L-vehicles Emissions and Noise mitigation Solutions

D6.2 Case studies and intervention options

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Table of contents

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101056777

Executive summary

The impact studies that will be carried out as part of the LENS (L-vehicles Emissions and Noise mitigation Solutions) project are outlined in this report, together with the approaches and required models. Several mitigation measures aimed at reducing pollutant and noise emissions from L category vehicles will be assessed, both at local level and at global level.

The foreseen mitigation measures are:

- Improvements to type approval regulations including lower noise and emission limits, and/or more effective roadside tests.
- Reducing vehicle tampering and modifications.
- Changing driving behaviour by various means.

Cost-benefits Analysis (CBA) will be performed for global impacts, where these are considered substantial. Also updated emission factors will be proposed, based on available measurement and analysis data. In order to carry out the impact studies, a number of developments are necessary and in progress:

- Integration of LENS data into existing modeling tools: The emissions and noise data collected during the LENS project's road and laboratory tests will be used to update the PHEM and ROTRANOMO modeling tools.
- Development of emission factors for L-category vehicles: the LENS project will use the PHEM model to create a set of representative emission factors for the different categories of L-category vehicles. These emission factors will be used to assess the environmental impact of L-category vehicles and to evaluate the reference and intervention scenarios.
- Development of local intervention scenarios: In addition to the national and European assessments, local intervention scenarios will be developed for the three LENS pilot sites. These scenarios will take account of local specificities, such as the composition of the vehicle fleet and traffic flows.
- Assessing the impact of regulatory changes: the models will be used to assess the impact of regulatory changes, such as the adoption of stricter Euro V + standards or the implementation of anti-tampering measures.

The expected outcome in LENS is a comprehensive assessment of the impact of L-category vehicles on air and noise pollution for the foreseen mitigation measures. These results will then be used to formulate public policy recommendations aimed at reducing this impact.

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List of Abbreviations

CBA	Cost-Benefit Analysis
EU	European Union
HEU	Horizon Europe
LENS	L-vehicles Emissions and Noise mitigation Solutions
LVs	L-category Vehicles
OEM	Original Equipment Manufacturer
GIS	Geographic Information Systems

List of Figures

List of Tables

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1 Introduction

1.1 Background

Numerous parameters have an impact on L-category vehicles (LVs) emissions and noise in real-life situations: driver behaviour, performances of technologies in real-world conditions, impacted by vehicle tampering. LVs include mopeds, motorcycles, tricycles, and quadri-mobiles.

The overall aim of the L-vehicles Emissions and Noise mitigation Solutions (LENS) project, funded by the European Union (EU)'s Horizon Europe (HEU) research and innovation programme under grant agreement No 101056777, is to characterise this sensitivity and assess the resulting contributions of LVs to road transport emissions and noise, at both global and local scales, in current and future situations, and for several intervention/mitigation scenarios. Figure 1 summarizes the global LENS approach.

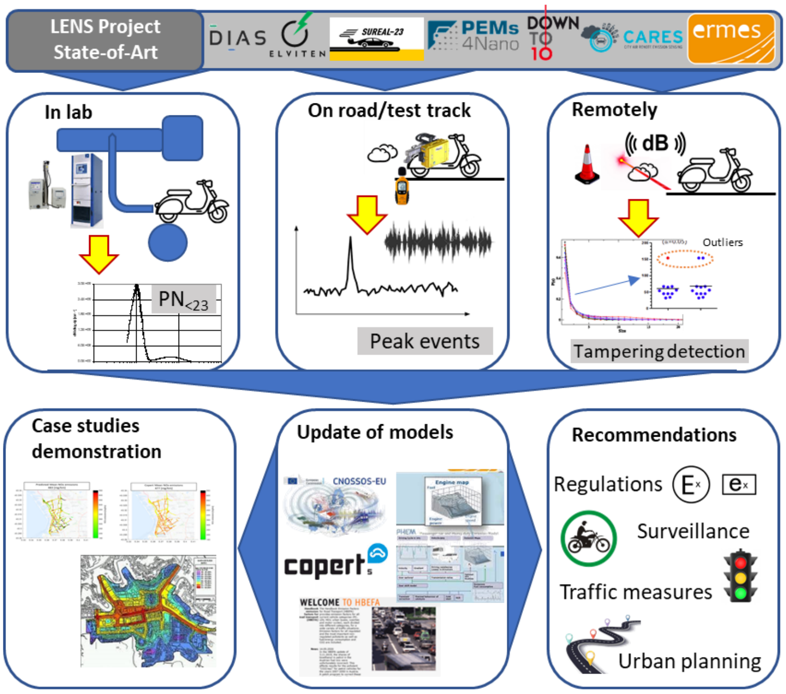

Figure 1: Overview of the overall methodology of the LENS project

This report is part of Work Package 6, which aims to review LVs real world operating conditions, to assess emissions and noise, to demonstrate intervention impacts, to provide technical and policy recommendations for cleaner, quieter LVs, and to deliver a free mobility app for riders with best practice guidance.

More specifically, Work Task 6.2 assesses the contribution of LVs to emissions and noise, without interventions, at different scales by (i) Adapting and enhancing the modelling and assessment tools with LENS findings, (ii) Assessing the current situation (inventory) and projecting how this is expected to develop

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in the future (baseline projection), both at a global state level (using SIBYL fleets and expected EV penetration) and at a local scale (using specific modelling domains (hot-spots, other) and adapted micro-models). Starting from this point, Work Task 6.3 focusses on mitigation measures and impact assessment, involving a series of steps to provide actionable insights into the effectiveness and implications of these mitigation measures:

- Identification and selection of interventions from the evidence gathered in WP3, WP4, and WP5
- Determination of modelling parameters and their respective values at various scales to accurately simulate the effects of these interventions.
- Conducting simulations of interventions both globally and within selected modelling domains established in Work Task 6.2.
- Evaluation of the benefits of interventions against their expected costs and other social challenges through impact assessment.
- Performing cost-benefit analyses for the most promising interventions at global scale.
- Analysing gender-specific impacts, drawing from existing literature wherever feasible.
- Assessing and discussing the anticipated impacts of interventions, culminating in the synthesis and summarization of findings in the deliverable 6.4 expected at the end of LENS project.

Finally, Work Task 6.4 synthesises final LENS recommendations by creating a summary catalogue of possible interventions (regulation, infrastructure, vehicles, users), including their characteristics, implementation scale and challenges, expected impacts and discuss associated costs, suitability based on findings and expected developments and conclude with recommendations suitable for different stakeholder groups (regulators, cities, enforcement authorities, riders, etc.) (D6.5)

1.2 Objective

The aim of this report, positioned at an early stage of LENS WP6, is to define in more detail the results to be provided in WT6.2 and WT6.3, by defining the framework for these assessments. It provides a description of the scenarios (cases studies and intervention options), the LVs modelling tools, and associated modelling domains considered.

1.3 Structure

Following this introduction, chapter 2 describes the cases studies and scenarios that will be considered during noise and emissions assessment studies carried out in LENS. Chapter 3 describes the modelling approach deployed in LENS, focusing on the models used for assessing noise and emissions at several scales, associated modelling domains, and developments required.

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2 Definition of intervention measures and scenarios

2.1 Composition of real-world situations

2.1.1 Road situations and real-world driving conditions

Scenarios need to be defined based on the most relevant and realistic intervention options and the most common and numerous situations. For interventions affecting noise at dwellings, the impact at local level is usually assessed from the change in traffic noise levels including all vehicle types at a single location; the impact at global level, such as a whole country or the EU, for example, takes the cumulative effects into account averaged over all roads and adjacent dwellings. In addition, the impact can be assessed in terms of changes in numbers of annoyed people, sleep disturbed people, or health impacts such as DALYs. For L-vehicles, this analysis is critical due to the lower numbers of these compared to cars, resulting in a masking of the effects. Another issue in this respect is that the dose-effect relationships for road traffic noise are only for combined traffic, whereas L-vehicles have a specific impact for single events, not well reflected in the dose-effect relationships specified in EU regulation (END). Studies in Austria have demonstrated that a much higher dose-effect curve is to be expected for motorcycles [1]. And in the EU study on L-vehicle sound limits [2], a single event approach was applied besides the average traffic noise approach.

In the context of LENS, the focus is on a limited selection of intervention options for L-vehicles and their effects in several situations. Given the importance of single events, the most common loud driving conditions, and situations where they have most impact are considered. Common driving conditions identified in urban measurements were, as established in the deliverable D6.1 of the LENS project:

- fast acceleration from standstill after crossings.
- accelerating from low speed on long straight roads.
- high continuous engine speeds such as for tampered mopeds.

For rural areas and some urban areas, uphill driving can be an issue due to heavier engine load and frequent gear changing.

In terms of the impacted surroundings, roads with dwellings close to the road and continuous building on both sides can lead to high exposure of inhabitants. In particular, high-rise buildings and street canyons can be hotspots for noise exposure and complaints, but also villages in valleys with roads on surrounding hillsides.

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Table 1: Real-world driving behaviour, with focus on critical driving conditions for emissions and noise as described in D6.1, indicative frequency of occurrence (from WP5), proven effects (expected from WP3)

Driving condition		Road situations (typical for occurrence of driving conditions)						
		At junction/ crossing	Just after junct./cross.	Just before junction	Long straight road	Winding road	Uphill road	Downhill road
Condition	**Vehicle operation**							
(1) Cold start (mainly for emissions)	Engine start	x	x					
(2) rpm burst	Stationary, short activation and release of accelerator	xx	x					
(3) Acceleration from standstill, G1, G2 Loaded + unloaded	Acceleration, late gear change	xx	xx					
(4) Max rpm passby esp. mopeds, scooters, sports MCs	Constant speed with max rpm	x	x	x	x	x	x	x
(5) Release from constant speed	Deceleration			x		x		x
(6) 'Max' acceleration from standstill, G1, G2	Acceleration	xx	xx					
(7) Acceleration at speed, from 50 to 100 km/h	Acceleration, may be varied	x	x	x	x	x	x	x
(8) rpm fluctuation	Variable speed	x	x	x		x	x	x
(9) Backfire (occurrence, distance not critical)	Multiple gear changing or manual operation	x	x	x	x	x	x	

Red = most frequent

2.1.2 Fleet composition and tampering

In addition, tampered vehicles can produce substantially higher noise levels than other traffic and thereby impact far more dwellings. So here, an assessment is required of the additional noise such vehicles will produce compared to untampered ones.

