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CALCULATING THE CARBON FOOTPRINT WITHIN THE FIELD OF ROAD FREIGHT TRANSPORT: A SPECIFIC APPROACH

Road freight transport is the most used means of transportation, due to convenience and adaptability. Therefore, this sector is predicted to continuously grow over the course of the years. However, internal-combustion engines used in road freight transport are responsible for a high proportion of the total air pollution. Determining the carbon footprint for organizations that operate within this specific industry represents a necessity from both environmental and economic points of view. The purpose of this paper is to calculate the carbon footprint of a freight transport organization and identify solutions that can be put into practice in order to decrease the level of CO_2 emissions.

Keywords: Carbon footprint; road freight transport; internal-combustion engine; CO_2 emissions; air pollution

1. Introduction

Air pollution has become one of the world's most difficult challenges to confront. Due to high industrial development, consumerism and increased emissions of various pollutants, including, but not limited to carbon dioxide (CO_2), particulate matter, nitrogen oxides, sulfur dioxides and volatile organic compounds. These pollutants cause serious harm not only to the environment and global climate, but also to individual human health, facilitating the development of respiratory diseases [1]. According to studies carried out by the World Health Organization, most of the world's population (99%) lives in areas in which air pollution exceeds the standard guideline limits, causing millions of deaths yearly [2]. Therefore, it is of utmost importance to reduce the levels of air pollution globally, to ensure a better quality of life and reduce the impact of climate change on the whole planet. While reducing the level of all pollutants should be the main objective, secondary objectives consist of finding methods of reducing the levels of each pollutant. One solution is not feasible due to the different chemical components, as well as the diversity of the industries that are responsible for these agents.

Even if in the past decade there were numerous discussions regarding the impact of CO_2 emissions on global climate change, it has been observed that the growth rate of CO_2 emissions has only increased [3]. Taking into account the fact that CO_2 is one of the main pollutants that affect not only the planet, but also human health and living conditions, it is of utmost importance that solutions for decreasing such emissions are identified and put into practice. The longer the issue persists, the greater the damages.

Road freight transport represents one of the industries that has a high contribution in global air pollution, releasing big quantities of pollutants such as CO_2, particulate matter and nitrogen oxides into the atmosphere. Whereas all these pollutants are generated through operations carried out in this industry, this paper shall focus solely on CO_2 emissions and identifying solutions to facilitate the decrease of a transport organization's carbon footprint.

The purpose of this article is to analyze the activities carried out by a road freight transport organization and assess the level of emissions caused. To accomplish this goal, it is necessary to identify the sources of direct and indirect emissions and assess their impact. Furthermore, this paper aims to calculate the carbon footprint of the organization.

2. Literature review

One of the biggest challenges the world is facing nowadays is climate change, which is fueled by increased levels of pollution. One of the main human-made factors that increase the levels

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of air pollution and, at the same time, enhance climate change, is the burning of fossil fuels [4]. Through continuous and growing use of non-renewable energy sources, more and more pollutants are released into the atmosphere, causing serious harm not only to the environment, but also to human health. All over the world, governments have tried to impose policies for regulating the levels of emissions of organizations to reduce their emissions and, in turn, decelerate climate change [5,6]. However, most of these policies fail to actually decrease the levels of air pollution, as most of them simply impose taxes on higher emissions.

CO_2 emissions, especially those generated by vehicles, contribute greatly to air pollution. A sustainable approach could increase the economic growth of the transport industry, while, at the same time, reducing its negative impact [7]. Therefore, to minimize air pollution and decrease the risks associated with this issue, it is necessary to properly understand the problem and how it can be tackled. The following section aims to provide valuable insights regarding the concepts of air pollution, CO_2 emissions and the carbon footprint, standing as a pillar for the study.

2.1. Air pollution

The main air pollutants are particulate matter (PM 10), fine particulate matter (PM 2.5), ammonia, methane, ozone, nitrogen oxides, sulfur dioxide and non-methane volatile compounds, and finally, CO_2 [1]. These substances are harmful by themselves, as well as through their interactions, causing serious damage to the environment and human health. To ensure a better quality of life, it is necessary to take action against air pollution as soon as possible.

