DELIVERABLE 3.2.1

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PROJECT N°	**FP7-233655**
ACRONYM	**CITYHUSH**
TITLE	**Functional noise specifications for purchasing green low noise vehicles**
Work Package 3	**Noise and vibration control at source – Acoustically green vehicles**
3.2	**Noise specifications for vehicle purchase and noise criteria for vehicle free access to Q-Zones**
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Project Co-Ordinator Partners			
	Acoustic Control	ACL	SE
	Accon	ACC	DE
	Alfa Products & Technologies	APT	BE
	Goodyear	GOOD	LU
	Head Acoustics	HAC	DE
	Royal Institute of Technology	KTH	SE
	NCC Roads	NCC	SE
	Stockholm Environmental & Health Administration	SEP	SE
	Netherlands Organisation for Applied Scientific Research	TNO	NL
	Trafikkontoret Göteborg	TPTA	SE
	TT&E Consultants	TTE	GR
	University of Cambridge	UCAM	UK
	Promation of Operational Links with Integrated Services	POLIS	BE

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Dissemination Level

PU	Public	✓
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restrictec to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for the members of the consortium (including the Commission Services)	

Nature of Deliverable

R	Report	✓
P	Prototype	
D	Demonstrator	
O	Other	

SEVENTH FRAMEWORK PROGRAMME

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0 EXECUTIVE SUMMARY

0.1 OBJECTIVE OF THE DELIVERABLE

It is expected that the municipalities want to purchase green vehicles because of their noise benefits and not only because of their low chemical emissions. The objective of this study is therefore to develop a universal functional noise specification to be included in green car purchase specification. This will help the buyer to ensure that their cars are environmentally friendly with respect to noise.

0.2 DESCRIPTION OF THE WORK PERFORMED SINCE THE BEGINNING OF THE PROJECT

The following has been performed within this work package (WP 3.2.1):

- Studies regarding proper test methods for type approval of passenger cars in urban areas with a focus on electric and hybrid cars
- Sound measurements on new hybrid and electric passenger cars
- Collection of noise emission data from normal passenger cars [1]
- Development of noise classifications covering the whole range in exterior noise from passenger cars based on the measured and collected noise data
- Proposal on suitable noise limit in order for a passenger car to be considered environmentally friendly with respect to noise

0.3 MAIN RESULTS ACHIEVED SO FAR

Sound measurements during type approvals of passenger cars should be performed according to the standard ISO 362:2007 (included in noise regulation ECE R51, method B). This standard gives a more adequate representation of real-world urban traffic noise compared to the earlier standard ISO 362:1998 (included in noise regulation ECE R51, method A).

Five different noise classes (A, B, C, D and E) covering the whole range in exterior noise from passenger cars according to ISO 362:2007 have been developed. Noise class A is the quietest class, while E is the noisiest. Information about these noise classes are given in the table below. The proposal is that a passenger car has to fulfil noise class A or B, i.e. $\mathbf{L_{urban} < 68\ dBA}$, in order to be considered as an environmentally friendly car regarding exterior noise.

Noise class	Noise limit ISO 362:2007 (L_{urban})	Environmentally friendly regarding noise	Typical passenger car types
A	<64 dBA	YES	Pure electric cars
B	64 - 68 dBA	YES	Hybrid cars
C	68 - 72 dBA	NO	Normal passenger cars
D	72 - 76 dBA	NO	Large passenger cars
E	>76 dBA	NO	Sport cars and pickups

0.4 EXPECTED FINAL RESULTS

The proposed noise limit in this study is expected to be included in the purchase specification of green passenger cars. This noise specification will help the buyer to ensure that their cars are environmentally friendly with respect to noise and not only regarding chemical emissions.

Similar "green" noise limits are expected to be developed for other vehicle categories as well.

The new regulation (ECE R51, method B) is expected to be fully implemented in the EU Directive as the only exterior noise testing method during type approval.

0.5 POTENTIAL IMPACT AND USE

The proposed testing method (ECE R51, method B) during type approval has been used by manufactures since 2007 and is therefore already a well-known noise testing method. However, some small changes in the full acceleration test may be needed when testing hybrid and electric passenger cars in order to include all relevant noise sources in an adequate way.

By updating the purchase specification due to the current noise data for quiet electric vehicles approximately every year or bi-annually, an up-to-date noise specification will always be available for electric or hybrid vehicles. More studies should therefore be performed in this area on a regularly basis.