In LENS report D5.1 an overview is given of tampering methods and their occurrence. It focuses on L-vehicle tampering and the negative consequences it can have on both air and noise pollution. More specifically, it describes the most common methods of L-vehicle handling currently applied in the European Union, and to assess their adverse effects on pollutant and noise emission levels. Various methods were used, including a literature review, the use of proprietary information and questionnaires, to create an effects table that documents the impacts of handling on pollutant and noise emission levels using a qualitative approach.

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The more common tampering methods observed were modifications of the exhaust (after-market silencer, removal of silencer or silencer modifications, catalyst removal, adjustable exhaust valve/dB killer, etc.), the intake (after-market air filter or air filter removal), the engine (porting cylinder head, increasing displacement, after-market camshafts, etc.) and the ECU (software modifications, engine speed limiter removal, etc.).

The motivations for this tampering have also been documented: the desire to increase power, improve handling, sound, or appearance, reduce fuel consumption, for example.

Finally, a qualitative analysis of the effects on noise and emissions (CO, HC, NOx, CO_2) of the most frequent modifications encountered in the fleet was carried out, and the experimental campaigns underway in WP3, WP4 and WP5 of the LENS project will enable these effects to be quantified, and their inclusion in the modelling tools to be parameterised accordingly. It would seem appropriate to select those tampering types that may be reduced by interventions, general (such as more enforcement) or specific (elimination of loud exhausts for example).

2.2 List of intervention measures

2.2.1 Type approval standards

Measures:

The first category of intervention measures that will be considered is the evolution of the regulatory framework and more specifically of the type approval standard.

Entry into force of stricter standards for vehicle type-approval for both pollutant emissions and noise will be considered: various scenarios concerning thresholds and procedures will be defined, covering tailpipe emissions tests, introduction of a PN limit, implementation of off-cycle emission testing, etc.

Consideration in the LENS assessment methodology (models and scenarios):

These scenarios will be translated into assumptions about related technological developments, from the most conservative to incremental technical advances and potential new breakthroughs.

Finally, these different technological evolution scenarios will be implemented in modelling tools, through parameterisation or the development of specific bricks. In this way, an assessment of emissions under real driving conditions for future vehicles meeting these potential standards (i.e. emission factors for Euro 5+ vehicles) will be drawn up. It will enable to assess the expected benefits of such a stricter standard on total emissions. This assessment was carried out by EMISIA, TNO and LAT as part of the study on the environmental effects of Euro 5 for DG GROW [3] and presented at MCWG meetings in 2016. New Euro 5+ scenarios will thus update these projections.

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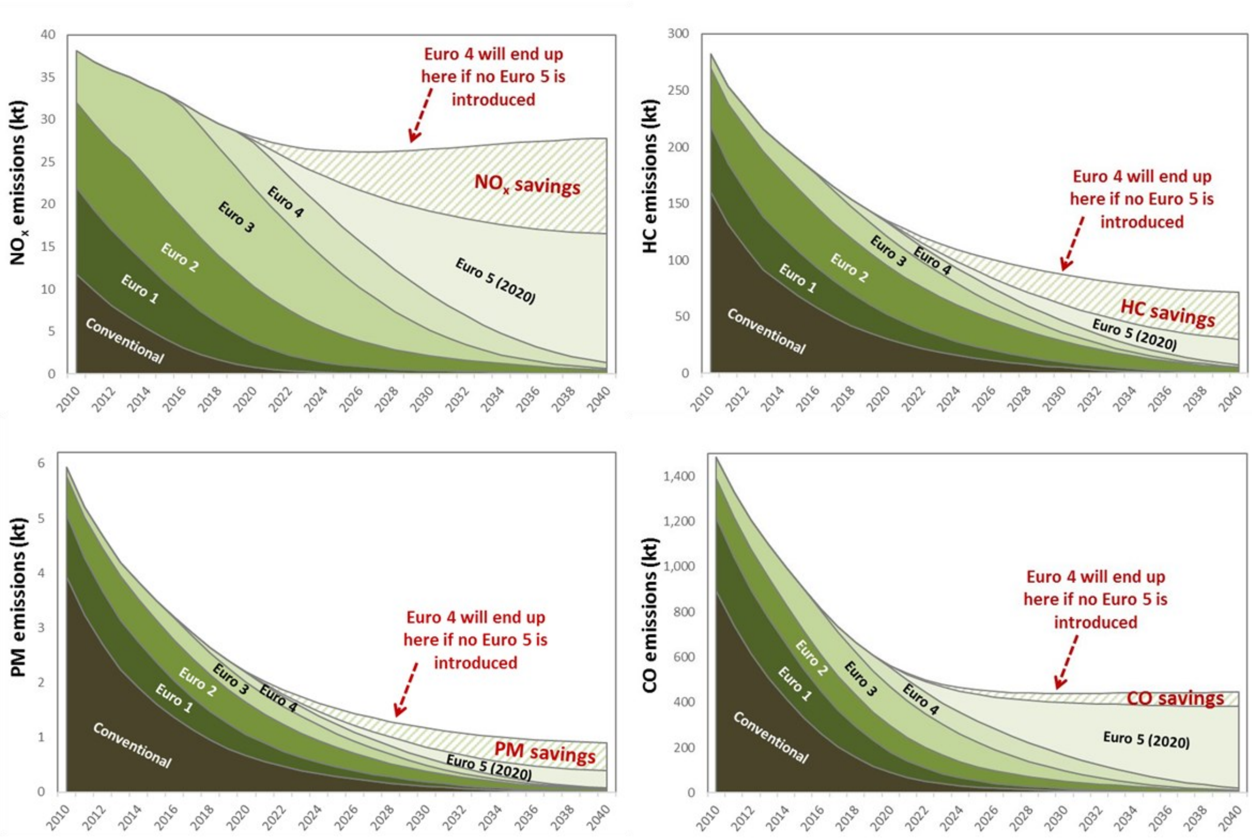

Figure 2: Evolution of total emissions from LVs conducted in the framework of the Euro 5 environmental effect study for DG GROW carried out by EMISIA, TNO and LAT

2.2.2 Anti-tampering measures

***Measures*:**
Many different measures can be envisaged to combat the spread of LV tampering. These include measures focused on strengthening roadside inspections (making them more effective (test method), increasing their number, increasing fines, etc.). It may involve making these modifications more difficult to carry out (prohibit non-certified and easily modified parts (e.g. dB-killers), prohibit sale of sound increasing parts, including tuning sets, delimiters, valves/flaps, ECU tuning systems, prohibit use of sound increasing parts, etc.).

Consideration in the LENS assessment methodology (models and scenarios):
The aim of these mitigation measures is to reduce the percentage of vehicles affected by tampering. The effect of modifications on emissions and noise at the scale of a tampered vehicle will therefore remain the same with these mitigation measures. Only the proportion of tampered vehicles is expected to decrease. Different scenarios will be considered, taking into account decreasing proportions of the fleet affected, from that observed today to the complete elimination of the phenomenon.

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2.2.3 Local regulations and rider behaviour

Measures:

Several local regulations can be considered to reduce on designated areas the contribution of LVs on emissions and noises, as examples:

- Implementation of road closure or restricted entry for LVs in designated areas.
- Establishment of specific speed limits in sensitive areas to ensure the safety of pedestrians, cyclists, and residents, as well as to mitigate environmental impacts.
- Low Emission Zones, Quiet Zones, and Protected Quiet Areas: Designation of zones where emissions and noise pollution are restricted or minimized, promoting cleaner air quality and peaceful environments for communities.
- Integration of innovative road design and infrastructure measures to enhance traffic management, improve accessibility, and prioritise sustainable transportation options.
- Enforcement of maximum sound limits at building facades or along roadways to mitigate noise pollution and protect the well-being of residents in urban areas.
- Automatic Enforcement: Deployment of automated enforcement technologies such as noise cameras to monitor and enforce compliance with noise regulations, ensuring accountability and consistency in noise control efforts.

These measures aim to impact both the local fleet composition and the riders behaviour. Additional measures can be deployed to additionally influence these behaviours:

- Implementation of strict penalties, including fines, mandatory re-certification programs, vehicle impounding, or license withdrawal, to deter and correct hazardous driving behaviour, ensuring compliance with traffic regulations and enhancing road safety.
- Enforcement of vehicle condition standards by law enforcement authorities through methods such as police inspections, roller rig tests, or stationary measurements, aiming to identify and rectify vehicle defects.
- Utilisation of informational and warning signs strategically placed along roadways to influence driving behaviour, raise awareness of potential hazards, and encourage adherence to traffic rules, promoting responsible and safe driving practices.
- Increase of fines: Adjustment and escalation of fines for traffic violations to serve as a deterrent and reinforce the importance of compliance with traffic laws, thereby discouraging reckless driving behaviours.

Consideration in the LENS assessment methodology (models and scenarios):

The impact of these mitigation measures will be considered by:

- Taking into account different compositions of the local fleet: the impact on the areas concerned will be assessed at the pilot sites (3 cities in Europe), by building modified hypothetical fleets: unchanged local fleet, local fleet excluding part of the LVs, local fleet excluding the LVs.

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- Taking into account changes on the behaviours (due to both local regulation or rider involvement): local speed profiles at pilot sites will be reconstructed, taking into account changes in signalling (speed limit, traffic lights, roundabouts) and behaviour (eco-driving, acceleration profile from a standstill, etc.). The methodology for these microscopic assessments is described in chapter 3.

2.3 Synthesis of selected mitigation measures and considered scenarios

The scenarios selected to cover current and future situations based on different intervention measures will be as follows:

- baseline scenario, current situation
- baseline scenario, expected future situation: No change in regulations or local measures, no change in user behaviour, "natural" renewal of the fleet with newer vehicles, including electric ones.
- expected future situation, intervention measures: several scenarios will be considered to assess the contribution of mitigation solutions:
    - Strict standards scenario (technological efficiency oriented)
    - Scenario focused on anti-tampering measures (standards and usage remaining the same)
    - Scenario focused on local measures: access restrictions, surveillance, road improvements
    - Scenarios focusing on behavioural changes (usage-oriented, standards and fleet remaining the same)
    - Combined scenario: scenario combining all mitigation measures envisaged.

