PAN
ARCHIVES OF ACOUSTICS
Vol. **39**, No. 3, pp. 333–341 (2014)

DOI: 10.2478/aoa-2014-0038

Electric Vehicles and Urban Noise Control Policies

Luigi MAFFEI, Massimiliano MASULLO

Department of Architecture and Industrial Design
Seconda Università degli Studi di Napoli
Via San Lorenzo, 81031 Aversa (CE), Italy; e-mail: {luigi.maffei, massimiliano.masullo}@unina2.it

(*received May 30, 2014; accepted July 29, 2014*)

Limited Traffic Zone (LTZ) is a planning strategy that is more and more adopted by municipalities in Europe to improve their environmental conditions. It consists in the prohibition for traditional vehicles to circulate in specific areas. Although the main aim is to tackle air pollution problems, positive effects are registered in terms of reduction of noise annoyance and in terms of improved "quality of life" if specific conditions are respected. On the other side under the drive of the global market, the number of circulating electric vehicles in urban sites is also increasing. In the next years we expect to experience a new and not well-known urban soundscape.

In this paper is presented an overview of recent urban projects and policies that deal with noise control and how these experiences will match into the next years with the sound characteristics of new electric vehicles for private and public transportation.

Keywords: soundscape, electric vehicles, limited traffic zones, urban noise control.

List of Acronyms

ICEV – Internal Combustion Engine Vehicle,
EV – Electric Vehicle,
HEV – Hybrid Electric Vehicle,
PHEV – Plug-in Hybrid Electric Vehicle,
BEV – Battery Electric Vehicle,
ARS – Access Restriction Scheme,
LTZ – Low Traffic Zone,
LEZ – Low Emission Zone,
ZEZ – Zero Emission Zone,
CCZ – Congestion Charging Zone,
CCS – Car Sharing Scheme,
e-CCS – Electric Car Sharing Scheme

1. Introduction

The concentration of the economic activities in urban areas has made these places of easier access to jobs and social opportunities and led to consequent strong urbanization phenomena. As reported in a recent statistical report of the EU (European Commission, 2013a) more than 74% of the EU-27 population live in urban areas. This concentration occurs also in other geographic areas: 82% in USA, 91% in Japan, 74% in Russia. As a consequence, high volumes of public and private vehicles circulate within urban areas, increasing even more the traffic congestion.

The cities are not more able to tolerate larger volumes of traffic (Maffei, 2009). Traffic congestion has negative impact on the quality of life. It causes impact on the individual sphere and on the environment, it influences the well-being and can play a relevant role in the social exclusion of the people (European Environment Agency, 2013b).

Key aspects are: road safety, air and noise pollution.

In 2011, 91.2% of road crashes occurred in urban and suburban areas (86% of injured persons and 56% of fatalities) while non-urban areas accounted only for 8.8% of road crashes but 44% of fatalities. The safety of pedestrians, cyclists and motorcyclists in urban areas remains a major challenge (IRTAD, 2013).

Air pollution is probably the aspect of major importance for health. Among the EU urban population it was estimated that more than 75% of the city dwellers were exposed in the period 2009 and 2011, to particulate matter ($PM_{2.5}$, PM_{10}) and benzo(a)pyrene (BaP) concentrations above WHO Air Quality reference values and a percentage between the 20% and 33% above the higher EU reference values (European Environment Agency, 2013a).

In a recent European Environment Agency report (European Environment Agency, 2013b) it is referred that, at least 100 million Europeans are exposed to daily average road traffic noise levels that are detrimental to health. Moreover in the European cities with populations of more than 250.000 inhabitants the percentage of the inhabitants exposed to long-term average road traffic noise levels exceeding 55 dB Lden was more than 62% while more than 42% was exposed to long-term average road noise levels exceeding 50 dB Lnight (European Environment Agency, 2012).

In a survey based on the perception of quality of life, which involved about 500 citizens for each one of the 79 European cities analyzed, it emerged that the size of the city plays an important role with regard to the noise issue: the 17 cities where more than 50% of the respondent were dissatisfied have at least 250.000 inhabitants, 12 of them are cities with over 1 million inhabitants. Ten of the 20 least satisfied cities were capitals and for 8 of them, the level of satisfaction was below 50%: Bucuresti (27%), Madrid (31%), Athina (33%), Roma (37%), Sofia (40%), Paris (43%), Warszawa (46%) and Praha (49%) (European Commission, 2013b).

In order to improve the quality of life of the urban centers, policy makers have to make fundamental choices about the urban space. They have to plan and manage the infrastructures, defining its loads, flow and capacity, the reserved and parking areas as well as the pedestrian facilities. They have also to look at new transport technologies which should assure environmental quality.

2. Urban noise related policies

The reduction of the number of vehicles per person circulating in the urban areas is expected to reduce the problems previously discussed. This intervention implies that two non-exclusive strategies can be undertaken.

On one hand, the development of the public transportation system based on rail infrastructure with high capacity and frequency (i.e. metros, trams) can be a structural solution to the problem as it determines a strong reduction of the private transport. This is however a very expensive and long term strategy, whose positive results can be observed only after several years.

On the other side the Access Restriction Schemes (ARSs) can be considered as one of the powerful policy instruments offering a significant potential for addressing the major challenges of urban sustainability (European Commission DG MOVE, 2013). Access Restriction Schemes (ARSs) can be applied in different manner (Point based, Cordon based, Area license based pricing, Distance or time based) (ISIS-PWC, 2010). In the urban areas, ARSs have as major scope the restriction of the accessing of specific vehicles.

