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# Noise Mitigation of a Postal Delivery Service by Electric Vehicles

Franco Cotana[a], Andrea Nicolini[b], Michele Goretti[c]
[a,b,c] Department of Industrial Engineering, University of Perugia
Via Duranti 67, 06125 Perugia, Italy

**ABSTRACT**

Environment protection imposes to develop sustainable technologies and to propose alternative systems to reduce acoustic pollution. The present paper compares noise contribution of postal delivery service vehicles, both traditional and electric models, in order to improve acoustic protection of postmen and citizens. Measurements of sound pressure levels were carried out by implementing the methodology described in Directive 97/24/EC of the European Parliament and of the Council, 17 June 1997, on certain components and characteristics of two or three-wheel motor vehicles, amended and corrected, and in Regulation n. 51 of the Economic Commission for Europe of the United Nations, concerning the approval of motor vehicles having at least four wheels with regard to their noise emissions. The method, consisting in tests for vehicles in motion and stationary vehicles, was integrated with SEL measurements in different road conditions. Measured sound levels due to detected vehicles were compared; noise mitigation obtained by electric vehicles was evaluated for different traffic conditions.

## 1 INTRODUCTION

Italian leader in postal services and in mail delivery is a public utility with an extensive presence throughout Italy, consisting in a network of about 14,000 post offices, over 46,000 postmen and over 40,000 vehicles. As concerns environment protection, it is necessary to pursue the aim of reducing noise pollution; for this purpose, limit values for sound level must be respected; subsequent reductions in limit values and changes in testing procedure may be decided on the basis of available technological potential and analysis of cost/benefit ratios, in order to permit production of vehicles able to meet more stringent limits.

Present paper gives a contribution to noise control, showing results of a comparison between a traditional two wheel motorcycle and an electric four wheel motor vehicle, as concerns acoustic performance. Sound pressure level and SEL produced by tested vehicles, belonging to mail delivery service, were measured in different test conditions according to standards. The effects of road surface and slope, together with exhaust system noise emissions, were particularly taken into account. Finally an assessment of noise mitigation granted by electric motor was carried out.

[a] Email address: cotana@crbnet.it
[b] Email address: nicolini.unipg@ciriaf.it
[c] Email address: goretti.unipg@ciriaf.it

## 2 STANDARD REFERENCES

Both two and four wheel vehicles under test already obtained certificates of component type-approval regarding noise pollution and documents fitting free movement of vehicles and free placing on market of components; however measurement procedure according to standards was applied in the present study as a reference to assess acoustic performance.

### 2.1 Directive 97/24/EC

Directive 97/24/EC [1]of the European Parliament and of the Council of 17 June 1997, concerning certain components and characteristics of two or three-wheel motor vehicles, applies to permissible sound level and exhaust systems too. Procedure governing the granting of component type-approval in respect of permissible sound level was set out in Directive 92/61/EEC. The Commission takes into account and assesses the cost-effectiveness of proportionate and reasonable measures for reducing pollutant and noise emissions; Member States may make provision for tax incentives only for motor vehicles conforming to air-pollution and noise-pollution measures.

Directive 97/24/EC describes measuring conditions and method for vehicle testing during component type-approval. As concerns noise, tests are provided both for vehicles in motion and for stationary vehicles.

### 2.2 Regulation N. 51

Similar measurement methodology is described in Regulation n. 51 of the Economic Commission for Europe of the United Nations (UN/ECE), which concerns the approval of motor vehicles having at least four wheels, with particular regard to their noise emissions.

For the purpose of Regulation, “Approval of a vehicle” means the approval of a vehicle type as concerns noise and “Noise reduction system” means a complete set of components necessary for limiting noise produced by a motor vehicle and its exhaust.

## 3 VEHICLES

Traditional two wheel motor vehicle under test was a model of Piaggio Liberty 125 motorcycle, equipped with Piaggio LEADER 2 valve, 4 stroke, single cylinder engine, having a capacity of about 125 $cm^3$ and automatic twist and go transmission (Figure 1).

Figure 1: Traditional two wheel motor vehicle.

Four wheel vehicle was provided with electric motor, having a maximum power of 5 kW and using Brushless technology: tested model was a Free Duck produced by Ducati Energia (Figure 2).


Figure 2: Electric four wheel motor vehicle.

## 4 MEASUREMENT INSTRUMENTS

Measuring system consisted of a precision sound-level meter 01dB Solo, meeting requirements of Class 1 instruments, in compliance with IEC standards.

At the beginning and at the end of every measurement session, system was calibrated by means of a sound calibrator that fulfils requirements of precision Class 1 according to IEC standards. Without any further adjustment the difference between readings of two consecutive checks was less than 0.5 dB and measurement results obtained were accepted.

The compliance of instrumentation system with IEC requirements must be verified at least every two years, by laboratories authorised to perform calibrations traceable to the appropriate standards.

