DELIVERABLE 3.5.3[1]

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3.5	Definition of a noise & annoyance standard for motorcycles in the urban environment
	Noise effect of restrictions on motorcycle use
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R	Report	✓
	Prototype	
	Demonstrator	
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SEVENTH FRAMEWORK PROGRAMME

1 see List of Deliverables, DoW – Annex I to the contract, p.32 (document 233655_CITYHUSH_AnnexI_DoW_2010-01-31_Corrections.pdf - available on the ftp-server)

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0 EXECUTIVE SUMMARY

0.1 Objective of the deliverable

Objective of this deliverable is to evaluate the effect of restrictions on the use of PTW to noise mainly, and the effect of noise as well as to socio-economic impact.

0.2 Description of the work performed since the beginning of the project

A literature research was conducted to find out plausible values for emissions, as well as other external costs like social impact and danger, of the PTW and cars. An impact assessment analysis of the possible options was performed based on the noise data acquired in the WP 3.5 of CITYHUSH, and tables prepared to outline benefits and costs of such options.

0.3 Main results achieved so far

The impact analysis was conducted and has showed that amongst the foreseen possible scenarios, only one may have a positive and measurable effect and therefore would make sense to be adopted, namely the substitution of all PTW with electrically driven ones.

0.4 Expected final results

Derivation of the best option to reduce noise levels, noise annoyance and noise health effects.

0.5 Potential impact and use[2]

Any European, national or local authority willing to support a reduction of noise in urban areas du to measures on the use of PTW (or other reasons having anyway the effect of a PTW reduction) has data on the effectiveness of different measure options and can profit to take appropriate decisions based on cost/efficiency analysis.

0.6 Partners involved and their contribution

TT&E SAperformed the literature research, collected data on the traditional PTW, performed the study and prepared the report. HEAD Acoustics provided noise data on electrically powered PTW.

0.7 Conclusions

The study suggests that the only effective measure is to use only electrically powered PTW, eventually by a progressive shift from traditionally powered ones.

2 *including the socio-economic impact and the wider societal implications of the project so far*

1 IMPACT ASSESSMENT

1.1 DEFINITION OF OBJECTIVE AND RELEVANT PARAMETERS

Objective of this report is to **obtain a set of indications on the effects of reducing PTW noise by different options**, eventually in different time periods. Examples are the introductions of checks to verify that the limits are respected and tampering is not introduced, development of new silencers, limitation of speed, banning of PTW, limitation to electric PTW.

Effects of the introduction of measures primarily meant for noise reduction measures include:

- annoyance;
- sleep disturbance;
- social impact;
- safety;
- CO_2 emissions;
- NO_x emissions;
- economic implications.

Except for the annoyance estimation, other parameters are mainly based on rough estimations, with the only purpose of addressing a general overview of all the side effects of measures against noisy PTW.

1.1.1 Annoyance

Annoyance is identified both outdoors and indoors. Annoyance is the primary objective of this study, which focussed on the noise reduction.

Under the different possible scenarios, the annoyance is quantified by means of the methodologies developed under the WP2 and also based on the measurements performed under this WP3.5 in Athens city centre. As defined in the previous chapters, the research conducted allowed establishment of the relationship between the number and conditions of PTW pass by and people's annoyance.

As a starting point, it is to be noted that the official NNGL publication from WHO reported that **above 35 dB $L_{night,outside}$ the first complains occur**, which is in other words the threshold for annoyance during nighttimes, indoors.

For what concerns the **number of events**, which are useful to be considered mainly in the small road where single events occur and not a constant flow of vehicles, it is observed that in the publication of the WHO is well explained that the relation to the single events has many times been discussed and the conclusion is that the overall levels are highly correlated to indicators considering the number of events and not only the levels. Therefore, mainly the overall effect in the L_{day}, $L_{evening}$ and L_{night} will be considered, and **no correction will be included for the number** of noisy events. However, **a correction is proposed** to account for the effect of the increased annoyance of the PTW because of the specific noise signature, based on the studies performed within this CITYHUSH WP 3.5 for noise outdoors.

