OPERATIONAL CONTEXT: INTERVENTIONS AND EXPECTED EFFECTS ON AIR QUALITY, NOISE AND HEALTH

Sub- ACTION A1.5

Annex 5 of Abacus on operational context on Noise Low Emission Zone

LIFE MONZA

Methodologies fOr Noise low emission Zones introduction And management

LIFE15 ENV/IT/000586

LIFE MONZA
Methodologies fOr Noise low emission Zones introduction And management

Technical Report A1.5

Action/Sub-action	Action A1: Operational context for Noise Low Emission Zones (LEZ) detection and management Sub-action A1.5: Operational context: interventions and expected effects on air quality, noise and health
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1. Introduction

Action A1 consists in a state-of-the art review about the legislative and technical requirements on noise LEZ as well as the most up-to-date noise and air quality monitoring systems.

The necessity is to update the current state of knowledge about the improvements concerning the technological and normative framework of the above-mentioned items of the Project, including a scientific review on the suitable health indicators of the effects due to noise and air pollution.

The action is divided in 5 sub-actions, each one coordinated by one associated beneficiary:

A1.1 Legal and Environmental framework for Noise LEZ introduction - MONZA

A1.2 Operational context: Noise Monitoring Systems - ISPRA

A1.3 Operational context: Air Quality Monitoring Systems - ISPRA

A1.4 Operational context: Health indicators - UNIFI

A1.5 Operational context: interventions and expected effects on air quality, noise and health – VIENROSE

In sub-action A1.5 the analysis of the state of the art about possible interventions into LEZ areas and their effects on air quality, noise and health have been performed. The most recent available design solutions for noise abatement, air quality improvement and positive effects on health in urban areas have been collected.

In particular, a field survey among all literature, specialized magazine, technical papers, results coming from EU-founded projects has been carried out.

The survey has been mainly focused on the effects of: low noise paving, interventions on traffic regulation, strategic actions and noise barriers.

Referring to the choice of the typology of low noise paving, special attention has been reserved to results of “Leopoldo Project” (a project at regional level, coordinated by Tuscany Region) that gives guidelines for planning, construction, control and maintenance of the paving of the ordinary roads. At this time, the results of Leopoldo phase 1 (related to the implementation of low noise paving in extra-urban contexts) are available and consequently reported in the abacus. In the next future, results from the on-going Leopoldo phase 2 (related to the implementation of low noise paving in urban contexts) are expected to be collected (on the base of networking activities established with the Leopoldo project partners) and upgraded in the abacus.

Referring to other design solutions (Intervention on traffic regulation, strategic actions and noise barriers) special attention has been reserved to results of “Hush Project” (www.hush-project.eu) and “SONORUS Project” (www.fp7sonorus.eu).

Referring to noise barriers in urban contexts some interesting solutions have been found in the experiences and results of “QUADMAP Project” (www.quadmap.eu) and “SONORUS Project”.

Referring to the effects on health and safety special attention was paid on the report “Urban traffic calming and health”(November 2011) by National Collaborating Centre for Healthy Public Policy (Quebec).

Table 1 – Abacus contents

Number of typology of intervention	Typology of intervention	Number of the schedule on the specific intervention	Specific intervention
1	Low Noise Pavings	1.1	Use-surface “open graded”
		1.2	Use-surface “gap graded”
		1.3	Use-surface “dense graded”
		1.4	Use-surface “microtappeto”
		1.5	Use-surface “dense graded with expanded clay”
		1.6	Use-surface “gap graded with a the addiction of polymer SBR/NR”
2	Interventions on traffic regulation	2.1	Chicane/road narrowings
		2.2	Roundabouts
		2.3	Speed bumps
		2.4	Safety islands
		2.5	Electronic devices for speed control
3	Strategic Actions	3.1	Urban Traffic Plan
		3.2	Public electric vehicles
		3.3	30 km/h zone
4	Noise barriers	4.1	Traditional noise barriers
		4.2	Low barriers

2. Technical report: operational context

2.1.Low Noise Paving

Referring to low noise pavings, special attention has been reserved to results of “Leopoldo Project” that gives guidelines for planning, construction, control and maintenance of the paving of the ordinary roads also in extra-urban and urban context. In particular “Leopoldo Project 1” is referred to extra-urban context, while “Leopoldo Project 2” is referred to urban context.

These guidelines will allow to identify technologies, materials and kind of interventions to be adopted for the construction and maintenance of road surfaces with the aim of improving the safety and ensuring the compatibility and required durability.

In particular, the Abacus related on sub-action A1.5, reports the effects of the following solutions:

- use-surface “open graded”;
- use-surface “gap graded”;
- use-surface “dense graded”;
- special use-surface “microtappeto”;
- use-surface “dense graded with expanded clay”;
- use-surface “gap graded with the addiction of polymer SBR/NR”.

For every solution considered, the abacus reports the following data.

Table 2 – Example of data sheets on low noise pavings

<table>
<tr><td colspan="6">Interventions – expected effects
1. TYPOLOGY OF INTERVENTION</td></tr>
<tr><td colspan="6">Field of application: urban/extra-urban, ecc..</td></tr>
<tr><td>1.0 SPECIFIC INTEVENTION (FOR EVERY TIPOLOGY CONSIDERED)</td><td colspan="2">Location:
_________</td><td colspan="2">Name of the tested street:
____
Mileage:
_______</td><td>Typology of location:
____
Altimetry
_______</td></tr>
<tr><td>Layers of the paving</td><td colspan="5"></td></tr>
<tr><td>Traffic Data</td><td colspan="2">Hourly flow</td><td colspan="2">Light vehicles</td><td>% Heavy vehicles</td></tr>
<tr><td>Average of Traffic in a day (24 h)</td><td colspan="2">Number of vehicles passed during one hour</td><td colspan="2">Number of light vehicles</td><td>Percentage of heavy vehicles</td></tr>
<tr><td colspan="6">Rolling noise CPX a 50 km/h</td></tr>
<tr><td>Date</td><td>Period between paving and testing
[months]</td><td colspan="2">Reference scenario (Srif)
[dB(A)]</td><td>Experimental scenario (Ssp)
[dB(A)]</td><td>Difference Srif-Ssp
[dB(A)]</td></tr>
<tr><td>month- year</td><td>number of months</td><td colspan="2">scenario without low noise paving</td><td>scenario with low noise paving</td><td>Difference between scenario without low noise paving and scenario with noise paving</td></tr>
<tr><td colspan="6">Level of roadside noise – SPB a 50 km/h</td></tr>
<tr><td colspan="6"></td></tr>
</table>

The proposed paving types cover both open paving (with high porosity) and closed paving. The results are encouraging because with different types of pavings good performance are achieved in extra-urban scenario that are well maintained over time.
Referring to effects on safety and health, general data reports that several low noise pavings improve adherence between road surface and tyre and consequently also the road safety.

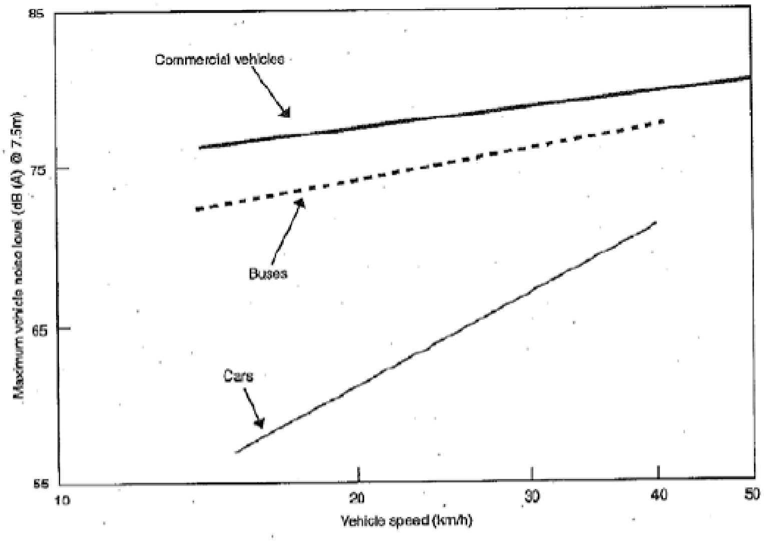
2.2.Intervention on traffic regulation

Referring to the interventions on traffic regulation, special attention has been reserved to results of "Hush Project". The action 5 of the Project reports a collection of solutions for noise reduction in urban areas.
In particular the Abacus A1.5 related to intervention on traffic regulation reports the effects of the following solutions:

a) chicane/road narrowings;
b) roundabouts;
c) speed bumps;
d) safety islands;
e) electronic devices for speed control.

