

FUTURE NOISE MAPPING & SOUNDSCAPING FOR WELLBEING

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1 INTRODUCTION

The term “soundscaping” is a relatively recent arrival on the acoustics’ stage, whereas it was commonly used to refer to sonic pieces created by artists. Murray Shaffer championed the idea in his 1977 publication, *The Tuning of the World*, introducing the idea that “a total appreciation of the acoustics environment can give us the resources for improving the orchestra of the soundscape” [1]. This approach immediately challenges the established way of dealing with the external sound environment, and at the time and until recently had not been absorbed into mainstream environmental acoustics. Whilst soundscape includes all sound it is the unwanted sound or “noise” that has been the primary focus of noise mapping and the health affects that result for humans, and more recently wildlife in their environments, whether in air or water are also attracting attention. Environmental noise has been largely limited to what can be objectively measured, but the promiscuous nature of sound in the environment today requires a more complete consideration for us to use sound to improve our health and wellbeing, as the absence of noise on its own is not the answer on its own.

Noise mapping has developed as a response to noise management; expressed through computer modelling how certain aspects of the sound environment, limited generally to how transportation sources, vary and are distributed around major urban densities of population. The assumptions shape the results, and because they represent long term averages, they do not represent the noise exposure as a short-term meaningful value that might be experienced in reality in biological time¹. Whilst current noise mapping approaches are useful when considering a national strategic picture, or delivery of compliance with legal obligations, and they produce a visual representation of something unseen, this creates a problem in terms of what represents reality as we perceive it to be.

Although designated quiet areas are identified within urban centres, as part of Action Planning, there is no information in current strategic noise mapping on areas that have low noise levels, because of the lower cut-off threshold. As a result quieter areas in urban centres such as parks, and tranquil areas in the countryside or the more positive aspects of the soundscape are often missed out completely. Here the mix of sound from a variety of other sources cannot be represented, and so areas where soundscape quality may be higher and so better for health and wellbeing are often black holes (absent) on noise maps. This gap has developed because the focus has understandably been on identifying and tackling the worst examples of noise pollution, and this has driven the noise abatement agenda and then its management to control it and reduce exposure of populations.

Recent work for Defra on gathering stakeholders views on feedback to inform round 4 mapping has revealed some areas for consideration in the future, which are worthy of further investigation for how a noise mapping approach could be evolved to represent the distribution of soundscape quality in a meaningful way, as well as just noise level.

The author has therefore quite separately from that work considered how practical soundscape mapping could be done, taking on board the new ISO standards and also recent policy changes in Wales for considering soundscape as part of planning decisions. This paper is written during the consultation period by the UK Government on Planning for the Future [6] and hopes to influence thinking on how to create healthier, better buildings and environments. One of the main conclusions from the Living with beauty report of the BBBE [5] is achieving a virtuous cycle for development, which includes at its heart encouraging place creation that is beautiful, and soundscapes are essential to that. The reforms therefore need acousticians to step up to help achieve this vision.

¹ Meaning a duration of time over which organisms experience change relevant to their immediate needs, so seconds, minutes, hours rather than months and years.

Whilst soundscapes can certainly apply inside [9] as well as outside, in this paper the external environment is focused upon. A similar illustration to the approach taken by the research group for internal soundscapes apply outside, in my opinion, as shown in Figure 1 below [9]. This helpfully identifies the region being neglected by noise mapping and of opportunity for soundscaping.

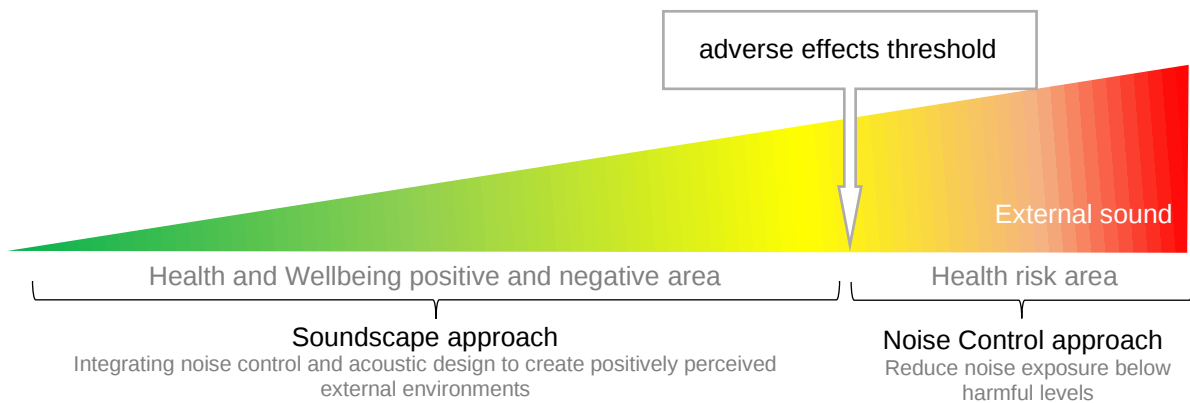


Figure 1: Variation of diagram from Torrens et al (2020) illustrating soundscape and noise control health outcomes, where the horizontal indicates increasing sound level