The decomposition of air pollutants may even take up to six decades [8]. Thus, it is of utmost importance to ensure that air pollution levels decrease as soon as possible. It has been observed that greenhouse gas (GHG) emissions, especially those related to the transport industry, have severely increased globally over the past two to three decades [9]. Heavy duty vehicles account for 6% of the total GHG emissions measured in Europe [10], as shown in Fig. 1.

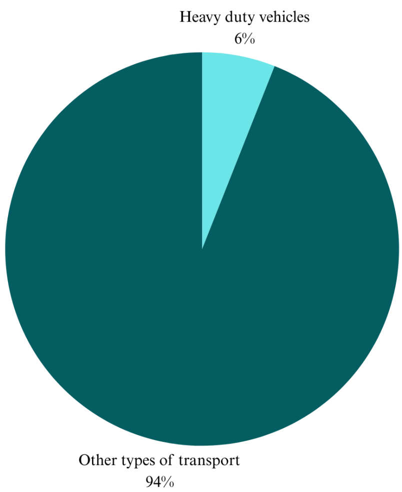

Fig. 1. Total GHG emissions measured in Europe

Considering the fact that the road freight transport industry is one of the industries that has showcased continuous growth, and, at the same time, is one of the main sources of GHG emissions [11], it is necessary to act now to reduce its harmful effects.

2.2. CO_2 emissions

Furthermore, road freight transport accounts for 73% of the CO_2 emissions related to heavy duty vehicles [10], as shown in Fig. 2.

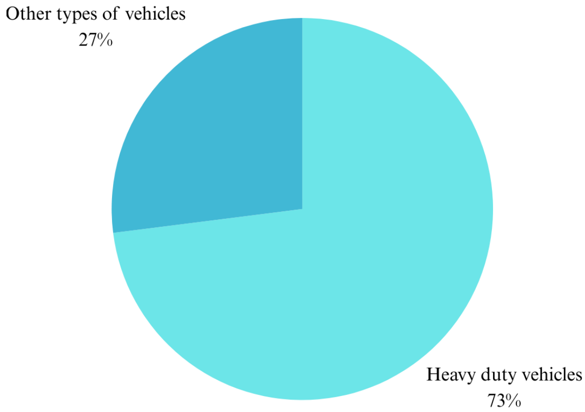

Fig. 2. CO_2 emissions for road freight transport

Furthermore, it has been proven that CO_2 emissions of an organization vary between seasons, showcasing that the level of emissions increases in winter due to the use of heating systems [12]. Furthermore, due to the environmental conditions such as temperature, wind and snow, the fuel consumption of vehicles increases in wintertime [13]. Therefore, in order to properly calculate the levels of CO_2 emissions, it is necessary to take into account all the factors that can contribute to a higher level of such emissions.

2.3. The carbon footprint

The carbon footprint is a useful tool for identifying the amount of CO_2 emissions produced by an organization, either directly or indirectly through carrying everyday activities [14]. Furthermore, this tool can be used as a starting point for reducing the level of greenhouse gas emissions of the company.

The calculation of the carbon footprint, which includes all the activities carried out at the level of one organization, serves as the basis for climate protection programs within the organization [15]. In addition, calculating the carbon footprint raises awareness both inside and outside of the organization regarding how the company and its activities affect the environment.

The carbon footprint can be seen as a predecessor to calculating the total GHG emissions of an enterprise [16]. The benefits of calculating the carbon footprint relate to better risk management practices, facilitating participation in mandatory

GHG reporting programs. What is more, calculating the carbon footprint, identifying and implementing solutions to decrease it may lead to lower costs for the organization in the long term.

3. Methodology

The research was carried out according to specific project guidelines that were imposed by the organization. This article summarizes the findings of the study and aims to provide a clear view regarding the specific carbon footprint of a road freight transport organization. To determine the carbon footprint, it is necessary to assess all of the systems that, directly or indirectly, contribute to the total level of CO_2 emissions. Therefore, an inventory of such systems has been carried out and presented in this paper. Taking into account the fact that different systems are powered by different types of energy, it is necessary to evaluate the energy consumption for each type of consumer and then express all values in a common unit of measurement. Furthermore, in order to determine the carbon footprint of the organization it is necessary to determine the amount of carbon emissions for both transport operations and secondary activities.

