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SUSTAINABLE ACOUSTIC DESIGN IN CONSTRUCTION – A HOLISTIC APPROACH

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Abstract
In many ways acousticians are only now coming to sustainability. The problem has been the absence of design tools. However, the parallel development of international standards In the areas of soundscape and acoustic classification now provide the basis for a holistic approach to preparing acoustic specifications for sustainability. This paper explores this concept and identifies the considerable challenges that face acousticians in the implementation of designs to meet sustainable specifications. These range from material availability, economics, acoustic performance, whole life cycle, and net carbon evaluations.

1.1 SUSTAINABLE DEVELOPMENT
The greatest problem with the concept of sustainable development is the sheer amount of definitions that are available. Consequently when acousticians approach the concept of sustainability they generally experience a combination of uncertainty about what to do, and some small measure of guilt about what they are not doing, and this makes many acousticians afraid to reveal what they feel is their lack of understanding of sustainable development. This is the 'elephant in the room' and it is much easier to pretend that it does not exist.

In order to keep the issue of a definition simple we must turn to the Bruntland Report [1]. The report defined 'sustainable development' as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. On the face of it this seems a very straightforward proposition but the wooly nature of 'needs' which are not defined, and 'future generations' which is also not defined, leads to many varied interpretations.

The Sustainable Development Goals (SDGs) are a collection of 17 interlinked global goals designed to be a "blueprint to achieve a better and more sustainable future for all" [2]. The SDGs were set up in 2015 by the United Nations General Assembly and are intended to be achieved by the year 2030.

The 17 SDGs are: (1) No Poverty, (2) Zero Hunger, (3) Good Health and Well-being, (4) Quality Education, (5) Gender Equality, (6) Clean Water and Sanitation, (7) Affordable and Clean Energy, (8) Decent Work and Economic Growth, (9) Industry, Innovation and Infrastructure, (10) Reducing Inequality, (11) Sustainable Cities and Communities, (12) Responsible Consumption and Production, (13) Climate Action, (14) Life Below Water, (15) Life On Land, (16) Peace, Justice, and Strong Institutions, (17) Partnerships for the Goals.

Most acousticians are familliar with the issues surrounding (7) Affordable and Clean Energy. Their involment includes environmental noise from traditional power stations and of course the 'renewable' resource of wind turbines. In this paper I will examine the issues that face construction that is (3) Good Health and Well-being and (11) Sustainable Cities and Communities.

The International Standards Organization has published more than 22,000 International Standards. For each SDG, ISO has identified the standards that make the most significant contribution. There are two new standards that affect good health and well-being, and sustainable cities and communities and these will be discussed in the following sections.

1.2 LAND USAGE
In terms of renewable/sustainable resources the most appropriate use of land is the starting point when looking at the sustainability of cities and communities. This paper looks at residential accommodation but the same principals apply to any other form of construction. Residential accommodation has a significant impact on good health and well-being for the entire population.

It is axiomatic that building residential accommodation right next to a motorway will have a significant detrimental effect on health and well-being and is to be avoided. Fortunately, acousticians have had a tool known as noise maps as part of the Environmental Noise Directive [4] for almost twenty years. This clearly show where the very high environmental sound levels are located and consequently planners can site more appropriate developments in those locations. In many ways locating wind turbines at the side of motorways is a sensible use of that land.

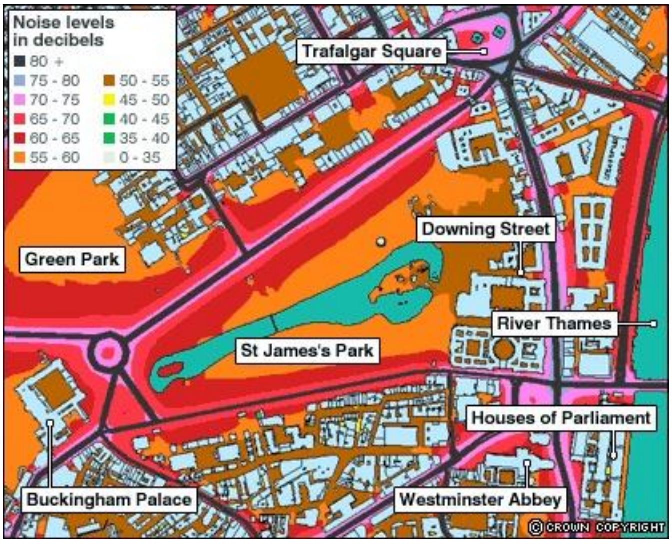

Figure 1 – A typical END noise map courtesy of the BBC.

