THE CONCEPT OF UNIFIED SYSTEM OF ROAD VEHICLES ENVIRONMENTAL LABELLING

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Abstract. Problem. *The growing propagation of multiple and inconsistent vehicle Access Restriction Schemes, including Low-Emission Zones, is creating extraordinary fragmentation of the European continent`s transport infrastructure access rules, where road transport becoming increasingly expensive, inconvenient, and linked to superfluous barriers, inhibiting economic development and interregional ties. The abovementioned substantiate a strong need for a unified system of road vehicles environmental labelling as a crucial element of any Low-Emission Zone regulation framework as well as environmental marketing and customer decision-making influence in favour of environmentally-friendly vehicles choice.* ***Goal.*** *The main purpose of the research is to develop a concept of unified vehicle environmental labelling to combine in a stable system past, current, and future road vehicle technologies.* ***Methodology.*** *The research method is based on a conceptual framework regarding road vehicle environmental labelling data structure needed to support environmental marketing and management of vehicle access to infrastructure in view of an analysis of positive and negative experience directly in the field, the relevant determinants and driving factors, as well as other related issues.* ***Results.*** *The research gives systems analysis of worldwide experience in the field of road vehicles environmental labelling with emphasise on low-emission zones access differentiation. It is studied many aspects in order to analyse positive and negative experience, including low emission zones faults or low efficiency in reducing air pollution. Key factors lead to faults of low-emission zones or its low efficiency in many cases are identified.* ***Originality and practical value.*** *The proposed concept of unified vehicle environmental labelling not only combine in a stable system past, current, and future technologies, and not only technologically neutral but also join on a unified basis, in a unified global system, vehicles developed, approved and produced under incompatible emission standards in different regions of the world.*

Keywords*: vehicle environmental labelling, emissions, emissions stickers, low-emission zone management, transport, vehicle access restriction, wheeled vehicles.*

Introduction

Air pollution costing the European economy between €427 and €790 billion per year [1], where road transport emissions directly linked to approximately 40 thousand premature deaths annually. Road noise and congestion are costing about €36 and €100 billion damage, respectively [2].

In efforts to solve the problem, the EU countries introducing, in particular, vehicle Access Restriction Schemes (ARS), including Low-Emission Zones (LEZs).

A crucial component of low-emission zones management (as well as environmental marketing) is road vehicles environmental labelling. But vehicle environmental labelling and emissions stickers introduced in the European continent, as well as the regulation in this area, are highly divergent and inconsistent among different countries, and the experience gained is very ambiguous.

Governments, thinking about an introduction of road vehicles environmental labelling or a shared national framework to regulate access restriction schemes, as well as local communities in willing to introduce LEZ, are faced with a problem of high uncertainty and many unknowns on this way.

The growing propagation of multiple and inconsistent ARS is creating extraordinary fragmentation of the European continent`s transport infrastructure access rules, where road transport becoming increasingly expensive, inconvenient, and linked to superfluous barriers, inhibiting economic development and interregional ties.

All the above mentioned substantiate a strong need for a unified system of road vehicles environmental labelling as a crucial element of any LEZ regulation framework as well as environmental marketing and customer decision-making influence in favour of environmentally-friendly vehicles choice.

Literature Review

The LEZs initially was implemented in the European cities in efforts to comply with the EU limit values for particulates matter (PM) and nitrogen dioxides (NO_2) [3]. Today, many different and incompatible with each other forms of ARSs (including LEZs), are established already in 24 European countries, and growing further [4, 5]. Already about 260 European cities have in operation LEZs with vehicle entry rules differentiated on vehicle environment class, age, type, designation, and others properties [3].

Nevertheless, there is no yet any common European standard regarding establishing ARS requirements and even requirements to vehicle environmental labelling as essential future to differentiate access to LEZs [6].

Furthermore, a comprehensive overview [7] of motor vehicles taxes in Europe in other major markets around the world demonstrates a significant number of countries that linked the level of vehicle taxation either directly or indirectly with their environmental properties and extraordinary diversity of used approaches in this area.

LEZs can establish permanents, periodic or condition-dependent (or 'dynamic change') access rules when a level of pollutants are expected to be high [1, 8].

LEZs can operate via direct access restrictions, or road pricing schemes. The last variant can be used to financially support relevant measures to improve the city's transport network, including environmental-friendly alternatives [9].

LEZs are enforced either manually using windshield stickers as in Berlin, Stuttgart, Paris, or with camera systems using license plate recognition as in Amsterdam, Brussels [2].

In general vehicle labelling can be implemented through:
- so-called environmental badges (windshield stickers) with manual control as in Berlin, Stuttgart, Paris;
- other techniques including Automated Number Recognition (ANR) systems with relevant databases of vehicles as in Amsterdam, Brussels;
- radio-frequency identification (RFID) as an alternative approach giving some preferences.

The most common exemptions in all the LEZs are [3]:
- ambulances and other emergency response vehicles;
- military vehicles;
- very old vehicles;
- vehicles used for transport of disabled or sick persons or used by disabled persons.

But in general, various cities demonstrate a lot of different and sometimes unique exemptions.

