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Sustainability measurement in a logistics transportation company

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Abstract

We present a preliminary study to the Decision Support System for Sustainable Logistics Transportation, using as case study, the Portuguese logistics transportation company Santos e Vale. In the last five years, it has reduced its fleet carbon footprint by 20%. Our research presents a systematic literature review of indicators, carbon footprint models, and reduction measures associated to the sector, using the PRISMA method. Moreover, we considered the application of methodologies and analytical models to measure the logistic transportation carbon footprint, such as in Greenhouse Gas Protocol, ISO 14064 and EN 16258. Our aim is twofold:(1) provision of standard methodologies and analytical models targeting the reduction of carbon footprint in logistics transportation, to a more sustainable operation;(2) future development of a Decision Support System, to assist the monitoring over time.

Keywords: Carbon footprint; Logistic transportation; Sustainability, Standards

1. Introduction

With the increase in greenhouse gas emissions and related climate change phenomenon, international regulators have set laws and regulations and countries have signed legally binding international treaties, to enforce companies' reduction of carbon footprint emissions, namely the Paris Agreement in 2015 (Delbeke et al., 2019), with operational details for the practical implementation agreed on at the UN Climate Change Conference (COP24) in Katowice, Poland (December 2018), and finalized at COP26 in Glasgow, Scotland (November 2021). Within the framework of this treaty, countries have agreed on joint commitments to reduce their emissions and enforce measures to mitigate and adapt to the impacts of climate change, namely, by setting fiscal measures to promote the development of more environmentally friendly practices by economic players, among other measures.

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Our research aims to look at the most recent literature and identify calculation methods that best address the carbon footprint reduction in logistic transportation, and then use Santos e Vale (SeV) as a case study.

SeV operates in the transport and logistics sector and has set a strategic objective under the Lean & Green Europe (L&G) initiative (Santosevale, 2020), of at least 20% in CO_2 emissions reduction, for a period of 5 years, in the following business areas: Logistics, Transport and Distribution. The L&G initiative is the largest European collaboration platform specifically aimed at reducing CO_2 emissions associated with the supply chain, forming a network of leading organizations in sustainable logistics to achieve decarbonization. Currently, it is implemented in 13 countries, with more than 600 companies, which has already allowed the reduction of 2.5 megatons of CO_2. In Portugal, GS1 is the Portuguese institution responsible for coordinating the initiative. Currently, SeV has 19 logistics platforms in mainland Portugal and annually generates around 40 million euro revenue (2020 data). SeV has a logistical area of more than 185,500 sqm, a fleet of over 500 vehicles, with more than 7,500 daily deliveries, corresponding to around 550,000 tons per year. According to company data, by 2020, SeV had already managed to reduce the impact of its activity in terms of carbon emissions to less than 10%.

1.1. Objectives and research question

Our research starts by looking at the recent literature and reviewing the latest methods to calculate the carbon footprint associated with freight transport, and the more relevant factors that impact the Greenhouse Gas Emissions (GGE) during transport logistics operations. This survey allows us to move to the next step of our research, where we aim to use the logistic transportation of SeV as a case study, automatically collect transportation data during logistics operations, identify patterns in such data and apply a standard analytical model to calculate the carbon footprint produced by such SeV activity. To this aim, we intend to apply standards methods and methodologies proposed in Greenhouse Gas Protocol, ISO 14064 and EN 16258.

This paper addresses, the following research question (RQ): “Which are the methods to calculate the carbon footprint associated with freight transport and the relevant factors that impact the Greenhouse Gas Emissions (GGE), during transport logistics operations?”

1.2. Methods

The Systematic Literature Review (SLR) was developed to answer the RQ defined in section 1.1, and we used the PRISMA methodology (Liberati et al., 2009; Moher et al., 2009). The PRISMA Statement consists in a checklist of twenty- seven items and a four-phase flow diagram that includes Identification, Screening, Eligibility and Included.