According to the studies consulted, the reduction of vehicles speeds can influence motorized traffic noise. Vehicle noise increases with speed. As Figure 1 shows, this association is stronger for cars than for heavy vehicles (commercial vehicles and buses), whose noise is mainly generated by the engine and the exhaust system, which does not vary much with speed, unlike the noise caused by the friction of tires on pavement [1]. Thus, by reducing driving speeds, calming measures should mainly help reduce the amount of noise generated by cars.

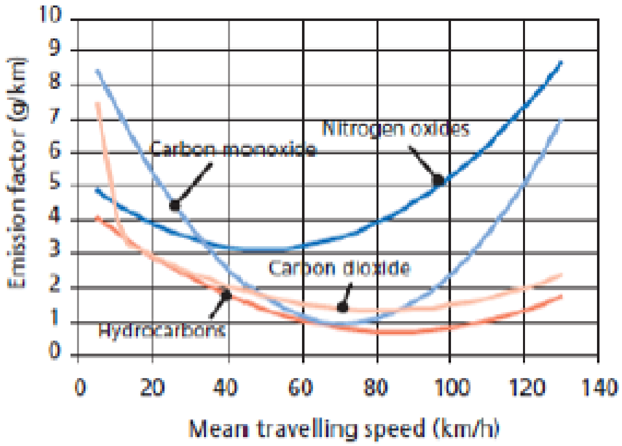
Figure 1 – Increase in maximum vehicle noise level according to speed for three types of vehicles



Source: Abbott et al., 1995, p. 9.

Referring to safety aspects and the effects on **health** see the study reported in the paragraph related to chicane and road narrowings.
Referring to the effect of the speed reduction on **air quality** is well established [2] that the variation of air pollutant emissions is connected to vehicle speed.
As illustrated in Figure 2, emissions generally follow fuel consumption, which appears graphically as a U-shaped curve; that is, fuel consumption and emissions per kilometre travelled are greater at low and at high speeds [3, 4, 5].

Figure 2 – Effect of mean travelling speed on emission levels from passenger cars with catalyst



Note: Values for nitrogen oxides (NO_x) and hydrocarbons (HC) have been multiplied by 10 and those for carbon dioxide (CO_2) have been divided by 100.

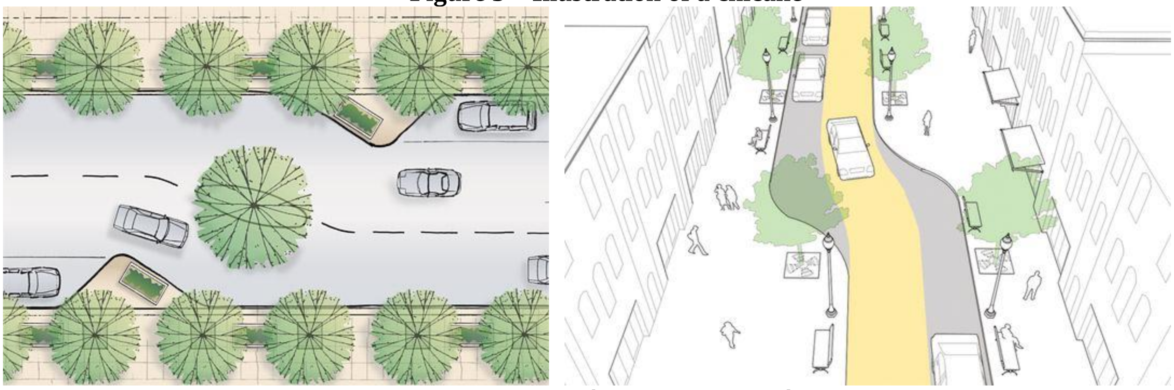
Sources: Adapted from Ntziachristos & Samaras, 2000, in WHO Regional Office for Europe, 2005, p. 25. Copyright 2000, reprinted with permission from Elsevier.

a) Chicane/road narrowings

Chicanes are a type of "horizontal deflection" used in traffic calming schemes to reduce the speed of traffic maintaining a smooth traffic behaviour. Drivers are expected to reduce speed as a consequence of paying more attention to the vehicle path.

The road narrowings can be an occasion for the implementation of cycle track in urban areas. From the acoustic point of view, a general speed reduction involves a consequent decrease of noise.

Figure 3 – Illustration of a chicane



Source: NACTO Urban Street Design Guide

Referring to safety aspects and the effects on **heath**, a study [6] reports the results of the comparison of the effectiveness of 149 traffic-calming interventions on roads with 48-km/h (30-mph) speed limits located throughout England.
These interventions were classified into three groups: the 79 interventions using speed cameras, the 39 using vertical deflections (alone or combined with horizontal deflections or road narrowings) and the 31 interventions using only horizontal deflections, narrowings, speed activated signs (n=4) or markings indicating the speed limit (n=1). The final unusual grouping is justified, according to the study, by the similarity of the associated results.
Table 3 summarizes the key results presented.

Table 3 – Comparison of the effectiveness of three types of calming measures

Calming measures	Average speed {CI 95%}	Personal injury collisions {CI 95%}	Fatal and serious collisions {CI 95%}	Number of personal injury collisions avoided (collision/km/year) {CI 95%}
Vertical deflections	-13.5 km/h* {-16.6 to -10.5}	-44%* {-54 to -34}	-35%* {-54 to -18}	-1.00* {-1.4 to -0.6}
Horizontal deflections or narrowings	-5.3 km/h* {-7.1 to -3.7}	-29%* {-48 to -8}	-14% {-44 to +32}	-0.78* {-1.6 to -0.2}
Speed cameras	-6.6 km/h* {-7.6 to -5.5}	-22%* {-30 to -13}	-11% {-26 to +6}	-1.03* {-1.4 to -0.8}

* Significant variation at, at least, $p < 0.05$.
Source of the data: Mountain et al., 2005.

Traditionally, the effectiveness of interventions is expressed in terms of a percentage reduction in the various types of collisions. Presented thus, interventions making use of vertical deflections are significantly more effective at reducing personal injury collisions than those making use of speed cameras. This result seems to correspond to the significantly more pronounced effect of vertical deflections on speed. However, if the effectiveness of interventions is expressed in terms of the number of personal injury collisions avoided, the significant effectiveness of the three types of calming measures is similar. The authors attempt to explain the variation in the results associated with these two perspectives by pointing to differences in implementation contexts. The speed cameras referred to in this article were installed, for example, on streets with high traffic flow and at sites where more personal injury collisions were recorded (almost double the collisions before the interventions) than at sites where vertical deflections were installed, usually on local streets with lower traffic flow. Thus, in addition to demonstrating the overall effectiveness of traffic calming measures at significantly reducing the number of collisions and personal injury collisions, the article underlines the importance of taking into account implementation contexts when comparing the effectiveness of different measures.

b) Roundabouts

Among the microscale traffic study in cities, one if the most important hotspot concerns the intersection. A possible solution for intersections consists on a replacing crossing by roundabouts.

The roundabout is a particular road junction where traffic moves in one direction round a central island to reach one of the roads converging on it.

The roundabouts have found a large use in recent years in many urban and extra-urban contexts thanks to a series of strengths:

- decrease of the traveling speed in the road section where the roundabout is located;
- reduction of conflict points between vehicles and consequently decreasing of the road accidents and their severity;
- smooth traffic flow due to a complete elimination of downtime;
- reduction of noise and air pollution compared to an intersection with traffic light;
- possibilities for heavy vehicles to change direction with a safer drive;
- improve architectural aspect of the junction.

