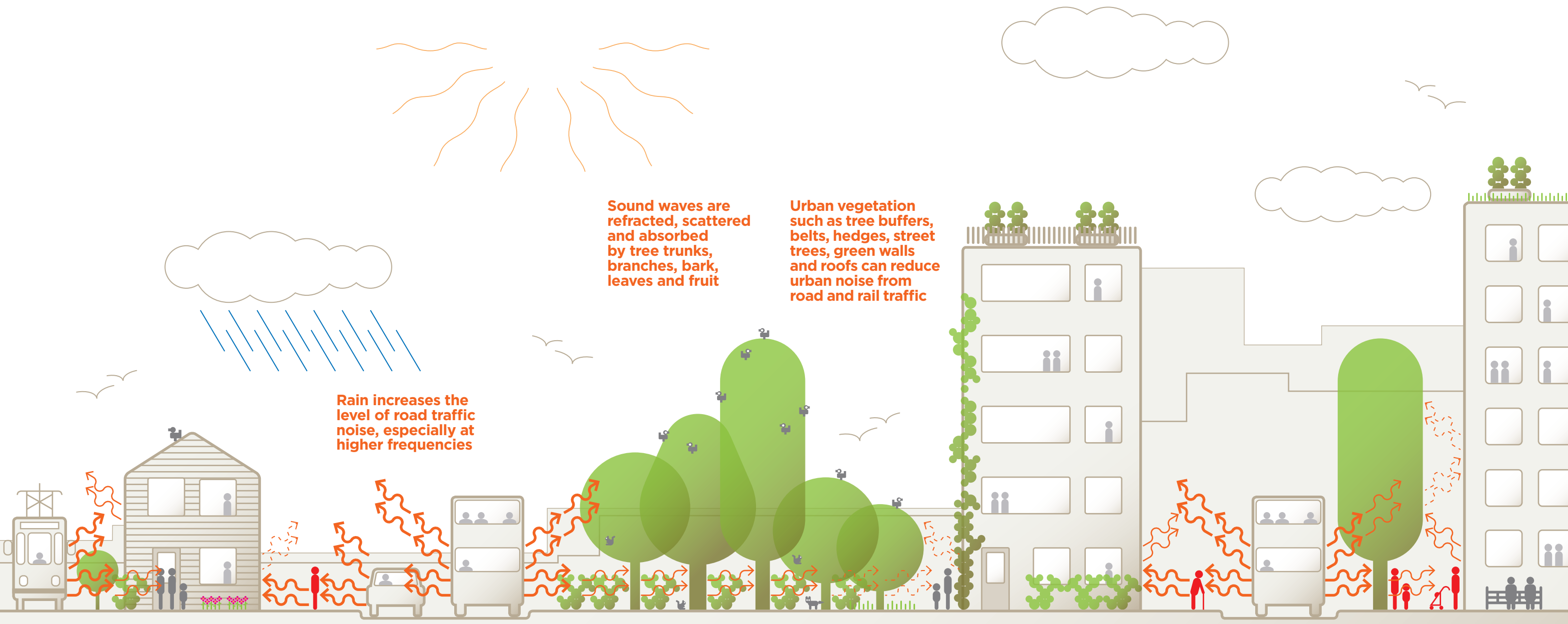
First Steps in Urban Noise

Recommendations for urban trees as noise* buffers

*Unwanted or unpleasant sound



Vehicle height, type, engine capacity, road surface, tyres, tracks and speed influence urban noise levels

Direct sound path between road traffic source and receiver, building or person

Subjective benefits due to the presence of greenery, such as lower perceived noise levels

A mix of tree species, including tall trees with large canopies in the middle of the buffer, is best for noise reduction

Shrubs and smaller trees planted close to the noise source will create a dense foliage layer

Soft permeable ground cover in and around the buffer will reduce noise

Sound reflects off building facades. Road traffic noise is louder on the street canyon with no trees compared to trees

Trees planted along a canyon street disrupt the reflections between buildings, thereby reducing sound reverberation. This results in quieter noise conditions for pedestrians and at the building facade