The Low Emission Zones (LEZs) are defined as that zones where the access for pollutant vehicles are banned. The category of the pollutant vehicles is generally established according to the more recent European emission standards (e.g. Euro 5, Euro 6) defined in Directives that time by time amend 1970 Directive 70/220/EEC. Others ARSs follow the principle of the "pay to pollute". In these areas called Congestion Charging Zones (CCZs) a payment is due to have the right to drive and to pollute the environment. The most relevant opposition to the CCZs is that it is intrinsically assumed that people with low income cannot afford driving in the city due to congestion charging (European Commission DG MOVE, 2013).

With specific reference to the noise pollution and to the influence on it due to vehicles' sound emission further strategies can be considered: 1) the control of the acoustic conformity of new vehicles; 2) the control of the market of replacement parts (e.g. exhaust silencers); 3) the periodical technical inspection (or by road side) on the acoustic performance of vehicles in use. Other strategies refer to the diffuse use of labels to certify the quality of components of the vehicles. This is the case of the recent labeling of the tyres sold in the European Community which must indicate the fuel efficiency, the safety-skid resistance and the rolling noise level in dB (de Graff, van Blokland, 2012).

Since the 1990s the hybrid technology has lead to the development of the two most popular hybrid electric vehicles (HEVs) (Honda Insight and Toyota Prius). In the 2000s the first plug-in hybrid electric vehicles (PHEVs) capable to drive solely by recharging their batteries from an electrical power grid (Pridmore *et al.*, 2010) was introduced in the market.

With the introduction of these technologies a more restrictive concept of limited areas respect to LEZs and CCZs was introduced. It is the Zero-Emission Zones (ZEZ) where the access is allowed only to all-electric vehicles. The LEZs, CCZs and recently the ZEZs can be considered as strategies to halve the use of conventional cars in urban areas by 2030 and phase them out of cities by 2050 which is the target of the EC (European Commission, 2011). As requirement, the construction of a charging infrastructure for plug-in hybrid and electric vehicles will change completely the urban environment of the future cities (OLEV, 2013) (Fig. 1).

Other solutions combine the principle of the car sharing scheme (CSS) with that of electric vehicles, combining two mobility solutions in the same service (e-CSS). This service is based on the sharing of electric car fleets of smaller size than the traditional urban cars (Fig. 2).

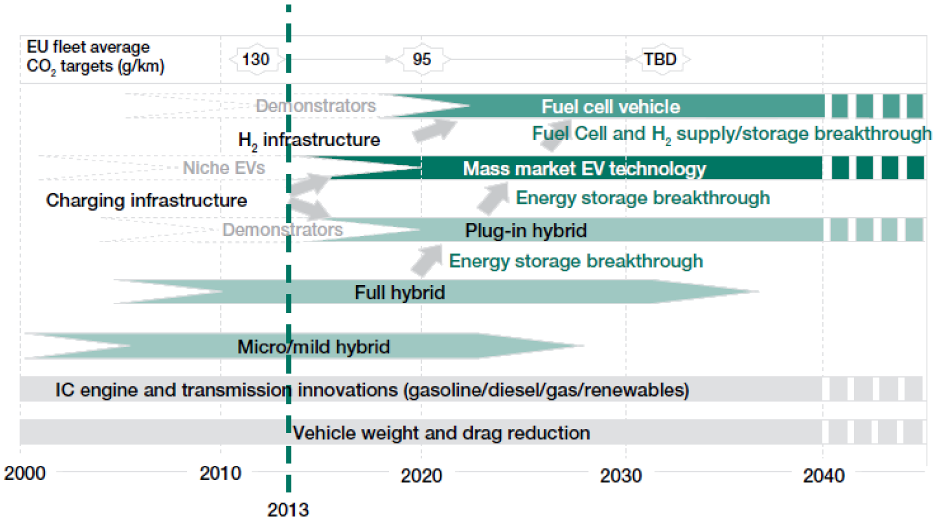

Fig. 1. View of the technology roadmap (NAIGT, 2009).

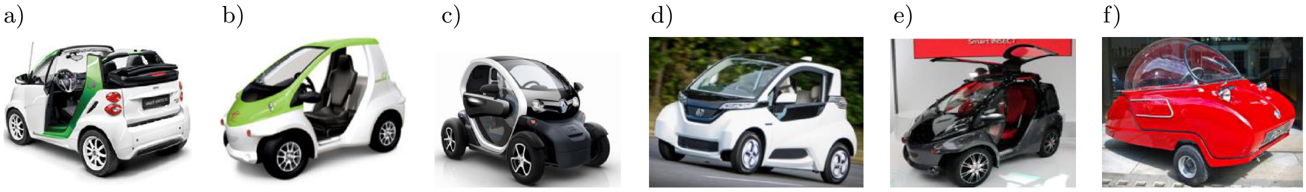

Fig. 2. a) Smart EV, b) Toyota COMS c) Renault TWIZY, d) Honda Micro Commuter, e)Toyota Insect, f) Peel Electric Mini-Cars.

3. Electric vehicles and noise emission

Even though the internal combustion engine vehicles (ICEVs) will continue to have an important role for years to come, automotive industries are working to extend their portfolio introducing new technologies: hybrid, electric and fuel cell vehicles (Fig. 3). On the other side further results, in terms of efficiency savings, are expected introducing lighter vehicles (OLEV, 2013).

