

FREIGHT TRANSPORT EMISSIONS CALCULATORS AS A TOOL OF SUSTAINABLE LOGISTIC PLANNING

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Abstract: The freight transport performance is growing. The transport sector is also one of the largest producers of emissions. This must be reflected not only by production companies but also by other stakeholders. The issue of transport emissions is particularly important for city residents, so today the concept of sustainable city logistics is emphasized. Companies should deal with the amount of produced emissions. The use of emission calculators would support operational, tactical and strategic business decision-making. The aim of this article is to analyse the approaches used in available free calculators of emission arising from the freight transport. The focus was on the transport modes that calculators include, input data, output data and methodologies used to calculate emissions. The method of systematic review was used to search analysed freight transport emissions calculators. The method of content analysis was used to analyse inputs, outputs and freight transport emissions calculator's methodologies. The method of qualitative comparative analysis was used to analyse and compare the freight transport emissions calculators.

Keywords: emission calculator, freight transport, well-to-wheel, tank-to-wheel, well-to-tank

1. Introduction

Transport is one of the key factors in development of any modern society, not an objective *per se*, but a means of economic development and a precondition for achieving the social and regional cohesion. Transport plays an important role in the social and economic development of the state. However, in relation to the environment it is a source of emissions, noise, vibrations and causes health and safety risks and thanks to transport, there is extensive land use [1]. The negative effects of transport on the environment are conditioned by the increasing transport requirements of society in connection with the process of globalization, which is also reflected in demands for transport infrastructure. Thus, the transport has negative impacts on environment for the two basic reasons: the construction of transport infrastructure and the harmful effects of traffic [1-2]. Transport sector influences all the aspects of human life, research, education, trade, entertainment, manufacturing, defence and culture [2].

Sustainable development is an important factor in development of individual economies. Litman [3] states that the concept of sustainable development is built on three pillars - economic, environmental and social. The current trend is to increase traffic efficiency while eliminating its negative impacts. The production of greenhouse gases, especially carbon dioxide, is the most discussed issue that belong to the environmental pillar. As the European Council of Transport Ministers [4] states, the sustainable development of transport becomes more important in the context of current transport problems, such as:

- unbalanced development of particular modes of transport,

- congestion - as a result of imbalance between modes of transport and the associated bottlenecks in transport infrastructure,
- harmful effects on the environment and public health,
- serious consequences of traffic accidents.

The aim of this article is to analyse the approaches used in free available emission calculators arising from the freight transport. The focus is on the transport modes that calculators include, input data, output data and methodologies used to calculate emissions.

2. Theoretical background

Road transport plays an important role in the consumption of energy and the greenhouse gas emissions in the world [5-7]. The greenhouse gas emissions are a global issue [8-9]. Climate change can be attributed to anthropogenic emissions and are expected to increase further in the future [10-11]. In this sense, emissions from transport sectors (land transport, shipping and aviation) significantly contribute to this effect [11-17]. In the case of the road vehicles, overall emissions from transport, especially on roads, are one of the main contributors [18-21].

It is well known that the energy consumption in society and emissions of pollutants from transport are affected not only by technical efficiency choice of method and content of carbon and pollutants in the energy sector, but also by the lifestyle and socio-cultural factors [22-23]. Improving the living standard of people will significantly increase energy consumption in the transport sector. In many areas, the environmental and health impacts caused by the transport sector are seriously increasing [24]. The World Economic Forum [25] calculated that the transport and logistics sector was responsible for 5.5 % of total emissions from human activity, at around 2 800 mega-tonnes annually. In 2015, the transport sector accounted for approximately 24 % of the worldwide CO₂ emissions from fuel combustion [26]. Abbasi and Nilsson [27], Mubarak and Zainal [28] discuss several negative impacts of logistics activities, such as visual pollution, congestion, intimidation, vibration, injuries and accidents.

The issue of the city logistics is addressed in many research areas at present time. New challenges and opportunities of the city logistics to exploit new sources of information are seen with the aim of ensuring sustainable systems primarily for the urban freight transport [29]. Only intelligent city logistics can make a significant contribution to its sustainability. There are many challenges for cities arising from the complex definition of a sustainable freight transport system. It must also ensure access to all modes of the freight transport, while reducing emissions of pollutants and noise and maintaining the economic efficiency of this type of business [30-31].

