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Best Spatial Planning Practices to Prevent the Effects of Environmental Noise on Health and Quality of Life

GUIDE

Québec

Best Spatial Planning Practices to Prevent the Effects of Environmental Noise on Health and Quality of Life

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Direction de la santé environnementale et de la toxicologie

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List of initialisms and acronyms

BAPE	Bureau d'audiences publiques sur l'environnement
CMHC	Canada Mortgage and Housing Corporation
dB	Decibels
dBA	A-weighted decibels
FCM	Federation of Canadian Municipalities
INSPQ	Institut national de santé publique du Québec
IRSST	Institut de recherche Robert-Sauvé en santé et en sécurité du travail
km	Kilometres
L_{Aeq}	A-weighted equivalent continuous sound level
L_{Amax}	Maximum A-weighted sound pressure level
L_{den}	A-weighted equivalent continuous sound level, for a period of 24 hours (1 day) or day-evening-night level
MAMOT	Ministère des Affaires municipales et de l'Occupation du territoire
MELCC	Ministère de l'Environnement et de la Lutte contre les changements climatiques
μPa	Micropascals
MSSS	Ministère de la Santé et des Services sociaux
MTQ	Ministère des Transports du Québec
NEF	Noise exposure forecast
OHV	Off-highway vehicle
Pa	Pascals
RAC	Railway Association of Canada
RCM	Regional county municipality
WHO	World Health Organization

Legend

Additional information

Definitions

Warning!

Highlights

- There are many sources of noise, which increase the difficulty of mitigating the effects. Some examples are noise from road and air traffic, as well as rail noise, noise from port (harbor) facilities or from construction sites.

- Land-use planning and management are some effective and key noise control and mitigation measures. These measures are planned and implemented by regional county municipalities (RCM), municipalities and proponents.

- There are various best environmental noise mitigation practices, from active transportation to street design, by way of the orientation of buildings and inner rooms, not to mention noise barriers and the addition of plants arranged in an optimal manner. Although the effectiveness of several of these measures has been quantified, they are poorly known.

- Since environmental noise has harmful effects on people's physical and psycho-social health and quality of life, applying these solutions will help properly protect sensitive places (residences, childcare and day-care centres, schools, hospitals, recreational parks, etc.), but also industrial, commercial, and recreational activities, as well as spaces designated for transportation infrastructure.

- In fact, the effects of noise are not limited to auditory effects, because they also have an impact on sleep, cardiovascular diseases, learning in educational institutions and the social acceptance of activities or projects.

1 Introduction

Environmental noise is a public health problem due to risks to people's health and quality of life. Noise is a growing concern for many residents who are seeing their quality of life affected.

Land-use planning and management are effective and key noise control and mitigation measures. This is a major planning tool for noise reduction in municipalities.

The purpose of this document is to help regional county municipalities (RCM), municipalities and proponents plan the use of their built environment, so as to properly protect sensitive spaces from noise (residences, childcare and day-care centres, school and hospital facilities, etc.), but also industrial, commercial and recreational activities, as well as spaces designated for infrastructure.

To do so, this document:

- presents the basic concepts to better understand noise and some technical aspects of its measurement;
- summarizes the main health issues associated with exposure to environmental noise;
- makes an inventory, in the form of tables, of best practices or potential solutions for reducing environmental noise, including their advantages and drawbacks;
- provides additional references for more details on the various measures suggested.

The proposed measures may be considered during land-use planning, but also for managing and correcting existing situations where noise is a problem. They pertain not only to traffic routes, but also to several other noise-producing activities. These aspects are usually considered in land-use planning in order to take into account any major constraints, which includes noise due to its impact on health and quality of life, and to ensure the sustainable development of living environments.

2 Environmental noise

2.1 Definition

Noise is defined by the World Health Organization (WHO) as any unwanted sound (1, 2). These unwanted sounds can be unwelcome, annoying or have a high enough power that could potentially cause adverse health effects (2, 3).

Environmental noise refers to any noise, regardless of its source, excluding noise in the workplace[I] (3). It therefore includes [translation] " . . . noise emitted from road, railway and air traffic, industries, construction and public works, as well as neighbourhood [indoor and outdoor] and noise from cultural or leisure recreational activities (playgrounds, nightclubs, shows, hunting, snowmobiling, etc.) (3)".

2.2 Environmental noise effects on health and well-being

A review of the scientific literature published in 2015 by the Institut national de santé publique du Québec (INSPQ) entitled *Avis sur une politique québécoise de lutte au bruit environnemental : pour des environnements sonores sains* (*Advisory on a Québec Policy to Fight Environmental Noise: Towards Healthy Sound Environments*), shows that noise is a public health issue (3). The INSPQ found that there is sufficient evidence[II] to establish a link between exposure to some sources of environmental noise and physical and psychosocial effects, as illustrated in figure 1. Environmental noise is therefore not just a mere nuisance, but rather an environmental pollutant that represents a risk to the public's health and quality of life. The impacts of environmental noise on health and quality of life can continue even after exposure has stopped (4). Noise also has well-documented economic effects.

2.2.1 Effects on physical health

Environmental noise has several effects on physical health that are not limited to the better-known auditory health effects, i.e. hearing loss and tinnitus. It is now proven that exposure to environmental noise can have the following effects on physical health (3):

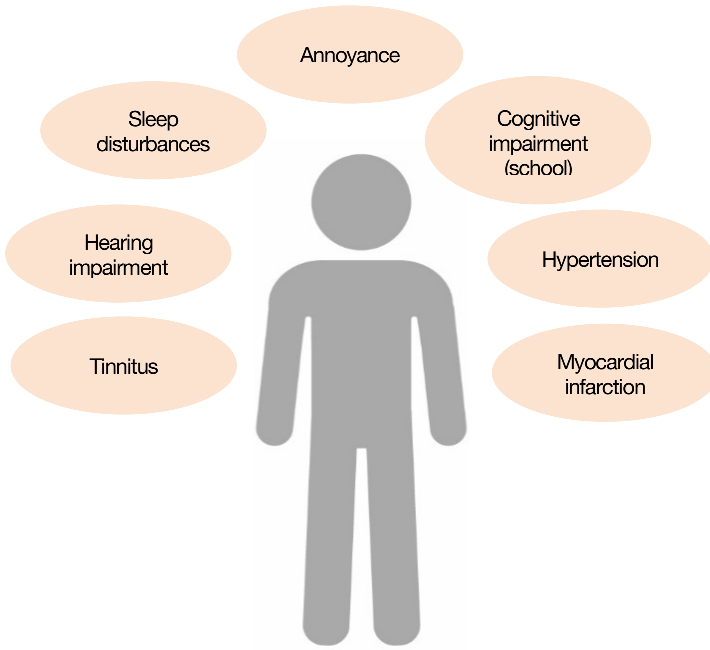
- Sleep disturbances: difficulty in falling asleep, increased movements, more frequent and extended awakenings, daytime sleepiness. These disturbances have repercussions that last beyond the night itself (perceived poor quality of sleep, drowsiness, fatigue, reduced motivation, decreased concentration, distractibility, etc.).
- Cardiovascular diseases: noise is a stressor that causes physiological reactions that have an impact on cardiovascular health (3). hypertension is an effect that is documented in adults who are chronically exposed to road and air traffic noise, as well as myocardial infarction for road noise.

[I] This definition therefore excludes noise emitted in the workplace and that exposes workers. However, the noise from a construction site or a business, for example, is considered to be environmental noise for the exposed residents.

[II] Other effects of environmental noise on physical or psychosocial health have been studied. However, the evidence available in the scientific literature is insufficient to draw a conclusion on the links between exposure to noise and these effects. These are therefore not addressed in this document.

Non-habituation to noise – It is important to know that there is no physiological adaptation to noise, even if we think we are used to it. “Hearing functions 24 hours a day. In fact, ears do not have ‘earlids’. This lack of protection means that they never rest” (3).

Figure 1 Multiple effects of noise on humans



Noise level without effects at night – According to the Night Noise Guidelines for Europe (WHO), there are apparently no health effects below a threshold of 30 A-weighted decibels (dBA) (annual average). This noise level is equivalent to 40 dBA outdoors.

2.2.2 EFFECTS ON PSYCHOSOCIAL HEALTH

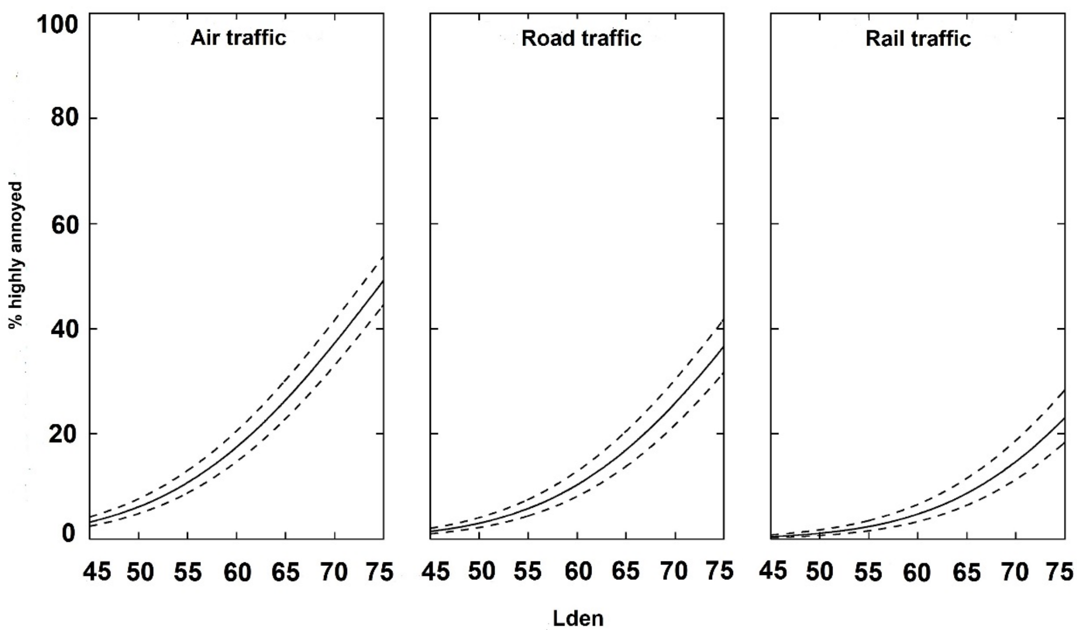
Environmental noise is also responsible for psychosocial effects on health:

- Effects on learning, particularly in an educational setting: noise inside and outside the class has adverse effects on academic performance (oral comprehension, reading comprehension, memory).
- Limited social acceptance: noise can also lead people or groups to complain or take legal action (3). These citizen reactions to noise reflect differences in society, particularly when it comes to the land-use development vision and model, and with respect to the need for tranquility (3).
- Nuisance, bother, annoyance (discomfort): nuisance is the most studied effect of noise and is a public health issue recognized by the WHO (3, 5). While not a disease, a major nuisance is an obstacle to quality of life and well-being.

Nuisance – Sometimes called “discomfort” or “annoyance” in public health, a nuisance is defined as [translation] “a possible undesirable effect on well-being or an indirect effect on physical health following exposure to a factor such as odour, noise, lice, bedbugs, etc. (6)”. It is a negative subjective reaction associated with a stressor such as noise.

Annoyance (nuisance) indicates how noise affects exposed populations, especially for people who report a significant annoyance (see figure 2). The degree of annoyance is influenced not only by the noise level, but also by other factors: acoustic (e.g. the type of noise), social (e.g. usefulness of the emission source, population expectations, etc.) and personal (e.g. sensitivity, fear of the source, benefits received, etc.).

Figure 2 Percentage of people highly annoyed at their home as a function of their noise level exposure (L_{den}) for air, road and rail traffic noise



Notes: Solid lines: the curves represent the proportion of people highly annoyed by the noise for each source based on the integration of results from a very large set of field studies with noise annoyance and noise exposure determined through meta-analyses. Broken lines: the curves indicate the range of uncertainty (confidence interval of 95%). L_{den}: day/evening/night exposure level, where evening exposures (7 to 11 p.m.) have been penalized by + 5 dBA, and those during the night (11 p.m. to 7 a.m.) by +10 dBA. These penalties help account for the greater annoyance caused by the noise throughout these two periods. For example, a 50 dBA noise during the day would produce the same percentage of people highly annoyed as a 45 dBA noise in the evening, or a 40 dBA noise at night. Source: reproduced from Miedema (7).

2.3 Economic effects

In addition to the health effects, the scientific literature also shows economic effects that can be attributed to noise. Based on a conservative estimate, the costs of environmental noise in Québec have been assessed as being at least $679 million in 2013 (3). Indeed, studies highlight lower land values in areas affects by traffic noise (3), which results in lower revenue for municipalities, but also for owners when selling their building. For neighbourhood noise, losses in property value are only partially documented (8).

3 Importance of land-use planning in noise reduction

Two major parameters influence the sound environment and fall under the jurisdiction of RCMs and municipalities. These are:

- Land-use planning (noise-compatible buildings. noise zoning, etc.)
- Buildings design (room plan, structure, shape, orientation, openings and balconies of buildings)

Actions taken with respect to these two parameters help limit or better control environmental noise and they can influence the effects on health.

For information purposes, the other important factors that influence the sound environment refer to the noise sources, i.e. vehicles and transportation infrastructure, as well as noisy machines, tools and equipment (3). While the responsibility for limiting the noise emitted by sources (e.g. vehicles, machines) falls to the federal government, the transportation infrastructure is either under municipal, provincial or federal jurisdiction, as the case may be.

4 Noise and its measurement: some basic elements

Noise is a variation of pressure that is observed in the environment where it propagates. Measured in micropascals (μPa), the unit of measure for acoustic pressure has been expressed in decibels (dB) for the sake of convenience. The threshold of audible sound is 20 μPa, and the threshold for the onset of ear pain is 20,000,000 μPa (or 20 pascals [Pa]). In decibels, these thresholds correspond to 0 dB and 120 dB, respectively.

Table 1 presents the noise level associated with various noise sources and the expected human reactions upon exposure to those levels.

Table 1 Scale of sound levels and human reactions

Typical noises	Noise level (in dBA*)	Human reactions
Jackhammer; gunshot near hunter's ear	**130**	Pain
Emergency vehicle siren	**120**	Onset of pain
Show with amplified music; nightclub	**110**	Tolerable for a short period, maximum vocal effort to be understood
Jackhammer 10 m away; motorcycle	**100**	
Gas lawnmower; alarm; heavy truck going 80 km/h on the highway, 10 m away	**90**	
Alarm clock; 2 cars going 80 km/h on the highway, 10 m away; many factories; noisy restaurants	**80–85**	Conversing is difficult, feeling of loud noise
Busy street; vacuum cleaner	**70**	Inconvenient for holding a telephone conversation
Normal conversation	**55–60**	
Moderate rain; washing machine	**50**	Onset of disturbance (annoyance)
Library; refrigerator; quiet street at night	**40**	Place considered quiet
Quiet room; quiet conversation	**30**	Feeling of calm
Light breeze in the trees	**20**	Feeling of great calm
Audible sound	**0**	Hearing threshold

* dBA: A-weighted decibels, to reflect the response of the human ear to noise.
Adapted from: Martin *et al.* (3).

