THE FUTURE OF STRATEGIC NOISE MAPPING – INTELLIGENT DESIGN TO SUPPORT INTELLIGENT POLICY

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1 INTRODUCTION

The Environmental Noise Directive (END)[1] was published 16 years ago and subsequently transposed into Regulations across the UK in 2006[2,3,4,5]. The END requires Member States to produce strategic noise maps, to report the results of this assessment to the European Commission and to prepare noise action plans to avoid, prevent or reduce the harmful effects, including annoyance, due to exposure to environmental noise.

Strategic noise maps produced under the END are generated every 5 years, resulting in a static and retrospective representation of the environmental noise climate. At the end of 2017, the third round of strategic noise maps were due to be generated and reported to the European Commission. The approach to designing and building each round of maps has varied across the UK and the Member States of the EU. The maps have also evolved between the three rounds.

This paper presents a high-level summary of the process of generating strategic noise maps in section 2, and goes on to examine a small number of the multitude of challenges and decisions taken in generating a noise map in section 3. In the context of the ongoing negotiations regarding the withdrawal of the UK from the EU, the future of the END and therefore also the Environmental Noise Regulations in a post-brexit UK are far from certain. This paper will therefore go on to discuss some of the limitations imposed by the framework of mapping required by the END in section 4 and conclude by examining the policy opportunities for innovating and delivering increased benefit from noise mapping in section 5.

2 PROCESS OF STRATEGIC NOISE MAPPING

The process of creating a noise map has evolved, arguably almost beyond recognition to that used at the outset of the END. At that time the majority of noise mapping projects will have been undertaken almost entirely within a noise calculation tool. Given the scale and complexity of the task, the exponential increase in computing power, software improvements, and advances in data science and availability, experience has demonstrated the most effective and powerful approach to generating strategic noise maps is to employ a staged process both starting and finishing in a GIS environment. A high-level summary of this staged process is shown in Figure 1 below.