The proposed correction is between the results obtained in past literature and those obtained during the new studies (see CITYHUSH Report 3.5.2), and is an increment of 12% of the annoyed people for those situations where traffic is so low that single events are heard separately.

Correlation between outdoor noise levels created by the PTW and the annoyance outdoors is derived as follows (**daytime** only):

$\%\mathbf{A} = 1{,}27 \cdot L_{Aeq} - 16$

Correlation between outdoor noise levels created by the PTW and the annoyance indoors is derived as follows (**day time and night-time**):

$\%\mathbf{HA} = 9.868 \cdot 10^{-4} (L_{DEN} - 42)^3 - 1.436 \cdot 10^{-2} (L_{DEN} - 42)^2 + 0.5118 (L_{DEN} - 42)$

1.1.2 Sleep disturbance

Concerning sleep disturbance, nothing was found in literature describing if the intrinsic characteristics of the PTW noise were or were not triggering sleep disturbance. Instead, the L_{eq} during nighttimes (e.g.: L_{night}) have been quite widely studied in health impact assessments.

It is considered that sleep disturbance is primarily triggered by the overall noise level anyway. Indeed, the mentioned WHO publication allows to state clearly what parameters to be used to assess whether or not sleep disturbance is relevantly increased by the PTW.

For what concerns the number of events, which is useful to be considered mainly in the small road, the WHO mentions that the events are relevant to an L_{Amax}, inside of 32-35 dB. So, at first guess it is decided to consider all events which will give more than 32 dB inside the sleeping room. The NNGL suggest to use 21dB noise reduction to consider an average effect of the building and window insulation, which corresponds to an $L_{Amax,outside}$ of 53 dB. In city centres, given that propagation of noise depends only on reflections and diffractions (since distances are short and ground is almost everywhere totally reflecting), the measurement positions used for the assessment of Athens city centre are considered as first guess.

Overall, it is decided that the two indicators used for nighttimes sleep disturbance will be:

L_{night} (main indicator)

and

number of events exceeding $L_{Amax,outside}$ of 53 dB.

1.1.3 Social impact

The use of PTW is essential due to two reasons: the first reason is that they are used to move inside the urban roads bypassing traffic queues and possibly consuming less fuel than a car. The second reason is for leisure. Basically, to the purpose of annoyance, only the first reason is considered, since it is assumed that in an urban environment, both in day and nighttimes the majority of PTW movements occur because of the necessity to move, and not for leisure. Therefore, in case that a ban or limitation of PTW is foreseen, alternative means of transportation shall be considered for people who need to move.

In this study it is assumed arbitrarily that in case that no option is foreseen to use PTW, the movements will be done by using the following set of transportation means:

- 15% on foot
- 5% bicycle
- 20% public transport
- 60% private car

This corresponds to an **increase of the number of car pass bys corresponding to 0,6 times the number of PTW initially running on the road**.

1.1.4 CO_2 emissions

Data provided by manufacturers matches the existing and foreseen emission limits. Basically, the data suggested as limit is tendentiously double of the reported measured combustion data by the manufacturers [11]. In order to quantify appropriately the benefit of modification or ban of PTW, the CO_2 emissions proposed in the following table were foreseen as the basic ones to be used in the calculation of the scenarios. These calculations are based on traffic scenarios and modal shifts introduced as a consequence of the ban of PTW, as described in the previous chapter.

Alternatively, the use of electric PTW is also considered. In this case, it shall be accounted that electric scooters will pose two problems: the first is the CO_2 emissions anyway foreseen at the moment for the amount of electricity produced to make them run ; the second is the disposal of used batteries. The disposal of used batteries is not considered for the moment given that not enough information is available on the lifetime of batteries to be used for the PTW and the threats for the environment due to the disposal of the specific type of batteries that a massive production of electric PTW will trigger to be used.