Key: Noise level
Higher
Moderate
Lower

Trees & Design Action Group

Forest Research

References
1 European Environment Agency. Link

2 WHO. Link

3 Terms highlighted in *green italics* are defined in the **Glossary**.

4 Rice, et al. 2022. Link

5 Waters et al. 2023. Link

6 Van Renterghem et al. 2015. Link

7 Kragh J. 1979. Link

8 Lai Fern Ow and Ghosh S. 2017. Link

9 Dodson M and Ryan J. 2020. Link

10 Embleton, T.F.W. 1963. Link

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13 Reethof, G et al. 1977. Link

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Impact of noise on health

Noise pollution poses a significant threat to public health, leading to numerous long-term health issues resulting in an estimated 6.5 million people suffering with chronic sleep disturbance[1]. In Europe around 40% of the population are exposed to road traffic noise levels exceeding 55*dBA*[2,3] (Fig. 1). Noise has emerged as a leading environmental annoyance.

Tree *buffers*, *belts* and *hedges* can be an effective strategy to reduce urban noise from road traffic, trains and trams. Tree buffers are often underestimated for their noise reduction potential, but with thoughtful placement and layout, they can significantly enhance the urban environment. Not only can tree buffers, belts, and hedges reduce actual noise levels, but they can also offer visual appeal that has been linked to improved perceptions of noise attenuation[4,5].

This First Steps Guide supports informed decision making on the use of tree buffers to reduce traffic noise sound waves. It includes details on vegetation recommendations, tree planting design, and appropriate buffer distances.

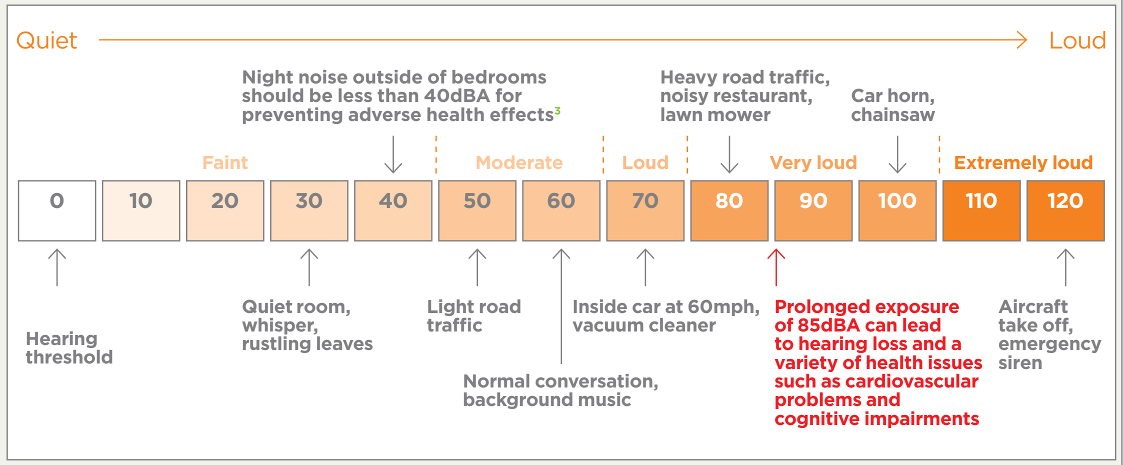
Primary sources of urban noise pollution come from road and rail traffic vehicles. Road traffic noise is considered more impactful than noise generated by rail traffic. This Guide mainly focuses on road traffic noise reduction by tree buffers but similar principles for vegetation measures can be applied for rail traffic[6,7].

How do trees and ground cover reduce urban noise?