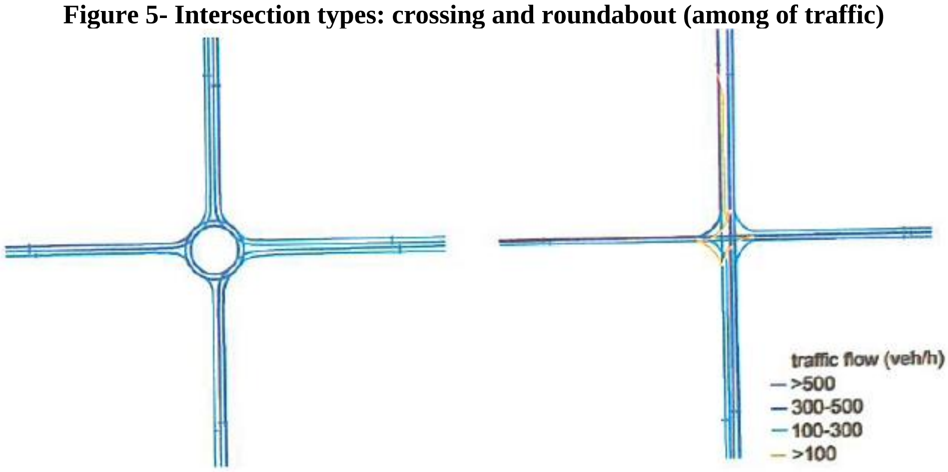
Figure 4 – Example of a roundabout in an urban scenario

Source: NACTO Urban Street Design Guide

To compare the effects of using roundabouts in the place of crossing intersections, the influence of vehicles kinematics is studied in SONORUS Project through a microscopic traffic assessment.

The two intersection types are based on the future urban development of Frihamnen in Gothenburg, with a different number of vehicles coming from the different streets approaching the intersection. The intention is to isolate key features that could help to understand their behavior and the sound environment impact. For this, it has been studied several indicators based on time patterns related to human annoyance for three scenarios of each intersection type. A flat and hard ground without buildings is modelled.

Figure 5- Intersection types: crossing and roundabout (among of traffic)



Source: Urban Sound Planning – The SONORUS project

In the scenarios, the same amount of the traffic was handled in both intersection types, adjusting the road layout. In figure 5, the amount of traffic is indicated, with a smaller total flow in the E-W direction compared with the N-S direction. Since vehicle types also have a strong influence on people's perception of the sound environment, it has been studied alternatives of including heavy-veicles (HV>12 tons as large buses and heavy duty vehicles) and medium-heavy vehicles (MHV= 3.5-12 tons) in comparison with having only light vehicles (LV<3.5 tons) for the peak hour as the worst-case scenario (table 4).

Table 4 – Scenarios for signalized crossing and roundabout :vehicle distribution

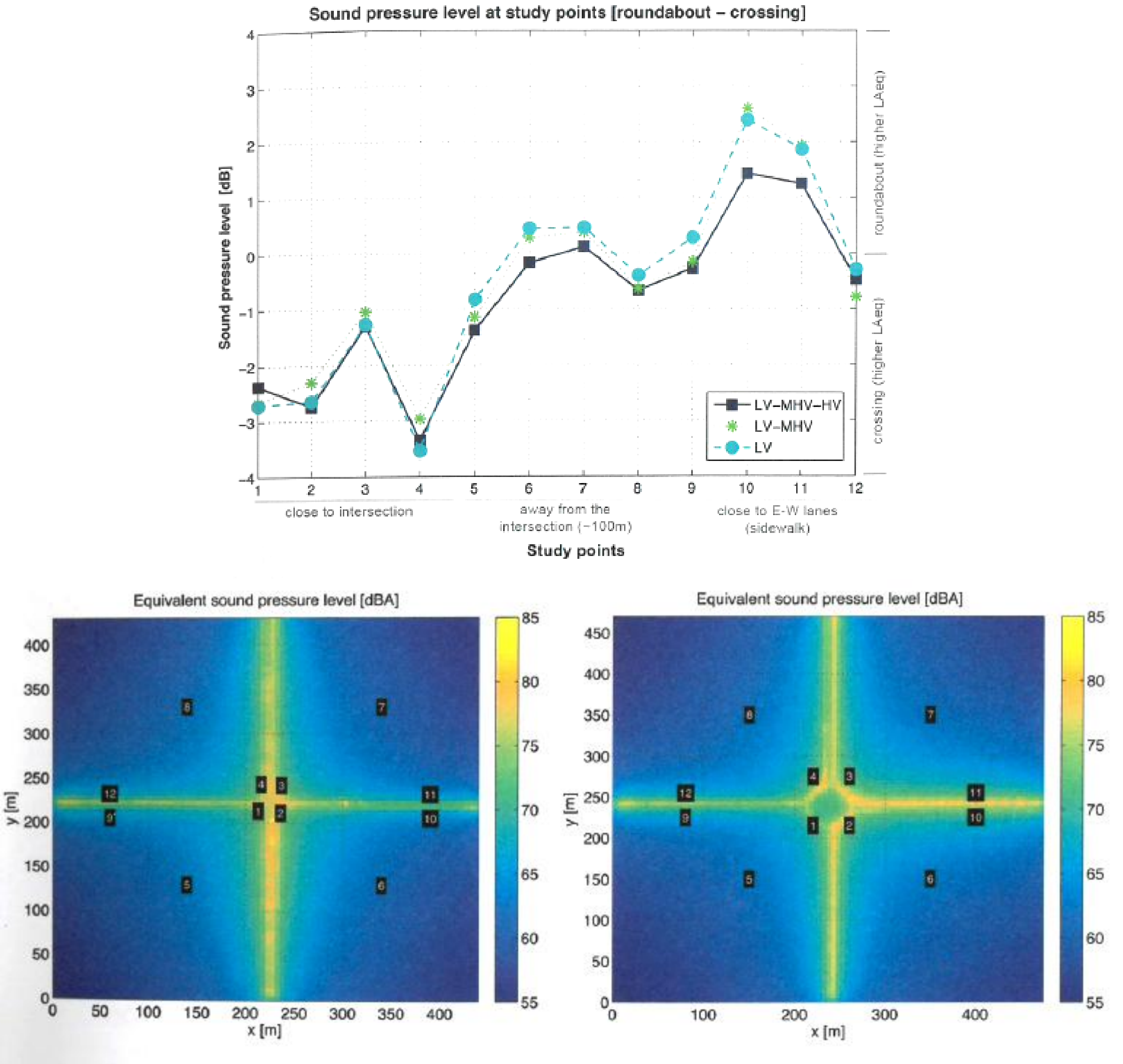
case	% Vehicles		
	Light (LV)	Medium-heavy (MHV)	Heavy vehicles (HV)
1) LV-MHV-HV	92	4	4
2) LV-MHV	96	4	-
3) LV	100	-	-

Source: Urban Sound Planning – The SONORUS project

To study the difference between these two intersection types, 12 study points are included.
The results, displayed in figure 6, show that not all study points are less noisy for a certain intersection type, since it strongly depends on how traffic is handled:

- queues at certain lanes make it difficult to enter the roundabout. In this case, if points are located close to the intersection, crossing has higher noise levels (1-4 Db).
- for sidewalks in the E-W direction, the roundabout tends to have higher noise levels (probably due to low traffic flow and the resulting higher driving speeds);
- for location points at 100 m of the intersection, the behavior is similar for both.

Figure 6- The consequences of replacing the intersection types in the sound pressure level (dB) including heavy, medium-heavy and light vehicles

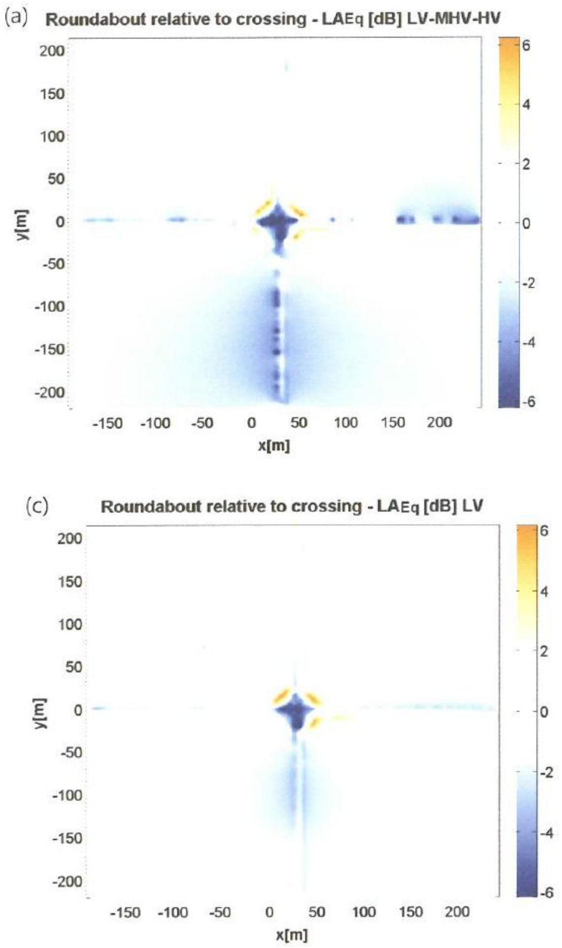


Source: Urban Sound Planning – The SONORUS project

The equivalent sound pressure level difference maps present a useful tool to observe the different behaviours of the two intersections (figure 7):

- with different vehicle types, the signalized crossing intersection is having a higher sound pressure level almost in the entire area (blue colour), being more equal when removing the heavier vehicles;
- the effect oh vehicle kinematics is present and it is observable as a stop-and-go behavior represented by blue dots that indicate higher noise levels due to interrupted traffic flow.

