the outbreak very accurately to a public water pump in the area as a result of this basic mapping exercise (Bernhardsen, 1999). This single case demonstrated the merit of mapping public health information spatially to inform policy responses on the ground.

The role of mapping in understanding environmental sustainability issues has increased considerably in recent years with the emergence of digital mapping in the form of Geographic Information Systems (GIS). GIS has transformed the nature and range of the applicability of mapping techniques in a variety of contexts. Although defining the exact role and meaning of a GIS can be difficult (see Chrisman, 1999), it is generally accepted that it is a digital cartographic system for storing, organising, analysing, managing and presenting spatial data (Murphy and Killen, 2010). In an environmental context, the real strength of a GIS is its versatility in terms of its ability to deal with a huge range of spatial data from a wide variety of contexts. In this sense, GIS have been used to inform many environmental research activities over the past decade and beyond. It has been utilised in community based management of wildlife (Lewis, 1995), for assessing the environmental impact of land cover change (Yuan, 2008), for flood risk mapping (Tran et al., 2009), water pollution detection (Shaban et al., 2010), understanding climate change impacts on the environment (Alijani et al., 2008; Jarnevich et al., 2010; Linsbauer et al., 2009; Mo et al., 2009) and for the sustainable management of forestry (Chertov et al., 2005), among many others. However, the use of maps for environmental sustainability research is by no means confined to the realm of GIS. More recently, community mapping techniques have been used as an innovative approach for informing locally derived sustainability indicators and practices (Fahy and O'Cinneide, 2009; Lydon, 2003).

One important consequence of the emergence of GIS and related digital mapping technology is the role that these technological improvements have played in enhancing visualisation of the results of environmental research. Enhanced visualisation may take a number of forms including improved photorealism, 3D visualisations and even the incorporation of results into virtual multimedia gaming environments (Ball, 2002; Drettakis et al., 2007; Sheppard, 2006). Together these approaches have the potential to play an important and more effective role in the dissemination of various forms of environmental sustainability research and related information, in a manner that is both intuitive and easy for the general public and local communities to understand. This is particularly important due to the increasing emphasis being placed on effective public communication of the results emerging from environmental research in recent years.

To summarise, it is clear that the role of mapping in informing environmental research is considerable. In particular, the emergence of digital mapping technologies has allowed for a wide variety of spatial data to be assimilated, analysed and represented graphically in a manner which aids understanding of issues that are pertinent to environmental sustainability. Noise pollution is one of the environmental sustainability issues where mapping has been of considerable importance in the recent past, and this will now be discussed in detail.

Noise mapping and environmental sustainability

Noise and public health: A sustainability issue?

Environmental noise is any unwanted or harmful sound created by human activities that is considered detrimental to health and quality of life (Murphy et al., 2009). In urban areas these unwanted sounds come primarily from road-based transportation but also from rail and airport transportation and various sources of industrial noise. In the European Union (EU), problems with noise pollution, and particularly night-time noise, have often been given similar concern ratings as those for global warming (CALM, 2007). In fact, preliminary results from the Environmental Burden of Disease (EBD) in Europe show that traffic noise was ranked second among the selected environmental stressors evaluated in terms of their public health impact in six European countries (WHO, 2011). The World Health Organisation (WHO) (2011) has recently acknowledged that contrary to the trend for other environmental stressors (e.g. second-hand smoke, dioxins and benzene), noise exposure is increasing in Europe. In other words, it is one of the only major environmental problems (with the exception of anthropogenic climate change) that is deteriorating rather than improving.

It is important to note, however, that discussions concerning noise pollution imply and perhaps overemphasise the negative aspects of the sound environment (Papadimitriou et al., 2009). We are all aware and have experiences of sounds that are not only associated with negative feelings and emotions but also with positive feelings and emotions, e.g., birds, music, etc. In this context, recent research around the sonic dimension of the landscape has started to receive more attention in the academic literature (Mazaris et al., 2009). Here, this research is often referred to within the context of the concept of 'soundscape', a term coined by Schafer (1977, 1994) to describe perceptions of the acoustic environment in a landscape setting. Thus, while there are other more positive aspects of the sound environment being researched, it is clear that it is the negative aspects that have the greatest need for attention given their ability to impact detrimentally on public health, quality of life and related environmental sustainability issues.