4.1 Variations of noise levels and perceiving them

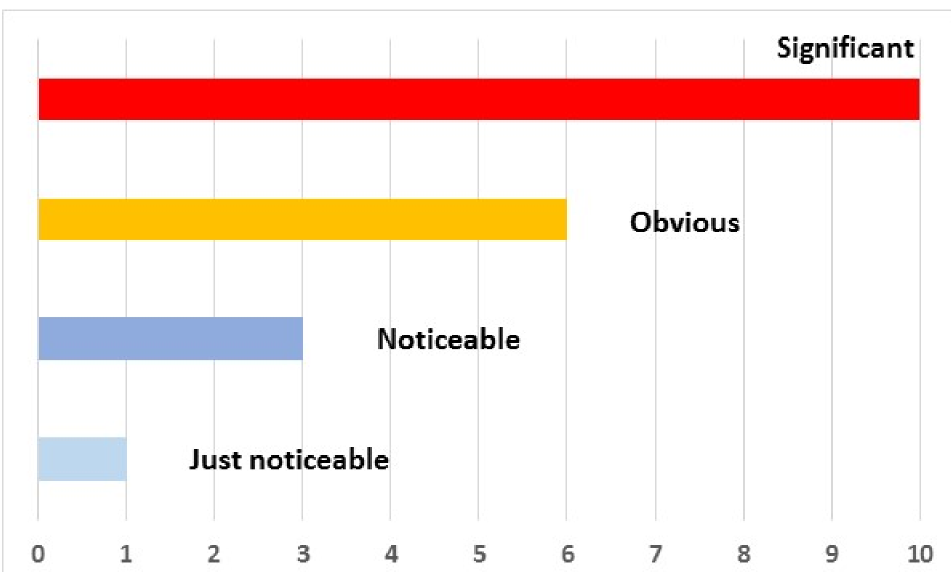
Noise is measured using a logarithmic scale. Thus, an increase of 3 dB is a doubling of the acoustic energy, whereas an increase of 10 dB corresponds to a noise level that is 10 times higher (see table 2). The increase of 3 dB corresponds to an audible increase in the noise level, but this increase will only be clearer, more audible at 6 dB (see figure 3).

Table 2 Correspondence between the variation of sound level in decibels (dB) and the increase in acoustic energy

+	X
An increase of the sound level by:	**... multiplies the acoustic energy by**
3 dB	2
5 dB	3
6 dB	4
7 dB	5
8 dB	6
9 dB	8
10 dB	10
20 dB	100

Adapted from: MTQ (9).

Figure 3 Perceived change of the sound based on the disparity between the sound levels



Notes: An increase of 3 dB in the noise level, which corresponds to a doubling of the acoustic energy, will be perceptible. At around 5 to 6 dB, the change will be perceived more obviously, so as a marked increase in the sound. At around 10 dB, the noise will be perceived as being twice as loud, even if it corresponds to an energy that is 10 times greater (see table 2). Finally, the weakest audible change is about 1 dB.

Source: Bruel and Kjaer (10).

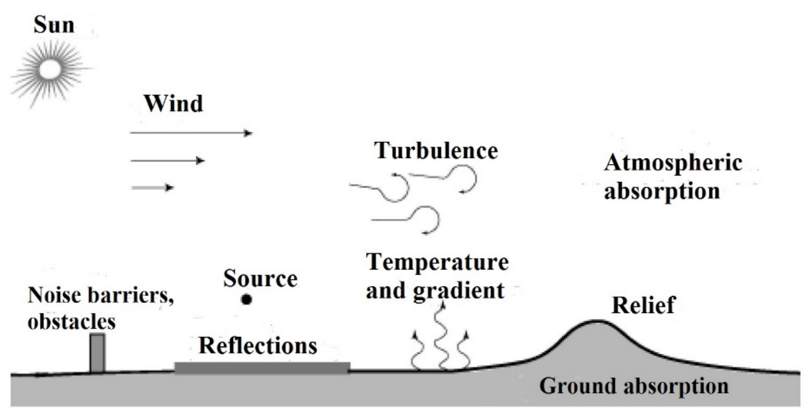
4.2 Factors that influence the noise level

The noise level at a given location is affected by several factors which influence its propagation. As for the perceived noise level, it is influenced by several parameters, including the human ear's response and the temporal variation of the noise level (the variation is illustrated in figure 5).

4.2.1 FACTORS AFFECTING NOISE PROPAGATION

In addition to distance from the source, several factors influence the propagation of noises outdoors. As illustrated in figure 4, the weather conditions (temperature, wind, etc.), and the topography of the location (relief, presence of natural or artificial barriers, etc.) play an important role in the propagation of the noise. The presence of reflecting surfaces (building, ground surface, body of water, etc.) may also have a significant influence on noise levels and exposure.

Figure 4 Factors that influence the propagation of noises outdoors



Source: translated from Premat (11).

4.2.2 THE HUMAN EAR'S RESPONSE AND INFLUENCE OF THE NOISE'S CHARACTERISTICS ON PERCEIVING IT

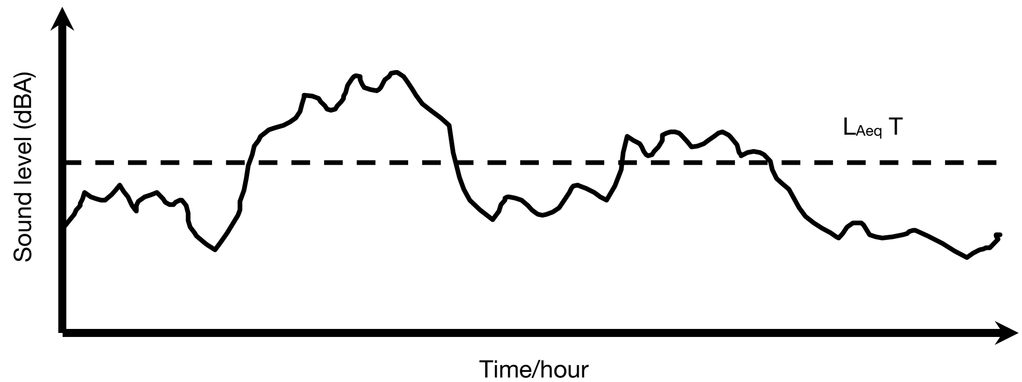
The human ear's response varies according to the frequency content of the noise. For example, the human ear does not perceive high-pitched (high frequency) or low-pitched (low frequency) sounds in the same way. When measuring noise, in order to account the human ear's sensitivity, the decibels are frequency weighted and results denoted as A-weighted decibels (dBA).

Other characteristics also influence the perception of noises, such as the tonal content of sound or the presence of impulse noises (which are loud, very short noises: shot of a firearm, hammering, door slamming, explosives, basketball in a park, etc.).

4.2.3 TEMPORAL VARIATION

Noise most often varies over time. The equivalent continuous sound level (L_{Aeq}), illustrated in figure 5, is a parameter or indicator that incorporates in a single measure of exposure, expressed in dBA, all the variations of noise that occurred throughout a given period of time (seconds, minutes, hours or day) and, therefore, that contains all sound energy with "A" frequency weighting. This indicator is often presented as "average noise level" (although not technically correct). In this way, this indicator helps consider and more easily compare intermittent, fluctuating (such as road noise) or even peaks of noise from a specific device on an industrial site. Noises with the highest levels have an influence on the L_{Aeq} indicator.

Figure 5 Indicator of noise exposure: the A-weighted equivalent continuous sound level (L_{Aeq})



Level = L; dBA = A weighting	Equivalent continuous sound level during a period of time (T) = eq T

Source: translated from OOAQ (12).

4.3 Acoustic assessment study

The wide variety of noise sources and the local conditions that affect its propagation sometimes make it difficult to choose the most appropriate mitigation measures to be implemented. An acoustic assessment study then become an important planning tool, in addition to being used to resolve situations with a noise problem.

Acoustic assessment studies can target various objectives:

- Defining the sound environment of a site or a living area;
- Assessing the impact of a noise source, a specific noise or potentially noisy activities, whether it is an existing or new source (predictive acoustic modeling);
- Identifying noise reduction or mitigation measures (barriers, distances from source, technical measures specific to a particular activity or equipment, etc.) and assessing the expected effect;
- Assessing the noise from inside dwellings (soundproofing tests), as well as the outdoor noise transmitted inside (e.g. facade along a traffic lane) in order to suggest a design plan for the walls, floors or facades.

Although some municipalities have resources available to carry out acoustic studies, this type of study is mostly done by specialist companies or academic experts who have the equipment necessary for measurement and software for noise exposure assessment and mapping.

In order to meet assessment and planning needs, the acoustic assessment study report should contain the following information:

- The mandate and objectives;
- The methodology;
    - Compliance with relevant standards, measuring periods, instruments used, calibration of the measuring instruments;
    - Description of the noise source(s) considered and their operating conditions (typical or maximal use, etc.);
    - Description of the weather conditions during measurement (for valid and representative measurement): temperature, wind direction and speed, cloud cover and precipitation;
- Choice of the site where the sound levels are assessed (e.g. most exposed sensitive environments near a source) with the description of the sites assessed, including the topography, the building's geometry, surfacing and soil condition;
- The sound levels assessed based on the relevant measurement indicators;
    - in typical conditions, with and without the contribution of certain sources of interest;
    - in conditions that are favourable for noise propagation (worst case scenario), with and without the contribution of certain sources of interest;
- A comparison of the sound levels with the existing guidelines and regulations, as well as the health-based recommended values.

4.4 Socio-acoustic survey

In some situations, it may be desirable to carry out a study that defines not only the sound environment, but also the annoyance caused by the given noise source. This kind of study, which is called "socio-acoustic", helps cross-check acoustic data (exposure levels) with data on annoyance. An international standard describes how this is carried out (ISO/TS-15666).

However, in the absence of a social or socio-acoustic survey, a municipality or an RCM could rely on the information from the management (or a management system) of noise complaints (nuisances) that incorporate both data from inspection or planning services and from police services. This could be the first step to analyze a situation and consider changes to planning or mitigation measures. As for the acoustic assessment study, it is still useful for complex situations, or to verify the effectiveness of the reduction achieved (before and after study).

5 Introduction to best practices for reducing environmental noise

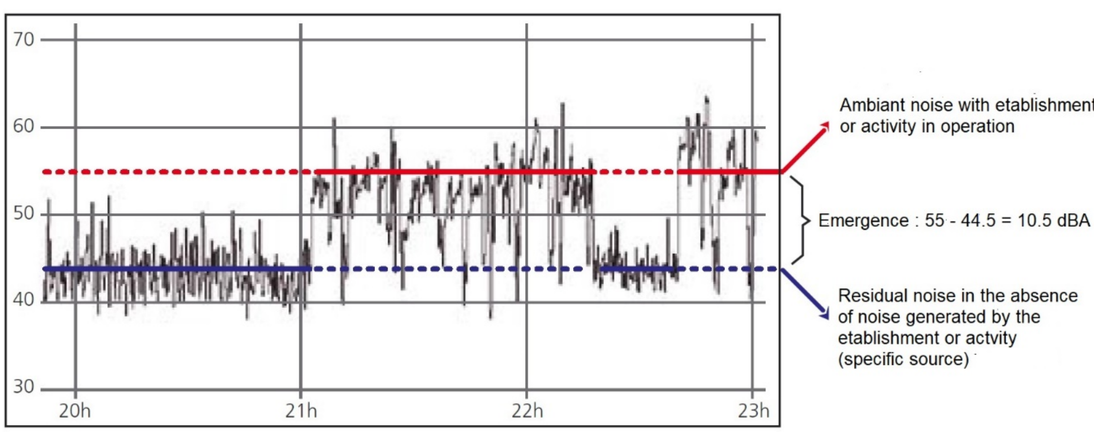
5.1 Two preventive measures: emergent noise and reciprocity

This guide encourages municipalities, RCMs, proponents and developers to adopt an overall vision of noise reduction, which based on emergent noise and reciprocity (see the definitions below). This vision must go beyond adopting a fixed and arbitrary exposure limit. For example, the criterion of 55 dBA (L_{Aeq} over 24 hours) suggested for outside noise by the Canada Mortgage and Housing Corporation (CMHC) in 1981 (13), and later taken up by other organizations, does not necessarily protect against the effects from chronic exposure to noise. In fact, a review of recent studies shows impacts on physical health (hypertension, myocardial infarction) and psycho-social impacts (annoyance) below the currently proposed thresholds, including that of the CMHC (3).

The emergent (or "emergence") noise is an indicator that can be prove useful for managing noise for new developments or when new noise sources are introduced in an environment. This indicator shows common points with the concept of "altered ambient noise" used by certain municipalities.

> **Emergent noise (or "emergence")** – Indicator that consists of calculating the arithmetic difference between the ambient noise level and the residual noise level (defined as being the level of ambient noise without the noise from a specific source). For example, in an environment where the ambient noise was 44.5 dBA before the introduction of a new noise source, and 55 dBA after its introduction, the emergent noise would be 10.5 dBA (see figure 6). This indicator helps estimate the impact of the noise that has or will be added by considering the previous soundscape of an environment. It can help assess the acceptability of certain noises and better manage the problems they cause, both in quiet areas and areas that are already noisy. An emergent noise is more noticeable and is possibly more annoying when the average deviation is greater than 5 dBA during the day or 3 dBA at night.

Figure 6 Emergent noise: example of emergence



Source: Translated from Esmenjaud and Poirot, p. 45 (14).

Reciprocity – [translation] “In land-use planning, the concept of reciprocity assumes that the standards that apply to facilities or activities that may lead to restrictions in local uses apply in a reciprocal manner when implementing sensitive uses. For example, if we require that an industrial activity be established at least 400 metres from a residential neighbourhood, by reciprocity, we should not allow residential uses to be established in less than 400 metres from that industrial activity. The purpose of the reciprocity principle is to offer a high-quality living environment to communities while providing facilities or activities that are sources of constraint with the space required to successfully carry out their activities without negatively affecting the neighbourhood. The concept of reciprocity is a key factor for protecting people and property, as well as the vitality of economic activities. It essentially results in the maintenance or definition of minimum distance separation between sensitive uses and uses that involve a risk or that cause nuisances (15).

5.2 Scope and use of the guide

In practice, several constraints limit the possible avenues for noise reduction, especially in built environments. As a result, this guide does not seek to impose measures, but rather to make decision-makers aware of effective measures that can be implemented to reduce environmental noise. In this case, it involves using the most appropriate measures by acting on exposed areas and existing noise sources in the environment, all while avoiding the creation of new situations of exposure to environmental noise, which are or could become a problem. In the medium and long term, this planning approach helps reduce noise pollution, avoid complaints or legal action, and improve the public’s health and quality of life.

Applying best land-use planning practices that reduce exposure to environmental noise can also provide solutions to safety, air quality, and climate change problems. For example, reducing traffic speeds help improve the safety of road users and pedestrians; reducing situations where a series of accelerations and decelerations is present reduces pollution. As for increasing plant cover for limiting noise propagation, it also helps combat heat islands.

5.3 Expected benefits of implementing the solutions presented

In most cases presented in this guide, the benefits of the measures are expressed as reductions in the noise level (dB). These results are from scientific publications, literature reviews that deal with solutions and that are carried out by panels, technical studies or best practices guides. They are indicative of the potential effectiveness of the measures presented, which depends on several factors. For example, although several measures in this document have already been used in Québec, the literature on effective noise reduction measures is largely from Europe. Some of the measures proposed in this context have not necessarily been validated in Québec. This aspect was considered in the presentation of the results.

Combining several measures – In every situation, the best results will be achieved by combining several noise reduction measures. Generally speaking, using a single solution is insufficient. This holds true both in undeveloped and built environments.

5.4 Note on scientific and technical references

To simplify the text, the scientific and technical references that support the information provided in this guide are rarely included with each measure presented. In most case, in the absence of a reference, the literature supporting the suggested measures may be found in the INSPQ's advisory on noise, *Advisory on a Québec Policy to Fight Environmental Noise: Towards Healthy Sound Environments* (3).

References to documents of interest can be found, if necessary, as follows, at the end of this guide:

- Bibliographical references: references cited in the document (see section 8.1);
- Key references (not always mentioned in the guide, but which may be a working base in addition to this guide): reports, guides and tools that may be used when implementing noise reduction measures, namely in terms of planning (see section 8.2);
- Additional references: reports or guides that deal with a different context or a specific noise source (see section 8.3).

6 Summary table for identifying best practices for environmental noise reduction

Table 3 gives an overall view and classifies effective measures that may be applied to reduce environmental noise. The following sections show an illustrated summary of each of these measures, as well as their advantages and limitations. The proposed measures are grouped by various sources of noise: transportation (road, railway, air and maritime), construction sites, fixed and nearby sources, specific activities (childcare and day-care centres, venues for amplified music, motorized recreation, quiet deliveries, etc.) and quiet areas.

> The numbers assigned to the measures in table 3 are used to better identify them in the guide and do not refer to any order of priority or effectiveness.