Engine rotational speed and vehicle speed were measured and checked compatibly with the accuracy of vehicle instruments.

Meteorological instrumentation used to monitor environmental conditions included measuring devices for temperature (accuracy within ± 1 °C), wind speed (± 1,0 m/s) and direction, barometric pressure (± 5 hPa) and relative humidity (± 5 %).

## 5 MEASUREMENT CONDITIONS

### 5.1 Test site

Any area in which there are no significant acoustic disturbances may be used as a test site. Flat surfaces which are covered with concrete, asphalt or some other hard material and are highly reflective are suitable; surfaces consisting of earth which has been tamped down must not be used. The test site must be in the form of a rectangle. There must be no significant obstacles and microphone must be at least 1 m from any object.

Tests were carried out in a suburban area of Perugia, reserved to park and sport facilities, where traffic noise was quite absent and background noise was very low, so that they didn't influence measurements (Figure 3).

Figure 3: Test site and microphone positions during noise measurements.

Test site consisted of a central acceleration section surrounded by a substantially flat test area. Acceleration section was level; track surface was dry and rolling noise was low. Test track paving respected required physical specifications concerning residual voids content, sound absorption coefficient and homogeneity: surface was as homogenous as possible within the test area. Designed area traversed by running vehicles was covered with dense asphaltic concrete, having suitable margins for safe and practical driving (Figure 4).

On test track the variations in free sound field between sound source and microphone didn't exceed 1 dB: in fact there were no large sound-reflecting objects within 50 m by the centre of acceleration section. Site surface was in accordance with requirements given in regulations. There was no obstacle to affect sound field close to microphone and sound source. Three observers carrying out measurements so positioned themselves as not to affect measuring instrument readings.

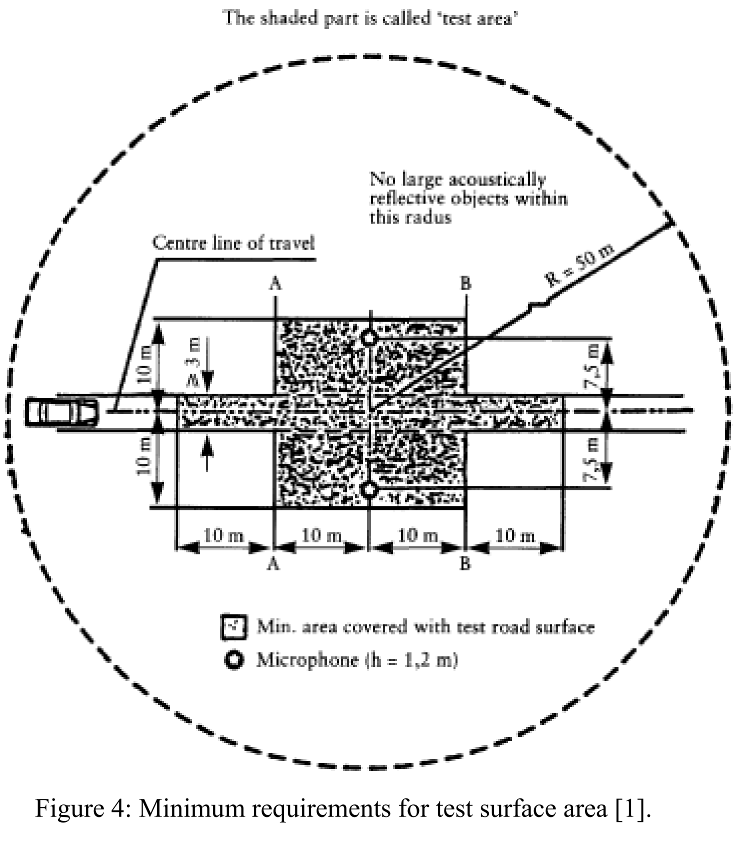


Figure 4: Minimum requirements for test surface area [1].

### 5.2 Weather and Environmental Conditions

Measurements were carried out on 10th April 2008 (traditional motorcycle) and on 22nd August 2008 (electric four wheel vehicle), under favourable weather conditions, being air temperature within the range from 20 °C to 30 °C.

Meteorological instrumentation was positioned adjacent to test area at a height of 1.2 m. Results were not affected by wind, whose speed at microphone height didn't exceed 5 m/s during tests; however microphone was provided with recommanded suitable windscreen.

"A"-weighted sound level of sound sources other than those of vehicles to be tested and of wind effects was at least 16 dB(A) below noise level produced by vehicles.

Difference between background noise and measured noise was always higher than 16 dB and test results didn't need any correction.

### 5.3 Vehicle Conditions

Before starting measurements, vehicles were brought to their normal operating conditions as regards temperature, tuning, fuel, etc. (as appropriate). During measurements vehicles were in running order, including coolant, oils, tools and driver. Tyres corresponded to requirements concerning size, tread surface and pressure appropriate to the test mass of vehicle. Measurements were made on unladen vehicles, as provided by regulations.

