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# The impact of traffic noise on economy and environment: a short literature study

Performed within the scope of the  
ECO<sup>2</sup> project *Noise propagation from  
sustainable vehicle concepts*

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## **Abstract**

This report discusses the societal impacts of environmental and traffic noise, and the benefits that could be withdrawn from their reduction. Environmental noise pollution is considered as one of the main environmental problems in today's society. Around 80 million European citizens are exposed to unhealthy noise level. These levels can affect health and well-being, the effects on which are reflected on working and living conditions, consequently affecting the economy. To deal with this issue, always stricter regulations are being voted by communities to set up action plans to prevent noise exposure and to reduce the noise at its source. The main source of environmental noise is transportation noise which is pulled up by always increasing needs for goods, energy, and personal transportation. Excluding airways traffic noise which affects only a small percentage of the population, reducing traffic noise comes down to either isolating roads or railways from living and working areas or achieving reductions of noise at its source - on ground vehicles. The position of the *ECO2 project Noise propagation from sustainable vehicle concepts* in the global effort to reduce noise pollution is described. The impact of traffic noise on health and environment is discussed, as well as various aspects of the impact on the economy. An estimation of the cost of traffic noise is presented for different types of vehicles, as well as the influence on housing prices, based on literature studies. Response from the state in terms of legislation is tackled. Finally, societal benefits of traffic noise reduction are discussed.

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# 1 Introduction

The following section presents the purpose of the ECO2 project *Noise propagation from sustainable vehicle concepts* and how it participates in a global effort to reduce noise pollution. The concept of environmental noise pollution is addressed first, with an emphasis on transportation noise. A more detailed analysis of sound sources on ground vehicles is then presented. The problem is thus presented from a society point of view down to the implications on the vehicle itself.

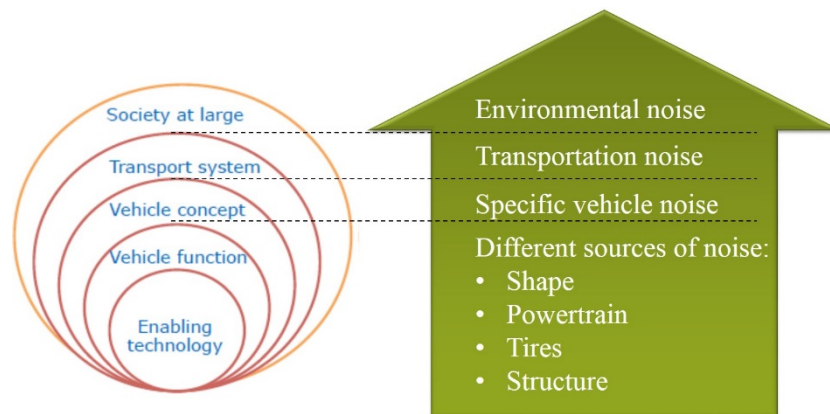


Figure 1: External noise from ground vehicles described with the ECO<sup>2</sup> system model

## 1.1. Environmental noise pollution

Traditionally, noise refers to unwanted sound, namely sound that disturbs everyday activities such as sleeping, discussing or working. We talk about environmental noise to address the ambient sound that can be heard within a community, generated by traffic, industries, neighbours or recreational activities. Environmental noise has been steadily growing during the last decades and is now becoming an important concern for society. As a response the European Union adopted in 2002 a Directive to assess and manage ambient noise in communities, a problem which has become a matter of public health [1].

## 1.2. Transportation: a growing source of noise pollution

A recent report published by the European Environment Agency shows that the main source of environmental noise in Europe is by far transportation noise [2], road traffic being the first source humans are exposed to – with the exception of people living near airport or railways. As global traffic increases, we can expect that this tendency will not change in the near future. Indeed, the total number of vehicles on the roads is globally rising, an increase sustained by the economic growth of emerging countries such as China and India. Their GDI per citizen is growing fast, leading to an increase in car ownership rate as shown in Figure 2. The Swedish Environmental Research Institute estimates that by 2030 the total number of cars in the world would exceed by far the double of the figure for 1995 [3].