Table 3 Summary table of the environmental noise reduction measures

No. and title of measure		Expected reduction	Page
Noise from road traffic			
Decreasing the number of vehicles and traffic management			
1	Promoting active transportation	3 dBA if reduced by 50%	24
2	Promoting public transit	3 dBA if reduced by 50%	24
3	Having noise emission requirements when replacing public transit vehicles	Variable	25
4	Decreasing the traffic volume on the target roads	3 dBA if reduced by 50%	26
5	Synchronizing traffic lights	2 to 3 dBA	26
6	Installing roundabouts	1 to 4 dBA	26
Adapted regulatory measures			
7	Restricting traffic	Up to 2 dBA	27
8	Restricting heavy trucks traffic at night	Up to 7 dBA	28
Reducing speed			
9	Using interactive speed signage	1 to 4 dBA	28
10	Lowering speed limits	1 to 4 dBA	29
11	Installing vertical obstacles: speed	1 to 4 dBA	30
12	Installing chicanes and curb extensions (bulb-out)	Variable	32
Reducing noise propagation using barriers			
13	Noise barriers (or Noise abatement walls)	5 to 12 dBA	33
14	Earth berms as noise barriers	5 to 12 dBA	35
15	Noise-compatible buildings as noise barriers	Up to 13 dBA	36
16	Multiple rows of vegetation - Optimized plant screens - Plant screens: natural woodland - Row of trees (not a barrier)	 - 5 to 6 dBA - 1 to 3 dBA - 0 to 2 dBA	37

Table 3 Summary table of environmental noise reduction measures (cont'd)

No. and title of measure		Expected reduction	Page
Noise from road traffic (cont'd)			
Separation distances (spatial separation or buffer zone)			
17	Establishing separation distances (buffer zones)	▪ 0 to 6 dB: local reduction ▪ 0 to 2 dB: general reduction ▪ Theoretically 3 dBA through doubling the distance (linear source: road noise)	38
Protecting buildings and residents			
18	Designing self-protecting buildings	0 to 20 dBA	39
19	Optimizing building layout (orientation and shape)	Up to 20 dBA	42
20	Soundproofing exposed facades	Up to 7 dBA ($L_{Aeq\ 24\ h}$)	43
21	Setting a limit for inside noise	Variable	44
Low noise emission roadways			
22	Maintaining and repairing damaged surfaces	Variable	44
23	Low-noise emission	Up to 5 dBA	44
Railway noise			
24	Prescribing a separation distance	▪ 0 to 6 dB: local reduction ▪ 0 to 2 dB: general reduction ▪ Theoretically 3 dBA through doubling the distance (linear source)	45
25	Installing noise barriers	5 to 15 dBA	46
26	Installing higher-performance acoustic windows	10 to 30 dBA	46
27	Set noise exposure ceilings in relation to land-use, at the receiving point	Variable	47
28	Implementing layouts that allow operators to stop	Variable	47
29	Implementing measures to reduce railway noise at the source	Variable	48
Air traffic noise			
30	Prohibiting any residential construction in the NEF30 or beyond area	Variable	50
31	Having soundproofing requirements for buildings located in the NEF25 area	Variable	50
32	Adopting operational restrictions and procedures that promote noise reduction	Variable	50
Noise from port facilities			
33	Mapping noise emitted by the port facilities	Variable	52
34	Protecting the facilities by avoiding proximity to sensitive uses	Variable	52
35	Using noise barriers	5 to 12 dBA	53
36	Planning bypass routes	Variable	53
37	Promoting the use of best practices with port authorities	Variable	53

Table 3 Summary table of environmental noise reduction measures (cont'd)

No. and title of measure		Expected reduction	Page
Noise from construction sites			
38	Mitigating noise from construction site activities	Variable (list of several measures)	55
39	Encouraging the use of less annoying back-up alarms	Variable	56
Fixed sources and neighbourhood noise			
40	Mitigating noise from fixed sources through measures used for transport noise		57
40.1	Measure 13 – Noise barriers	5 to 12 dBA	
40.2	Measure 14 – Earth berms as noise barriers	5 to 12 dBA	
40.3	Measure 15 – Barrier buildings	Up to 13 dBA	
40.4	Measure 16 – Multiple rows of plants (optimized arrangement)	5 to 6 dBA	
40.5	Measure 17 – Establishing separation distances	Theoretically 6 dBA through doubling the distance (occasional or geographically restricted/localized source)	
40.6	Measure 18 – Designing self-protecting buildings	0 to 20 dBA	
40.7	Measure 19 – Optimizing building layout	0 to 20 dBA	
40.8	Measure 20 – Soundproofing exposed facades	Up to 7 dBA ($L_{Aeq\ 24\ h}$)	
40.9	Measure 21 – Imposing a maximum value at the receiving point	Variable	
40.10	Measure 32 – Adopting operational restrictions and procedures that promote noise reduction	Variable	
41	Requiring a noise forecast acoustic study for new fixed sources	Variable	58
Planning measures and management practices specific to certain uses			
Specific activities			
42	Snow disposal site (snow dumps)	Variable. Slamming of panels (reduced impact noises of around 15 dBA) (list of several measures)	58
43	Motorized recreation	Variable (list of several measures)	59
44	Sports areas in inhabited areas	Variable (list of several measures)	60
45	Venues for amplified music	Variable (list of several measures)	61
46	Quiet deliveries	Observing sound level of 60 dBA	62
47	Limiting noise for sensitive buildings	Variable	62
Quiet areas			
48	Developing and protecting quiet areas or areas with lower noise levels	Variable	63

6.1 Noise from road traffic

The *Politique sur le bruit routier* (1998) (16) of the ministère des Transports du Québec (MTQ) proposes an integrated planning approach that aims to prevent noise problems by means of shared responsibility, i.e. through road projects planning (MTQ) and land-use planning (municipalities and RCMs). On the one hand, this approach requires RCMs to identify current or projected traffic lanes that represent an anthropogenic constraint and to adopt minimal zoning and subdivision rules. On the other hand, this policy also proposes a corrective approach that allows, in certain circumstances, for the implementation of noise mitigation measures for sensitive areas along roadways, where the noise level is particularly high. This policy may therefore be an interesting avenue for resolving certain situations affected by traffic noise. However, these situations can occur even below the criteria of the *Politique sur le bruit routier*. This policy must therefore be seen as a starting point for an integrated management approach for environmental noise caused by road traffic.

In addition, the MTQ published the guide *Combattre le bruit de la circulation routière* (17) which presents different noise reduction techniques. These measures deal with land-use planning, building design and managing noise-emitting sources. This guide, in addition to going over some of the measures included in the *Politique* and the guide, proposes additional measures for reducing environmental noise.

6.1.1 Decrease in the number of vehicles and traffic management

Measure 1 – Promoting active transportation

Measure 2 – Promoting public transit

Reducing the number of vehicles through a modal shift helps reduce noise, in addition to the favourable impact on road safety and air pollution. Developing active transportation and public transit is key for limiting the number of vehicles and improving the public's health and quality of life.

Active transportation, the least noisy means of transportation, and public transit can be promoted through physical planning based on the concept of "complete streets" (see photo 1). These developments allow for safe and efficient travel for all categories of users, regardless of their age or capacity (pedestrians, cyclists, persons with reduced mobility, public transit users, motorists, truck drivers, emergency vehicles, etc.) (18).

➔ **Limitation:** For an appreciable decrease of 3 dBA, the number of vehicles on a road must be reduced by 50%.

Photo 1 Examples of "complete street" planning: public transit, bike lanes, textured sidewalks and walkways for pedestrians

Dowtown intersection with many features: highly visible pedestrian crosswalks, bike lanes, addition of trees and good pavement marking. City of Charlotte, Mecklenburg County (NC). Photo credit: City of Charlotte, Department of Transportation).

Transformation of an undivided, four-lane boulevard into a "complete street" (traffic flow: 20,000 vehicles/day) with a center turn lane, bike lanes and ramps for sidewalk access. City of Charlotte, Mecklenburg County (NC): East Boulevard. Photo credit: Charmcheck.org

Source: Complete Streets, on Flickr: https://www.flickr.com/photos/completestreets/4686193634

Measure 3 – Having noise emission requirements when replacing public transit vehicles

Public transit vehicles are sometimes a major source of noise. It is possible to have increased requirements for vehicle components in order to reduce noise when renewing the fleet (19).

Vehicles with better sound performance can reduce noise at the source by up to 8 dBA. Hybrid or electric buses also reduce the noise in sections where the speed is under 40 km/h. At low speed, the use of these buses reduces both sound and air pollution (see photo 2).

Photo 2 Using an electric bus in a sensitive environment (Old Québec)

Electric speed travelling at low speed in Vieux-Québec. Photo credit: Nova Bus.

Source: courtesy of Nova Bus.

➔ **Limitations:** Soundproofing vehicles adds to their weight and may make access difficult to certain parts in the engine compartment. Additional costs are also expected upon acquisition (around 3% for a potential reduction of up to 8 dBA per vehicle).

Measure 4 – Decreasing the traffic volume on the target roads

Interventions may help reduce traffic volume on selected traffic lanes, often by redirecting traffic to better suited lanes. For example, decreasing traffic volume on the road that cuts through a village through planning a by-pass road may be especially advantageous. A 20% reduction in traffic volume can reduce the noise by around 1 dB, whereas a high decrease of 50% results in a decrease of 3 dB.

➔ **Limitations:** Generally, a major decrease in traffic volume can be done mainly on secondary roads. To be fully efficient, applying this measure must not result in an increase of speed in the zones in question. Decreasing traffic volume could be an option that is less socially acceptable, too costly or simply not realistic. It must therefore be combined with other measures, such as improving the offer of active transportation and public transit, and developing alternative routes. Deviating a part of the traffic volume could affect previously unaffected areas.

> **Toll to reduce traffic volume –** This is a measure that some road users are willing to pay for, but which poses a fairness problem, in addition to the costs required to implement and manage it. In the experience of London and Stockholm, no decline in the noise levels (0 dB) has been observed. In these two cities, noise reduction has not been as clear as desired, because with the decrease in traffic volume (increased offer of public transit and zone avoidance), there has been an increase in speed (20–23).

Measure 5 – Synchronizing traffic lights

Synchronizing traffic lights helps decrease noise by reducing accelerations and decelerations between lights. A noise reduction of 2 to 3 dB is possible if there is a constant speed between traffic lights and respect for the speed limits (3).

Measure 6 – Installing roundabouts

Compared with intersections, roundabouts (see photo 3) makes driving more fluid and regular, which reduces the noise emitted. They can reduce noise by 1 to 4 dB (L_{Aeq}), compared with intersections, with or without traffic lights. Roundabouts also have the advantage of reducing the number and seriousness of accidents.

➔ **Limitations:** Roundabouts can be a constraint for pedestrian and cyclist safety. They must therefore be designed to ensure the safety of all road users. Small roundabouts with a raised, paved central part (an overrun area to allow passage of large trucks) can create more noise when this section is used by motorists travelling at higher speeds.

Photo 3 Example of an intersection reconfigured into a roundabout

Even in a dense environment, developments that help reduce noise can be carried out. Intersection before and after implementation of aroundabout.
Source: Bendtsen, p. 88 (24).

6.1.2 ADAPTED REGULATORY MEASURES

As a complement to planning, adopting regulatory measures helps reduce noise. However, they are less sustainable when they call on behaviour management.

Measure 7 – Restricting traffic

Traffic restrictions for certain vehicles can reduce traffic volume and environmental noise. These restrictions can affect certain types of vehicles (e.g. motorcycles or heavy trucks), traffic lanes in question (e.g. a downtown area), or a defined period of time (e.g. rush hour).

In a downtown area, during rush hour, prohibitions on access to personal vehicles on certain streets has helped reduce noise by 2 dBA.

The noise level generated by heavy trucks is higher than for cars. Traffic restrictions applied to them can reduce noise levels further. Reducing the proportion of heavy-duty vehicles in one lane from 10% to 0%, whose driving speed is from 50 to 80 km/h, reduces the noise level by 1 to 2 dB. These are essentially European results. However, modelling with software used in North America, the *Traffic Noise Model*, gives different results for a constant speed. The following decreases could be achieved if the proportion of heavy vehicles went from 10% to 0% on a road: by 4 to 6 dBA at 50 km/h and by 2 to 5 dBA at 80 km/h, calculated at distances of 15, 50 and 100 m from the road.

➔ **Limitations:** Despite the impacts during the target periods, prohibiting personal vehicles in certain areas during rush hour would not decrease or would only have a minimal impact on the average noise level in a day. In downtown areas, the restrictions must be offset by an improved offer of public transit. Increasing prohibitions, by limiting the flow of certain vehicles, often leads to major objections from a section of the population. They can also result in the displacement of vehicles to other arterial roads that are not necessarily designed or intended for the volume or types of displaced vehicles.

Measure 8 – Restricting heavy trucks traffic at night

Restrictions for heavy trucks during night-time (see photo 4) are particularly effective. This measure ensures better sleep by removing significant noise peaks (emergent noise) in night conditions. It can help reduce road noise at night by up to 7.2 dB (L_{Aeq} from 10 p.m. to 6 a.m.), based on surveys carried out in Austria.

In Europe, on certain roads or areas targeted by night-time prohibitions, only low-noise heavy trucks traffic that has received approval (certification) is permitted 24 hours a day.

Photo 4 European example of a sign announcing a traffic restriction for heavy trucks at night

Source: Kloth *et al.* (19).

➔ **Limitations:** Despite the decrease in noise peaks during the night, there is apparently no decrease or rather a minimal impact on the daily noise average. Prohibitions may result in transposing a fraction of truck noise during the day, particularly in the early morning.

6.1.3 Reducing speed

Vehicle speed has a major influence on the noise they generate. In addition to directly decreasing the posted speed limits, it is possible to affect traffic speed through measure that involve signage and monitoring. Planning (configuration, calming measures) or static measures (e.g. speed limit signs) also help lower vehicle speed and reduce noise in certain areas, in addition to increasing safety for all road users.

Measure 9 – Using interactive speed signage

Interactive signage or “radar speed signs” or “speed-activated sign” (see photo 5), i.e. posting the legal limit or the vehicle’s speed on a screen, generally helps lower traffic speed by 5 to 10 km/h (some studies report decreases of up to 20 km/h). This speed reduction results in decrease of noise of 1 to 3 dB (L_{Aeq}) for a specific location. Interactive signage is therefore more effective than static signage alone for lowering speeds and has a potential effectiveness that is similar to police monitoring or automated radar monitoring.

➔ **Limitations:** Its effect is highly local, since it is limited to the location of the sign. The long-term effect is yet to be determined.

Photo 5 Examples of interactive speed signage

Source: provided by and courtesy of Traffic Innovation.

Source: MTQ: https://www.transports.gouv.qc.ca/fr/securite-signalisation/securite/Pages/radar-pedagogique.aspx

Measure 10 – Lowering speed limits

Reducing the speed by 10 km/h helps mitigate noise by 1 to 4 dB for light vehicles, and by 1 to 3 dB for heavy-duty vehicles.

Effectiveness conditions for reducing speed limits. Lowering the speed also has an effect on road users because it is an important risk factor for safety.

The effectiveness conditions for this measure are:

- Informing the public about the expected benefits (noise reduction, increased safety, reduced pollution) in order to avoid issues with social acceptance;
- Applying the measure to priority areas;
- Applying control measures (police enforcement) to ensure that speed limits are observed.

→ **Limitation:** The noise reduction that can be achieved is influenced by the effective speeds before the change.

Decreasing the speed is sometimes applied over a time slot, such as in certain European cities (see photo 6). This application aims to limit the disturbance cause by road traffic during the sleeping period.

Photo 6 Example of decreasing the speed limit over a specific period of time (at night)

Nächtliche Geschwindigkeits-begrenzung

Source: Bonacker *et al.*, p. 24 (25).

The layout of certain roads encourages compliance with speed limits. The effect of the layout design to mitigate noise may be increased or consolidated by combining it with other land-use planning (see photo 7).

Photo 7 Example of decreasing the speed limit on a boulevard and separation distances

A layout that promotes compliance with the speed limit, combined with a sidewalk that increases the separation distance with dwellings and that facilitates active transportation. The effect of trees and shrubs on the noise level in this layout is very limited. In fact, a row of trees or shrubs does not result in a significant decrease in the noise level because one needs a sufficient density of trees (and trunks) for noise reduction. However, in this case, the trees are used as a visual barrier (or even transition) between the noise source and the receiving environment (see also measure 16).