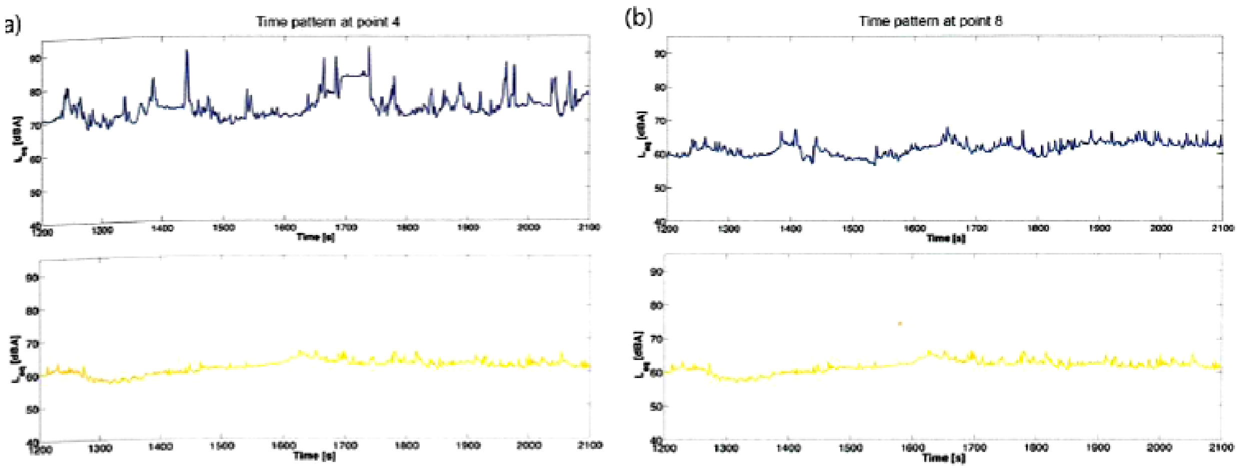
Figure 7- Equivalent noise level difference maps for the crossing and the roundabout for the three vehicle types: light, medium-heavy and heavy veicles (a), light and medium heavy vehicles (b) , light vehicles (c).

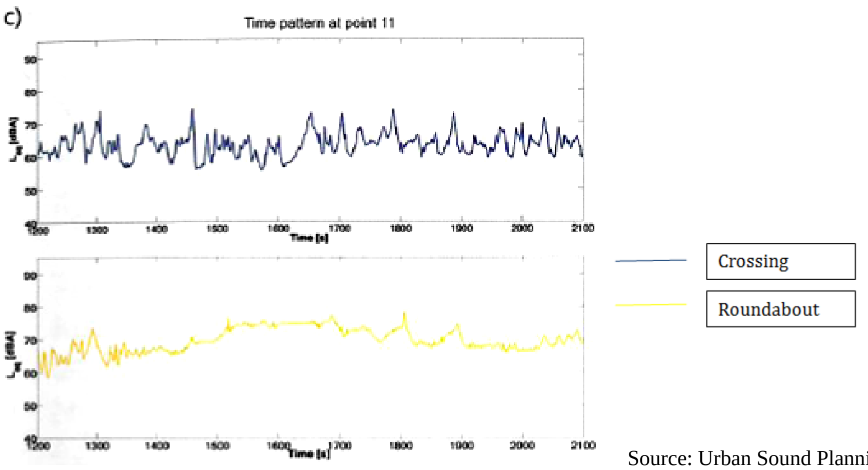


Source: Urban Sound Planning – The SONORUS project

At high traffic variations, as the ones present in dense urban environments, time patterns, as shown in figure 8, become relevant since noise annoyance is partly determined by the noise events resulting from traffic flow.

Figure 8 - Time patterns at (a) study point 4 (at the intersection), (b) study point 8 (at 100m of intersection), and (c) study point 11 (at sidewalk) for the signalized crossing and roundabout

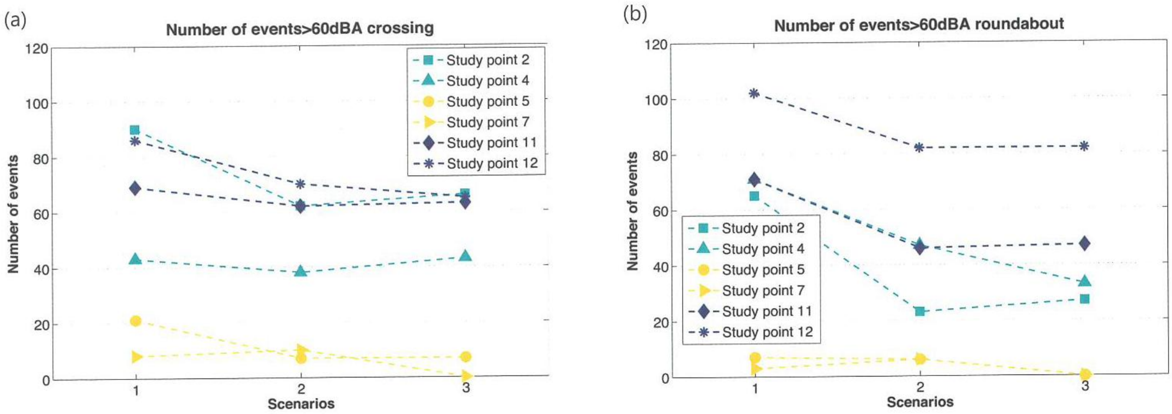




Source: Urban Sound Planning – The SONORUS project

In the study of number of events above 60 dBA for these two intersections (see figure 9), it is possible to conclude that:
- there is a strong influence of heavy vehicles , resulting in a larger number of events, specially in the roundabout scenarios;
- as soon as the heavy vehicles are removed, the differences start to smear out;
- the behaviour within this type of analysis is rather different than in the study of sound pressure level. The implicit rule to yield to vehicles in the roundabout results in a higher congestion of certain parts of the network, as these vehicles need a larger gap to enter the roundabout, turning it into a complex situation in the case of high traffic flow;
- the signalized crossing maintains a more constant behavior throughout the inclusion or exclusion of different vehicles types. In this sense, research has appointed that the presence of heavy vehicles let to higher unpleasantness scores in the roundabout cases.

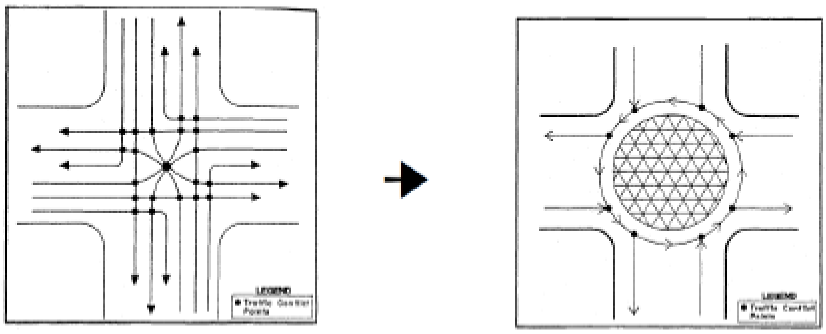
Figure 9 - Number of events above 60 dBA for the signalized crossing (a) and the roundabout (b)



Source: Urban Sound Planning – The SONORUS project

Referring to safety aspects and the effects on health, a roundabout reduces the number of points of potential conflict (locations "where the paths of two vehicles or the paths of a vehicle and a cyclist or pedestrian cross or intersect" - source: Ministère des Transports du Québec, 2007) between public road users, which can result in a reduction in the number of collisions [7].