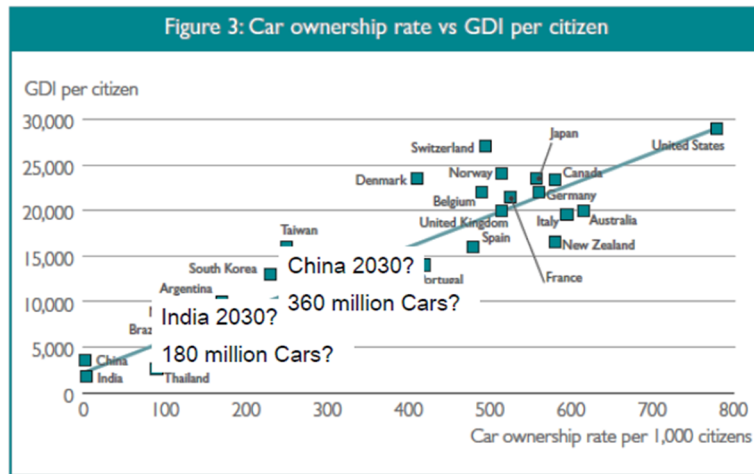


Figure 2: Car ownership vs GDI per citizen, figure from [4]

Even though noise from cars and trucks have been reduced by respectively more than 85 and 90% between 1970 and 1996, road traffic noise has not been significantly reduced during the last 15 years of this period [5]. This is a consequence of an increase in traffic, both in number of vehicles on the road and in terms of frequency and distance of the trips. For example, between 1970 and 2007, the population in the US has increased by one third whereas traffic on roads has been multiplied by three [6].

Transportation noise results from traffic in railways, roads and airways, the latter being of concern mainly in the proximity of airports. If we exclude airways, reducing transportation noise comes down to three solutions:

- Protecting people from traffic noise by setting up noise barriers for example.
- Taking actions to modify the traffic in sensitive areas.
- Reducing the noise at its source by changing the design of road vehicles.

The current project focuses on this last solution.

### 1.3. Noise generated by ground vehicles and purpose of the project *Noise propagation from sustainable vehicle concepts*

The purpose of this project is to understand and simulate the sound generation and propagation from ground vehicles in a realistic environment in order to develop technological ways of achieving noise reduction in an early design process. Noise from ground vehicles can be generated by different mechanisms and the relative powers of those different sources depend on the vehicle type and the operating conditions. In general the following sources can be identified:

- Powertrain noise.
- Rolling noise.
- Structure-born noise.
- Aerodynamic noise.

The different steps of the project include modelling sound propagation in urban environment, identifying sound sources with a particular focus on aero-acoustic sources and setting directions of improvement for noise reduction by modifying the vehicle shape, as well as by altering the vehicle body materials and components for example.

#### **1.4. Purpose and outline of the report**

In this report, some aspects of the ecological and economic impacts of traffic noise are discussed, in order to get a societal background for the research led in this project. First we give an overview of the societal impact of traffic noise pollution – on health and on the environment - and present some of the measures which have been taken by authorities to deal with this problem. Then we discuss the cost of traffic noise and how it can be estimated, and we explain some of the potential benefits associated with its reduction. Finally we give some elements of reflexion on how the problem of reducing transportation noise is likely to evolve in the near future.

## 2 Reducing noise pollution : an environmental health issue

In 2014, an estimated 125 million people were affected by noise levels greater than 55 dB  $L_{den}$  (day-evening-night level) related to road traffic [2]. This figure has increased during the past decades, and we can expect this growth to continue because of an always growing urbanization. In addition to annoyance and sleep disturbance, transportation noise exposure has been shown to be associated with health problems [7], [8]. Noise pollution in general can also have other psychological effects and can affect reading abilities and long-term memories of children [9].