The noise emission from vehicles is generated by the tyre/road interaction and the propulsion system. These emissions increase as the car speed increases. As shown in Fig. 4, tyre/road noise increase more rapidly than the propulsion noise and over 50 km/h dominates the noise emission of vehicles. As consequence

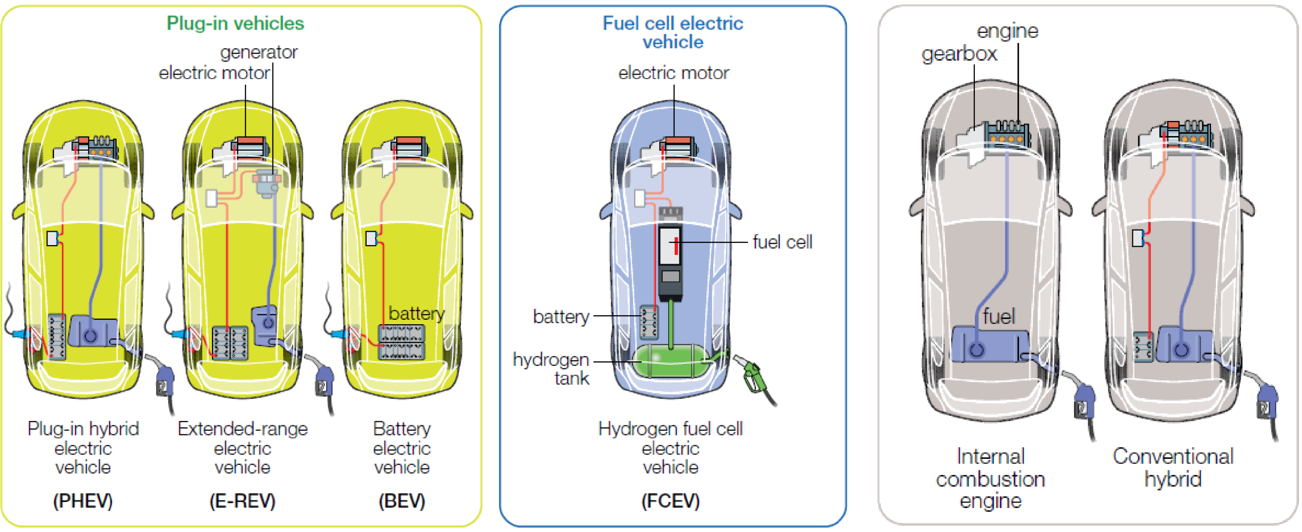

Fig. 3. Technologies and system of present and future vehicles (OLEV, 2013).

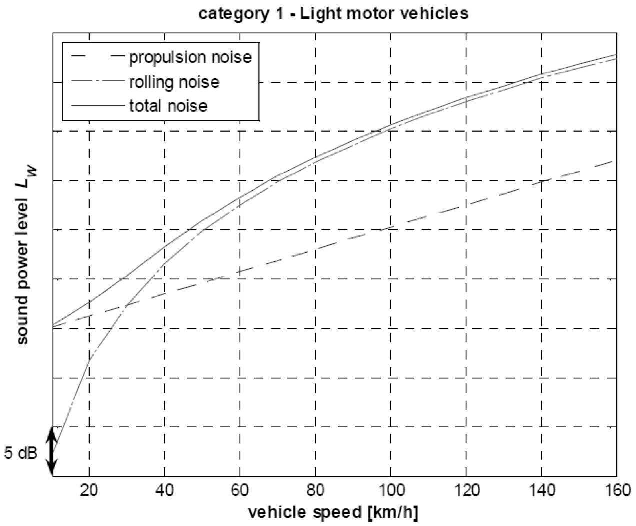

Fig. 4. Propulsion noise, the tyre/road noise and the total A-weighted level from a passenger car as function of speed vehicles (van Blokland, Peeters, 2007).

relevant differences between PHEV/HEVs and conventional ICEVs can be found in the low speed region where the electric propulsion is expected to be quieter than the conventional internal combustion engines.

In the last decade several studies measured the differences between the pass-by noise of PHEV/HEVs and ICEVs. Despite differences of the measurement techniques and modalities (type vehicles, speeds, microphone distance/height, background noise, type of tires and pavement) some important conclusion can be observed.

De Graff and Von Blokland have found that the difference of the sound pressure levels between PHEVs and ICEVs reach 7 dB at low speeds while at 40 km/h there is hardly any difference and over 60 km/h there is no difference at all (de Graaff, van Blokland, 2011). The Ford Motor Company Germany compared the pass-by of 11 cars at constant speed of 30 km/h (Dudenhoffer, Hause, 2012). The cars were Battery Electric Vehicles (BEVs) and ICEVs of similar models. BEVs were found quieter (2–4 dB) than the comparable ICEVs. Lower differences were found between BEVs and more recent typologies of ICEVs.

In line with these results, the authors of this paper, through a recent measurement campaign, have found that recent ICEVs models have $L_{A,\max}$ comparables with HEVs (Fig. 5).

Similar differences were also observed in a previous study aimed to investigate the perception of approaching electric vehicles. For the test a HEV (Toyota Prius 1.4 Hybrid) and a old ICEV (Ford Fiesta 1.2 TDI) were used and 5.5 dB at 30 km/h and 3.5 dB at 50 km/h were found as differences in $L_{A,\max}$ (Maffei *et al.*, 2014). In a Dutch study the propulsion noise of a HEV and of a conventional diesel vehicle, were compared by means of measurements with a microphone positioned under the hood. All was repeated for several speeds and urban driving conditions. In idling condition the difference was about 15 dB; 5–6 dB between 15 and 50 km/h and no difference was registered at higher speeds (Jabben, Verheijen, Potma, 2012). The same paper reports a further comparison between two subcompact cars, one being electric (Think City, 74 kW) and the second one with diesel engine (VW Polo, 34 kW) at speeds 10 and 50 km/h. The noise reductions due to the use of the electric car was about 10 dB (at 10 km/h) and 2.5 dB (50 km/h).