Our literature search was performed during the month of April 2022 and was set to a five-year period, between 2018 and 2022, limiting our SLR to the most recent studies conducted by the scientific community. We started with a preliminary review using the google scholar search engine, to identify the keywords used by the community related to carbon footprint calculation, carbon footprint prediction and freight logistics. As a result, we identified the following keywords and derived their logical relation in a query, subsequently used in the PRISMA framework, in the following way:

("Carbon Footprint" OR "Ecological Footprint") AND "Freight Transport" AND ("Data Analytics" OR "Machine Learning" OR "Prediction") AND (LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT- TO (PUBYEAR , 2018)) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "cp")) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (LANGUAGE , "English"))

1.3. Systematic literature review results

Our SLR PRISMA flow diagram (see Fig. 1, where "n" is the number of retained articles, and “e” is the number of excluded articles), particularly in the "Identification" phase, depicts the application of the query defined in (2.1) in the Scopus and ScienceDirect repositories. As result we obtained 117 journal papers (62 papers from Scopus and 55 ScienceDirect), and 15 conference papers (12 conferences from Scopus and 3 ScienceDirect). Only journal and conference papers published in English were considered. Additionally, 3 articles were included through other sources, which were identified through the recommendation of the Professors involved in this project. Considering that we use more than one repository, 16 duplicate papers were identified, validated by using the Mendeley tool.

In the "Screening" phase, we considered 119 articles, based on the reading of the abstract.

Subsequently, in the "Eligibility" phase, we proceeded to a complete reading of the papers, and identified at this stage the papers for inclusion in the scope of our search, in the "Included" phase.

The final records assessed for eligibility were 48 articles, and after full reading and content analysis, we included 24 articles in our literature review.

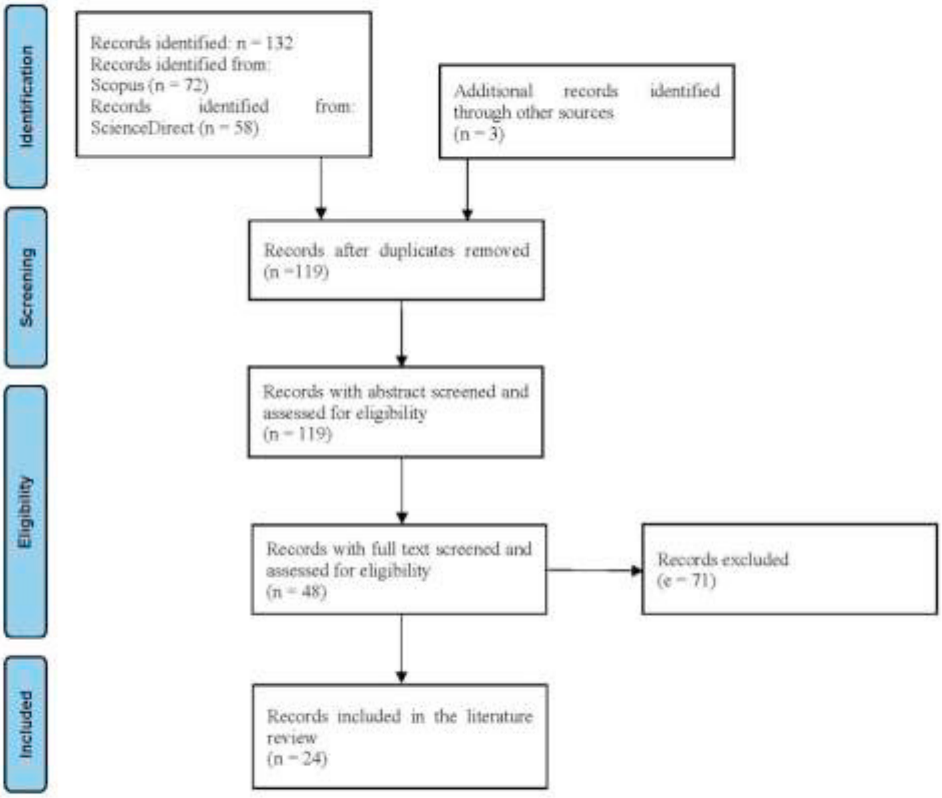

Fig. 1. PRISMA flow diagram.