## 6 MEASUREMENT METHOD

### 6.1 Measurement Nature

Measurements were carried out using "A" frequency weighting and "Fast" time response.

Maximum sound level $L_{AFmax}$ and Single Event Level SEL, both expressed in "A"-weighted decibels (dB(A)), were measured at any transit of vehicles under test.

Noise produced by vehicles were measured according to methods described in regulations for vehicle in motion and vehicle when stationary. Test made on stationary vehicle provided a reference value for traditional motorcycle having an exhaust system, whereas in the case of vehicle powered by electric motor, emitted noise was only measured in motion.

### 6.2 Measurement of Noise from Vehicles in Motion

At least two measurements were made on each side of vehicles. Preliminary measurements were made for adjustment purposes and their results were disregarded.

Microphone was located at a distance of 7.5 m from CC' reference line (Figure 5) of track and 1.2 m above ground. Maximum sensitivity axis (PP' line) was horizontal and perpendicular to vehicle path (CC' line).

Two lines, AA' and BB', parallel to PP' line and situated respectively 10 m forward and 10 m rearward of that line, were marked out on test runway.

Test vehicles were driven in a straight line over the acceleration section so that longitudinal median plane of vehicles was as close as possible to CC' line and approach AA' line at a specified steady speed. When the front of vehicles reached AA' line, throttle was fully opened as rapidly as possible and held in fully-opened position until the rear of vehicles crossed BB' line; then throttle was closed again as rapidly as possible.

Maximum sound pressure level expressed in dB(A) was measured as vehicles were driven between lines AA' and BB'. Tested vehicles were equipped with automatic transmission and without manual selector: traditional two wheel vehicle approached AA' line at various uniform speeds of 30, 40, 50 km/h while electric four wheel motor vehicle was driven up to 35 km/h, being its maximum on-road speed value.

Conditions giving the highest noise levels were then retained. As the difference between two consecutive measurements on the same side of vehicles wasn't higher than 2 dB, measured noise emissions by vehicles in motion were considered valid. Recorded values were those corresponding to the highest sound levels.

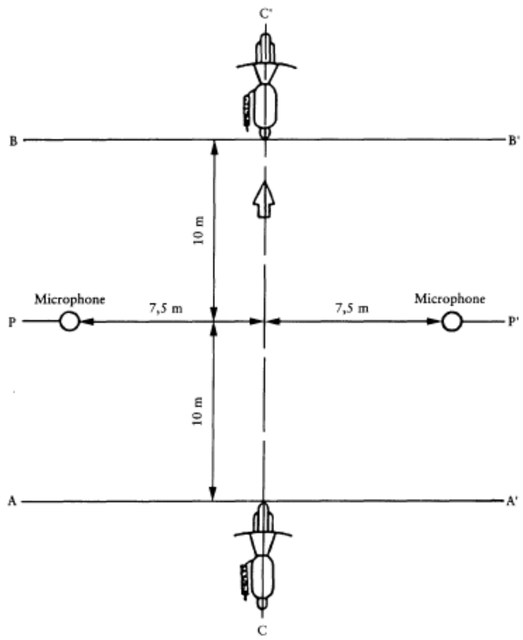


Figure 5: Test for vehicle in motion [1].

According to regulations, to allow for lack of precision in the measuring instrument, the values read during measurement should be reduced by 1 dB: our purpose is not to obtain component type-approval, so in the present study measured values were only rounded off to the nearest 0.5 dB.

### 6.3 Noise from Stationary Vehicle: Exhaust System

Maximum sound level expressed in (dB(A)) was measured during operations and three measurements were taken at each test condition.

Microphone was positioned level with exhaust outlet or 0.2 m above track surface, having diaphragm faced towards exhaust outlet at a distance of 0.5 m from it. Microphone maximum sensitivity axis was parallel to track surface at an angle of 45° to vertical plane of exhaust emission direction (Figure 6 and Figure 7).