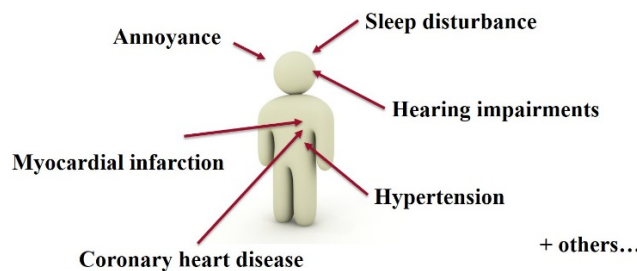


Figure 3: Health effects of environmental noise

### 2.1 Impact on health: burden of noise-related disease

According to experts from the European Union, around 20% of the European Union population suffer unacceptable noise levels which can have long-term impact on their health [5]. Recent studies have highlighted the medical impact of environmental noise. Not only noise can be partly responsible for causing hearing impairments such as tinnitus but it can also affect blood circulation. Indeed hypertension, coronary heart disease and myocardial infarctions have been proved correlated to repetitive high noise level exposure. According to the EEA, more than 900 000 cases of hypertension are caused by environmental noise each year [2]. Furthermore, in 2005, 61 epidemiological studies had objectively or subjectively established a relationship between transportation noise and myocardial infarction [10]. Figure 4 shows the effect of road traffic noise on myocardial infarction: being exposed regularly to higher noise levels increases the prevalence and incidence of myocardial infarction. Disability-adjusted life-years (DALYs) lost due to environmental noise are estimated to be around 61 000 for ischaemic heart disease, 45 000 for cognitive impairment of children and 22 000 for tinnitus [7].

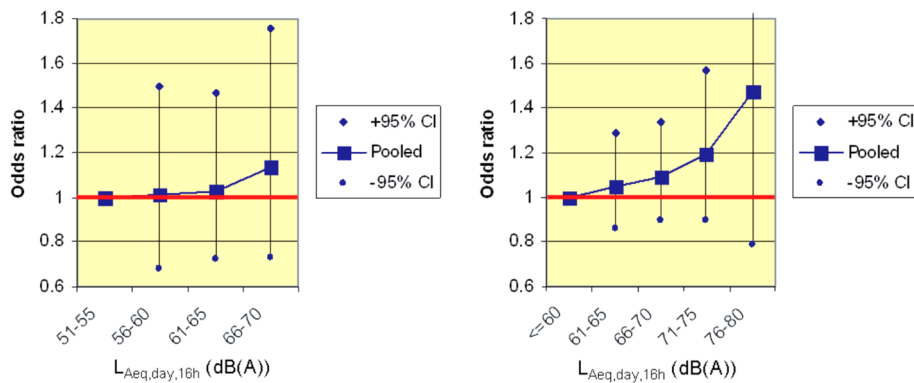


Figure 4: Pooled effect estimates (meta-analysis) of the association between road traffic noise and the prevalence (left) and incidence (right) of myocardial infarction (odds ratio +/- 95% confidence interval). Figure from [7], adapted from [10].

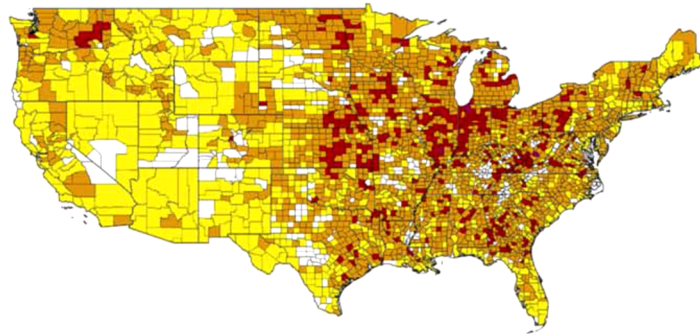
## 2.2 Annoyance, sleep disturbance and cognitive effects

Other effects which are not classified as diseases but have to be accounted for are annoyance and sleep disturbance. In 2014, it was estimated that around 20 million adults in Europe were annoyed by environmental noise, and a further 8 million suffer sleep disturbance [2]. According to a rapport of the European Federation for Transport & Environment (T&E) [11], traffic noise is the main cause of sleep disturbance. Even if it requires a noise level of at least 40 dB to awake someone, a noise level of as little as 32 dB can cause lighter sleep, increasing hormone levels, blood pressure and affecting well-being the following day. In the European Union, it is estimated that DALYs lost due to environmental noise are around 903 000 in Europe for sleep disturbance and 654 000 for annoyance [7].