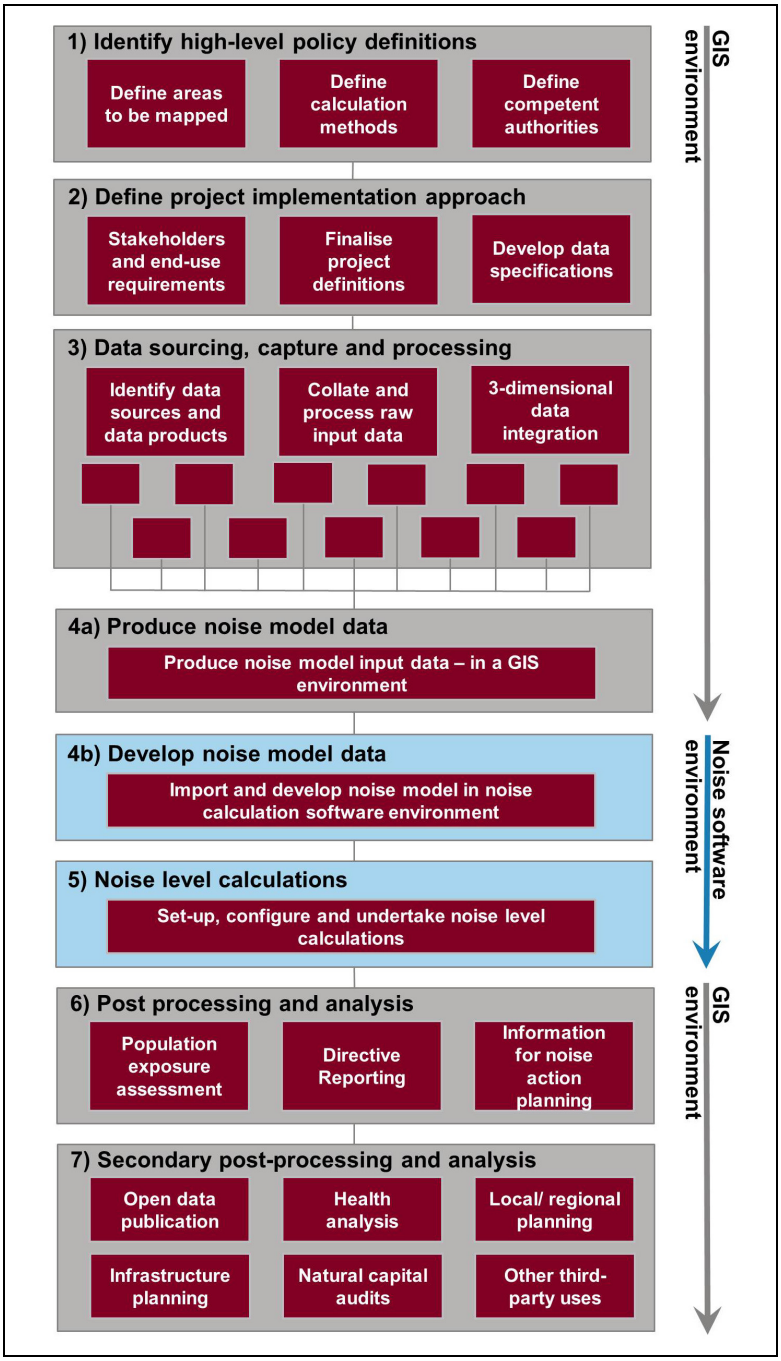

Figure 1 High-level overview of a common step-by-step approach to strategic noise mapping

3 CHALLENGES OF STRATEGIC NOISE MAPPING

Noise modelling and generating strategic noise maps on a national scale is a complex activity. The process requires a wide range of highly detailed information to be acquired and integrated within a proprietary software environment. There are a huge number of decisions taken at every stage of the process, where for each decision, invariably many options are available that would satisfy the regulatory regime. Each and every one of these decisions will have an implication on the noise level results, the population exposure assessment and therefore perhaps most significantly how the results ultimately may be appropriately used or interpreted.

In this section of the paper we have presented, by way of an example a very small selection of the hundreds of challenges or decisions that are encountered in developing strategic noise maps, across the various staged phases of the process.

3.1 Policy framework of strategic noise mapping

The Directive provides high level definitions for some aspects of the END however, perhaps unusually for such a complex technical policy, the Directive was not accompanied by formal technical guidelines setting out clear technical specifications on how to implement the various stages. As a consequence, the approaches taken by many Member States in transposing, defining, implementing and reporting the END vary both across and within Members States. Each of these individual decisions will have a potentially significant impact on the subsequent results and therefore the potential application and re-use of those results.

An example of this is the definition of agglomeration boundaries. The END and the Regulations provide a high-level description of the requirements for identifying agglomerations.

Article 3 (k) of the END indicates that an *" 'agglomeration' shall mean part of a territory, delimited by the Member State, having a population in excess of 100,000 persons and a population density such that the Member State considers it to be an urbanised area"*.

The Regulations in the UK indicate that to identify agglomerations the relevant authority "*must identify areas-*
(a) having a population in excess of 100,000 persons and a population density equal to or greater than 500 people per km2 and
(b) which it considers to be urbanised."

These descriptions provide a high-level framework for the subsequent definition and delimitation of agglomerations, however they are far from prescriptive and allow for a multitude of implementation approaches to be adopted. A relatively common approach has been used across the UK, based upon an urban areas approach, as delimited by a published data product.

This is in contrast to methods often employed across other Member States where agglomerations are defined using administrative geographical units (for example the equivalent of Local Authority areas, Wards or Census Output Areas). An example of the potential differences is shown in Figure 1 below, whereby three agglomerations are identified in Wales using an Urban Area approach (shown in black outline) compared to four agglomerations identified using an alternative approach based upon Lower Level Super Output Areas (shown in red).