However, in March 2012 the English government scrapped some 500+ pages of planning guidance and replaced it with the National Planning Policy Framework [5]. This document placed an obligation on planners to “identify and protect tranquil areas which have remained relatively undisturbed by noise and are prized for their recreational and amenity value for this reason.”

This left English acousticians with a quandary in that they had no reliable way of identifying tranquil areas. This absence of a standard approach to establish tranquil areas led to the realisation that the development of the Soundscape standards offered a way forward.

1.3 SOUNDSCAPE

Soundscape represents a paradigm shift from noise control policies towards a new multidisciplinary approach as it involves not only physical measurements, but also humans and social sciences with a focus on how people actually experience an acoustic environment in context. The soundscape standards had a difficult birth in that many ‘traditional acousticians’ relied extensively on what they can measure with instrumentation and were deeply distrustful of psychometric measurements which are made using people and not instruments.

In acoustics, the general focus has historically been on scientific objective measurements using the decibel scale over the frequency range of normal human hearing. This approach ignores the psychoacoustic effects of the sound being assessed by people. The big hurdle with defining what is a tranquil area is that it does not just mean areas having low environmental noise levels because the subjective response of people has a major influence.

The acoustic environment is a physical phenomenon which can be measured with instruments. Soundscapes are perceptual constructs and consequently soundscape is defined as ‘the acoustic environment as perceived or experienced by and/or understood by a person or people, in context’.

The ISO 12913 series of standards on Perceptual assessments of soundscape quality currently consists of three parts. Part 1 provides the definition and conceptual framework [6]; Part 2 explains how to collect the data and what should be included in a report [7]; and Part 3 which covers data analysis [8]. A fourth part is being developed currently that will deal with soundscape design and interventions.

So how do you measure the quality of a soundscape?

The big challenge with respect to measuring a soundscape is that soundscape is a multifaceted phenomenon and hence cannot be measured with a few single numbers. In general, soundscape has to be measured, assessed/evaluated through human perception of the respective acoustic environment. The soundwalk method is an empirical method for identifying a soundscape and its components and is the most frequently applied method to collect data to explore areas of human response to an acoustic environment. The essential purpose of a soundwalk is to encourage participants to listen discriminately and to make judgements about the sounds heard. There are three different approaches to this.

Soundwalk Method A

This uses a questionnaire to collect data on how people perceive an acoustic environment in situ, e.g. in a soundwalk. The questions are presented and the participants mark their perception using a five-point ordinal-category scale.

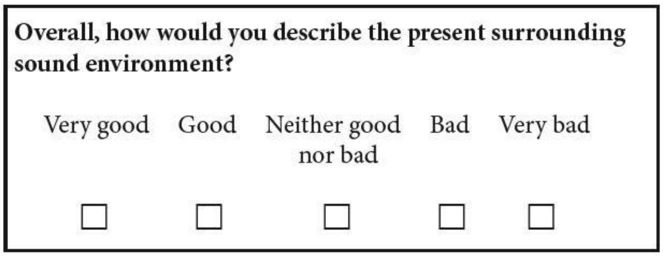

Figure 2 – A simple example of a soundwalk method A questionnaire

Soundwalk Method B

Method B is very similar but uses five-point unipolar continuous-category scale with additional verbal labelling ranging from ‘not at all’ to ‘extremely’.

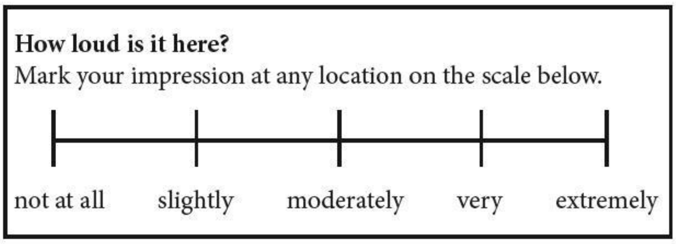

Figure 3 – A simple example of a soundwalk method B questionnaire

Method C

Method C is not an actual soundwalk but is instead, a narrative interview and is based on COST TD0804 STSM [8]. The guidelines refer to satisfaction with the living space, residential experience, experiences with/relation to sounds in daily life, daily routines, co-inhabitants, neighbours, spatial identification of sound effects within residences, effects of various kinds of sounds, assessment of the effect that varying sounds have upon overall sound exposure and actions to improve residences with regard to sound exposure.

