



A Policy Indicator for Road Traffic Noise Emission

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ABSTRACT

A Policy Indicator Tool has been developed to globally quantify the large scale effects of road traffic noise source mitigation measures on average façade noise levels along different types of roads and overall numbers of annoyed and sleep disturbed people. Types of mitigation measures include vehicle noise limits, tyre noise limits (and label), road type and surface, traffic parameters, noise barriers and dwelling insulation. The Policy Indicator has been applied in the Netherlands to assess the overall effect of potential new vehicle and tyre noise limits, and which other measures are required to fully benefit from these. In this paper the Policy Indicator is explained and several scenarios are illustrated showing which measures are required to reduce the numbers of annoyed and sleep disturbed population by almost half. One of the main benefits of this approach is to efficiently evaluate the future impact and justify tighter vehicle and tyre noise limits, especially if applied on an EU-wide scale or for several individual countries.

Keywords: Road traffic noise, Future traffic emission levels, EU Regulation
I-INCE Classification of Subjects Number(s): 52.3,63.8

1. INTRODUCTION

Noise is second only to air pollution for environmental impact on public health, with road traffic as a major contributor. In the Netherlands, around 3 million people are annoyed or sleep disturbed, and 1.5 million are seriously annoyed or seriously sleep disturbed by road traffic noise. It is mitigated most cost-effectively by reducing noise emission at the source for vehicles, tyres and road surfaces.

Information on numbers and location of annoyed and sleep disturbed people is widely available from surveys and from noise mapping of major roads and agglomerations, as required by the Environmental Noise Directive 2002/49/EC, combined with dose-effect relationships. Authorities use this information to inform the public and to reduce noise exposure and its impact. This policy is based on the premise that mitigation of noise at source (vehicles and tyres) is well regulated at European level. But the link between noise mapping and limits for noise sources is lacking, as noise in general and noise source mitigation for vehicles and tyres are under the remit of four different European Directorates: DG Environment, DG Energy, DG Mobility and Transport and DG Growth.

It is therefore important to make a link between the various noise source mitigation measures and amenity and health effects. Insight into the contributions from each noise source to numbers of annoyed and sleep disturbed people helps prioritise noise mitigation measures for vehicles, tyres and roads.

A Policy Indicator has been developed by TNO to link noise source mitigation measures to numbers of affected people. It has been implemented as a tool which enables the user to quickly determine from a limited number of inputs the effect of noise control at source on average noise levels at the dwelling façade and on estimated numbers of annoyed and sleep disturbed people. Examples of policy measures that can be assessed are quieter tyres based on the noise label, quieter vehicles based on their type approval limit, quiet road surfaces, noise barriers, changes in roads and traffic flow.

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In this paper the structure and implementation of the Policy Indicator is set out, followed by several calculated future scenarios for 2030. Finally, its potential use for national and international policy is discussed.

2. POLICY INDICATOR

2.1 Model and inputs

The Policy Indicator is based on a straightforward model, shown schematically in Figure 1 and described in more detail in (1). The approach is similar to that applied in the Venoliva study for the European Commission in 2011 (2), but improved to better incorporate the effects of noise mitigation measures such as quiet road surfaces in combination with quieter tyres. The noise emission is calculated with the European CNOSSOS model (3), corrected to produce noise levels comparable to the Dutch statutory traffic noise model SRM I and II (4) and emission measurements from Germany (5). The advantage of the CNOSSOS model is that a split is made between rolling noise and powertrain noise, allowing to separately take into account the effect of noise limits, tyre label and road surface. The sound power emission curves as a function of speed for light and heavy vehicles at constant speed are shown in Figures 2 and 3. The road types and lengths used in the analysis are listed in table 1; traffic flow rates typical of urban areas are set out in table 2.