0.6 PARTNERS INVOLVED AND THEIR CONTRIBUTION

The partners involved in this study are:

- Acoustic Control (ACL)
- Stockholm Environmental Protection Agency (SEP)
- Traffic & Public Transport Authority (TPTA) in Gothenburg

ACL have been in contact with SEP regarding access to suitable electric vehicles for sound measurements and regarding electric vehicles in Sweden in general. SEP and

TPTA has given their input and remarks regarding the content in this report. HAC has also been involved in some technical discussions.

0.7 CONCLUSIONS

The following conclusions are given in this study:

- Type approval according to ECE R51 method B (ISO 362 :2007)
- Full acceleration test from 30 km/h instead of 50 km/h for electric passenger cars with weak engines (e.g. PMR < 40). More studies should be made in this area
- A passenger car that are considered environmentally friendly has to fulfil **L_{urban} < 68 dBA** (i.e. noise class A or B)
- Similar noise limits should be developed also for other vehicle categories in order to be ranked as environmentally friendly with respect to noise.

1 INTRODUCTION AND OBJECTIVE

A multitude of city administrations throughout Europe has decided to invest in environmentally vehicles. E.g. in Stockholm there is several on-going projects targeting at the use of environmentally friendly vehicles in cities. By decision of the Mayor of Stockholm, all vehicles paid and used by the City of Stockholm shall be of the environmental friendly type.

It is expected that the municipalities want to purchase vehicles because of their noise benefits. The definition of environmental vehicles has up to now only included chemical emissions as criteria and not noise. The objective of this study is therefore to develop a universal functional noise specification to be included in green car purchase specification. This will help the buyer to ensure that their car is environmentally friendly also with respect to noise.

2 TESTING METHODS FOR EXTERIOR NOISE TYPE APPROVAL

A universal and functional noise specification for green vehicle purchase requires a proper noise testing method that considers the actual driving conditions and provides the basis to evaluate new propulsion technologies like hybrid and pure electric vehicles.

2.1 ECE REGULATION 51, METHOD A

The current noise Regulation No 51 (R51) of the Economic Commission for Europe (ECE) has been in force since 1970 (Directive 70/157/EC) with several amendments since then. The measurement method is based on ISO 362:1998 and seeks to measure the highest noise levels produced in urban traffic with a focus on driveline noise, i.e. so called full acceleration tests (or full throttle acceleration) in urban areas. Therefore, the test method is based on a full throttle acceleration test starting from 50 km/h or less, depending on the vehicle category.

Since the technical design of vehicles has changed significantly over the last decade, the correlation between the test conditions for type approval and the conditions for normal urban driving has gradually decreased. New test conditions were therefore required to be more representative of normal urban driving behaviour in order to affect noise exposure in urban areas more efficiently.

2.1.1 Limit values

The regulated limit has been strongly reduced since the start in 1970, see Figure 2.1 below. However, almost no noise level decrease has been seen in real urban traffic. Note that the limit value for passenger cars is 74 dBA.

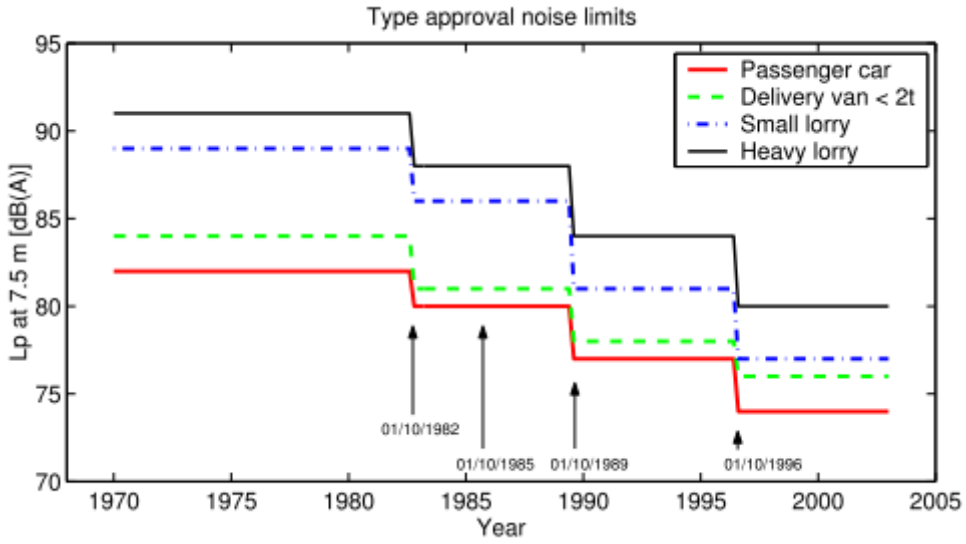

Figure 2.1 Historical development in EU type approval noise limits based on ECE R51 method A. The figure is taken from reference [3] page 51.

