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# Valuing transport noise impacts in public urban spaces in the UK: Gaps, opportunities and challenges

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## Abstract
Transport noise is the dominant noise source in urban areas. Its impacts on people at their residential locations are included in economic appraisal in the UK and many other countries, and guidance and analysis tools were developed for the valuation of the impacts. However, for transport noise impacts on people in public urban spaces, e.g., urban streets, squares and parks, there is still a lack of national methodologies. This paper will discuss the gaps, opportunities and challenges in developing a national methodology for these places in the UK. Currently, evidence is lacking on pathways of transport noise impact on people and dose-response relationships at non-residential locations, and the values people place on sound environment quality at these locations. However, opportunities are emerging, with increasing attention to the urban realm in UK transport policy, and recent progress and transitions in urban sound environment research, including association between public health and urban soundscape, standardisation in soundscape research and practice, and crowdsourcing sound environment evaluations. The associated challenges, as compared to methodology for residential locations, may include calculating noise from non-free-flow traffic, defining and adding diverse receptor types, estimating dynamic affected population, accounting for diversity in level and source of background sound, and obtaining large and consistent data for dose-response or willingness-to-pay analyses.

Keywords: Transport noise, Public urban space, Transport appraisal, Valuation, Soundscape

## 1. Introduction

Public urban spaces, including urban streets, squares, parks, etc. (Figure 1), are important assets in cities worldwide. They can be places where people meet, where social and economic exchanges occur, a venue for eating and drinking, for culture, and a place for other activities including forms of exercise, play and rest. It has been argued that good public urban spaces should be sociable, accessible, comfortable, and support diverse uses and activities (PPS, 2003). The quality of these spaces plays an important role in forming people’s impression of a city.

Figure 1. Examples of public urban spaces: urban street (left); urban square (mid); urban park (right).

Sound, together with other physical and biological features, contributes to the quality of public urban spaces, and influences people’s experience in these places (Southworth, 1969). Unwanted sound such as transport noise, which is dominant in urban areas, can degrade the quality of public urban spaces (Jiang et al., 2018), and thus potentially reduce the social, economic and health benefits that people obtain from them, and may deter people from using them when use is an option rather than a necessity.

Economic appraisal methods are widely used to analyse changes in transport networks from a welfare economics perspective (Nellthorp, 2017). The impact of transport noise in public urban spaces is currently not very well covered in transport appraisal. Transport Analysis Guidance (TAG), the UK guidance on transport modelling and appraisal, includes valuation of noise changes experienced at home (residential locations), but for noise impacts at non-residential locations there is no valuation (Department for Transport, 2015). Nijland and Van Wee (2008) found the same was true across European countries for which data was available. This has implications for the ability of appraisals to capture the full benefit of noise reduction strategies in urban areas, or to capture the unintended consequences of strategies which act to increase transport noise exposure.

This paper will discuss the gaps, opportunities and challenges in developing a national methodology for valuing transport noise impacts in public urban spaces in the UK. While the discussion is aimed to be UK-focused, it may also be applied or give implications to other countries or to a global context, since the issue seems not have been addressed anywhere else. Section 2 gives an overview of relevant aspects of noise impact appraisal in the transport sector. Section 3 identifies some critical gaps in the current evidence base. Section 4 highlights key opportunities emerging from recent acoustic research and from increasing policy interests in place quality and 'urban realm'. Section 5 discusses challenges in developing and implementing a national methodology. Section 6 concludes the paper.

## 2. An overview of current noise impact appraisal and assessment

UK noise impact appraisal procedures are set out in TAG (Department for Transport, 2015) for transport projects. These share a common set of marginal noise values (£ per household per dB) with other policy areas in the UK (Defra, 2014). The values are calculated using an impact pathway approach, which contains dose-response functions for sleep disturbance, annoyance and a set of health impacts (heart attack/acute myocardial infarction (AMI), stroke and dementia), for road, railway and aviation noise respectively. To monetise the impact, outputs of the dose-response functions are applied by a disability weighting and a standard Disability Adjusted Life Years value of £60,000.