2. Results

2.1. Carbon footprint in logistics transportation

The logistics transport sector has an extensive environmental, social, and economic impact in society. Logistics and passenger transport by combustion vehicles contribute with about 25% to CO_2 emissions. Due notorious environmental degradation, regarding the increase in Greenhouse Gas Emissions (GGE), such as CO_2, several measures have been implemented.

According to Wen (2022), in China in 2019, almost 4,713 billion tons were transported, of which 72.9% through land vehicles, which have the highest levels of pollution. As shown in the study of Leach (2020), currently about 99.8% of vehicles used for land transport is powered by internal combustion engines, and 95% of this energy comes from fuels produced from oil. Leach (2020) study concludes that the reduction of pollution levels associated with the logistics and transport activity involves changing some existing practices in the sector, namely related to the development of engines with lower energy consumption and the use of hybrid vehicles. Zhao (2020) developed holistic research that analysed publications of research articles between the years 2000 and 2019, and he explored gaps and possible aspects of improvement, to identify recommendations and future orientations for the development of sustainable transport. Zhao (2020) analysis resulted in the following research topics: 1) indicators of sustainable transport and performance model, 2) sustainable transport policy, 3) stakeholder involvement, 4) supply chain management and logistics, 5) environmental impact, 6) travel behaviour, 7) new vehicle fuels, 8) the strategic planning of transport, and 9) cycling and public transport.

Gorges (2021) research sought to study companies' mobility transition based on the literature review analysis on corporate mobility and its management. Gorges identifies that the main goal of companies is to achieve zero emissions, via reduction of the carbon footprint. Gorges identified the following needs derived from concrete business motivations: to analyse the modes of transport and their impact on the carbon footprint; to analyse the drivers' behaviour; to identify measures that allow the reduction of emissions; to develop tools for monitoring the carbon footprint; to examine the factors and their relationship with the carbon footprint; to understand the impact of information systems; and to develop sustainable organisations.

Umar (2020) developed a study on the long run and casual effects of innovation, financial development and transport infrastructure on CO_2 emissions, using the combination cointegration approaches during the period 1971 to 2018, the author demonstrated that: (1) innovation is observed to be a significant predicter of CO_2 emissions during the period 2007 to 2013; (2) in the long run, there are negative relationships between CO_2 emissions and financial development, showing that in the long run CO_2 emissions will result in lower financial returns; (3) during the periods from 2000 to 2015, and 1985 to 1989, transport caused significantly more CO_2 emissions, suggesting that enhancements in innovation and transport infrastructure should be made to achieve environmental sustainability goals.

García-Olivares (2018) analysed the technologies and systems being proposed or proven as an alternative to fossil fuel-based transport, and their prospects for entering the post carbon era, both from a technological and energy perspective. His analysis concludes that 100% renewable transport is achievable, but not necessarily in line with an indefinite increase in resource consumption.

There is a high relationship between logistic transportation activity and CO_2 emission as demonstrated in the presented articles. Transportation, namely land transportation, influences in a very significant and negative way the pollution levels, especially in what concerns with GGE. In the next section, we will analyse in more detail the methodologies proposed for the calculation of the carbon footprint in logistic transportation.

2.2. Models for carbon footprint calculation

We identified various literature studies on methodologies, models, and protocols for calculating the carbon footprint. Wang (2018) identified and developed a comparative analysis between the various existing models for carbon footprint (Cf) calculation, used to quantify GGE. Various protocols, such as Publicly Available Specification (PAS) 2050, GHG Protocol Product Standard (GHG Protocol), and ISO 14067 Carbon Footprint of Products (ISO 14067), was developed for calculations of Cf. Wang's study focused on the calculation of CF in the context of MDF production.

These models and protocols follow the life cycle thinking approach. The calculation formula as provided in the different protocols is the same (Equation 1), but its interpretation may vary according to the adopted protocol, where Ef, GHG is the GHG emissions from fuel combustion in the stationary sources (kg CO_2e), f represents the types of energy employed, FCf represents the energy consumption of the type of energy, and EFf, GHG is the emission factor for the type of energy f by GHG.

$$E_f, GHG = FC_f * EF_f, GHG \quad (1)$$

Wang (2018) identifies the differences associated with calculating the carbon footprint, mainly related to the interpretation of some factors considered in the calculation formula.