While LEZs considered as the primary tool to overcome local toxic air pollution problem [10] its actual efficiency is a question. It is varying in a wide range from a proved significant reduction of pollution [11–14], moderate [15, 16], to rather a small reduction [3, 17] and up to no effects being observed [18] due to many reasons.

The LEZs impact on air quality depends on many factors, including [14]:
- the emissions standards set;
- the LEZ enforcement approach and therefore control efficiency;
- types of vehicles affected;
- the LEZ borders spacing;
- vehicle fleet renewal rules and schemes including retrofit permission;
- the structure of the vehicle fleet before the LEZ was implemented;
- the importance of different pollution sources in that city, and how severe air quality problems are.

The design is critical for the effectiveness of LEZ [12].

It can be identified the following hypothesis of what key factors lead to faults of LEZ or its low efficiency in many cases:

1) the number one factor is 'Off-cycle' emission. Exactly failed Euro emission standards have undermined LEZs in the past [3]. Initially predicted effects of many LEZ schemes were overestimated since official 'Euro' emission limits do not reflect real-life emission;

2) moreover, the initial environment properties of vehicles tend to degrade. Old vehicles in actual operation due to emission control systems malfunction or degradation can be a source of enormous emissions. Such vehicles play a decisive role in total emissions of traffic flow even if they share small. In such a case, any initiatives to increase the share of clean vehicles, including pure electric transport, do not have any perceptible effect;

3) based on idling tests, current technical inspection procedures even prescribed by the latest EU directives 2014/45 and 2014/47 are unable to identify a many of emission control systems malfunctions during actual driving. Furthermore, onboard-diagnostic systems (OBD) are widely discredited that lead to wide-spread

non-conformity with the emission standards, even in the case of relatively new vehicles [19];

4) the rules violations.

The European Commission White Paper 'Roadmap to a Single European Transport Area – Towards a competitive and resource-efficient transport system' [20] declared the following: 'Develop a validated framework for urban road user charging and access restriction schemes and their applications, including a legal and validated operational and technical framework covering vehicle and infrastructure applications'. Nevertheless, until now, the Commission maintains a neutral role with respect for the principle of subsidiarity, and refrain from promoting specific traffic management tools, including LEZ schemes [21, 4].

In [22], it is proposed the following recommendations concerning a national framework:

▪ developing a system for vehicle requirements. For example, developing the sticker system as used in Germany and France;

▪ a common list of exemptions, with a possibility for some local adaptations;

▪ ban versus the possibility of paying a charge;

▪ if an Automatic Number Plate Recognition (ANPR) will be used, prepare the necessary national databases;

▪ if retrofitting is allowed, have national standards of how to classify different retrofitting technologies;

▪ national road signs for LEZs;

▪ define the day charges to enter the zone and the fines for non-compliance'.

In [21], it is stated that: 'Any LEZ scheme implemented needs to have clear and measurable objectives, and efficient control and monitoring systems. It has to follow the principles of better regulation, notably simplification, reduction of administrative burdens and impact assessment, including cost/benefit analysis. This is not currently the case in most of the cities where LEZs exist'.

As a result of the increasing prevalence of traffic restrictions based on wildly divergent and inconsistent ARS regulations the European continent going looks like a "patchwork" [3], where transport becoming increasingly expensive and inconvenient.

To avoid fragmentation and ensure a seamless transport system, there is a need for developing a unified system of road vehicles environmental labelling as a crucial element of any LEZ framework.

The detailed analysis of different labelling systems is presented in [23–26] and in many other sources, including [27] with an attempt to establish some specific common approaches regarding LEZ planning and implementation. And, it can bee seen that the variety and incompatibility of different labelling systems are enormous.

The study [23] gives no empirical evidence of a substantial effect of 'the car labelling' Directive 1999/94/EC on the supply of more efficient vehicles.

[23, 24, 28–33] and many other sources prove evidence that CO_2 labelling is not very efficient measure itself to stimulate the automotive industry to develop and produce much more energy-efficient vehicles.

[12, 28, 33–35] and many other sources prove evidence that the automotive environmental labelling influence on consumer behaviour and 'environmentally friendly purchases' is quite limited if no strong financial background involved in a decision-making process.

Generally speaking, the European car labelling does not have received wide recognition, do not reflect the actual properties of vehicles properly, and do not foster efficient and well-informed consumer choices [28].

Green marketing in the automotive industry has analysed in many studies, including [36–43]. These studies confirm the gap between recognition the consumer awareness on sustainability issues and enactment of environmentally friendly consumption [36].

Emissions stickers, as LEZ access control element, introduced in Germany [44], Austria [45], France [46], the United Kingdom [47], as well as in Belgium, Denmark, Italy, Hungary, Spain, Norway, Sweden [48]. Here the approaches of labelling are incompatible either in the fleet environmental differentiation either in the data presentation form.

Motorway toll is a wide-spread economic instrument in European countries [49]. Road charging and the Eurovignette Directive overview is given in [50]. Road charging differentiation regarding road wear intensity and vehicle environment properties is broadly considered a reasonable and equitable approach.