Source: Google Street View (Sept. 2015).

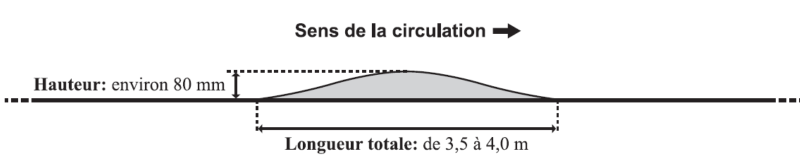
Mandatory stops in a row – This measured is applied to reduce speed and to discourage taking a route, but it does not offer any benefit for noise reduction. This is due to noise peaks caused by stops and restarts. These peaks are up to 10 dB noisier than the ambient noise level. Successive stops in a row therefore increase the average noise by around 2 to 3 dBA compared with homogeneous traffic.

Measure 11 – Installing vertical obstacles: speed humps

Rounded speed humps (see figure 7 and photo 8) may help significantly lower speed, thereby helping to reduce noise.

The lowered speed achieved by speed humps varies from 11 to 18 km/h, with a noise reduction of 2 dBA (L_{Aeq}), provided that the traffic consists primarily of light vehicles (low proportion of heavy-duty vehicles). They also lead to a decrease of maximum noise (maximum A-weighted sound pressure level [L_{Amax}]): heavy-duty vehicles (2 dBA), buses (4 dBA) and cars (10 dBA). The average cost was under $5,000 in 2009, according to the municipalities that the MTQ consulted.

Figure 7 Diagram of a speed hump



Note: Speed humps help reduce vehicle speed and traffic noise. Source: MTQ (26).

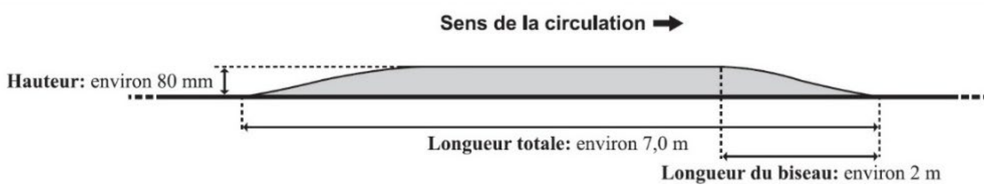
➔ **Limitation:** The spacing between obstacles must allow for regular driving, because accelerations-decelerations increase noise.

Photo 8 Round speed humps combined with a pedestrian crosswalk

Note: Speed humps are often combined with a pedestrian crosswalk to improve their safety. Photo credit: Richard Martin, INSPQ.

- **Limitations:** In some cases, a greater nuisance has been reported by residents living near this type of obstacle due to the noise peaks caused by vehicles going over these obstacles. Attention must also be paid to traffic deviated to other adjacent roads to avoid these obstacles. Other vertical deviations (e.g. flat speed humps [see figure 8], cushions) lower the traffic speed of heavy-duty vehicles less than round speed humps. These types of obstacles therefore tend to increase the maximum noise when trucks or heavy-duty vehicles go over them, as well as during vehicle acceleration and deceleration. However, they may be employed near park areas when residences are further away (see photo 9).

Figure 8 Flat speed humps



Source: MTQ (21).

Photo 9 Flat speed humps with a pedestrian crosswalk

Flat-top speed humps should not be used in residential areas with heavy-duty vehicle traffic. However, when placed near a park, they ensure safety and quiet. Photo credit: Richard Martin, INSPQ.

Flat-top speed humps – It should be noted that these speed humps are less effective in reducing noise in areas where several heavy-duty vehicles pass through due to their configuration and the fact that they clear the obstacle at a higher speed than automobiles. They are still useful in areas where residences are further away.

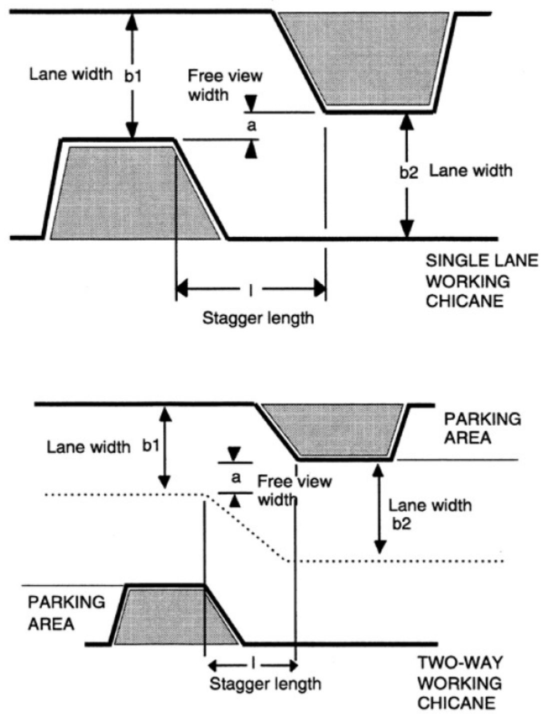
Measure 12 – Installing chicanes and curb extensions (bulb-out)

Chicanes involve narrowing the traffic lane or creating an artificial deflection ("S" curves) with the aim of forcing drivers to slow down (see photo 10, on the left). This means helps ensure that the established speed limits are observed. As for curbs (sidewalk) extensions, which also narrow the traffic lane, they also provide more space for trees. In addition, curbs extensions allow for pedestrians to cross the road more safely due to the narrower roadway.

➔ **Limitations:** Chicanes, that is, very pronounced "S" deflections (see photo 10, on the right), likely have a negative effect on the noise level and nuisance. Chicanes may increase the noise level for automobiles by up to 3 dB due to the accelerations and decelerations needed to clear the chicane (22). These layouts must be used with caution, especially on traffic lanes with large trucks, but less pronounced deflections can be done. In the case of curbs extensions, noise reduction has not been quantified. Finally, the addition of trees must not negatively affect safety.

Photo 10 "S" deflection at the entrance of a neighbourhood in Candiac and examples of chicanes

An "S" curve helps reduce vehicle speed and the noise level.
Photo credit: Gabrielle Manseau.
Source: Tremblay *et al.*, p. 32 (27).



Chicanes with pronounced deflections are likely to result in accelerations and decelerations that will increase the noise level.
Source : Ellebjerg *et al.* (22).

6.1.4 REDUCING NOISE PROPAGATION USING BARRIERS

Noise barriers can limit noise propagation to sensitive areas by reducing the noise transmitted. Even if they are used mainly to reduce the propagation of road noise, noise barriers can also help mitigate the noise from fixed sources, particularly where the space does not allow for other noise reduction measures to be used.

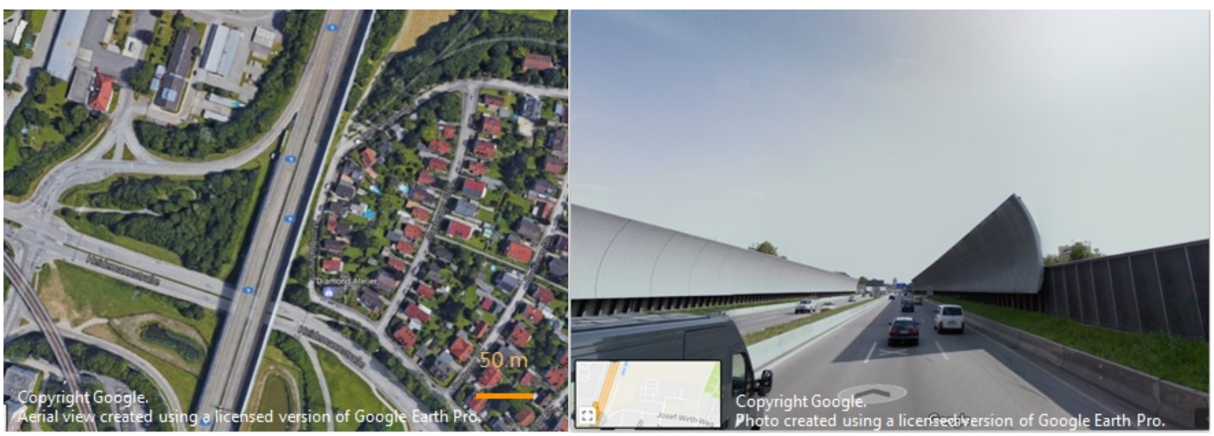
Measure 13 – Noise barriers (or Noise abatement walls)

Noise reduction of 5 to 12 dBA can be achieved for areas protected by noise abatement walls (see photos 11, 12 and 13). The effectiveness of barriers varies in particular based on the materials used, their arrangement, height and shape of their top edge. Effectiveness can be increased if the barrier is combined with other measures (e.g. road surface that emits less noise, lowering the speed limit, etc.). The combination of several types of barriers (e.g. adding multiple rows of plants) helps maximize the effectiveness of this measure.

Photo 11 Examples of noise barriers in high-density urban environments and for a residential area along a highway and its interchanges

Noise abatement walls can be used in high-density urban environments. The wall profile, which closes in on the road at the highest point, increases their effectiveness, as is the case in Italy, in a highly dense environment.

Source: Bendtsen *et al.*, p. 38 (29).



Barrier 9 m high erected in 2006 in Munich on highway A-9 in an area where 147,000 vehicles pass through every day, including 5% heavy traffic.

Source: Google and Google Earth Pro in Beckenbauer 2017 (30).

Photo 12 Example of a noise barrier developed in Québec

Side view from residences.

Side view from the highway.

This noise barrier was developed along highway 116 in the Saint-Hubert borough in Longueuil. The wavy texture of the wall-barrier's surface makes it structurally more resilient. Its curved top edge, which closes in on the highway, as well as its layout, in sections with varying depths, contributes to the effectiveness of noise reduction. The presence of plants, in front of or behind walls, plays more of an aesthetic role, because the small amount of plants used cannot effectively reduce the noise. It should be noted that visual integration efforts have been made in this noise barrier with respect to the materials and colours used, in order to promote social acceptance of the project.

Source: photos provided by the Direction de l'environnement at MTQ.

Photo 13 Example of a noise barrier installed in Québec with additional plant component

Green noise barrier installed in an area near highway 117, in Laval, north of boulevard Dagenais, in order to protect buildings located on rue de l'Ombrette.

Green noise barrier installed along a part of highway 15, in Laval, along rue Guillemette. The wall is primarily made up of soil retained by a geotextile membrane that is inserted in a wooden structure. The entire wall is surrounded by vegetation (willow).

Source: photos provided by the Direction de l'environnement at MTQ.

A noise barrier standard is available from MTQ (28). The estimated cost for a concrete wall (MTQ, personal correspondence, 2017) varies from $3 to 6 million per kilometre.

➔ **Limitations**: The presence of noise barriers may result in a potential partitioning effect. They can free up more space in terms of soil compared with earth berms as noise barriers. Their limited height does not protect upper levels or sensitive buildings that are farther away (provides local protection). Noise levels will be substantially lower only for the acoustic “shadow zone” behind the wall. Sound abatement walls may affect the immediate environment (microclimate, winds, sunshine, etc.), and its aesthetics may be a critical factor for social acceptability.

Parameters that influence the cost of barriers – Several parameters can have an influence on the costs of noise barriers, which explains the rather wide range of estimated costs. These parameters include:

- the specific design of the planned barrier;
- the height;
- the length;
- the materials used;
- the public services (or urban technical networks) to be displaced;
- the costs of expropriation;
- the soil bearing capacity, which may limit the choice to certain types of foundations or require the installation of major foundations);
- etc.

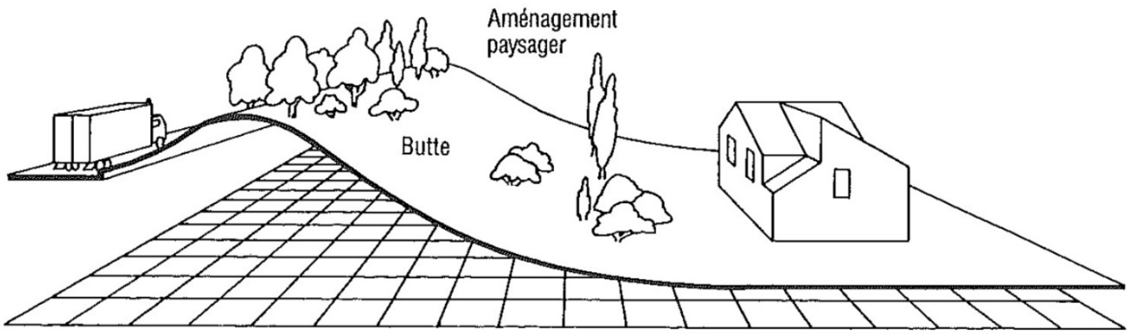
Measure 14 – Earth berms as noise barriers

Earth berms (see figure 9) require more space on average than noise abatement walls. Noise reduction of 5 to 12 dBA can be achieved for the protected area. The effectiveness of the barrier varies based on its layout and height. Effectiveness can be increased if the barrier is combined with other measures (e.g. road surface that emits less noise, lowering the speed limit, etc.). The combination of several types of barriers (e.g. adding a noise barrier at the top or vegetation) helps maximize the effectiveness of this measure. Compared with a noise abatement wall of a similar height, earth berms are slightly more effective.

This measure also has the advantage of being generally less costly than noise abatement walls. In addition, the costs can sometimes be less in the event material (soil or other) is available after construction activities on the site.

➔ **Limitations:** Requires more space than walls. However, the space required may be reduced, notably through using a retaining wall. The measure is more difficult to apply in an already built environment. When the earth berm is high, there may be a partitioning effect due to the considerable mass of this structure, although the top of the berm is further away compared to a wall. However, this effect can be lessened by adding a wall-barrier on top, which helps reduce the height of the earth berm. The limited height of earth berms does not protect upper levels or sensitive locations that are farther away (provides local protection).

Figure 9 Example of an earth berms and noise-reduction landscaping



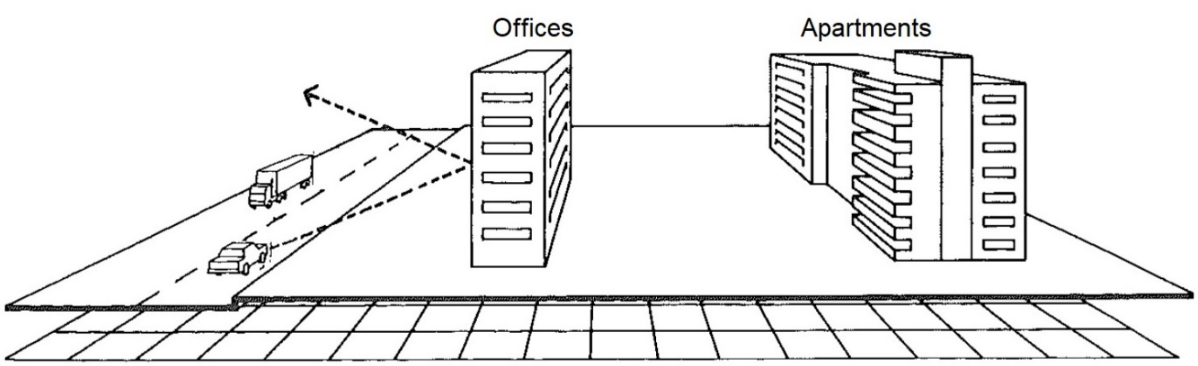
Source: MTQ (17).

Measure 15 – Noise-compatible buildings as noise barriers

Commercial buildings can be located between a noise source and sensitive locations (see figure 10). This measure is also discussed in the section on protecting dwellings and residents (see measures 18 Designing self-protecting buildings et 19 Optimizing building layout (orientation and shape)).

Noise reduction of up to 13 dBA can be achieved for the protected area. The effectiveness varies depending on the layout and height of the barrier building. Effectiveness can be increased if the barrier is combined with other measures (e.g. road surface that emits less noise, lowering the speed limit, etc.).