Table 2: Synthesis of considered scenarios for emissions and noise assessment in current and future situation, at local and global scale

<table>
<tr><th colspan="2" rowspan="3">Scenarios</th><th colspan="4">Interventions measures</th></tr>
<tr><th colspan="3">Regulation</th><th rowspan="2">Rider behaviour</th></tr>
<tr><th>Type approval</th><th>Anti-tampering</th><th>Local regulation</th></tr>
<tr><td rowspan="2">Baseline scenarios</td><td>S1. Current situation</td><td></td><td></td><td></td><td></td></tr>
<tr><td>S2. Expected future situation</td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="5">Intervention scenarios</td><td>S3. Strict standards scenario</td><td>X</td><td></td><td></td><td></td></tr>
<tr><td>S4. Scenario focused on anti-tampering measures</td><td></td><td>X</td><td></td><td></td></tr>
<tr><td>S5. Scenario focused on local measures</td><td></td><td></td><td>X</td><td></td></tr>
<tr><td>S6. Scenarios focused on behavioural changes</td><td></td><td></td><td></td><td>X</td></tr>
<tr><td>CS. Combined scenario</td><td>X</td><td>X</td><td>X</td><td>X</td></tr>
</table>

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3 LENS modelling approaches

This chapter synthesis the modelling approaches proposed for LENS project to assess the contribution of LVs to emissions and noise at different scales, focuses on the description of the tools, and how the selected case studies (domains, scenario, mitigation measure) described previously are considered.

3.1 Vehicle emission and noise models

A detailed level of modelling is necessary to account for the real behaviour of technologies in all life situations, and require considering the particular situations of use of a specific vehicle at a high time frequency. This is the case whether the final aim is to evaluate impacts on this same microscopic scale, or for very macroscopic inventories of impacts (with an additional stage of evaluation/aggregation on statistically representative situations). The models used in the LENS project, for both pollutant emissions and noise, are described below.

3.1.1 Pollutant emission models

The pollutant emission model PHEM [4]

For microscopic exhaust emission simulation, all emission test data measured within the project together with data gained by a parallel data collection campaign will be used to parametrise the vehicle emission model PHEM (Passenger car and Heavy duty[1] Emission model).

PHEM is an instantaneous emission model based on equations of vehicle longitudinal dynamics and engine emission maps, which has been developed by TUG since the late 1990's. It calculates the fuel consumption and emissions of road vehicles in 1Hz for any given driving cycle based on the vehicle longitudinal dynamics and emission maps (Figure 3). The engine power demand is calculated in 1Hz from the driving resistances and losses in the transmission line. The engine speed is simulated by the tire diameter, final drive, and transmission ratio as well as a driver gear shift model. Base exhaust emissions and fuel flow are then interpolated from engine maps. Depending on the vehicle emission control technology and on the available data for model parametrisation different options for emission simulation exist:

a) Using vehicle tailpipe emission maps (tailpipe emissions depending on engine speed and power)
b) As a) but with correction functions for transient effects and catalyst space velocities and temperatures
c) Using raw exhaust engine emission maps and catalyst models for conversion efficiencies as function of catalyst space velocities and temperatures.

The temperatures of catalytic converters are simulated by a 0-dimensional heat balance and from the heat transfer between exhaust gas and the catalysts material and from the exhaust line to the ambient.

[1] After Extension to LVs, we may have to use a different name.

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Beside the detailed simulation of the aftertreatment system, PHEM offers also a simplified cold start routine, which calculates the cold start extra emissions as function of the cumulative energy loss flows and average positive engine power after start [5].

Since the vehicle longitudinal dynamics model calculates the engine power output and speed from physical interrelationships, any imaginable driving condition can be illustrated by this approach. The simulation of different air resistances and payloads of vehicles in combination with road longitudinal gradients and variable speeds and accelerations can thus be illustrated by the model just like the effects of different gear shifting behaviour of drivers.

In LENS we will test the options a) and b) for the simulation of exhaust emissions of LVs, in case that also engine out emission data is available, option c) shall also be investigated.

For a user-friendly simulation, we will produce a set of “average vehicles” representing average vehicles for different LV categories. The user then simply defines the shares of these vehicle categories in the vehicle fleet.

All test data generated by LENS project experimentation is collected in a database, named LENS DB, which allows structured queries providing already the data formats needed by PHEM. PHEM has automated routines to produce the tailpipe emission maps and cold start functions from the test data per vehicle. This routine is also used to produce the vehicle emission factors for HBEFA (Handbook on Emission factors, www.hbefa.net), where hundreds of measured vehicles are used to produce the average emission maps per vehicle segment in the regular updates, [6].

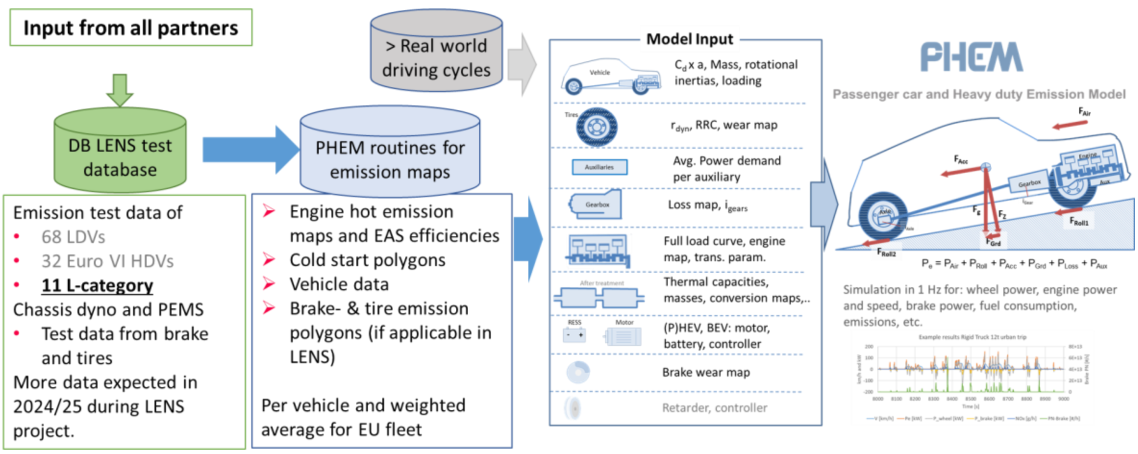

Figure 3: Schematic picture of the data and workflow to produce emission factors for LVs

Once the simulation method is selected, the model will be applied to produce the necessary emission maps and vehicle data (masses, rolling- and air resistance coefficients, inertias, transmission ratios etc.). The data for the single vehicles shall be combined to weighted averages for different LVs classes. The data set then will be used for:

- Producing emission factors with PHEM for a set of representative driving cycles (Figure 4) for different road gradients and driving styles.

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- Producing a set of cold start extra emission factors for typical start conditions.
- Any other analysis for specific sets of traffic situations if needed (the model can also be used e.g., for local microscale modelling by partners if needed).

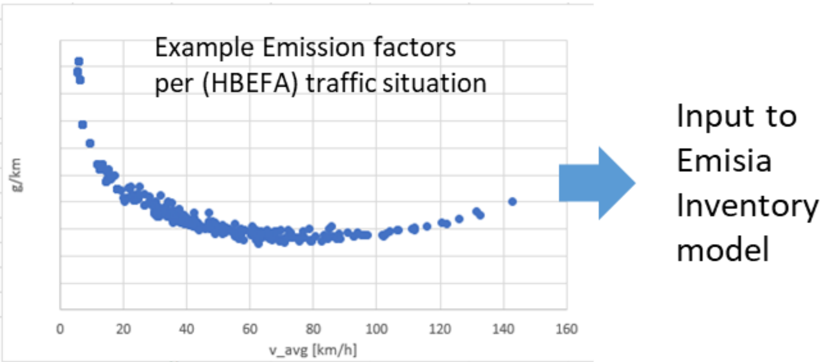

Figure 4: Schematic picture of emission factors plotted over average cycle velocity

The pollutant emission model MobSim

Over the last 10 years, IFPEN has also developed vehicle-layer microscopic models of pollutant emissions. Approaches, inputs, and outputs are very similar to those of PHEM described above and are not detailed here. These specific developments were necessitated by the alternative uses made of these models, which feed a free mobility smartphone application - Geco air [7] - and simulation studies on extended real-use databases (several million kilometres) [8]. This tool, developed in the form of a Python package, also includes, as a complement to this modelling component, libraries linked to the analysis of real usage data collected on a large scale: mapmatching, characterisation and classification of conditions, positioning of conditions in relation to regulatory conditions and in particular RDE boundaries, etc.

As the perimeters are close, the results of these two pollutant emission models will be compared and possible synergies sought. Both PHEM and MobSim models will be tested for accuracy for modern L-category vehicle emission simulation and joint efforts are planned to improve the simulation methods where necessary (some subroutines for L-category engine and aftertreatment behaviour may have to be developed).

3.1.2 Noise emission model

The ROTRANOMO [9] model was developed within the research project "Development of a Microscopic Road Traffic Noise Model for the Assessment of Noise Reduction Measures", Acronym ROTRANOMO, funded by the European Community under the 'Competitive and Sustainable Growth' Programme (1998-2002). This model is based on actual driving condition in terms of vehicle speed pattern for single vehicles with a high time resolution of 1 Hz or even higher. The high time resolution is necessary to consider the fluctuations in driving conditions and their effects on noise emission adequate. Propulsion noise and rolling noise are modelled separately for the following reasons:

- The propulsion noise level is basically determined by the acoustical performance of the vehicle. The acoustical performance depends on the noise limits that had to be fulfilled when the vehicle type

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was homologated. Engine speed and load determine the actual propulsion noise level of a vehicle in the fleet. These parameters are derived from the vehicle speed pattern by an accompanying drivetrain model. The propulsion noise emission is then calculated as function of normalised engine speed and engine load. The engine load is calculated using in-built algorithms for driving resistance, gear ratios, full load power curves, etc. (For further details see deliverable D4.2, Intermediate report on the powertrain model of the ROTRANOMO project).

- The tyre/road noise emission is calculated as a function of vehicle speed, road surface and tyre specific parameters. The noise emission model uses a detailed vehicle category classification with subcategories within the car, truck, bus, and motorcycle categories. In order to derive coefficients for the above-mentioned approximation functions for propulsion noise and tyre/road noise for each subcategory calibration measurements were carried out on a series of vehicles and tyres. The results of these measurements were then implemented into the vehicle noise emission model.

The noise emission calculation model, which calculates the noise emission for each second and each vehicle in terms of rolling noise, propulsion noise and total noise levels, consists of two parts. The first calculation step is the determination of normalised engine speed and load (this calculation may require several loops depending on the outcome of the plausibility check). The second step is the calculation of noise levels for each dataset.