International practice is described by Mackie and Worsley (2013), Nijland and Van Wee (2008) and Nellthorp et al (2007), which covered most EU countries plus US, Australia and New Zealand. Key findings are that: 1) most of the surveyed countries do include noise in transport appraisal, following a period of development since the 1990s; 2) a range of methods are used to derive values for changes in noise exposure, including hedonic pricing, choice experiments and contingent valuation; 3) the values generally show a reasonable level of comparability across countries, with some exceptions (e.g. see Nellthorp, 2010); 4) the values used are based on noise experienced at residential locations – there is generally very little attention given in cost-benefit analysis to noise experienced in public urban spaces or elsewhere. Finding 4 is further confirmed by the most recent version of EU handbook on the external costs of transport (CE Delft, 2019) which recommends using noise values taken from research that are based predominantly on exposure at home, and an updated review on the Australia (Transport for NSW, 2018) and New Zealand (NZ Transport Agency, 2018) practices which shows that their noise valuations have remained residential focused. While the US guidance does briefly mention non-residential locations, e.g., parks, the values are merely costs of noise abatement measures that are reasonable for the locations, evaluated by e.g. equivalent number of residences based on lot size (U.S. Department of Transportation, 2011).

It is important to recognise that the noise assessment methods which underpin the appraisal – providing the quantitative and qualitative data on changes in noise due to a project or policy – are not quite so limited in scope. Noise assessment methods in the UK are defined by DMRB Volume 11 (Highways Agency et al, 2011). The types of "sensitive receptor" that the guidance advises the analyst to consider include dwellings, hospitals, schools, community facilities, national parks, conservation areas, cultural heritages, public rights of way, etc. Other receptors are not listed but are not excluded – e.g. parks, squares and other open spaces. Since streets are public rights of way, they are also – in theory – in scope. Some assessment methods categorise receptors by their level of sensitivity (e.g., Scottish Government, 2011;

U.S. Department of Transportation, 2011), and the level of significance of the noise impact will be a function of the receptors' sensitivity to noise and the magnitude of the noise impact.

In conclusion, national appraisal methods already address transport noise, however there is a focus on noise experienced at residential locations. The underlying assessment methods do cover non-residential noise receptors and identify receptors of different sensitivities, which are of interest in developing a valuation and appraisal methodology – however there remains a lack of focus on public urban spaces, and for the receptors that are covered there is a lack of the types of outputs needed for valuation and appraisal (i.e. annoyance/nuisance metrics, wellbeing measures or willingness-to-pay (WTP)).

## 3. Gaps

Monetary valuation of noise impact can typically be achieved by three approaches: impact pathway, revealed preference, and stated preference. This section discusses gaps associated with each of these approaches.

### 3.1. Evidence on impact pathways and dose-response relationships

The current UK noise impact valuation uses an impact pathway approach. The evidence base for such an approach is built upon studies that explore dose-response relationships between exposure to transport noise and the proportion of people experiencing a validated measure of physiological and behavioural consequences or increased risks, e.g. Guski et al. (2017) for annoyance, Basner & McGuire (2018) for sleep disturbance, and van Kempen et al. (2018) for cardiovascular and metabolic effects. However, the main focus of these existing studies is on noise at residential locations. Defra's noise modelling tool (Defra, 2014), which is used to calculated noise impact values in TAG, was also developed based on such residence-focused studies (Berry & Flindell, 2009; Maynard et al., 2010; WHO, 2011).

Currently, there is not much comparable research of the same depth and rigour for noise impact in public urban spaces. While there has been a growing amount of research and surveys on people's perception, preferences and/or evaluations of sound environment in public urban spaces (e.g., Axelsson et al., 2010; German et al., 2008; Jeon et al., 2018; Puyana-Romero et al., 2016; Yang & Kang, 2005; Yu & Kang, 2010), limitations are that: 1) they had either very small sample sizes, or very short questionnaires with limited numbers of questions, or both, so bias and confounding factors cannot be ruled out with confidence when exploring impact pathways; 2) the studies are mostly attitudinal, so their data may not be in the ideal quality and/or format for dose-response analysis; 3) survey methods or questionnaire designs are not standardised in these studies, so there is a lack of consistency for meta-analysis; 4) most of these studies do not have a specific interest in transport noise, so they lack some of the detail in defining and measuring transport noise that is found in the literature for residential locations.

### 3.2. Evidence on revealed and stated preferences

Most studies on monetary valuation of noise impact have used the revealed preference approach of hedonic house price modelling to analyse how changes in house prices reflect individuals' WTP for lower noise exposure (e.g. Navrud, 2004; Bateman et al., 2004; Lindgren, 2018). There has also been a growing interest in applying stated preference methods, e.g., choice experiments and contingent valuation, to value noise impact (Bristow et al., 2015).