Environmental Analysis should be considered as background for proper vehicle labelling design. A general concept of an EU type label which classifies the four major impacts that are noise, gaseous emissions, fuel consumption and damage to the infrastructure is proposed in [51]. It is suggested that road usage and track access charges should be related to the size of their environmental footprint as classified on its environmental label.

In [52] it is given considerations regarding eco-labelling is an Environmental Product Information Schemes (EPIS). It is proposed the term 'Low or Zero-emission Vehicle' (LZV) to define a sufficiently environmentally-friendly vehicle using firstly two main criteria:

- strict limits for the local pollutants NO_x, volatile organic compounds (VOC) and PM;
- strict limits for CO_2 emissions, which imply reduced fossil fuel consumption.

Besides, [52] proposed to include in the future also:

- strict cold start emission limitations at low ambient temperatures;
- life cycle perspective on CO_2 emissions including production, use and recycling;
- strict vehicle noise emission restrictions.

Is should be noted that the term 'strict' is quite blurred here and requires periodic revision as technology develops.

[53] gives a set of sustainability goals, objectives and performance indicators that can be useful for balancing economic, social and environmental goals.

The principles of life cycle assessment (LCA) and environmental economics are used in [54, 55, 56] and other studies in the field, including the ACEEE's vehicle environmental rating methodology [57]. For instance, [55] and other studies argued that EVs total environmental impact is a challenge if considering the whole life cycle. Nevertheless, LCA is quite tricky for practical regulation purposes due to lack of needed data.

Vehicle aggregated environmental ranking approaches can be considered as a good base for assessment of the total environmental impact of road vehicles in a framework for regulation in the field of atmospheric air protection.

For instance, Toxicity-weighting [58] is used by Risk-Screening Environmental Indicators (RSEI) Model by the United States Environmental Protection Agency [59] and a part of many air pollution indexing systems around the world [65]. However, there is no standard methodology today is widely recognised yet [60].

An overview of four road vehicle environmental ranking methodologies is given in [61], covering 'Greenscore' in the US, 'Ecoscore' in Belgium, 'VCD Environmental Car list' in Germany, and 'Australian Green Vehicle Guide'.

A significant disadvantage of mentioned methodologies is that the pollutants emissions effect is attenuated by considering emission standards` limit values instead of real emission values. Furthermore, the pollutants list is too limited. Weighting by different impact categories is highly subjective and cannot be considered as entirely justified.

The differentiation of conditions of access of vehicles to road infrastructure, aimed at limiting the use of environmentally 'dirty' vehicles, if being fair and reasonable, should be applied in proportion to the amount of environmental damage. The development of approaches for assessing such harm and appropriate basis for labelling of vehicles can be considered as essential progress in this area.

The widely recognised approach in the field outlined in [62, 63] where aggregated toxicity calculated merely as the sum of known pollutants, each multiplied on its relative toxicity coefficient corresponds to carbon monoxide as well-known poison.

Consequently, in [64, 65] it was developed Environment Zones (EZ) unified classification and Environment Hazard Level (EHL) unified classification based on reduced emissions of 64 known pollutants establishing aggregated toxicity road vehicles of different categories.

Aim and objectives of the article

The aim and primary objective of the research are to draw the main contours of a concept of road vehicle unified environmental labelling as important part on the way of solution of the problem of extraordinary fragmentation of ARS approaches in the European continent, based on the above-done analysis of the experience of ARS and LEZ around the world, the relevant determinants and driving factors.

The Concept of Unified System of Road Vehicles Environmental Labelling

The specific requirements for vehicles, enforcement methods, and even the main goals of the introduction of LEZ in different cities and countries may differ significantly based on the situation with air pollution and the real possibilities to control it, taking into account economic constraints, the level of income and purchasing power of the population, social aspects and many other factors.

General provisions as the basis for the concept of a unified system of road vehicles environmental labelling.

Analysis of the experience mentioned above of vehicle labelling gives grounds to propose the following general provisions as the basis for the concept of a unified system of road vehicles environmental labelling as an instrument for

environmental management and innovation management in the field.

A unified system of road vehicles environmental labelling should give local administrations and communities a principal possibility of flexible choice of a specific level of requirements based on a set of standardised solutions corresponding to the main types of environmental damage from the operation of transport and the significant environmental properties of vehicles of various designs.

Assessment of the level of ingredient pollution of atmospheric air by a vehicle should take into account both the exhaust gases of the engines and the products of wear of tires, road surfaces and brakes as well.

It is advisable to introduce a reduced level of the total toxic effect of a vehicle, not limited to specific emissions of particulate matter and nitrogen oxides.

The level of ingredient pollution of atmospheric air by a vehicle must be dynamic; that is, it must take into account degradation of emission control systems during vehicle operation.

The products of tire and road surface wear are functions of a mass of vehicle, axle load distribution, as well as its wheel formula. It should take into account the number of swivel wheels for multiaxial heavy vehicles and associated wear rate of pneumatic tires when the vehicle is turning.

A factor of the intensity of road surface wear should be considered separately, as it plays an essential role in critical road infrastructure. The factor of the intensity of road surface wear can prevail over the factor of ingredient pollution of atmospheric air when calculating the cost of toll travel on roads passing far from large settlements.