Environmental noise also has cognitive effects on people. These effects are specific to the kind of work and the sensitivity of the individual, but need to be accounted for. Children in particular may present symptoms such as concentrating, focusing and remembering difficulties, reading impairment, and reduced sound discrimination abilities [11].

## 2.3 A threat for wildlife

Environmental noise is not only harmful to humans: it also affects wildlife. Some animals are extremely sensitive to sound, and anthropogenic noise pollution can affect the way they communicate between each other, mate and hunt. Such a change in behaviour has been observed in avian species for example [12]. A study on the average proximity to the nearest road in the US shows that 83% of the land area falls within 1061m of a road [13]. At this distance, an average automobile will be heard with a noise level of 20 dB(A) (if this same car generates a level of 68 dB(A) at 15m), this value being almost doubled for trucks and motorcycles [6]. Figure 5 shows that there are very few areas in the US where ground traffic noise cannot be heard. Noise levels have been measured on 55 sites in 14 National Parks in the United States: it turns out that more than half of these sites are exposed to audible noise during more than a fourth of daylight hours [6].



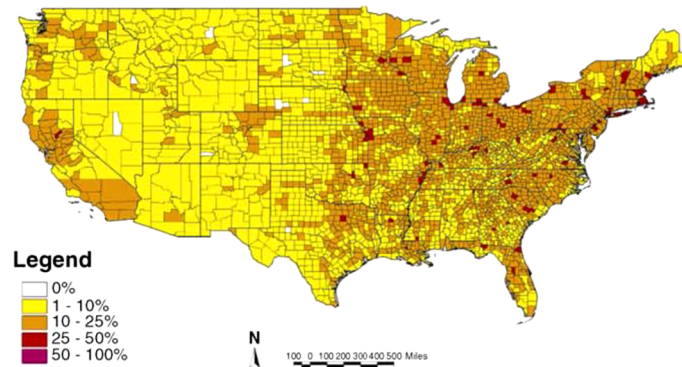


Figure 5: Percent of US county areas in which transportation noise from railway (top) and highway (bottom) networks is noticeable. Figure from [6], adapted from [14].

## 2.4 Response from the state

To respond to the non-stopping increase of noise pollution, the European Parliament and the Council adopted in 2002 a Directive aiming at assessing and managing environmental noise [1]. This Directive participates in the development of a noise policy that was initiated in 1996 by the European Commission in the Green Paper of Future Noise Policy [5], in which environmental noise was addressed as a main environmental issue. It sets the basis for developing measures against harmful noise sources in communities, making avoiding, preventing or reducing the effects of noise pollution on health a priority concern. It defines common methods for noise mapping, for developing local action plans and for informing the public. The overall goal of the European noise policy is to protect citizens from noise levels which are harmful for their health and for their quality of life.

The previously described Directive tackles community noise, but other Directives aiming at reducing specific noise sources have also been laid down since the 70s. These directives concern noise emission limits for specific products, targeting product categories such as motor vehicles, motorcycles, tyres, aeroplanes, household appliances and outdoor equipment. One example is the Council Directive 70/157/EEC of 6 February 1970 on the approximation of the laws of the Member States relating to the permissible sound level and the exhaust system of motor vehicles, that defined the maximal noise level allowed for motor vehicles intended to be used on the road [15]. This Directive applied in particular to cars and trucks. Several amendments of this directive have been adopted since then, as explained in Section 4.1. Other more specific Directives have been passed, such as the Directive 2001/43/EC which addresses noise levels from tyre-road interaction [16].

More information can be found in the Handbook on the Implementation of EC Environmental Legislation [17].