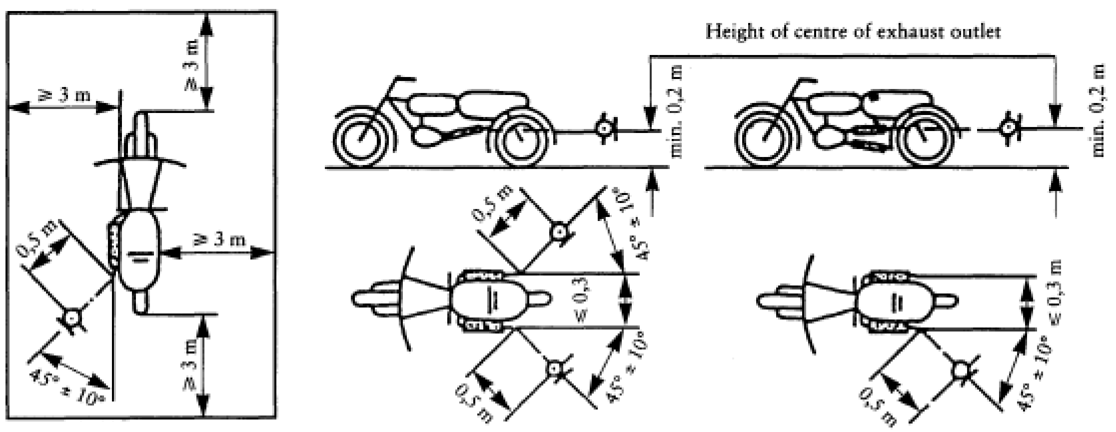


Figure 6: Test for stationary vehicle [1].

Figure 7: Microphone position during exhaust system noise measurements (stationary two wheel vehicle).

Engine rotation speed was held steady at a high and a medium value.

When a constant engine speed was reached, throttle was returned swiftly to the idle position. The sound level was measured during an operating cycle consisting of a brief period of constant engine speed and throughout the deceleration period, the maximum sound-level meter reading being taken as test value.

Only measurements which varied by no more than 2 dB in three consecutive tests were recorded. The highest among three measurements was test result.

### 6.4 SEL Measurements

Tests on mail delivery vehicles were finally integrated with Single Event Level measurements, in order to assess and compare also specific contribution of noise emitted by traditional motorcycle and electric four wheel vehicle during their transit. SEL, expressed in dB(A), were measured both on level road and gradient road.

## 7 MEASUREMENT RESULTS

Results were not affected by wind. “A”-weighted sound level of sound sources other than those of vehicles to be tested and of wind effects were at least 16 dB below sound level produced by vehicles. Microphone was provided with recommended suitable windscreen. Difference between background noise and measured noise was always higher than 16 dB and test results didn’t need any correction. Readings were rounded off to the nearest 0.5 dB and results were not obtained by deducting 1 dB from measured values, differently from what provided by regulations.

Figures 8 to 19 shows frequency analysis and time history of the most significant measurements; Table 1 resumes obtained results and comparison between tested vehicles.

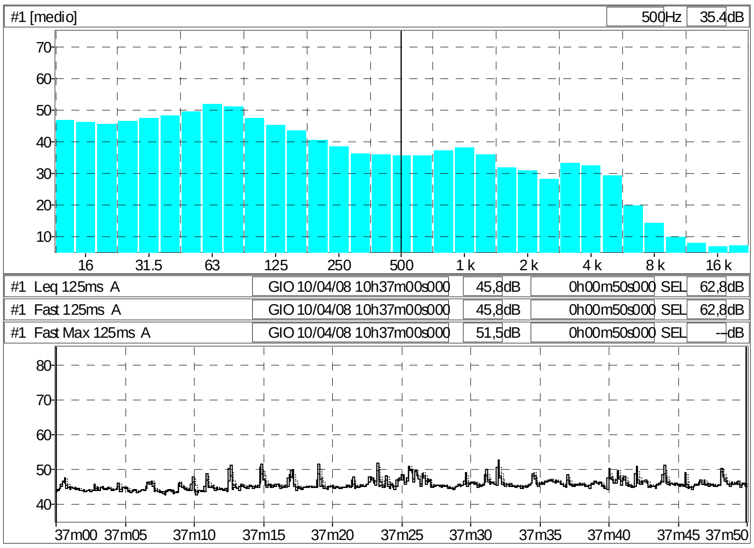


Figure 8: Traditional two wheel vehicle – Background noise.

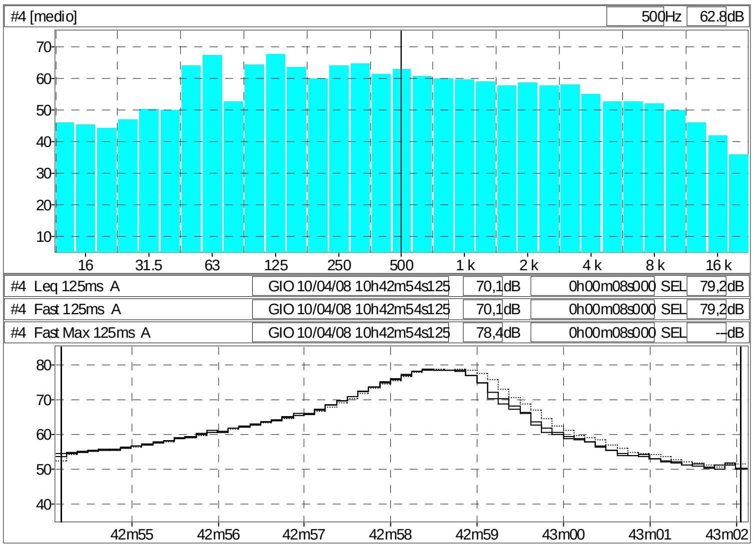


Figure 9: Traditional two wheel vehicle – Speed of 30 km/h (right side).