The assessment of the parametric pollution level of the vehicle should take into account at least the external acoustic noise during the movement.

LEZs should use a unified, flexible labelling system that is consistent with unified vehicle labelling regarding the permissible levels of ingredient and parametric contamination.

The scale and system of gradations of the permissible level of ingredient and parametric contamination should cover both vehicles of various technological levels that are in operation today, and vehicles that will be put into operation in the future. At the same time, the size of the minimum step between neighbouring 'ecological' levels should be appropriate from the point of providing the benefits of cleaner technologies visible to the consumer. However, its size should not lead to an excessively large number of gradations (that is, the total number of levels used today and which will also be used in the future for regulatory purposes as technology advances).

The initial lack of differentiation of LEZs led to the need subsequently to introduce zones with more stringent requirements and a different name, like ULEZ, or even ZEZ. However, for example, all-electric vehicles are also significant sources of wear products. Furthermore, in the future other technological solutions may turn out to be comparable to EVs in terms of the reduced level of damage, even taking into account only local air pollution during operation.

Therefore, it is evident that a unified differentiation and classification of LEZs according to the permissible level of ingredient air pollution is needed, coordinated with a unified system of environmental labelling of vehicles.

Differentiation of access to road infrastructure, ideally, should be based solely on the factors of local damage. That is, it should be determined by a level of ingredient pollution of the atmospheric air with toxic products with a pronounced local harmful effect, a level of parametric pollution (at least, acoustic noise when driving) and a factor of wear intensity and destruction of road surface.

The last factor should take into account usage of studded tires.

It is necessary to provide a possibility of using certain incentives for motorists used tires with relatively low acoustic noise.

In the future, it is also possible to differentiate according to the degree of tire wear and total toxicity of their wear products, taking into account materials and production technology.

Energy efficiency or greenhouse gas emissions should ideally not be used directly as a tool for differentiating access to road infrastructure. These indicators should be factors that determine, first of all, the level of taxation of vehicle purchase and, thus, stimulate the consumer's choice in favour of more energy-efficient vehicle options. The level of consumer costs, in any case, is already directly related to the level of energy efficiency of the vehicle.

At the same time, their use to differentiate access to transport infrastructure can be justified as a tool to reduce the overall level of energy consumption and greenhouse gas emissions, with, of course, other alternatives to travel. For example, the use by a well-to-do category of people in some cities of heavy 'prestigious' off-

road models of passenger vehicles for moving short distances within the central part of the city is hardly an optimal solution for society as a whole.

An introduction of additional charges for use in LEZs of extremely heavy passenger cars (i.e., that is similar in size to tractors) can to some extent stimulate their owners to preferentially use other more environmentally friendly alternatives for travel within the city. Heavier vehicles not only consume more energy per mileage but also tend to emit more toxic pollutants in use, including wear products. Thus, such measures seem to be quite fair from the point of view of the implementation of the 'polluter pays' principle.

Environmental labelling applied to vehicles as stickers should include vehicle-specific identification in order to reduce the potential for fraud (the registration number and, besides, 17-digit vehicle identification number (VIN) also is strongly recommended).

Environmental labelling should also include a mark about social or another special purpose of the vehicle, which gives it the right, under certain conditions, for certain exemptions regarding established rules, including access rights and preferential terms of payment for road infrastructure use.

Following the experience accumulated in different cities, taking into account social aspects, it is necessary to develop a unified system of marks on the purpose of vehicle. In should provide local administrations and communities flexibly approach for management of access to LEZs, taking into account both public consensus and the need to limit a share of 'privileged' vehicles in order to achieve primary goals.

Such a unified marking system should include standard designations for at least such vehicles (examples of possible designations are given in quotation marks):
- "A" – ambulance vehicles;
- "ERV" – emergency response vehicles (fire trucks, emergency vehicles of gas services, and so on);
- "P" – police vehicles;
- "SV" – special utility vehicles of communal service;
- "CV" – construction vehicles;
- "WM" – work machines;
- "DP" – vehicles regularly used by persons with disabilities or for their transportation;
- "L" – vehicles used by individuals or families with low income;

- "NS" – vehicles of non-profit organisations that perform essential social functions;
- "D" – diplomatic vehicles;
- "MIL" – military vehicles;
- "S" – sports vehicles;
- "RV" – rare veteran vehicles.

Above mentioned list of designations is not a list of vehicles exempted from the regulation. Local authorities should have rights to establish definite rules for access, including possible special rules and exemptions for mentioned above vehicles. Nevertheless, it should be established common exemptions covering at least ambulance vehicles and other emergency response vehicles.

This concept of a unified system of road vehicles environmental labelling defines some principles of labelling the level of environmental hazards, energy efficiency indicators, specific emissions of carbon dioxide and other significant environmental properties of wheeled vehicles during their operation in order to implement the regulation in this area through incentives and other measures to acquire and use environmentally friendly and energy-efficient vehicles, reduction of air pollution and in general the harmful effects of transport on the environment and human beings, reduction of specific consumption of fuel and energy resources by transport and its negative impact on climate change.

