

STUDY ON THE OPTIMIZATION OF DESIGN SPEEDS REQUIRED BY THE NEED TO REDUCE TRAFFIC POLLUTION

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Abstract

Pollution is closely related to traffic characteristics (vehicle fleet, its composition in terms of motorization, park maintenance level, etc.), existing road infrastructure (depending on the classification of public roads into technical classes, the level of service) and last but not least, the speed of traffic on the public road network (depending on the designed geometric elements, local context, geographical position and climate). Determining optimal traffic speeds in order to reduce pollution is a highly debated topic for all categories of public roads, including highways, which by definition are designed and executed with distinct geometric elements to ensure high-speed road traffic. When adopting the geometric elements, the design speed adopted in accordance with the legislation in force, plays an essential and decisive role both in the design of new roads and in the rehabilitation of existing ones.

The comparative study of the maximum design speeds (imposed by regulations) with the optimal ones in terms of reducing air pollution (recommended by specialized studies), can provide new perspectives from the point of view of all traffic participants by correlating the optimal average speeds with the designed geometric elements.

Key-words: Pollution, greenhouse gas emissions, motorization level, design speed, optimal traffic speed, trends in traffic speeds, adaptation of design speed, minimum fuel consumption.

1. INTRODUCTION

Air pollution occurs due to the emissions of gases, smoke and dust particles released excessively into the atmosphere, which becomes harmful to the population and the environment when certain values are exceeded.

Greenhouse gases and in particular the ratio of these gases plays an important role in determining air quality. Greenhouse gases occur naturally in the atmosphere, ensuring that the earth's surface temperature is preserved. Human

activity makes a major contribution to the excessive accumulation of these gases, causing an increase in the greenhouse effect and, consequently, global warming.

Reducing the emissions of these gases is a general worldwide goal.

2. GREENHOUSE GAS EMISSIONS (GES)

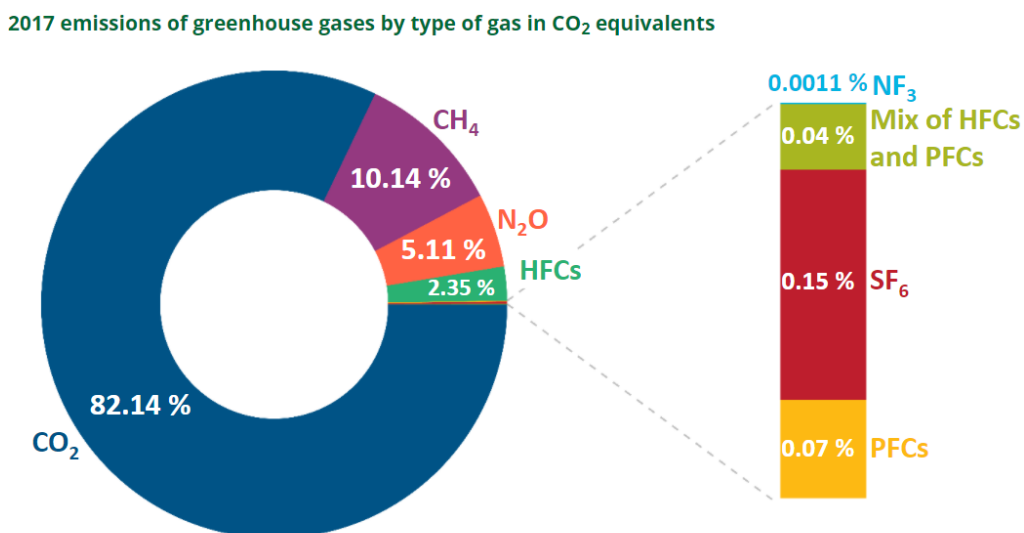
2.1 Overview of greenhouse gases

The most abundant greenhouse gases in the Earth's atmosphere are: water vapor (H₂O), carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), ozone (O₃), chlorofluorocarbons (freons) and hydrofluorocarbons. The contribution of each gas depends on a number of factors, not just on the amount emitted.

The increase in greenhouse gas emissions is primarily due to human activities, while the burning of fossil fuels, coal and oil, fuels used in all industries plays a significant role, generating significant amounts of CO₂ and other harmful substances.

2.2 Greenhouse gas emissions

According to the inventory report prepared by the European Commission in December 2017 on greenhouse gas emissions by type of gas, expressed in CO₂ equivalent, the significant share of CO₂ emissions proper can be observed in relation to other specific gases.



Source: Data on emissions from the aggregated EU inventory reported to the UNFCCC in 2019.

Figure 1. Greenhouse gas emissions expressed in CO₂ equivalent [1]

Rising greenhouse gas emissions (GHG) from human activities have made a major contribution to the increasingly higher global warming, with an alarming impact on the planet's climate patterns, on human lives and on economic development. Regional and local climate changes are affecting ecosystems and causing extreme weather events such as droughts, floods and other natural disasters. Rising temperatures pose an increased risk of damage, hence the need to address this issue is increasingly persistent at all levels - local, regional and international. [1]

2.3 Evolution of greenhouse gas emissions

In view of the concerns raised by the governments of the European Union member states regarding the implementation of comprehensive programs for the reduction of greenhouse gas emissions, we are noticing their significant decrease. According to the annual report on progress in reducing greenhouse gas emissions, there has been a 3.7% decrease in GHG emissions from one year to the next, while GDP has risen. In 2020, GHG emissions were 24% lower than in 1990. Frans Timmermans, the Executive Vice-President for the European Green Pact said, in regard to these results: “The European Union is proving that reducing emissions is possible at the same time as ensuring economic growth. Today's report, however, confirms once again that we need to step up our efforts in all sectors of the economy to achieve our common goal of climate neutrality by 2050.” [2]