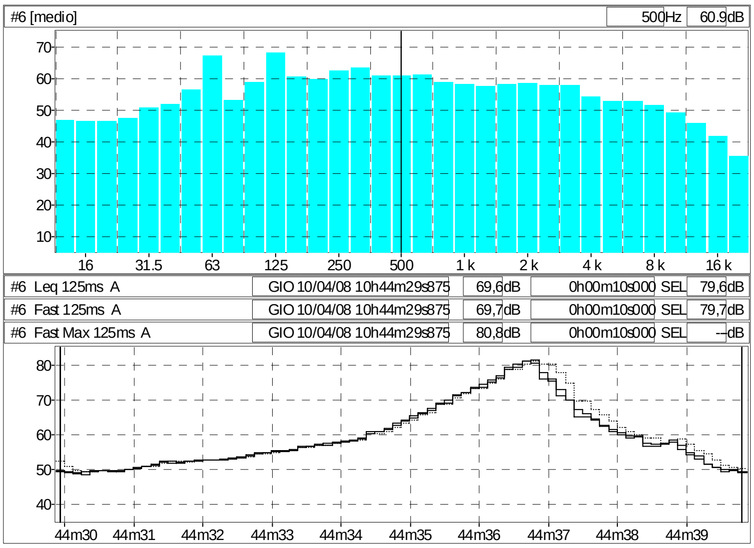


Figure 10: Traditional two wheel vehicle – Speed of 50 km/h (right side).

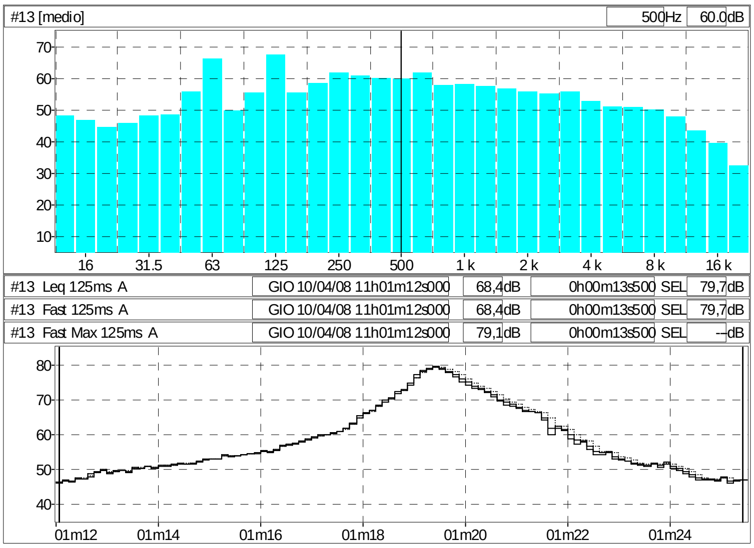


Figure 11: Traditional two wheel vehicle – SEL on level road (right side).

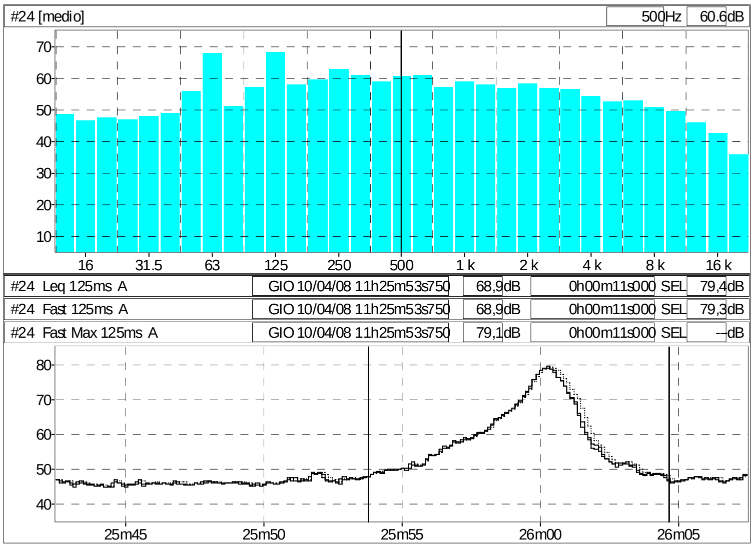


Figure 12: Traditional two wheel vehicle – SEL on gradient road (right side).