### 3 Economic impacts and benefits of transportation noise reduction

We have discussed in the previous section some of the environmental impacts of traffic noise. This section deals with economic impacts of transportation noise on health, ecology and housing. We also discuss here the economic impacts linked to cross-functionalities in the process of noise reduction in vehicle design. In its report of 2002, T&E claims that stricter vehicle noise regulations would have a benefit impact largely outweighing the cost for society by a factor of 30 to one [11]. The societal cost of rail and traffic noise has been estimated to 40 billion euros per year in the EU (0.4 % of the GDP), with 90 % of this cost being related to passenger cars and goods vehicles.

#### 3.1 Health and well-being related impacts of transportation noise on economy

We have shown in Section 2 that regular exposure to high levels of environmental noise can have harmful effects on human health and on well-being. Both effects have direct or indirect economic effects on society, as presented in Figure 6.

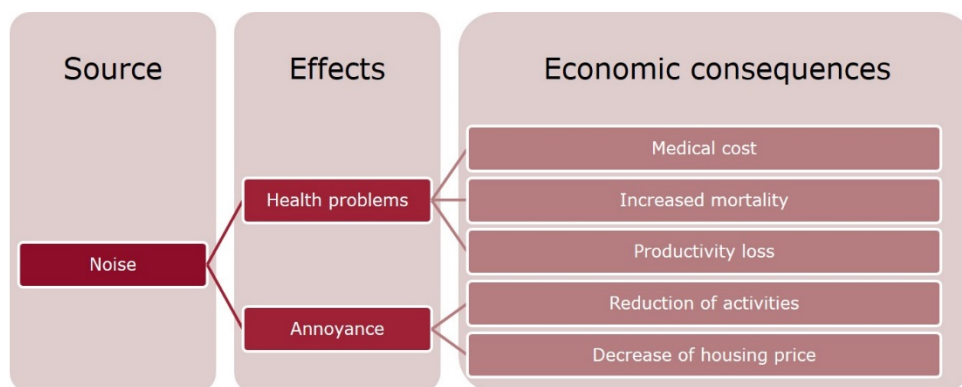


Figure 6: Impacts of traffic noise and economic consequences

Noise related diseases generate a direct cost for the society that has to pay for medical treatments and an indirect cost through the absence of work of sick people. Increased mortality also has a cost and need to be taken into account.

To these costs need to be added the effects linked to annoyance and sleep disturbance, as mentioned in Section 2.2. This has an indirect impact on economy. Many workplaces with jobs involving high cognitive thinking are located in urban areas, likely to be subject to high levels of transportation noise. This annoying noise will alter working conditions, affecting the productivity of the workers leading to a loss for the employers and for the society. A loss of productivity can also be attributed to sleep disturbance which causes tiredness and reduces well-being and work efficiency during the day.

#### 3.2 Economic impact of the effect of traffic noise on ecology

The ecological impact is difficult to price through a demand curve because it has an altruistic value. This impact is therefore hard to take into account in a process of decision making in the industry. This does not mean that it should be neglected anyhow.

#### 3.3 Evaluating the cost of transportation noise through housing price impact

To be able to deal with the problem of noise pollution, it can be convenient to estimate a quantitative value of its cost on society. One of the possible solutions is to use a hedonic price method, for example based on the housing market. This method evaluates the amount of money people are willing to pay to live in a quieter area. In this process the price of a house is assumed to reflect its characteristics which allows an estimation of how much people are willing to pay for a change in each of those characteristics.

For example, Wilhelmsson has estimated in 2000 the impact of traffic noise on the values of single-family houses in Ångby (Sweden) [19]. He calculated that a single-family house would lose 30% of its value if it was located near a road with loud traffic. Bateman studied the decrease in price per increase in decibel in traffic noise in Scotland. His results indicate that an increase in traffic noise of 1 dB triggers a decrease in housing price by around 0.20% [20].

Based on these hedonic price method studies, a cost for transport noise can be estimated for global transport and for individual means of transportation. The Victoria Transport Policy Institute gives a selection of estimated transport noise costs for a few countries worldwide [21]. The figures are exposed in Table 1.

Country	Percent of GDP
France	0.24
Germany	0.20
Norway	0.23
UK	0.50
US	0.06 – 0.21
Japan	0.20
OECD, average	0.15

Table 1: Estimates of total transport noise costs, from [21]

The same institute also gives a literature review of specific noise costs for different types of vehicles, exposed in Table 2.