2.2 ECE REGULATION 51, METHOD B

The new ECE R51 method, based on ISO 362:2007, was prepared by WG42, a joint workgroup of ISO TC43/SC1 "Noise" and ISO TC22 "Road vehicles" and amended by WP29 in 2007 to be implemented in Directive 2007/34/EC. Development and evaluation were notably carried out in 2004 for technical accuracy and practical considerations by over 180 vehicles included in a first monitoring test program. In 2007/2008 the European Commission launched a new monitoring procedure for 2 years application in order to establish new limit values to be applied for the new test method B. During that time, the noise tests during type approval were measured according to the current method A as well as the new method B.

The measurement procedure in method B is based on an estimation of partial throttle operation at 50 km/h for light vehicles (M1, N1 and M2<3.5t) and at 35 km/h for heavy vehicles (M2>3.5t, N2, N3 and M3) which represents normal urban driving behaviour. For light vehicles, it seeks to approximate real partial throttle operation with a weighted average of a wide-open throttle test (wot) from 50 km/h with a constant speed test at 50 km/h. This ensures a better consideration of all noise sources emitted by road vehicles in urban traffic compared to what was achieved by the earlier applied method. Therefore, a decrease of limits regarding this new method will affect noise exposure in urban areas more efficiently than method A. It also provides the basis for evaluation of new propulsion technologies like hybrid and fuel cell vehicles in a technological neutral manner.

2.2.1 Proposal for new vehicle categories and new limit values

The European Automobile Manufacturers' Association (ACEA) gave a proposal on new vehicle subcategories and new limit values in August 2010 [2] based on the new collected monitoring data from method B.

Table 2.2 Proposal for new subcategories and equivalent limit values. The table is taken from reference [2] page 9.

Category	Subcategory		Equivalent limit values in dB(A)	
			On Road	Off Road [1)]
M1	M1-1	pmr <125 kW/t	72	74
	M1-2	125 kW/t < pmr <= 150 kW/t	73	74
	M1-3	pmr > 150 kW/t	75	75
N1/M2-A	N1/M2-A1	GVM <= 2500 kg	72	74
	N1/M2-A2	GVM > 2500 kg	74	75
N2/M2-B	N2/M2-B1	rated speed > 3000 min^{-1}	76	77
	N2/M2-B2	rated speed <= 3000 min^{-1}	78	79
N3	N3-1	2 axles, Pn <= 180 kW	79	80
	N3-2	2 axles, 180 kW < Pn <= 250 kW	81	82
	N3-3	2 axles, Pn > 250 kW	82	83
	N3-4	> 2 axles	84	85
M3	M3-1	Pn < 180 kW	76	77
	M3-2	180 kW < Pn <= 250 kW	78	79
	M3-3	Pn > 250 kW	80	81

[1)] off road as defined in R.E.3 and in addition have a wading depth exceeding 500 mm and a hill climbing ability exceeding 35°

2.2.2 Comments on the new test method B applied on hybrid/electric vehicles

The WG42 committee has had access to extensive in-use data to determine the actual driving behavior from light duty vehicles in urban traffic. To establish the operation criteria in method B, WG42 used the in-use vehicle data which showed that the most traveled speed is 50 km/h in urban areas [5]. Furthermore, a traffic noise study [6] showed that 73 % of the annoyed people lives along main streets with speed limit 50 km/h, while 23 % lives along residential streets with speed limit 30 km/h. The test speed for light duty vehicles were therefore set at 50 km/h.

The main idea with the wot (wide-open-throttle) test from 50 km/h is to simulate a worst-case-scenario with a focus on driveline noise, while the idea with the constant speed test at 50 km/h is to focus on tyre/road noise. The weighted average (L_{urban}) is then a combination of both driveline and tyre/road noise so that all relevant noise sources are considered. However, this may not be the case for low noise vehicles with weaker engines, i.e. hybrid or pure electric vehicles.