The requirement for new thinking was articulately well by Schulte-Fortkamp[15] in 2018: “*Soundscape is a paradigm shift in the area of noise and noise control*”. It is time to recognise that noise is only part of the story, where acoustics and wellbeing are concerned, and to encourage thinking of how to design and encourage better, more pleasing soundscapes that connect us to the natural world and help humanity and nature thrive in the future sustainably. This could in different times seem perhaps idealistic, and indeed could be described distinctly part of creating beautiful places, but this is exactly what the Government is now aspiring to do, and what as an industry we can do to respond to help achieve it in short order. What needs to be understood is that soundscape is a fundamental part of that vision, yet it is not mentioned.

2 TERMINOLOGY

Dealing with sound in both a positive and negative sense requires a shift of thinking by acousticians to expand the usual range of parameters and terminology, adding in an equal and opposite side to the scale used to describe noise. Our industry has the skills base, but requires some expansion of thinking. Clarity of the terminology is therefore necessary to assist practitioners, academics and others working with sound to develop a more common language in practice. The reason for this is made clear when musicians speak to acousticians about sound and often use similar terms with very different meanings.

Soundscape is now defined as “*the acoustic environment as perceived or experienced and/ or understood by people, in context*” [2].

Soundmark is a sound feature with character within the soundscape that has community interest [1], such as Big Ben, or the local village clock, or church bells.

Noise on the other hand is generally understood to be described as unwanted sound, or a particular part of the soundscape as described, which may have negative effects, as documented from early times [7].

A growing evidence base supports and confirms that a physical and mental health effect from prolonged exposure to noise exists and is a risk factor for cancers and heart disease and as an outcome for dementia. Although the quality of the evidence is qualified by ARUP’s report from January 2020 for Defra, it suggests there is more work needed and care required to consider the cross

correlation with other pollutants like air pollution [10]. Non acoustic factors have been long recognised as confounders for strong population dose relationships [26]. Noise is objectively quantified as the sound pressure level, frequency and time variance into the parameters we are familiar with (such as $L_{Aeq}(t)$, $L_{AMax}(t)$, $L_{A10}(t)$, $L_{A90}(t)$ over frequency range 20Hz to 20kHz for humans and other ranges and weightings for other species).

Sound of quality or value can be described in terms of its euphonic quality from the Greek meaning a sound that is *"pleasing to the ear"* [7], which has been proposed as a candidate by the author in another paper to describe the other side of the perception scale that is required to complete the description of soundscape. A euphonic soundscape would therefore be one that is pleasing to the ear.

The "perceived affective quality" in method A of ISO 12913-2:2018 allows for the 8 point response scale from the questionnaire to be applied, but equally part 3 suggests a 5 point scale of very good to very bad is also suggested for overall appropriateness. These remain under evolution at this time, generally used by academics. Kang suggests a framework based on sounds, space, people, environment and also a SoundScape Index Descriptor (SSID) as a single index [8].

Wellbeing is defined as part of health by the WHO in its constitution as *"a state of complete physical, mental and social well-being and not merely the absence of disease or. infirmity"* [12] and the link to noise exposure is important to understand. The concept of wellbeing has risen in popularity in recent years, but the evidence is generally low quality according to the recent review by ARUP for Defra [3]. However for mental health (where an absence of impact can be considered an indication of wellbeing) as a proxy, a particular watch on quality of life research will assist this area to develop but further research is required.

Tranquillity is a tricky concept which appears to have grappled with the challenges of describing a value positively attributed with an environment, objectively. Pheasant, R. J. et al [8] describes in addition the idea that *"In a world of sensory overload, it is becoming increasingly important to provide environments that enable us to recover our sense of wellbeing. Such restorative ("tranquil" environments need to comprise sufficient sensory stimulation to keep us engaged, whilst at the same time providing an opportunity for reflection of relaxation"*. This has also been described as "soft fascination". Pheasant qualifies this by determining *"tranquillity represents a complex interplay between the visual and auditory activity evoked by everyday scenes"*, and that a general absence of manmade sound and presence of wilderness scenes assists. He warns very directly that *"even when a soundscape is being characterized the visual scene is likely to be an important modifying factor in auditory perception"*. This is important when considering the sensory crossover that seemingly occurs when making a judgement about the quality of a soundscape. His team went on to develop a Tranquillity Index and demonstrate in 2009 with Watts that cognitive function between the medial prefrontal cortex and the auditory cortex were enhanced for tranquil conditions.