The outlook for 2050 tends to significantly reduce EU emissions. In accordance with the Kyoto Protocol (1997) and the Paris Agreement (2015), to which it has committed itself, the EU intends to reduce its greenhouse gas emissions by 20% by 2020, by 40% by 2030 and by 80-95% by 2050. The results obtained so far and the estimates expected for 2050 are presented schematically, as follows:

Estimates of past and future emissions compared to the emission reduction targets

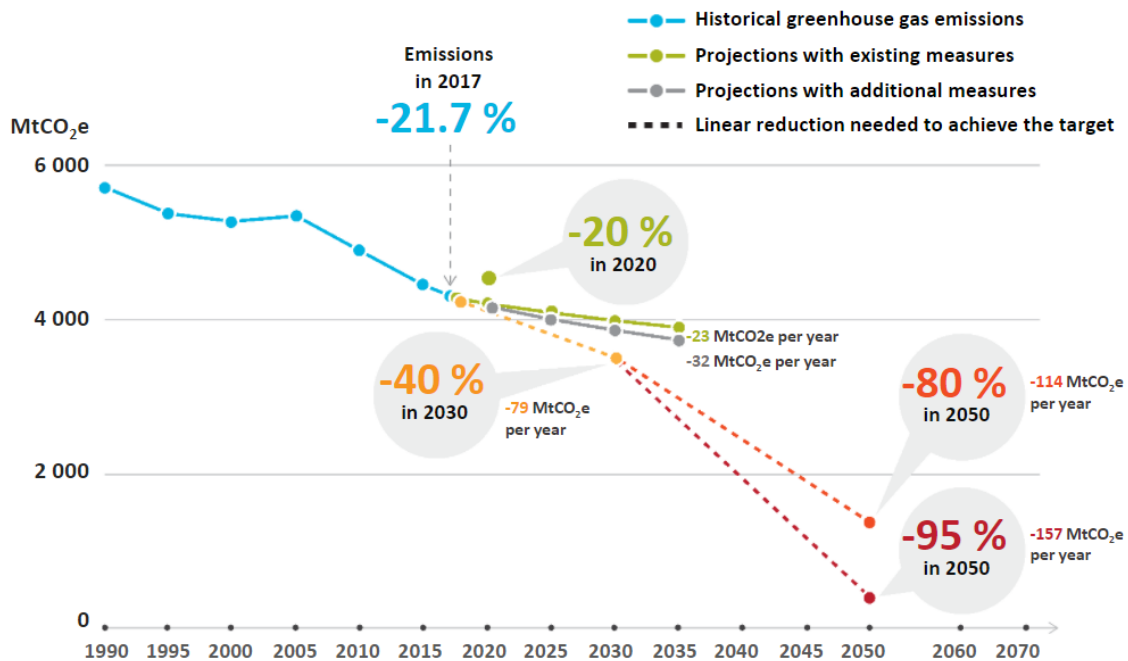


Figure 2. Estimation of GHG emission reductions at EU level [3]

Romania as an EU member state must implement all measures on reducing GHG emissions, therefore since 1990, total emissions have been reduced by about 55%. This reduction is due to the major changes that took place in 1990-2005, in the national economy, largely due to the reduction of industrial capacities. As of 2005, the policies adopted according to the European model began to take effect, with reductions in greenhouse gas emissions occurring at the same time as GDP growth. In 2019, there was a 26% decrease in emissions compared to 2005.

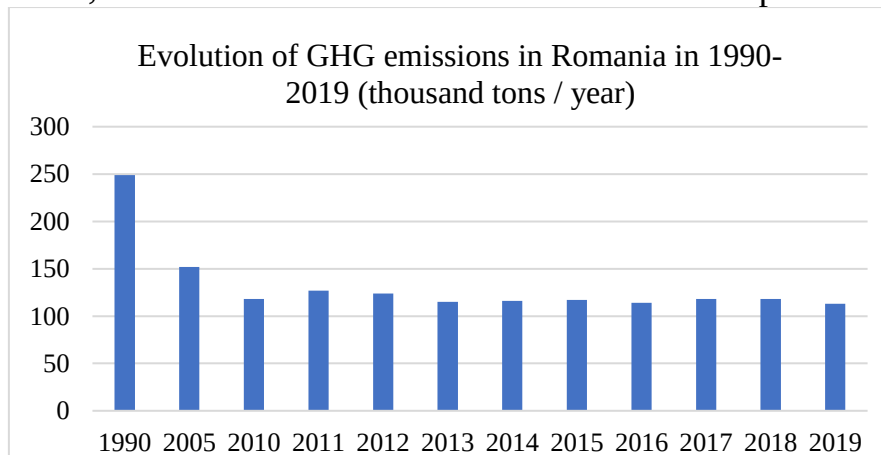


Figure 3. The evolution of the reduction of GHG emissions in Romania

2.4 Sources of GHG emissions

Analyzing the studies and reports in the field prepared by the specialized commissions of the European Union we can conclude that all economic sectors contribute to GHG emissions, while the energy sector plays a very important role, its share being much higher.[5]