The result is a copy of the input data file supplemented by vehicle acceleration, normalised engine speed and load and the noise levels. The noise levels estimated represent the noise at a location at 7.5 m distance from the drive path in the middle of the vehicle at a height of 1.2 meter above the road. This data can be used as basis for macroscopic models like TRANECAM or any user specific analyses of source contributions or parameter influences like road surface.

Vehicle category/subcategory classification of ROTRANOMO

Concerning the vehicle category classification, the ROTRANOMO model uses the same approach as the PHEM model. The main categories are passenger cars, light duty vehicles, heavy duty vehicles, buses, and motorcycles. Within these categories there are further differentiations with respect to engine capacity or vehicle mass and emission stage.

The current, recently updated version of the ROTRANOMO model contains numerous subcategories, only those specific to LVs are specified here in the Table 3. Motorcycle classes were integrated into the model based on an extended analysis of TUEV Nord’s measurement results; it was concluded that two engine capacity classes would be sufficient, up to 150 cm^3 and above 150 cm^3. The first class covers mainly scooters. For each capacity class, an additional class was foreseen for vehicles fitted with replacement/illegal silencers, because the noise emission of these vehicles is significantly higher than for original motorcycles. It is intended to implement L1 category vehicles (mopeds) within this year.

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Table 3: LVs categorisation of the ROTRANOMO model

40001	motorcycle <= 150 cm³	stage 0, up to Euro 3
40011	motorcycle <= 150 cm³, manip.	stage 0, up to Euro 3
50001	motorcycle <= 150 cm³	stage 1, Euro 4, 2016 to 2025
50011	motorcycle <= 150 cm³, manip.	stage 1, Euro 4, 2016 to 2025
60001	motorcycle <= 150 cm³	stage 2, Euro 5, from 2026 on
60011	motorcycle <= 150 cm³, manip.	stage 2, Euro 5, from 2026 on
40002	motorcycle > 150 cm³	stage 0, up to Euro 3
40012	motorcycle > 150 cm³, manip.	stage 0, up to Euro 3
50002	motorcycle > 150 cm³	stage 1, Euro 4, 2016 to 2025
50012	motorcycle > 150 cm³, manip.	stage 1, Euro 4, 2016 to 2025
60002	motorcycle > 150 cm³	stage 2, Euro 5, from 2026 on
60012	motorcycle > 150 cm³, manip.	stage 2, Euro 5, from 2026 on

Modelling of propulsion noise emission

Based on the experience of previous research projects, the vehicle related noise sources (engine, powertrain, exhaust, intake) are summarised and modelled as function of engine speed and engine load. A further split into diverse sources is possible in principle but at present there is no data available for the modeling.

The propulsion noise is described by two normalised engine speed dependent functions, one for no or negative engine load and one for full engine load. The partial load condition is covered by a linear interpolation between both curves. In order to cover the whole range of vehicles from motorcycles to heavy duty trucks it is necessary to use normalised values for the engine speed, given by:

$$n_{norm} = \frac{n - n_{idle}}{s - n_{idle}}$$

where n is the actual engine speed, n_{idle} is the idling speed and s is the rated speed.

Both the low engine load function and the full engine load function can be modelled as polynomial functions of n^{th} degree. For example:

$$L_{noload} = a_0 + a_1 * n_{norm} + a_2 * n_{norm}^2 + (\ldots) + a_i * n_{norm}^i + (\ldots) + a_n * n_{norm}^n$$

describes the propulsion noise curve at no load condition, where a_0 to a_n represent the coefficients of the polynomial function.

The load influence is modelled as an additive to the low load value and calculated using the equations:

$$DL_p = \left(L_{wot}(n_{norm}) - L_{noload}(n_{norm})\right) \times \left(P_{norm}\right) \quad \text{if } P_{norm} \geq 0$$
$$DL_p = 0 \quad \text{if } P_{norm} < 0$$

where DL_p is the increase in noise emission due to the engine load P_{norm}, L_{wot} is the propulsion noise level at full load and L_{noload} the propulsion noise level at no load condition.

The polynomial functions for each subcategory were derived by an analysis of the results of the vehicle noise emission calibration measurements (see ROTRANOMO deliverable D43).

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Modelling of tyre/road noise

The tyre/road, or rolling, noise component L_{roll} is modelled in the ROTRANOMO model as a function of the tyre, the road surface, and the vehicle speed:

$$L_{roll} = L_{r50}(SMA0/11) + B \times \log(v/50\ \text{km/h}) + DL_{surface}$$

where L_{r50} (SMA 0/11) is the rolling noise at 50 km/h on stone mastic asphalt with a maximum chipping size of 11 mm, B is the slope of the regression curve, v is the vehicle speed and $DL_{surface}$ is the surface specific correction coefficient. This coefficient provides the additional noise attributed to a particular surface when compared with SMA (0/11).

Average values within a vehicle subcategory are used as tyre specific coefficients.

On the basis of the results of the tyre/road noise emission calibration measurements (see ROTRANOMO deliverable D 43) logarithmic functions of the following form

$$L_{roll} = A + B \times \log\left(\frac{v}{km/h}\right)$$

The results of the ROTRANOMO model calculations are time pattern of engine speed and load, propulsion noise, tyre/road noise and total noise levels added to the vehicle speed pattern, normally on a second-by-second basis. Noise measurements currently being carried out in the WP3 and WP4 of the LENS project will enable the ROTRONOMO model to be updated.

The increase of the noise emission for vehicles with replacement/illegal silencers compared to original vehicles is modelled as synthesised in Table 4. These values are historically, and it is intended to revise them with findings in WP 3/4 in the next coming work.

Table 4: Increase of noise emissions due to replacement/illegal silencers compared to original vehicle as modelled in ROTRONOMO

	No load		Full load	
	Idling speed	Rated speed	Idling speed	Rated speed
Up to 150cc	+ 4 dB(A)	+ 1 dB(A)	+ 6 dB(A)	+ 2 dB(A)
Above 150cc	+ 6 dB(A)	+ 2 dB(A)	+ 10 dB(A)	+ 5 dB(A)

3.2 Assessment at global level (state level)

3.2.1 Modelling approach and tools

Pollutant approach

COPERT [10]

COPERT serves as the EU standard vehicle emissions calculator, utilizing vehicle population, mileage, speed, and environmental factors to compute emissions and energy consumption for specific regions or countries. It has been developed for official road transport emission inventory preparation in EEA member countries. However, it is applicable to all relevant research, scientific and academic applications. Its methodology is

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transparent and technologically advanced, aligning with the standards set by the UNECE LRTAP Convention and covering a comprehensive range of pollutants, including greenhouse gases, air pollutants, and toxic species.

COPERT includes emission factors tailored for a diverse range of vehicle types, totalling over 450 individual classifications, including Passenger cars, Light commercial vehicles, Heavy-duty vehicles (such as trucks and buses), L-category vehicles (mopeds, motorcycles, quads, and mini-cars). It considers emissions during thermal stabilised engine operation, commonly referred to as 'hot' emissions, as well as emissions generated during the warming-up phase, known as 'cold start' emissions. Additionally, COPERT accounts for non-exhaust emissions originating from fuel evaporation, tyre wear, and brake wear emissions, providing a holistic approach to estimating vehicle emissions.

COPERT key characteristics are synthesize here:

- Internationally recognised: it is used by the large majority of European countries for reporting official emissions data.
- Reliable and widely recognized emission factors.
- The emission factors are developed within the collaboration and supervision of the members of the European Research for Mobile Emission Sources (ERMES) group.
- Speed dependent emission factors.
- Calculates emissions at a national, regional, or local scale, and for annual to daily estimates.
- Technologically advanced and transparent: its methodology is published and peer-reviewed by experts of the UNECE LRTAP Convention.
- Used in the framework of many research projects worldwide.
- Includes all main pollutants: greenhouse gases, air pollutants and toxic species.

The breakdown of COPERT for L-category vehicles is presented in detail within the following Table 5. For each of the categories listed, corresponding Euro standard technologies are also provided (Conventional, Euro 1, Euro 2, …, Euro 5).

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Table 5: L-category vehicles in COPERT

Fuel	Segment
Petrol	Mopeds 2-stroke <50 cm^3
Petrol	Mopeds 4-stroke <50 cm^3
Petrol	Motorcycles 2-stroke >50 cm^3
Petrol	Motorcycles 4-stroke <250 cm^3
Petrol	Motorcycles 4-stroke 250 - 750 cm^3
Petrol	Motorcycles 4-stroke >750 cm^3
Petrol	Quad & ATVs
Diesel	Micro-car

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The measurements conducted within the LENS project, including on-road RDE tests and laboratory-based testing, will compile a comprehensive dataset for emissions and noise. This dataset will be utilized as input for the PHEM model, which will derive emission factors for L-category vehicles, in accordance with the methodology described earlier in section 3.1.1. Subsequently, these emission and noise factors will be integrated into COPERT. This updated version of COPERT, enriched with insights from the LENS project, will become the primary tool for estimating emissions from LVs at global / state levels. It will be utilized for calculating emission and noise for baseline as well as for any scenarios developed within the framework of WT6.3, which will assess the impacts of the various interventions.

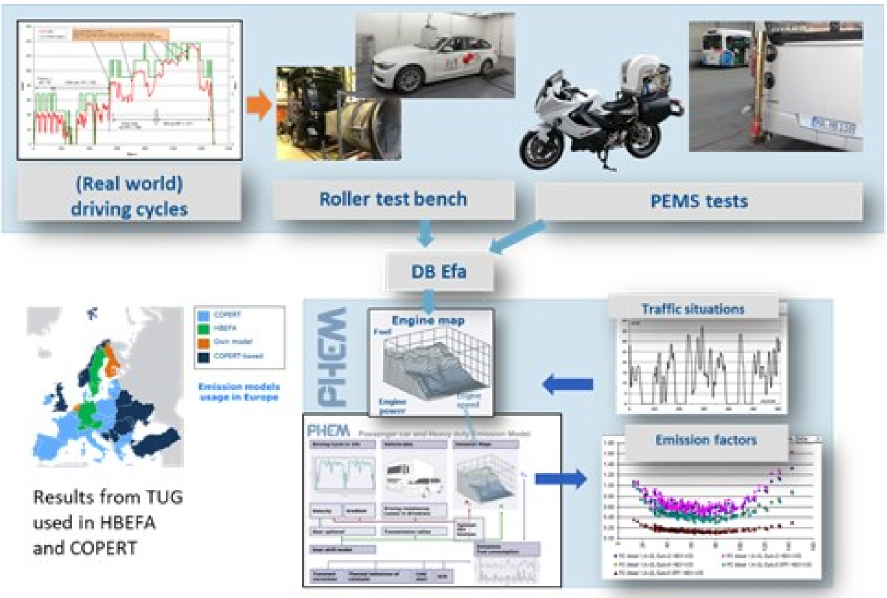

Figure 4: Synthesis of workflow to produce emission factors for COPERT & HBEFA

SIBYL [11]

SIBYL is a modeling tool designed to forecast the effects of evolving vehicle technology on future fleets, energy usage, emissions / noise, and costs. Its primary purpose is to aid policymakers, vehicle manufacturers, and consultants in conducting policy impact assessments, enabling them to estimate the potential effects of different policy options on emissions from road transport.