It would seem quite reasonable then to make the link that tranquillity is one aspect of soundscape quality, and that the idea of soundscape being analogous with landscape may be a fortuitous analogy. It therefore becomes problematic to see soundscape in isolation from non-acoustic factors when determining the quality index. This often explains problems with noise effects and the strength of evidence, when considered in isolation from other non-acoustic factors.

3 DEFRA STAKEHOLDER FEEDBACK ON NOISE MAPPING

Report NO0256 for Defra [14] makes 7 recommendations after research covering 63 stakeholder organisations that are put forward for consideration in the tendering of round 4 noise mapping. These reflect recommendations based on the views of the respondents, as interpreted by the authors of the report. Three of those recommendations are particularly relevant to the future of noise mapping and directly include soundscape:

- recommendation 2 – Design the architecture for a sound quality mapping system which includes the ability to incorporate a two-tier sound map (national & local) with the ability to recalculate and use existing and uploaded data sets.

With tier 1 focusing on a National strategic noise picture, which can express the legislative requirements and tier 2 can be added to be available to Local Authorities to upload to, manage and use a tool to determine their local policy and action plans for sound quality, combined with other existing datasets to assist with identifying “win-wins”.

- recommendation 3 – Evaluate and enhance evidence where applicable for sound quality mapping : To determine a methodology for mapping soundscapes.
Commission a research project to explore how sound quality might be mapped using the soundscapes ISO methods, or a simplified version using crowd sourcing data, validated by experts. Propose how this might fit into national mapping framework for sound other than the from manmade transportation sources
- recommendation 7 – Better future planning – Add an option to consider the Sound Quality within layer 2.
Enable soundscape to be mapped, evolving the idea of Quiet Areas to include subjective scales related to ISO standards or a simplified ranking such as low, med, high quality. In this way concepts like Tranquillity, Pleasantness and Vibrancy for an area can be mapped, as part of a Quality of Life Map/ Wellbeing Maps.

These recommendations indicate that there is an appetite from stakeholders to evolve noise mapping to include further data to that only required for regulatory compliance. The shift is a call to include sound that has a bearing on the quality of a soundscape and so its environment's quality.

Understanding how this could be done in practice is an opportunity explored in the remainder of this paper, in accordance with the opinions of the author.

4 ANTHROPOGENIC NOISE OVERLOAD

Noise has been an inevitable consequence and legacy of the economic activity through industrialisation, and in that sense anthropic noise is taken to be the combination of noise made by humans directly, and indirectly through human technology. John Cage wrote in 1937 “Wherever we are what we hear is mostly noise”[13], who was most famous for his reactionary performance piece 4'33" of silence. He hints at something more fascinating than simply the binary solution of silence. He suggests it is musical even, when we focus on it. If we are suffering from human associated noise overload then it is tempting to aim for silence as an antidote, but the respite needed does not require solitary confinement of the auditory system, which can be quite unsettling. This is too crude an approach and one which noise management and control has pursued for years as the primary goal, when focusing on unwanted anthropogenic sound. Perhaps more accurately we are missing the right kind of soundscape in which to thrive, which is a working hypothesis that this paper adopts.

Whilst hard research evidence on soundscape quality is only now beginning to build, it can be confidently proposed that the absence of anthropogenic noise appears to lead to a higher soundscape quality, where the residual is natural sound [8]. Multiple papers by Kang support this position, and case studies, such as Sheffield and Brighton show how anthropic/ technological noise can be teased away from the natural and mapped. This is where the assumption that silence (or absence of sound) as the goal is flawed. What is meant by this idea must relate to the anthropic noise, because humans as well as other animals rely on the stimulus from their soundscape to keep safe or to hunt. Detecting a local quieting of soundscape may actually prompt alarm as an evolutionary warning that there is a predator about and acute listening and increase cognitive function is triggered as a defence mechanism and a release of stress hormone in preparation of evasive action. Sound is therefore linked directly through our evolved physiology to our feeling of safety and security. It is described as “the sentinel of the senses” [28]. Our brains are constantly analysing and interpreting our sensory environment. Baars & Gage (2010) note “The central role of the auditory perception system is to extract information from the listening environment in order to determine what is happening around us” [29]. In high noise environments this ability is masked, and effectively sonic blindness can result, prompting increased cognitive activity, as the brain continues to attempt to scan the environment for threats unconsciously. This increases attention, alertness and activation and is a resource hungry process which can leave us feeling tired and also with reduced performance for complex tasks and

impaired memory. It although does not appear to affect speed of activation, unsurprisingly given this retains the ability to react in the face of threat [22].