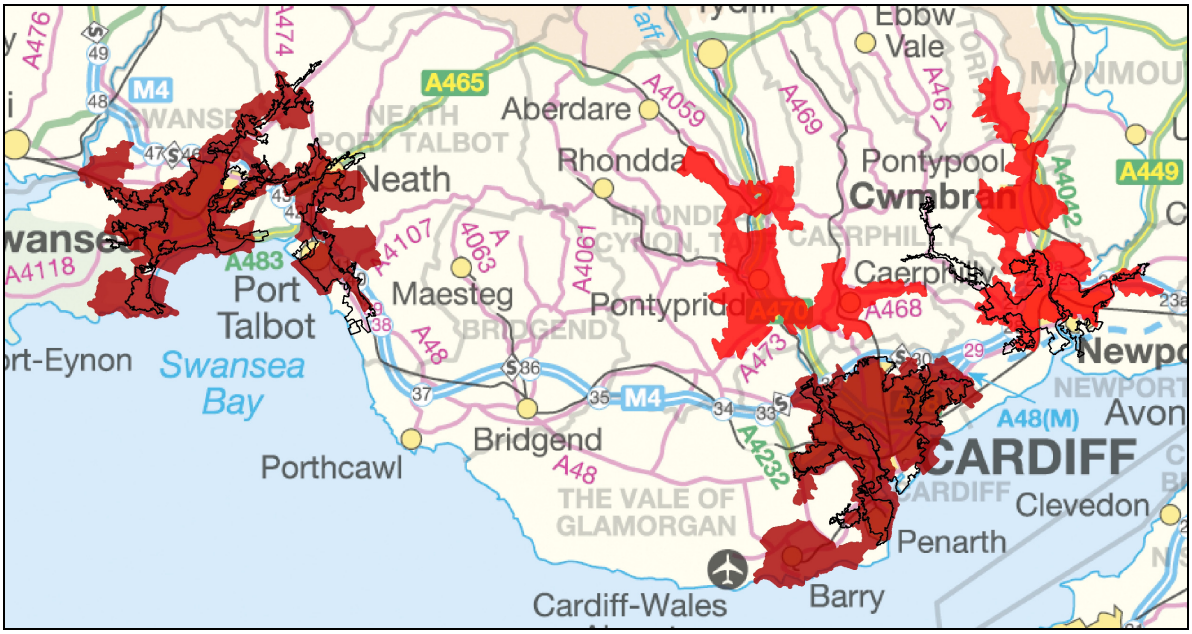

Figure 2 Comparison of agglomeration boundaries identified using an urban areas approach (black outline) with the potential boundaries based upon Lower Level Super Output Areas (shaded in red). Contains OS data © Crown copyright and database right 2018. Contains public sector information licensed under the Open Government Licence v3.0.

The difference in the number and size of agglomerations is apparent, whilst the administrative approach would also identify approximately 30% more people. It is therefore obvious how a decision such as this could lead to potentially significant difference in both statistical and operational outcomes.

3.2 Management framework for strategic noise mapping

The Directive requires that "*Member States shall designate...the competent authorities…for implementing the Directive*". By its very nature strategic noise mapping, noise action planning and noise management are activities that require interactions with a huge number of cross-cutting disciplines, data sources and stakeholders. Given this, there are a variety of options available for defining the implementation approach and organisational or management structure for noise mapping projects. The organisational approach used can have a significant impact on the type of project that ensues and therefore the type of maps that are created. For example, you can imagine a project carried out by a road or railways authority may have a slightly different focus to a project directed by, say a planning authority.

Across the UK a (predominantly) centralised approach has been favoured, whereby responsibility has been placed upon central or devolved government (or their agencies). This contrasts with decentralised approaches used by some Members States which can be argued to be more similar to the local air quality management regime in operation in the UK.

Further organisational differences can be observed in the departments responsible for noise mapping. The responsibility seems to fall principally between either environment-focused departments/agencies or transport-focused departments/agencies. For example, in England the majority of the Directive has been implemented by the Secretary of State for the Environment, Food and Rural Affairs, with the exception of Airports where the Airport Operator is identified as the competent authority (or the Secretary of State for Transport in the case of designated airports). In contrast, the Regulations in Northern Ireland identify both transport and environment departments, agencies and organisations.