Terms and Definitions

In this concept, the proposed terms are used in the following meaning:

1) current Environmental Hazard Level (EHL) of ingredient pollution of a wheeled vehicle is a conditional average level of main negative impact on the environment during the operation of a wheeled vehicle due to emissions of significant pollutants into the atmosphere, aggregated to carbon monoxide as a reduced indicator, based on their relative toxicity, taking into account age of vehicle and a corresponding degradation of its environmental properties;

2) indicators of energy efficiency of wheeled vehicles is a system of indicators that together characterise the efficiency of energy use of wheeled vehicles in different operating conditions, and is the basis for comparing vehicles, appropriate consumer information, informed choice of vehicles and implementation of incentives and use of the most energy-efficient vehicles under the prevailing conditions of their operation;

3) emissions of carbon dioxide by a wheeled vehicle is average emissions under typical operating conditions that characterise the design of

the vehicle as a whole or its heat engine (internal combustion engine);

4) environmental labelling of wheeled vehicles is a system of measures using special labels and other means of labelling, electronic chips, electronic databases and other means of determining, creating, storing, transmitting, displaying and using the information on the essential environmental properties of a wheeled vehicle, as bases for the regulation of its access to the market and infrastructure, cost of the use of road infrastructure, including in LEZs;

5) the essential in-use environmental properties of a wheeled vehicle include:

- current environmental hazard level (EHL) of ingredient contamination;
- type of motor fuel or another energy source;
- propulsion type;
- energy efficiency indicators;
- average specific emissions of carbon dioxide;
- the level of acoustic noise (sound pressure) when driving a vehicle;
- factors of intensity of road wear and formation of wear products of pneumatic tires and road surface, taking into account the total structural weight of vehicle, maximum load on one axle, the wheel formula taking into account swivel wheels, and other essential design parameters.

6) environmentally friendly wheeled vehicle is a vehicle whose environmental hazard level of ingredient contamination in-use corresponds to a certain minimum of technically achievable and economically acceptable values in comparison with other vehicles on the market, in accordance with the current level of science, technology and engineering, or meets the most stringent (high), current at the time of assessment, international standards (technical regulations) for emissions of toxic pollutants, taking into account the type of energy (fuel) used by it;

7) energy-efficient wheeled vehicles - a vehicle whose energy efficiency indicators in operation correspond to a set of technically achievable and economically acceptable values in comparison with other vehicles on the market, in accordance with the current level of development of science, technology and technology, or which meets the most stringent, current at the time of assessment, international standards (technical regulations) for energy efficiency or specific emissions of carbon dioxide, taking into account the type of energy (fuel) used by it;

8) environmental zones are zones of regulated use of road and other infrastructure, a designation of which and other means of access control and payment for use are coordinated with the system of environmental labelling of wheeled vehicles and differentiated according to their essential ecological properties;

9) the principle 'polluter pays' is the principle according to which the costs of society associated with measures to prevent, control and reduce pollution, reimbursed by the polluter;

10) the essential environmental properties of a wheeled vehicle at the stages of its production and disposal include data on:

- total energy consumption and greenhouse gas emissions, emissions of toxic substances generated during the production and subsequent disposal of the vehicle, its spare parts and operating materials;
- availability of affordable technologies and degree of recycling of construction materials;
- hazards of wastes generated during vehicle disposal and availability of ffordable technologies for safe handling and disposal of such wastes;

11) database of a life cycle of wheeled vehicles is a database containing specified information concerning a life cycle of wheeled vehicles registered in the country or being in-use. It should contain, in particular, available structured data regarding:

- vehicle production;
- significant design features;
- conformity assessment;
- first access to the operation, license plate;
- a period of operation including related events;
- results of periodic technical inspection;
- maintenance and repair, restoration, replacement of structural elements subject to periodic replacement;
- changes in design (re-equipment);
- significant environmental properties as dynamic features;
- subsequent utilisation, decommissioning and reuse of construction materials and vehicle components.

The regulation should extend to the labelling of essential environmental properties of wheeled vehicles at least under the following commodity codes of the harmonised tariff schedule:

- 8701 20 – 'Road tractors for semi-trailers';
- 8702 – 'Motor vehicles for the transport of ten or more persons, including the driver';

▪ 8703 – 'Motor cars and other motor vehicles principally designed for the transport of persons (other than those of heading 8702), including station wagons and racing cars';

▪ 8704 – 'Motor vehicles for the transport of goods';

▪ 8705 – 'Special purpose motor vehicles, other than those principally designed for the transport of persons or goods (for example, wreckers, mobile cranes, fire fighting vehicles, concrete mixers, road sweepers, spraying vehicles, mobile workshops, mobile radiological units)';

▪ 8711 – 'Motorcycles (including mopeds) and cycles fitted with an auxiliary motor, with or without side-cars; side-cars'.