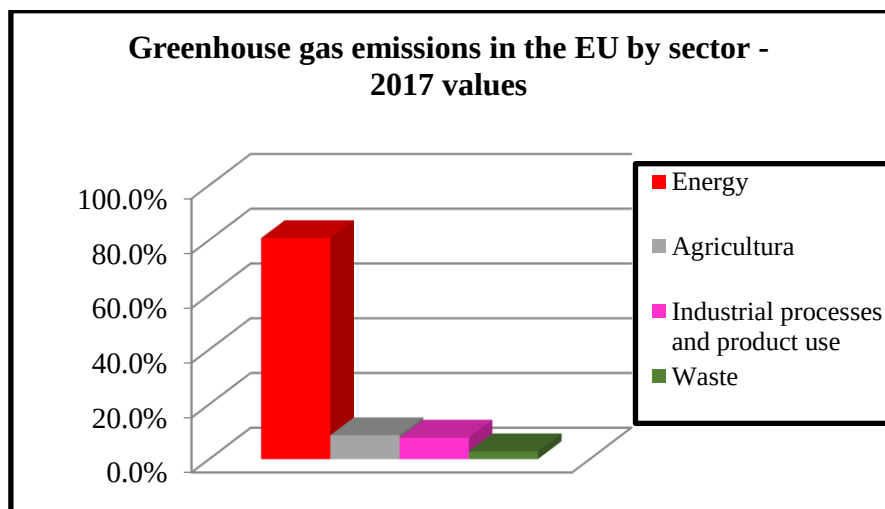


Figure 4. Share of EU greenhouse gas emissions by sector of activity (for 2017) [5]

Analyzing the greenhouse gas emissions in Romania, depending on the sector of activity, the results show percentages similar to the average values recorded in the European Union, as follows:

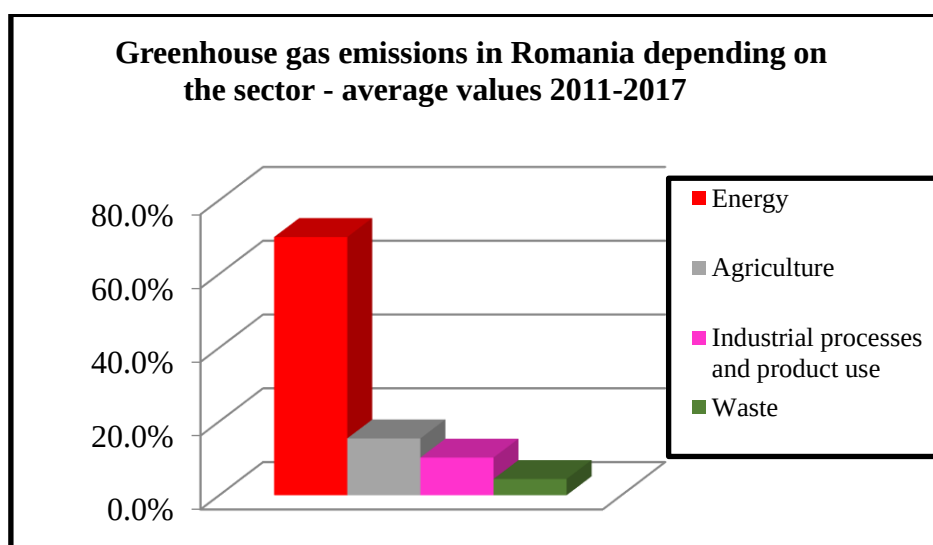


Figure 5. Share of greenhouse gas emissions in Romania by sector of activity (average values for 2011-2017) [6]

Specialized studies show that the energy sector dominates greenhouse gas emissions, therefore it is the sector for which the largest reductions are required, as a priority over other fields.

The energy sector also includes transport, with an average percentage of GHG emissions of about 24% in the EU in 2016, mainly due to domestic traffic.

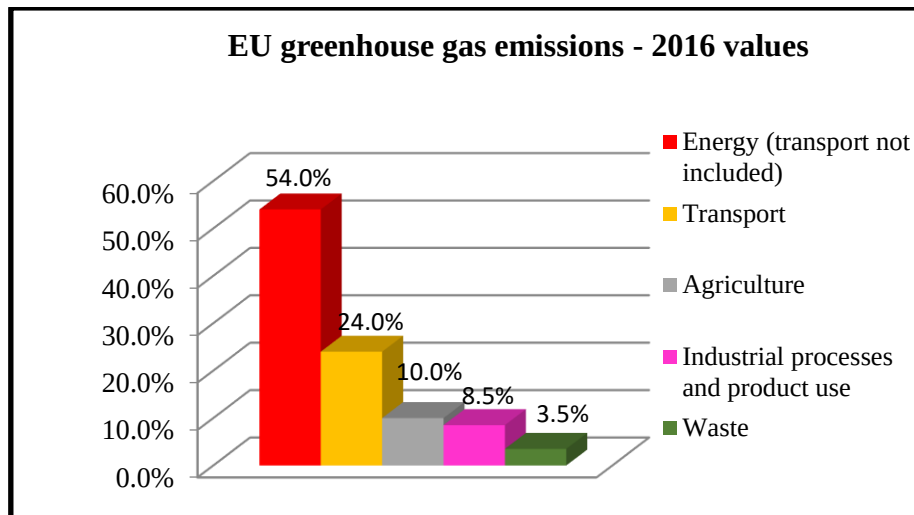
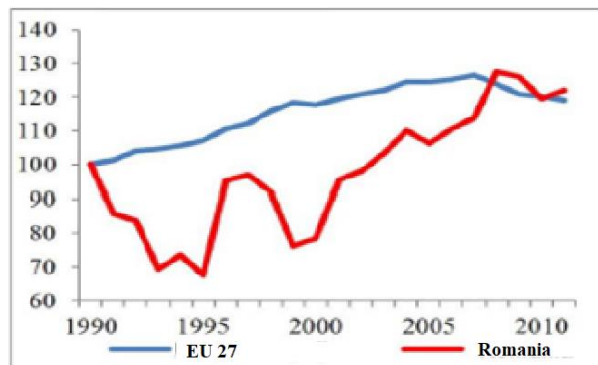


Figure 6. Share of EU greenhouse gas emissions from transport [6]

Although total greenhouse gas emissions are declining as a result of policies implemented in the EU and implicitly in Romania, the effective percentage of GHGs generated by transport shows significant growth trends compared to the values recorded in previous periods. In Romania, the percentage of emissions generated by transport is lower than the EU average, but it has a faster growing rate. The variation over time, as well as their comparison with the values recorded in the EU-27 is presented below:



Source: EEA

Figure 7. The variation of GHG emissions from transport in the EU 27 compared to Romania [7]

Although emissions from other sectors are generally declining, those from the transport sector show an upward trend from 1990 to 2016 (Figure 6). Most of the greenhouse gas emissions associated with transport are generated by road transport.