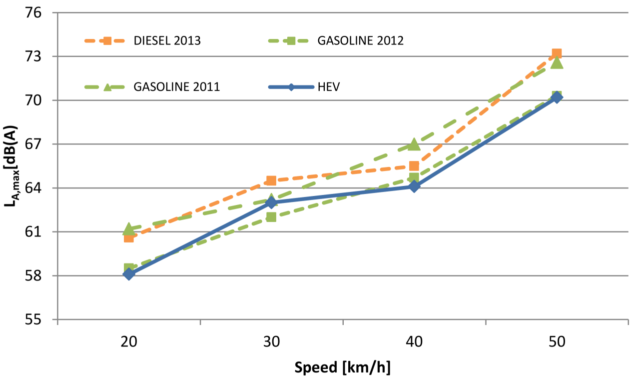

Fig. 5. Maximum noise levels of new ICEVs and a HEV, for pass-by between 20–50 km/h.

Kaliski *et al.* compared the noise emission of a HEV with data from a ICEV fleet under cruise and full throttle conditions. They found out that the HEV has lower sound emission level below 24 km/h under cruise conditions and below 40 km/h under full throttle. The comparison of the spectrum showed that lower levels for the HEV are present below 500 Hz. This could indicate a potential reduction of the noise pollution at large distances (Kaliski, Old, Blomberg, 2012).

In a paper on the "state of art" of the noise from electric vehicles, Møller Iversen *et al.* (2013) noticed that the maximum noise reduction between cars of the same model but with different propulsion (HEV and ICEV) was contained between 1 and 15 dB at 10 km/h; no differences were found at speeds over 25 km/h.

At this early stage of the market penetration of electric transportation systems, a typical urban traffic condition is determined by a dominant presence of ICEVs with an increasing expected number of HEVs. The background noise strongly influence the car passing-by perception in case of PHEVs/HEVs. In the EVADER project, the variability of the background noise during working days and along main roads in Barcelona, Darmstadt and Paris has been measured. The background noise is in a range between 46–59 dB(A) in locations with low traffic volumes and between 65–83 dB(A) in locations with moderate traffic volumes. In these conditions of high variability, the sound emission of HEVs can be highly masked and its detection decreases (Dubois, 2012).

This introduces other matters mainly connected with pedestrian safety and in particular to visual impaired people safety (Ashmead *et al.*, 2005; Goodes, Bai, Meyer, 2009; Garay-Vega *et al.*, 2010; Glaeser, Marx, Schmidt, 2012).

Maffei *et al.* in a laboratory test using the Immersive Virtual Reality (Maffei *et al.*, 2014) found out that also for normally sighted people wrong decisions based on audio-visual perception in crossing the road can be taken. At a speed of 30 km/h the number of hits crossing the road was higher if the approaching vehicle was a HEV rather than a less recent ICEV diesel.

In order to reduce this potential problem the Japanese and USA Governments, as well as the EU, have formulated official documents (Public Law 111-373 – JAN. 4, 2011) (Japan MLIT JASIC, 2010) (EU Commission, 2011) promoting the addition of alert sound to allow blind and other pedestrians to reasonably detect a nearby PHEV/HEV.

More recently, to harmonize these actions, UN/ECE/WP29/GRB (Working Party on Noise, World Forum for Harmonization of Vehicle Regulations) has established an Informal Group for Quiet Road Transport Vehicles (IG-QRTV) to develop Global Technical Regulation (GTR) for acoustic requirements of quiet vehicles.

Additional warning sounds were designed to alert pedestrians to the presence of electric drive vehicles (HEV, PHEV and EV) travelling at low speeds. The EVADER project stated that the proposed warning signal should be easily detected by in noisy situations, by people of any generations and they must be universally recognized as a warning signal. Some requirements proposed by the IG-QRTV are that: a warning device should have a sound pressure level (SPL) equal to that of a typical ICE at the same distance, but with a different loudness. The emission spectrum of the warning signals should consider that older age people lose their audibility at higher frequencies. For optimal audibility a frequency band from 0.5 kHz to 3.5 kHz is recommended. Other recommendations concern the localization (0.5–4 kHz) and the directivity of the signal. Too much or too little directivity are not appropriate for safety and for environmental reasons. In fact a pedestrian positioned to the side of the vehicle will not receive the full warning signal if this is too spatially focused. On the other side if the sound radiates equally in all directions the passing-by noise of a quiet vehicle can mask the sound coming from the following vehicle (Garcia, Haide, Boverie, 2013; Dubois, Baudet, Chamard, 2012). Several studies have proposed or compared different warning signal in terms of detection (Parizet *et al.*, 2013; Robart, Parizet, Garcia, 2012; Voigt *et al.*, 2011) one of them proposing a cross cultural experiments between German and Japanese subject (Yamauchi *et al.*, 2012). Moreover in a study of Misdariis *et al.* (2013) on the detection of several warning signals it was found out that reaction times are significantly and predominantly decreasing along the course of the experience (several days), meaning that a learning effect occurs.

New future technological and wearable solutions could represent alternatives to the introduction of warning signals to improve the safety of both, visual impaired and seeing pedestrians. In fact the pedestrian safety involves also the large part of seeing people which deliberately choose to totally neglect sound cues (Sandberg, 2012) because of the use of personal music players (Heller *et al.*, 2008) or cell phones with earphones (Nasar, Hecht, Wener, 2008).