Measurements show that for electric vehicles with a low power-to-mass ratio[1] (e.g. PMR<40), the main focus at wot test from 50 km/h is on tyre/road noise instead of the driveline noise due to the quite driveline. The weighted average (L_{urban}) is then only considering tyre/road noise. This may be correct for urban traffic conditions at main streets with speed limit 50 km/h and with very few traffic lights. However, it does not give a fair picture of the noise reduction potential on streets where the acceleration phase normally starts from speeds below 50 km/h, i.e. main streets with speed limit 50 km/h and with lots of traffic lights or residential streets with speed limit 30 km/h. A wot test with a start speed below 50 km/h gives more room for the driveline noise. Therefore, it is here recommended that the wot (wide-open-throttle) test for electric cars with weaker engines (e.g. PMR<40) are to be performed at a lower start speed, e.g. 30 km/h.

[1] Dimensionless quantity used for calculation of acceleration according to the equation: PMR = Pn/m x 1000 kg/kW, where Pn is the engine power in kilowatts and m is the test mass in kilograms.

3 MEASURED AND COLLECTED NOISE DATA FROM PASSENGER CARS

Sound measurements on passenger cars (M1) have been performed according to ECE R51 method B based on ISO 362-1:2007. Measurements on one hybrid and four pure electric cars were performed by ACL in June 2011. Noise emitted from 34 normal passenger cars were collected from measurements performed by the SAE Cooperative Research Program [1].

The measured and the collected noise data are summarised in Figur 3.1 below. It presents the constant speed test at 50 km/h (L_{crs}), the wide-open-throttle tests from 50 km/h (L_{wot}) and the final result, L_{urban}, which is calculated as a weighted average of L_{wot} and L_{crs} in order to simulate real urban driving conditions and to include all relevant noise sources.

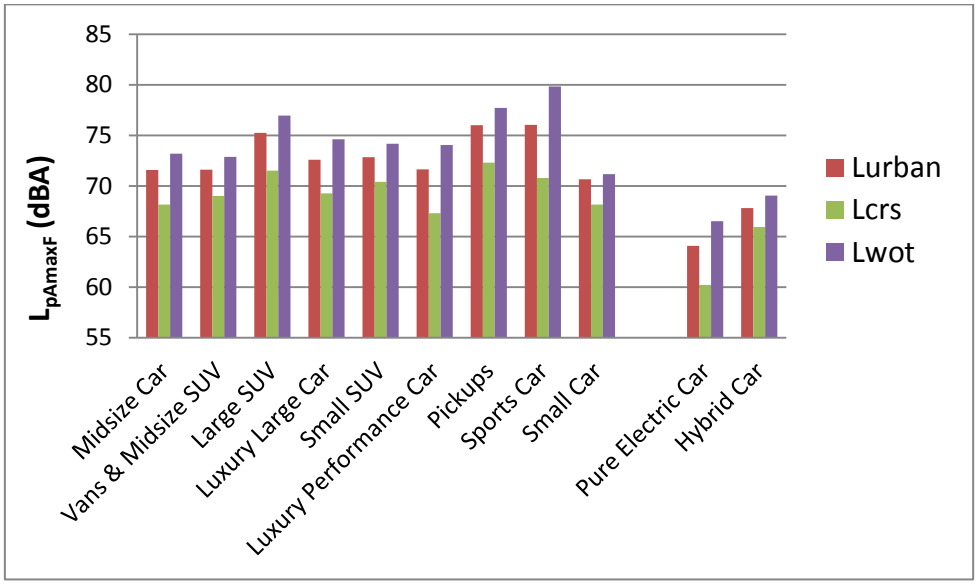

Figure 3.1 Measured and collected exterior noise data from passenger cars according to ECE R51 method B (ISO 362-1:2007).

The results presented above reveal that electric and hybrid passenger cars emits about 5-10 dBA lower noise levels compared to normal passenger cars during normal urban driving on a urban main street with speed limit 50 km/h and with very few traffic lights.

The measurement results on the hybrid/electric cars are presented in detail in Deliverable 3.2.2.

4 EXTERIOR NOISE CLASIFICATION

4.1 NOISE CLASSES FOR PASSENGER CARS

Five different noise classes (A, B, C, D and E) covering the whole range in exterior noise from passenger cars according to ISO 362:2007 have been developed. Noise class A is the quietest class, while E is the noisiest. Information about these noise classes are given in the table below.