Utilising fleet dynamics, expected market trends, and projected growth scenarios, SIBYL can project emissions, fleet composition, activity levels, energy consumption, and associated costs up to the year 2050.

SIBYL projections are calibrated against higher-tier energy and/or activity projections and hence can be used to further understand potential problems or inconsistencies observed for individual countries. The following figure illustrates the scenario building process within SIBYL. It includes a range of options for the development of user-defined scenarios with a variety of conventional and more advanced vehicle types.

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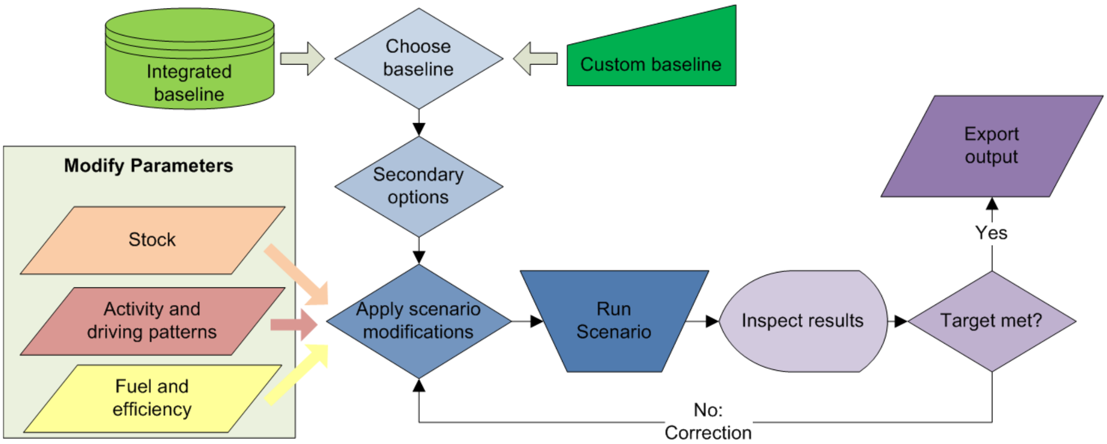

Figure 5: Scenario building and testing in SIBYL.

SIBYL's outputs are imported to COPERT and to cost assessment models, in order to calculate the total emissions and benefits as well as the associated new technology implementation costs, towards the cost-benefit calculation.

Furthermore, SIBYL includes integrated, reliable, and up-to-date baseline data on vehicle fleets and road transport activity for all Member States and the EU as a whole. This data reflects current national situations and leverages recent statistical information to provide insights into real-world conditions. In total, the software encompasses data from 34 European countries, including the EU27 Member States, the UK, Iceland, Norway, Switzerland, Liechtenstein, the Republic of North Macedonia, and Turkey. Additionally, a single EU27 data file is available for emission modeling at the European level. This file has been compiled by consolidating the populations of all EU27 countries and calculating the weighted average of their mileage, average speeds, and other relevant parameters, such as monthly temperatures. Therefore, this consolidated file is expected to provide a very good approximation of aggregated emissions in Europe as a whole.

The assessment of LVs' impact for both the baseline and the scenarios with the interventions to be developed, will be significantly facilitated by these data.

Noise approach

The TRANECAM model [12]

The TRANECAM model was originally developed for the German Federal Environment agency and was updated with funding of the EU-commission and the Norwegian Pollution Control Authority. The model calculates the L_{eq} for each hour of the day separately for a workday, a Saturday, and a Sunday. Within a road category the traffic situation varies in relation to the actual hourly traffic volume. The traffic volume is separated into distinct categories and subcategories and within these subcategories into different emission stages (related to different type approval limit values). The contributions of the different emission stages to the L_{eq} are summarised for each hour of the day and afterwards summarised to L_{day}, $L_{evening}$, L_{night} and L_{den}. The calculation is carried out separately for propulsion noise, rolling noise and total noise. The model is intricately linked to the structure of the HBEFA 42. For the calculation of the necessary noise emission factors the ROTRANOMO model was used with the same driving cycles per traffic situation as used for HBEFA 42.

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Figure 6 shows a flowchart of the noise emission calculation. The model contains the following databases:

- emission factors (L_{eq} levels) for each vehicle layer and each road/traffic situation category. A vehicle layer is defined by the vehicle category, its subcategory, and the emission stage; the emission stage is defined by the actual noise limitation legislation at the time when the vehicle was type approved.
- weighting factors that specify the share of each layer on the vehicle category. These weighting factors can be defined separately for urban, rural and motorway roads.
- diurnal traffic load distribution curves and weekend factors for each vehicle category. The weekend factors specify the difference in traffic load between a workday the Saturday and the Sunday. Special factors for holiday seasons are not foreseen.

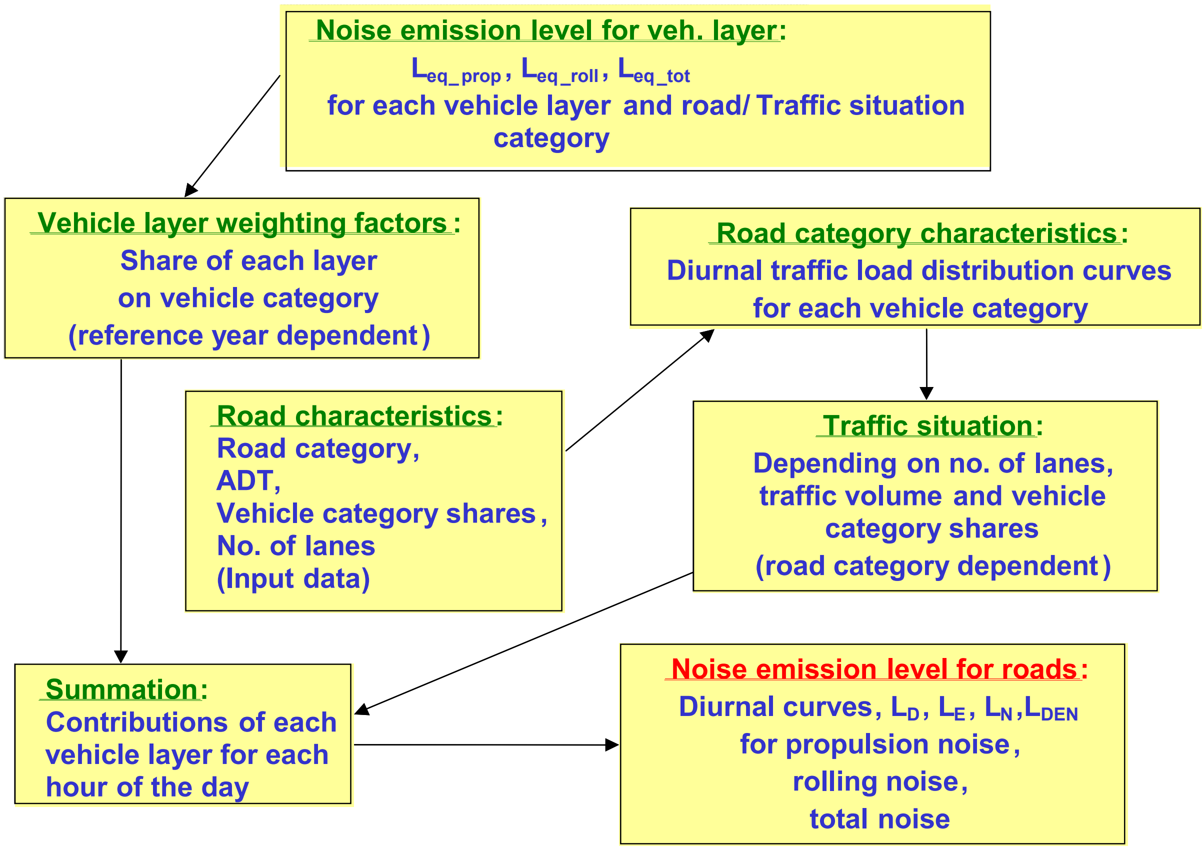

Figure 6: Flowchart of the noise emission calculation with the TRANECAM model

The noise emission levels for vehicle layers build the basis of the TRANECAM model. They were calculated with the ROTRANOMO model using the same vehicle speed cycles as the exhaust emission model PHEM has used for the calculation of the emission factors for the Handbook HBEFA 42.

The following input data is needed to run the TRANECAM calculations:

- Road category,
- Function of road within the network,

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- Direction type,
- Average daily traffic (ADT, alternatively as workday or annual average),
- Number of lanes,
- Vehicle category shares,
- Road surface type.

The vehicle subcategorisation and the road surface categorisation are the same as shown in the description of the ROTRANOMO model.

CNOSSOS [13] noise emission factor update

The noise measurement results and the Rotranomo updated models will be used to update the LV part of the CNOSSOS-EU noise calculation method, the common methodological framework under the Environmental Noise Directive (2002/49/EC). More realistic noise source levels for LVs taking into account tampering, operating conditions, driving behaviour and traffic flow will thus help improve CNOSSOS-EU.

Scenario global modelling of L-vehicle noise, impact analysis and single event analysis

In a study on feasibility of sound limits for L-vehicles [2], a cost-benefit analysis was performed on the effects of changing sound limits for type testing for the pass-by test. The method can also be applied for other mitigation measures than changes to sound limits. It was formulated specifically to estimate effects of mitigation options at EU level, i.e. all relevant roads and vehicles in the EU. This type of modelling is at global level for the purpose of impact analysis over long term timescales, taking gradual fleet, traffic, and infrastructure changes into account. Also a cost-benefit analysis was performed for different scenarios based on the cost of mitigation versus the monetized benefits. In the context of LENS, the CBA will only be applied to mitigation options at global level, and in the cases there is a substantial positive environmental impact.