Figure 10 - Number of points of conflict (black dots on the diagrams) at a traditional intersection and in a roundabout



Sources: Stein, Kittelson, Newton, & Hottmann, 1992, p. 43 in Ewing, 1999, p. 111.
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A study in the United States [8] reports the evaluation of safety gains resulting from the replacement of 24 intersections controlled by stop signs or traffic lights with as many roundabouts. Table 5 summarizes the results.

Table 5 – Effectiveness of roundabouts

Calming measure	Collisions	Personal injury collisions	Fatal and incapacitating injury collisions
Roundabout (n=24)	-38%*	-76%*	-89%*
Single-lane roundabout replacing stop signs (n=9)	-61%*	-77%*	-
Multi-lane roundabout replacing stop signs (n=6)	-5%	-	-
Single-lane roundabout replacing traffic lights (n=4)	-35%*	-74%*	-

* Significant variation at, at least, $p<0.05$.
Source of the data: Retting et al., 2001.

According to this study, reduced speeds and fewer points of conflict at roundabouts can explain the significant reduction in the number of collisions recorded and in the seriousness of those that occur. It is interesting to note that replacement of an intersection controlled by stop signs with a single-lane roundabout is particularly effective at reducing the number of collisions and injuries. Since the majority of collisions occur at intersections, the study concludes that replacing intersections controlled by traffic lights or stop signs with roundabouts, where conditions permit, has considerable potential for reducing collisions, but above all for reducing injuries and deaths.

c) Speed bumps

The speed bumps are the common name for a family of traffic calming devices that use vertical deflection to slow motor-vehicle traffic in order to improve safety conditions.

The speed of a vehicle passing over a bump decreases with the height of the bump. Its height is between 5 cm to 15 cm and it can be long from less than 30cm to nearly 3 meters (often used as pedestrian crossing).

The speed bumps longer than 3 m are often called anti-speed bumps, and are often used to slow down traffic in residential neighbourhoods. The use of anti-speed humps is widespread in the world, and are most often located where the speed of vehicles traveling on the road is rather low.

Each of these devices can be made of a variety of materials as asphalt, concrete, recycled plastic, metal etc.

From acoustic point of view, the speed bumps are very effective in keeping low the vehicles speed and consequently in reducing the vehicle noise emissions. Nevertheless, if crossed at high speed or by trucks, it can cause a significant impulsive noise.

Figure 11 – Illustration of a speed bump (at left) and an example of speed bump for pedestrian crossing (at right)

Source: NACTO Urban Street Design Guide Source: Pilot-area "Brozzi-Quaracchi" in Florence of HUSH Project

Referring to safety aspects and the effects on **health** of this intervention, an article [9] presenting an observational case control study evaluates the effectiveness of speed humps at reducing collisions causing death and injury among child pedestrians under 15 years old in the city of Oakland, in the United States. The article analyzes the admission data of hospital emergency departments over a period of five years (1995-2000) to identify children living on local streets who were admitted after being struck by a car while walking near their home (radius of 0.4 km). The article concludes that speed humps make the environment safer for child pedestrians.

All the studies consulted [10,11] that considered the effects of individual interventions on **air quality** evaluated these effects by examining the air emissions of motor vehicles.

In 2005, the Society of Automotive Engineers International published a report [12] on the impact of speed humps on air pollutant emissions. However, the method used casts doubt on the validity of the results obtained. To simulate a road without speed humps, the authors drove at a constant speed of 50 km/h on a road with seven speed cushions installed on it, and to simulate the presence of seven 80 mm speed humps (the highest kind), they drove on the same road, slowing down to 16 km/h to go over the speed cushions and accelerating up to 32-50 km/h between them. Using equipment installed on the car to measure emissions in real time, they simulated the impact of speed humps on a car with a very heavy load, thus producing results that are probably not very representative of a car with an average load. Moreover, by slowing down more than necessary to easily go over the simulated speed humps, and then accelerating rapidly between the speed humps, the authors simulated an aggressive driving style, which probably led to an overestimation of average emissions on the calmed road. Indeed, the authors state that their results are "probably a representation of an unsmooth driver who is in a hurry to negotiate a traffic-calmed road driving a heavily laden car". Table 7 summarizes the results obtained.

Table 6 – Effects of speed humps on air emissions

Calming measures	Type of vehicles (gas-powered cars)	CO	HC	CO_2/Fuel	NO_x	PM
Speed humps	With catalytic converter	+117%	+148%	+90%/+35%	+195%	-

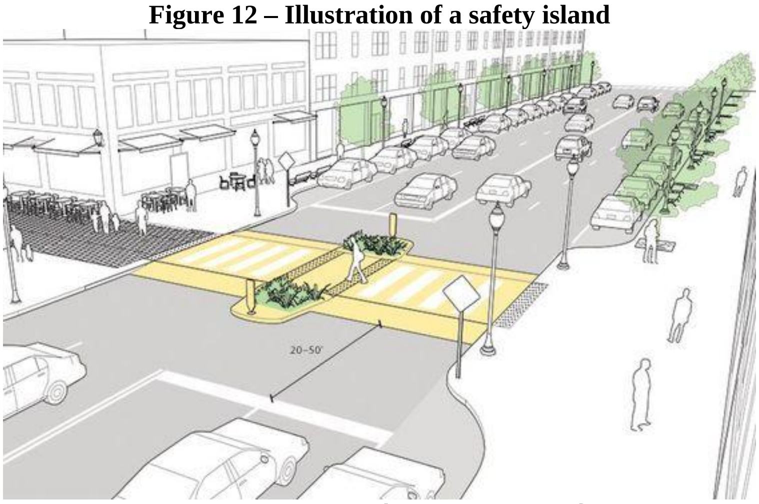
Note: No statistical significance test mentioned.
Source of the data: Daham et al., 2005.

According to these results, speed humps engender significant increases in air emissions. However, by changing the driving style (from calm to aggressive) between the control cycle and the experimental cycle, the authors introduced a confounding factor into their study. Moreover, these results are probably not representative of a car with an average load. Therefore, these results should be interpreted with caution.

d) Safety islands

The safety islands are installed on a busy or wide road to assist pedestrians to cross the road in two stages. They are a very useful structure for the safety of pedestrians crossing the road. They allow pedestrians to concentrate on traffic from one direction at a time.
Road permitting, the safety island should have a width of about 2.00 meters, to protect even bicycles and prams.
Safety islands with less width can be useful and efficient especially as an indication of traffic calming. In fact, safety islands are also effective as possible structures of "traffic calming" when:
- they are built in series;
- they are installed in conjunction with a pedestrian crossing (zebra).
In this case, islands and the zebra jointly are a strong and clear indication that the road is high and extensive presence of pedestrians. The drivers of vehicles have to drive with low rate of speed because they have to "live" with pedestrians. In addition, safety islands prevent overtaking, especially of motorcycles. Safety islands are more efficient when accompanied by an adequate road sign that announces in advance its presence (about 40-50 meters). Otherwise the island can become a dangerous obstacle.

Figure 12 – Illustration of a safety island



Source: NACTO Urban Street Design Guide

e) Electronic devices for speed control

Electronic devices for speed control include all systems that allows the speed control of vehicles. They can be fixed or movable.
The most common types are speed cameras and tutor systems (SICVE). The SICVE (Information System for Speed Control) is used mainly on highways and detects the speed average of vehicles.
Other systems for speed control are intelligent traffic lights for limiting the traveling speed of the vehicles. Through a speed measure system placed close it, the traffic light recognizes the vehicle passing with too high speed and activates the procedure for blocking it.
Other devices are traffic and speed bollards places close to vertical speed limit signals. They work as psychological deterrents because they allow to read the speed of the vehicle in real time.

Figure 13 – Example of speed camera

Referring noise reduction it is not guaranteed because the reduction of vehicle speed is very close to the electronic device installed. And often linked to a noisy stop-and-go driving conditions.