State regulation in the field of essential environmental properties and environmentally friendly use of wheeled vehicles:

1) state regulation in the field of essential environmental properties of wheeled vehicles is carried out to:

▪ protect the lives, health and interests of citizens and the state by introducing incentives and other measures for the acquisition and dominant use of environmentally friendly and energy-efficient vehicles, reducing air pollution and another harmful impact of transport on the environment and human;

▪ reducing the specific consumption of fuel and energy resources by transport and its negative impact on climate change;

2) the state shall regulate the essential ecological properties of wheeled vehicles during their commissioning and in the whole fleet of wheeled vehicles in operation on the territory, as well as environmentally friendly use of wheeled vehicles, by, in particular:

1) establishment of mandatory and progressive environmental requirements (emission standards), in particular, defined by international technical regulations, for wheeled vehicles entering the market for the first time for free circulation;

2) determination and labelling of:

▪ current environmental hazard level (EHL) concerning ingredient contamination of air;

▪ energy efficiency indicators;

▪ specific emissions of carbon dioxide;

▪ acoustic noise;

▪ factors of intensity of road wear and formation of wear products;

▪ and other determined significant environmental properties of wheeled vehicles;

3) bringing to consumers environmental hazard level, energy efficiency indicators, specific emissions of carbon dioxide, acoustic noise, factors of intensity of road wear and formation of wear products, and other determined significant environmental properties of wheeled vehicles offered on the market, to make an informed and reasonable choice in favour of environmentally friendly and energy-efficient wheeled vehicle designs, taking into account the adopted and prospective fiscal and other measures to stimulate, in particular, the advantages in the use of such vehicles of infrastructure facilities, including the advantages in terms of access to environmental zones, parking lots and other facilities;

4) establishment of a progressive system of taxation of purchase of wheeled vehicles, which will stimulate the accelerated and economically feasible renewal of fleet for environmentally friendly and energy-efficient constructions of wheeled vehicles, based on their essential environmental properties;

5) introduction of the 'polluter pays' principle, by, in particular, introduction of environmental zones of regulated access and payment for the use of road and other infrastructure, differentiated depending on the essential environmental properties of wheeled vehicles;

6) targeted use of financial resources collected through payment for access to environmental zones and use of toll roads and other infrastructure, payment of fines for violation of established requirements for environmental labelling, payment and conditions of access to environmental zones and other toll infrastructure, exclusively to finance measures to prevention, control and reduction of environmental pollution by wheeled vehicles, reduction of transport consumption of fuel and energy resources, including the development of environmentally friendly, safe, convenient and comfortable public transport as an attractive alternative to private transport, development and maintenance of road infrastructure, and other measures aimed at sustainable development of road transport;

7) use of environmental hazard level and other identified significant environmental properties of wheeled vehicles, as advantages during tenders for the supply of vehicles and tenders for transportation, depending on the conditions of transportation and the corresponding importance of individual environmental properties of vehicles;

8) implementation of measures to maintain the environmental properties of the vehicle laid down by the manufacturer during the entire period of its operation;

9) introduction of progressive, following the development of equipment, technologies and measures:

a) periodic technical control of wheeled vehicles for operation with the determination of the efficiency of the main structural elements responsible for the control of emissions of pollutants into the atmosphere and acoustic noise level (sound pressure);

b) selective roadside instrumental control of pollutants emissions and acoustic noise level;

10) stimulation of economic and rational use of fuel and energy resources by wheeled vehicles in operation by business entities, organisations and institutions;

11) establishing liability for violation of defined rules of environmental labelling of wheeled vehicles, their admission to infrastructure facilities and payment for the use of infrastructure facilities, and use of vehicles that do not meet the established requirements for suitability for operation;

12) establishing a progressive system of taxation of fuel and energy resources used by wheeled vehicles.

The last should:

▪ stimulate reduction of air pollution by conscious choice of consumers in favour of vehicles using more environmentally friendly energy sources, taking into account existing technologies;

▪ help to optimise (balance) the structure of consumption of different types of energy by a whole fleet of wheeled vehicles.

Environmental labelling of wheeled vehicles during the first registration

The first registration of vehicles is carried out under the condition of definition and marking of all in-use essential environmental properties of the wheeled vehicle:

▪ current environmental hazard level (EHL) of ingredient contamination;

▪ type of motor fuel or another energy source;

▪ propulsion type;

▪ energy efficiency indicators;

▪ average specific emissions of carbon dioxide;

▪ the level of acoustic noise (sound pressure) when driving a vehicle;

▪ factors of intensity of road wear and formation of wear products of pneumatic tires and road surface, taking into account the total structural weight of vehicle, maximum load on one axle, the wheel formula taking into account swivel wheels, and other essential design parameters.

Environmental labelling of wheeled vehicles already being in operation

Labelling of wheeled vehicles in operation shall be carried out on an obligatory basis, in particular, during the periodic inspection or maintenance, repair of the wheeled vehicle, following the above mentioned essential environmental properties, but excluding labelling of energy efficiency and average specific carbon dioxide emissions. The last shall be carried out voluntarily, in particular, where relevant data are available in a national database of a life cycle of wheeled vehicles. It should be provided default (as the first approach) values of essential environmental properties based on known parameters of vehicle design.

Environmental labelling of transit or temporarily imported wheeled vehicles

Labelling of transit or temporarily imported wheeled vehicles shall be carried out on an obligatory basis using a simplified approach based on default (as the first approach) values of essential environmental properties. In the case of a need to obtain exact preferences regarding access and cost of use of infrastructure, their owners can obtain exact values of essential environmental properties in a prescribed procedure based on available and proved data.