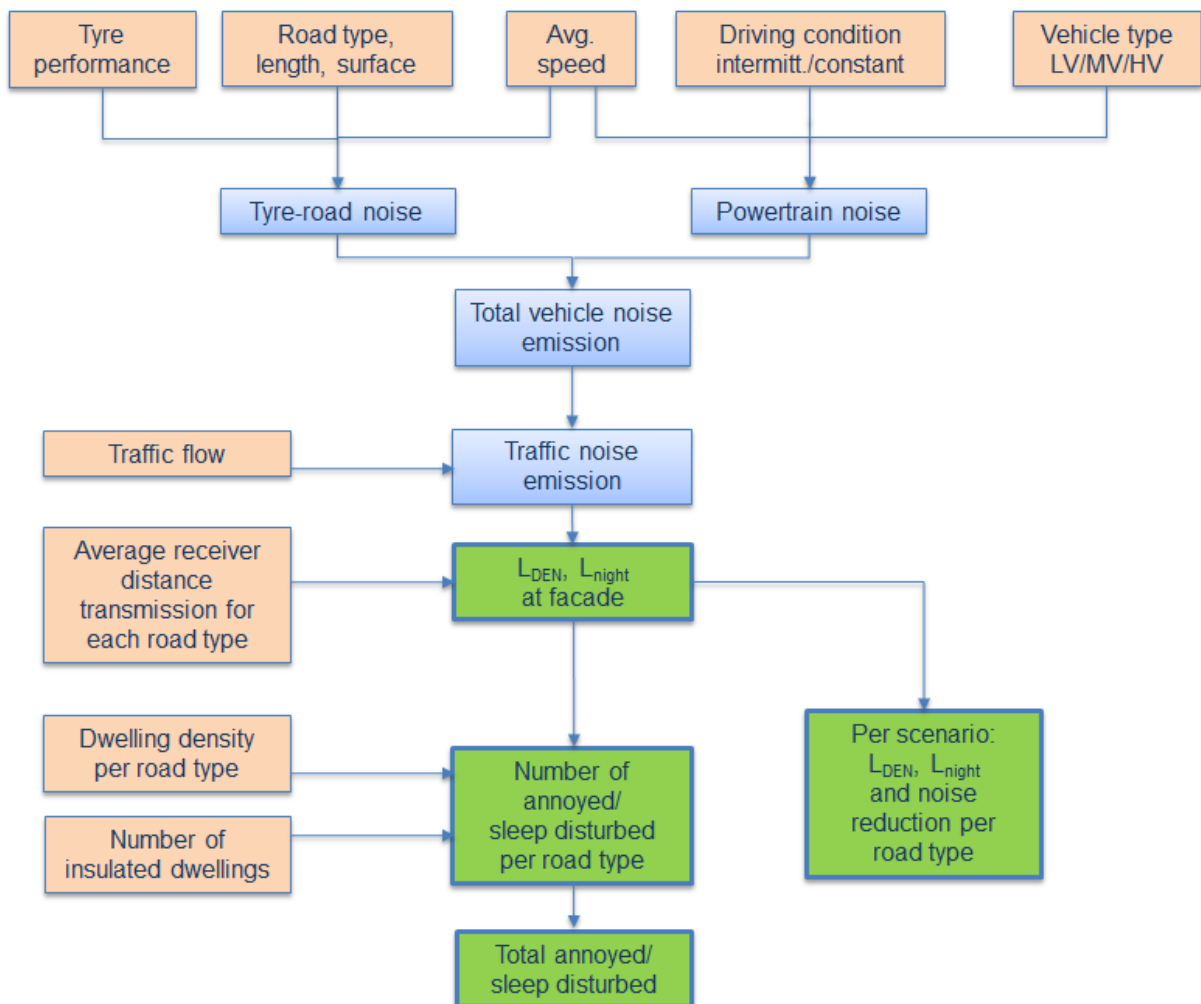


Figure 1 – Scheme of the calculation model with input parameters in red and outputs in green.

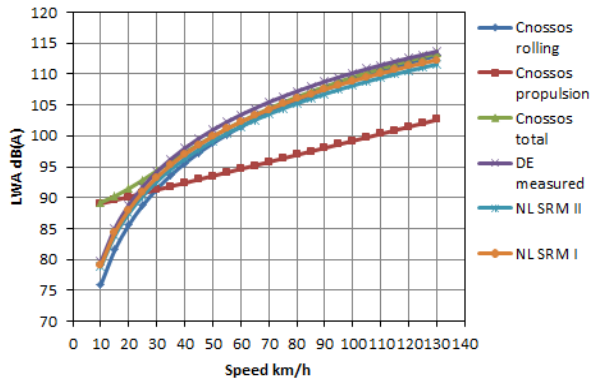


Figure 2 – Sound power emission curves for light vehicles at constant speed for EU Cnossos and Dutch SRM models and German measured data