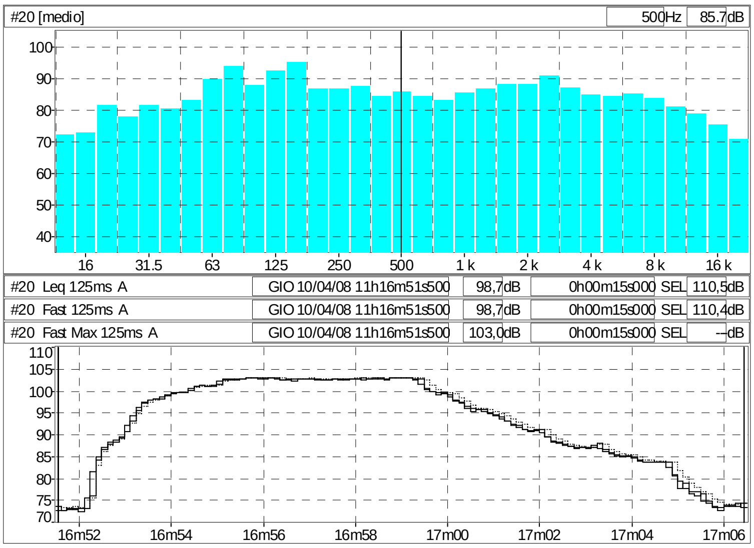


Figure 13: Traditional two wheel vehicle – Exhaust system noise (high engine speed).

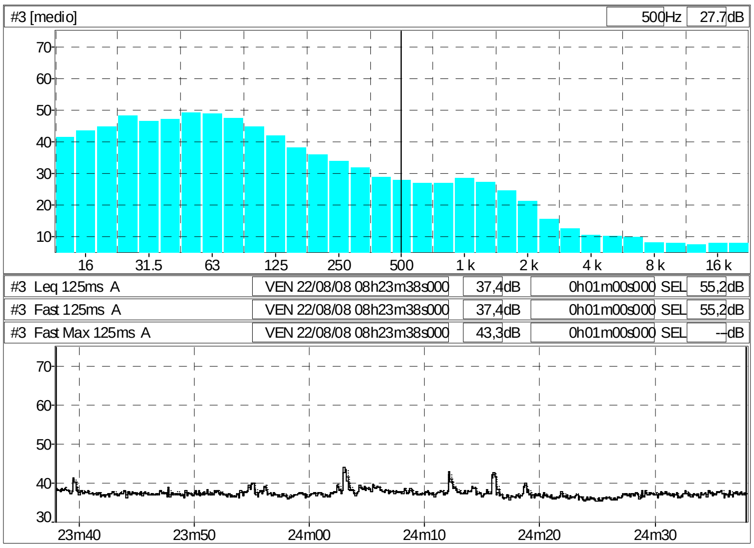


Figure 14: Electric four wheel vehicle – Background noise.

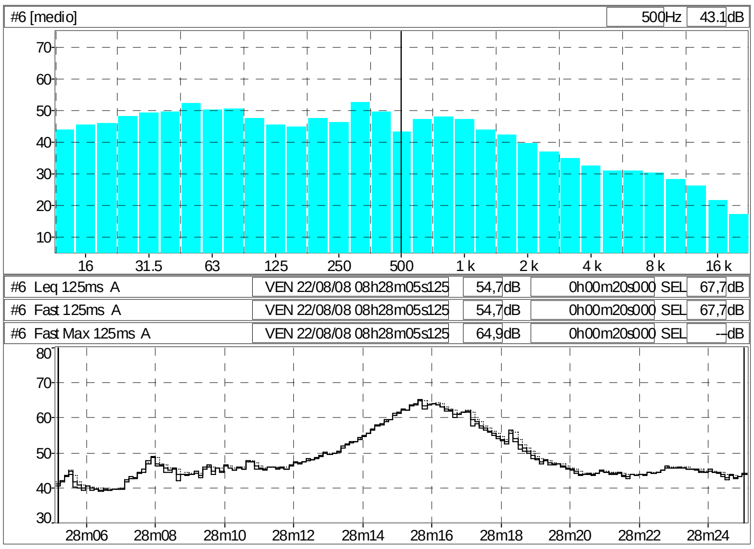


Figure 15: Electric four wheel vehicle – Speed of 30 km/h (right side).

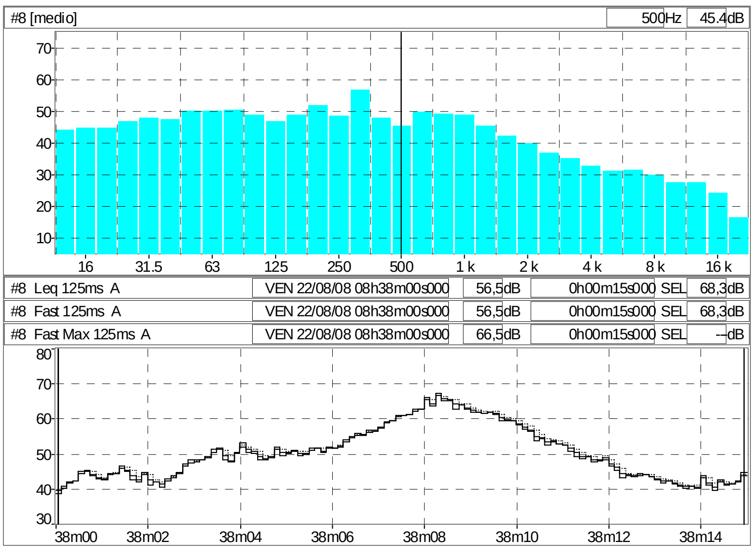


Figure 16: Electric four wheel vehicle – Speed of 35 km/h (right side).