The relationship between noise pollution and human health has been the subject of much research over the last two decades. To a large degree, the primary focus of this research has analysed the impact of noise on the auditory system, with the result that it is now well established that prolonged exposure to excessive noise levels can lead to direct hearing loss and/or hearing impairment (see Prasher, 2003; Ingle et al., 2005). However, the bulk of the most recent research has tended to concentrate on the non-auditory effects of prolonged noise exposure. A considerable amount of social survey data has demonstrated that the most important non-auditory effects of environmental noise exposure are annoyance and sleep disturbance. In fact, studies have shown that annoyance from transportation noise produces a series of negative emotions some of which include anger, disappointment, unhappiness, anxiety and clinical depression (Fidell et al., 1991; Fields, 1998; Miedema, 2003; Michaud et al., 2005).

Perhaps a more serious concern from a public health perspective is the unmasking of a link between excessive noise exposure and negative cardiovascular outcomes (Babisch 2006; Belojevic et al., 2008). Through a series of recent studies, Babisch et al. (2003, 2005) have provided demonstrable causal evidence that annoyance and sleep disturbance resulting from road traffic noise is associated with a higher incidence of heart disease in middle-aged men. In a recent WHO report, it is estimated that 'the burden of disease from environmental noise is approximately 61,000 years for ischaemic heart disease in high-income European countries' (WHO, 2011: xv). However, this is not the only population cohort at risk; children appear to be particularly susceptible to excessive noise exposure. The most consistent impacts on children exposed to excessive noise levels are considered to be in the arena of cognitive impairments. In particular, tasks involving central processing and language comprehension, including reading, attention span, problem solving and memory appear to be most negatively affected from exposure (Evans and Lepore, 1993; Evans et al., 1995; Evans and Maxwell, 1997). Adding to this, the reduced motivation of children inside and outside learning settings is also a considerable problem (Evans et al., 2001).

Research conducted by Carter (1996) has shown that exposure to noise during the night can lead to considerable disruption in the stages of the sleep cycle, and particularly deep sleep stages which are considered essential for physical recuperation (Naitoh et al., 1975; Thiessen, 1988) while Ohrstrom and Skanberg (2004) have shown that the quality of sleep at home is reduced considerably after exposure to traffic noise when compared to a quiet reference night. The problem with over-exposure to night-time noise is that it produces a number of secondary effects as a result of sleep disturbance including affecting deep sleep stages, arousals and awakenings and this produces a number of secondary effects (i.e. those that can be measured the day after the individual is exposed to night-time noise) including psychological and physiological symptoms as well as reduced performance in adults (Ohrstrom et al., 2006).

Table 7.1 shows a summary of the results from a recent WHO study investigating the burden of disease resulting from environmental noise in Europe (WHO, 2011). The results of the study are the first comprehensive effort at identifying the impact of excessive environmental noise on public health. In many instances, the calculations are based on data taken from environmental noise maps constructed as part of EU member state requirements under the terms of the EU Environmental Noise Directive (END). As can be seen, the impacts are highly significant and demonstrate the detrimental impacts of excessive environmental noise exposure on public health and overall quality of life.

Table 7.1. Burden of disease from environmental noise in Europe

Noise-Induced Exposure	**Public Health Impact**
Annoyance	587,000 DALYs[4] lost for inhabitants in towns >50000 population
Sleep Disturbance	90,3000 DALYs for EUR-A[5] inhabitants in towns >50000 population
Cardiovascular Diseases	61,000 years for ischaemic heart disease in high-income European countries
Tinnitus[6]	22,000 DALYs for the EUR-A adult population
Cognitive Impairment in Children	45,000 DALYs for EUR-A countries for children aged 7-19 years

Source: Adapted from WHO (2011)

In summary, the previous discussion points towards a growing body of evidence linking excessive environmental noise exposure to detrimental impacts on public health. If we are to take the previously outlined concept of environmental sustainability seriously, it is clear that current level of exposure poses a considerable threat to public health and the general welfare of existing and future generations in cities. Thus, in order to maintain environmentally sustainable cities, it is important to implement policies that attempt to mitigate the worst impacts on these and other serious environmental concerns.