Mitigation effect by L_{den} analysis

In the above mentioned report, the approach to assess the effect of input parameters on the Lden level is described, illustrated in the flow chart in below. It follows the principles of environmental noise models such as CNOSSOS or other national models which estimate the sound exposure level L_{den} at the dwelling façade. It takes into account the road situation, traffic flow, average vehicle sound emissions as a function of speed, sound propagation, and dwelling situation. For the purposes of the study, also specific sound emissions of L-vehicle categories, their driving condition (constant speed or intermittent) and the presence of tampering were taken into account. An average L_{den} was then estimated for each road type and characteristic situation. The effects of changes in sound emission of the vehicles, either by sound limits and/or by reduced tampering, could then be assessed in terms of changes in L_{den} levels at the dwelling facade. In turn, for a given total road length in the EU, dwelling density per road type and distance to the road, an estimate was made of the amenity and health benefits of reduced noise exposure. These are generally analysed over a specified appraisal period, which was 2020-2040 in the 2017 study. Costs and benefits are calculated per annum, including interest rates and discounting over the whole period.

The effects of changed sound limits of L-vehicles on overall L_{den} levels over time are low, due to the long-term averaging together with other traffic, but somewhat higher for Southern European countries which

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have larger fleet numbers of L-vehicles. Therefore, a distinction between northern and southern EU fleets was made.

This approach allows to assess the effects of average speed, traffic flow, vehicle source levels including tampering, all at a global level, i.e. using averages for each parameter. For L-vehicles, it is limited to vehicle categories only for mopeds and for motorcycles, besides cars, medium and heavy-duty vehicles.

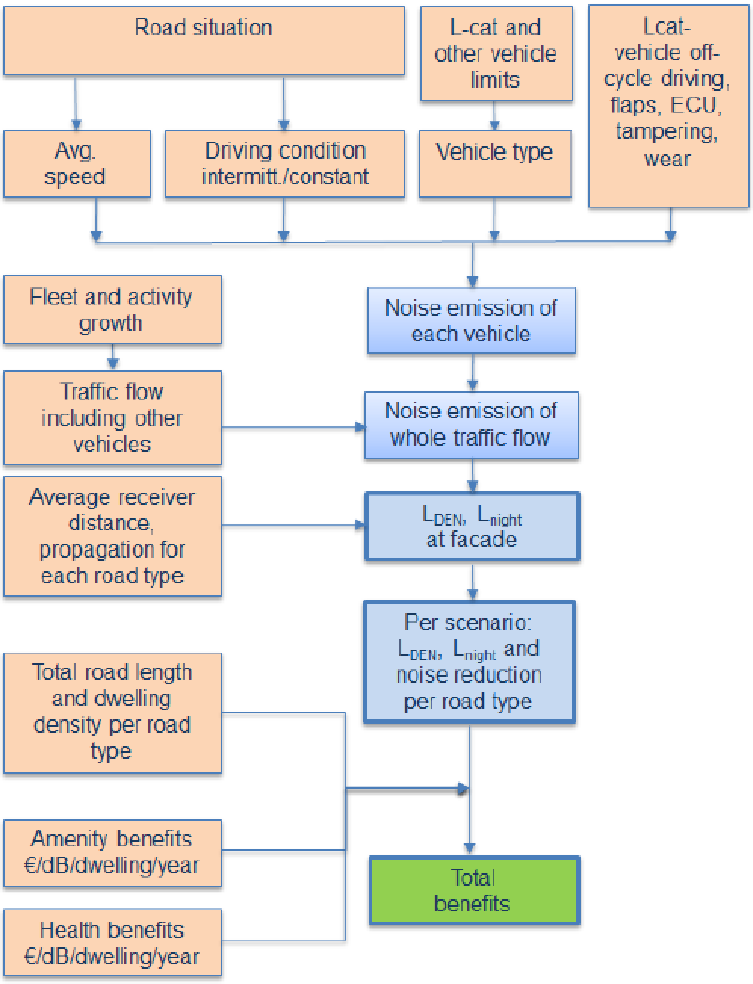

Figure 7: Schematic diagram for traffic noise calculation model and monetized benefits of noise reduction of L-vehicles, from [2].

In the Phenomena study [14] and a EU-study on sound limits for M and N category vehicles [15], a similar methodology was applied, but impact of mitigation scenarios was also determined in terms of numbers of seriously annoyed people, sleep disturbed people and in DALYs, which are all health related factors that can be determined from the L_{den} level with dose-effect relationships for road traffic noise, which are specified in the European END regulation. Exposure distributions (histograms) of L_{den} noise levels were calculated for specific reference situations (road, traffic and building density types) and compared for different mitigation scenarios, as shown in
Figure 8.

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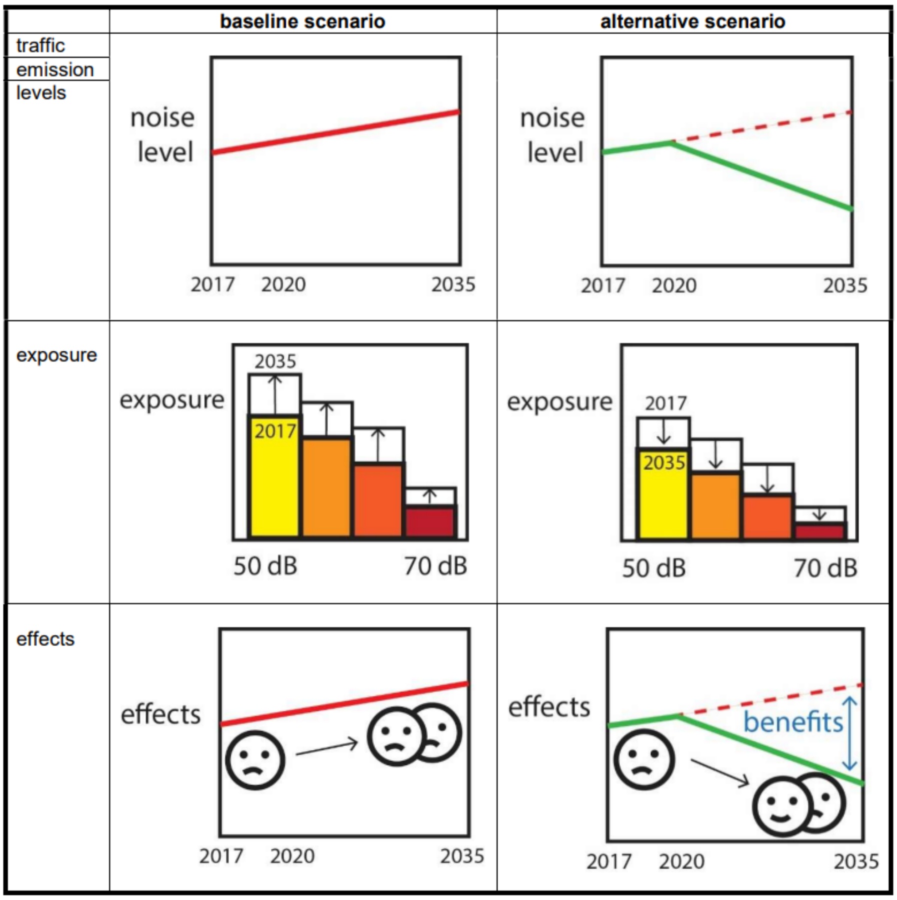

Figure 8: Methodology for calculating health effects for a baseline scenario and an alternative scenario. The difference between the two is equal to the health benefits. (Source: Phenomena Study).

The dose effect relationships for traffic noise are not a good indicator specifically for noise from LVs, as indicated in an Austrian study [1], therefore these should be applied in LENS if possible.

Mitigation effect based on single events

As an alternative to the above, another approach using L_{den} levels, an indicative approach was proposed and applied in the L-cat sound limit study based on single events, which are known to be the source of complaints, given that the actual maximum sound pressure levels can be much higher than the L_{den} levels. It derives an average maximum sound pressure level $L_{pAFmax,avg}$ over all L-vehicle pass-bys at all locations with high engine noise. As this is a non-standard approach it is summarised below. It takes into account the following factors.

Average single event level and reduction

Average $L_{pAFmax,avg}$ for L-vehicles, based on type approval level L_{TA}, adjusted for tampering, engine speed, acceleration (loading) and off-cycle driving condition; this requires a level difference ΔLi and percentage pi of vehicles (fleet fraction) for each of these factors:

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$$L_{\text{AFmax,avg}} = L_{TA} + \sum (p_i \times \Delta L_i)$$

The difference in the average single event level due to mitigation is then

$$\Delta L_{\text{AFmax,avg}} = \sum (p_i \times \Delta L_i)$$

Examples of level adjustments ΔLi and fleet portions pi and the resulting reductions in average single event levels are shown in Table 6 for scenarios with reduced type approval sound limits.

Vehicle mileage with single events

Number of kilometres per vehicle per year during which single events occur: $N_{km,veh,y}$,
based on annual vehicle mileage d_y, activity rate per road type p_a and portion of road affected f_{road}:

$$N_{km,veh,y} = d_y \times p_a \times f_{road}$$

Only residential roads, main roads, and rural roads, at parts with intermittent traffic (one third) were included in the analysis, as most of the noise impact is present there.

Total number of single events

The total number of single events per year $N_{tot,y}$ for all households is obtained from $N_{km,veh,y}$, active fleet size N_{veh}, the number of households per km $N_{hh,km}$ and the portion of each km affected, f_{km}:

$$N_{tot,y} = N_{km,veh,y} \times N_{veh} \times N_{hh,km} \times f_{km}$$

Impact and monetised benefits

The monetized impact of noise mitigation V_{tot} is calculated based on the average single event noise reduction and the total number of single events per year and a monetized valuation per single event V_{se}:

$$V_{tot} = \Delta L_{\text{AFmax,avg}} \times \text{N}_{\text{tot,y}} \times \text{V}_{se}$$

An indicative value for V_{se} was proposed of 0,001 Euro/dB/household/year per event, covering both health and amenity benefits. This value can be compared with valuation of reductions in L_{den} levels, being effectively much lower by comparison. The remaining cost-benefit analysis is done in analogy with the L_{den} approach outlined above.

This methodology can be modified if required to fit the scope of the LENS project. For example, the reduction in the average single event level could be used as an impact indicator instead of taking all the road lengths and types into account. Further refinement would also be possible in terms of driving conditions, or even using specific dose-effect relationships to take absolute sound levels into account, and to derive numbers of seriously annoyed and sleep disturbed people.