However, as is the case with impact pathway approach, revealed and stated preferences studies on noise impacts in public urban spaces or other outdoor settings are very limited. A search in literature returned very few relevant studies. Using contingent valuation, Veisten et al. (2011), Calleja et al. (2017) and Iglesias-Merchan et al. (2014) estimated WTP for noise barriers along a riverside walkway to reduce noise from a busy street, reduction of general noise in an urban forest park, and reduction of anthropogenic noise along a hiking route in a national park, respectively. Barreiro et al. (2005) and Sñlensminde (1999), using contingent valuation and choice experiment respectively, estimated WTP for reduction of road traffic noise in an urban context without clearly specify where the noise were experienced. Values obtained in these studies are helpful but very limited in scope.

From the quietness perspective, URS Scott Wilson (2011) studied economic value of Quiet Areas in the UK, but found it difficult to separate the benefits of the sound/noise characteristic of quiet areas from their other characteristics, e.g., landscape, ecosystem services and air quality, which all influence the economic value of a place (Holzman, 2012; Kim et al., 2020; Panduro & Veie, 2013). Wardman et al. (2011) valued a range of local environmental quality attributes, including access to Quiet Areas. Whilst this is helpful for understanding the welfare impact of Quiet Areas, it does not answer the question about valuation of changes in noise exposure in Quiet Areas, or in public urban spaces more generally.

Another relevant literature body would be valuation of road design and traffic control projects (e.g., by-passing, traffic calming) of which the benefits, intended or not, often include noise reduction on and near the roads (e.g., Garrod et al., 2002; Grudemo, 2006). However, such studies often lack a clear depiction of the specific noise impacts, during their surveys/experiments or in the resulted publications.

## 4. Opportunities

### 4.1. Progress in urban sound environment research

Three emerging areas in urban sound environment research are giving rise to new opportunities for developing methods of valuing transport noise impact in public urban spaces.

First, the growing interest in associations between public health and urban soundscape (Aletta et al., 2018) will help to gain evidence for identification of impact pathways for valuing transport noise impact in public urban spaces. While pleasantness and annoyance ratings have already been widely used in soundscape evaluation studies, which can contribute to the construction of an annoyance pathway, development of health impact pathways will make the impact appraisal more compatible with current TAG and future transport strategies which promote public health (See Section 4.2).

Secondly, the emerging development of crowd sourcing sound environment evaluations (e.g., Aiello et al., 2016; EPFL, 2017; Radicchi, 2017) has provided the potential to acquire large samples for public space noise surveys at low cost. Thirdly, on the other hand, progress is being made in standardisation in soundscape research and practice. The Soundscape Indices (SSID) project (2018-2023) is working to develop measurable soundscape indices for soundscape prediction, design, and standardisation (Kang et al., 2019). And following ISO 12913-1, which defined and established conceptual framework of soundscape (ISO, 2014), ISO/TS 12913-2, which standardises soundscape data collection and reporting requirements, has recently been published (ISO, 2018). Such progress will enable dose-response or stated preference analysis of transport noise impact in public urban spaces using richer and more consistent data in the future.

### 4.2. Increasing attention to the urban realm in (UK) transport policy

Over the last ten years there has been increasing attention to the urban realm in the UK transport sectors, from both a planning/design perspective and an appraisal/valuation perspective. (e.g. Millard et al., 2018; Nellthorp, 2016; DfT, 2018b). Urban realm refers to all the space that is publicly accessible between the buildings in an urban environment, hence urban realm is – essentially – synonymous with public urban space. Measuring and valuing the impact of improvements in the urban realm will contribute to the business case for redesigning streets, squares, junctions, transport hubs and other parts of the urban fabric. Sound environment, among with air quality, visual amenity, safety, facilities, etc., is an important attribute of the urban realm, and need to be included and conceptualised as part of people's overall experience of the urban realm in appraisals.

The UK Department for Transport (DfT), which is responsible for the development of national guidance and analysis tools for transport project appraisal, is updating the appraisal guidance and has emphasised the impacts of transport projects on location attractiveness, place quality and public health in its new strategy (DfT, 2018b). Whilst location attractiveness goes beyond the urban realm attributes discussed in this section (to include agglomeration for example), the quality of the urban realm is certainly central to the understanding of location attractiveness and place quality. Noise is also certainly a major impact of transport projects that can threaten or enhance public health. Thus, valuing impacts of transport noise in public urban spaces is highly relevant to the new strategy, and to the development of appraisal methods.

## 5. Challenges

A list of challenges in developing and implementing a national methodology for valuing impacts of transport noise in public urban spaces are identified and discussed in this section. The list is not intended to be exhaustive.