Vehicle Class	Urban, Peak	Urban, Off-Peak	Rural	Average
Average car	0.013	0.013	0.007	0.011
Compact car	0.013	0.013	0.007	0.011
Electric car	0.004	0.004	0.004	0.004
Van/light truck	0.014	0.013	0.007	0.011
Rideshare passenger	0.000	0.000	0.000	0.000
Diesel bus	0.066	0.066	0.033	0.053
Electric bus/trolley	0.040	0.040	0.020	0.032
Motorcycle	0.132	0.132	0.066	0.106
Bicycle	0.000	0.000	0.000	0.000
Walk	0.000	0.000	0.000	0.000
Telecommute	0.000	0.000	0.000	0.000

Table 2: Estimated noise costs of various types of road vehicles. Values for 2007 in USD per vehicle mile. [21]

It can be interesting to compare the cost of traffic noise pollution with the cost of other environmental impacts such as air pollution. A comparative of the different external costs of cars for EU-27 is given in Table 3 taken from a report published by Technische Universität Dresden in 2008 [22].

	Accidents	Air Pollution	Noise	Climate Change (low)	Climate change (high)	Up + Downstream (high)	Up + Downstream (low)	Other	Total
Cost for EU-27 (Mio € /a)	154.042	26.762	7.905	39.486	137.969	37.366	20.930	10.240	373.284

Table 3: Total external costs of cars for EU-27 by cost categories in 2008, from [22].

We can see that the external cost of noise is not negligible compared to the cost of air pollution.

### 3.4 Indirect impacts related to cross-functional conflicts in the vehicle design process

Reducing noise emitted by ground vehicles is a complex problem that involves cross-functional sub-problems, as modifying the shape or components of a vehicle in order to reduce its emitted noise is likely

to affect other important characteristics of the vehicle. The following paragraphs tackle various problems associated with the reduction of aerodynamic noise, engine noise, structure-born noise or tire-rolling noise on ground motorized vehicles.

One of the main purpose of this project is to predict and reduce aerodynamic noise. Aerodynamic noise is dependent on the shape of the vehicle. To reduce it, one needs to alter the shape. This will also affect the aerodynamic performances of the vehicle, in particular the drag. And drag is directly linked to fuel consumption. Acting on aerodynamic noise by changing the shape of the vehicle is thus likely to affect fuel consumption in a positive or negative way.

Another way to affect external noise propagation from ground vehicle could be to modify its body components by introducing multi-functional body panels, allowing a better attenuation of the sound generated from the engine or from the vibrations in the structure. This panels would affect many characteristics of the design, such as the weight of the vehicle, the mechanical properties of the structure, the overall functional design and the shape. Each of these characteristics are correlated to the performance of the vehicle in different areas. Weight is related to fuel consumption, dynamic/stability properties and safety among others. Mechanical properties of the structure are also related to safety and dynamic issues. The shape will mostly affect fuel consumption through aerodynamic forces.

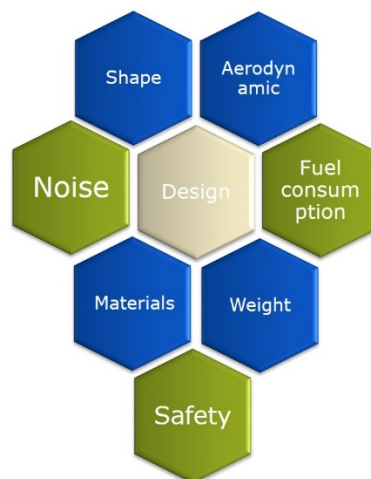


Figure 7: Illustration of some of the cross-functional conflicts linked to sound reduction in vehicle design. In green, performance values, in blue, vehicle properties.

To sum up, reducing the noise generated by a specific vehicle type is not a problem that can be treated as an isolated problem: it is a cross-functional problem that needs an understanding of the overall design of the vehicle.