Forms of environment labelling

Forms (design) of environment labelling, indicators and methods for determining the essential environmental properties of wheeled vehicles are going far beyond a single publication and will be highlighted in other ones.

As an example, in Table 1, Table 2, and Table 3 is shown developed in [64, 65] Environment Zones (EZ) unified classification and Environment Hazard Level (EHL) unified classification based on reduced emissions of 64 known pollutants establishing aggregated toxicity of respectively petrol-powered and diesel-powered passenger cars (PC), light commercial vehicles (LDV), and heavy-duty vehicles (HDV). The numbers in cells of the tables are a vehicle age range corresponds with designated EHL.

This EZ and EHL unified classification was developed on the base of the above-presented concept.

Electric vehicles (EVs) here lay down in class 0, and class 1 of EHL corresponds respectively to 5 and 6 g/km for PCs and LDVs and 5 and 6 g/tkm for HDVs of reduced emissions of various wear products.

The same default values to be developed for other categories of vehicles powered by liquified petroleum gas (LPG), compressed of liquified natural gas (CNG or LNG), blended fuels (bioethanol/gasoline blends and biodiesel/diesel blends) and including vehicles certified in accordance to non-European emission standards, including the United States automotive emission standards as well.

Table 1 – Default values of dynamic Environment Hazard Level (EHL) of petrol-powered passenger cars and light commercial vehicles of different Euro classes and ages in view of Environment Zones unified classification

Petrol powered Passenger Cars (PC) and Light Commercial Vehicles (LCV)

Environment Zone	I						II			III			IV			V			VI									
EHL, #	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
RE, g/km	5	6	8	10	13	16	20	25	32	40	50	63	79	100	126	158	199	251	316	398	501	630	793	999	1258	1583	1994	2510
Euro-6							0	1-5	6-12	13-20																		
Euro-5							0	1-4	5-10	11-16	17-25																	
Euro-4								0	1-4	5-8	9-14	15-21	22-30															
Euro-3									0	1-3	4-7	8-12	13-18	19-26														
Euro-2												0	1-2	3-5	6-10	11-15	16-21	22-29										
Euro-1														0	1	2-4	5-7	8-11	12-16	17-22	23-30							
Euro-0															0	1	2-3	4-5	6-8	9-12	13-17	18-23	24-31					
Pre-Euro																			0	1	2-3	4-5	6-8	9-12	13-17	18-23	24-31	32-40

Table 2 – Default values of dynamic Environment Hazard Level (EHL) of diesel-powered passenger cars and light commercial vehicles of different Euro classes and ages in view of Environment Zones unified classification

Diesel powered Passenger Cars (PC) and Light Commercial Vehicles (LCV)

Environment Zone	I						II			III			IV			V			VI									
EHL, #	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
RE, g/km	5	6	8	10	13	16	20	25	32	40	50	63	79	100	126	158	199	251	316	398	501	630	793	999	1258	1583	1994	2510
Euro-6++											0	1-8	9-19	20-33														
Euro-6+												0	1-8	9-19	20-33													
Euro-6													0	1-8	9-19	20-33												
Euro-5													0	1-6	7-14	15-25	26-37											
Euro-4														0	1-5	6-11	12-19	20-30	31-43									
Euro-3															0	1-4	5-9	10-16	17-25	26-35								
Euro-2															0	1-3	4-7	8-12	13-18	19-26	27-37							
Euro-1																0	1-2	3-5	6-9	10-13	14-19	20-27	28-36					
Euro-0																	0	1	2-4	5-7	8-10	11-15	16-21	22-28	29-38			
Pre-Euro																		0	1	2-4	5-7	8-10	11-15	16-21	22-28	29-38		

Table 3 – Default values of dynamic Environment Hazard Level (EHL) of diesel-powered heavy-duty vehicles of different Euro classes and ages in view of Environment Zones unified classification

Heavy-Duty Vehicles (HDV)

Environment Zone	I						II			III			IV			V			VI									
EHL, #	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
RE, g/tkm	5	6	8	10	13	16	20	25	32	40	50	63	79	100	126	158	199	251	316	398	501	630	793	999	1258	1583	1994	2510
Euro-VI							0	1-2	3-6	7-10	11-15	16-21	22-30	31-40														
Euro-V												0	1-2	3-5	6-10	11-15	16-21	22-29	30-40									
Euro-IV													0	1	2-3	4-6	7-10	11-14	15-20	21-26	27-35							
Euro-III														0	1	2-3	4-6	7-10	11-14	15-19	20-26	27-35						
Euro-II																0	1	2-3	4-6	7-10	11-14	15-19	20-26	27-35				
Euro-I																	0	1	2-3	4-6	7-10	11-14	15-19	20-26	27-35			
Euro-0																		0	1	2-3	4-6	7-10	11-15	16-21	20-26	27-35	36-46	47-60
Pre-Euro																			0	1	2-4	5-10	11-15	16-21	22-28	29-37	38-49	50-64

In such a way, environmental zones (EZs) road signs and vehicles environmental labelling stickers will have the same system of numbering and similar design, including a colour representing EZ and vehicle emission minimal requirement stringency.