4. Examples of application in Europe

In the research conducted on 417 European cities (ISIS-PWC, 2010) was found that the 70% of the investigated cities have Access Restriction Schemes (including schemes that have been planned but have not, or not yet, been implemented). Italy represent the nation with the major number of cities having information on ARSs. Interesting results of this research allow us to understand the characteristics of the ARSs. The two main expressed motivation for the application of ARSs are: the environment (64%) and the traffic congestion (35%). For the 61.5% of the investigated cities the ARSs are targeted to the private cars and freight cars and in the 29.6% of them only to private cars. In the 82% the ARSs do not consider charges. In the 71% of the cases the restriction are applied for 24 h. The access restriction schemes foresee, for the 53% manual control, for the 23% stickers and only for the 23% the use of technology systems. The 59% of the ARSs is represented by LEZs. The public information concerning the implementing of the ARSs has a relevant role in its application. In the investigated cities the information dissemination was done before (78%), during (66%) and after (34%) of the cities. This approach ensure the people awareness and decrease the number of violations (European Commission DG MOVE, 2013).

Maffei *et al.* (2013a) studied possible variations in the sound levels and in the subjective soundscape perception as a consequence of the implementation of a Limited Traffic Zone in the historic centre of Naples in Italy (Fig. 6, left) which is, at the moment, the largest example of application of a LTZ in Europe. Recently LTZ was implemented over the Naples historic centre; nevertheless, not a word was said about soundscape or perceived loudness of the site and the whole informative campaign launched by the local authority was focused on the aspects related to the traffic and the air pollution.

The study was based on the comparison between campaigns of objective measurements and subjective survey (Fig. 6, right). The first campaign of objec-

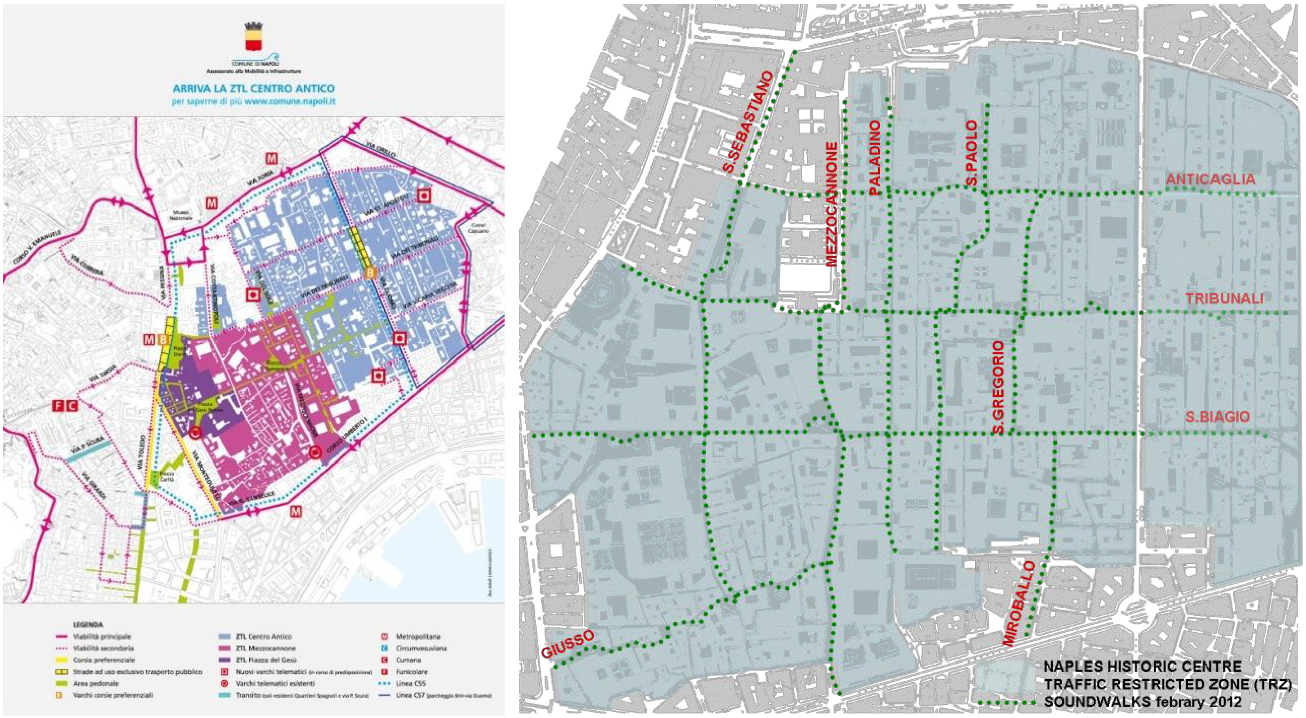

Fig. 6. Naples Historic Centre LTZ (left), soundwalks' paths 2012A, 2012P, 2013P (right) (Maffei *et al.*, 2013a).

tive measurements concerned the sound levels before the introduction of the LTZ (2012A). The second and the third one were carried out, soon after (2012P) and one year later (2013P) the implementation of the LTZ (Fig. 6, right).

The results shown that after a short period in which a reduction of the environmental sound level was experienced, the noise increased newly (Fig. 7).