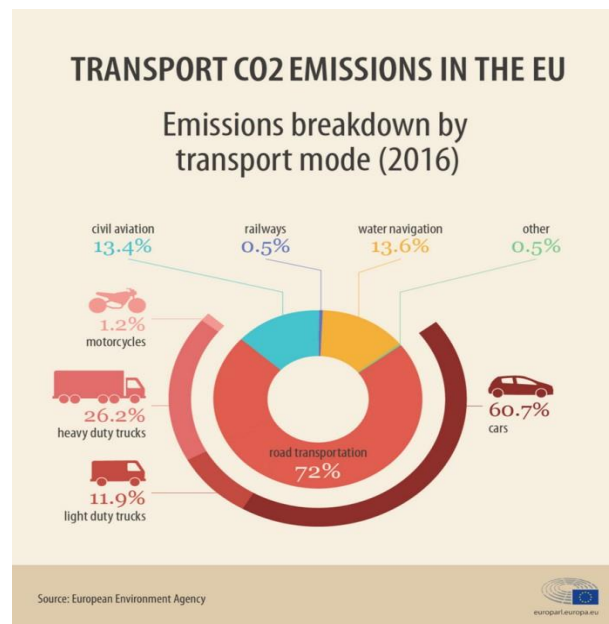


Figure 8. Transport GHG emissions in the EU [8]

3. GHG EMISSIONS GENERATED BY ROAD TRANSPORT

3.1 General information on transport

In the EU, one third of total final energy is consumed in the transport sector, most of which comes from burning fuel, which is responsible for a significant share of EU greenhouse gas emissions. Although total greenhouse gas emissions are declining, emissions from transport have increased in 1990-2020, a growing trend in the future. Due to this trend, the transport sector is a major obstacle to achieving the EU's climate protection goals. [9]

Analyzing the variation of GHG emissions generated by transports in Romania, we find an increase starting with the year 2000, a much faster growth than the EU average. As a percentage of the total GHG emissions from all sectors, transport in Romania accounts for about 14-15%, a value below the EU average of approx. 20.0%. This trend is due to the increasing share of road transport, the source of most GHG emissions in the transport sector. The analysis of the statistical data shows that the modal share of cars in Romania is around the EU

average, while the number of car owners in Romania is among the lowest in the EU. [10]

3.2 Evolution of the motorization index in Romania

The vehicle motorization index is an indicator that shows the number of cars owned by a country per 1000 inhabitants. Until 2019, Romania held the last place in terms of vehicle motorization index among the EU countries.

The National Institute of Statistics' data show a continuous increase in the number of vehicles, therefore compared to 2010, when a 5,418,989 road vehicles were registered, at the end of 2020 they amounted to 9,222,280.

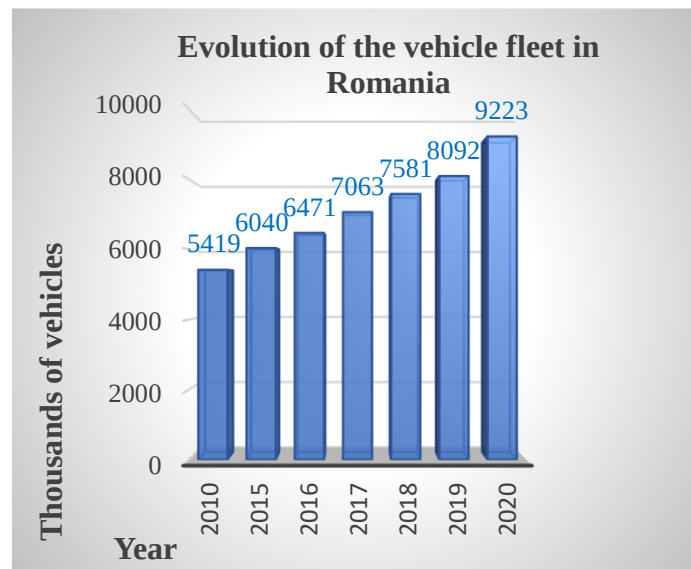


Figure 9. Evolution of the vehicle fleet in Romania [11]

The increase in the number of vehicles in the context of the current demographic decline leads to an increase in the degree of motorization.

Given the growth trends of the national economy, experience shows that the degree of motorization will continue to increase in the future.

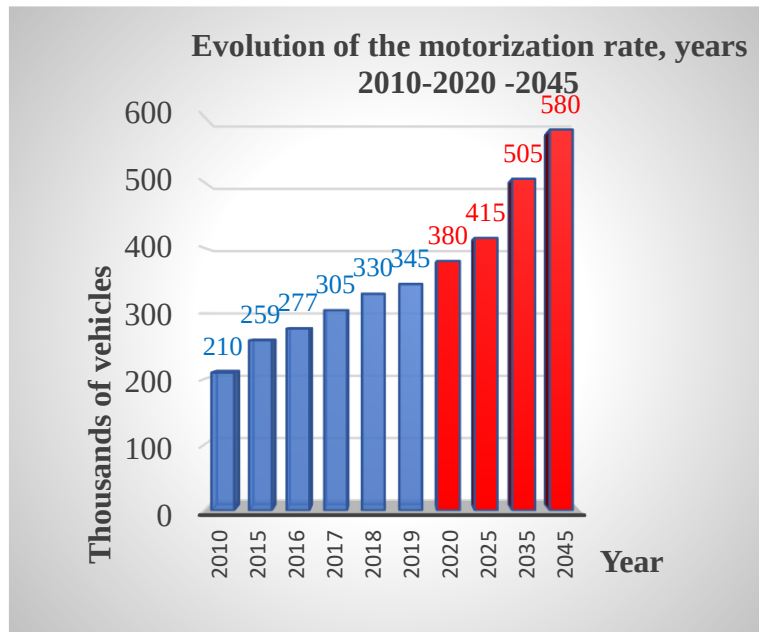


Figure 10. Evolution of the motorization rate in Romania [12]