### 5.1. Calculating noise from non-free-flow traffic using a suitable noise metric

Traffic is often non-free-flow on streets adjacent to or used as public urban spaces. Such traffic flow patterns are not well captured by current mainstream road noise calculation models, particularly not by the UK standard model CRTN which treats traffic as line sources with steady flow (Department of Transport, 1988). While microscope traffic simulation, which accounts for individual-vehicle characteristics as a function of time, combined with noise emission and propagation models is already achievable (De Coensel et al. 2005; Estévez-Mauriz & Forssén, 2018), noise impact assessment practice, which provides noise exposure change data for valuation, has not yet been able to afford to adopt it and agree on a standardisation of such calculation for complex urban traffic conditions.

Also, perceived noise nuisance may be more strongly related to some particular metrics, e.g., % heavy goods vehicles in urban stop-start conditions (Highways Agency et al., 2011), than to the usual noise metrics. Moreover, transport projects at/near public urban spaces, e.g., pedestrianisation, can make substantial changes to dominant sounds at these locations. A noise metric suitable for both before- and post-project scenarios requires a deeper understanding of these issues.

### 5.2. Defining and adding diverse receptor types

Receptors of transport noise impact in pubic urban spaces can include people on streets or in parks, engaging in activities such as walking/running/cycling, stopping to converse with others, resting, eating and drinking, window shopping/outdoor shopping, play, etc. There is evidence that the impact of transport noise, e.g., on annoyance, depends on the activity a person is trying to engage in (Bartels et al., 2015). So the question is, should these different types of receptors be treated differently in valuation? For instance, should different impact pathways or WTP values be applied to different types of receptors?

In noise impact assessment, various receptor types are often defined and categorised by their sensitivities to noise, and level of significance of the noise impact is a function of the receptors' sensitivity to noise and the magnitude of the noise impact. Such an approach can be potentially useful for valuation too. However, the level of impact significance is usually treated qualitatively, determined by a receptor-sensitivity-to-impact-magnitude matrix. A quantitative version would be much more desirable for valuation, but would also require more research and empirical data to develop.

### 5.3. Estimating dynamic affected population

Unlike static residential properties that can be easily counted to estimate number of receptors in current noise impact appraisal for residential locations, receptors in public urban spaces are spatially and temporally dynamic, making estimation more difficult.

For baseline scenarios, counting number of users of the public urban spaces, ideally on different days and times, and by receptor type, might be an option especially for small projects. For post-project scenarios, number of receptors might be estimated by pedestrian modelling and forecasts based on census and market data, which has been used in urban realm valuation (e.g., Transport for London, 2014; West Yorkshire Combined Authority, 2016). However, such estimation would not be able to estimate number of receptors within each specific noise band which is needed to calculate noise exposure. Receptors in public urban spaces are expected to use the spaces at different times and locations for different durations. Aggregating noise impacts over these in a methodical and balanced manner could be a major challenge, which might prompt a search for new type of data on pedestrian location and time.

### 5.4. Accounting for diversity in level and source of background sound

The high diversity in level and source of background sound in public urban spaces makes it hard to know the real consequence of changes in noise exposure. Noise annoyance at a given location is influenced by levels and sources of other audible sounds (Jeon et al., 2010; Schulte-Fortkamp, 2000). So as illustrated in Figure 2, the same 5 dB reduction in transport noise might be experienced and valued very differently on a street with landscaped setbacks where it is more tranquil with more natural sounds, on a street with commercial development where it is more vibrant with more human sounds, and on a street where landscaped setbacks are taken for commercial development.

Moving from ‘noise’ to ‘sound’ via a soundscape approach might be a better solution, so that values of the soundscapes before and after a transport project are compared. However, no theories or tools for soundscape valuation have been developed yet, and this is a key research challenge.