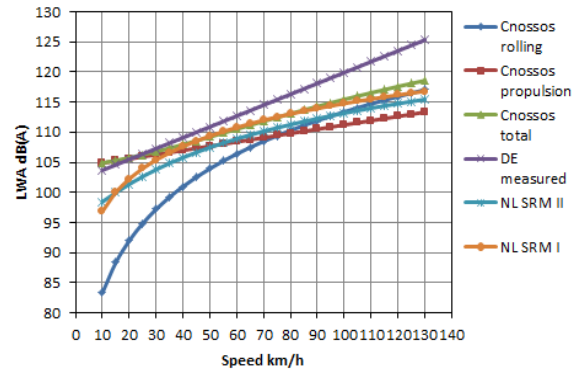







Figure 3 – Sound power emission curves for heavy vehicles at constant speed for EU Cnossos and Dutch SRM models and German measured data

The source sound power levels for each vehicle category (light, medium and heavy vehicle categories used in statutory calculation methods) are separately determined for rolling noise and powertrain noise. The rolling noise is calculated by default for standard dense asphalt concrete (DAC) and for the noise level indicated on the tyre label. The reduction in rolling noise for quieter tyres is derived from the tyre label and the type of road surface. The powertrain noise is derived from type approval data and calculated as a function of the vehicle category and the acceleration condition (intermittent or constant traffic flow). For powertrain noise, percentages of the vehicle fleet can be specified that comply with the EU noise limits from particular years of introduction (see Figure 4). A percentage of hybrid or electric vehicles can also be specified. The reduction of powertrain noise is determined from the fleet percentages that fulfill current or future limits, or are hybrid or electric vehicles, which are assumed to have respectively 5 dB or 10 dB less powertrain noise than 2015 levels.

Table 1 - Road data for the Netherlands including road types and lengths, numbers of exposed inhabitants, average façade distance and noise characteristics as applied for the Policy Indicator.

Road / traffic type	Residential street	Residential street	Main street	Main street	Arterial road	Urban motorway	Rural motorway	Rural main road	Total
Vehicle operating condition	accelerating	free flow	accelerating	free flow	free flow	free flow	free flow	free flow	
Speed range km/h	v<50	v<50	v≈50	v≈50	60<v<80	v=100 / 80	v=120 / 80	60<v<80	
Speed LV km/h	30	50	50	50	80	100	115	80	
Speed MV km/h	30	40	40	50	70	85	85	80	
Speed HV km/h	30	40	40	50	70	85	85	80	
Total road length	15569	31610	7061	14336	3284	332	2185	32606	106982
Percentage of total road length	15%	30%	7%	13%	3%	0%	2%	30%	
Selected road length (km)	12455	25288	6355	12902	2627	265	1529	16303	77724
Percentage of total selected road length	16%	33%	8%	17%	3%	0%	2%	21%	
Average number of exposed inhabitants/km	115	115	273	273	300	400	400	40	
Characteristic distance from road (m)	15	15	15	15	15	50	50	50	
Annoyance penalty, dB	3	0	3	0	0	0	0	0	
Noise sources									
	Powertrain + tyre/road	Tyre/road + powertrain	Powertrain + tyre/road	Tyre/road + powertrain	Tyre/road	Tyre/road	Tyre/road	Tyre/road	
	Powertrain	Powertrain + tyre/road	Powertrain	Powertrain + tyre/road	Powertrain + tyre/road	Powertrain + tyre/road	Powertrain + tyre/road	Powertrain + tyre/road	
									
									
									

The noise emissions of the traffic flow are calculated for each road type (residential, main, arterial roads and motorways, see Table 1) with their particular driving conditions, from the noise emission of each vehicle category and the average traffic flows. The input data for traffic and for each road type comprise:

- the total lengths of the characteristic road types with dwellings along them (Table 1);
- the total length and type of quiet road surfaces (Figure 4);
- the total length of noise barriers (Figure 4);
- percentages of sound insulated dwellings (Figure 4);
- the population density along the road (Table 1);
- average driving speeds for each vehicle category (Table 2);
- average traffic flows for each vehicle type (Table 2).