Environmental noise policy evolution and the EU Environmental Noise Directive

Within the context of an emerging evidence base suggesting links between exposure to environmental noise and public health concerns, noise policy gained greater prominence in EU environmental policy throughout the 1990s. In 1993, the Fifth Environmental Action Programme of the European Community established as a basic objective that individuals should not be exposed to noise levels which may endanger their health and quality of life (European Community, 1993) and established a number of targets for mitigating exposure by the year 2000. Later, the EU Green Paper on Future Noise Policy was published ([European Commission, 1996). It focused on stimulating public discussion on a future approach for EU

[4] DALYs are the sum of the potential years of life lost due to premature death and the equivalent years of 'healthy' life lost by virtue of being in states of poor health or disability (WHO, 2011).

[5] EUR-A is a WHO epidemiological sub-region in Europe comprising Andorra, Austria, Belgium, Croatia, Cyprus, the Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Luxembourg, Malta, Monaco, the Netherlands, Norway, Portugal, San Marino, Slovenia, Spain, Sweden, Switzerland and the UK.

[6] Tinnitus is defined as the sensation of sound in the absence of an external sound source (WHO, 2011).

environmental noise policy as well as outlining a framework for the assessment and reduction of noise exposure and the future actions for noise mitigation.

The key document linking noise exposure to public health concerns was produced by the WHO – *Guidelines for Community Noise* (Berglund et al., 1999). According to the document, 40 per cent of the population of European Union (EU) countries were exposed to road traffic noise with an equivalent sound pressure level exceeding 55 dB(A) during daytime, the level above which they considered prolonged exposure to have adverse health effects; the corresponding figure for night-time was 30 per cent. Taking all exposure to transportation together, the WHO estimated that approximately 50 per cent of EU citizens lived in zones of acoustical discomfort. Just a few years later, the Sixth Environmental Action Programme of the European Community was adopted by the Council and the European Parliament and specifically targeted the problem of environmental noise. The Programme stipulated that future environmental noise policy should aim at 'substantially reducing the number of people regularly affected by long-term average levels of noise, in particular from traffic' as well as 'developing and implementing instruments to mitigate traffic noise' (European Commission, 2002: 10, 12).

At the EU level, these policy documents, together with academic research on noise and health dose–effect relationships, have been instrumental in the development of a legislative framework for the management of environmental noise in Europe. As a result, the EU passed Directive 2002/49/EC, also known as the Environmental Noise Directive (END) (European Union, 2002). Recognising the potential public health concerns, it seeks to develop a common approach towards the avoidance, prevention and reduction of the harmful effects of exposure to environmental noise using a strategic noise mapping process. This highlights the importance of mapping approaches to issues of environmental sustainability.

The 'global assessment' of noise exposure is to be achieved using strategic noise maps for major roads, railways, airports and agglomerations using the harmonised noise indicators L_{den} (day–evening–night equivalent sound pressure levels) and L_{night} (night-time equivalent sound pressure levels). A noise map is simply a means of presenting calculated and/or measured noise levels in a representative manner for a particular geographic area (Murphy and King, 2010) while strategic noise maps are defined within the Directive as maps 'designed for the global assessment of noise exposure in a given area due to different noise sources for overall predictions for such an area' (European Union, 2002: 14). Strategic noise maps are to be used as a basis for identifying levels of population exposure within agglomerations. In this regard, the Directive requires competent authorities in each member state to provide estimates of the number of people living in dwellings or individual buildings that are exposed to various noise categories at the most exposed building façade and separately for different modes of transport (European Union, 2002: 24). Thus strategic noise maps must be accompanied by relevant assessment data detailing the level of noise exposure for each area under consideration.