Trees influence sound waves mainly by *absorption*, *refraction* and *scattering*. The greater the surface area of the tree, from branches, trunks and leaves the better the noise reduction[8,9]. Foliage is the most effective part of the tree for absorption and scattering of sound, particularly at high frequencies[8]. Branches and trunks also play a role in reducing noise, and are not subject to seasonality. Evergreen trees (such as pine) retain their leaves/needles and can provide sound reduction all year, whereas a deciduous tree buffer (such as beech, lime) is more effective at sound reduction in summer when they are in full leaf[9]. The impact of deciduous trees losing their leaves in winter, compared to being in full leaf, could be as much as 3dBA less noise reduction[10]. A change of 3dBA is typically recognised as the smallest difference in noise level that humans can perceive[3,5].

Large, ovate, elliptical, and highly tactile leaves exhibit better noise absorption and scattering properties compared to small narrow leaves[11,12] (see TDAG's *Tree Species Selection for Green Infrastructure: A Guide for Specifiers*). Rough tree bark, especially covered in moss, is particularly effective at absorbing sound[13,14].

Fig. 1 **Decibel scale sound level**



'Tree buffers, belts and hedges are often underestimated for their noise reduction potential. By strategically planting trees along roads, railways, and tram lines, urban planners can create quieter, more pleasant environments for residents, reducing the impact of unwanted noise pollution and enhancing overall quality of life.'

Decomposing leaves on the ground in a tree buffer will result in better sound reduction, especially at lower frequencies[15]. Soft ground cover enhanced by root systems, and mulch, in and around the trees can reduce sound. This is the result of *interference* between direct and ground-reflected sound, known as 'ground effect'[12,15].

Sound build-up in urban street canyons is increased by multiple reflections from solid building facades that result in *reverberation*. Research suggests individual street trees, and green and living walls can help mitigate the build-up of sound in urban canyons by as much as 2-3dBA[5,16,17,18].

Perceived sound reduction

Visual scenes with vegetation are perceived to have reduced road traffic noise than those without, with studies showing equivalent reductions of up to 10dBA[5]. This effect, known as *psychological sound reduction*, can sometimes provide a subjective benefit that exceeds the actual physical noise reduction performance. Urban tree buffers will attract wildlife, enhancing biodiversity. Birdsong can serve as informational masking, redirecting attention away from road traffic noise and promoting mental restoration[5]. Considering both physical and psychological factors, there is a strong case for broader implementations of vegetation buffers in urban environments.

Tree buffer site characteristics

The United States Department of Agriculture National Agroforestry Centre (USDA) recommends tree buffers can reduce traffic noise dependent on three site distances (Fig. 2)[20]. (A) This is measured from the middle of the road to the edge of the tree buffer, (B) the buffer width and (C) setback distance (Fig. 2). For a tree buffer 30m wide, 9m in height and a minimum distance from the middle of the road of 6m and low traffic speed (<40mph) a reduction of between 5-8dBA is possible[20]. Ideally buffer length should be twice as long as the distance from the noise source to the receiver and run parallel to the road[20,21].

Key factors associated with noise reduction

Noise reduction is highly associated with buffer width, vegetation density, height and ground cover[5,20,21,22].

In general, the wider and denser the foliage of a tree buffer combined with soft ground cover the greater the sound reduction[9,21]. In urban settings space is often limited and a 30m wide buffer might not be possible. Tree buffers of 10-15m width can reduce road noise by up to 6dBA compared to grass alone[14,23,24]. Relatively narrow tree buffers or single lines of trees can be effective offering up to 5dBA compared to shrubs[9]. Such a reduction is noticeable and could improve noise comfort and health. A single line of conifers densely planted with shrubs can reduce sound by 5dBA