With noise not exclusively linked to anthropic sound how noisy a place is does not necessary relate to how good the quality of the soundscapes may be, such as waves on a beach, or near a waterfall. This means that non acoustic factors are an important part of what sound has positive effects on us and what is injurious to our health and wellbeing. This is beyond what causes us physical hearing damage. This context is important as we tackle the idea of what is one person's music and another's noise. Challenging examples include vibrancy, where some human noise is considered to be a positive thing for social cohesion, where nightlife that is "dead" does not offer enough stimulation from sound to fit the intended purpose. In this way sound behaves more like a nutrient. The idea that creating a diverse soundscape that allows a variety of activities, from relaxation and restoration to exciting and actively stimulating is perhaps the direction of travel soundscaping must now consider. This mix may need to provide the right level and type of sound that matches the needs and expectations and needs of those in the locality. It is a complex challenge to achieve a balance that helps humans and nature thrive, but one that had evolved through the pristine soundscapes of the pre-industrial world.

5 THE POST COVID ERA

Since people have encountered lockdown to control the pandemic of Covid-19 one of the legacies already apparent that people have heard for the first time what their environment sounds like without the majority of anthropogenic noise. Dubbed the "anthro-pause" the underlying soundscape has emerged and been a delight for many, with people under flightpaths hearing birds and much more nature than normal. The Natural History Museum has worked with the Quiet Project, and the Institute of Acoustics to provide a piece on this, in which they say *"People in cities across the world felt as though the birds were singing louder. In fact, with competing urban noise down by five decibels (60% quieter), the birds were probably actually singing quieter. And this is good news."* [27].

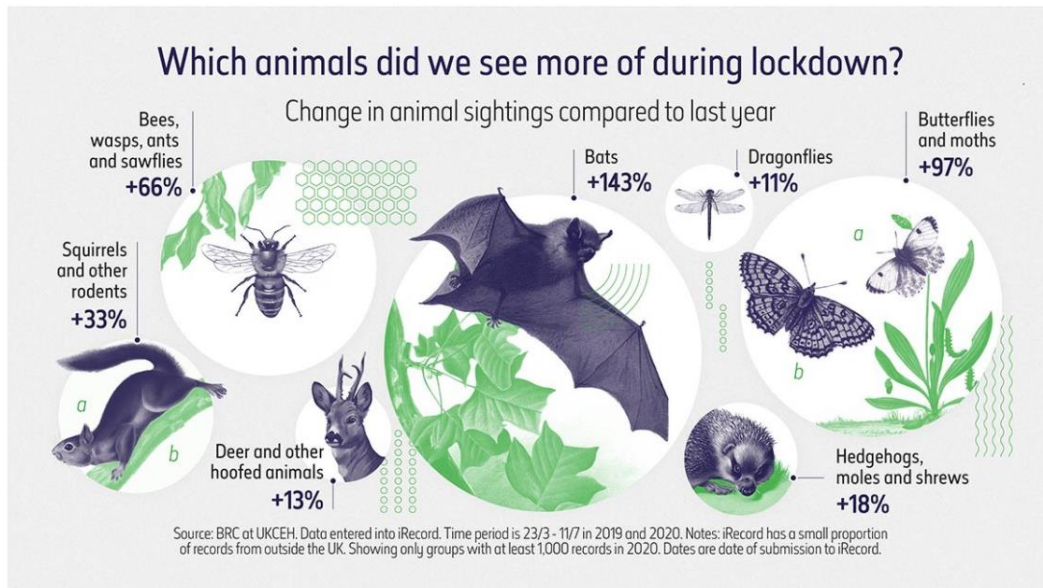


Figure 2: Extract from Natural History Museum Website showing increased public awareness of nature during lockdown

The reveal of more natural soundscapes have created a public memory and appreciation which had been eroded and masked and lost by anthropic noise. This presents an opportunity to communicate the benefits to the public of soundscape mapping, to improve their environments. In a post Covid era where the quality of one's home and recreational space is appreciated more intently there is the chance to use soundscape mapping to guide the public to higher quality places.

The focus on building homes remains a priority for the Government, and the reform of the planning system in England raises the important question of how safeguards will be put in place to protect people adequately from noise, and also design improved healthy environments in and around homes, in a sustainable way. Policy still does not give adequate weight or consideration to the quality of soundscapes, in my opinion, which could allow for windows to be kept open to provide natural ventilation for instance. Wales have grasped the nettle directly in their Well-being of Future Generations (Wales) Act (2015) [20], defining sustainable development to mean improving the economic, social, environmental and cultural wellbeing of Wales. Soundscapes are part of the Noise and Soundscapes action plan (2018-2004) and in response to the question why noise and soundscapes matter the response is that *“tackling noise and improving soundscapes contribute to achieving all seven of the wellbeing goals”*. It is very much hoped that the UK Government will see the value added also, as part of its reform.