Figure 10 Using buildings as noise barriers



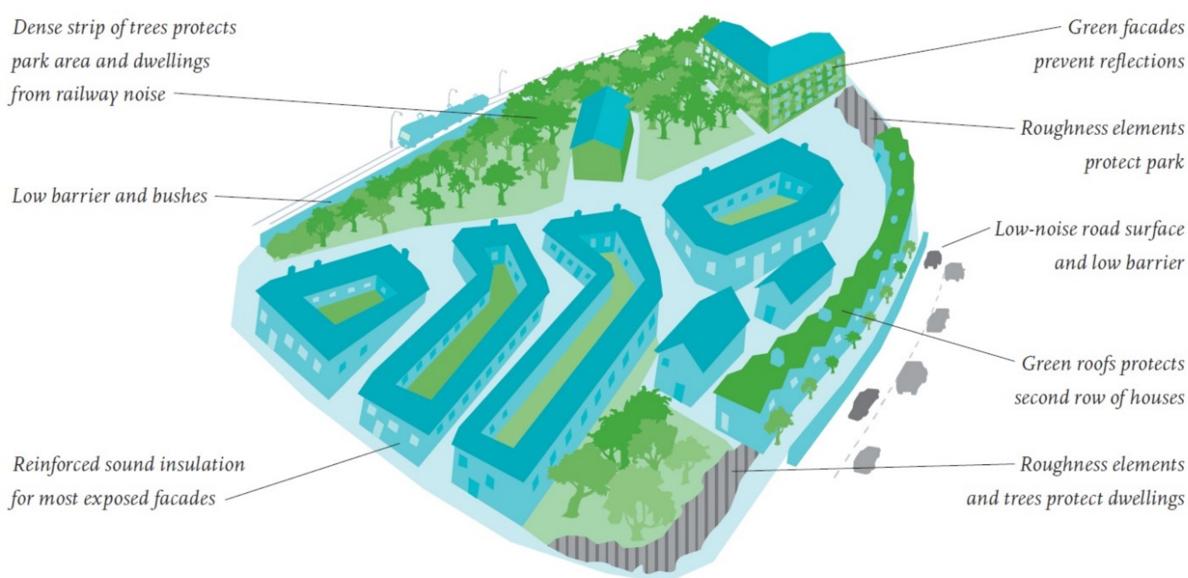
Source: MTQ (17); translation by the authors.

➔ **Limitations:** This measure is especially suitable along major highways in peri-urban areas. It is not always possible to plan the installation of compatible commercial uses near sensitive locations that we wish to protect (saturation phenomenon).

Measure 16 – Multiple rows of vegetation

A depth of **optimal vegetation** (15 m wide or more) is equivalent to a conventional concrete barrier 1 to 1.5 m high, placed directly along the highway and can help reduce noise by 5 to 6 dB at 50 metres from a traffic lane (31). If the depth is at least 30 m, the reduction could approach 10 dBA. A highly effective plant barrier relies mainly on three parameter that will “block” the propagation of noise: the extent of the plants over 15 m and more in depth, plants near the noise source and the tree trunk diameter and their arrangement (optimal planting for blocking noise) (see figure 11). A dense plant barrier (wooded area with **“natural” plants**), with a depth of approximately 30 metres, provides mitigation ranging from 1 to 3 dBA. A **row of trees** placed near the street can provide a reduction not exceeding 2 dBA.

Figure 11 Examples of plant barriers combined with other noise reduction solutions



Combining solutions to protect the quiet sides of noise-exposed dwellings

Note: The design of the greenbelt is important: trunk spacing, trunk diameter, depth, planting layout, shrub density (including bushes, hedges, etc.). A depth of optimal vegetation (15 m or more) is equivalent to a conventional concrete barrier 1 to 1.5 m high, placed directly near the highway (reduction of 5 to 6 dB).
Source : Zetterquist, p. 36 (31).

One of the advantages of this type of barrier is the psychological effect it can have on residents. By concealing the noise source from them, although the sound level is not always significantly reduced, the vegetation can lead to better acceptance. In addition, trees themselves can be a source of pleasant sounds that can mask ambient noise, such as during windy periods. Finally, a document prepared by the MTQ suggests certain arrangements and planting possibilities (see Additional references*:* Dagenais *et al.*, 2007; Zetterquist, 2013).

➔ **Limitations:** The presence of vegetation does not lead to a systematic reduction of the noise level, because its density must be sufficiently large to have a noticeable effect. Full potential is achieved when the vegetation is mature. This type of barrier is mainly effective in the summer and only offers local protection.

There are others ways to use vegetation to mitigate environmental noise (green facades, green roofs, etc.). For a summary of green noise reduction methods and their efficiency, see Zetterquist (2013; p. 46–47) in Additional references.

6.1.5 SEPARATION DISTANCES (SPATIAL SEPARATION OR BUFFER ZONE)

Determining, maintaining and protecting a minimum separation distance between a noise source and sensitive or vulnerable areas is a basic measure. These distances often refer to unoccupied spaces or even those allocated for a non-sensitive use.

Measure 17 – Establishing separation distances (buffer zones)

Establishing a minimum separation distance between a noise source and sensitive areas is a measure whose effectiveness can widely vary. According to European experts, applying separation distances provides local reduction of road or railway noise from 0 to 6 dB, whereas overall reduction varies from 0 to 2 dB. It is difficult, even impossible, to predict its effectiveness without predictive simulations (modelling) that account for conditions that influence noise propagation: nature of the noise source, type of built environment, land topography, weather conditions (wind, temperature, humidity, absorption or reflection of sound waves, etc.). For road noise (a typical linear source), each time the distance doubles between a receiver (e.g. a sensitive location) and the road , there is a theoretical decrease of 3 dBA.

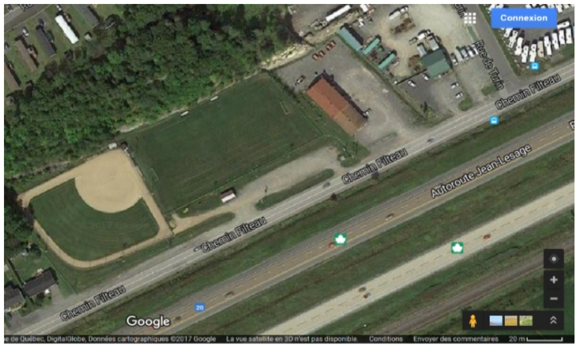
This measure can be combined with other solutions to increase the effectiveness: barrier building (non-sensitive uses), barrier comprising multiple, dense rows of plants, etc.

Conditions for the effectiveness of separation distances – Applying the principle of reciprocity may ensure a protective distance with respect to the noise source causing the annoyance:

- The distances must be established by taking into consideration possible later expansions or modifications;
- Predictive simulations help in better predicting the effectiveness. However, one must consider favourable situations for propagation in the simulations, that is, conditions that correspond to a maximum noise for residents (see Figure 4 on the propagation factors).

→ **Limitations:** The cost of the land can be a limitation. This measure may be difficult to apply in an already built environment, where the space needed is hardly available. Ideally, buffer zones should not be used for an outside sensitive use (e.g. sports fields, parks) (see photos 14 and 15). The effectiveness of separation distances can vary under certain conditions (e.g. for high-rise buildings or when the propagation conditions are favourable for noise).

Photo 14 Example of a non-optimal use of land buffer: municipal park unprotected from road noise



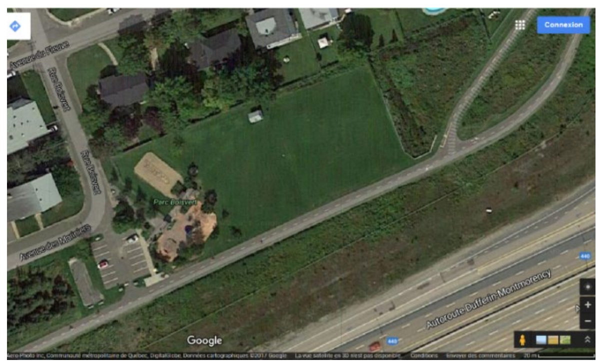
Soccer and baseball fields facing a service road and highway 20. Satellite image.

Source: Google, Aéro Photo inc., Communauté métropolitaine de Québec, DigitalGlobe (Sept. 2016).

Photo 15 Example of a non-optimal use of separation distance: municipal park and residences unprotected from noise along a highway

Park and residences along highway 440 (Dufferin–Montmorency).

Source: Google, Aéro Photo inc., Communauté métropolitaine de Québec, DigitalGlobe (2017).



6.1.6 Protecting buildings and residents

Measure 18 – Designing self-protecting buildings

Self-protecting buildings means using one of its parts as a noise barrier for rooms that are sensitive to noise. As summarized in table 4, self-protection measures can reduce noise up to 20 dB (orientation of the openings, design of balconies, walls, roof, windows and doors, interior soundproofing, etc.). With the optimal layout of noise sensitive living spaces (rooms), the reduction can reach 10 dB, which is also a significant decrease in the noise.

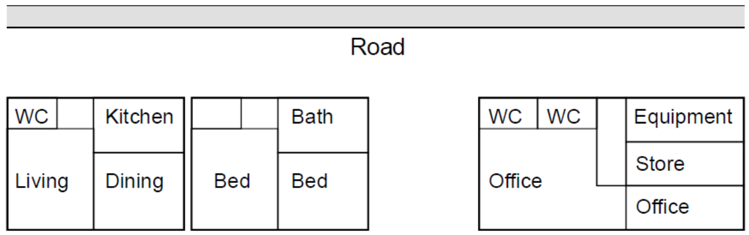
Table 4 Example of gains made by various noise mitigation measures applied through optimal design of a building against noise

Type of measure	Reduction
Self-protecting building (protection by parts of the building)	0 – 20 dB
Layout of the living spaces	0 – 10 dB

Translated from: European Commission Working Group 5¨Noise Abatement, p. 33 (32).

The rooms that are most sensitive to noise must be placed at the opposite side of the noise source, i.e. in the following order of importance: bedrooms, living room, dining room, kitchen, playroom, entrance hall, bathroom, wardrobe, storage space (see figure 12). For balconies, wing walls (see figure 13, on the right) or adjacent buildings can serve as protection.

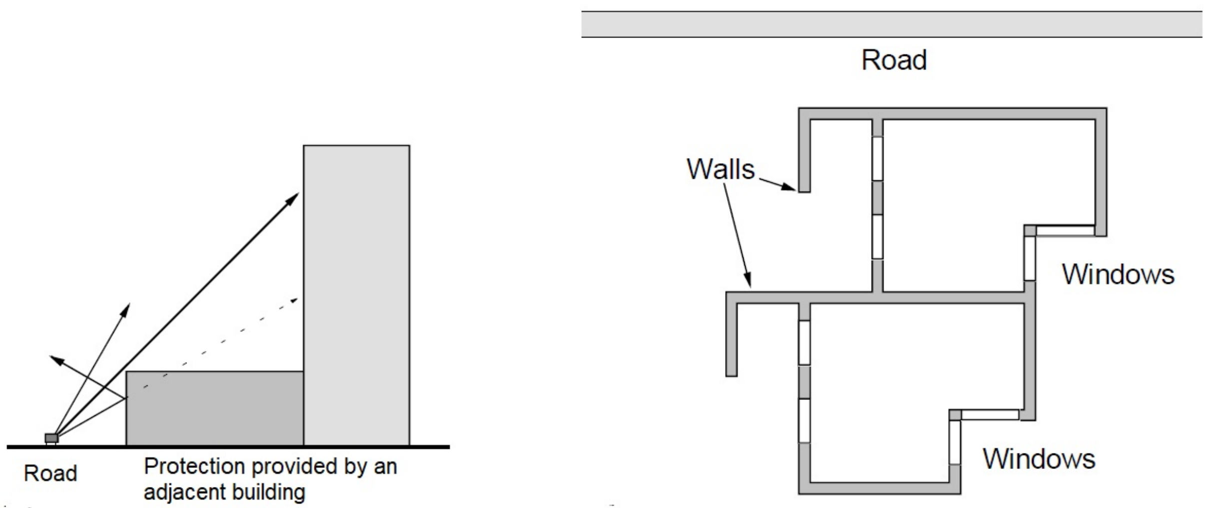
Figure 12 Example of a noise-compatible optimal living space layout



Note: Spaces that require lower exposure to noise, such as bedrooms or living rooms (on the left) and working spaces (on the right) must be situated opposite any noise sources (e.g. the road).

Source : European Commission Working Group 5 Noise Abatement, p. 31 (32)and Kloth (19).

Figure 13 Examples of self-protected buildings



Note: On the left, it is possible to incorporate sections directly in a building during design so that they act as noise barriers for rooms that are more sensitive to noise, with the goal of considerably reducing inside noise. On the right, solid wall extensions (wing walls) can also reduce internal noise and can limit noise on balconies. In addition, one must plan the layout of operable windows away from noise sources.

Source: European Commission Working Group 5¨Noise Abatement, p. 31 (32) and Kloth (19); left figure annotated by the authors.

Protecting sensitive buildings from noise – Designing sensitive buildings (residences, schools, childcare and daycare centres, retirement homes, hospitals, etc.) requires special attention. The following aspects should be considered:

- Location:
  - for example, avoiding the vicinity of police or fire stations (see photo 16), high-traffic boulevards or highways;
  - promoting installation near parks (see photo 17);
  - maintaining a separation distance from major public roads (or using noise barriers). Play areas must not be affected by noise to allow children to socialize with one another and for undisturbed communication with educators.
- Orientation:
  - ensure that the building and the outside play area (schools, childcare and day-care centres) are not facing the noise, as shown in photo 16;
  - opt for placing operable windows on the quieter sides;
  - ensure that windows that open up to traffic lanes are sealed and have a glazing with higher acoustic performance.

➔ **Limitation:** In some cases, the lack of operable windows on the side of noise sources could negatively affect the building's ventilation. It would then become necessary to use an appropriate ventilation system.

Photo 16 Example of a layout not to use for a childcare and daycare centre

The play area of this childcare and day-care centre is fully open to a public road and there are windows on the noisy sides (police station and traffic lane). Photo credit: INSPQ.

The vicinity of a police or fire station, as well as the proximity of a major traffic lane do not allow for a desirable noise level for childcare and day-care centre activities. Satellite image.

Source: Google, Aéro-Photo inc. DigitalGlobe, U.S, Geological Survey, USDA Farm Service Agency.

Photo 17 Example of a favourable layout for a childcare and day-care centre, taking into account environmental noise

The childcare and day-care centre is located in a quiet environment, near a school and municipal park, and on a street with a speed limit of 30 km/h. The distant play area is only partially open to the public road. Satellite image.

Source: Google Earth, Aéro-Photo inc. Communauté métropolitaine de Québec, DigitalGlobe. Map data (2018).

Measure 19 – Optimizing building layout (orientation and shape)

For better building layout, it is possible to maximize the barrier effect (see measure 15 Noise-compatible buildings as noise barriers) and to minimize noise reflections by exterior walls. Noise can be reduced by up to 20 dB with this measure.

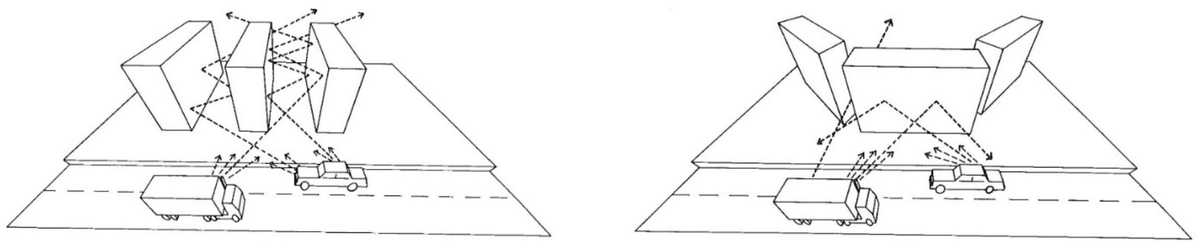
For example, photo 18 shows a U-shaped building that is directly facing a noise source (highway), whose form concentrates the noise and increase its reflections. Through better orientation of the buildings, it is possible to create protected areas and to limit facades exposed to noise (see figure 14, on the right).

Photo 18 Example of a non-optimal shape design for a building exposed to road noise

Apartment building unprotected from noise near a highway. With its U-shaped architecture, it is facing the noise source and has many balconies. This form means that the noise is reflected and concentrated. In the left-hand corner, the bird's eye view clearly shows the form of the building, which is facing the noise source.