Noise action planning is also a major concern, notably within the context of noise mitigation and the preservation of areas of good sound quality. In the Directive, action plans are 'designed to manage noise issues and effects, including noise reduction if necessary' (European Union, 2002: 14). In fact, it is a requirement that competent authorities draw up action plans for the major roads, railways and agglomerations within their remit, and that these plans are reviewed every five years once adopted and on an ongoing basis by accounting for major new developments.

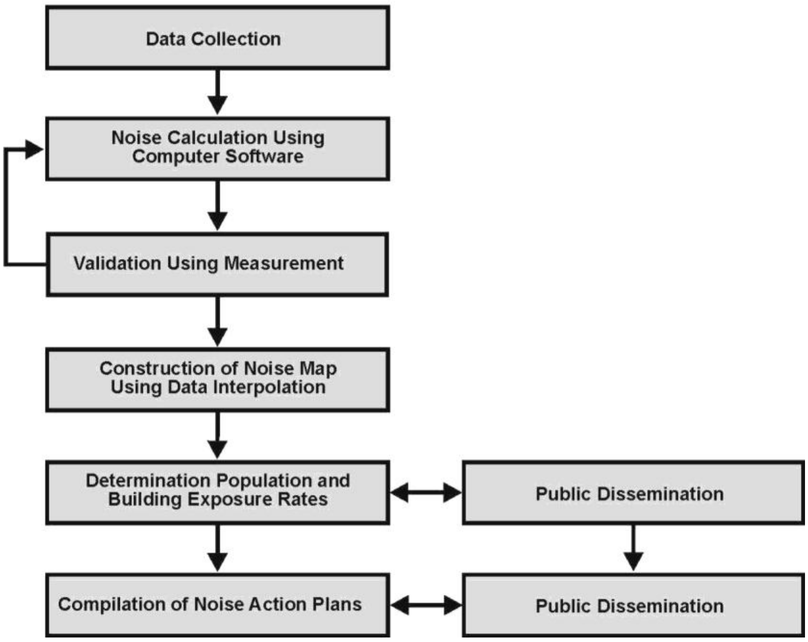
A final area of concern is in terms of dissemination of information to the public. One of the core objectives of the END is to raise awareness of noise issues, and particularly of noise as a potential public health concern. As a result, the importance of dissemination of information to the general public is a major area of concern. It can be achieved in a variety of ways from using enhanced visualisation techniques, to holding public meetings regarding results, to placing noise maps and associated data on display in local libraries and associated citizen information centres, to news reports in various media outlets.

Environmental noise and sustainability: mapping public exposure to noise

Methodological approach: the case of Dublin, Ireland

The methodological approach used for estimating human exposure to noise involves a series of steps where either a GIS mapping environment or similar is used as a basis for housing the data necessary to undertake the analysis. This procedure involves four main components: strategic noise mapping, estimating population exposure, noise action planning and dissemination of information to the general public. A representation of the steps in the approach is illustrated in Figure 7.1. In order to outline the process a case study of Dublin, Ireland will be examined to assess the extent of population exposure to noise and to assess the impact of various mitigation measures on reducing exposure and improving the sustainability of public health in the city with respect to environmental noise reduction (see Murphy and King, 2011).

Figure 7.1. Schematic of the noise mapping process



Study area and data acquisition

Dublin is Ireland's primary city and is located on the east coast of the island. Until the global economic recession in 2007, the city witnessed rapid economic and population growth. The population of the city region[7] now stands at 1.8 million (Central Statistics Office, 2011). The city centre is the main destination in the region for employment, shopping, entertainment and education (Dublin City Council Traffic and Transportation Strategic Policy Committee, 2009). Moreover, major road and rail infrastructure converges at the central area and most of the travel is dominated by the private car, which means that the volume of traffic in the city centre and the surrounding area is high relative to outer locations (King et al., 2009). Given that road transport is the major source of environmental noise in cities, Dublin city is particularly susceptible to high levels of environmental noise exposure.

The data required for noise mapping is primarily information relating to road traffic flows on the links within the study area which are representative of (say) a three- to six-month period for the year being studied. Traffic composition as well as traffic speed data along road links is also required. Building height and geometry information is also needed as this affects the path of sound waves in the built environment. In addition, depending on the calculation method being utilised, local meteorological and topographical information may be needed.