Table 2 – Average traffic flow rates for each road type and vehicle category
Light , Medium and Heavy (LV, MV, HV)

	Residential street intermittent	Residential street free flow	Main street intermittent	Main street free flow	Arterial road	Urban motorway	Rural motorway	Rural main road
Speed kmh	<50	<50	<50	<50	50-70	70-120	80-130	50-100
Characteristic traffic flow rates in vehicles/hour								
DAY 12h	Intermittent	Free Flow	Intermittent	Free Flow	Free Flow	Free Flow	Free Flow	Free Flow
LV	123,5	123,5	573,1	573,1	2030,6	2645,3	2645,3	951,6
MV	3,3	3,3	20,9	20,9	78,9	264,5	264,5	42,6
HV	3,3	3,3	21,5	21,5	81,0	202,3	202,3	45,8
EVE 4h		0,0		0,0				
LV	62,7	62,7	293,0	293,0	1039,4	1093,7	1093,7	488,8
MV	0,9	0,9	5,5	5,5	21,9	120,0	120,0	12,0
HV	1,4	1,4	9,2	9,2	34,0	120,0	120,0	19,2
NIGHT 8h		0,0		0,0				
LV	20,8	20,8	95,5	95,5	338,2	567,5	567,5	157,1
MV	0,7	0,7	4,5	4,5	16,3	80,0	80,0	9,2
HV	1,0	1,0	6,6	6,6	24,6	80,0	80,0	13,7

Noise mitigation measures on the infrastructure or dwellings are taken into account as follows. Quiet road surfaces are adjusted for with Dutch rolling noise correction factors for several common surface types. The effect of noise barriers is taken at an average 10 dB reduction in the Lden and Lnight levels at the façade. For sound insulated dwellings (only those remediated by authorities), 2.4 inhabitants per dwelling are deducted from the numbers of exposed people.

The average Lden and Lnight noise levels at the façade are calculated at 15 m or 50 m from the road centerline depending on the road type and assuming a situation without obstructions, reflections and with a hard surface between source and receiver. For residential roads and main roads with speeds up to 50 km/h a distinction is made between free flowing and intermittent traffic; one third of the road length is assumed to have intermittent traffic (accelerating or braking) due to junctions, crossings and obstacles. A penalty of 3 dB is applied for this. This approach was also taken in the Venoliva study (2).

Using the calculated Lden and Lnight levels for each road type, the roadside population densities, the road lengths with dwellings and the established dose-effect relationships for annoyance and sleep disturbance (6,7), the numbers of (seriously) annoyed and (seriously) sleep disturbed people are calculated for each road type.

The total number of annoyed people has been slightly adjusted to Dutch survey data from 2003 (8) and extrapolated to 2015 according to population growth.

The Policy Indicator tool is implemented in a spreadsheet shown in Figure 4.

Policy Indicator for Road Traffic Noise TNO

v5d June 2015

Vehicle and Tyres		Approved for limits			Approved for limits			Approved for limits			Approved for limits		
Vehicle	Type	2015	2016	2020/22	2024/26	Hybrid	Electric	2015	2016	2020/22	2024/26	Hybrid	Electric
Cars (C1)		100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
Vans (C2)		100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
Buses (C3)		100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
Lorries (C3)		100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
Trucks (C3)		100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
Restore defaults													
Tyres	Type	min		max		Selected		Current					
Restore defaults	C1	66	69	70	74	70	70	70	70				
	C2	69	70	71	76	72	72	72	72				
	C3	70	71	72	78	75	75	75	75				
Restore defaults													

Infrastructure	Road type	Residential street	Main road	Arterial road	Urban motorway	Rural motorway	Rural road	Total km
Road length inhabited (km)		37743	19257	2627	265	1529	16303	77724
Exposed/km		115	273	300	400	400	40	11755426
%Insulated dwellings		0,0%	2,0%	1,0%	1,6%	1,0%	1,0%	127357
Length of quiet road surface (km)		0	9628	2627	265	1150	5380	
Type		DAB	DGD	ZOAB	ZOAB2	ZOAB	DAB	
km barrier length		0	250	500	133	750	250	
Restore defaults								