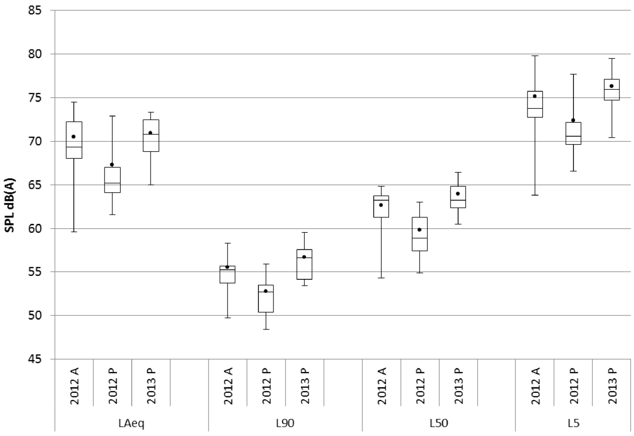

Fig. 7. Variation of the equivalent and percentile levels for the entire soundwalk over the years (Maffei *et al.*, 2013a).

A possible explanation of this tendency could be a more concessive policy for the vehicles' authorization access led by the Municipality, such as electric vehicles and freight traffic at any time of the day. The subjective surveys were also coherent with this trend. The assessment of the sound aspect become worst between 2012 and 2013. Moreover, the percentage of people not noticing the sound variation due to the LTZ increased from 17% to 45%. The differences between the ante LTZ and post LTZ condition were probably more evident to the subjects in a short-term period, while a kind of perceptual habit appears after a while.

In 2008 the Municipality of London launched a LEZ strategy, with the aim to improve the air quality within the London district. The LEZ was implemented in different phases by its introduction till to year 2012, when also large vans and minibuses were under restrictions. Particulate matter concentrations in several sites within the LEZ were found to be stable or in decrease tendency after introduction of the scheme (Ellison, Greaves, Hensher, 2013), while no information was made available concerning the effects of the scheme on noise levels. Nevertheless in the 2013 the Mayor of London set out to create the world's first big city Ultra Low Emission Zone (ULEZ) in the centre of London by 2020. This ambitious project consider in this area the exclusive use of buses and taxis with hybrid technology. The plan is supported by a large urban charging network of 1300 publicly accessible charging points across the city (OLEV, 2013).

This vision is similar to the new concept of quiet zone (Q-zone) defined in the City Hush project (Stenlund, 2011). In this project a new classification in 5 noise classes was developed. The classes cover the complete range of the exterior noise levels for passenger cars (ISO 362:2007) from the quietest (Noise class A) to the noisiest class (Noise class E). At difference of the conventional LEZ or ZEZ the criteria for the vehicles' access in Q-zone is that each car has to guarantee acoustic requirements to be considered adequate for the access. In the Noise class A, the pure electric cars will be, probably, the only typologies of vehicles that can satisfy the proposed requirements.

The presence of car-sharing schemes (CSSs) in the urban areas is becoming even more diffuse. Several private companies offer this service in different European cities and some of them propose the use of compact electric fleets (Civitas Modern, 2012). An example of this e-CSS was implemented in the city of Vitoria-Gasteiz in the Basque Country. The fleet consists of 6 electric vehicles: 4 BEVs (Peugeot IONs) for short trips and 2 larger PHEVs BYD F3DM for longer trips. The analysis of the data on the use of this e-CSS has shown that the smaller BEVs are used in a large percentage (84%) for an average distance of 2 km/reservation.

5. Urban soundscape scenarios

In the next years the soundscape in urban sites could be subjected to modifications nevertheless several scenarios should be considered. These scenarios are strongly dependent by the policies that national and local authorities intend to develop but also by the efforts of the transport industry in improving present technologies and in developing new ideas, prototypes and final products.

In the basic scenario, no restrictions policies are adopted and there is a slow but constant migration from ICEVs to HEV/EVs. A study (Kaliski, Old, Blomberg, 2012) applied to the city of New York and in particular to Park Avenue showed that keeping constant the actual traffic flow with its composition (cars, busses, trucks) and low average speed (14.5 km/h), although the replacement of all ICEs with HEV/EVs, the predicted reduction of the equivalent sound level is around 1.0 dB during the day and 2.5 dB at night. The reasonable assumption that trucks will not change anyway propulsion system into the next year has strong influence on this prediction.

Similar results are reported in a study (Verheijen, Jabben, 2010) applied to an area of the city of Utrecht. With fully electrified vehicles the highest reductions up to 4 dB could be predicted along the secondary urban roads and at crossings. Along the main roads, where the average speed surpasses 50 km/h, the reduction is much lower. The overall noise reduction in the area is approximately 3 dB. Considering the number of exposed inhabitants and dose-response relationships, the study estimates, however, a reduction of the number of annoyed inhabitants of 33% and of the severely annoyed by 36%.

The same group of research (Jabben, Verheijen, Potma, 2012) investigated, with drive-by measurements of the noise emitted and with measurements of tyre/road noise, how much less noise is emitted from an EV compared to an ICEV. This combination allowed for a prediction of noise in a future situation in a city where 90% of the vehicle fleet is either hybrid or electric. It was showed that below 30 km/h a noise reduction of up to 6.1 dB can be obtained if 90% of the vehicle fleet is replaced by electric vehicles with silent tyres and up to 4 dB without silent tyres.

The basic scenario could be radically modified in worse if regulations on pedestrian safety impose to HEV/EVs the use of warning signals. The soundscape and the reaction of the population will be strongly influenced by the sound characteristics of the warning signal (loudness, spectrum, directivity) but also by the efforts of the PHEV/HEVs industry in building up a common approach to the problem. The modern technologies based on auralization (Genuit, 2013), and immersive virtual reality (Maffei *et al.*, 2013b; 2013c; Ruotolo *et al.*, 2013) can, however, permit to search and build up the best solution which guarantees both the pedestrian safety, an improved soundscape and consequently a better quality of life.