Source: Image: Google (Street View); Inset: satellite image, Google, DigitalGlobe, Sept. 2016.

Figure 14 Orientation of buildings in relation to roads influences the sound environment



Note: On the left, the building orientation does not allow for effective noise reduction and the reflections propagate the noise. On the right, the inner courtyard is protected, and only one of the building facades is exposed to noise. If an interior layout protects some rooms from noise (bedrooms, living room, dining room), and if the balconies are not exposed to the noise source, the residents will have better health and quality of life, and the traffic lane can be used to its full potential. In addition, the oblique orientation in relation to the road helps minimize the noise received.

Source: MTQ (17).

Land-use conditions for optimal buildings layout against exterior noise:

- Place the greatest distance possible between the source and the sensitive activity;
- Place noise-compatible activities between the noise source and sensitive areas: parking area, open spaces, shopping or commercial areas;
- Develop in clusters instead of in a line, which tends to be more exposed to noise, in addition to posing a problem for road safety with the proliferation of driveways;
- Orient the buildings with an angle of approximately 45 degrees from the noise source to reduce the noise reflection on the walls and to protect openings.
- Use the natural space, the form of the buildings and plants in a sufficient concentration and that are arranged to make a barrier (see measure 16 Multiple rows of vegetation).

Measure 20 – Soundproofing exposed facades

For new constructions in areas that are already affected by noise, in addition to requirements regarding building layout and design, it is necessary to set soundproofing requirements. In areas already affected by noise, one must plan for soundproofing requirements for the exposed facades, especially for renovation programs.

In Norway, soundproofing the facades of housing units affected by road noise has shown a considerable decrease in the noise level by 7 dBA ($L_{Aeq\ 24\ h}$) with closed windows, in addition to reducing the proportion of people highly annoyed by the noise from 42% to 16%.

➔ **Limitations**: There are no provisions or guidelines for outdoor noise in the *National Building Code*. Soundproofing dampens the noise received, but it does not in any way reduce the negative effects of noise for outdoor uses (courtyard, parks, etc.). Improving existing dwellings remains a challenge. Although municipalities can adopt specific rules for construction (s. 118) under the *Act respecting land use planning and development* (CQLR, c. A-19.1), they do not usually use it to require specific measures for soundproofing from outdoor noise.

Conditions for the effectiveness of measures that involve design and soundproofing:

- Inform the developers, principal contractors and builders about better designs for buildings and about soundproofing, and require that they consider noise from the planning stage of their project;
- Incorporate the prevention of the nuisance caused by noise when analyzing the issuance of a construction permit (requesting that a noise forecast modeling study be carried out by the proponents);
- Use specialized sound resources in the absence of requirements for outside noise in the *National Building Code of Canada 2015*. It is important to note that the soundproofing or sound insulation of exposed facades differs from the requirements set out in the current Code, since these requirements only cover certain inside noises (airborne and impact sound transmission);
- Only opt for soundproofing if the other solutions (noise barriers, separation distances, management measures, etc.) are inapplicable or have not resulted in sufficient reduction.

Measure 21 – Setting a limit for inside noise

While it is not a measure that directly affects the emitted noise levels, it is possible to set an exposure limit inside buildings. For example, Europe has limits for inside noise generated by national roads during the day, which is generally between 30 and 40 dBA (L_{Aeq}). Night-time limits are lower by 5 to 10 dBA, but are not below 30 dBA, however (29).

➔ **Limitation:** Setting a limit for inside noise must be paired with measures to reduce noise at the source, mitigation measures or soundproofing to ensure that the limit is observed and that it provides benefits.

6.1.7 Low noise emission roadways

The composition and condition of roads surfaces have an impact on noise from vehicular traffic.

Measure 22 – Maintaining and repairing damaged surfaces

Cracks increase the tire-road contact noise and accentuate the “body noise” from heavy-duty vehicles. A regular maintenance and repair of damaged pavements helps noise abatement, and also adds to their longevity. In sensitive areas, noise should be one of the criteria used for selecting roads that requirement maintenance or repaving. For example, it would be advisable for a local road infrastructure intervention plan to incorporate a criterion involving areas sensitive to road noise for prioritizing interventions.

Measure 23 – Low-noise emission pavements

The tire-road contact noise becomes the predominant source of noise starting at 30–35 km/h for cars (light vehicles) and 55–60 km/h for trucks. Some types of pavements help significantly in reducing noise emission and its propagation. These surfaces have mostly been developed in Europe and are highly effective. In Québec, these kinds of surfaces exist, but do not perform as well for noise reduction, because they are different from the ones used in Europe (porous asphalt) due to the climate.

The difference between the different types of surfaces used on roads in Québec is about 5 dBA, excluding concrete-cement surfaces, which are generally noisier.

The selection criteria for the asphalt used by the MTQ include the consideration of the tire-road contact noise. Among the asphalt recognized by the MTQ, three (IEG-10, SMA-10 and EGM-10) perform the best for noise reduction. The criteria are accessible on the MTQ website (33).

Combined with other measures (e.g. speed reduction), a better performing pavement could, in some cases, avoid the need for installing a costlier noise barrier.

➔ **Limitations:** There is no acoustic categorization system for surfaces to assist in decision-making. However, the MTQ is carrying out a comparative study to identify the least noisy types of concrete surfaces.

For transportation noise from **non-road sources** – Like the measures proposed for road noise, the best noise reduction outcomes are achieved by applying a combination of different measures. These can involve the emission source, the propagation of the sound and protection of residents (receiver).

Some of the proposed measures can be difficult to apply in built environments, particularly in densely built-up area, or result in significant costs, as is the case for noise barriers.

6.2 Railway noise

Reducing railway noise (see photo 19) requires the awareness and cooperation of several stakeholders, namely the federal or provincial government, depending on the network. In some case, it may be advantageous to map out the noise and monitor noise levels at different periods in order to identify the locations most affected and the best measures to implement to reduce exposure to noise. However, the fact remains that a layout and management that consider constraints will limit the effects of people's health and quality of life in a sustainable way.

Photo 19 Freight train (cargo)

Photo credit: Richard Martin, INSPQ.

Measure 24 – Prescribing a separation distance

Implementing a separation distance between railway transportation infrastructure and sensitive locations can be an effective measure for reducing noise levels (see photo 20). This kind of provision should be found in the zoning by-laws. The distances set must be maintained to protect not only people, but also the infrastructure. Separation distances can also reduce the vibrations transmitted by trains to buildings that are near rails and the annoyance that they cause. Through this measure, local reduction may reach up to 6 dB, with a possible overall reduction of up to 2 dB, according to European experts.

Photo 20 Moving railway tracks to maintain a separation distance: quality of life and intermodal strategy

In Valleyfield, the main rail track of rail carrier CSX, which passed through the downtown, was moved outside of sensitive areas. The financial involvement of the city, company and Gouvernement du Québec resulted in the establishment of an intermodal terminal in the industrial and port park south of the city, which is near highways.

Source: courtesy of INFOSuroit.com.

For example, in 1981, the CMHC recommended caution for any residential construction located less than 100 m from a railway (13). The Federation of Canadian Municipalities (FCM) and the Railway Association of Canada (RAC) recommend carrying out an acoustic study for certain distances (see measure 27 Set noise exposure ceilings in relation to land-use, at the receiving point). Since the effectiveness of the distances mentioned by these organizations was not assessed, they must be validated by a study, because they could prove to be insufficient in several cases.

➔ **Limitation:** The effectiveness varies based on the distance, but also based on the topography and the noise propagation conditions (see figure 4 on the factors that influence propagation). A case-by-case analysis with a predictive acoustic study is advisable in order to apply the appropriate distances from the area and, if necessary, to add additional measures.

Measure 25 – Installing noise barriers

As with road noise, the use of noise barriers helps reduce sound levels near railways. The type of barrier used (wall, earth berms, barrier building, multiple rows of vegetation) will depend on the constraints and local needs.

Two types of noise barriers have been identified, and they perform differently:

- low barriers that are 0.5 to 1 m tall, approximately 1.7 m from the track, are only effective with barriers (fairing) that covers the car or wagon wheels (from 2 to 11 dBA);
- higher barriers, from 1.5 to 4 m, usually located 4 m from the track, can result in a reduction of 5 to 15 dBA.

➔ **Limitations:** The effectiveness varies based on the barrier height and the distance between the source and the exposed site. The effect on noise reduction remains very limited for high-rise buildings. More the noise barriers restrict access to the tracks. The additional maintenance cost must be taken into account.

Measure 26 – Installing higher-performance acoustic windows

Soundproofing is the last measure applied when the other means put in place do not allow for the noise exposure limits to be observed. Windows, due to their lower soundproofing capacity, are often one of the main entrance points for bruit inside buildings. Replacing windows on the facade most exposed to environmental noise with higher-performance acoustic windows can reduce the noise by 10 to 30 dBA.

➔ **Limitation:** The decrease in noise varies depending on the acoustic performance of the new windows and on the types of windows that are replaced. The most significant reductions (30 dBA) have been made in Europe when replacing single glazed windows.

Measure 27 – Set noise exposure ceilings in relation to land-use, at the receiving point

Like road noise (see measure 24 Prescribing a separation distance), it is possible to adopt regulations that impose a limit on the noise level for given locations (e.g. inside sensitive locations or buildings). For locations where this new noise limit is lower than existing sound levels, compliance with this limit will result in noise reduction.

To observe the noise limits, the FCM and the RAC (34) recommend that any new sensitive use within an area of influence from the noise undergo an acoustic study to evaluate the noise impact. According to these two associations, the minimum zones to consider based on railway activities are as follows:

- Rail marshalling (marshalling yards, freight rail yards): 1,000 m;
- Principal main lines: 300 m;
- Secondary main lines: 250 m;
- Principal branch lines: 150 m;
- Secondary branch lines; spur lines: 75 m.

➔ **Limitations:** The potential noise reduction varies depending on the existing noise exposure levels before imposing the limit. This kind of measure must be supported by implementing other management measures (noise barriers, soundproofing, separations distances for new constructions or infrastructure, acoustic studies, etc.) that will allow for the limit to be observed.

Measure 28 – Implementing layouts that allow operators to stop train whistling at a public grade crossing

Sound-signalling devices of trains (whistles) are a significant source of noise and nuisance for residents living near railways. Through an established procedure (see inset), the use of the whistle can be eliminated by replacing it with barriers and signal lights.

Conditions to stop using sound-signalling devices (35):

- The request must be made by the municipality with the railway company concerned;
- The residents and Transport Canada must be informed;
- The installation of barriers and signal lights is required.

➔ **Limitations:** The process may vary depending on whether it is a railway under federal or provincial jurisdiction. Risk mitigation measures may also include other measures, such as installing fences along the railway right-of-way. A safety analysis specific to each grade crossing covered by the whistle exemption is often necessary. The cost of the work falls to the municipality that makes the request, and this work is generally not eligible for a grant.

Measure 29 – Implementing measures to reduce railway noise at the source

Several source reduction measures result in substantial reductions of railway noise (see table 5). Applying these measures, in collaboration with external partners, can be an interesting solution, especially in built environments, where applying planning measures can be more difficult.

Table 5 Measures to reduce railway noise at the source

No.	Measure	Expected reduction
29.1	**Implementing a program to lubricate (lubrication stations) and grind tracks to avoid squeal noise**	10 to 12 dBA
29.2	**Replacing cast iron tread-brake blocks by composite brake blocks on freight wagons)**	8 to 10 dBA
29.3	**Installing absorbers for wheels and rails dampers (with other resilient track technologies) near the noise affected areas.**	2 to 7 dBA

→ **Limitations:** The proposed measures require the awareness and cooperation of external partners, i.e. the operators and owners of the railway wagons and infrastructure. Some measures may already be applied; in that context, the expected gains could be lower.

Marshalling yards (rail yards, classification yards) – They are among the noisiest sources and cause the greatest nuisance. Their layout requires that noise be properly accounted for: considerable separation distances, retarders (rail brakes) (see photo 21), railway lubrication stations (friction modifiers), noise barriers, limit in the development of nearby sensitive uses (reciprocity), etc. Furthermore, some operational procedure can also be implemented: schedule that reduces work at night, reduced activities near residential areas, limiting the engine operation of shunter (switcher) locomotives used for marshalling when they are waiting, better soundproofing of the engine, etc.

→ **Limitations:** Railway companies might not be in favour of reducing work schedules at night due to the effect on their productivity.

Photo 21 Braking of wagons by retarders in a marshalling yard

Example of a retarders (rail brake) in a marshalling yard in Europe. This kind of device limits impact noises when assembling trains by slowing down the rail cars before they are hitched to other cars. The retarders can reduce noise by 5 to 20 dBA.

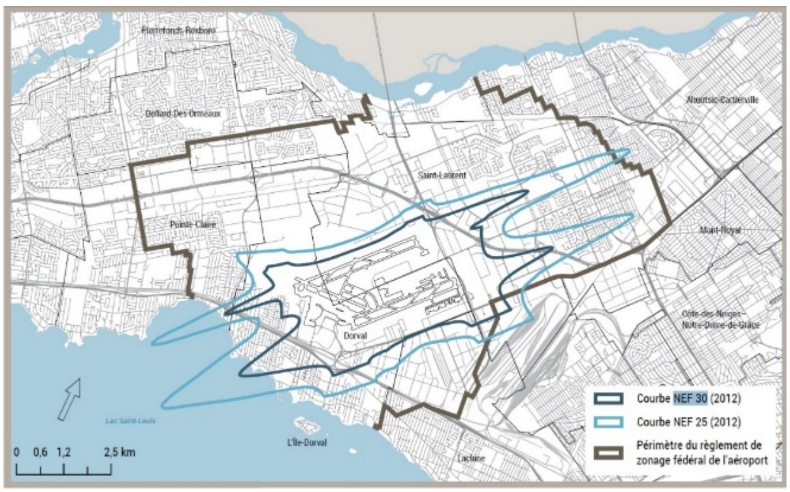
Source: Réseau ferré de France, p. 8 (36).

6.3 Air traffic noise

The decision to plan and determine the location of an airport or private airfield is under federal jurisdiction. Thus, just like for railway noise, reducing air traffic noise requires the awareness and cooperation of several stakeholders: the airport administration, municipality, transporters, Transport Canada and residents of the noise-affected areas.

Conditions for good planning – It is important to acquire and analyze the noise exposure forecast (NEF) produced by the airport (see photo 22). This map, which shows noise-affected areas, is key for guiding choices related to land-use planning in the vicinity of an airport. The NEF, proposed by Transport Canada for planning and managing the areas near airport facilities, provide a measurement of actual and forecasted aircraft noise. It is a complex measure that represents all the noises produced by the airplanes at an airport.

Photo 22 Example of a noise exposure forecast (NEF) from the Montréal–Trudeau Airport (contour map), specifying the constraint zones



Source: Conseil d'agglomération de Montréal, p. 120 (37).

Negative effects associated with air traffic noise begin appearing at level NEF_{25}.* Starting at level NEF_{30}, houses must be protected by additional soundproofing and effects on outside noise (courtyards, balconies) or when opening windows cannot be avoided. The NEF_{30} area is therefore not compatible with residential use and Transport Canada recommends that new residential development should not proceed.

These maps were produced by the largest airports (e.g. Montréal–Trudeau, St-Hubert-Longueuil and Jean-Lesage in Québec City), but also for some regional airports, in an *ad hoc* way, as part of a project launched in 2013 by the Conseil des aéroports du Québec. At the time, this project was funded by the MTQ's Air Transportation Assistance Program. It is therefore relevant to have maps produced with the levels of current service. In some cases, it is also necessary to have maps with the expected or projects noise levels, considering, among other things, a change in the infrastructure's use, the type of airplanes used and the operation frequency.

* Compared with the dBA, a value of NEF25 corresponds to approximately 56 dBA (L_{dn}), and NEF33 to 65 dBA (L_{dn}). The NEF value represents the noise produced by all aircrafts types operating at an airport, based on the actual and predicted aircrafts movements, by runways and based on day and night events occurrences.

Measure 30 – Prohibiting any residential construction in the NEF_{30} or beyond area

This recommendation is consistent with what Transport Canada says: “New residential development is therefore not compatible with NEF_{30} and above, and should not be undertaken.” (38). In addition, in the case of new airports, Transport Canada recommends not authorizing the use of land in the NEF_{25} area for sensitive uses. This prohibition is already in place in Ontario.