### 3.5 Economic cost of the policy on noise reduction

Setting up facilities for measurements and controls has a cost for communities. This cost is nevertheless partially paid by fees coming from vehicle and equipment manufacturers and importers. Performing efficient noise reduction also has a cost for vehicle manufacturers, a cost that is partially passed onto the buyers [1].

### 3.6 Benefits and drawbacks for vehicle manufacturers

Noise emitted by ground vehicles has two different types of listeners: drivers who are active users and people around the vehicle who could be referred to as passive users. Noise is perceived differently and has different functions for these users. Noise is a factor of annoyance for everyone but also has some useful functions. For example outside the car noise helps people to localize the car in space, whereas

inside the car noise helps the driver to use the engine in an efficient way. Sound also has an impact on image. For users sound is associated with brand. A vehicle which is unpleasant to hear either from the inside or the outside will be less likely to attract buyers.

The policy of noise reduction has a cost for vehicle manufacturers who have to invest in research and development to reduce the noise emissions of their products. Vehicle manufacturers who are not abiding to the maximum noise level emissions stated in the law have to pay fees.

But reducing noise emissions can also be beneficial for industries. As stated earlier, noise is a criteria of quality for buyers and is also important for customers of potential buyers in case of business to business transactions. Some of the external costs of noise can also have a drawback on vehicle manufacturers. Health costs will affect potential buyers whose purchasing power will be reduced.

## **4 Perspectives for the future**

In order to develop a long term policy on noise transportation within communities or within the industry, a clear view on on-going and future legislations is needed, as well as a view on future transportation systems and related technologies.

### **4.1 Recent, on-going and future legislation on noise emissions from road vehicles**

The EU recently adopted an Environment Action Program to 2020, a program one of the aims of which is to decrease noise pollution in the EU by 2020 to match the recommendations of the World Health Organization [23]. In addition to that, in order to update the current standards for vehicle noise to future goals, the European Commission proposed in 2011 a new regulation for stricter noise emission standards for cars, trucks and buses. After a series of negotiations with the many actors involved, the regulation was adopted in 2014 [24]. This regulation aims at setting a 4 dB(A) noise reduction for cars and 3 dB(A) for trucks, in two steps. The first step is foreseen to apply 7 years after publication of the regulation and sets a reduction of 2 dB(A) for passenger cars, buses and light trucks, and a reduction of 1 dB(A) for heavy duty vehicles. The second step shall follow after 5 years, and sets 2 dB(A) reduction for all vehicles concerned. A new test method should also be implemented. The outcome of this regulation was criticized by NGOs such as the European Public Health Alliance (EPHA) and the Health and Environment Alliance (HEAL) [25] who deemed it insufficient.

### **4.2 Evolution of technology and vehicle concepts**

Achieving a drastic reduction in noise levels from a given ground vehicle requires technological innovation. As we mentioned in Section 3.4, reducing the noise emitted by a vehicle cannot be efficiently done without a broad understanding of the vehicle design and functionalities. As design and technological tools evolve, noise reduction strategies also evolve. As an example, the current development of electric vehicles changes the relative contribution of the vehicle noise sources. The powertrain noise will be drastically reduced and aerodynamic noise will become more important, not only at high speeds. New issues of safety will also arise since vehicles have to be heard by other vehicles and by pedestrians.

## **Conclusion**

Transportation noise has a cost due to its impacts on health, ecology and housing prices. This cost is not negligible compared with other costs of traffic such as air pollution. The growing awareness for this issue has led to reactions from governments and communities. Actions are being taken by communities to reduce transportation noise through always stricter legislation which put a pressure on manufacturers to design more silent vehicles. The European Federation for Transport & Environment claims that benefits of this policy can outweigh costs by 30 times. Costs and benefits of a noise reduction policy are specific to each actor but benefits are to be withdrawn for everyone. Furthermore this balance cost-benefit has to be adjusted by taking into account cross-functions. It is not necessarily beneficial to reduce noise emissions by any means: noise reduction within a vehicle design process must be accounted for as one of the design targets together with others such as fuel consumption in order to reduce the environmental and economic impact in a global and efficient way.

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