2.3. Strategic Actions

Referring to Strategic Intervention, special attention has been reserved to results of “Hush Project” and “Sonorus Project”.
In particular, the Abacus A1.5 related to Strategic Actions reports the effects of the following solutions:

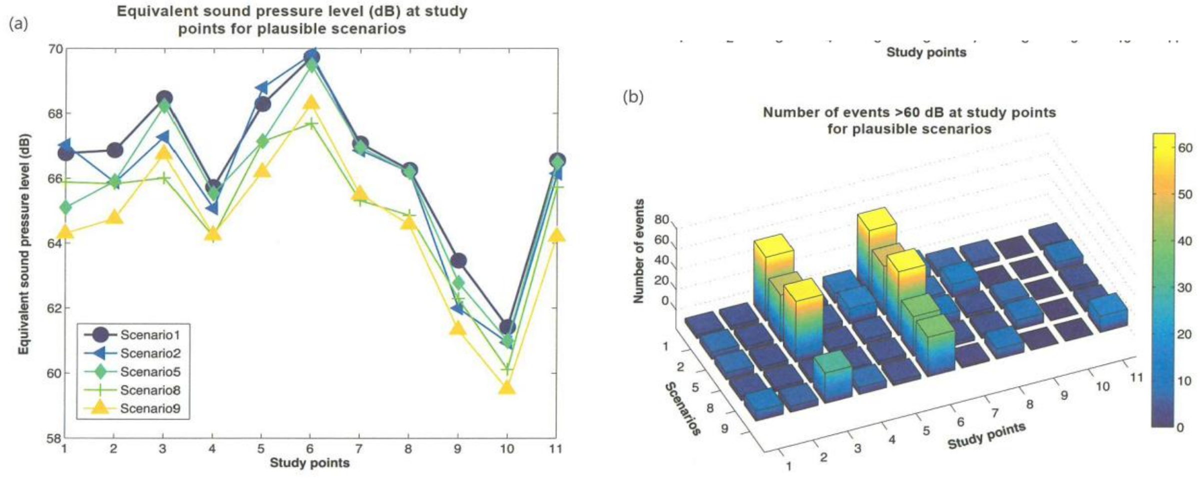
a) Urban Traffic Plan;
b) public electric vehicles;
c) 30 km/h zone;
d) safety islands.

a) Urban Traffic Plan

A major concern in the planning of our city is to improve mobility, which is directly connected to transport management and traffic design decisions. Moreover, these decisions are deeply linked to the characteristic of the sound environment. Environment noise levels depend on the strengths of the sources and on the propagation paths. Transport decision have consequences on both of them. The SONOROUS Project focuses on the transport management and traffic design, looking towards a more efficient transport layout, bringing opportunities to improve the sound environment by studying time patterns and vehicle kinematics, strongly linked with annoyance and health effects among citizens. The mainstream prediction tool for traffic noise is though static traffic flow analysis. These instruments, commonly knowns as noise mapping prediction tools, are very useful as a first attempt to study the noise level exposure of larger areas (macroscopic analysis, with mean speed and flow – veh7d as input, and day-evening-night noise level as output). In urban areas, traffic is characterized by high fluctuations in term of acceleration due to the presence of pedestrians, intersections, parking places, etc… (microscale level). In such situations, the traffic noise assessment can be underestimated by noise prediction software. Here, features from transport dynamics become relevant, having a strong influence in the source strength. The dynamic assessment tool consists of a series of microscopic traffic simulations that allow for the inclusion of vehicles kinematics.
To test it in a real case scenario and explore its possibilities, the new urban development of Frihamnen test site has been used. The study focuses on 9 traffic alternatives:
Scenario 1. base – scenario for the future plan;
Scenario 2. remove a road and move its traffic towards other adjacent roads;
Scenario 5. reduce speed in the highway located near the area;
Scenario 8. remove medium-heavy and heavy vehicles;

Scenario 9. neglect the effect of acceleration.
In case the heavy and medium-heavy vehicles are removed from the network (scenario 8), equivalent sound pressure level (LAeq) reductions at the selected points are between 1 and 3 dB. The same occurs if acceleration noise is omitted.

Figure 14 – Equivalent sound pressure level (a) and number of events above 60 dBA (b) for all study points and plausible scenarios



Source: Urban Sound Planning – The SONORUS project

In the case study (see figure 14), the number of noisy events as the ones above 65 dB, are drastically reduced in the scenario without heavy vehicles (scenario 8) for the majority of the points (up to 60% less noise events at several points). In case there is a change in the traffic network (scenario 2), the reductions are visible at several study points, however, other ones are heaving an increase in the number of noise events as a consequence of the added traffic. In figure 14, the equivalent sound pressure levels (a) and number of events above 60 dB (b) are plotted for the different scenarios.

b) Public electric vehicles

The electric buses appear, among the electric road vehicles, the fastest growing types, despite the low transport capacity of these vehicles and logistical needs that characterize them as the need to recharge the batteries.
The emerging logic is set up service networks in historic city centres closed to private traffic, sometimes the public electric vehicles don't replace the existing public services but integrate them..

c) 30 km/h zone

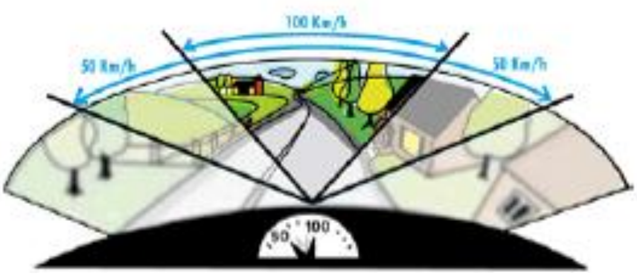
30 km/h zone is a strategy for traffic calming in urban road network. It was introduced in Italy in 1995 within the Directive on Urban Traffic Plan (PUT).
As the name suggests, the 30 km/h zone is an area where the speed limit for urban roads is fixed on 30 km/h instead of the normal 50 km/h allowed in urban areas.
The lower speed limit allows a better coexistence among cars, bicycles and pedestrians.
The 30 km/h zone can be implemented in every city if there are streets with speed limits not exceeding 50 km/h. If there are roads with a speed limit at 70 km/h, it is necessary to create areas with speed limit at 50 km/h.
In 30 km/h zone, the projects should provide also interventions in favour of pedestrians and cyclists such as the reduction of motor traffic space in favour of the space reserved to the cycle paths and sidewalks, and the creation of areas used for social purposes.

To help reducing the speed of motor vehicles is necessary to provide a series of structural measures such as optical and/or acoustic retarders, bumps, roundabouts and traffic islands without creating obstacles to emergency vehicles.
30 km/h zones could create a noise reduction of 3-4 dBA inside the 30 km/h area, connected to speed reduction of light vehicles.

Figure 15 – Example of 30 km/h zone

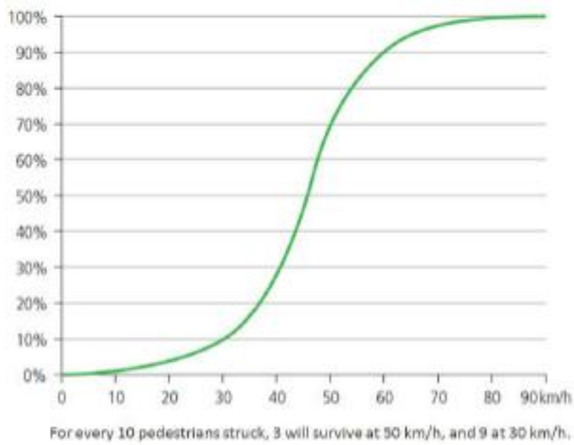
According to the studies consulted, the reduction of vehicle speed can influence road **safety**. A research shows that the number and severity of collisions increases with speed [3]. A report even suggests that each decrease of 1.6 km/h in an urban setting results in a 3 to 6% decrease in collisions, depending on how major a road is being considered [13]. As Figure 16 illustrates, increasing speed decreases a driver's field of vision, which goes from slightly wider than 150 degrees at very slow speeds to around 75 degrees at 100 km/h, thus reducing the likelihood that a dangerous situation will be noticed in time. Moreover, increasing speed increases stopping distance, that is, the distance travelled by the vehicle during the time it takes a driver to react plus the vehicle's braking time, which accordingly reduces the likelihood that the vehicle will stop in time to avoid a collision or that it will have slowed down enough to avoid a serious collision. For example, a car travelling at 30 km/h on dry pavement, and whose driver takes two seconds to react, will stop after travelling a distance of a little over 20 metres. At 50 km/h, the same car would have travelled twice that distance, a little over 40 [14]. The seriousness of collisions also increases with speed, especially when vulnerable road users, such as pedestrians and cyclists, are involved. By aiming to reduce driving speeds (often to about 30 km/h), and particularly those of the fastest drivers, traffic-calming strategies should help reduce the number and severity of collisions.