In this study, Wang concludes that the Cf calculation varies depending on the interpretation of the factors considered in the formula, namely related to the cut-off criteria, other boundary issues, and the Biognic Carbon.

Roukounakis (2020) developed a methodology for calculating the Cf of a highway road. The total GGE were calculated based on several factors, namely fuel and electricity consumption, air conditioning associated gases and waste disposal. Regarding the calculation of emissions, the model relates the following variables: vehicle-kilometres; average speed; and vehicle categories associated with transport capacity in tons.

Dong (2020) proposes a model for quantifying Cf for diesel trucks and investigates the influence of road gradient on carbon emissions from trucks. He concludes that gradient provides higher levels of GGE emissions and therefore, transportation routes and road construction with severe gradients should be avoided.

2.3. Main factors that impact carbon footprint analytics

We explored the different factors and their influence on Cf. Li (2022) carried out research on test emissions from heavy-duty, diesel-powered vehicles in China, to evaluate the integrated effects of Selective Catalytic Reduction (SCR), speed, and air-fuel ratio on CO_2 and nitrogen oxide emissions. Li's results reveal that CO_2 emission levels based on average distance at high speeds (50-90 km/h) are lower than those based on low speeds.

Li (2021) studied the influence of several factors on CO_2 emissions in the transportation industry and developed future CO_2 emission forecast scenarios. Li used four algorithms to develop his analysis: neural network, extreme machine learning, genetic algorithm optimized neural network, and genetic algorithm optimized extreme machine learning.

Fan (2021), associated with the simulation of the financial impacts, quality, and CO_2 emission in the transport of refrigerated goods by ship. A calculation formula of CO_2 was developed, and a set of sensitivity analyses were performed on it through the variation of several components of the equation. From the analysis carried out, he concluded that the speed of transport is intrinsically related to CO_2 emissions.

Ternel (2021) developed a study on the current and future predictions of the GGE analysis of mid-range passenger cars. The study shows that plug-in hybrid electric vehicles are the best solution to mitigate GGE. Ternel also concluded that biofuels provide significant benefits regarding GGE emissions in a short period of time.

Osorio-Tejada (2018) developed a well-to-wheels approach for assessing the environmental impact of road freight services. In this study he concluded that speed, load, and road gradient generate variations of up to 145% in the estimated GGE emissions.

Mangina (2020) evaluated models for freight transport using data analysis. Three algorithms (Horizontal Cooperation, Pooling and Physical Internet) were developed, using historical road freight transport data from the European market, for the period between 2011 and 2014. To calculate the total emissions, a simplified formula proposed by the European Association for Forwarding, Transport, Logistics and Customs Services (CLECAT) was used, where GT is the GGE per tonne kilometres (g CO_2/t- km), $Tcap$ represents the transport capacity, gt represents the emissions factor depending on the vehicle weighting, Wg represents the gross weight, and d represents the distance.

$$G_T = T_{cap} * g_t \tag{2}$$

$$T_{cap} = \frac{(W_g - \phi + \chi) * d}{1000} \tag{3}$$

Mangina (2020) concluded that by using the pooling algorithm, there is a 12% reduction in road freight transport emissions and an increase in transport efficiency of about 23%.

Alves (2019) proposed a method for classifying truck drivers based on time series to describe their driving efficiency. The study aimed to develop a methodology to reward drivers who present more ecologically sustainable driving. Correlation analyses were developed to identify the variables with the highest correlation with fuel consumption, and the following were identified: Acceleration, Acceleration Pedal Use, Brake Pedal Use, Engine Speed, Vehicle Speed.

Palander (2018) developed a quantitative analysis of energy performance from the optimization of timber transportation. Palander (2018) demonstrated that there has been an upward trend in the increase of the average load weight and a transition to 7 to 9 axle vehicles, which allows the transport of higher loads. As a result of this transition, Palander (2018) observed a significant increase in energy efficiency. However, this does not achieve the goals set by the government, demonstrating that the success of the goal involves other measures besides using vehicles with higher transport capacity.