6 THINKING BEYOND NOISE MAPS

In the words of Albert Einstein “you can’t use an old map to explore a new world”.

It is relatively clear now though that too much anthropogenic noise is undesirable for human health and wellbeing, but how to decide what the optimal balance is for sound is a challenging question.

The scientific approach requires this be done in a reproducible way, rather than as an artistic, creative composition. The engineering approach does however allow for a design that includes creative elements, albeit towards a repeatable solution, which may be the element that acousticians should accept that we need to embrace more freely (as if designing a space to be suitable for music for instance). Applying these skills will improve the quality of soundscapes, and could make use of the ability to remove sound instantly once a source is interrupted. This is something that cannot happen with air pollution, for example, and is a potential asset of sound.

Three approaches are considered appropriate to begin this paradigm shift in sound quality mapping:

1. Minimise anthropogenic noise dominance in the soundscape, except in areas or for planned periods where it is part of social cohesion and vibrancy planning, with design for adequate protection, access to high quality soundscapes nearby and respite periods
2. Encouraging natural sound that improves the quality of the soundscape that is in keeping or creates the character of the area and provides a diverse variation in sound that balances euphony with the noise in the environment
3. Identifying areas where wilderness and natural soundscapes are still pristine, or can be improved or created; then protect these areas for the benefit of nature and enjoyment of human connection to it (such as national parks and pocket parks in urban areas)

Using soundscape methodologies, as set out in the ISO standard, it ought to be possible to create a variance maps for soundscape quality. These factors rendered into a single Soundscape Quality Index (SQI) could then be mapped, taking account of whether then soundscape quality is low (i.e. noise polluted) or high (i.e. dominance by natural sound for instance).

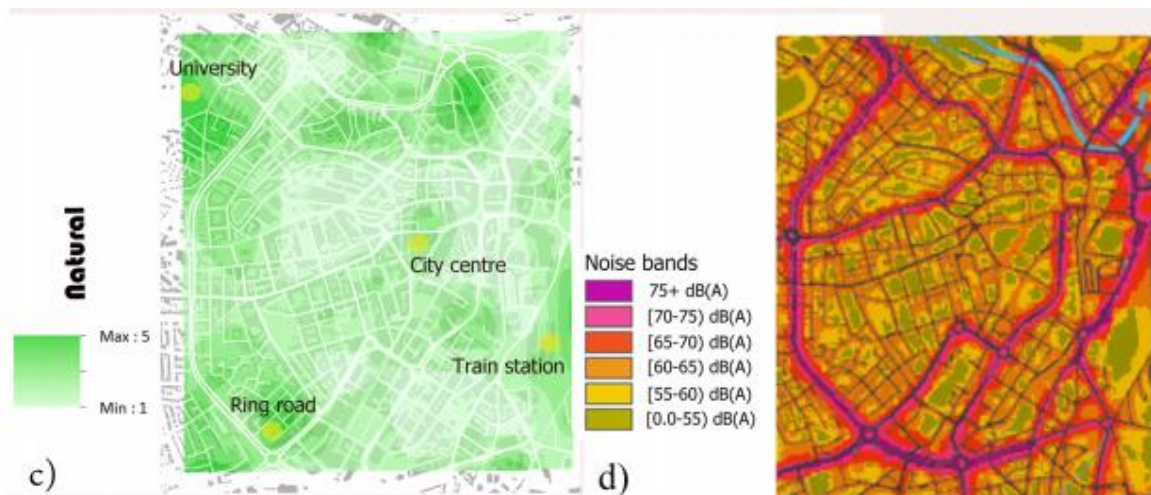
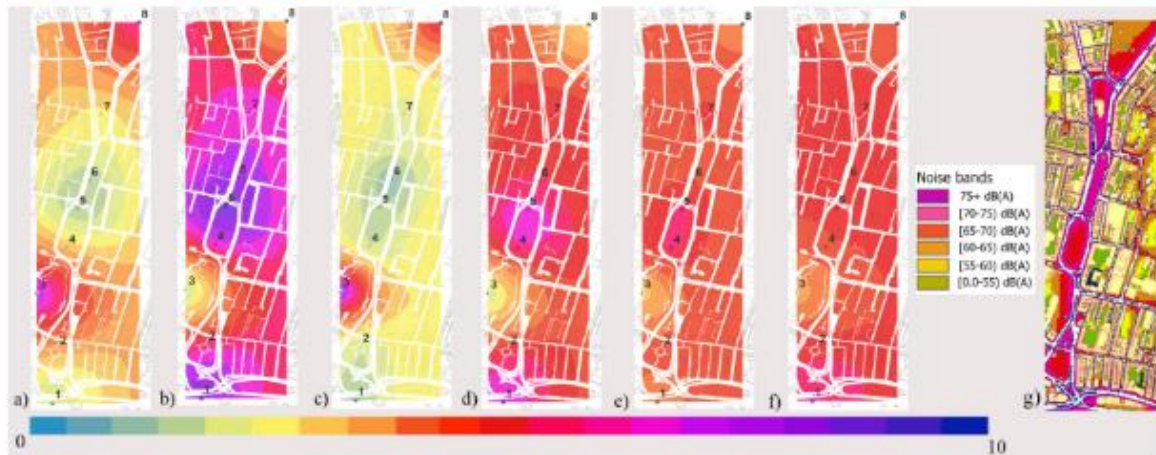