Physical Measurements

So, what about physical measurements? Annex D of Part 2 [7] specifies how to perform binaural measurements by means of an artificial head measurement. In contrast to recordings based on a monaural microphone, binaural acoustic measurement systems record sound as if a human listener is present in the original; sound field, maintaining all spatial information. Classical acoustic indicators are to be measured and reported in accordance with ISO 1996-1. Psychoacoustic parameters play an important role with respect to auditory sensation. Such parameters as sharpness, tonality, roughness and fluctuation strength can yield information with greater differentiation than the consideration of sound pressure alone.

1.4 PLANNING FOR GOOD LAND USE

We can now identify from the ENDs noise maps, areas that would be detrimental to SDG 3 – Good health and well-being so local authorities can avoid building in those locations or use them for noise insensitive developments. At the other end of the spectrum we can now identify tranquil areas that will be beneficial to SDG 3 – Good health and well-being'

The Environmental Noise Directive has been around for about twenty years, however, it is only recently with the advent of the Soundscape series of standards that national governments could put it at the heart of their planning policy. In 2018 the Welsh Government issued their Noise and Soundscape action plan for 2018 – 2023.

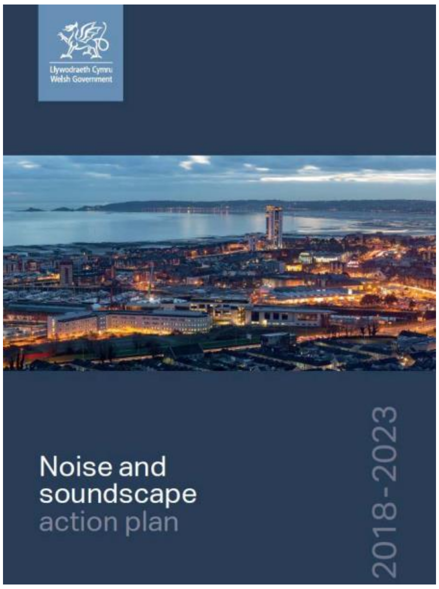

Figure 4 – Welsh governments action plan

In 2018 I was delighted to present representatives of the Welsh Government with the John Connell Soundscape award at the Palace of Westminster in London. This underlines the significance of Soundscape for land usage.

Figure 5 - John Connell Soundscape Award 2018 Winner: the Welsh Government, Planning Policy Edition 10 and Noise and Soundscape Strategy 2018-2023. Pictured (L to R): Lisa Lavia, Noise Abatement Society; Joanne Smith, Welsh Government; Martin McVey, Welsh Government; Sonia Phippard CBE, Defra; Phil Dunbavin, PDA Acoustics. Image credit: Noise Abatement Society

1.5 OTHER LOCATIONS

The locations that are neither too noisy or tranquil could be used for residential development. What was needed was a holistic approach to specifying the performance of such housing. If the break in of traffic noise is unbearable or noise from the immediate neighbours is a nuisance this will not contribute to SDG (3) Good health and well-being, and this is obviously not sustainable.

The ISO standard on the Acoustic Classification of Dwellings [10] was published in April 2021. This standard describes class criteria and procedures for acoustic classification of dwellings. The main purpose of this classification standard is to make it easier for developers to specify a standardized level of acoustic quality other than the quality defined by national regulations, and for users to require or be informed about the acoustic quality. An additional purpose of this standard is to help national authorities to define a specific class in building regulations as the minimum requirement for acoustic conditions in dwellings.

The term 'dwelling' refers to detached and attached dwelling-houses, flats (apartments) as well as rooms in other buildings used for residential purposes. Energy performance ratings of buildings currently use A to G classifications. For the purposes of acoustics and sound insulation, the technical specification classifications uses A to F.