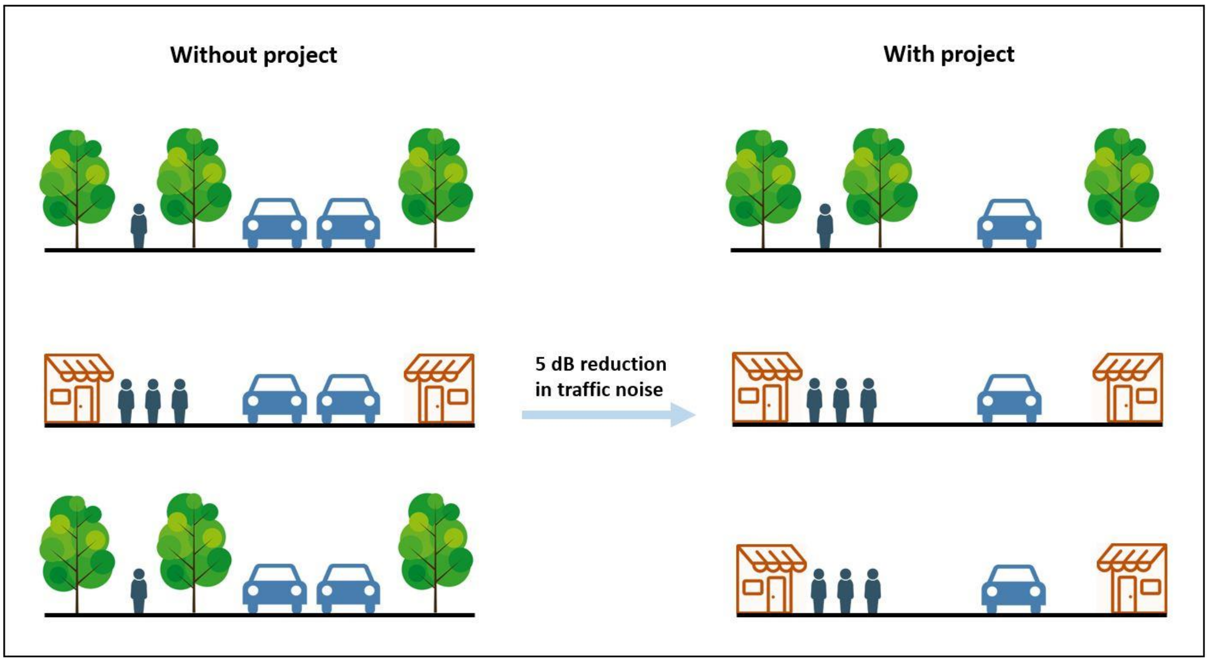


Figure 2. The same 5 dB reduction in three different project scenarios.

### 5.5. Obtaining large and consistent data for dose-response or willingness-to-pay analyses

Considering data availability, hedonic house price modelling would normally be a more viable option to estimate monetary values of noise impact. However, it is probably not suitable for public urban spaces, since the values would mainly reflect people's WTP for residential locations. As for stated preference or impact pathway approach, it is unlikely that sufficient standardised high quality data will be available in the very near future, despite the opportunities identified in Section 4.1. Indeed, soundscape standardisation itself will require substantial research inputs before it can be used for data collection and analysis, and dose-response relationships need long-term observations if long-term impacts such as health impacts are to be considered.

## 6. Conclusions

This paper discussed gaps, opportunities and challenges in developing a national methodology for valuing transport noise impacts in public urban spaces in the UK, which are currently not very well covered in transport appraisal.

Critical gaps identified include evidence on pathways of transport noise impact on people and dose-response relationships in public urban spaces, and people's WTP for sound environment quality at these locations. The existing literature focuses primarily on noise impact at residential locations. The available urban soundscape literature might have some implications for impact pathways and dose-response relationships, however, the data has limitations of sample size and consistency, and lacks a specific focus on transport noise. The very limited amount of research on economic value of Quiet Areas is relevant to WTP for sound environment quality in public urban spaces, but does not answer the question about valuation of changes in noise exposure and does not cover public urban spaces more generally.

Key opportunities are emerging from recent progress in urban sound environment research and from increasing attention to the urban realm in (UK) transport policy. The growing interest in associations between public health and urban soundscape will help to produce evidence for identification of impact pathways. The development of crowd sourcing sound environment evaluations and progress in standardisation in soundscape research and practice will enable dose-response or stated preference analysis using richer and more consistent data in the future. On the other hand, increasing attention to the urban realm by researchers and policymakers in the UK is helping to structure the question about the value of traffic noise changes in the urban environment, recognising interdependencies with other place quality attributes and different uses of the urban realm. The answer will require insights and inputs from several disciplines, and progress is being encouraged from both a planning perspective and an appraisal/valuation perspective.

The paper also identified some substantial challenges, including calculating noise from non-free-flow traffic, defining and adding diverse receptor types, estimating dynamic affected population, accounting for diversity in level and source of background sound, and obtaining large and consistent data for dose-response or willingness-to-pay analyses. Recent research has begun to tackle these challenges, but there remains a need for further work in all these areas.

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