Figure 3: An extract from Kang's work on Sheffield showing natural soundscape compared with the Defra noise maps [23] and below for a 10 point scale for a section of Brighton mapping a)pleasantness, b)unpleasantness, c) calm, d) chaotic, e) eventful, f) monotonous, g) round 1 noise map (Defra) .



Cross validation with soundwalks (meaning an active listening walk through the environment) showed good agreement with prediction approach. The natural soundscape map indices use here is a simple 5 point scale with the higher number indicating a greater presence of natural sound. The 10 point scale also provides an intuitive and quite insightful understanding of the soundscape quality, but this could feed into a single index for ease of mapping. This is the sort of idea for mapping layers that reflect more closely what people would experience, and will potentially open up the usefulness of such data sets for cross over with others like air quality and geographical data. This approach would also responds to the call from stakeholders that was picked up from the Defra report NO0256 to allow cross-over of mapping.

This requires thoughts about how soundscape quality is represented over time, and whether long term averages are sufficiently meaningful to the variations over hours, months and years.

What is likely to be more helpful is a dynamic map which enables the rendering of data sets to respond to local or national strategic questions, such as how do I travel to work in the most pleasant way? Variations over rush hours or annual peaks like tourist seasons could then be taken into account, enabling the use of the data set for more health and wellbeing focused outcomes tailored to individuals as well as a strategic picture that could be useful in planning pleasing and healthy places to live.

7 SENSORY CROSSOVER

Mapping an area around the soundscape only is likely to be inadequate to capture the crossovers of the senses that include non-acoustic factors. The work on tranquillity has shown the importance of the visual and auditory information together, along with other non acoustic factors. It also demonstrates how objectively these complex environments can be quantified scientifically. The early work on soundscaping and the emergence of the ISO standard is building on this. It therefore makes little sense to consider sound maps without regard of overlays for the visual land maps and other data sets, such as air quality maps.

Sensory profiling offers a detailed insight into what we might call our personal preferences [24], and can be helpful in determining trends for sound, as part of the wider sensory response and has been compared with the appreciation a good wine [25]. For music in the acoustics of the concert halls this analogy holds well, and Lokki (2014) uses this to demonstrate that sensory evaluation works remarkably well in describing the quality of the acoustics, and provide a method for capturing the variance of human perception for a soundscape. The sensory profiles for sound for the six concert halls are presented below from the article to illustrate the method, which is consistent with the approach taken in the ISO standard, which could be applied in a similar way but with regard also for the other sensory aspects such as the visual, and potentially also the smell, touch and taste effects of those environments.

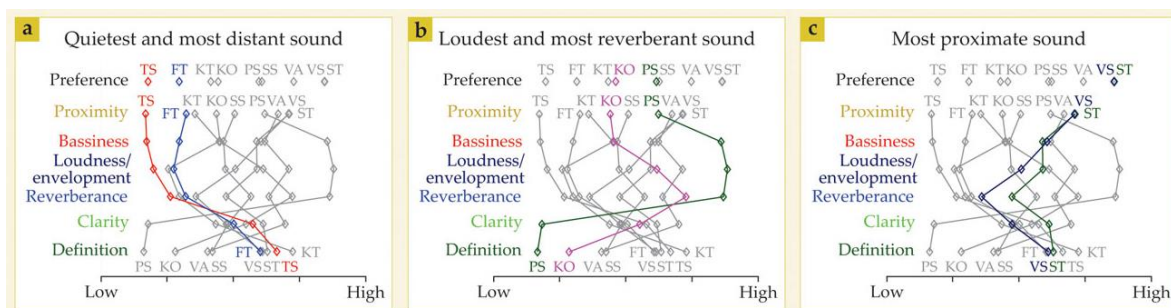


Figure 4: Sensory profiling of six concert halls (TS, FT, KO, PS, VS, ST) by 20 listeners [26].