The data for the case study was provided by Dublin City Council including 24-hour traffic flow information along the road links in the study area for a six-month period from January to June 2007. The traffic flow data was derived using Dublin City Council's traffic monitoring system, which provides hourly traffic counts at junctions within the study area. Traffic composition data was unavailable on all links and was assumed to be 90 per cent light vehicle and 10 per cent heavy vehicles. This is in keeping with the Good Practice Guide for Noise Mapping (WGAEN, 2008). Building geometry, building height information and road network information were provided by Dublin City Council in the form of Geographic Information System (GIS) shapefiles. Annualised meteorological information was acquired from the closest weather station to the study area – Dublin Airport. Data such as mean temperature, mean relative humidity and mean atmospheric pressure were included in the noise calculations.

Noise Modelling

As part of the development of the END, the EU developed two harmonised noise indicators, L_{den} and L_{night}. L_{den} is an annual noise indicator which describes the average day–evening–night-time equivalent sound pressure level over a complete year while L_{night} describes the night-time equivalent sound pressure level over a complete year. These harmonised noise indicators were used to gauge average noise emission levels in the study area. Both L_{den} and L_{night} represent the annual A-weighted long-term average sound pressure level determined over the entire day and night periods respectively. The day period varies slightly across the EU, but is generally taken to be from 07.00 to 19.00 while evening and night-time periods are taken to be from 19.00 to 23.00 and 23.00 to 07.00 respectively. It is worth noting also that the night-time period is given additional weighting over the day and evening periods in calculations due to the fact that night-time noise is associated with the greatest array of associated public health concerns.

[7] This includes the four administrative authorities of Dublin and the surrounding counties of Meath, Kildare and Wicklow.

In order to fulfil the requirements of the END, many different calculation approaches have been used in the first phase of noise mapping.[8] Murphy and King (2010) have identified a total of 25 different calculation methods used across Europe for estimating noise levels from road transport, rail transport, industry and air transport. However, work is currently ongoing to develop a common European assessment method (King et al., 2010). For the current case study, the UK Calculation of Road Traffic Noise (CRTN) method was used to calculate noise levels.[9] These were than validated using measurements to ensure the model provided an accurate representation of the urban sound environment.

Noise mapping and population exposure estimation

In order to produce a strategic noise map, the process proceeds by calculating noise levels at receiver points on regular grids placed over the study area (Figure 7.2). In terms of representation, the grids range from five to twenty square metre resolutions. Normally, noise maps are then completed through a process of spatial interpolation within a GIS.[10] For the current study, a standard grid spacing of 10 metres was chosen. All calculations were performed at the standard receiver height of 4 metres above the ground. The results from the strategic noise mapping exercise are shown in Figure 7.2. In order to estimate exposure, the noise level at the most exposed façade must be determined (European Union, 2002). Thus, for the current study separate calculations were undertaken for the completion of strategic noise maps and for estimates of noise at building façades. For façade calculations the recommendations outlined in the Good Practice Guide for Noise Mapping (WGAEN, 2006) were followed. Receiver points were placed at 0.1 metres in front of the façade; a spacing of 3 metres between calculation points was used.

Population exposure was estimated by determining the number of residential units for each building in the study area. Once determined, each residential unit was assigned an average household size value equivalent to the census enumerator area (EA) where the building was located. This value was obtained from the 2006 Census of population data for 162 EA's falling within the study area. Information on the number of residential units in each building was acquired from the Irish GeoDirectory database for 2007. The GeoDirectory is a complete database of every building in Ireland, among other things it contains information detailing the number of residential units in each building. It is updated on a quarterly basis by the Irish Postal Service and is the most complete building database available in Ireland. Given the number of residential units for each building in the study area and the average household size associated with each building location, it is possible to compute estimates of the residential population for each building.

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[8] The first phase of noise mapping was completed in 2007. The second phase is due to be completed in 2012.