➔ **Limitations:** Even if municipalities have limited powers in terms of airport layout, it is important to observe the principle of reciprocity in development restrictions in the NEF_{30} area. While it may be difficult to restrict new developments in an already built environment, the fact remains that adding new residential developments should be avoided.

Measure 31 – Having soundproofing requirements for buildings located in the NEF_{25} area

According to Transport Canada, new residential developments in areas affected by noise should include measures for better soundproofing the building interior:

> Annoyance caused by aircraft noise may begin as low as NEF 25. It is recommended that developers be made aware of this fact and that they undertake to so inform all prospective tenants or purchasers of residential units. In addition, it is suggested that development should not proceed until the responsible authority is satisfied that acoustic insulation features, if required, have been considered in the building design. (38).

The National Research Council of Canada (NRC) has published some technical documents on soundproofing against aircraft noise and upon which acoustics firms can rely to propose specifications that can be applied for outside noise (see Additional references: Bradley *et al.*, 1998; Bradley *et al.*, 2001).

➔ **Limitation:** Given the nature of air traffic noise, soundproofing buildings is less effective than for road noise. Installing better soundproofed windows in bedrooms, even with an appropriate ventilation system, may lead to a negative perception of the indoor climate and does not fully eliminate the noise nuisance. In Québec, whether it is in the *National Building Code* or the *Construction Code* (CQLR, B-1.1, r.2), there are no requirements for noise coming from outside. Soundproofing buildings does not have an effect on outdoor noise levels, which can limit outdoor uses at certain times in the year.

> **Improving the soundproofing of sensitive buildings** – Near european and american airports, programs are in place to improve the protection of sensitive buildings against air traffic noise. However, these programs have never existed in Canada. The costs of a soundproofing programs for existing buildings can be funded from a specific noise charge required from transporters and passengers using the airport (“polluter pays” type measure). This is the case for airports such as as London–Heathrow, Amsterdam Schiphol, Paris–Orly, Charles de Gaulle Airport in Paris, Bordeaux–Mérignac, Nice Côte d’Azur, Beauvais–Tillé, and Basel Mulhouse.

Measure 32 – Adopting operational restrictions and procedures that promote noise reduction

Several management measures, such as operating restrictions and operational procedures, can be implemented to reduce air traffic noise (see table 6). All the suggested measures will be useful for public airports.

However, in the case of private airports, two measures may be adapted (operating hours and flyover restrictions), not to mention separation distances for new housing.

➔ **Limitation:** Requires the awareness and cooperation of external partners (municipalities, airport, operators, NAV Canada and citizens).

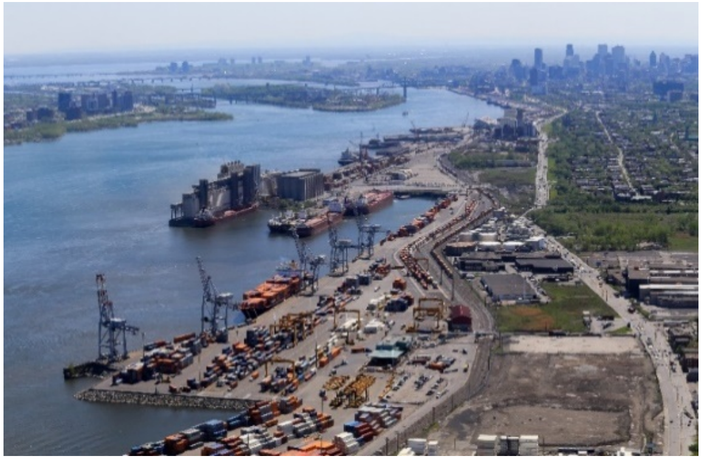
Table 6 Operating restrictions and operational procedures that promote noise reduction

No.	Measure	Comments and clarifications
32.1	▪ **Real-time noise monitoring systems for the largest airports** ▪ **Periodic noise levels monitoring at smaller airports (e.g. regional airports)**	▪ Promotes the implementation of noise reduction measures and compliance with the limits set to protect neighbouring areas. The noise levels may be associated with data on the flights, the weather and complaint monitoring. The noise levels data should be publically accessible in real-time (with a slight delay for safety reasons).
32.2	**Having a curfew for the noisiest airplanes**	▪ Protects sleep; ▪ Encourages the use of less noisy airplanes at night or for early departures in the morning.
32.3	**Implementing a continuous descent approach**	▪ Considered a “win-win” choice; ▪ Reduces the surface area of the zone exposed to noise.
32.4	**Using runways far from sensitive uses at night and noise preferential routes**	
32.5	**Prohibiting engine tests at night**	▪ To be combined with setting up noise barriers in the test areas.
32.6	**Implementing a specific noise charge f**	▪ Helps fund noise mitigation measures; ▪ Results in noisy aircraft avoiding airports with noise charges.
32.7	**Setting noise limits at the airport**	▪ Should be paired with monitoring noise levels.
32.8	**Restricting flyovers above sensitive-use areas**	▪ For tourist flights (airplanes and helicopters).
32.9	**Setting up and participating in a complaint management committee**	▪ Recommendation of Transport Canada. Must include participation of residents affected by the air traffic noise.

6.4 Noise from port facilities

Activities related to marine navigation and shipping (e.g. port facilities) are under federal jurisdiction. Actions to control the noise from these activities require not only awareness, but also cooperation from port authorities, municipalities and residents in the areas affected by the noise pollution. Administration of the largest ports usually falls to the federal government. Noise abatement is aimed at the noise emitted by vessels, rolling stock (which often includes railway equipment and wagon marshalling) and operations. These are often characterized by loud noises (impact noises), tonal noises (back-up alarms) and low frequency noises (rumbling from engines, compressors, generators, etc.). Low frequencies have the distinctive feature of propagating over greater distances and being more annoying.

Photo 23 Port activities



Aerial view of a part of the Port of Montréal.

Loading a container ship.

Photos credit: Port of Montréal. Source: courtesy of the Port of Montréal.

Measure 33 – Mapping noise emitted by the port facilities

Preparing a noise map helps in planning developments near port facilities, while accounting for local characteristics. It helps identify noisy sites in all the facilities, which helps the port authority manage the sound environment.

➔ **Limitation:** More static means compared with continuous noise monitoring (see measure 38.6 Conducing continuous active and real-time noise monitoring).

Measure 34 – Protecting the facilities by avoiding proximity to sensitive uses

Ports should not get closer to sensitive-use areas, just like sensitive uses should not get closer to port facilities. As a result, municipalities should apply the principle of reciprocity using a zoning by-law preventing the development of sensitive uses in the areas exposed to noise from port facilities, as well as the development of port activities near areas intended for sensitive uses (see measure 17 Establishing separation distances (buffer zones)). However, applying a minimum separation distance between a port and sensitive-use areas is a measure whose effectiveness can widely vary. Apart from the distance, other conditions, such as weather or topography, influence the noise propagation.

➔ **Limitation:** Measure that may be difficult to apply in an already built environment where the space needed is hardly available.

Measure 35 – Using noise barriers

The use of noise barriers or barrier buildings (e.g. hangars, containers positioned as barriers) helps protect residential sites that are already affected by noise. The effectiveness is similar to what can be obtained for road noise (from 5 to 12 dBA for the protected area) and will vary based on the height of the barrier and surrounding buildings (see measures 13 Noise barriers (or Noise abatement walls), 14 Earth berms as noise barriers, 15 Noise-compatible buildings as noise barriers, 16 Multiple rows of vegetation). This measure is already used in European ports.

Photo 24 Example of a barrier

A barrier building or stacking several containers can help limit noise propagation to sensitive locations.

Source: Port of Montréal.

- **Limitations:** The limited height of the noise barriers does not protect upper levels or sensitive buildings that are farther away (provides local protection). They can result in a partitioning effect, affecting the immediate environment (sunlight, wind, etc.) and their aesthetics can be a critical factor for acceptance.

Measure 36 – Planning bypass routes

This measure allows for transport to access the ports to be done outside sensitive areas. If such routes cannot be built, it is appropriate to put in place traffic management measures with the municipality, which will aim in particular to limit the noise, as well as improve the safety of residents due to heavy vehicles traffic (see measures 5 Synchronizing traffic lights, 6 Installing roundabouts, 7 Restricting traffic, 8 Restricting heavy trucks traffic at night, 9 Using interactive speed signage, 10 Lowering speed limits, 11 Installing vertical obstacles: speed humps, 12 Installing chicanes and curb extensions (bulb-out)).

- **Limitations:** In general, management measures that address behaviours (except those involving planning) are not as sustainable as planning that dictates how to behave.

Measure 37 – Promoting the use of best practices with port authorities

Best practices specific to ports have been identified in order to reduce or limit noise in surrounding areas (see table 7).

- **Limitations:** Some ports are subject to legislation and federal regulations, which can limit the actions or requirements that an RCM or municipality could have.

Table 7 Best practices for reducing noise from port facilities

No.	Measure	Comments and examples
37.1	**Setting-up of real-time noise monitoring**	▪ Helps manage the noise and limit the effects in sensitive areas. The Port of Vancouver has such a measure in place.
37.2	**Limiting noise at night**	▪ Concentration of activities that take place 24 hours a day to certain sections of the ports, far from sensitive uses.
37.3	**Applying less noisy loading or transshipment procedures**	▪ Soundproofed pumps on ships, closed conveyors, quieter electric generators, back-up alarms with a broadband signal, etc. (see measure 39 Encouraging the use of less annoying back-up alarms).
37.4	**Connecting vessels to shore-side electricity**	▪ Limits the noise from auxiliary engines, electric crane engines, etc.
37.5	**Ensuring that truck transporting containers have shock absorbers (rubber plates) on their platforms**	▪ Limits impact noises.
37.6	**Soundproofing residences**	▪ When the actions taken do not help reduce the noise in sensitive environments (interventions on facades or windows) (see measure 20 Soundproofing exposed facades).
37.7	**Using less annoying back-up alarms**	▪ Many cranes and trucks are equipped with back-up alarms (*beep-beep-beep*) that can cause noise annoyance over great distances (see the alarms suggested in measure 39 Encouraging the use of less annoying back-up alarms).
37.8	**Helping develop a noise action plan for each port facility**	▪ Discussions between the municipality and the port authority in a context of management and sustainable development. ▪ Measure that requires the awareness and cooperation of external partners.
37.9	**Participating in the implementation of a complaint management committee that includes residents**	▪ Collaboration and openness measure that helps in implementing solutions.

6.5 Noise from construction sites

Densely built-up urban environments brings its own share of construction activities, development and redevelopment. Since construction work is carried out in build environments, near or within residential areas, measures must be taken to limit and mitigate the noise from this work to lessen the impact on quality of life of the residents in the affected area. These measures must also pay attention to road noise from heavy truck traffic, and this problem should be incorporated in work-site planning. In addition, accounting for the presence of several adjacent work-sites and their cumulative impact helps avoid sound “escalation”.

Measure 38 – Mitigating noise from construction site activities

Table 8 lists the measures that help limit noise annoyance caused in the vicinity of construction sites.

Table 8 List of measures to mitigate noise from construction sites

No.	Measure	Comments and examples
38.1	**Requiring low-noise emission equipment**	▪ The equipment sold in North American is different from what is used in Europe, even if it is often the same manufacturers who adapt or design their machines or tools based on the market requirements. For example, when issuing a permit, the New York City provides a vendors' list of low-noise emission products or machinery that must be used in priority. ▪ The MTQ has basic rules concerning requirements for **low-noise emission** equipment for roadwork sites.
38.2	**Providing sufficient and realistic information on the noise emitted by a construction site for people living near a construction site**	▪ Especiallyimportant for medium- or long-term sites.
38.3	**Installing temporary noise barriers (walls, sound screens) (see Photo 25)**	▪ Reduces noise by up to 10 dBA (under optimal conditions).
38.4	**Taking into account the time of day and sensitive uses in choosing exposure noise limits and mitigation measures**	▪ For example, limiting non-emergency work in the evening and prohibiting it at night near sensitive locations; ▪ The MTQ has developed a standard and proposes specifications as a roadwork site noise management tool (39, 40); ▪ The Ministère de l'Environnement et de la Lutte contre les changements climatiques (MELCC) proposes guidelines for noise levels from industrial construction sites (41) to limit noise from construction activities of fixed sources.
38.5	**Planning quiet deliveries**	▪ Allow for equipment or goods delivery during night or early in the morning, provided that appropriate practices are used (see Additional references: specific guide for construction of the UK Department of Transport, 2014).
38.6	**Conducing continuous active and real-time noise monitoring**	▪ Measure for the largest work-sites. Monitoring systems help make the data publicly accessible in real time on the Internet, in addition to providing alerts to site manager and operators in order to comply with the limits set. ▪ In use at the MTQ.
38.7	**Setting penalties in the event of non-compliance with the imposed conditions**	▪ Measure incorporated in the contracts and subject to noise monitoring.
38.8	**Applying soundproofing measures to residences and dwelling units**	▪ For example, installing storm windows, air conditioning units to compensate for the inability to open windows and to mask the noise, etc. ▪ Used on a work-site for the underground highway ("Big Dig") in Boston.

Note: The specifications that the MTQ adopted for noise management on construction sites involving its network's infrastructure provides more details on this Ministry's requirements and on a number of the measures summarized in the previous table (40).

Photo 25 Temporary noise barriers for construction sites

Plywood barriers with a soundproofing product limit nuisance in areas affected by medium- and long-term work.
Source: Lafontaine *et al.*, p. 12 (42).

Measure 39 – Encouraging the use of less annoying back-up alarms

The noise from back-up alarms (*beep-beep-beep*), that are used to draw attention to danger when reversing vehicles on work-sites, may be a source of annoyance in the surrounding area and are often the subject of complaints. These alarms are mandatory under the *Safety Code for the Construction Industry* (c. S-2.1, r.4; s. 3.10.12, paras. 1, 2 et seq. 3c).

There are so-called "broadband" sound alarms that emit a different sound (*psht, psht*), which is deemed less aggressive to the ear. The use of broadband alarms on work-site vehicles is an effective measure for reducing the annoyance caused to people living near a work-site.

Since some municipal by-laws require tonal alarms (*beep-beep-beep*), these could be modified to include broadband alarms, with the mandatory training described below (see *Limitation*):

➔ **Limitation:** This type of alarm complies with the criteria set out in the *Safety Code for the Construction Industry*, including standard SAE J994. However, given that the use of this type of alarm is still relatively recent, it is essential that adequate training to recognize these alarms is given to all staff and individuals who visit the work-site to ensure their safety.

6.6 Fixed sources and neighbourhood noise

Using the same area or the same building for different uses can lead to conflicts. Environmental noise, whether it is industrial or commercial in nature, or comes from recreational activities, is often a decisive factor in this type of conflict.

While there are no quantified noise limits, it is nevertheless possible to refer to memorandum of instruction 98-01 from the MELCC on the "Traitement des plaintes sur le bruit et exigences aux entreprises qui le génèrent", which is used for project authorization, or Hydro-Québec's standard "Bruit audible généré par les postes électriques- TET-ENV-N-CONT001".

The following sections recall how some of the measures presented for transport noise can be applied to mitigate noise from fixed sources. In addition, they present reduction measures that are specific to certain uses (motorized recreation, venues for amplified music, noisy sport areas).

Considering environmental noise from fixed and neighbourhood sources when land-use planning aims to allow for accountability and the co-existence of various activities, as well as to ensure residents' quality of life.

Measure 40 – Mitigating noise from fixed sources through measures used for transport noise

Several noise management measures for noise from road traffic or for noise from non-road traffic can be applied for noise from fixed sources or neighbourhood noise. Table 9 summarizes these main measures, and also provides clarifications and examples of applications for fixed sources. It is worth consulting the presentation of the measures in their respective section for a complete description, including their limitations.