In this way the combined resources for mapping are likely to be able to provide value greater than the sum of its parts. By focusing the elements or layers of the maps on physical, mental and social well-being and tackling the anthropogenic overload that causes disease we can consider these more to be like wellbeing maps, linked to a typical sensory response and with the scope to account for the variance of that response by the population to embrace population diversity. This directly answers and aims to deliver on the WHO's definition, and also would contribute to smarter urban design and sustainable cities.

8 SUSTAINABLE OUTCOMES

When considering what should form part of sound and wellbeing maps it is important to consider what a sustainable outcome might look like, as this is an important end goal to bear in mind if it is to be achieved.

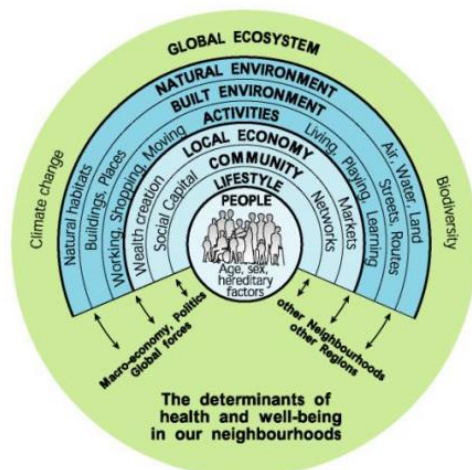


Figure 5: The Health Map (Barton & Grant 2006)



Figure 6: UN 17 Goals (2019) – triple bottom line

The challenge of creating a sustainable future rises before humanity on the horizon beyond the challenge of climate change, which is the immediate roadblock that is beyond the immediate Covid pandemic. If those immediate challenges can be addressed then the much more multifaceted issue of sustainability must be ultimately dealt with if humans are to continue to thrive on this planet. It is therefore our greatest challenge, given our population size.

It is commonly understood that the ecological triple bottom line (the 3 P's) shown in Figure 6 should be addressed, which is “planet, people, prosperity” [18] and which has been recently expanded to express as a quadruple bottom line with “Progress” or “Place” being used [19].

Well-being of Future Generations (Wales) Act (2015), defines sustainable development to mean improving the economic, social, environmental and cultural wellbeing of Wales [20].

Wales recognise that soundscape contributes to all aspects of wellbeing [21], and so is central to people's quality of life and sense of place, and figure 5 shows how important it is to consider that along with other factors to achieve health and wellbeing. The soundscape is also important to the ecosystem and the ability of the organisms within to survive and thrive in their environments where sound as noise pollution is otherwise an inhibitor (such as in the oceans, or near roads). It is therefore necessary to progress our innovation and evolve noise mapping to consider soundscape quality and wellbeing as an outcome, as part of delivering sustainability. Embracing a scientific approach that uses the advantages of our digital age will help deliver the benefits to humanity and our ecosystem.

9 CONCLUSIONS

The approach to noise mapping has been considered in its role to meet regulatory minimums, but it is expected that a new approach to mapping is needed to shift the focus from reducing health impacts, to include consideration of soundscape quality which support improved health and wellbeing outcomes. Sound maps that form part of other data sets, such as air quality and visual quality may together provide useful information for society that can assist to improve and maintain peoples wellbeing and therefore form a part of wellbeing maps. This may also include efforts to make improvements in the ecosystem's resilience and help course correct humanity towards a more sustainable future.

By applying the emerging and demonstrated soundscaping methodologies a simple Soundscape Quality Index (SQI) could be developed which maps the quality of soundscapes and so will be provide a progression from noise mapping, which recognises how sound can change how we feel. Using this information to aid urban design and planning at the masterplan stages then it will be possible to create high quality places to live, work and recoup and enjoy at leisure with support improved for physical, mental, social and ecological health and wellbeing. Harnessing the natural capital advantages of the natural soundscape supports the idea of sound being a part of wellbeing mapping across the whole

of the UK, which would assist to identify areas for protection and improvement to restore noise polluted areas. This would also result in improved euphonic soundscapes, and the ability to manage areas of noise intelligently using good design [30].

This review indicates, following encouragement by stakeholders, that a change of approach is needed to embrace and meet the challenges of a changing world, beyond the current regulatory minimums which are focused on noise only. The digital age presents new opportunities to deliver improved mapping and sustainable outcomes for humanity using sound as an important connecting medium. Sound is the sentinel of the senses and Acousticians are an integral part of making improved outcomes for wellbeing possible; but it is likely to be essential to do this by working with other disciplines in urban and rural planning and development strategies and social and medical sciences. Development without this is likely to be ultimately unsustainable.