This said, the values foreseen and used in this study for the PTW emissions are the following:

Table 1.1

Moped (50cc engine): 40 g/km
Average scooter (125-350 cc engine): 100 g/km
Motorbike (350 cc up to1300cc): 170 g/km

In the measurement taken the scooters and mopeds were grouped together. This means that between 40 g/km and 100 g/km (or maybe 140 g/km if it is considered that the scooters may be old) are the possible values for the CO2 production. Therefore, it was decided quite arbitrarily to keep a mean value of 90 g/km.

It is considered that a PTW electric vehicle will use 0,15 kWh/km, and that 1kWh electricity corresponds to approximately 0,4 kg of CO_2 [e.g.: EU-25 average] it means that the **electric PTW are expected to produce about 60 g/km CO_2**. This number seems to be quite reasonable when compared to the numbers given for traditional mopeds (40 g/km), and in the case of most recent **small cars, which approximately have 120-150 g/km of CO2 production**.

1.2 OTHER MINOR RELEVANCE PARAMETERS

1.2.1 Safety

It is not the objective of this project to evaluate the effects on the safety of the shift to electric PTW or ban of PTW. Nevertheless, it shall be recalled that the EC has set up an observatory (http://ec.europa.eu/transport/wcm/road_safety/erso/knowledge/Content/45_poweredtwowheelers/safety_of_ptw_s.htm)

aiming to monitor the safety of the PTW. It is reported that data is available, but precise conclusions cannot be drawn since quality and availability of data do not allow appropriate matching. The safety of PTW is recognised to be a problem in European countries and especially in South European countries. The relevance to safety depends mainly on the km driven.

Nothing is said concerning the safety of electrically driven PTW. It is so assumed that, since the only difference between a traditional PTW and an electric one is that the electric one might be more silent, and therefore less identifiable if in the middle of traditionally propelled road vehicles, a **slight increase in their danger might be foreseen**. Instead, the traditional and electrically driven PTW have approximately the same mechanics concerning wheels, lights and brakes, and comparable weight, **so no danger reduction or increment effect is foreseen as a consequence**.

1.2.2 NO_x emissions

Concerning the NO_x emissions, some limit values can be used to assess the potential benefit of using electrically driven PTW. In this case it is considered that the use of electricity has an NO_x impact of 0,6 g/kWh, and therefore 0,15 kWh/km * 0,6 g/kWh = 0,09 g/km. This has derived under the same conditions as given before and for an electric energy production mix typical of the EU.

In the absence of a large literature and limits on these air pollutants, the PTW manufacturers studied that in their case the emission seems to be as follows:

Table 1.2

0,04 g/km for two strokes (mainly due to oil burning)
0,004 g/km for four strokes

It might be concluded that the NO_x emissions due to the use of electric PTW are about 2 to 10 times the corresponding NO_x emissions of fuel based PTW. These data are much lower than the limits and seem to be overoptimistic. It is finally considered that on a car, the emission will be 0,25 g/km. Given the uncertainties on the reliability of the data, in the absense of other data found, and having a look at the limits as well, it is considered that **there will be almost no effect on the NOx emissions, except in case of the shift to cars**, where considering the factor 0,6 due to shift between PTW and car use, thus giving a correction factor of: Nox(PTWban)/NOx(PTW)=(0,25*0,6)/0,09=**1,66**.

For completeness, the limits of the Directive 2002/51/EC for PTW are proposed hereafter:

Table 1.3

	Class	HC (g/km)	CO (g/km)	Nox (g/km)
A (2003)	<150 cm^3	5,5	1,2	0,3
	≥150 cm^3	5,5	1	0,3
B (2006)	<150 cm^3	2	0,8	0,15
	≥150 cm^3	2	0,3	0,15

1.2.3 Economic implications

Concerning the costs of operation, the following is found.

Cost of electricity, based on data acquired from EU sources, is e.g.: in Italy 0,260 €/kWh, in Greece 0,089 €/kWh.

Considering a consumption of 0,15 kWh/km, this leads to between 0,013 and 0,039 €/km for electric PTW.