Table 9 Best practices for reducing noise from fixed sources

No.	Measure	Comments and clarifications
40.1	**Measure 13 – Noise barriers**	
40.2	**Measure 14 – Earth berms as noise barriers**	▪ For electric power stations, for example.
40.3	**Measure 15 – Buildings as noise barriers**	
40.4	**Measure 16 – Multiple rows of trees (optimized arrangement vegetation belt)**	
40.5	**Measure 17 – Establishing separation distances**	▪ For fixed sources, each time the distance is doubled reduces the sound level by 6 dBA (compared with 3 dBA for road noise). ▪ For industrial facilities, mine sites, quarries, sand pits, electric power stations, etc.
40.6	**Measure 18 – Designing self-protecting buildings**	▪ To be combined with measure 19.
40.7	**Measure 19 – Optimizing building layout**	▪ For industries: dust extractors or ventilators should be located on the side opposite to a sensitive area or, even, their soundproofing should be improved.
40.8	**Measure 20 – Soundproofing exposed facades**	▪ Wind turbines, industries, etc.
40.9	**Measure 27 – Imposing a maximum noise exposure value at the receiving point**	▪ To be paired with audit measures to ensure that the set limit is observed.
40.10	**Measure 32 – Adopting operating restrictions and operational procedures that promote noise reduction**	▪ Wind turbines: operating restrictions where certain weather conditions that promote noise propagation; ▪ Industries and businesses: avoid delivery hours at night due to back-up alarms and handling of materials or noise from the equipment used; ▪ Concentrate the noisiest activities during the day; ▪ Develop quiet deliveries (see measure 46 Quiet deliveries); ▪ Introduce broadband back-up alarms (see measure 39 Encouraging the use of less annoying back-up alarms); ▪ Covered delivery dock (barrier) to limit outside noise.

Measure 41 – Requiring a noise forecast acoustic study for new fixed sources

Noise can be prevented or better managed when an acoustic study is required upon installing new fixed sources of noise. Among potentially noisy fixed sources, there are industries, new businesses (restaurants, patios, bars, etc.) or certain recreational activities (race tracks, sites for music or pyrotechnical shows firing ranges, etc.).

An acoustic forecast study (see section 4.3) helps estimate the noise levels, the potential for annoyance and identify the mitigation measures that could be applied by the proponent for any new activity introduced in an environment. Aside from projects where a noise forecast acoustic study is required by the MELCC, its requirement by municipalities and RCMs for new activities could ensure their sustainability by limiting the impacts on the residents' health and quality of life, as well as complaint management. The approach could also include a requirement to consult the neighbourhood.

Reciprocally, establishing sensitive uses near noisy industries or businesses, as well as converting businesses into housing units in areas affected by the noise, require a noise impact assessment.

- ➔ **Limitations:** In Québec, this type of study is usually required for major projects submitted for public consultations, such as those submitted to the consultation process of the Bureau d'audiences publiques sur l'environnement (BAPE). In addition, it is necessary to control the effectiveness of the mitigation measures in place following the initial acoustic study. This validation will be done through a follow-up acoustic study.

6.7 Planning measures and management practices specific to certain uses

Several uses, whether they are one-off or recurring, may require the implementation of planning or management practices to limit the impact of environmental noise. The following sub-sections present measures that can be implemented for these different types of use, in addition to presenting some advice for developing and protecting quiet areas.

Some of the proposed measures require the awareness and cooperation of external partners.

6.7.1 SPECIFIC ACTIVITIES

Measure 42 – Snow disposal site (snow dumps)

Snow disposal sites (see photo 26) are characterized by noisy operations that often take place at night. These sites also generate a significant traffic volume for a long period. Near sensitive locations, the planning and mitigation measures presented in table 10 should be considered.

Photo 26 Example of a snow disposal site

Example of a mound on a snow disposal site for Québec City (see measure 42.3 Erecting a snow wall as noise barriers at the site boundary on the side with sensitive locations). This kind of mound (snow wall) can be used as a noise barrier to protect sensitive populations. However, at the beginning of the winter season, other measures should be used due to the reduced amount of snow available to erect this kind of mound. Photo credit: Camille Simard, Radio-Canada Québec.

Source: Camille Simard – Twitter: https://twitter.com/camillesimard/status/705455361554259968

Table 10 Planning and mitigation measures for snow disposal sites

No.	Measure	Comments and clarifications
42.1	**Establishing separation distances**	▪ The fixed distance must respect an outside noise level of 40 dBA at night or the ambient noise level prior to snow disposal site installation (the higher of the two).
42.2	**Erecting a temporary noise barrier**	▪ Before the winter season begins, the noise barrier can be made of plywood and rock wool—noisy side—held up by a wire fence. This measure aims to absorb the noise as long as a snow wall is not in place.
42.3	**Erecting a snow wall as noise barriers at the site boundary on the side with sensitive locations**	▪ This measure must be implemented during the day, after the first precipitation events.
42.4	**Requiring mufflers in good condition for all equipment**	▪ Snow blowers, bull dozers, loaders, power shovels and trucks that access the site.
42.5	**Prohibiting and controlling the use of engine breaks on traffic lanes and on-site**	
42.6	**Requiring the installation of shock absorbers on the panels of dump trucks**	▪ Limits the impact noises caused by panel slamming. This kind of device reduces impact noises by around 15 dBA.
42.7	**Planning the site by ensuring that access roads have the least noise impact possible**	▪ Reducing the speed reduces the noise and increases safety on the site and the access roads.

Measure 43 – Motorized recreation

The noise from motorized recreation includes the noise from off-highway vehicles (OHV) and the noise from all kind of race tracks (stock car, motocross, F1, etc.). Table 11 proposes several measures that can be applied to reduce these kinds of noise, some of which are taken from the *Act respecting off-highway vehicles* (CQLR c. V-1.2; ss. 6, 12 and 27).

The measures to be implemented for these types of use are varied and must be adapted to each situation, by taking into consideration the specific features of the environments. For example, a race track used every weekends requires the application of several measures to limit its impact on residents' health and quality of life.

Table 11 Planning and mitigation measures for noise from motorized recreation

No.	Measure	Off-highway vehicles	Race tracks
43.1	**Establishing minimum separation distances**	X[A]	X[B]
43.2	**Specifying usage constraints based on the time of day**	X[A]	X
43.3	**Limiting the speed based on the distance from residences**	X[A-B]	
43.4	**Setting up temporary noise barriers**	X	X
43.5	**Treating path surfaces (e.g.: grading trails, spreading snow, etc.)**	X	
43.6	**Consulting residents ahead of time**	X	
43.7	**Prohibiting vehicles without mufflers at certain times for races, and always for off-highway vehicles**	X	X
43.8	**Monitoring noise levels in real time**		X
43.9	**Implementing integrated planning to mitigate the effects**	X	X
43.10	**Following up on complaints, in cooperation with residents**	X	X

[A] Legal provisions of the Act respecting off-highway vehicles (CQLR, c. V-1.2 ; s. 12). For more information, see the *Guide d'aménagement et d'entretien des sentiers de motoneige au Québec* by Joly and Marcil (2011), in Additional references.

[B] On flat land, distances of several km may be necessary.

Measure 44 – Sports areas in inhabited areas

Practising sports is very important for health, but in the case of noisy sports areas, some measures help better regulate these activities so as to limit noise annoyance.

In a municipality, practising certain sports or activities (skateboarding, basketball, soccer, baseball, football, free swims in public pools, etc.) sometimes produce a significant level of noise that causes a nuisance when there are dwelling units nearby. Table 12 proposes some measures that help reduce their impacts on the sound environment.

Table 12 Planning and mitigation measures for noisy sports areas

No.	Measure	Comments and examples
44.1	**Analyzing and predicting noise impacts at the design stage**	
44.2	**Using materials and surfaces that limit impact noises**	▪ For skateboards, for example (see the guide by Robinson-Chouinard *et al.* in the Additional references).
44.3	**Maintaining separation distances**	▪ The area with the noisiest activity will be placed as far as possible from sensitive locations, but attention must be paid to not reduce accessibility. For example, carefully choosing the location within a park.
44.4	**Prohibiting and monitoring night-time use**	
44.5	**Prohibiting the use of compressed air flutes during indoor and outdoor competitions**	▪ Limit the nuisance in the neighbourhood and protect the spectators' hearing.

Noise barriers – Noise barriers are to be avoided in parks. These produce a partitioning effect and can result in undesirable behaviour.

Measure 45 – Venues for amplified music

Music venues, whether indoor or outdoor, expose the public to potentially very high noise levels. Table 13 presents the measures proposed for these two kinds of venues. Some of the measures proposed, such as ceiling levels (average noise and maximum level), can reduce the environmental noise levels around and in the venues. Other measures, such as continuously displaying the noise level during the event, is aimed more at protecting the auditory health of exposed individuals in a venue.

Some boroughs or municipalities have made best practices guides for these types of uses (see, for example, the guide for the Plateau-Mont-Royal borough in Additional references for other examples of measures for noise in bars, performance spaces and restaurants).

Table 13 Planning and mitigation measures for music venues

Type of noise	No.	Measure	Comments and clarifications
Indoor noise	**45.1**	**Limiting indoor noise (limit for the average and maximum level; layout of the premises)**	▪ Set a limit for the average and maximum noise level; ▪ The layout of the premises has an influence on noise propagation and on the participants or spectators' exposure.
	45.2	**Continuous display of the noise level**	▪ This information would allow the public to adjust its exposure time based on the received noise levels.
	45.3	**Planning a hearing recovery area where the noise level is under 85 dB**	▪ To limit hearing loss.
	45.4	**Providing hearing protection**	
	45.5	**Requiring adequate soundproofing to limit indoor noise from going outside**	
Outdoor noise	**45.6**	**Modelling the sound propagation (acoustic modeling study)**	
	45.7	**Choosing suitable sites**	
	45.8	**Maintaining separation distances**	
	45.9	**For outdoor shows, installing a sound system that is both optimal for the site and limits propagation off the site**	▪ Orientation of the speakers, delay towers, etc.
	45.10	**Managing the noise levels in real time for outdoor spectators**	▪ Monitor the noise during shows; ▪ Account for weather conditions (e.g. wind direction).
	45.11	**Establishing use constraints based on the time of day (night)**	▪ Mainly the respect the rest period for the residents of a site at night (e.g. at 11:00 p.m.).
	45.12	**Carrying out acoustic follow-up**	
	45.13	**Establishing noise limits for outdoor shows with acoustic monitoring**	▪ This measure has been used in the Ville-Marie boroughs in Montréal, for example.

Measure 46 – Quiet deliveries

Quiet delivery is an innovative practice put in place to allow for less noisy deliveries by using adapted vehicles, equipment and materials. The noise level emitted by this activity must remain under 60 dBA (according to the PIEK certification[III]). This limit helps reduce emergent noise ("emergence"). In addition to its effect on noise, this measure allows deliveries in the evening and at night (outside peak hours) and limits greenhouse gases by avoiding congestion. Practices that allow for quiet deliveries include:

- using adapted delivery vehicles (quieter loading-unloading vehicles and equipment, etc.);
- specific road networking planning (e.g. area with lowered sidewalks);
- specific vehicles modifications for noise abatement at delivery points (modifying floor coverings, door opening/closing, etc.).

Some guides are available to help in implementing this kind of measure, such as the publications by the UK Department for Transport (2014 and 2015), by Hayes *et al*. (2007), Finlay (2008), as well as the Mayor of London (2018), which can be found in *Additional references*.

> **Quiet delivery** – In France, in 2012, a chain of stores won the "Décibel d'Or" award in the "City and transport" category by applying the quiet delivery measure on 130 trucks in its fleet of vehicles, which serves 300 stores spread throughout large urban areas.

➔ **Limitation:** Implementing this kind of measure requires the awareness and cooperation of various external partners (manufacturers of equipment and delivery vehicle conversion, dealers, training staff, communication, etc.), as well as amendments to regulations.

Measure 47 – Limiting noise for sensitive buildings

Schools, hospitals, retirement homes and childcare and day-care centres are all considered sensitive buildings because they concentrate vulnerable populations. The measures for childcare and day-care centres were discussed in measure 18.

Schools

The key elements to protect school buildings and their students against outdoor noise are: the sound quality of location chosen and the use of traffic management measures applied to limit noise (measures 4 to 12), e.g. the noise from heavy vehicles. The indoor noise level is affected by outdoor noise and has an impact on student learning (see *Effects on psycho-social health: cognitive effects*). Integrating these buildings (schools, hospitals, retirement homes and childcare or day-care centre) into parks or near parks (see photo 27) is still a measure that allows for a separation (buffer) zone. In addition, by making sure to integrate vegetation in an optimal manner (for blocking noise; see measure 16 Multiple rows of vegetation), this will further contribute to a healthier sound environment, but also take action on air pollution and climate change.

Photo 27 Example of an insufficient separation distance near a highway for schools and a park

Source: Google, Aéro Photo inc., Communauté métropolitaine de Québec, DigitalGlobe, 2017.

[III] Developed in the Netherlands for quiet deliveries. The certification makes it possible to distinguish vehicles that observe the peak level of 60 dBA (L_{Amax}) for loading and unloading, at a 7.5 meter distance.

Hospitals

Hospitals are now often embedded in the urban fabric and have been stripped of their buffer zone. For existing buildings, managing traffic near these buildings, namely by limiting speed and heavy vehicle traffic (see measures 7 Restricting traffic, 8 Restricting heavy trucks traffic at night, 9 Using interactive speed signage, 10 Lowering speed limits), are still measures that help provide the quiet required for hospitalized individuals to rest and recover. When building new hospitals, expanding or renovating existing buildings, self-protection measures against noise should be integrated into the structure (see measure 18 Designing self-protecting buildings).

Retirement homes

These buildings should be located in areas that are hardly affected by transport noise and should avoid lands in the vicinity of major roads or high-traffic commercial areas. These types of buildings should also apply self-protection measures for noise (see measure 18 Designing self-protecting buildings). Openings and balconies also require protection from traffic noise.

6.7.2 QUIET AREAS

Measure 48 – Developing and protecting quiet areas or areas with lower noise levels

Areas with lower noise levels have a positive contribution to the public's health and quality of life. As a result, they would benefit from being both protected and developed. They can also be integrated with other measures to fight against air pollution, heat islands and to facilitate surface water management. This measure can involve small and large spaces, as well as conservation areas. Environments strongly affected by noise in particular could benefit from such spaces being maintained or integrated. The noise levels for these spaces are lower than the ambient noise of an area or allow one to hear natural noises (conservation areas, parks, etc.). To maximize their impact on quality of life in urban environments, these spaces should allow for a noise level of at least 5 dBA below the area's ambient noise.

The definition of these areas does not depend solely on noise level, but also refers to noise perception. For example, the presence of natural noise sources, which is often perceived as being more acceptable, can be beneficial (see photo 28). Furthermore, several assessment criteria can be combined for quiet areas that are suited to every environment and that have various functions that go beyond the low level of noise (see table C-2 in the French version of INSPQ's advisory on environmental noise [3]). Noise is therefore only one of the components of these locations, whose benefits are also influenced by other factors (e.g. vegetation, layout of the location, play areas, accessibility, safety, etc.).

Photo 28 Example of a small urban park

The noise level at Paley Park, in New York City, in the morning and afternoon, is around 70 dBA, whereas in the late morning and early afternoon, it is around 66 dBA. A special feature of this park is a wall with a waterfall. This is a good example of using a "natural" noise source to mask surrounding noise. For other views of the park, visit the New York Architecture site: http://www.nyc-architecture.com/MID/MID141.htm. Photo credit: Lou Giansante. Source: New York Beyond Sight – Art Education for the Blind: http://www.nybeyondsight.org/paley-park.shtml

➔ **Limitation:** Depending on their location, some sites may require police surveillance at night to ensure the neighbourhood is quiet.

7 Conclusion

Considering the risk for health and quality of life, and their growing role, environmental noise is a real public health problem that must be discussed. Land-use planning is one of the essential tools for preventing or rectifying certain situations where noise is an issue.

This guide, which is intended for municipalities, RCMs and proponents, proposes a plethora of measures that can prove useful in managing noise and preventing its effects. Having the best practices assembled in the same document helps users take into account their context and their noise reduction objectives. In particular, it will be useful to mitigate existing problems, but also to offer choices when creating development plans, maps or town planning regulations, whether as part of urban expansion or land use densification or for preserving quiet environments. In addition, greater consideration for noise will help limit the loss of property value and, as a result, of property taxes, that are associated with a pollutant that can be better controlled.

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