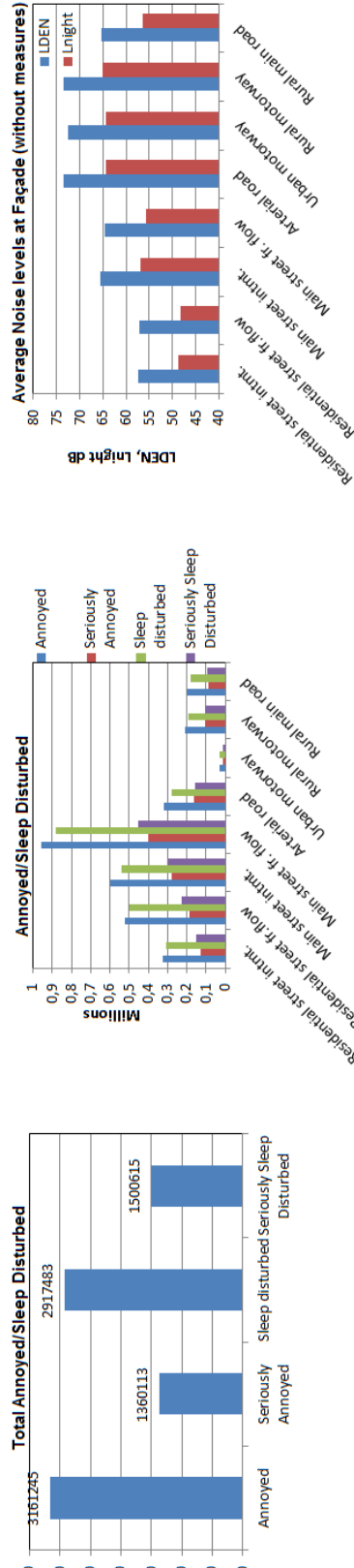


Figure 4 - Policy Indicator Tool, with vehicle and road input data at top left and right, and numbers of annoyed and Lden/Lnight levels below

3. SCENARIOS FOR 2030

3.1 Description of scenarios

An application of the Policy Indicator is illustrated by evaluating several scenarios for 2030. The situation in 2015 is taken as the reference scenario (1). Subsequent scenarios for 2030 assume a 1% annual growth in road traffic (2), the best possible separate mitigation measures for vehicles (3), tyres (4) and road surfaces (5) and the combination of all of these (6), as listed in Table 3.

Table 3 - Scenarios for the evolution of noise emission levels of road traffic sources.

Scenario	Description
1. Situation in 2015 (reference)	Fleet composition, road infrastructure, mitigation measures and demographics in the Netherlands in 2015.
2. 2030 including 1% growth	1% growth in traffic, no extra measures and autonomous influx of quieter vehicles and tyres, with a fleet distribution as in Table 5.
3. 2030 Scenario 2 + quiet vehicles	Scenario 2 with 3 dB quieter vehicles compared to the EU-limits for 2024/2026 (9) (Table 4).
4. 2030 Scenario 2 + quiet tyres	Scenario 2 only with quieter tyres. Tyres 2 dB quieter than the limits for 2020 proposed by the Netherlands (12) (Table 6).
5. 2030 Scenario 2 + quiet road surfaces	Scenario 2 with wider application of quiet road surfaces only (2-layer ZOAB with fine top layer), on all roads with dwellings and speed limit of 50 km/h or more, except calmer streets in residential areas.
6. 2030 Scenario 2 + all measures	Combination of Scenarios 2,3,4 and 5.

The currently foreseen European noise limits for vehicles as listed in Regulation 540/2014/EU (9) are set out in Table 4. These are valid for a number of vehicle classes and have been converted to three categories used in the Dutch calculation method (reference 4): light, medium and heavy vehicles. These limits are most relevant for the powertrain noise. As vehicle lifetime is on average about 13 years, a combination of vehicles with type test approval for different limits will be circulating in 2030, assuming an autonomous influx of new vehicles. This is indicated in Table 5 with percentages of the fleet approved for each limit, used for the calculation scenario 2, the situation in 2030. In scenario 3, full implementation of the 2024/26 vehicle noise limits minus 3 dB is assumed.

The noise emission of tyres is subject to limits according to UNECE Regulation 117, adopted by the EU (10), applicable from 2016. In scenarios 2 and 3 it is assumed that the tyre regulations are unchanged. The Netherlands has proposed tighter limits (11) for 2020 that have not yet been adopted. Scenario 4 assumes full implementation of the Dutch proposal for 2020 minus 2 dB (Table 6). The lifetime of tyres is about 4 years which means that new tyre limits take effect much sooner than vehicle noise limits.

Significant noise reductions are achievable with quiet road surfaces. Therefore scenario 5 assumes widespread introduction of quiet road surfaces on all roads with dwellings nearby, with a speed limit of 50 km/h or more, except for calmer streets in residential areas.

Table 4 - EU vehicle noise limits for 2016-2026 (9), with conversion to equivalent limit values for each vehicle category of the Dutch calculation method. In the last column the noise emission for scenario 3 with quieter vehicles is shown.