Since the L-cat sound limits study, further developments have taken place, such as:

- more available roadside monitoring data of L-vehicles.
- studies on impact of noise from L-vehicles.
- identification of loud driving conditions (LENS D6.1).
- insight into tampering effects (LENS D5.1).
- new valuation figures for environmental noise impact on health.

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These could potentially be included in future analysis, if they are deemed to have a significant effect.

Table 6: Examples of several scenarios for modified sound limits for motorcycles, with and without illegal exhausts and off cycle sound emission (from [2]). Level excess above the type approval level for Lurban, weighted average level excess and average single event reduction, with affected fleet portions (left column). Percentage 'IL' refers to vehicles with illegal exhausts (tampered or off-cycle), speeding/rpm indicates higher than the permitted road speed and/or higher than normal engine speed.

Scenario	Fleet portion	Level excess	Average level excess	Average single event reduction
Reference situation (2020), 25% IL		dB	dB	dB
25%	illegal exh or off cycle	15	9,5	
10%	speeding/high rpm	10		
10%	both	20		
55%	normal	5		
L-cat limits -2 dB, 25% IL				
25%	illegal exh or off cycle	15	8,4	1,1
10%	speeding/high rpm	10		
10%	both	20		
55%	normal	3		
L-cat limits -5 dB, 25% IL				
25%	illegal exh or off cycle	15	6,75	2,75
10%	speeding/high rpm	10		
10%	both	20		
55%	normal	0		
L-cat limits -2 dB, 0% IL				
25%	illegal exh or off cycle	0	3,65	5,85
10%	speeding/high rpm	10		
10%	both	10		
55%	normal	3		
L-cat limits -5 dB, 0% IL				
25%	illegal exh or off cycle	0	2	7,5
10%	speeding/high rpm	10		
10%	both	10		
55%	normal	0		

Mitigation options and appraisal period

As mentioned above, the appraisal period is required to assess the impact of mitigation options, as most of these take effect over time, for example:

- New sound limits for vehicles only affect the new fleet and gradually over time as the old fleet is replaced; the same is the case for other changes to vehicle sound regulations.
- Measures to reduce tampering may also take years to take effect, depending on the type of measure.

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- Improved and increased enforcement to change driving behaviour and reduce tampering may take effect in the short or medium term if well-conceived.
- Mitigation measures at local level such as road design may work in the short term but not at wide scale.

Consequently, mitigation measures that affect the noise production of the existing fleet are most effective in the short and medium term, given the lifespan of L-vehicles.

The foreseen LENS impact assessments for selected mitigation solutions will require updated input data for:

- Current sound and pollutant emission levels per LV group and their expected evolution.
- Assumed driving conditions per road situation.
- Levels of tampering and effects on noise and pollutant emission.
- Fleet size and evolution including electrification.
- Relevant road lengths.
- Vehicle intensities per road situation.
- Exposure distributions per road situation.
- Geographic factors (Northern/Southern EU).

3.2.2 Scenarios studied on a global scale: necessary developments and expected outcomes

Within the framework of WP6, inventories of emissions originating from LVs will be undertaken, along with an analysis of their contribution to overall road traffic emissions. Scenarios with and without interventions will be investigated and evaluated at both the aggregated EU27 and Member state levels. To effectively accomplish this task, the latest COPERT and SIBYL detailed data will be utilized, along with the updated models. This approach will enable the formulation of targeted strategies for mitigation and intervention at both the European Union and state levels. Since there are certain input data necessary for conducting the Cost-Benefit Analysis (CBA), such as country-specific data (road (sub)types, lengths, exposed inhabitants, etc.), it is necessary to assess the availability of these data on a country-by-country basis. In case such data are not available, or it is deemed appropriate to follow a more global approach, the CBA will be conducted for the aggregated EU27.

EMISIA will utilise the COPERT and SIBYL tools to develop and evaluate the baseline scenario at both EU and state levels. This scenario assumes no changes in regulations, local measures, or user behaviour, and anticipates the natural progression of the vehicle fleet with the introduction of newer vehicles, including electric ones. Additionally, EMISIA will explore various intervention scenarios aimed at mitigating emissions and noise pollution. These interventions will encompass a range of possibilities, from regulatory adjustments to technological innovations, all aimed at evaluating their potential impact on emissions and noise reduction.
For instance, the model can simulate a scenario where stricter legislative limits are imposed at a specific year, such as the adoption of Euro V+ standards. This entails tighter emissions thresholds or enhancements to the type approval testing process. Moreover, the models can be customized to explore scenarios focused

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on anti-tampering measures, ensuring adherence to ISO standards and usage guidelines through customised emission and noise factors. Local interventions, including implementing access restrictions, enhancing surveillance mechanisms, or improving road infrastructure, can also be examined within the intervention scenarios. Additionally, the model can investigate scenarios targeting behavioural changes within the vehicle fleet, considering factors such as usage patterns, adherence to ISO standards, and fleet management practices.

Each scenario can be independently evaluated to assess its efficacy in reducing emissions and noise pollution. Furthermore, synthesizing a combination of these scenarios, incorporating various interventions, can also be examined.

Beside the elaboration of the generic set of emission factors, the model PHEM and its input data set for the LVs is planned to be used for analysis of the effects of specific measures altering driving behaviour, traffic flows and routes. For automated analysis of driver effects, an eco-driver model from the H2020 project uCARe can be adjusted for LVs. The subroutine of PHEM adjusted any measured driving cycle toward "eco-driving style" by modifying acceleration, deceleration, maximum speed, and gear shifting. The settings for LVs need to be elaborated when some measured speed trajectories from trips in eco-style are available. PHEM simulates then the original cycle and the altered eco-drive cycle and provides reduction potentials for energy consumption and emissions.

3.3 Assessment at local level

3.3.1 Modelling approach and tools

This paragraph describes the methodology use to assess noise and emissions at a local scale, based on the R-TAMS tool developed by IFPEN. This work has already been carried out in research projects by IFPEN on passenger cars [16]. LENS allows to extend this approach to LVs. This assessment, carried out in conjunction with the macroscopic assessment at state level describe just above, aims to determine local exposures according to the microscopic specificities of infrastructures and uses.

This modelling methodology estimates road traffic pollutant emissions and noise for each road branch in a study area, based solely on static information (number of lanes, gradient, signs, etc.) and dynamic information (average speed) provided by Geographic Information Systems (GIS).

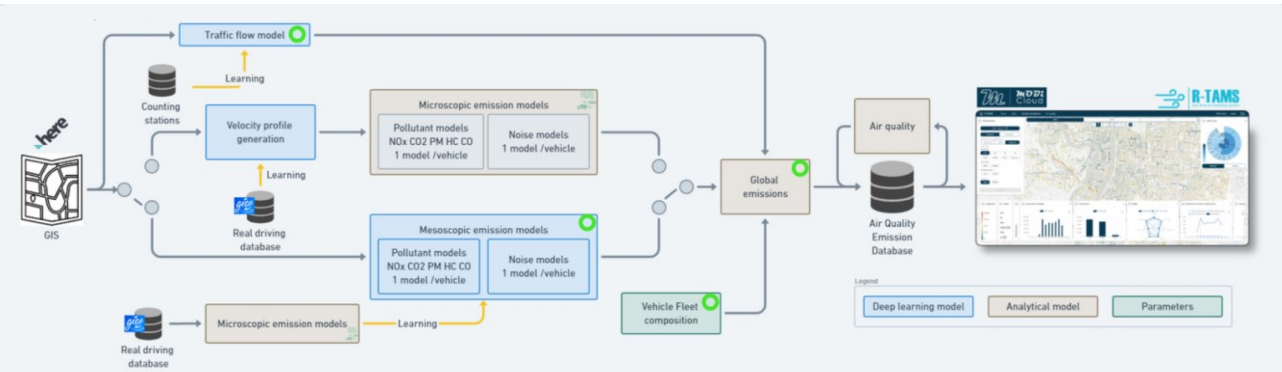

Figure 9: General framework of microscopic and mesoscopic modelling approaches under R-TAMS.

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These tools make it possible to estimate all the factors impacting emissions, i.e. traffic volume, vehicle fleet, and emission factors taking into account driving style and infrastructure for noise and the following pollutants: NOx, CO_2, CO, HC, PM exhaust and PM non-exhaust (brakes and tires). It is implemented as SAAS platform and replicable to any territory for calculating emissions inventories at different scales, analysing KPIs and visualizing emissions and air quality. Figure 10 shows an example of the platform's, named R-TAMS, outputs, with an assessment of local pollutant emissions from road transport in a given area, for several scenarios and taking account of spatial and temporal specificities (top); and an assessment of the associated impact on air quality (bottom).