The number I EZ can be divided into two levels in the future if it will be necessary to distinguish battery-powered EVs from ultra-low emission future vehicles with improved internal combustion engines or maybe other propulsion technologies.

Presented dynamic default EHLs are a subject for revision during a vehicle periodical technical inspection or selective roadside instrumental control of emissions. Technically defective vehicles should be assigned a worse EHL via a prescribed procedure to reflect higher emissions in order to restrict its access to populated areas.

A vehicle manufacturer should have a right to determine, establish and prove another degree of vehicle environmental properties degradation intensity if being based on an appropriate program of in-use emission control and evidence of sufficiently effective treatment of fleet. It can be considered as a powerful incentive for activities to maintain vehicle emissions under prescribed limits during the whole time of life, not only during the type approval process.

Conclusions

The proposed concept of unified vehicle environmental labelling not only combine in a stable system past, current, and future technologies, and not only technologically neutral but also join on a unified basis, in a unified global system, vehicles developed, approved and produced under incompatible emission standards [66, 67] in different regions of the world.

Prospects for further research should include development first of all such technically sophisticated parts as:

▪ default values of dynamic environment hazard level (EHL) system covering all types of road vehicles and motor fuels;

▪ a system of energy efficiency indicators altogether representing more closely actual energy consumption in various concrete conditions of driving, in contrast, to test results in unified driving cycles;

▪ a system of acoustic noise (sound pressure) classification as a useful option of access differentiation base;

▪ a system of factors of intensity of road wear and formation of wear products of pneumatic tires and road surface;

▪ relevant national electronic databases and technical means of control.

Then it should be developed standards regarding at least environmental zones regulation unified framework, including vehicle labelling (both for marketing purposes in sale points and onboard stickers design) and road signs data presentation forms relevant to the concept.

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Концепція уніфікованої системи екологічного маркування дорожніх транспортних засобів

Анотація. Розповсюдження різноманітних та несумісних схем обмеження доступу транспорт-

них засобів, зокрема зон з низьким рівнем викидів, що постійно збільшується, створює надзвичайну фрагментацію правил доступу до транспортної інфраструктури європейського континенту, де автомобільний транспорт стає дорожчим, незручним та таким, що створює зайві бар'єри, перешкоджаючи економічному розвитку та міжрегіональним зв'язкам. Вищезазначене визначає гостру потребу в уніфікованій системі екологічного маркування дорожніх транспортних засобів як вирішального елементу будь-якої системи регулювання зон з низьким рівнем викидів, а також екологічного маркетингу та впливу на прийняття рішень споживачами на користь вибору екологічно сприятливих транспортних засобів. Основною метою дослідження є розроблення концепції уніфікованого екологічного маркування транспортних засобів для поєднання в стабільній системі минулих, сучасних та майбутніх технологій дорожніх транспортних засобів. Метод дослідження базується на концептуальній основі щодо структури даних екологічного маркування дорожніх транспортних засобів, необхідних для забезпечення екологічного маркетингу та управління доступом транспортних засобів до інфраструктури відповідно до аналізу позитивного та негативного досвіду безпосередньо в цій сфері, відповідних детермінант та рушійних факторів, а також питань. Дослідження визначає системний аналіз світового досвіду у сфері екологічного маркування дорожніх транспортних засобів з акцентом на диференціації доступу до зон з низьким рівнем викидів. Досліджено декілька аспектів з метою аналізу позитивного та негативного досвіду, зокрема дискредитованих зон з низьким рівнем викидів або зон з низькою ефективністю щодо зменшення забруднення повітря. Ідентифіковані ключові фактори, що призводять до невдач запровадження зон з низьким рівнем викидів або їхньої низької ефективності. Запропонована концепція уніфікованого екологічного маркування транспортних засобів не тільки поєднує в стабільній системі колишні, нинішні та майбутні технології і не тільки є технологічно нейтральною, але й об'єднує на єдиній основі, в єдину глобальну систему транспортні засоби, розроблені, затверджені та вироблені за несумісними екологічними стандартами, що впроваджені в різних регіонах світу.

Ключові слова: екологічне маркування транспортних засобів, викиди забруднювальних речовин, екологічні маркери, навколишнє середовище, управління зонами з низькими викидами, транспорт, обмеження доступу транспортних засобів, колісні транспортні засоби.

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Концепция унифицированной системы экологической маркировки транспортных средств

Аннотация. Целью исследования является разработка концепции унифицированной экологической маркировки транспортных средств для объединения в стабильной системе прошлых, современных и будущих технологий дорожных транспортных средств. Предложенная концепция унифицированной экологической маркировки транспортных средств не только сочетает в стабильной системе прошлые, нынешние и будущие технологии, является не только технологически нейтральной, но и объединяет на единой основе и в единую глобальную систему транспортные средства, разработанные, утвержденные и произведенные в соответствии с несовместимыми экологическими стандартами, внедренными в различных регионах мира.

Ключевые слова: экологическая маркировка транспортных средств, выбросы загрязняющих веществ, экологические маркеры, окружающая среда, управление зонами с низкими выбросами, транспорт, ограничение доступа транспортных средств, колесные транспортные средства.

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