Figure 16 – Narrowing of field of vision as speed increases



Source: Société de l'assurance automobile du Québec, 2011.

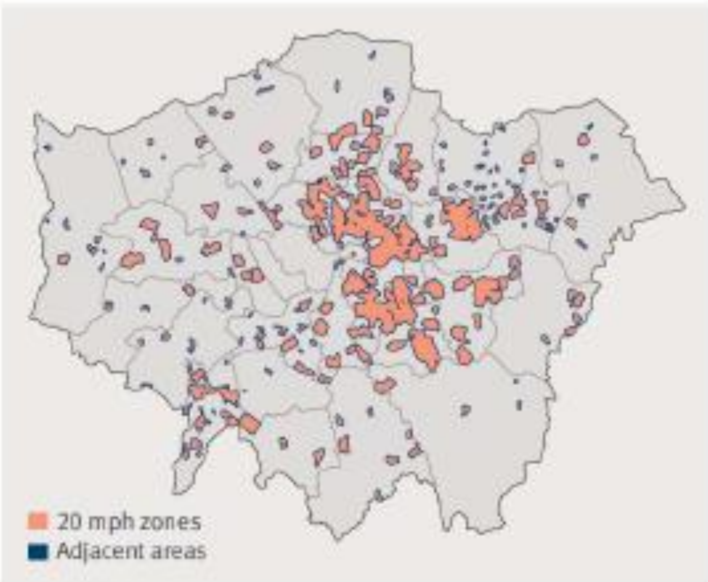
Figure 17 – Probability that a pedestrian will die as a result of a collision with a car in relation to the speed at impact



Source: Adapted from Bureau de prévention des accidents, 2008b.

Referring to speed limited zones, a report [15], as well as a more synthetic article in a scientific journal [16], examine the 399 zones with 20-mph (32-km/h) speed limits that have been installed in London, U.K., gradually since 1990 (see Figure 18).

Figura 18 – 20 mph zones and adjacent areas in London, UK



Source: Grundy et al., 2009, p. 2.

They evaluated the effects of these zones on collisions, injuries and deaths occurring within the zones and on their periphery. Typically, the entrance to and exit from the zones are marked with signs, and traffic within the zones is calmed, in particular, through the use of vertical deflections (e.g., raised intersections) and horizontal deflections (e.g., chicanes). The size of calmed zones ranges from a 0.07-km stretch of road to an area covering 37 km of roads, with a median size of 3.6 km. The authors used collision data collected by the police department over a period of twenty years (1986-2006) to calculate the effect of the zones on the roads within them and to verify whether collisions had migrated to adjacent roads (within 150 m). The data was also used to control for the phenomenon of regression to the mean and for the underlying downward trend in the number of collisions occurring in London. According to the results presented, the 20-mph zones are responsible for a significant reduction in the number of collisions; specifically, a reduction of 37.5% (CI 95%: -31.6 to -43.4), with no indication of collision migration. In fact, even after controlling for the underlying downward trend, a significant reduction in collisions of

7.4% (CI 95%: -3.8 to -11.0) was observed on the periphery of the calmed zones. This reduction cannot, however, be explained with reference to the article. The authors speculate that it may be due to the proximity of the 20-mph zones or to other interventions on these roads (e.g., speed cameras on the main roads bordering the zones). Table 8 presents the key results concerning the number of road injuries by category of user.

Table 7 – Effectiveness of 20-mph (32-km/h) zones at reducing personal injury collisions occuring within them

	Pedestrians {CI 95%}	Cyclists {CI 95%}	Drivers or passengers {CI 95%}	Motorcyclists {CI 95%}	Total {CI 95%}
Personal injury collisions (PICs)	-32.4%* {-37.7 to -27.1}	-16.9%* {-29.0 to -4.8}	-52.5%* {-62.4 to -42.5}	-32.6%* {-43.4 to -21.7}	-41.9%* {-47.8 to -36.0}
0-15 years	-46.2%* {-55.5 to -36.8}	-27.7%* {-49.1 to -6.3}	-	-	-48.5%* {-55.0 to -41.9}
Collisions with persons killed or seriously injured (KSI)	-34.8%* {-47.5 to -22.18}	-37.6%* {-60.9 to -14.4}	-61.8%* {-71.7 to -52.0}	-39.1%* {-59.1 to -19.0}	-46.3%* {-54.1 to -38.6}
0-15 years	-43.9%* {-61.3 to -26.6}	-	-	-	-50.2%* {-63.2 to -37.2}

* Significant variation at, at least, $p < 0.05$.
Sources of the data: Grundy et al., 2008b; 2009.

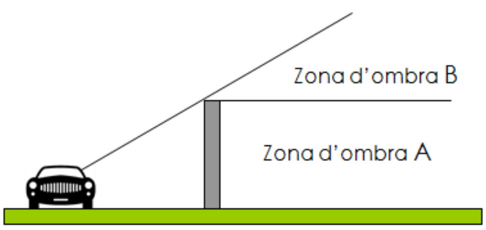
These results show that the 20-mph zones significantly reduced the number of personal injury collisions (PICs) and of collisions with persons killed or seriously injured (KSI) for the various groups of public road users. The point estimates suggest that the 20-mph zones are particularly effective at protecting children (0-15 years old). A comparison of the measure's effectiveness at reducing PICs and KSI collisions in large zones (more than 3.6 km of road) and in small zones (3.6 km and less) revealed no significant difference.

2.4.Noise barriers

a) Traditional noise barriers

The barriers allow the reduction of the sound pressure that reaches the receiver. In fact, the barrier is interposed between the source and the receiver in a way that the sound waves reach it only by diffraction path.
According to DM29/11/200 noise reduction of a noise barrier is 14 dB in zone A and 7 dB in zone B. Outside these zones, the noise attenuation is 0 dB.

Figure 19 – Noise reduction zones of an acoustic barrier



From an acoustic point of view, the barriers can be divided into reflecting and absorbent types.
The effectiveness of the barrier depends on:

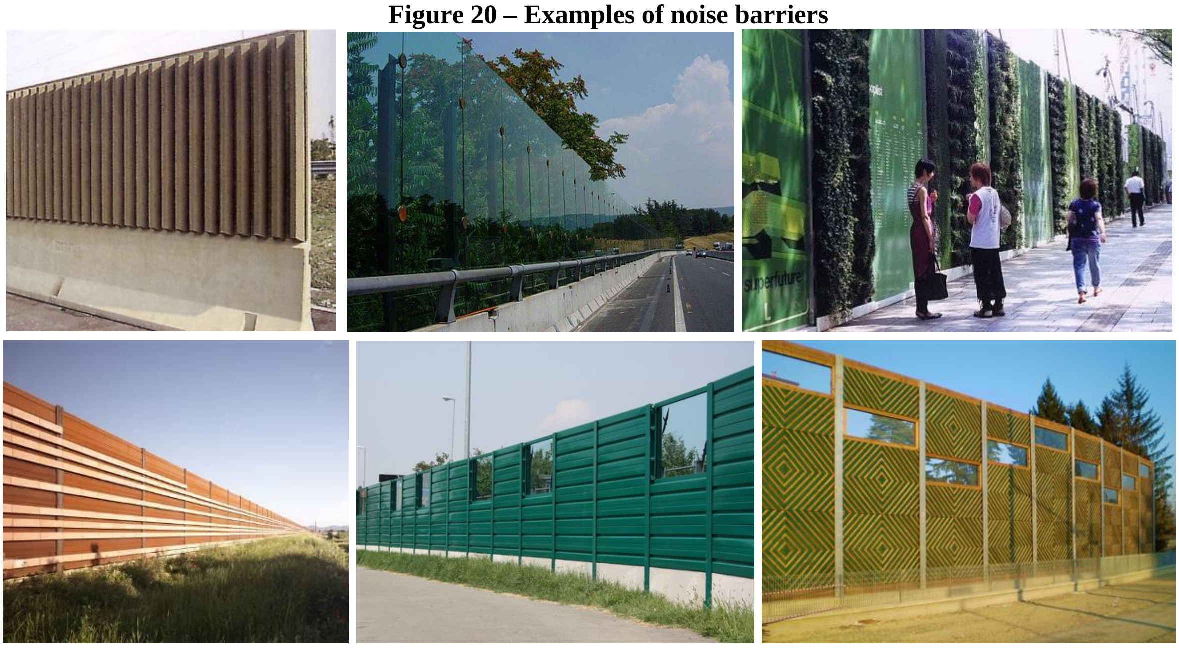
- location: it is appropriate to keep it as close as possible to the sound source;
- height, such as not to allow the visibility of the source from the receptors;

- length: to reduce as much as possible the lateral diffraction effects which produce a reduction of attenuation;
- thickness: it reduces the amount of diffracted energy that reaches the receptor;
- sound insulation: it must be such as to make insignificant the contribution of transmitted energy compared to the diffracted one.
- sound absorption: the sound absorption barriers are generally used to prevent the reflection of sound.