Vehicle class EU Regulation	EU limits				Vehicle category for NL calculation method	Equivalent limit values				Scenario 3 2030+quiet vehicles
	2015 Current	2016 New vehicle types	New vehicle types from 2020 and new regulation from 2022	New vehicle types from 2024 and new regulation from 2026		2014/15	2016	2020	2024	
M1 (PMR≤120kW/t)	72	72	70	68	LV (Light)	72.3	72.1	70.2	68.3	65.3
M1 (120<PMR≤160kW/t)	73	73	71	69						
M2 (m ≤ 2,5t)	74-75	72	70	69						
M2 (2,5t<m≤3,5t)	75	74	72	71						
N1 (m ≤ 2,5t)	73	72	71	69						
N1 (2,5t < m ≤ 3,5t)	74	74	73	71	MV (Medium)	76.9	77.6	75.8	74.7	71.7
M2 (3,5t<m≤5t, Pn≤135kW)	76	75	73	72						
M2 (3,5t<m≤5t, Pn>135kW)	76-78	75	74	72						
M3 (Pn≤150kW)	77-78	76	74	73						
M3 (150<Pn≤250kW)	79	78	77	76						
M3 (Pn>250kW)	79-81	80	78	77						
N2 (Pn≤135kW)	75-77	77	75	74						
N2 (Pn>135kW)	78-80	78	76	75	HV (Heavy)	80.7	82.2	80.7	78.7	75.7
N3 (Pn≤150kW)	78-79	79	77	76						
N3 (150<Pn≤250kW)	81-83	81	79	77						
N3 (Pn>250kW)	81-83	82	81	79						

Table 5 - Percentages of vehicles of the whole fleet in 2030 approved for the various limits, with autonomous introduction of new vehicles (scenario 2).

Vehicle/Tyre	Approved for 2015 limits	Approved for 2016 limits	Approved for 2020/22 limits	Approved for 2024/26 limits	Hybrid	Electric
Cars/C1	0%	30%	45%	20%	3%	2%
Vans/C2	0%	30%	45%	20%	3%	2%
Buses/C3	0%	30%	45%	20%	3%	2%
Lorries/C3	0%	30%	45%	20%	3%	2%
Trucks /C3	0%	30%	45%	20%	3%	2%

Table 6: Limit values for tyres in dB(A) from 2016, the Dutch GRB proposal for 2020 (11) and the situation for scenario 4 in 2030 with quiet tyres.

Tyre class	EU/UN Regulation 117 for 2016	NL proposal for 2020	Scenario 4 2030+quiet tyres
C1	70-74	67-71	65-69
C2	72-74	70-72	68-70
Traction tyres	73/73/75	71/73/73	+2
C3	73/73/74/75	69/71/71	67/69/69
Traction tyres	+2	71-73	+2

3.2 Results

The numbers of annoyed and sleep disturbed people for the reference situation in 2015 and for the various types of road are set out in Figure 5, and in Figure 6 and Table 7 for the totals for each scenario. The corresponding Lden noise levels at the façade for each scenario and road type are shown in Figure 7.

A moderate annual growth in traffic of 1% is not compensated by the foreseen European noise limits by 2030. A small increase in numbers of annoyed people still occurs. In scenarios 3 and 4, with quieter vehicles and quieter tyres respectively, numbers of (seriously) annoyed and sleep disturbed are reduced by around 10%. In scenario 5, in which the quietest road surfaces are implemented for all roads with dwellings except calmer roads in residential areas, larger reductions of (seriously) annoyed and sleep disturbed of 17-27% are expected. Combination of all mitigation measures as in scenario 6 results in reductions of 37-51%.