The organization also operates as a freight forwarder. Even if these activities also generate a high level of CO_2 emissions, it is nearly impossible to calculate the emissions for this type of activities due to lack of access to proper information regarding the emissions of suppliers.

3.1. Company overview

The company that was analyzed is a medium-sized business entity with more than 20 years of experience in the market of road freight transport. The main field of activity of the company is road transport of goods. To carry out its activity successfully, the company operates through its own fleet of 67 trucks. Secondly, to be able to honor all contractual obligations and respond to all customer requests, the company also operates as a freight forwarder. Fig. 3 illustrates the proportion of transport activities carried out through its own fleet and through freight forwarding operations.

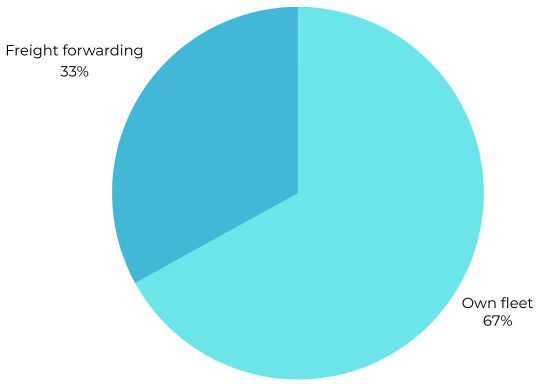

Fig. 3. Transport operations distribution: owned fleet versus freight forwarding

To ensure the continuity of daily transport operations, as well as their safety in terms of the means of transport used, the company carries out service activities exclusively for its own fleet. These activities are carried out on the premises of a service location, where multiple service equipment, specific machines and the necessary products can be found.

3.2. Inventory of technical systems that pollute the atmosphere

In carrying out the company's daily activities, multiple technical systems are used. This section will identify the main types of technical systems used according to their place and purpose. Thus, the type of system as well as the equipment used is divided into 3 categories: office supplies, service, transport and internal mobility.

Within the first category, types of systems used in the conduct of office operations will be mentioned. The following technological systems are used to perform the operations: scanner, Xerox Multifunction Unit, computers, mobile phones, laptop. Also, other technological systems used within the company to increase employee comfort are air conditioner and heating system using natural gas.

The second category comprises of equipment used in truck repair and maintenance activities emit dust, gases and/or smoke, thus polluting the atmosphere. Within the selected organization, the following technological systems can be identified: lathe, welding machine, angle grinder, self-tapping, crane.

Furthermore, the third category includes the main sources of air pollution within the company. The fleet through which it operates totals 67 units made up of tractors and trailers. Thus, in this category we can fit the different types of assemblies consisting of a tractor and a trailer, depending on their emission class: Euro 3, Euro 4, Euro 5 and Euro 6. In addition, the company owns a fleet of 10 vehicles used for carrying out activities related to road freight transport. All the vehicles used by the organization use diesel. The inventory of the vehicles used by the company to carry out transport operations and related activities, specifying the number of units, power and specific consumption of each system is presented in TABLE 1.

TABLE 1

Inventory of the vehicles used

System type	Quantity (units)	Power (kW)	Specific consumption (%/100 km)
Euro 3 truck	1	316	38
Euro 4 truck	1	346	37.5
Euro 3 car	1	85	7.3
Euro 4 car	2	63	6.1
Euro 5 car	2	95	5.6
Euro 5 truck	19	331	36.5
Euro 6 car	5	160	7.3
Euro 6 truck	46	309	37.5

4. Results

The operation of any system requires the consumption of an amount of energy. From this perspective, the energy consumed will be classified into two categories: Type C and Type E. Type C energy is the energy that is provided by classic fuel (heavy fuel, diesel, gasoline, coal from various categories), whereas Type E energy is electricity supplied from the national energy network or from another source.

It is known that most types of classical fuel are substances whose composition is not constant. That is why the calorific value varies depending on the type of fuel. To have a common term of comparison, the International Energy Agency (English International Energy Agency – IEA) recommended to consider a calorific value of 10,000 kcal/kg, and as the value of the calorie to take *the international calorie,* equal by definition with 4.1868 J. In this study, the value associated with 1 *toe* is rounded up to 42 GJ.