In addition to the organisational structure of a project, it goes without saying that the extent of funding will also have a significant impact on the output of a strategic noise mapping project. In general, it is fair to say that noise levels will in general decrease, with increased spend because more features will be included which may obstruct or reduce noise levels such as noise barriers, fully representative terrain features etc...

3.3 Noise map implementation decisions

The scope of a strategic noise mapping project is defined not only by the provisions of the END and Regulations. Invariably there will also be a huge number of additional decisions including some fairly fundamental scope issues that must be determined at the outset of a project. For example, neither the Directive nor the Regulations in the UK define the extent of roads that should be mapped and assessed inside agglomerations. In comparing strategic noise map results from round two of the END (completed in 2012) two very different methods can be observed in England and Wales. Figure 3, below presents an example of the strategic noise map results for an agglomeration in England (Leicester)[6] compared to an agglomeration in Wales (Cardiff)[7].

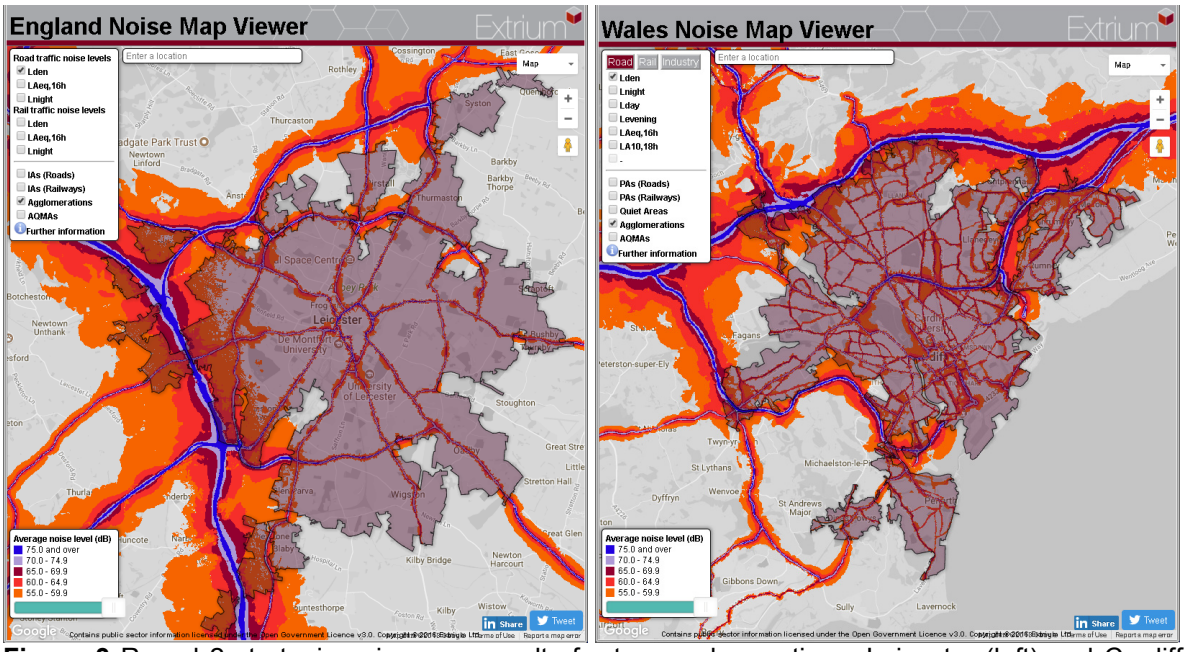

Figure 3 Round 2 strategic noise map results for two agglomerations: Leicester (left) and Cardiff (right).