10 REFERENCES

- [1] Shaffer. M, The Soundscape – the tuning of the world (1977), Destiny Books, ISBN 978-089281455-8
- [2] ISO/TS 12913-1:2014 Acoustics - Soundscape Part 1: Definition and conceptual framework
- [3] ISO/TS 12913-2:2018 Acoustics - Soundscape Part 2: Data collection and reporting requirements
- [4] ISO/TS 12913-3:2019 Acoustics - Soundscape Part 3: Data analysis
- [5] [Living with Beauty – Promoting Health Wellbeing and Sustainable Growth, Report of the Better Building, Building Beautiful Commission \(BBBE\) \(Jan 2020\)](#)
- [6] [Planning for the Future, White Paper by MHCLG \(Aug 2020\) for consultation.](#)
- [7] [Rogers P, Euphony – A case for evolving acoustics language to include positive or valued sound, Proceedings of the IOA, p. 1,2-3, Vol.41. Pt 1. 2019.](#)
- [8] [Kang J, UCL, Urban Sound Planning – A soundscape approach, Acoustic 2019, Proceedings of Cape Schanck, Victoria, Australia](#)
- [9] [Torrens S et al, Five questions on the indoor soundscape approach in regenerative buildings, Internoise Soul \(2020\)](#)
- [10] [Review of Evidence relating to Environmental noise exposure and specific health outcomes, ARUP, January 2020, Ref: NO0254](#)
- [11] WHO, Environmental Noise Guidelines for the European Region, 2018.
- [12] [WHO Constitution, 1946](#)
- [13] [Cage. J, The Future of Music: Credo \(1937 in Richard Kotelantcz \(ed.\)](#)
- [14] [Noise mapping \(round 4\) Stakeholder Review by, Sustainable Acoustics Ltd. report for Defra, dated 9th July Ref: NO0256.](#)
- [15] [Schulte-Fortkamp, B Soundscape, Standardization and Application, Euronoise 2018, PACS No. 43.50, 43.66](#)
- [16] Pheasant R. J. et al, The importance of auditory-visual interaction in the construction of “tranquil space”, Journal of Environmental Psychology (2010), doi: 10.1016/j.jenvp.2010.03.006
- [17] Rosier, R. L. & Langkilde, T. (2011) Behavior Under Risk: How Animals Avoid Becoming Dinner. Nature Education Knowledge 2(11):8
- [18] [UN 17 Development Goals \(2019\)](#)
- [19] https://en.wikipedia.org/wiki/Fourth_Bottom_Line
- [20] Well-being of Future Generations (Wales) Act (2015)<https://www.futuregenerations.wales/wp-content/uploads/2017/02/150623-guide-to-the-fg-act-en.pdf>
- [21] Noise and soundscape action plan (2018 - 2023) : <https://gov.wales/sites/default/files/publications/2019-04/noise-and-soundscape-action-plan.pdf>
- [22] [Jafari, M et al, The Effect of Noise Exposure on Cognitive Performance and Brain Activity Patterns, Journal of Medical Science \(2019\) Sep 15; 7\(17\): 2924-2931](#)
- [23] [Margaritis, E. Kang J, Soundscape mapping in environmental noise management and urban planning : case studies in two UK cities \(2017\), Noise Mapp 4:87-103](#)

- [24] [Varela, P, Areas G, Sensory profiling, the blurred line between sensory and consumer science. A review of novel methods for product characterization \(2012\), Food research International 48, 893-908](#)
- [25] [Lokki T, Tasting music like wine: Sensory evaluation of concert halls, Physics Today \(2014\) Jan, 67,1,24.](#)
- [26] [Flindell IH, Stallen PM. Non-acoustical factors in environmental noise. Noise Health \[serial online\] 1999 \[cited 2020 Sep 25\];1:11-6](#)
- [27] Nature Liberated by Lockdown, Anthropocene (published September 2020), <https://www.nhm.ac.uk/discover/nature-liberated-by-lockdown.html>
- [28] Davis H. Preface. In Stevens SS, Warshofsky F, ed. (1970) Sound and hearing. Netherlands: Time Life Books. Cited in Jones DM, Hughes, RW, Macken WJ. (2010). Auditory distraction and serial memory: The avoidable and the ineluctable. Noise Health. 12:201-209.
- [29] Baars, B. & Gage, N.M. (2010). Cognition, Brain and Consciousness: Introduction to Cognitive Neuroscience. 2nd ed. Oxford: Elsevier.
- [30] ProPG : Planning and Noise, New Residential Development, May 2017, ANC, IOA, CIEH.