The classes A to F specify different levels of acoustic conditions in dwellings. Class A is the highest class, class F is the lowest class. The indication '*npd*' can be used for dwellings where no acoustic performance is required or determined, or if the performance does not meet the requirements of class F.

The classification includes criteria for the six classes A-F for each of the following five acoustic aspects:

- airborne sound insulation;
- impact sound insulation;
- airborne sound insulation of building envelopes against outdoor noise from traffic, industry or other sources;
- sound pressure levels in the dwellings from service equipment;
- reverberation time or ratio of the equivalent sound absorption area to the walkable surface in common access areas or stairwells and corridors with dwellings opening onto them.

This leads to a holistic set of performance specifications which will promote good health and well-being.

Airborne sound insulation

The technical specification gives class ratings for three situations:

1. Between habitable rooms in a dwelling and rooms outside the dwelling in all directions.
2. From common stairwells or access areas into habitable rooms in dwellings, where there is an entrance door in the separating wall.
3. From premises with noisy activities into habitable rooms in dwellings.

With respect to housing the first category is the most important. The classes of airborne sound insulation for separating walls and floors are given in Table 1 below.

Table 1: Airborne sound insulation – Class limits

Type of space	Class A	Class B	Class C	Class D	Class E	Class F
Between habitable rooms in a dwelling and rooms outside the dwelling in all directions.	$D_{nT,50} \geq 58$	$D_{nT,50} \geq 54$	$D_{nT,A} \geq 52$	$D_{nT,A} \geq 48$	$D_{nT,A} \geq 44$	$D_{nT,A} \geq 40$

In a similar fashion numerical limits are presented for impact sound isolation, facade sound insulation, sound from building services equipment , and the reverberation time of common spaces.

The acoustic classification scheme provides a way of balancing all the acoustic aspects of a development to promote good health and well-being. The starting point is the consideration of the external environmental sound climate. This is unlikely to change significantly and can be used to specify the facade sound insulation. Having quantified the facade sound insulation then the other elements of the design can be specified to complement it and produce a holistic set of acoustic performance criteria.

1.6 HOUSE DESIGN

Acousticians have been designing to specific sound insulation values since the science began. In the design stage of a building, the performance can be calculated using the ISO 12354 series [11] or from estimations from known typical performance.

The acoustic performance of most current building materials or products are well established having been laboratory tested using the BS EN ISO 10140 series of standards [12]. In a similar fashion new materials can also be tested to determine their acoustic performance.

1.7 SUSTAINABLE MATERIALS AND PRODUCTS

This is where acousticians need to rely on the experts with respect to the sustainability of material, products, or construction methods. One of the problems is that many commercial products are labelled as “green” just because they contain small percentages of natural or recycled materials or because they are not harmful to human health. Clearly that approach is far too simplistic.

The real sustainability of a product has to be assessed during all its life cycle and this can be done by using Life Cycle Assessment (LCA) procedures, which analyse the potential impacts deriving from the entire life history of a product. This starts with material extraction, production, transport, construction, operating and management, de-construction, and disposal, through to recycling and reuse. This should be done using ISO14040:2006 – Environmental Management – Life cycle assessment [12].

LCA analysis results are available as “eco-profiles” in various databases. The most well-known are Ecoinvent [13], BRE Eco-profiles and Eco-indicator. Ecoinvent is a Swiss LCA database which takes into account various impact assessment results: Cumulated Energy Demand, Non-Renewable Energy fraction, Global Warming Potential and Acidification Power. A comparison based on the Ecoinvent database between the environmental impacts of some traditional and some natural sound insulation materials was reported by Francesco Asdrubali in his 2006 Euronise paper [14]. Figure 6 shows the estimated primary energy for the extraction, transport, production and packing of different insulating materials.