In theory, the increase in the number of vehicles / the degree of motorization is beneficial to a country, this indicator showing the increase of the population's living standard. In Romania's case, we can say that this increase is mainly due to the excessive import of used cars from the EU, cheap and in poor technical condition. This aspect is also made evident in the figures showing the average age of the vehicle fleet in Romania, about 16.5 years, one of the highest in the EU member states, while the value of this indicator for the entire European continent is approx. 10.8 years.

Thus, as the number of cars increases in the current conditions, the increase in the volume of greenhouse gas emissions generated by traffic is inevitable, especially due to the high share of vehicles using fossil fuels (about 51% of the vehicle fleet registered in the country) are diesel-fueled and about 43% are Otto type vehicles).

Analyzing the composition of the vehicle fleet and the perspective of the evolution of traffic values, we can say that reducing greenhouse gas emissions in this sector will be particularly difficult.

3.3 The National Strategy for Reducing Greenhouse Gas Emissions

The National Strategy on Climate Change and Low Carbon Green Growth Program [13] identifies key actions for all sectors of the economy to reduce greenhouse gas emissions. For achieving the level proposed for 2030, Romania

needs additional investments that are particularly expensive, in parallel with maintaining economic growth at the expected level. Although the costs of reduction measures in transport are particularly high compared to other areas of the economy, action is essential given that the largest emissions increases are expected in this area. According to the strategy, the actions proposed for implementation in the four sectors will reduce emissions by about 25% compared to the level expected by the “status quo 2050” scenario (scenario without project). The estimated reductions for the four base sectors with the related costs are presented below.

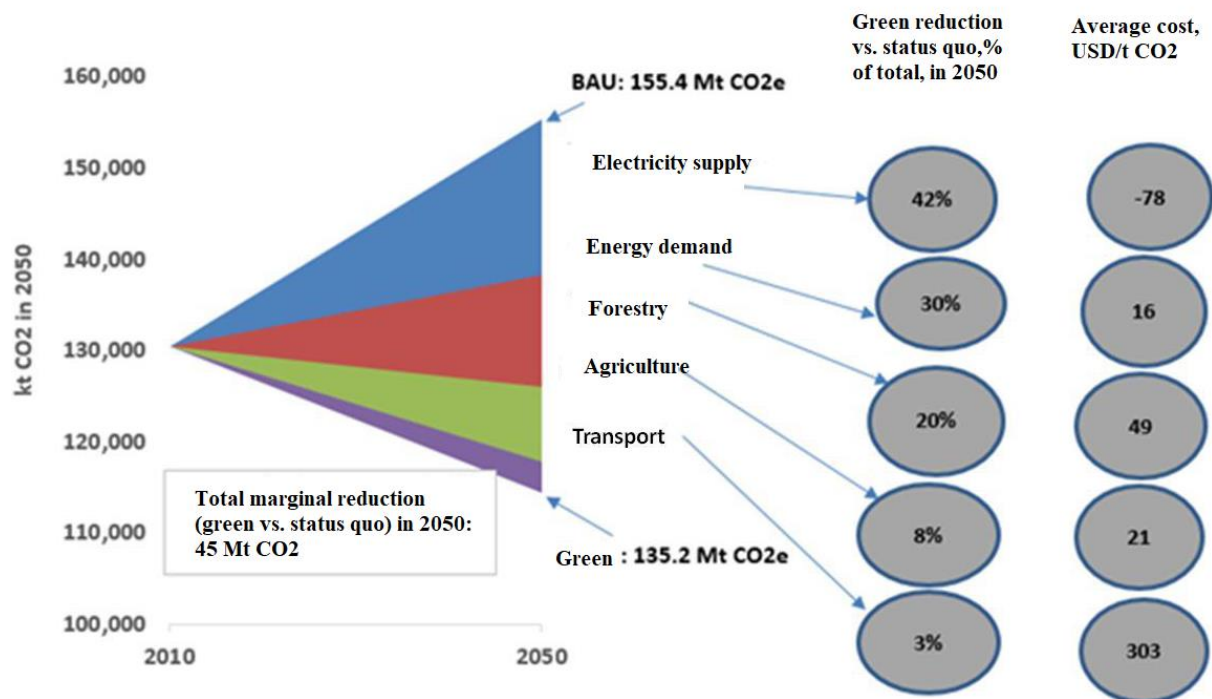


Figure 11. Emissions reductions, by sector by 2050, the average cost of green measures [13]

The strategic objectives for reducing emissions from transport cover all types of transport and are embodied in specific programs, of which we can mention:

- Increasing travel speed by updating road design regulations;
- Reducing the number of conventionally powered vehicles;
- Use of low carbon fuels;
- Completion of the TEN-T network for road and rail transport and a high-speed rail network;

- Implementation of a functional multimodal network in the entire UEC;
- Establishing connections between all the airports and seaports with the railway network (preferably high speed);
- Increasing the efficiency of transport and the use of infrastructure through the use of intelligent systems;
- Introduction of economic incentives for ecological transport;
- Stimulating the renewal of the national vehicle fleet;
- Increasing the efficiency of urban traffic;
- Increasing road safety and reducing the number of road accident victims, etc.