4.1. Determination of fuel consumption related to the road transport of goods

The annual fuel consumption (Diesel) related to the logistics operations is presented depending on the emission class of the truck used. To determine the fuel consumption per trip, Eq. (1) will be used:

$$C_{per\ load} = \frac{C_{per\ 100\ km} * km}{100} \qquad (1)$$

Where: $C_{per\,load}$ – fuel consumption per trip; $C_{per\ 100\ km}$ – consumption per 100 kilometers traveled; km – the number of kilometers traveled.

TABLE 1 showcases typical routes for one heavy duty vehicle used for road freight transport, over the course of one year. This table is representative for understanding how this sector

TABLE 2

Monthly and annual fuel consumption for EURO 6 trucks

Month	Route	Goods	Km	No. of routes	Fuel consumption per 100 km (litres/100 km)	Consumption per route	Monthly consumption
1	2	3	4	5	6	7	8
January	Lehliu – Constanta	Sunflower meal	167	3	37.50	62.63	1284.75
	Constanta – Lehliu	Rape	167	2	37.50	62.63	
	Buzau – Constanta	Sunflower meal	236	5	37.50	88.50	
	Brăila – Constanta	Barley	103	1	37.50	38.63	
	Constanta – Făurei	Soybean meal	218	6	37.50	81.75	
February	Constanta – Făurei	Soybean meal	218	3	37.50	81.75	969
	Fundeni – Constanta	Wheat	225	2	37.50	84.38	
	Slobozia – Brothers	Sunflower meal	198	4	37.50	74.25	
	Constanta – Ivesti	Soybean meal	269	2	37.50	100.88	
	Slobozia – Căzanesti	Sunflower meal	30	5	37.50	11.25	
March	Slobozia – Căzanesti	Srot sunflower	30	5	37.50	11.25	733.875
	Constanța – Căzănești	Soybean meal	174	2	37.50	65.25	
	Căzănești – Cocorăști	Husk rice	133	5	37.50	49.88	
	Oltenița – Lehliu	Rape	68	3	37.50	25.50	
	Lehliu – Banca	Soybean meal	295	2	37.50	110.63	
April	Constanta – Făurei	Soybean meal	218	1	37.50	81.75	1233.375
	Brăila – Constanta	Barley	203	2	37.50	76.13	
	Buzau – Constanta	Sunflower meal	236	5	37.50	88.50	
	Constanta – Bacău	Soybean meal	380	3	37.50	142.50	
	Tecuci – Buzau	Sunflower	115	3	37.50	43.13	
May	Sahateni – Lumina	Fodder	252	3	37.50	94.50	932.25
	Tecuci – Buzau	Sunflower	115	3	37.50	43.13	
	Constanta – Cotești Gara	Soybean meal	274	3	37.50	102.75	
	Constanța – Căzănești	Soybean meal	174	1	37.50	65.25	
	Lehliu – Targu Frumos	Soybean meal	389	1	37.50	145.88	
June	Roman – Constanța	Sunflower	459	3	37.50	172.13	1250.625
	Constanta – Brăila	Barley	203	5	37.50	76.13	
	Brăila – Calarasi	Sunflower	148	1	37.50	55.50	
	Lehliu – Targusor	Soybean meal	389	1	37.50	145.88	
	Brăila – Constanta	Sunflower	203	2	37.50	76.13	
July	Făcăeni – Constanta	Barley	105	10	37.50	39.38	1314
	Constanța – Săhăteni	Soya beans	247	4	37.50	92.63	
	Sageata – Constanta	Wheat	253	4	37.50	94.88	
	Movila – Constanta	Rape	106	1	37.50	39.75	
	Negru Vodă – Constanța	Rape	58	6	37.50	21.75	