In the case of traditional fuel powered PTW, it is assumed that a consumption of 0,04 l/km, and at a gasoline cost of 1,5 €/l, the overall cost of fuel consumption will be 0,06 €/km, which is therefore 2/3 as the electric PTW run in Italy, and 1/4 if run in Greece.

Considering the initial cost, there are a lot of different PTW on sell, whose initial price is approximately between 1000 € (these are electric mopeds) and 10000 €. The electric PTW are basically a modified version of the fuel propelled PTW, and costs as found on the market are within the same range.

Concerning the maintenance costs, it is assumed that the major cost will be the substitution of the batteries (brakes and tyres last for a long period and most of the times for all the life of the PTW). No information is available on the duration of the batteries and on the eventual costs of dismissal. Notwithstanding values found, given the poor confidence on the available data on fuel consumption of the two types of PTW (fuel and electric), and given that on the basis of the numbers found on the market, there is slight evidence of convenience of one type in respect to the other, moreover if the costs of the batteries are included, it will be considered that there **roughly are no economic implications in choosing a traditional or an electric based PTW**.

1.3 Simulation and analysis of the possible scenarios

In this section it is outlined which are the scenarios considered for restrictions to be imposed to PTW. The analysis is focused on two of five sites described and analysed in the Deliverable 3.5.2, and specifically a location next to a major road, and a location in a minor road. Moreover, it is hypothesised that a second row of buildings (or apartments on the rear of the building) exists, for which it is assumed to consider all events as on the front door and a 20 dB reduction.

The first scenario, the base one, is considered to be exactly what was measured in Athens, both regarding the traffic type (percentages of different vehicles amongst cars, scooters, noisy scooters, motorbikes, noisy motorbikes, busses and other vehicles), and the noise levels.

The second to the fourth scenarios correspond to: silent motorbikes and standard scooters; silent scooters and standard motorbikes; both silent motorbikes and silent scooters . By silent it is meant that they respect the noise limits imposed by law and they are therefore not tampered. For modelling, it was assumed that all PTW exceeding the maximum value would instead be attributed exactly the maximum noise value. In this case there is no shift between other means of transport, but all passing by scooters and motorbikes are considered to be "as they should have been following the EU regulations on noise limits".

The fifth scenario includes only electric PTW. The data on electric PTW has derived from available data on existing electric scooters and motorbikes as well as from measurements conducted by HEAD Acoustics on two scooters under different running conditions. The values found on these two scooters (7,5 m from the centre of the running path) are of an average L_{Amax}=54,7dB and SEL=60,9dB. It is considered that further improvements will be available and will reduce the maximum values found so as to have some 2-3 dB less. Based on this consideration, and given that a bit further than 7.5m from the vehicle the maximum noise levels will be reduced further, it was assumed that the electrically driven PTW would not contribute to identifiable noisy events that may cause arousal during nighttimes (events are, at the facade, $L_{A,max}$ less than 53 dB). A 1 dB more than scooters is assumed for the electrically driven motorbikes, considered to be representative of the extra tyre noise due to bigger and wider tyres, and thus the values used for calculations are: SEL(scooter)=60,9dB; SEL(motorbike)=61,9dB.

The last scenario foresees the total ban of the PTW. At this stage, only the effect of the scenario WITHOUT considering advanced models for modal shift is considered. i.e.: in evaluating the effect of total ban it will be only considered that for each PTW less there is a corresponding 0,6 car pass by. The exclusion of only the PTW, and the shift to electric scooter would mean having a 100% electric scooter fleet.

Table 5.4

SCENARIO	*Major road*	*Minor road*
Base	CASE 1	CASE 2
Silent motorbikes only	CASE 3	CASE 4
Silent scooters/mopeds only	CASE 5	CASE 6
Silent PTW (all)	CASE 7	CASE 8
Electric PTW (all)	CASE 9	CASE 10
Total ban of PTW	CASE 11	CASE 12

2 RESULTS

The main objective of this report is to focus on the effect of different noise reduction measures on annoyance and health.