[9] This method has been used as the default noise calculation method in Ireland for many years. See O'Malley et al. (2009) for more information.

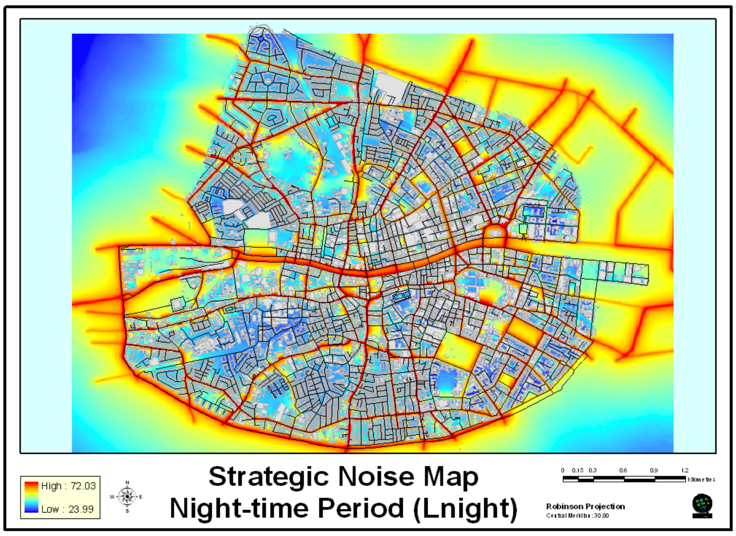
[10] The main interpolation methods available within a GIS framework are nearest neighbour, kriging and inverse distance weighting.

Figure 7.2. Constructing a uniform receiver grid for noise calculation

Figure 7.3 shows the results of the strategic mapping procedure for the night-time period in Dublin. The key reason for mapping environmental noise lies in the ability of policy makers to easily identify 'noise hotspots' – areas where noise pollution is greatest – so that noise mitigation measures can be put in place. These may include anything from reducing travel demand, reducing speeds, implementing traffic calming measures, to noise attenuation by erecting noise barriers along roadsides.

It is notable from Figure 7.3 that very high levels of noise are evident along the main routeways for the night-time period because these are the routes with the greatest road traffic volumes. The results for population exposure are quite striking. They suggest that 27.2 per cent of residents are exposed to noise levels exceeding 70 dB(A) for L_{den} while the corresponding figure for night-time noise exposure (L_{night}) greater than 40 dB(A) is 84.3 per cent. The results indicate that the rates of exposure are high in Dublin, and this is particularly the case for night-time noise where the adverse public health implications are considerable within the context of public health sustainability.

Figure 7.3. Strategic night-time noise map for Dublin



Caveats for noise mapping research

As with the vast majority of approaches relying heavily on numerical modelling, there are some methodological limitations with the existing approach. First, in the case of strategic noise mapping it is common for commercial software packages to be used for calculating noise levels. While most of these packages offer a mapping component within the software, they fall far short of the capability of a GIS for digital mapping and spatial data manipulation. Indeed, the quality of the mapping components can vary considerably between the various software offerings, and this can cause difficulties for standardised comparisons between cities within the EU and regionally within individual nations.

There is a further issue relating to the use of spatial interpolation. The mapping component in commercial software does not provide the user with a choice of spatial interpolation method to be used. In fact, many of them do not specify the method being utilised in the mapping process at all. However, within a GIS there is a choice of a number of interpolation methods, and the EU Directive does not provide guidance on what method to use. Thus different approaches towards interpolation are being used across the EU, adding further to the difficulty of comparison across EU states.

Visualisation is also an issue. In the first phase of noise mapping, numerous colour schemes have been used between and within states to graphically represent the noise environment. However, this can be quite confusing for the general public, and the absence of guidance on a standardised colour scheme for noise mapping fails to aid public understanding of environmental noise as a health concern. Murphy and King (2010) have pointed out that an ISO standard exists and this standard, until it was revised recently, specified a colour scheme for the presentation of acoustic graphics (see ISO, 1996). The adoption of such a standardised approach towards the visual representation of noise mapping information would certainly help to increase understanding of noise mapping representation across the EU.