3.4 The Trans-European Transport Network

Starting from the climatic effects generated by traffic and the evolution data expected until 2050, following an in-depth study, the creation of the unified transport network at European level was born, called TEN-T and it aims to make connections between the different modes of transportation, as well as between European regions. The TEN-T network has two basic components: the core network (with completion prospects in 2030) and the connection network that provides access to local traffic (with completion prospects in 2050) to the core network.

The analysis of the TEN-T network reveals that Romania is connected to the east and west to the central network through high-speed roads (highways) with superior geometric elements that ensure constant speeds, cross-border connections, access to different safe and high flow modes of transportation by optimizing infrastructure, increasing efficiency and reducing greenhouse gas emissions.

According to the data presented, road traffic in Romania has higher growth prospects than the average data expected in the EU, which in itself leads to an increase in greenhouse gas emissions. This is exacerbated by the current composition of the vehicle fleet, which will have negative long-term effects on the results obtained in the field of environmental protection.

Given the characteristics of existing traffic and the existing public road network, in parallel with the policies implemented as an EU Member State, we consider it would be beneficial to study certain technical aspects aimed at adopting functional parameters for public roads, differentiated according to traffic composition, land conditions, the administrative and functional framework of the public road, taking into account the objectives of reducing greenhouse gas

emissions (pollution). By optimizing some technical parameters depending on the importance and role of the public road, we can ensure traffic conditions that lead to the reduction of greenhouse gas emissions and implicitly to the achievement of the target goals from the environmental point of view. The detailed and customized study of the technical parameters is very important because in Romania the existing network of public roads consists mainly of the existing assets, as the length of the new road sectors (mainly highways) is particularly low.

4. DESIGN PARAMETERS

4.1 Overview of the public roads in Romania

The increase of mobility and the evolution of passenger and freight traffic requires the expansion and modernization of transport infrastructure for every state.

According to the National Institute of Statistics, road travel in Romania accounts for about 75% of all travels made for the purpose of passenger transport and just under 50% of the travels for the transport of goods (NIS, 2010 data). These statistics show that in both cases, road transport is the most important and used mode of transport. [14]

The road transport system consists of two basic elements: the vehicle and the road. The entirety of road communication routes intended for vehicular traffic are composed of routes located outside the built-up area and within the built-up area of the localities included in the category of public roads. From the point of view of reducing greenhouse gas emissions, a number of programs and treaties can be identified that refer primarily to the "vehicle" component and almost not at all to the "road" component, although both elements play a key role in determining traffic conditions. [15]

Improving traffic conditions in the country can be achieved either by expanding the network of public roads (construction of new routes according to specific parameters) or with the rehabilitation / modernization of the existing routes, based on a detailed development plan that sets out the main objectives starting from the technical condition of the existing network at a given time.

When planning the works, a number of basic principles are taken into account, such as:

→ giving priority in planning works for roads in the trans-European TEN-T network or those open to international traffic, important routes from an economic, administrative and tourist point of view;

- creating organic links between the different categories of roads (motorways, express roads, European national roads, main national roads, secondary national roads, county roads, rural roads, inter-village roads and streets) in order to ensure a network of functionally and technically homogenous unitary roads in accordance with the requirements of the national economy;
- determining specific routes and parameters in terms of traffic and operational safety;
- assessment of the technical condition of the existing network;
- determining the required intervention works for ensuring the functional parameters;
- the possibility of including them in operational programs and ensuring the financial resources necessary to carry out the planned investments.

4.2 Technical characteristics of public road routes

Establishing the technical characteristics when designing a new road or modernizing an existing road is a complex activity that starts from the classification of the road in terms of traffic and the administrative role to which it must correspond for the expected prospective duration.

According to Government Decree No. 43/1997 [16] on the legal status of roads, including subsequent amendments and additions, the classification of roads is made from several points of view, as follows:

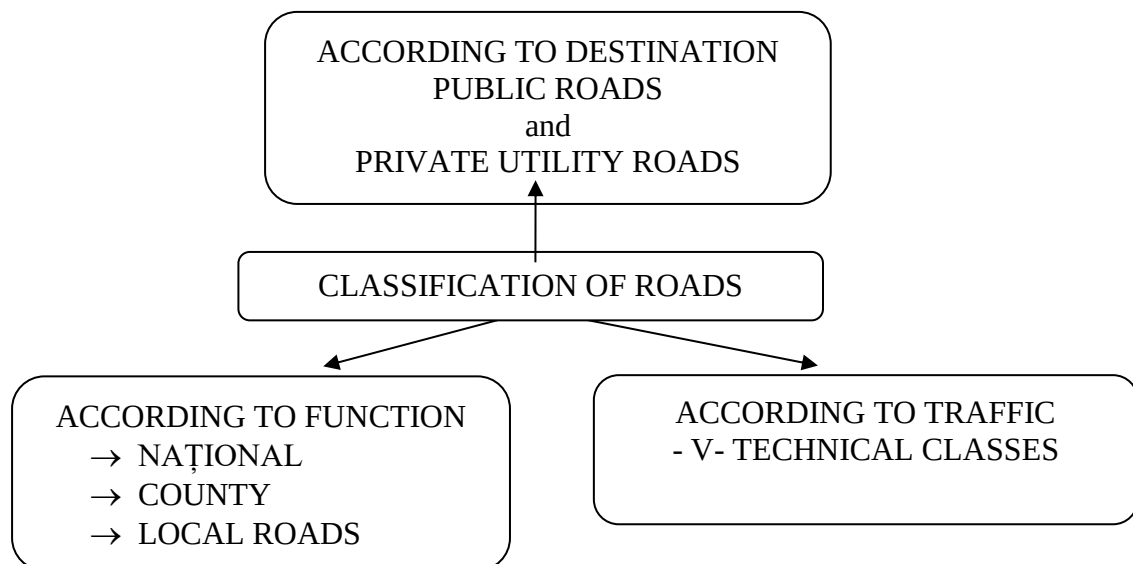


Figure 12. Classification of public roads according to O.G. no. 43/1997 [16]