Table 4.1 Five different noise classes covering the whole range in exterior noise from passenger cars.

Noise class	Noise limit ISO 362:2007 (L_{urban})	Environmentally friendly regarding noise	Typical passenger car types
A	<64 dBA	YES	Pure electric cars
B	64 - 68 dBA	YES	Hybrid cars
C	68 - 72 dBA	NO	Normal passenger cars
D	72 - 76 dBA	NO	Large passenger cars
E	>76 dBA	NO	Sport cars and pickups

The upper limit of noise class A-D and the measured and collected exterior noise data (L_{urban}) are presented in Figure 4.1 below. Note that noise class C corresponds to the proposed equivalent limit for M1-1 shown in Table 2.2 (L_{urban} 72 dBA).

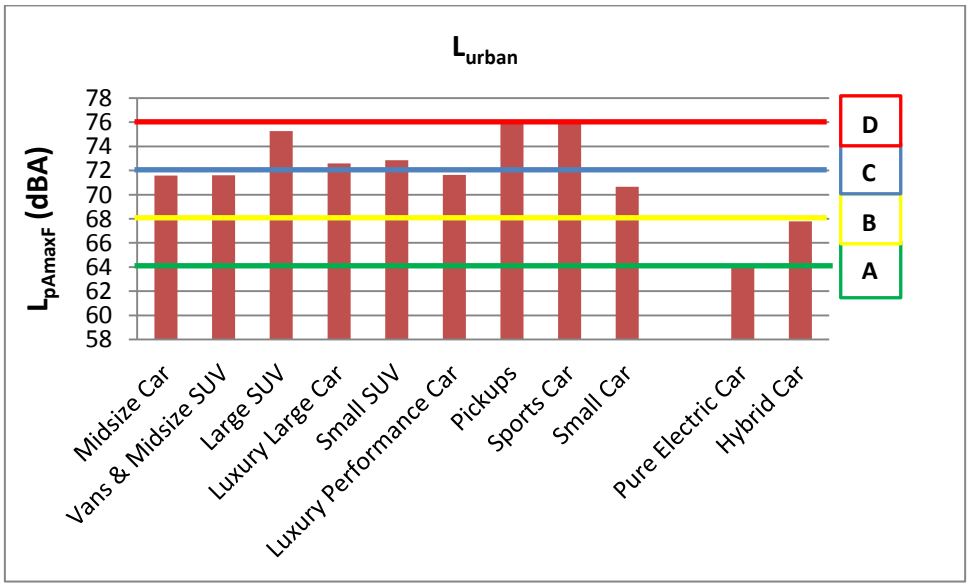

Figure 4.1 Measured and collected exterior noise data (Lurban) from passenger cars including the upper limit of noise class A-D.

4.2 ENVIRONMENTAL FRIENDLY PASSENGER CARS WITH RESPECT TO NOISE

There exists up to now no definition on what qualities regarding noise that shall be required from a vehicle in order to be considered a "quiet" vehicle. The definition of environmental vehicles are up to now only including chemical emissions and not noise. Therefore, a proposal is given on what noise limit a car has to fulfil in order to be considered as a quiet environmental friendly car.

The proposal is that a passenger car has to fulfil noise class A or B, i.e. **L_{urban} < 68 dBA**, in order to be considered as an environmentally friendly car regarding exterior noise, see Table 4.1. This information will help the buyer to ensure that their cars are environmentally friendly with respect to noise and not only regarding chemical emissions.

4.3 FURTHER WORK ON OTHER VEHICLE CATEGORIES

This study handles passenger cars only. Similar work can be performed on other vehicle categories as well. However, this requires access and analysis of exterior noise data on these types of vehicles with new propulsion technologies like hybrid and fuel cell vehicles. In 2008, ACL performed similar studies on hybrid city buses as part of another project. These results are however not presented in this deliverable.

5 REFERENCES

[1] Moore, D.B. *The revised ISO 362 standard for vehicle exterior noise measurement*, Article in *Sound and Vibration*, Oktober 2006

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[3] TNO report, *VENILOVA – Vehicle Noise Limit Values – Comparison of two noise emission test methods – Final report*, 30 March 2011

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[5] Steven, H. *Investigations on Improving the Method of Noise Measurement for Powered Vehicles*, Report Number 10506067 by order of the Germany Federal Environmental Agency, August 1999

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