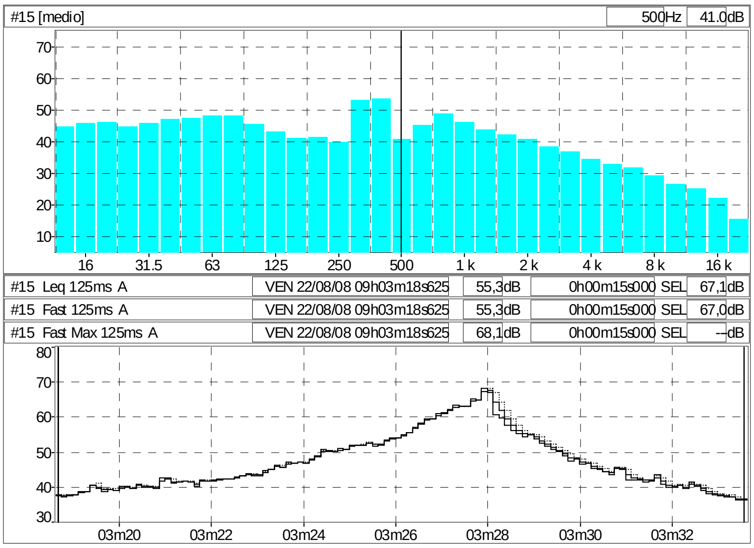


Figure 17: Electric four wheel vehicle – SEL on gradient road (right side).

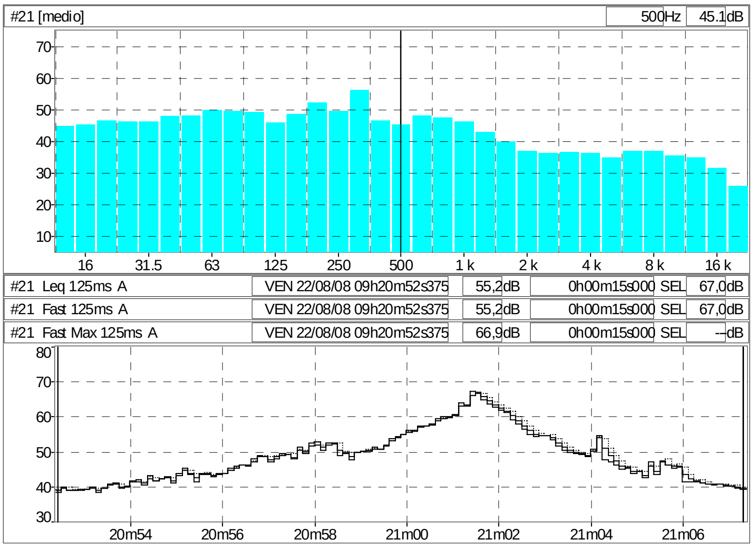


Figure 18: Electric four wheel vehicle – SEL on level road (right side, booster on).

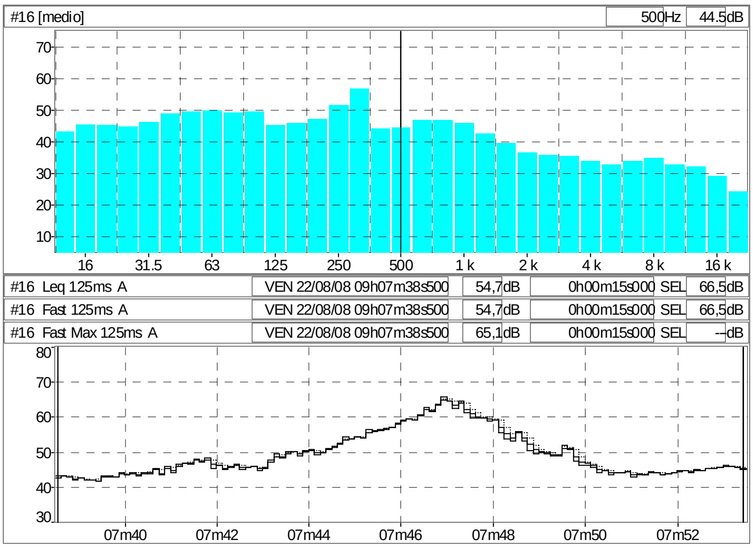


Figure 19: Electric four wheel vehicle – SEL on level road (right side, booster off).