It can be seen that the extent of roads mapped inside agglomerations appears very different where Motorways and A-roads have been mapped in England, whilst Motorways, A-roads, B-roads and other non-classified urban roads have been incorporated in Wales. It is therefore apparent how big an impact this type of decision can have on the noise level results and population exposure statistics. Defra have previously undertaken research to compare the impact of different methods used in round 1 and round 2, revealing some large differences, for example where population exposure levels for round 2 results can be as little as 4% of those calculated in round 1 in individual noise level bands[8].

3.4 Noise mapping data sourcing and processing

By its very nature noise modelling and strategic noise mapping require a large amount of data from a wide variety of sources and stakeholders to be collated and brought together in a single three-

dimensional noise model environment. As is the case with many environmental models the data that is available has not been designed for the assessment of propagation and calculation of noise levels, because the data is invariably designed for another primary purpose and is being used second or third-hand. The multitude of data sources will also not be engineered to interact or work naturally with one-another, and will therefore need to be processed and prepared to allow them to be integrated into a single three dimensional noise model environment. This process is one of the main challenges encountered in developing a strategic noise map.

There can be a tendency for the noise specialist to focus on the acoustic qualities of the data, potentially at the expense of the spatial and contextual aspects of the data. The spatial and contextual qualities, however, can have a more significant impact on the accuracy and validity of the results, as demonstrated by a variety of research including work previously undertaken for Defra looking at accuracy and uncertainty for strategic road noise mapping in 2005 and in 2007 for railway noise maps[9,10].

The extent of mapping required increased significantly between the first and second round of the END. For example the threshold for agglomerations fell from 250,000 to 100,000 and the number of agglomerations captured by this rose from 23 to 65 in England. The change in thresholds combined with the 5 year interval between maps and the rapid advances in data and technology has resulted in a tendency for each round of mapping to be treated as an individual or new exercise ("rip and replace"). The third round of strategic noise maps in 2017 has arguably been the first opportunity to attempt to introduce the concept of change into strategic noise maps.

Introducing change retrospectively into a 5 year old one-off time-stamped noise map that was not designed to be updated can present a large number of significant technical challenges. In order to generate a fully consistent output the data sources and methods need to be fully reproduced, however invariably without an ongoing and planned data management approach the licensing and data sources can change, for example UK governments have licensed different height products across all three rounds of the END, each product with a different production method, accuracy and therefore implication on their use for strategic noise maps.

Invariably this approach can struggle to give a consistent or comparable result in absolute terms and will reflect a combination of the real world changes interlaced with changes introduced as a result of updates to data and methods. It is therefore fair to conclude that in order to provide consistent and comparable results through time, a system would be required to incorporate updates in a managed way controlled by appropriate standards and license agreements, whilst also having the potential to benefit from existing tools such as geodatabase technologies, OS MasterMap Change Only Updates, and other data services such as traffic data feeds and APIs that have proliferated since END regulations were laid.

3.5 Noise calculation method and software

Noise calculation software can be an extremely powerful tool, it also produces seductive images which look credible, however the validity of results is controlled principally by the quality of input data and also the manner in which the results are calculated in a software tool. It has been demonstrated how different software tools can produce different results and different versions of the same software tool can also produce different results, however it can be argued that the configuration and operation of the tool provides a bigger influence on the output than the software tool itself.

It is easy to treat the noise level calculation process as a black box, however in order to be able to do so confidently, it is important that the calculation is operated in a controlled way by appropriately skilled experts who can select the appropriate software (and version), configure it for the data being used and configure the software appropriately including defining software settings with accuracy and sensitivity of the results in mind.

For road traffic strategic noise maps, the calculation method set out in the Regulations requires that the CRTN method is used to generate a $L_{A10,18h}$ level. The Regulations also indicate that this 18 hour result should then be adjusted to ultimately give daytime, evening, night, $L_{Aeq,16h}$ and DEN levels, all derived from a single 18 hour result.