TABLE 2. Continued

1	2	3	4	5	6	7	8
August	Făcăeni – Constanta	Barley	105	9	37.50	39.38	1527.75
	Constanta – Făurei	Soybean meal	218	8	37.50	81.75	
	Mărculești – Constanta	Wheat	153	4	37.50	57.38	
	Crisan – Constanta	Wheat	74	7	37.50	27.75	
	Mihăilești – Constanța	Wheat	255	1	37.50	95.63	
September	Constanța – Tufești	Soybean meal	163	3	37.50	61.13	1358.25
	Buzau – Constanta	Sunflower meal	236	6	37.50	88.50	
	Constanța – Banca	Soybean meal	343	3	37.50	128.63	
	Constanta – Târgu Frumos	Soybean meal	468	1	37.50	175.50	
	Focuri – Iasi	Sunflower	44	5	37.50	16.50	
October	Târgu Frumos – Constanta	Sunflower	468	1	37.50	175.50	1225.125
	Constanța – Săhăteni	Soybean meal	247	4	37.50	92.63	
	Mihăilești – Constanța	Maize	255	4	37.50	95.63	
	Constanta – Bacău	Soybean meal	373	1	37.50	139.88	
	Carligi – Constanța	Sunflower	418	1	37.50	156.75	
November	Constanța – Banca	Soybean meal	343	2	37.50	128.63	1061.25
	Belcești – Constanta	Maize	487	2	37.50	182.63	
	Constanța – Tufești	Soybean meal	163	2	37.50	61.13	
	Traian – Lehliu	Soy beans	161	2	37.50	60.38	
	Fundeni – Constanta	Sunflower	261	2	37.50	97.88	
December	Constanța – Banca	Soybean meal	343	3	37.50	128.63	969.375
	Dagata – Buzau	Sunflower	257	2	37.50	96.38	
	Galati – Constanța	Barley	230	2	37.50	86.25	
	Iasi – Buzau	Sunflower	282	1	37.50	105.75	
	Constanta – Ploiesti	Soybean meal	300	1	37.50	112.50	
					Annual consumption		13859.625

operates, highlighting the routes, the number of routes per month, number of kilometers per route, the specific fuel consumption, the monthly and the annual consumption. The consumption was calculated according to Eq. (1).

To be able to determine the amount of fossil fuels used for road freight transport operations, the whole fleet needs to be analyzed. TABLE 3 showcases the annual consumption according to each type of heavy-duty vehicle used and the annual fuel consumption for the whole fleet, expressed in liters.

TABLE 3

Monthly and annual fuel consumption for the whole truck fleet

Truck type	Number of units	Annual consumption (l)
Euro 3	1	13130
Euro 4	1	12957
Euro 5	19	255346
Euro 6	46	640887.4
Total fuel consumption per year		922320.4

4.2. Determination of fuel consumption related to activities related to the road transport of goods

To correctly determine the fuel consumption of an organization, it is necessary to also calculate the fuel consumption related to the adjacent activities. The first consumers that will be analyzed are the vehicles used to carry out related activities, but not transport of goods. These will be presented in TABLE 4, alongside characteristics such as emission class, number of units, engine power, specific consumption distance travelled per year and the annual consumption expressed in liters. The annual consumption was obtained using Eq. (1). The distance travelled covers all of the vehicles for the specified type.

TABLE 4

Inventory of auto vehicles used for activities related to transport activity

Emission class	No. of units	Engine power	Specific consumption (l/100 km)	Km	Annual consumption (l)
EURO 3	1	85	7.3	8522	622.08
EURO 4	3	63	6.1	31325	1910.78
EURO 5	2	95	5.6	22510	1260.63
EURO 6	5	160	7.3	22437	1637.83
TOTAL				84796	5431.32

In addition, through carrying out everyday operations, the organization uses a total of 72352 kWh, according to internal data. TABLE 5 summarizes the total fuel and energy consumption. Note that the fuel quantity is expressed in tonnes, and 1 liter of Diesel is the equivalent of 0.83 kg, according to the density of the substance.

TABLE 5

Monthly consumption of various electrical consumers of the warehouse

Month	kWh
January	5670
February	5234
March	6342
April	5634
May	5487
June	6780
July	6271
August	5968
September	6010
October	5710
November	6659
December	6587
Total consumption	72352 kw

4.3. Determination of the carbon footprint

To determine the carbon footprint, there are two situations that need to be addressed. Firstly, the results obtained correspond to a type C fuel, the energy being provided by classic fuel. At the end of the calculations, fuel quantities are obtained, expressed in tonnes per year. The volume of fuel used is determined using Eq. (2).