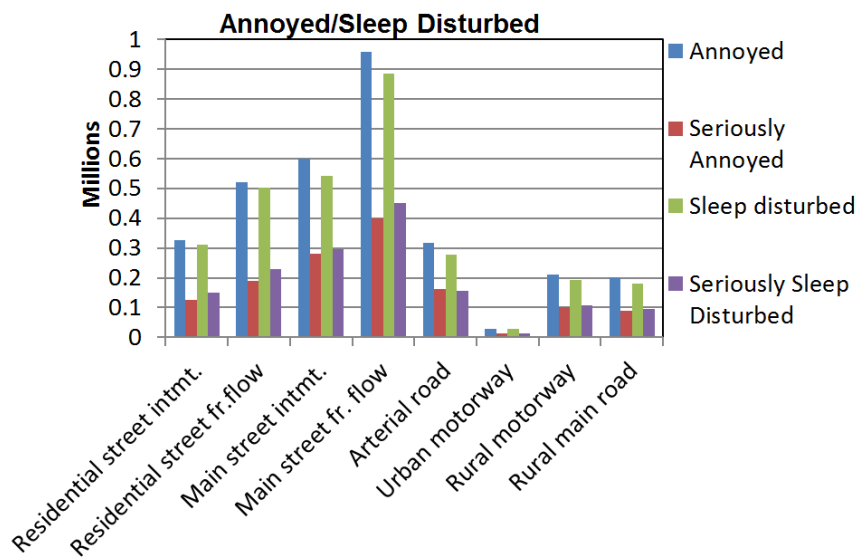


Figure 5 - Numbers of annoyed and sleep disturbed for the different road types for the reference situation in the Netherlands in 2015.

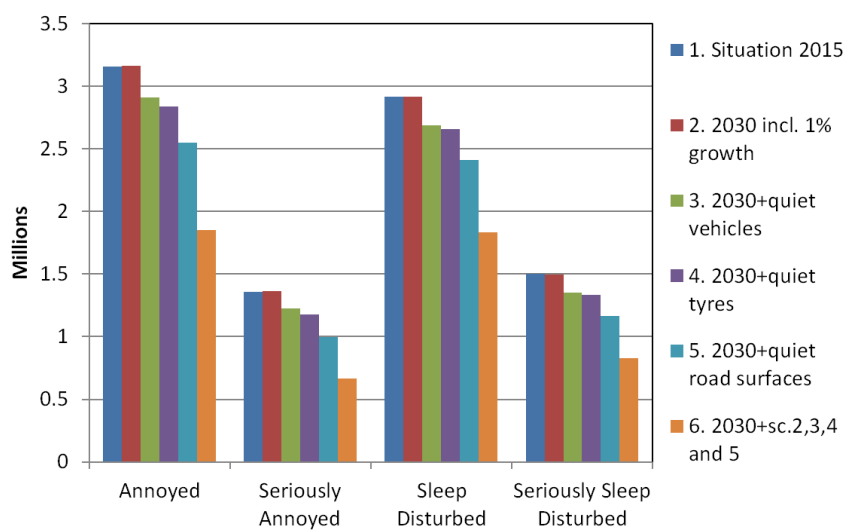


Figure 6 - Total numbers of (seriously) annoyed and (seriously) sleep disturbed people for the scenarios 1-6 listed in Table 3.

Table 7 - Numbers and percentages of (seriously) annoyed and sleep disturbed people in the Netherlands for each scenario.

Scenario	Annoyed	Reduction from Sc.1	Seriously Annoyed	Reduction from Sc.1	Sleep Disturbed	Reduction from Sc.1	Seriously Sleep Disturbed	Reduction from Sc.1
1	3161245		1360113		2917483		1500615	
2	3165333	-0.1%	1364278	-0.3%	2914577	0.1%	1499111	0.1%
3	2914022	8%	1222993	10%	2687540	8%	1354446	10%
4	2840506	10%	1176935	13%	2660222	9%	1335718	11%
5	2550716	19%	995040	27%	2411667	17%	1166955	22%
6	1854576	41%	664176	51%	1832317	37%	831292	45%