The fact that strategic noise maps for roads produce night-time results based upon an 18 hour daytime flow, can be argued to be a significant limitation to the validity and subsequent application of the results. With the increased availability of more granular and diurnal input information, this approach can cause an increased challenge to both the generation and subsequent use of noise maps. The introduction of new assessment methods, be it common noise assessment methods adopted by EC Directive 996/2015[11] or an update to the Regulations and CRTN may both provide an opportunity for improvements in this area.

3.6 Post processing – exposure assessment

The results of strategic noise maps are most commonly conveyed either cartographically as a surface (or as noise level contours) or presented statistically in terms of the numbers of people exposed. This population exposure assessment can have as significant an impact on the nature of the results as the noise model inputs and the calculation environment. Exposure results are a function of both the data and methods used to generate a population model and also the manner in which the noise level results and population data are analysed together in the exposure assessment.

As is the case with almost every stage of the noise modelling process there are a huge variety of options for tackling this exposure assessment. For example, in the UK it has been common for the whole population of a building to be assigned to the most-exposed noise level, perhaps following a precautionary approach. This approach contrasts with those commonly used on the continent, where population is distributed around a building. Naturally these approaches can produce very different results and from indicative tests, UK results could be in the region of 5-30% lower by using a method to distribute population around a building, depending on noise level and location.

The examples provided here briefly illustrate how different decisions can give very different results. There are hundreds of decisions found through all stages of the modelling process. A very small selection of examples has been provided to demonstrate the significance each decision can have individually, before even considering the collective impact.

4 LIMITATIONS OF NOISE MAPPING UNDER THE END

The END is now 18 years old, three rounds of strategic noise maps and action plans have been generated over fifteen years. It could therefore be argued to be a relatively mature policy area, however, it is commonly voiced that strategic noise maps and noise action plans under the END have had a limited impact on noise policy and noise management on the ground in the UK. Strategic noise maps have undoubtedly raised the profile and therefore increased awareness of environmental noise in the UK however some of the potential shortcomings are discussed here that may have limited the power of strategic maps as a policy tool.

When the END was introduced it was relatively common for there to be little or no noise policy in place in a number of Member States across the EU. The END was therefore serving the purpose of filling this hole and providing a basis of a new noise management regime. This was obviously not the case in the UK, where the Directive was introduced into a relatively longstanding noise management and noise policy regime. Given the pre-existence of this policy framework it can be argued that the Regulations and implementation of the END have been engineered principally to comply with the headline requirements of END reporting. The strength of strategic noise maps and

to a lesser extent noise action plans have therefore been limited without the overt end-use requirement beyond compliance with the END.

It is also fair to say that the five year interval for creating strategic noise maps and action plans introduced by the END has created a significant challenge. An interval of this length has promoted the view that the exercise is a one-off, time-stamped map rather than an ongoing and evolving representation of the noise environment. It is apparent that the latter could be a powerful toolset for the evolution, development and implementation of policy, whereas the former has a greater potential, without a specific domestic end-use requirement, to be viewed as a burden and a cost.

It can be argued that the centralised approach to the majority of the implementation of the END in the UK has been hugely successful at achieving compliance with the END, however it is probably fair to say that this approach has caused challenges with ensuring effective stakeholder engagement. These shortcomings are perhaps the opposite challenges to those that may have been observed in the more decentralised approach that can be found in air quality management.

Strategic noise mapping and the availability of data to support it have both developed at a huge pace over the course of the 18 years since the END was introduced. This evolution combined with the number of decisions and options available for generating a single noise map as illustrated in section 3 means that a huge variety of approaches have been taken in different countries and across the three rounds. The assessment has therefore not been entirely consistent either across the UK or through time. This lack of consistency can limit the comparability of results in absolute terms and can cause significant challenges in isolating the real-world change in exposure.