There are also methodological problems with regard to the estimation of population exposure. Despite the methodology outlined previously, there is no standardised methodology for the estimation of population exposure as part of the Directive. Thus, different approaches have been used in different member states and some are wholly inadequate. In fact, some states have not used façade calculations at all to estimate exposure but have simply used noise maps (see King et al., 2011). Clearly, the variation in approaches creates significant difficulties in terms of preventing any direct comparison of the scale of the exposure problem across the EU. Thus, for a variety of reasons (see Murphy and King, 2010, it is likely that significant over-estimation of exposure has occurred in most EU states and as a result there is the potential for policymakers to over-estimate the health risks associated with noise exposure resulting from the noise mapping process. Given that the estimation of exposure is directly related to dose–effect relationships associated with environmental noise exposure, this concern should be addressed as a matter of priority.

As mentioned already, the Directive requires that noise mitigation measures should be implemented in areas considered to be of poor sound quality. These mitigation measures tend to be traffic and land-use planning measures, technical measures to reduce noise sources, reduction of sound transmission or regulatory measures/economic incentives. Overall, the most important issue for policy makers is to ensure that they take account of the severity of the noise situation under consideration and the potential implications for implementing any measure in a local context. Moreover, policy makers must take care to preserve areas of good sound quality. There is a temptation in noise mapping studies to ignore areas that are of good sound quality and concentrate on 'noise hotspots'. However, areas of good sound quality should be monitored on an ongoing basis to ensure satisfactory standards are being maintained.

A key goal of the END is to raise awareness of the issue of environmental noise in the EU. To this end, the efficient dissemination of noise mapping information to the general public is crucial if this awareness-raising agenda is to be achieved. To date, it seems that this element of the noise mapping process, which should occur in conjunction with the emergence of population exposure results and the development of action planning (see Figure 7.3), has been given little serious consideration in relative terms in the noise mapping process (see King et al., 2011; Murphy and King, 2010). This is something of a concern, and it is important that serious engagement of the public in relation to the results of noise mapping needs to occur, using various different dissemination avenues and technologies.

Conclusion

One of the key points to take from this chapter is that the issue of environmental sustainability is wide-ranging. The scope of human–environment interactions to negatively impact upon the environment is considerable. Thus, sustainability issues need to be at the forefront of all considerations where human activities have the potential to affect the environment. While this approach is important in all areas, it is particularly pertinent for public health. The foregoing discussion has focused on noise pollution as an issue for environmental and public health sustainability. The sustainability of public health implies that environmental quality should not only be maintained at standards that ensure the preservation of good quality public health but that policies should be put in place to improve environmental quality and its impact on the well-being of individuals. Within this context, new and existing approaches applied in different settings that aid the uncovering of potential threats to environmental sustainability are highly important.

The methods outlined in the current study rely heavily on cartographic approaches to understanding environmental problems. More specifically, they highlight the potential of digital cartography, and in particular, Geographic Information Systems for acting as a storage, data manipulation and data representation system for environmental research in the social sciences. In the specific case of noise mapping, the methodology conveys the role of mapping techniques in exploring the extent of the problem of noise pollution from transportation in cities, an issue which had previously not been very well understood by the general public or policy makers. While there are still concerns in this regard, it is clear that the use of mapping techniques to graphically represent the scale and extent of the level of population exposure to noise in cities has served to raise public awareness about noise pollution as an environmental and public health sustainability issue. Thus, by improving our understanding about the nature and scale of the exposure problem in cities, policies can and have been formulated and implemented to support the mitigation of noise in vulnerable areas while protecting those areas of good sound quality.

An important point for the reader to bear in mind is that the techniques used here are not specific to noise research, but can be more or less universally applied in any research which involves the utilisation of spatial data, mapping and technology to improve our understanding of environmental and related phenomena. Perhaps most importantly, it is the employment of mapping, and digital maps in particular, which allows researchers, policy makers, local communities and the public more generally to visually inspect and identify interesting trends in data that can aid our present and future understanding of environmental issues and potential solutions.

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