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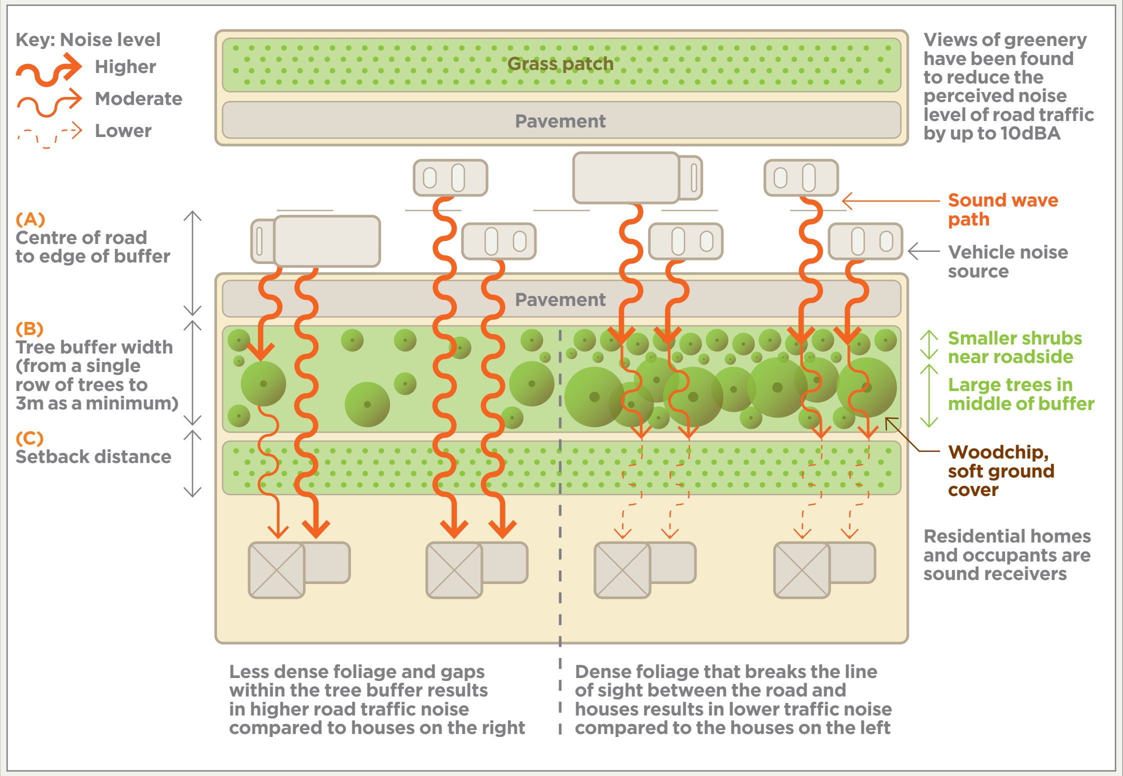
Fig. 2 **Tree buffer site characteristics**



Glossary

Absorption.
Sound enters a material and typically gets converted to heat, reducing the intensity.

Belts.
Usually consists of multiple rows of trees and shrubs, designed to cover a larger area. Generally wider than tree buffers, ranging from 20-50m or more.

Buffers.
Consists of a variety of trees and shrubs varying in depth and height.

dBA.
Decibels A weighted (dBA) is sound pressure level in decibels compliant with British Standard (EN 61672-1:2013). Road traffic noise is in the frequency range of 500-1300Hz.

Hedges.
A dense row of shrubs or low-growing trees planted closely together to form a boundary or barrier.

Interference.
Sound travelling directly between the road and pedestrian combines with sound reflected from the ground. When the direct and reflected sound are out of phase the total sound level is reduced.

Inverse Square Law.
A road of continuous traffic behaves like a 'line' source for which an inverse distance law applies (3dB per distance doubling).

Psychological sound reduction.
Gustav Fechner (1801-1887) realised use of the word 'noise' introduces a subjective element to an individual's decision of whether sound has value.

Refraction.
Bending of sound as it passes from one medium to another with a different density and sound speed.

Reverberation.
Persistence of sound in a particular space because of many reflections.

Scattering.
When sound waves are forced to deviate from a straight path due to irregularities in the medium through which they pass.