Other scenarios contemplate areas in which Access Restriction Schemes have been already applied.

A first possibility is that local regulations emphasize the air quality aspects rather than the noise aspects of the environment. In these areas more and more traffic of PHEV/HEVs will be then allowed. With or without warning signals this traffic can become again the dominant sound source and it will contribute to change and probably to worsen the actual soundscape.

A second possibility is that local regulations introduce limitation to the private traffic and/or directly or indirectly to the sound emission of PHEV/HEVs. This is the case for example of areas in which only electric public vehicles are allowed (busses, taxis) or areas in which only EVs with silent tyres are allowed. If in this areas there is a relevant presence of human activities (commerce, craftsmanship) the influence of the traffic on the soundscape could be not significant.

Finally a positive scenario can be imagined in a long term and it involves a new concept of transportation in cities' centers. More and more prototypes of light electric vehicles, not necessarily identified as cars, are designed, developed, manufactured and introduced in the market to have a corner in private transportation system inside cities center. They are characterized by small dimensions (1–2 passengers), light weights (partially open, new materials), very low velocities (max 30 km/h) and by a design which is shaped on the final user (young people, old people). All these characteristics have a positive feedback on the sound emission, which could be comparable to that of an electric bicycle. The development and the predominance of this concept depends on the action that on one side policy makers, mainly through specific subsidies and regulation, and on the other side stake-holders (designers, industrialists, associations of citizens) implement.

6. Conclusions

In the last decade more and more cities have adopted Access Restriction Schemes (LTZ, LEZ, ZEZ, CCZ) aimed to reduce the air pollution of urban areas with high traffic congestion. At the same time with the arrival of electric propulsion systems and its expected diffusion over the next few years, possible scenarios with a significant reduction of the urban noise pollution and new soundscapes can be imagined.

However, relevant modification will be obtained only if the strategic and technological solutions will be implemented in a proper way.

A great effort should be made to design innovative technological solutions, as alternative to the use of warning signals, to improve the pedestrian safety of impaired and seeing people.

A new concept of car, more light, compact and with a low maximum speeds that integrates the electric propulsion systems and low noise tyres, should be designed.

Policy makers and stakeholders should manage at the best the use of ARSs. Schemes with acoustic requirements of access (such as Q-zones) should be implemented. In these urban areas the citizens will experience a new soundscape and will be able, gradually, to learn and accustom to the new sound stimuli developing also a new awareness towards the risks associated to new vehicles.

References

1. Ashmead D.H., Guth D., Wall R.S., Long R.G., Ponchillia P.E. (2005), *Street crossing by sighted and blind pedestrians at a modern roundabout*, Journal of Transportation Engineering, **131**, 11, 812–821.
2. Civitas Modern (2012), *Electric vehicles use and e-car sharing scheme in Vitoria*, Vitoria-Gasteiz.
3. de Graaff E., van Blokland G. (2011), *Stimulation of low noise road vehicles in the Netherlands*, Proceedings of Internoise, Osaka.
4. de Graff E., van Blokland G. (2012), *Measures on road traffic noise in the EU Input paper for the Interest Group on Traffic Noise Abatement*, M+P.BAFU.11.01.1.
5. Dubois F. (2012), *Notes of ambient noises in European cities*, D1.1: Database of noise environment, eVADER Electric Vehicle Alert for Detection and Emergency Response.
6. Dubois F., Baudet G., Chamard J.C. (2012), *EVADER: Electric Vehicle Alert for Detection and Emergency Response*, Proceedings of the Acoustics 2012, Nantes.
7. Dudenhoffer K., Hause L. (2012), *Sound Perception of Electric Vehicles*, ATZ, 114.
8. Ellison R.B., Greaves S.P., Hensher D.A. (2013), *Five Years of London's low emission Zone: Effects on vehicle fleet composition and air quality*, Transportation Research Part D 23, 23, 25–33.
9. EU Commission (2011), *Proposal for a regulation of the European Parliament and of the Council on the sound level of motor vehicles*, 2011/0409 (COD).
10. European Commission DG MOVE (2013), *Results of the public consultation 'The urban dimension of the EU transport policy'*, Final report of public consultation, COWI.
11. European Commission (2013a), *EU transport in figure*, Statistical pocketbook 2013.
12. European Commission (2013b), *Quality of life in cities*, Flash Eurobarometer 366, Regional and Urban Policy.
13. European Commission (2011), *White Paper on transport Roadmap to a single European transport area. Towards a competitive and resource-efficient transport system.*
14. European Environment Agency (2012), *The contribution of transport to air quality*, EEA Report n. 10/2012.
15. European Environment Agency (2013a), *Air quality in Europe – 2013 report*, EAA Report n. 9/2013.
16. European Environment Agency (2013b), *A closer look at urban transport*, EAA Report n. 11/2013.
17. Garay-Vega L., Hastings A., Pollard J.K., Zuschlag M., Stearns M.D. (2010), *Quieter Cars and the Safety of Blind Pedestrians: Phase I*, Final Report.
18. Garcia J., Haide M., Boverie S. (2013), *D4.1: State of the Art report concerning acoustic warning strategies*, eVADER Electric Vehicle Alert for Detection and Emergency Response.
19. Genuit K. (2013), *What will be the influence of e-mobility on soundscape*, Proceedings of Meetings on Acoustics, **19**.
20. Glaeser K.P., Marx T., Schmidt E. (2012), *Sound detection of electric vehicles by blind or visually impaired persons*, Proceedings of Internoise 2012, New York, USA.
21. Goodes P., Bai Y.B., Meyer E. (2009), *Investigation into the Detection of a Quiet Vehicle by the Blind Community and the Application of an External Noise Emitting System*, Society of Automotive Engineers.
22. Heller M., Kuzel M., Kwasniak A., Cuadrado J. (2008), *Individuals' Abilities and Behaviors and Current Technologies in Intersection Crosswalks*, ITE Journal, **78**, 12.