It has been made clear by looking at the results that scenarios 1 to 8 do not display any significant variations, since noise levels are reduced only up to 1,4 dB and the percentages of annoyed outdoor and highly annoyed indoor decrease by maximum 4%. This means that any legal enforcement measure intended to confine the PTW (only scooters and mopeds, only motorbikes or all the PTW) to the noise limits foreseen by law will have a very limited effect. Though it is recognised that generally speaking, in road noise, even a few dB of reduction are a great and hard achievement, it is clear that sensible effect on road noise will be obtained if measures are simultaneously taken for car noise.

Scenarios 9-10 and 11-12 are those who display the highest (positive or negative) effects. The scenario 11-12, corresponding to the total ban, is not the best because the assumption that still 60% of the PTW users will choose to use a car to run along the same road section causes noise to be reduced only very partially due to the increased number of cars. Other parameters also display a still limited effect (CO_2 and NOx reductions).

The maximum effect is obtained therefore with the use of electric scooters. Namely, 2,3dB is the reduction on the major road and 2,7dB is the noise reduction on the minor road. Correspondingly, the % annoyed outdoors is reduced by 3,3% to 4,1% and the highly annoyed indoor are reduced between 1,3% and 7,5%. The relevant results are presented in table 2.1

Table 2.1 – The values of the noise and other parameters evaluated as a function of the scenario.

Scenario		Major road	Major road -20dB	Minor road	Minor road -20dB
1-2 Base scenario	Lden	78,9	58,9	71,2	51,2
	%A outdoor (incl. PTW penalty)	82,8	57,4	72,9	47,5
	%HA indoor	48,9	9,3	27,4	4,3
	Number events >52dB, per hour	385,0	385,0	38,3	38,3
	Lnight	69,1	49,1	60,3	40,3
	CO2	4609,6		819,2	
	NOx	9,9		1,8	
	Danger	-		-	
3-4 Silent motorbikes	Lden	78,6	58,6	70,9	50,9
	%A outdoor (incl. PTW penalty)	82,3	56,9	72,6	47,2
	%HA indoor	47,8	9,0	26,7	4,1
	Number events >52dB, per hour	385,0	385,0	38,3	38,3
	Lnight	68,9	48,9	60,0	40,0
	CO2	4609,6		819,2	
	NOx	9,9		1,8	
	Danger	-		-	
5-6 Silent scooters and mopeds	Lden	78,1	58,1	70,2	50,2
	%A outdoor (incl. PTW penalty)	81,2	55,8	71,5	46,1
	%HA indoor	46,1	8,6	25,2	3,8
	Number events >52dB, per hour	385,0	385,0	38,3	38,3
	Lnight	68,6	48,6	59,4	39,4
	CO2	4609,6		819,2	
	NOx	9,9		1,8	
	Danger	-		-	

	Lden	77,7	57,7	69,8	49,8
	%A outdoor (incl. PTW penalty)	80,6	55,2	71,1	45,7
	%HA indoor	44,8	8,3	24,4	3,6
	Number events >52dB, per hour	385,0	385,0	38,3	38,3
	Lnight	68,3	48,3	59,1	39,1
	CO2	4609,6		819,2	
	NOx	9,9		1,8	
	Danger	-		-	
9-10 *Electrically driven PTW only*	Lden	76,6	56,6	68,6	48,6
	%A outdoor (incl. PTW penalty)	78,7	53,3	69,6	44,2
	%HA indoor	41,5	7,5	22,0	3,0
	Number events >52dB, per hour	323,0	323,0	26,7	26,7
	Lnight	67,6	47,6	58,1	38,1
	CO2	4011,2		725,0	
	NOx	10,6		1,9	
	Danger	Increased		Increased	
11-12 *Total ban of PTW*	Lden	77,3	57,3	69,4	49,4
	%A outdoor (incl. PTW penalty)	80,0	54,6	70,6	45,2
	%HA indoor	43,6	8,0	23,6	3,4
	Number events >52dB, per hour	360,2	360,2	33,7	33,7
	Lnight	68,0	48,0	58,7	38,7
	CO2	4267,9		768,0	
	NOx	11,6		2,1	
	Danger	Decreased		Decreased	