Wong (2018) analysed the operation of three logistics companies in Hong Kong and developed a metric analysis of measuring GGE. Truckload utilization and transportation routes were analysed in detail, as well as the correlation on truckload utilization against truck capacity, cargo volume, fuel consumption, truck size, travel distances and the number of destinations. Wong (2018) developed an integrated model, where Cf achievement goals are defined, targeting Cf reduction initiatives by penalizing transport times and distance, minimizing the number of trucks, and fostering improved truck utilization.

Schmitz Gonçalves (2019), modelled scenarios of energy use and GGE in the transport sector up to 2030. Three scenarios were developed based on different policy commitments. The method is based on a bottom-up approach, requiring multi-sector collaborative efforts to not only account for direct energy use, but also balance transport and energy activity across modes, justifying each case in terms of development stage and energy supply capacity.

In the study by Armiño (2022), the sustainability of the transportation activity is analysed, proposing the application of new Machine Learning (ML) techniques. In this research, Hybrid Unsupervised Exploratory Plots is used, along with new Exploratory Projection Pursuit techniques, allowing the development of a set of visualizations to support decision making.

Baral (2021) performed a stochastic analysis based on transport vehicles powered by various energy sources, namely, diesel, hybrid, and electric trucks. He concluded that the use of hybrid and fully electric trucks powered by hydrogen and renewable sources of electricity, respectively, allows achieving a large Cf reduction, especially in the context of long-distance transportation.

Magazzino (2021) critically evaluated the effect of dependence on fossil fuels and pollutant emissions from the transport sector on the performance of logistics operations. He implemented a Neural Network Algorithm in a multivariate framework to analyse the correlation between Logistics Performance Indexes, demand for petroleum products, and CO_2 emissions from fuel combustion in the transportation sector. The study was able to demonstrate a high correlation between Logistics Performance Indexes and fuel consumption, as well as high GGE.

Cunha (2022) applied statistical analysis, ANOVA, to develop characterizations of energy performance and manufacturing quality of products in a factory. Cunha's (2022) study allowed inducing the influence of certain factors on energy performance, allowing developing predictive scenarios regarding energy consumption and manufacturing quality.

4. Conclusions and next steps

This paper aims to enforce transport logistic companies' reduction of carbon footprint emissions, with metrics promoting the development of more environmentally friendly practices in their operations. In our SLR based on PRISMA methodology, we concluded that the application of standards methodologies for calculating the carbon footprint measurement of logistic transportation, such as standards by Greenhouse Gas Protocol, ISO 14064 and EN 16258, is happening in the Logistics Transportation industry and are being adopted by logistic companies to help monitoring the achievement of fleet carbon footprint reduction, a goal also aligned with the Lean & Green Europe program aims. The results of our SLR were discussed in Section 3, first in highlighting the trends in carbon footprint in logistics transportation, followed by an analysis of calculation models to achieve sustainable metrics in carbon footprint evaluation, and finally, explaining the main factors that impact carbon footprint analytics ranging from quantitative analysis to ML techniques.

This research is a preliminary study towards the development of a Decision Support System, with regards to SeV actions targeting carbon footprint reduction. Future work involves the identification of patterns in collected logistics data, the detection of system inefficiencies via data analysis, and the application of a standard analytical model to calculate the carbon footprint produced by SeV activity, towards a more sustainable logistics transportation. In this respect, we intend to apply standards methodologies and models proposed in Greenhouse Gas Protocol, ISO 14064 and EN 16258 on collected data from SeV own vehicle tracking system (integrated in their TMS – Transportation Management System). Such dataset is already available and characterizes SeV's logistic transportation activity between January 1st 2022 and June 30th 2022, with 133 company-owned vehicles. The dataset features the vehicle use and IDs, transport activity performed, information on the trip start and end date, the duration of the trip in seconds, the time between trip stops, the total kilometers travelled, the number of liters of fuel consumed, the maximum speed reached, the average speed, the origin point of the trip, geographic coordinates of the trip point and the origin point, and the type of fuel. This dataset will feed into the mentioned standard models to measure and monitor carbon footprint reduction.

We can point out as limitations to our work, the coherence and quality of the available logistics data collected from SeV operations.

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