Depending on the estimated traffic values, public roads fall into five traffic classes called technical classes. The correlation of road categories from an administrative and functional point of view with the technical classes determined in accordance with the current rules is carried out as follows:

Table 4.1 Technical classes / Traffic characteristics - Decree 1295-2017 [17]

Public road technical class	Name of traffic intensity	Average annual daily intensity		Recommended road type
		Standard (vehicles)	Headcount (physical)	
I	Very intense	> 21.000	> 16.000	Motorways or express roads
II	Intense	11.000-21.000	8.001-16.000	Express roads or 4-lane roads
III	Average	4.501-11.000	3.501-8.000	European national roads, main national roads and county roads
IV	Low	1.000-4.500	750-3.500	Main national roads, secondary national roads, county roads and rural roads
V	Very low	<1.0000	<750	Secondary national roads, county roads, rural roads and inter-village roads

The design of new roads and the modernization / rehabilitation of existing ones is based on the adoption of technical parameters related to the classification of the road into technical classes (depending on traffic), administrative classification, land conditions, etc. as follows:

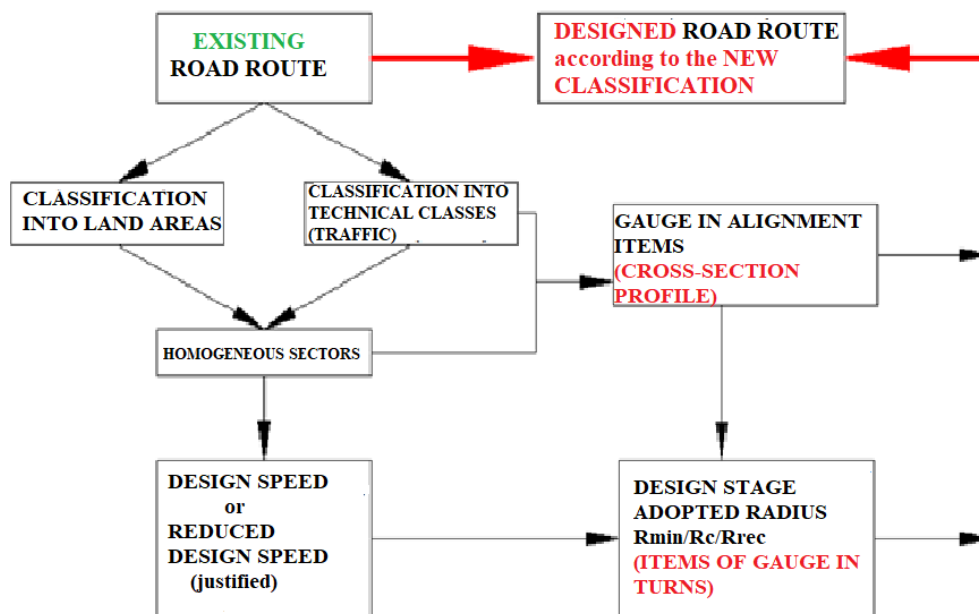


Figure 13. Classification of public roads according to OG no. 43/1997[16]

Items are adopted into the plan based on STAS 863-85 [18] depending on the design speed. We can see that the current valid standards and norms do not specify issues related to optimal traffic conditions in terms of gas emissions or environmental protection although these items are becoming increasingly important in terms of future traffic conditions.

The natural question is related to the interdependence between the basic parameters adopted in the design process that characterize a road route and the level of gas emissions resulting from the traffic on the resulting route.

4.2.1 Design speed or base speed

Design speed is the basic parameter that defines the basic parameters of a new route or existing road route proposed for modernization. The basic speeds are chosen according to the expected technical class and the specific land of the studied sector. We should point out that currently the local legislation (STAS 863/85, respectively Decree 1296/2017) contains small divergences regarding the minimum design speeds (km/h).

Table 4.2 Design speed (base) – STAS 863/85 [18] respectively Decree No.1296-2017[19]

Road's technical class	Minimum / maximum number of lanes	Width of the lane	Minimum design speed (km/h)			Road type
			lowland	hill	mountain	
I	min. 2 lanes / direction	3,75	140	120	100	Motorways
II	min. 2 lanes / direction	3,50	100 120	80 100	60 80	Express roads and European national roads 4-lane roads
III	2	3,50	80 100	50 80	40 60	European national roads, main national roads and county roads
IV	2	3,00	60 80	40 60	30 50	Main national roads, secondary national roads, county roads and rural roads
V	2	2,75	40 60	40 50	25 40	Secondary national roads, county roads, rural roads and inter-village roads

Comparing the values from the two collectively valid normative documents, it can be seen that there is a tendency to increase the design speeds

for all categories of roads. The natural question is how do vehicles on these routes perform in terms of greenhouse gas emissions.

Analyzing the variation of greenhouse gas emissions depending on speed, we can conclude that the engines work optimally in terms of fuel consumption in the range of 55-85 km/h for the average speed of travel. Optimal fuel consumption leads to minimal greenhouse gas emissions. Each type of vehicle has a specific speed range that leads to minimum fuel consumption, depending on engine type, fuel, age and load. In addition to the mechanical characteristics, we must also take into account the driving style of each driver, as well as traffic congestion.