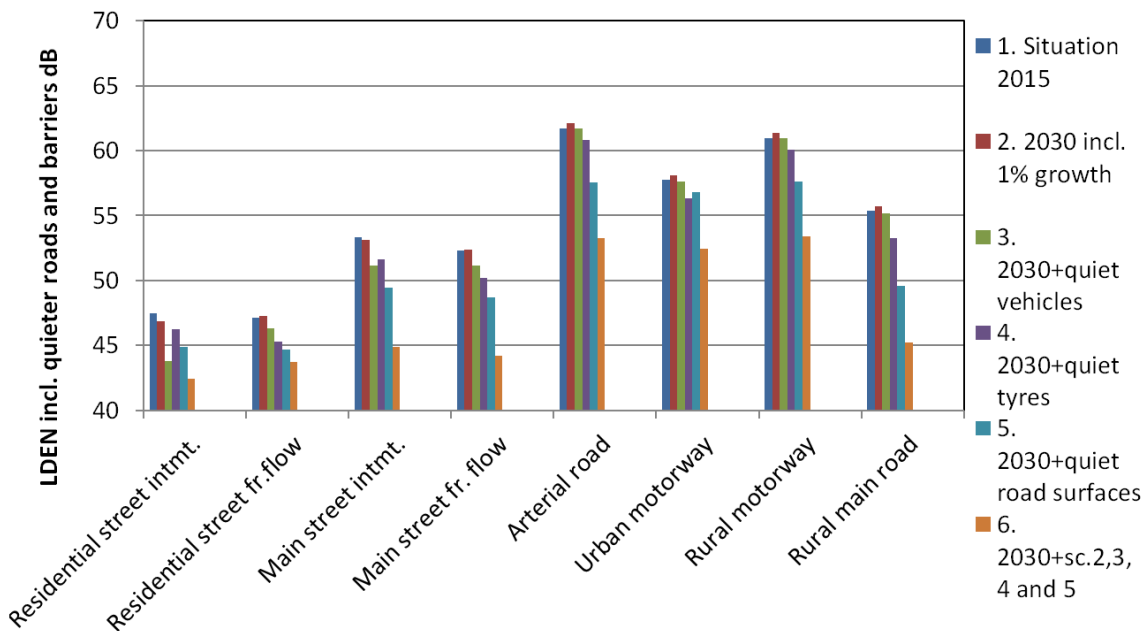


Figure 7 - Lden noise levels at the façade for the different road types for the scenarios 1-6 listed in Table 3, including effects of quiet road surfaces and noise barriers (where present).

4. CONCLUSIONS

The Policy Indicator can be used for large areas such as countries, regions or major agglomerations. It is not intended or suited for the assessment of small areas or specific locations, and is no replacement for statutory calculation methods and noise mapping, but can be considered as an additional tool for policy support. In particular, the Policy Indicator can be used to underpin focused and integral policies for noise emission derived from health-related targets. The Policy Indicator has been developed for the Netherlands. Such a tool can be developed for other countries as well or for the EU as a whole. In the EU 55-60 million people are seriously annoyed or sleep disturbed (12). A combination of all possible

source oriented measures as has been evaluated for the Netherlands would reduce these by around 50%. Individual mitigation measures can also be assessed, such as tightening of tyre noise limits (11) or incentives for swifter introduction of quieter vehicles.

As the vehicle fleet, tyres, road lengths, surfacing, population distribution and other parameters can vary between member states, the potential for noise reduction and reduced health impacts may even be larger in some parts of the EU. Especially in urban areas where the largest number of inhabitants are affected, the benefits of tighter limits for both vehicles and tyres are evident.

The above scenarios clearly illustrate that quiet road surfaces are quite effective. These are however expensive and not covered by international regulation.

Quieter tyres are also effective in reducing annoyance and sleep disturbance. A key point is that this measure is practically cost neutral if gradually implemented. The noise limits for tyres are given in ECE regulation R117 and EU Regulation on General Safety (10). The Netherlands has already proposed tighter limits in the ECE (11). The proposal is underpinned with a calculation of reductions of annoyed and sleep disturbed people, using the Policy Indicator. The European Commission has the obligation to evaluate and revise the Regulation on General Safety, which specifies the tyre noise limits. The Commission started this process in 2012, starting with safety, but has not yet reviewed the tyre noise limits. Here lies a task for the member states with the results of the Policy Indicator at hand.

Besides noise limits, the public can also be encouraged to buy better tyres. Calculations with the Policy Indicator show that starting the Dutch awareness campaign 'Choose the best tyre' (13) makes sense.

Quieter vehicles also contribute to the reduction of annoyance. Not much can be done currently in relation to the noise limits as the Regulation on Vehicle Noise (9) was revised in 2014. Voluntary change to quieter vehicles can be incentivised. A means to achieve this could be the development and introduction of a vehicle noise label (14). The Commission is also obliged by the same regulation to perform an assessment of such a label and to make a proposal to the Council and the European Parliament. The calculation with the policy indicator also demonstrates that incentivising quieter vehicles can be effective. This type of measure is also highly cost-effective, in the same way as for tyres.

ACKNOWLEDGEMENTS

The development of the policy indicator was supported by the Netherlands Ministry of Infrastructure and Environment, which is gratefully acknowledged.

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