$$V = \frac{Q_{Diesel}}{\rho} = \frac{981{,}91\ \text{t}}{0{,}83\,\text{t/m}^3} = 1.183{,}02\,\text{m}^3 \qquad (2)$$

Secondly, the results obtained correspond to type E fuel, where the energy consumed is of electrical nature, expressed in kWh. The equivalent volume of liquid fuel consumed in a year is determined if the energy equivalent of one ton of oil equivalent (*toe*) is H_E = 42 GJ/t, using Eq. (3).

$$Q_{eequiv.\,fuel}\left(toe\right) = \frac{w_{total}}{H_E} = \frac{260.46\ \text{GJ}}{42\ \text{GJ/t}} = 6.2\,toe \qquad (3)$$

Furthermore, it is known that 1 tone of diesel is the equivalent of 1.01 *toe*. Therefore, to determine the equivalent quantity of fuel, it is necessary to apply Eq. (4).

$$Q_{eequiv.\,fuel}(t) = Q_{eequiv.\,fuel}(toe) \cdot 1.01 = \\ = 6.2 \cdot 1.01 = 6.202 \approx 6.2\ \text{t} \qquad (4)$$

The volume of the fuel equivalent quantity is calculated using Eq. (5).

$$V = \frac{Q_{equiv.\,fuel.}}{\rho} = \frac{6{,}2\ \text{t}}{0{,}83\ \text{t/m}^3} = 7{,}46\ \text{m}^3 \qquad (5)$$

Thus, the total volume of fuel used is 1,190.48 m^3.

To determine the carbon footprint, it is necessary to identify the equivalent amount of carbon used per year. For diesel, the carbon equivalent is E_C = 715 kg C/m^3. The equivalent amount of carbon (expressed in kg/year) is expressed through Eq. (6):

$$Q_{equiv.\,carbon} = V \cdot E_C = 1.190{,}48 \cdot 0{,}715 = \\ = 851{,}2\ \text{t/year} \qquad (6)$$

The next step is to identify the amount of CO_2 emissions. It is known that 1 ton of carbon corresponds to 3.66 tons of CO_2. To identify the amount of CO_2 emissions, Eq. (7) is applied.

$$Q_{equiv.\,CO_2} = Q_{equiv.\,carbon} \cdot 3{,}66 = \\ = 851{,}2 \cdot 3{,}66 = 3115{,}39\ \text{t} \qquad (7)$$

The forested area that assimilates the service activity is calculated using Eq. (8), considering that the CO_2 sequestration rate is on average 5.2 tone CO_2/ha, for forests.

$$S_{foreet}\left(hag\right) = \frac{Q_{equiv.\,CO_2}}{5{,}2} = \frac{3115{,}39}{5{,}2} = 599{,}11 \qquad (8)$$

It is known that one hectare of forest is equivalent to 1.4 hag (hag – global hectares). For this value, the ecological footprint is determined using Eq. (9) and expressed in *AE* (hag).

$$\text{AE} = S_{forest} \cdot 1{,}4 = 599{,}11 \cdot 1{,}4 = 838{,}75\ \text{hag} \qquad (9)$$

5. Recommendations and Conclusions

All in all, it is clear that road freight transport organizations have increased levels of emissions, that contribute to global issues such as air pollution and climate change. Due to recent interest in measuring and reducing GHG emissions, it is necessary to assess how the organization performs in this area and what can be done in order to decrease these values.

To address the issue of high CO_2 emissions, the following solutions are proposed: (1) replacing the vehicles used for road transport of goods with electric heavy duty vehicles; since this solution is still very hard to implement, a similar solution has been proposed, (2) which implies replacing the older vehicles with newer models, that have a lower level of emissions; (3) purchasing and installing solar panels, which also reduce costs associated with electricity; (4) reducing fuel consumption by turning off the engine when the vehicle is stationary, unless it is absolutely necessary to have the engine running; (5) using a good ventilation system for servicing activities and (6) replacing the vehicles used for activities related to the transport of goods with electric vehicles.

Further research shall focus on the potential positive impact of the proposed recommendations regarding reducing the carbon footprint of the organization. The solutions should be also analyzed in terms of cost, to assess the feasibility of their implementation and whether or not, from an organizational point of view, implementing these recommendations has real and measurable benefits.

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