Table 1: Measurement results.

| Condition | | Parameter [dB(A)] | Traditional two wheel | Electric four wheel |
|---|---|---|---|---|
| Vehicle in motion | Background | $L_{AFmax}$ | 51.5 (51.5) | 43.5 (43.3) |
| | **30 km/h** | $\mathbf{L_{AFmax}}$ | **78.5 (78.4)** | **65.0 (64.9)** |
| | 35 km/h Right side | $L_{AFmax}$ | – | 66.0 (65.9) |
| | | $L_{AFmax}$ | – | 66.5 (66.5) |
| | 35 km/h Left side | $L_{AFmax}$ | – | 66.0 (65.9) |
| | | $L_{AFmax}$ | – | 66.0 (66.0) |
| | **35 km/h Final result** | $\mathbf{L_{AFmax}}$ | **–** | **66.5** |
| | 40 km/h | $L_{AFmax}$ | 80.1 | – |
| | 50 km/h Right side | $L_{AFmax}$ | 81.0 (80.8) | – |
| | | $L_{AFmax}$ | 79.5 (79.3) | – |
| | 50 km/h Left side | $L_{AFmax}$ | 77.5 (77.7) | – |
| | | $L_{AFmax}$ | 78.0 (77.9) | – |
| | **50 km/h Final result** | $\mathbf{L_{AFmax}}$ | **81.0** | **–** |
| | **Gradient road** | **SEL** | **79.5 (79.4)** | **67.0 (67.1)** |
| | **Level road** | **SEL** | **79.5 (79.7)** | **66.5 (66.5)(1)** |
| | | | **–** | **67.0 (67.0)(2)** |
| Stationary vehicle | Exhaust – Med engine speed | $L_{AFmax}$ | 97.0 (97.1) | – |
| | | $L_{AFmax}$ | 96.5 (96.7) | – |
| | | $L_{AFmax}$ | 98.0 (97.9) | – |
| | Exhaust – High engine speed | $L_{AFmax}$ | 102.5 (102.6) | – |
| | | $L_{AFmax}$ | 102.5 (102.6) | – |
| | | $L_{AFmax}$ | 103.0 (103.0) | – |
| | **Exhaust Final result** | $\mathbf{L_{AFmax}}$ | **103.0 (103.0)** | **–** |

(1) Booster off.
(2) Booster on.

## 8 CONCLUSIONS

Result analyses shows that noise produced by traditional two wheel vehicle is higher on left side, because of exhaust system position: the difference between two sides of tested motorcycle was up to 3.5 dB. Noise emissions from exhaust outlet was considerable (103 dB(A) at high engine speed) and a proper silencer system should be adopted.

On the contrary, electric four wheel vehicle is not provided with exhaust system and produces very lower sound pressure levels, being $L_{AFmax}$ approximately 13 dB less then motorcycle noise for a speed of 30 km/h.

Also SEL measurements confirm results, both in gradient and level road conditions, so the substitution of traditional vehicles for postal services with electric ones significantly contribute to reduce noise pollution.

Such a solution may be extended also to public and private vehicles by providing proper incentives.

Future developments in experimentation will consist in measuring and comparing noise produced by hybrid vehicles, which will replace some traditional motorcycles on mail delivery service. A light four wheel vehicle (178 cm of length and 96 of width) equipped with an endothermic and an electric motor, in order to recharge batteries, will be introduced. The aim will be to reduce environmental impact of delivery transportation according to "Intelligent Energy for Europe" program, having Italian postal service as leader and involving also Belgian and Hungarian postal services, the Municipality of Perugia (Umbria, Italy), an environmental association, the vehicle manufacturer and the Universities of Perugia and Rousse (Bulgaria). Experimentation with hybrid-electric vehicles will start in Perugia with four wheel vehicles which will be able to move easily thanks to an autonomy of 50 km, if electric, and of 300 km, if hybrid. These low environmental impact vehicles will be tested by Italian postmen in the historical centre of Perugia: being equipped with four wheels, they will be also safer than small common motorcycles (146 cm of length and 90 cm of width).

## 9 ACKNOWLEDGEMENTS

The authors acknowledge the support and contribution of Poste Italiane mail delivery service in the research.

## 10 REFERENCES

[1] Directive 97/24/EC of the European Parliament and of the Council of 17 June 1997 “concerning certain components and characteristics of two or three-wheel motor vehicles” Official Journal of the European Union, L 226, 18.08.1997, p. 1 (1997).

[2] Regulation n. 51 of the Economic Commission for Europe of the United Nations (UN/ECE), “Uniform provisions concerning the approval of motor vehicles having at least four wheels with regard to their noise emissions”, Official Journal of the European Union, L 137, 30.05.2007, 68–115 (2007).