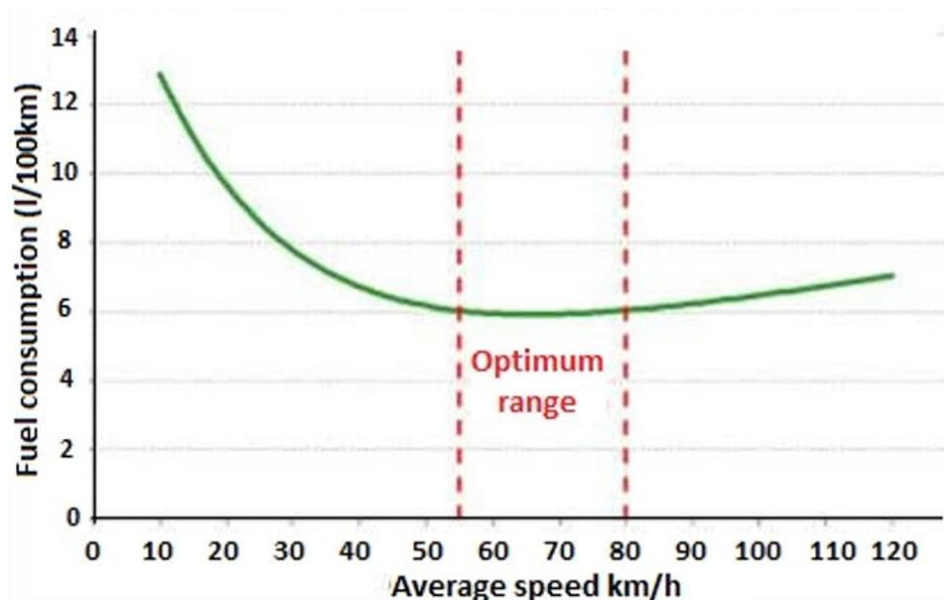


Figure 14. Fuel consumption depending on the speed [17]

Analyzing the design speeds imposed by the normative acts, we can observe that on high-traffic public roads (technical class I, II and part of III) the design speed is 80km/h only in the hill and mountain regions, and in all the other areas the design speeds lead to fuel consumption and implicitly higher greenhouse gas emissions.

Adapting traffic speed to the road conditions means, in fact, travelling the route at a speed close to the design speed, depending on the vehicle. We must point out that vehicles travel a given route at a given speed depending on the existing facilities:

- Connection radius to the flat turns with the superelevation resulting from the facility;
- Longitudinal slope;
- Vertical connection;

- Gauge items in cross-section profile;
- Characteristics of road surface.

From these considerations it follows that the parameters that define the characteristics of a route have a significant effect on greenhouse gas emissions.

Analyzing the research conducted in the field [Environmental effects of road geometric and operational features – Frederica Nobili, Francesco Bella, David Llopis-Castello, Francisco Javier Camacho-Torregrosa, Alfredo Garcia], published in 2018 on the occasion of the 21stEURO Working Group on Transportation Meeting, we can conclude that the gas emissions are largely affected by speed variations (accelerations / decelerations) performed by drivers, either due to the driving style, or to the need to adapt the speed to traffic conditions. The study is based on the results obtained by non-linear modeling of fuel consumption and greenhouse gas emissions for different types of vehicles. (El-Shawarby et. al. 2005) and indicates the speed range shown in Figure 14. It should be noted that the literature in the field contains numerous studies on fuel consumption and / or greenhouse gas emissions, depending on the speed of vehicles and only a small number of studies that take into account and analyze the effect of the geometric parameters of the road.

We should emphasize some conclusions taken from the specialized studies that refer to the effect of the technical design parameters on greenhouse gas emissions:

- Fuel consumption has a parabolic variation depending on the longitudinal slope (Boriboonsomin and Barth-2009) which has significant effects on light-duty vehicles;
- Increasing the longitudinal slope by 1% leads to an increase in emissions by a percentage of min. 9% (Park and Rakha-2006);
- Decreasing the speed by 20 km/h compared to a decrease of 10 km/h, due to the longitudinal slope, leads to a higher increase in fuel consumption (Ko et al.-2013);
- Fuel consumption decreases along the length of the vertical connection curve as the connection radius increases, provided the speed is maintained (Ko et al.-2012).

5. CONCLUSIONS

Climate change due to the effects of greenhouse gas emissions is an issue that remains the focus of international attention. The programs implemented to reduce these emissions are beginning to show the first results, but there are still a

number of problems in the various branches of the economy that have not been properly studied.

We can see that greenhouse gas emissions have reached a downward trajectory in terms of total values, but there are still industrial sector, such as transport s in which there have been increases in values.

Given that economic development entails increased transport, expected growth in the coming periods (forecasts to 2050) reveals a natural necessity to study / look for alternatives that can lead to lower gas emissions from transport, especially road transport.

In road transport there are several trends in reducing greenhouse gas emissions with reference to the component: VEHICLE, while there are very few studies and trends on the component: ROAD.

A trend that becomes clearly outlined regarding the ROAD component is reflected in the increase in design speeds without making any reference to the optimal traffic speeds in terms of greenhouse gas emissions.

The design speed entails the provision of technical components for public roads classified in different technical and administrative classes.

There are numerous studies in the field that research fuel consumption and / or greenhouse gas emissions, depending on the speed of vehicles and a very small number of studies that take into account and analyze the effect of the geometric parameters of the road.

The current local design normative acts and standards contain no provisions regarding the implementation of the environmental factor for the purpose of reducing greenhouse gas emissions. Considering the aspects presented above, we believe it is quite necessary to initiate some steps regarding the introduction of some design criteria that also consider the aspects of reducing the toxic emissions on all types of public roads.

New road classification criteria could also be implemented in order to obtain a network of high-speed roads (Motorways / Expressways / European National Roads / Bypass Roads) and a network of roads of local interest (National / County / Rural) where the components required by environmental protection and in particular the reduction of greenhouse gas emissions are the basic criterion in terms of route design.

Thus, increasing the design speed by norms by 10 to 20 km/h would significantly reduce pollutant emissions and bring enormous benefits to the environmental impact.

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