By looking at the overall benefits, again the situation with **all PTW electrically driven is the best**. In figure 2.1 and figure 2.2 the radar plot shows that CO2, NOx, number of events exceeding 53dB are reduced in scenario 10-11, corresponding to the electric scooters only, with the only exception of NOx emissions. But, as anticipated, the NOx emissions estimations are based on partial data from the PTW manufacturers, moreover it is foreseen that as a result of the CAFE programme the NOx of electrically driven PTW will substantially decrease, thanks to a good balance of electricity production from renewable sources and improvements in the industrial process of electric generation in large power plants. The only remaining doubtful point is the safety of the electrically driven PTW. Concerns were raised recently at the level of EU Parliament on the danger of electrically driven vehicles, and a proposal was put forward to produce electric vehicles emitting a specific safety sound. Studies are not available at the moment concerning the safety of the electrically driven PTW, though it is the opinion of the author of this report that electrically powered PTW will not be more dangerous than traditionally powered ones, given that, in silent environments, the noise will still be approximately 50 dB, far above the threshold of 40 dB which is typically the background noise in a silent environment.

In noisy environments however, the pedestrians (the only ones which may suffer from increased danger) are anyway very careful for vehicles, since in a noisy environment it is unlikely that a pedestrian is aware of all vehicles surrounding him thanks to noise, given that single vehicles already differ by easily 10dB amongst them, and thus some of them are masked by noise of others. Overall, danger is considered to be constant for all scenarios 1-10, and reduced only in scenarios 11-12 thanks to the use of only cars, which protect the driver and the passenger much more than a PTW can , in case of an accident.

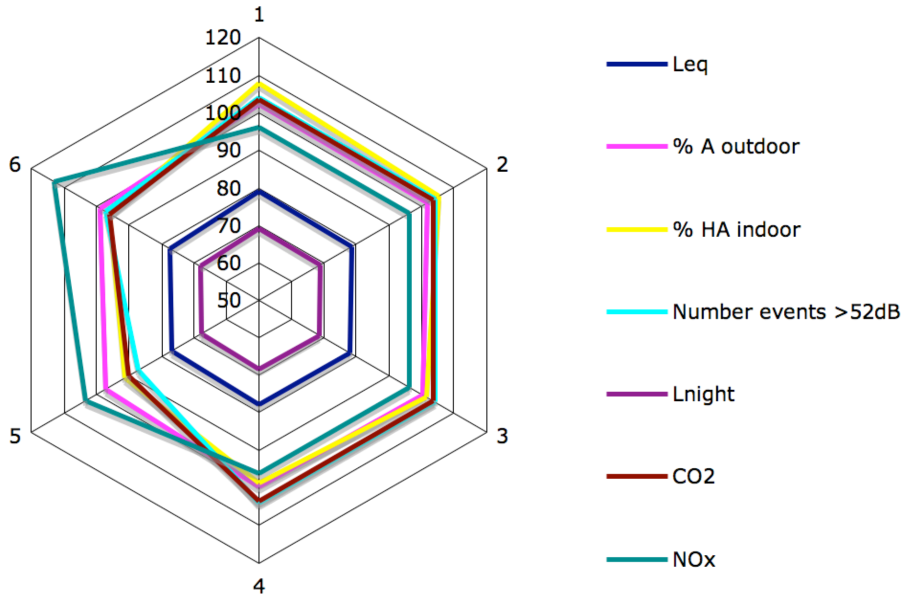

Figure 2.1The radar graph shows the effect on the different parameters considered in the impact study. The numbers correspond to the scenarios on major road at the most exposed location. All values except for the noise values are presented in percentage respect to the average value (e.g.: %CO2 g/km emission respect to the average for all scenarios).