Besides acoustic issues, when an acoustic barrier is installed in a specific place, the esthetical aspects and landscape impact should be considered as well.

In general, panels of a noise barrier can be of different materials such as wood, transparent materials, concrete, metal, earthnware, strengthened ground, plan covered, etc…

Figure 20 – Examples of noise barriers

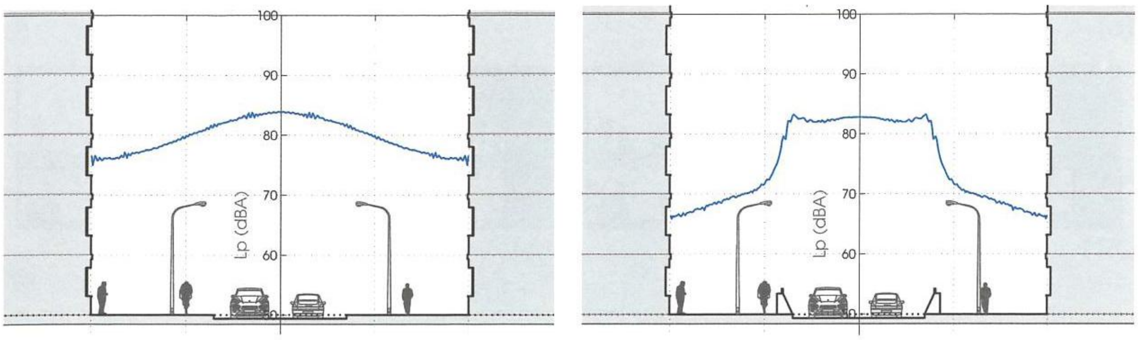


Referring to air quality aspects, roadside noise barriers have shown to reduce the near road air pollution concentration levels. Within 15–50 m from the roadside, air pollution concentration levels at the lee side of the noise barriers can be to reduce up to about 50% compared to open road values [Bowker et al., 2007; Baldauf et al., 2008; Heist et al., 2009; Ning et al., 2010; Finn et al., 2010]
Noise barriers force the pollution plumes coming from the road to move up and over the barrier creating the effect of an elevated source and enhancing vertical dispersion of the plume. The deceleration and the deflection of the initial flow by the noise barrier, force the plume to disperse horizontally. A highly turbulent shear zone characterized by slow velocities and a re-circulation cavity is created in the lee side of the barrier and further enhances the dispersion; all of which result in a well-mixed zone with lower pollutant concentrations downwind behind the barrier. [Bowker, G.E., Baldauf, R., Isakov, V., Khlystov, A., and Petersen, W. (2007). The effects of roadside structures on the transport and dispersion of ultrafine particles from highways. Atmos. Environ. 41, 8128–8139]

b) Low barriers

In the urban context, motorized traffic and pedestrians or cyclists are often found in the same street canyon. Small barriers have little effect on the exposure of façades flanking the street except for the lowest floors, yet they can reduce the level near pedestrians if shaped correctly.

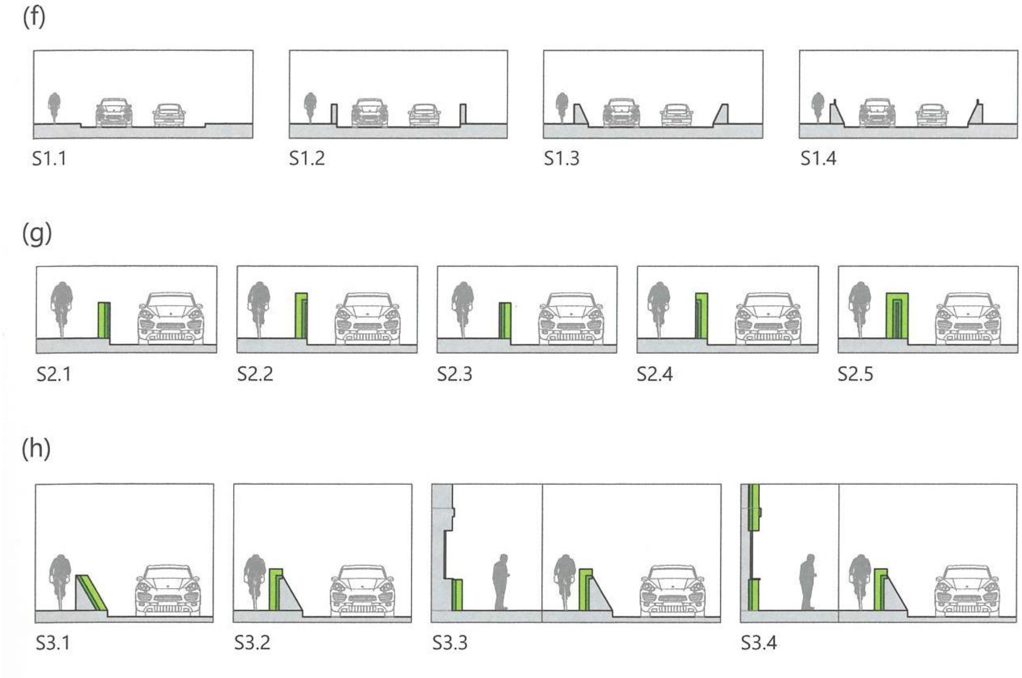
Figure 21 – Reduction of noise level at pedestrians by a low inclined barrier



Source: Urban Sound Planning – The SONORUS project

In the following figure are shown some street case studied in the frame of SONORUS Project about low barriers.

Figure 22 – Street cases: low barrier shape (f), absorption on a vertical low barrier (h).



Source: Urban Sound Planning – The SONORUS project

The main results on this street cases can be summarized below:
- a small vertical barrier reduces noise levels with more than 4 dB(A) for pedestrians;
- inclination of a low barrier additionally reduces 3 dBA for pedestians (8 dBA in total);
- 30 degrees inclination is the most beneficial for this canyon dimensions;
- different absorbation gives reduction of pedestrian exposure within 4 dBA range;
- the most efficient face to place the absorption is the source side (S2.3) (additionally 2 dBA);
- the least efficient face is the receiver side S2.2;
- the addition of absorption on the top of the barrier (in S.2.2 or S.2.4) reduces additionally 1 dBA for pedestrians, despite the small surface;

- the maximum reduction achieved compared to the non-barrier case is of nearly 9 dB(A) with all surfaces absorbent (S2.5).

However, the addition of absorbtion on an inclined low barrier has different effects than on a vertical one:

- different absorption treatment for an inclined low barrier varies by 2 dBA;
- the most efficient faces for adding absorption are receiver side and top;
- the addition of absorption on the source side has no additional effect for the inclined barrier case;
- absorptive wainscot does not additionally reduce noise for pedestrians.

3. Conclusions

This report reports the state of the art about possible interventions into LEZ areas and their effects on air quality, noise and health have been performed.

The sub-action A1.5 collects the most recent available design solutions for noise abatement, air quality improvement and positive effects on health in urban areas.

The Abacus of solutions will be updated and integrated with low noise pavings solutions in urban scenario by the results of Leopoldo 2 Project that is ongoing, as agreed by networking with partners.

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