One of the original aims of the END was to fill in gaps in data and knowledge of noise exposure at a European level. The policy has struggled to align the requirement for providing headline exposure information at a national or pan European level with the inherently local nature of noise pollution and propagation. During the early stages of the END, due to the limitations of technology and data availability, it was not possible to generate a national scale noise map that could be used for all purposes from national reporting to local noise management and assessment. A common divide was therefore introduced whereby strategic noise maps, were believed to be of a lower resolution compared to those required by local assessments. This division was perhaps valid at the time, however given the advances in data and technology is no longer a true barrier. The divide causes a significant challenge to the application and re-use of strategic noise maps, beyond their use for the END. It can be therefore be argued that END policy has not kept up with the changes and advances in data and technology which would promote the alignment of appropriate toolsets with policy.

Noise pollution has always suffered relative to other perhaps more media-friendly environmental issues, hence being dubbed “the Cinderella pollutant”. It is probably fair to say that this issue has served to some degree as a limitation to the policy and the resulting strength of strategic noise maps. The health evidence base also has historically not been as strong as can be found in other disciplines, however the evidence base has advanced significantly to the point that noise pollution has now been promoted alongside other forms of pollution in the latest annual report of the Chief Medical Officer[12].

5 FUTURE OPPORTUNITIES FOR STRATEGIC NOISE MAPS

This paper has summarised the process of generating strategic noise maps (section 2), examined a small number of the many decisions taken in generating a noise map (section 3), articulated some of the limitations imposed by the framework of the END (section 4) and will conclude by examining some potential opportunities for innovating and delivering increased benefit from mapping.

It is generally accepted that the complexity of noise mapping and its associated data requirements exceed that which has typically been applied to air quality mapping. If you also consider the large number of stakeholders associated with the generation of noise, the large number of

people affected and by implication, the number of organisations who have an interest and or a role to play in the management of environmental noise, it is apparent that the discipline requires cross-discipline coordination of policy, stakeholders and data management.

Traditionally, environmental pollution problems have been examined to a large extent individually within the expertise of the discipline in question. This somewhat silo'd approach has resulted in disciplines that share a relatively common problem, duplicating effort in a large number of complex and time-consuming activities. Traffic models, 3d terrain models and population models will have been created many times over for multiple environmental assessments including for example noise, air quality and carbon emissions.

Over recent years it is apparent that policy direction is now looking to examine and address the spectrum of pollution more holistically, as articulated, for example by the recent Chief Medical Officer for England Annual report[12], Defra's 25 year Environment Plan[13] and the Well-being of Future Generations (Wales) Act 2015[14]. In order to align the policy with the toolsets, a holistic approach to pollution policy should perhaps also be accompanied by a holistic approach to generating the associated evidence base, perhaps derived from a single common underlying environmental model. Strategic noise maps could form a component of this environmental model alongside air quality and carbon assessment tools.

To achieve this it will be critical for the noise community to join up with other disciplines who, not only share a common problem in the cost and time involved in capturing data, who also may have a role to play in the implementation of noise management. This joined up approach would not only enable the sharing of knowledge and experience, it would also help reduce cost, improve quality and thus provide a shared confidence in the data underpinning environmental assessments. This approach has the potential for a wider benefit in terms of gaining stakeholder support and ensuring decisions are based upon robust evidence.

The development of a combined environmental pollution model would without doubt be a politically, scientifically and technically complex undertaking, however the potential benefits to the taxpayer in terms of reduced costs and increased benefits are obvious.

In addition to the potential to harness the benefit from joining up with other disciplines, there is an opportunity to move from mapping on a five yearly Directive driven cycle, creating one-off time-stamped maps towards a more regular output derived from a system engineered to meet specific domestic end-use requirements. This approach could be engineered to support a wider range of domestic applications including perhaps transport assessments, planning, and health impact assessments.

Computing, data and technology are continuing to advance at a huge pace. It will be important for the future of noise policy and noise mapping to maximise the potential benefits that can be realised from these advances. The proliferation of new data sources including the publication of open data sources, detailed 3D city and BIM models, 5G digital terrain models, the improved granularity of traffic statistics including ANPR statistics and real-time or GPS derived traffic information all provide opportunities for advancing and improving the output and therefore potential relevance of noise mapping outputs of the future.

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