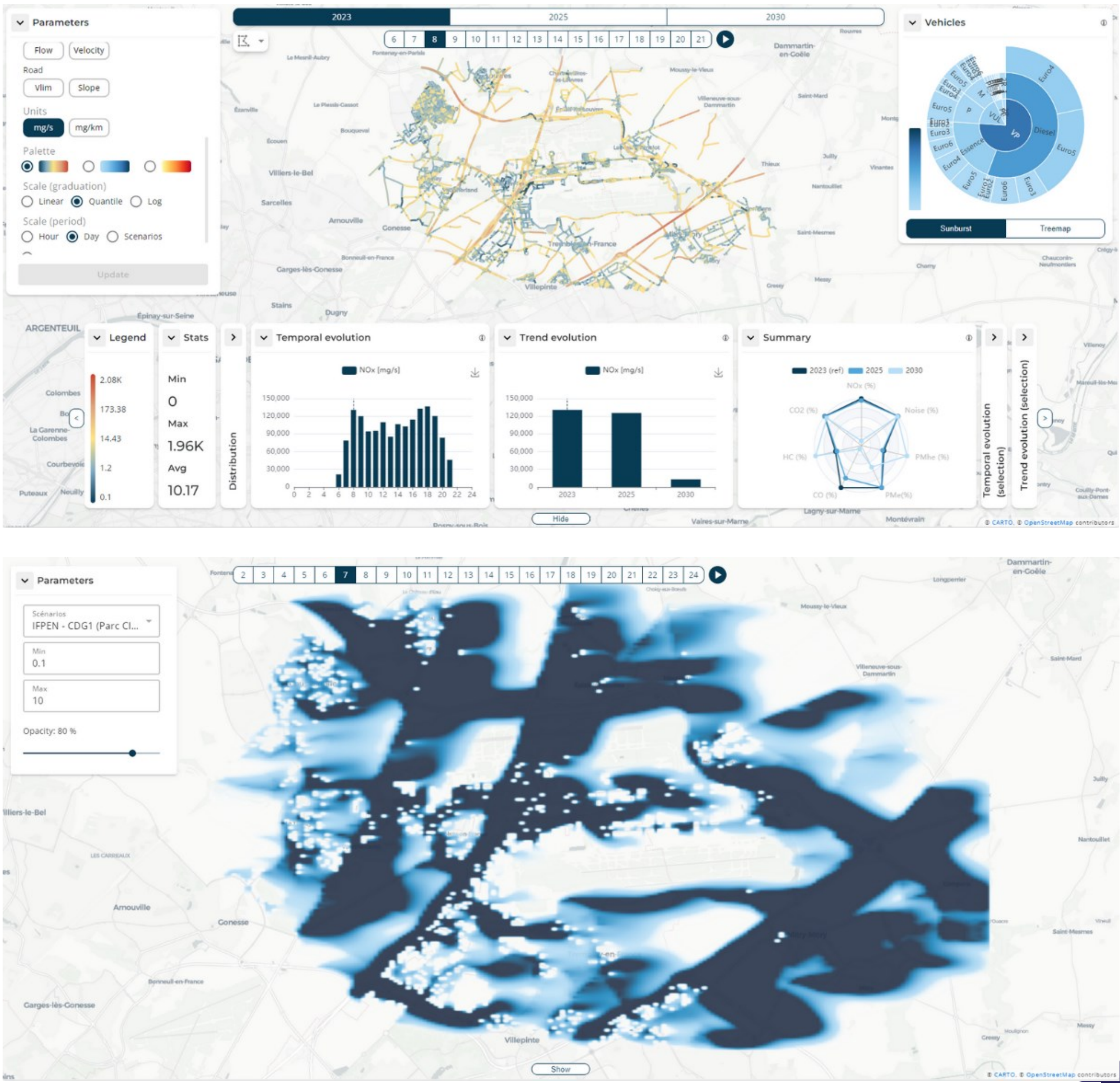

Figure 10 - Examples of R-TAMS outputs: assessment of local pollutant emissions of road transport on a territory, for several scenarios and taking into account spatial and temporal specificities (on top); assessment of associated impact on air pollutant concentration (on bottom).

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The platform, operational prior to the launch of LENS, covers the PCVs. Ongoing work on LENS will enable to add LVs.

3.3.2 Scenarios studied on a local scale: necessary developments and expected outcomes

The proposed approach is based on information provided by the GIS for each road branch. It can therefore be replicated on any territory. However, as part of the LENS project, local assessments will be particularly detailed in the three locations selected for the WP5 pilot experiments. This will make it possible to take into account local specificities, such as vehicle flows and the local vehicle fleet, using field surveys or any other data collected from local authorities.

Calculations will be carried out at a "mesoscopic" scale, typically the whole city, and findings aggregated at this scale compared with global assessments at the state level. The added value of the approach will be to offer focus at a finer scale of "hot spots", typically the scale of a street or crossroads, to study the specifically high nuances linked to particular uses or infrastructures.

The same scenarios listed above to assess current and future situations considering different intervention measures will also be evaluated at this microscopic scale on the pilot study territories. Depending on the measures, this will be achieved by modifying or recalibrating the various workflow components:

- to take account of technological developments (e.g. to meet stricter regulatory requirements), modifications of the vehicle model will be fitted for both pollutant emissions and noise, accordingly to adjustments made in PHEM (for emission factor generation and global scale assessment) and in ROTRONOMO.
- to take account of behavioural changes (eco-driving, acceleration, etc.), modifications of the speed profile generation model will be set. Some local regulation as speed limits or specific infrastructures will also be considered by their effects on speed profile. For example, it will be possible to analyse the effect of changing the speed limit on a road from 50 to 30 km/h, notably on acceleration profiles after a stop, which are known to have a major impact on noise emissions in particular.
- to take account of local regulation (access restrictions or bans, etc.) and anti-tempering mitigation measures, modifications of the local fleet will be considered.

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4 Conclusions

This report aimed to define the impact studies that will be carried out as part of this project to assess various measures to reduce pollutant and noise emissions from L-category vehicles. It presented intervention scenarios (regulations, technological limitations, anti-tampering measures and driver behaviour) and the modelling tools used to assess their impact at European and local levels, based on case studies. The ultimate aim of LENS project is to provide policy recommendations for cleaner, quieter L-category vehicles.

The main types of intervention envisaged to reduce emissions and noise from L-category vehicles are as follows:

- Changes in certification standards: These include the introduction of more stringent emissions and noise standards, covering tailpipe emissions testing, the introduction of a PN limit, the potential implementation of off-cycle emissions testing, and on the standard method for roadside enforcement testing for noise. These scenarios will be translated into assumptions about the corresponding technological developments, from the most conservative to incremental technical advances and potential new breakthroughs.
- Anti-tampering measures: Many different measures can be envisaged to combat the proliferation of manipulation of L-category vehicles. These may include measures aimed at strengthening roadside checks (by making them more effective, increasing their number, increasing fines, etc.). It may involve making these modifications more difficult to carry out (banning non-certified and easily modifiable parts, prohibiting the sale of noise-increasing parts, etc.).
- Local regulations and driver behaviour: Several local regulations can be considered to reduce the contribution of L-category vehicles to emissions and noise in designated areas, for example: closing roads or restricting access to L-category vehicles in designated areas, introducing specific speed limits in sensitive areas, setting up low-emission zones, quiet zones and protected quiet zones, incorporating innovative road and infrastructure planning measures, enforcing maximum noise limits on building facades or along roads, and implementing automatic enforcement. These measures aim to influence both the composition of the local fleet and driver behaviour. Additional measures can be deployed to influence such behaviour: implementation of strict penalties, enforcement of vehicle roadside inspection, use of information and warning signs strategically placed along roads, and increased fines.

The LENS project uses various modelling tools to assess emissions and noise from L-category vehicles.
To assess pollutant emissions, LENS uses the PHEM, MobSim and COPERT models:

- PHEM (Passenger car and Heavy-duty Emission model) is an instantaneous emission model based on longitudinal vehicle dynamics equations and engine emission maps. PHEM will be used to generate emission factors for various representative driving cycles, road gradients and driving styles. LENS test data will be used to parameterize PHEM.
- MobSim is another microscopic pollutant emission model developed by IFPEN. Like PHEM, it uses real-life data to simulate emissions under various driving conditions. The results of PHEM and MobSim will be compared, and synergies sought.

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- COPERT is the EU's standard vehicle emissions calculator. It uses vehicle population, mileage, speed, and environmental factors to calculate emissions. COPERT includes emission factors for over 450 vehicle types, including L-category vehicles. The LENS data will be used to update the emission factors for L-category vehicles in COPERT.

To assess noise, LENS mainly uses ROTRANOMO, a microscopic road traffic noise model that calculates the noise levels of individual vehicles as a function of their speed and acceleration. It considers propulsion noise and rolling noise separately. ROTRANOMO uses a detailed classification of vehicle categories, including sub-categories for L-category vehicles. Noise measurements made as part of the LENS project will be used to update the ROTRANOMO model.

In addition to PHEM, MobSim, COPERT and ROTRANOMO, LENS also uses the SIBYL and TRANECAM tools to model large-scale and national impacts:

- SIBYL is a modelling tool used to forecast the effects of changing vehicle technology on future vehicle fleets, energy consumption and emissions. It is used to assess the impact of different policy options on road transport emissions.
- TRANECAM is a model that calculates the 24-hour average noise level for different road types and traffic situations. It is used to assess the impact of noise limit modifications and other mitigation measures on noise exposure.

Table 7: Overview of models and outputs for foreseen analysis of noise and emissions at local and global level in LENS.

	Model/approach	Local	Global	Outputs
Pollutant emissions	PHEM	X	X	1hz emissions [mg/s] on generic real-driving use cases, dataset of emission factors [mg/km] to feed COPERT
	MobSim & RTAMS	X		Emissions [g/h] of the fleet on each road segment of a dedicated local area
	COPERT		X	Emission factors per vehicle category [mg/km] & Total emissions [tonnes] at state level
	SYBYL		X	Total emissions [tonnes], benefits, and implementation costs of mitigation solutions (CBA)
Noise emissions	Rotranomo	X		L_{eq}
	Tranecam	X	X	L_{den}
	CNOSSOS	X	X	Emission factor per vehicle category (for L_{den})
	Phenomena/MN/Lcat		X	L_{den} + CBA
	Single events	X	X	Delta L_{Amax} average

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LENS will use a platform called R-TAMS to assess the local impact of L-category vehicles. R-TAMS is a modelling platform that estimates pollutant emissions and road traffic noise for each road section in a study area. It considers traffic volumes, vehicle fleets and emission factors. R-TAMS will be used to assess the impact of mitigation measures in the three cities selected for the WP5 pilot experiments.

CBA is foreseen for mitigation measures at global level, for those scenarios with substantial impact. Approaches used in previous studies such as EU sound limits studies [2],[15] and the Phenomena study [14] can be adopted where required, for example noise scenarios and single event analysis.

In order to carry out the evaluations required for the LENS project, several developments are necessary and on-going:

- Integration of LENS data into existing modelling tools: Emissions and noise data collected during the LENS project's RDE road and laboratory tests will be used to update the PHEM, COPERT and ROTRANOMO modelling tools.
- Development of emission factors for L-category vehicles: the LENS project will use the PHEM model to create a set of representative emission factors for the distinct categories of L-category vehicles. These emission factors will be used to evaluate both reference and intervention scenarios.
- Development of noise emission factors for L-vehicles suitable for use in the EU noise mapping model CNOSSOS-EU.
- Consideration of eco-driving: An eco-driving model from the H2020 uCARe project will be adapted to L-vehicles to analyse the effects of modified driving behaviour on emissions.
- Development of local intervention scenarios: In addition to national and European assessments, local intervention scenarios will be developed for the three LENS pilot sites. These scenarios will take account of local specificities, such as the composition of the vehicle fleet and traffic flows.
- Assessing the impact of regulatory changes: The models will be used to assess the impact of regulatory changes, such as the adoption of stricter Euro V+ standards or the implementation of anti-tampering measures.

Using this combination of modelling tools and new developments, LENS aims to provide a comprehensive assessment of the impact of L-category vehicles on air and noise pollution. The results of these assessments will be used to develop public policy recommendations aimed at reducing this impact.

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