23. IRTAD (2013), *Road Safety Annual Report 2013*, International Traffic Safety Data and Analysis Group. OECD/ITF.

24. ISIS-PWC (2010), *Study on Urban Access Restrictions*, Final Report.

25. Jabben J., Verheijen E., Potma C. (2012), *Noise reduction by electric vehicles in the Netherlands*, Proceedings of Internoise 2012, New York (USA).

26. Japan MLIT JASIC (2010), *Guideline on measures against the quietness of hybrid vehicles*, QRTV-03-01, Japan.

27. Kaliski K., Old I., Blomberg L. (2012), *Sound emissions from a plug-in electric vehicles*, Proceedings of Internise 2012, New York, USA.

28. Maffei L. (2009), *Acoustic and vibration exposure and comfort inside urban and extra-urban transportation*, 17th International Congress on Sound and Vibration, Kraków, Poland.

29. Maffei L., Di Gabriele M., Masullo M., Aletta F. (2013a), *Soundscape approach to evaluate the effectiveness of a Limited Traffic Zone as environmental strategy*, Proceedings of Internoise 2013, Innsbruck, Austria.

30. Maffei L., Iachini T., Masullo M., Aletta F., Sorrentino F., Senese V.P., Ruotolo F. (2013b), *The Effects of Vision-Related Aspects on Noise Perception of Wind Turbines in Quiet Areas*, International Journal of Environmental Research and Public Health, **10**, 5, 1681–1697.

31. Maffei L., Masullo M., Aletta F., Di Gabriele M. (2013c), *The influence of visual characteristics of barriers on railway noise perception*, Science of the Total Environment, **445**, 41–47.

32. Maffei L., Masullo M., Sorrentino F., Di Gabriele M. (2014), *Preliminary studies on the relation between the audio-visual cues' perception and the approaching speed of electric vehicles*, Proceedings of Meetings on Acoustics, **20**.

33. Misdariis N., Gruson A., Susini P. (2013), *Detectability study of warning signals in urban background noises: A first*, Proceedings of Meetings on Acoustics, **19**.

34. Møller Iversen L., Marbjerg G., Bendtsen H. (2013), *Noise from electric vehicles – 'state-of-the-art' literature survey*, Proceedings of Internoise 2013, Innsbruck, Austria.

35. NAIGT (2009), *An Independent Report on the Future of the Automotive Industry in the UK*, New Automotive Innovation and Growth Team, BERR Department for Business Enterprise and Regulatory Reform.

36. Nasar J., Hecht P., Wener R. (2008), *Mobile telephones, distracted attention, and pedestrian safety*, Accident Analysis and Prevention, **40**, 1, 69–75.

37. OLEV (2013), *Driving the Future Today A strategy for ultra low emission vehicles in the UK*, Office for Low Emission Vehicles.

38. Parizet E., Robart R., Chamard J.C., Schlittenlacher J., Pondrom P., Ellermeier W., Biancardi F., Janssens K., Speed-Andrews P., Cockram J., Hatton G. (2013), *Detectability and annoyance of warning sounds for electric vehicles*, Proceedings of Meetings on Acoustics, **19**.

39. Pedestrian Safety Enhancement Act of 2010 (2011).

40. Pridmore A., Wynn D., Hazeldine T., Milnes R. (2010), *An overview of the factors that limit new technology and concepts in the transport sector*, European Commission Directorate-General Environment and AEA Technology plc.

41. Robart R., Parizet E., Garcia J. (2012), D2.2: Perceptual test 1: Detectability, eVADER Electric Vehicle Alert for Detection and Emergency.

42. Ruotolo F., Maffei L., Di Gabriele M., Iachini T., Masullo M., Ruggiero G., Senese V.P. (2013), *Immersive Virtual Reality and Environmental Noise Assessment: an innovative audio-visual approach*, Environmental Impact Assessment Review, **41**, 10–20.

43. Sandberg U. (2012), *Adding noise to quiet electric and hybrid vehicl es: An electric issue*, Acoustics Australia, **40**, 3, 211–220.

44. Stenlund F. (2011), D3.2.2: Noise criteria for vehicles to enter Q-Zones, CITYHUSH.

45. van Blokland G., Peeters B. (2007), *The Noise Emission Model For European*, D.11, IMAGINE project.

46. Verheijen E., Jabben J. (2010), *Effect of electric cars on traffic noise and safety*, RIVM National Institute for Public Health and the Environment.

47. Voigt K.S., Schulte-Fortkamp B., De Coensel B., Botteldooren D. (2011), *Analysis of perception, adaptive design and rating of warning signals in different soundscapes*, 37th Annual Convention for Acoustics (DAGA'11), Düsseldorf, Germany.

48. Yamauchi K., Menzel D., Fastl H., Takada M., Nagahata K., Iwamiya S.-I. (2012), *Cross-cultural study on feasible sound levels of possible warning sounds for quiet vehicles*, Proceedings of Internoise 2012, Osaka.