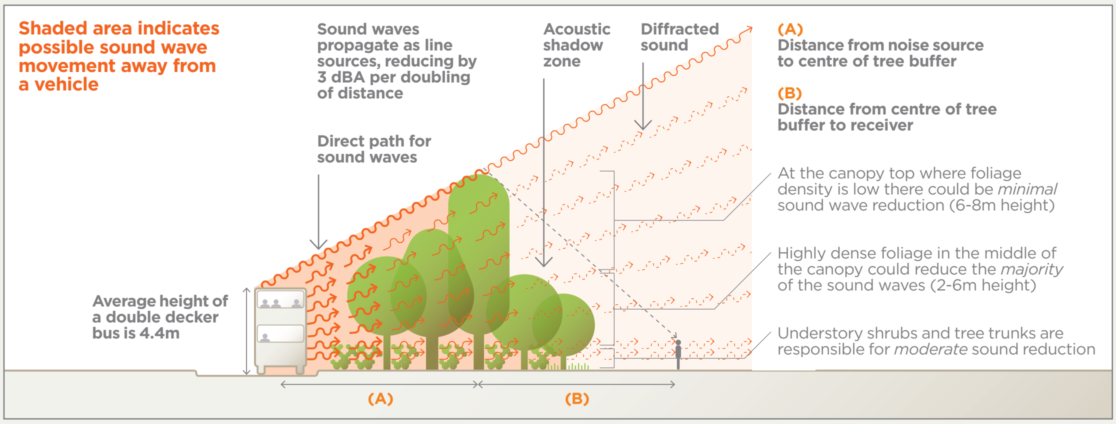
and a 3m wide tree belt of the evergreen Australian pine was able to provide 3dBA noise reduction[22, 24,25].

Foliage density through the horizontal plane of the buffer should be dense and impenetrable with no gaps that allow light to penetrate (Fig. 2 and 3). Approaches to help achieve foliage density from the ground up and through the horizontal plane of the tree buffer are highlighted in Box 1.

Tree Buffer Recommendations

In summary, tree buffers can significantly reduce noise. Optimal buffers can achieve better results by incorporating additional design elements and species selection. The design and planting scheme must be considered alongside this guidance provided. Specifically, plants should be selected based on environmental conditions, soil type, pit depth, and other relevant factors to ensure the survival of trees and shrubs. Additionally, it is crucial to ensure that the planting does not cause any environmental or ecological harm. Tree buffer recommendations for optimal noise reduction can be seen in Box 1 below[9,20].

Fig. 3 **Acoustic shadow zone for an urban tree buffer**



Box 1 **Key factors for an optimal urban tree buffer to reduce road traffic noise**

Vegetation
- Create dense foliage from the ground up and along line of sight for effective noise attenuation.
- Use varied tree species with large canopies, large leaves, rough bark, and moss-covered surfaces.
- Mix broadleaf evergreens and deciduous trees for year-round noise reduction.
- Select tree species known to be capable of withstanding exposure too, or can mitigate urban pollution found in the soil, water and air.

Height
- Tallest trees should create an acoustic shadow zone for a sound receiver.
- Bushy shrubs should form a foliage wall to meet the tree canopy layer or at least 1.5m in height.

Ground Layer
- Soft, permeable ground cover (eg soil, mulch, grass) absorbs noise better than hard surfaces.
- Minimal ground management allows ground vegetation to proliferate.

Planting plan
- Increase vegetation density with irregular, abreast, hexagonal, or random planting pattern of trees and shrubs for optimal noise reduction.
- Plant smaller trees and low shrubs near the roadside, larger trees in the middle of the buffer[5,24].

Traffic speed
- Low-speed traffic (<40mph): Noise levels are generally lower in level compared to high-speed traffic, with less high frequency content.
  - Recommended buffer width, 3-15m.
- High-speed traffic (>40mph): Increased noise due to road-tyre contact, aerodynamic noise, greater number of heavy goods vehicles.
  - Recommended buffer width, >15m.

Note: Many electric vehicles are fitted with Acoustic Vehicle Alerting Systems (AVAS) that produce sound below 16mph to alert pedestrians, which can potentially be perceived as noise in certain contexts.

'A densely planted buffer of trees and shrubs, with a width of 3m and of sufficient height to create an acoustic shadow for the receiver, can reduce noise by 5dBA, especially when combined with soft ground.'

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