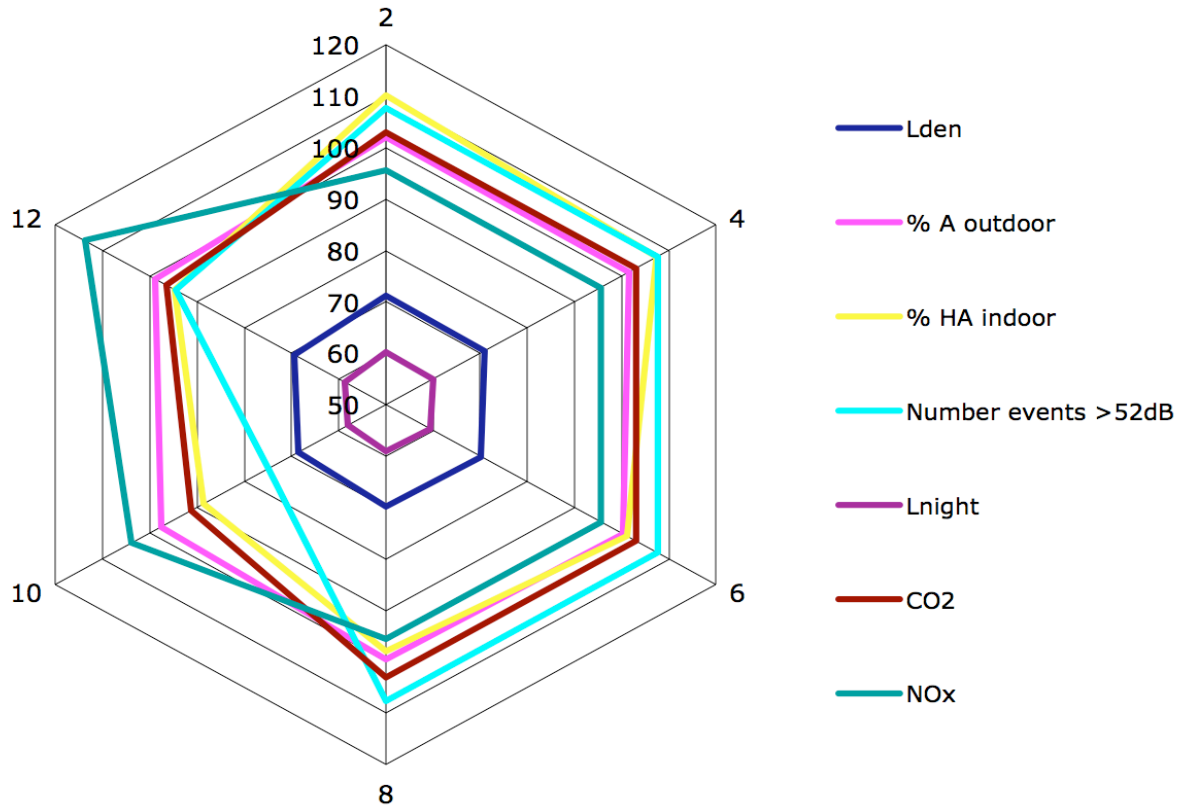

Figure 2.2 The radar graph shows the effect on the different parameters considered in the impact study. The numbers correspond to the scenarios on minor road at the most exposed location. All values except for the noise values are presented in percentage respect to the average value (e.g.: %CO2 g/km emission respect to the average for all scenarios).

3 PROPOSALS

The best option for noise reduction is therefore the use of only electrically driven PTW, because:

(a) they make less noise (about 20dB less as foreseen in the target of CITYHUSH for each pass-by, and overall a reduction of approximately 2,5dB on the overall traffic noise on the road)

(b) they reduce annoyance, both indoors and outdoors

(c) they reduce the health risk during nighttimes, because less noisy events are heard inside houses

(d) they reduce overall air emissions and are at "zero emissions" in urban environment

(e) they are at the same cost for the owner

(f) they are as safe as other PTW

(g) they allow maintenance of the flexibility of movement typical of small transportation means within urban environment.

Other solutions instead show slight improvements and are therefore not encouraged for their low effectiveness.

Given that it is impossible and anti-economical to suddenly shift to only electrically driven PTW, the appropriate way forward may be to shift to electrically driven gradually and by substituting them only whenever old ones have reached end of life.

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