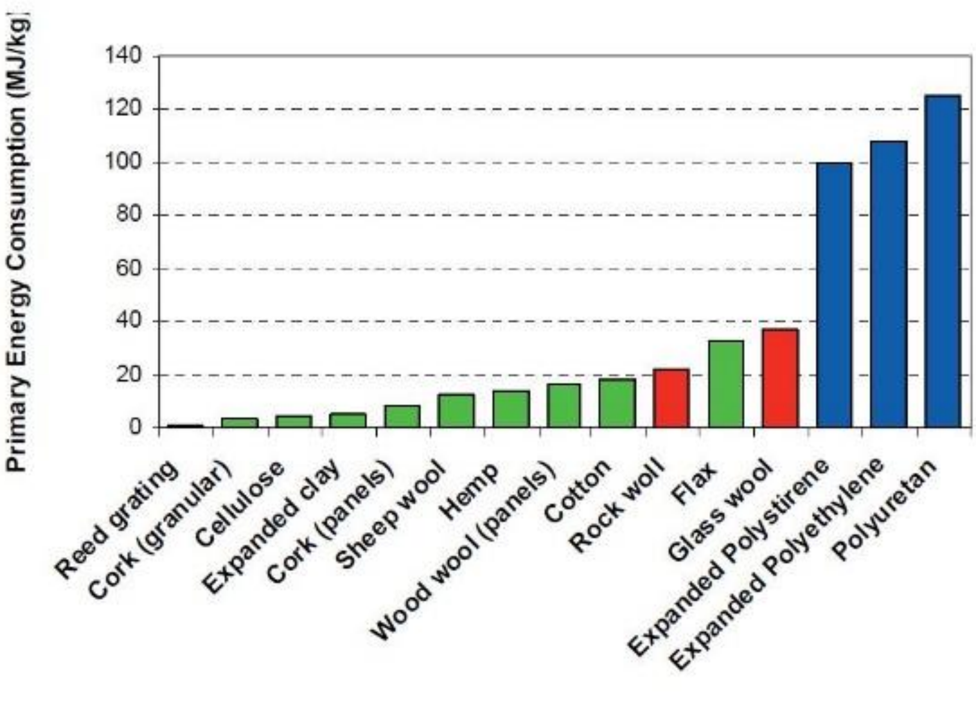

Figure 6 – Estimation of primary energy consumption of some sound insulating materials’ life cycles. [14]

1.8 SUSTAINABLE MATERIALS USES IN ACOUSTICS

Currently there are three main uses for sustainable materials in acoustics. The most common one is as acoustic absorbers to control reverberation times and other features of rooms and halls. In order to be built into a design the manufacturers of the material need to provide the absorption coefficients as they would for traditional absorbers.

Secondly, these absorptive materials have also been used to replace traditional materials in traditional building walls as shown in Figure 7 below without significant degradation in performance [14].

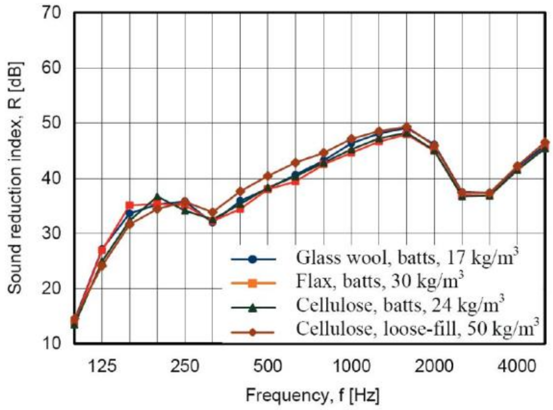

Figure 7 – Sound reduction index for a 125mm thick wall with 100mm insulation material. [14]

The third use is as isolating layers to provide impact isolation for floors. These typically use cork or recycled tyres.

1.9 THE HOLISTIC APPROACH

It is at this point that the holistic approach meets a significant problem and that is the availability of materials from manufacturers that have LCA data and relevant acoustic performance data. The two properties need to be considered together and my personal experience is that many design teams do not include both experts in sustainable materials and acousticians. The input of both disciplines are required and this will need a change in thinking for construction companies if they are to achieve their objective of constructing sustainable buildings.

1.10 THE FUTURE

A key factor for all designers over the coming years will be the net-zero ambitions for a construction project and the level of technical specifications for non-energy areas and embodied carbon. It is likely that designers may take a judgement on whether an 'A' rating is still desirable if it conflicts with the need to provide significantly enhanced specifications, which may (not always) impact on net-zero outcomes. It is not yet clear how many of the European countries may adopt or use the new classification scheme but it will be an interesting future factor to follow.

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