Reducing the greenhouse gas emissions, of which carbon dioxide is important, has been the major environmental objective for most governments in the developed world [32-33]. Natr [34] notes that carbon dioxide is the most environmentally harmful. He further specifies that several percent CO₂ concentrations cause human breathing difficulties. The long-term effects of CO₂ on the human body can lead to fatal consequences. The increase of the concentration of CO₂ in the air, considered to be the main cause of global warming, is mainly due to the burning of fossil fuels and the decline of forests [35-36]. The CO₂ emissions produced by the road freight transport should therefore be monitored and evaluated. The information obtained can be used to support the decision-making processes at the level of individual transport companies, logistics services providers as well as in the decision-making of state administration bodies and local governments.

European standard EN 16258 Methodology for calculation and declaration of energy consumption and greenhouse gas emissions of transport services (freight and passengers) was approved by the European Committee for Standardisation in 2012 [1, 37]. Currently, there are

three main approaches to measuring energy consumption and produced emissions - Well-to-Wheel, Well-to-Tank and Tank-to-Wheel approaches (see Figure 1) [37]:

- Well-to-Wheel (sum of total Well-to-Tank and Tank-to-Wheel) - an approach based on the monitoring of energy consumption and associated emissions production that covers the whole process from the generation of electricity or fuel, through the supply to the appropriate transport means through the distribution network, to the consumption associated with the operation of the means of transport. This approach is based on the sum of Tank-to-Wheel and Well-to-Tank values.
- Well-to-Tank - energy consumption and production of emissions related to the production of energy or fuel, the indicator covering all activities from the extraction of raw materials through the production of energy or fuel, up to the supply to the respective means of transport through the distribution network. The indicator does not include the transport mode.
- Tank-to-Wheel - energy consumption and production of emissions related to the operation of the means of transport. The indicator does not include the next life cycle of the fuel or the transport means.

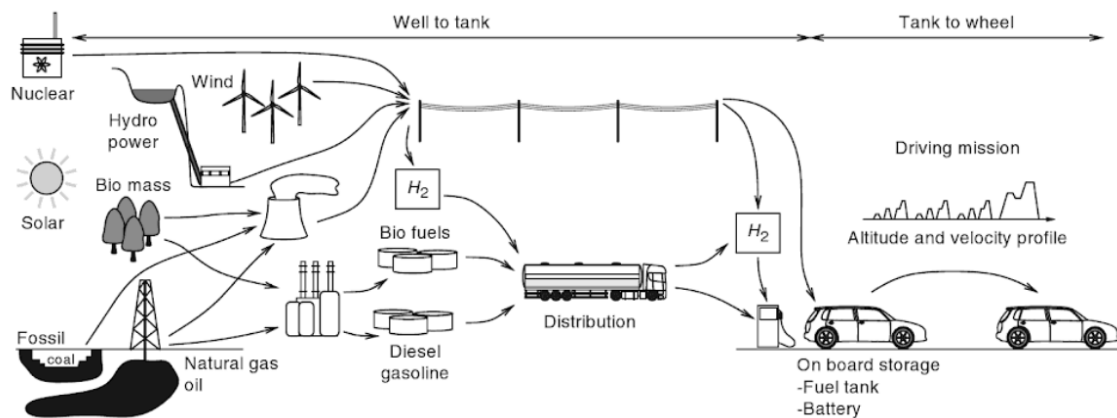


Figure 1 Well-to-Tank and Tank-to-Wheel [37]

Scientific methods (systematic review, content analysis, and qualitative comparative analysis), results and discussions are presented in the following sections.

3. Methods

The method of systematic review is used to search freight transport emissions calculators. The systematic review method is a systematic, explicit and repeatable procedure designed to identify, evaluate and synthesize the results of researchers, academics and practitioners [38]. The scientific method allows an author of a review to minimize its own personality and influence the content of the text by authors own views [39]. This scientific method is well known and often used by researches, for example [40-42]. The method of systematic review consists of the following steps: select research areas, select sources, choose search terms, do the systematic review, synthesize the results, produce descriptive review [38].

The method of content analysis is used to analyse inputs, outputs and freight transport emissions calculator's methodologies. The method of content analysis is a research technique for making replicable and valid inferences from texts or other meaningful matter to the context of their use [43]. The method of content analysis has been used, for example, in [44-46].

The method of qualitative comparative analysis is used to compare the freight transport emissions calculators obtained using the method of a systematic review. The method of

qualitative comparative analysis is a data analysis technique for determining which logical conclusions a data set supports [47]. The qualitative comparative analysis begins with listing all the combinations of variables observed in the data set, followed by applying the rules of logical inference to determine which descriptive inferences or implications the data supports [47]. Figure 2 shows the processing procedure.

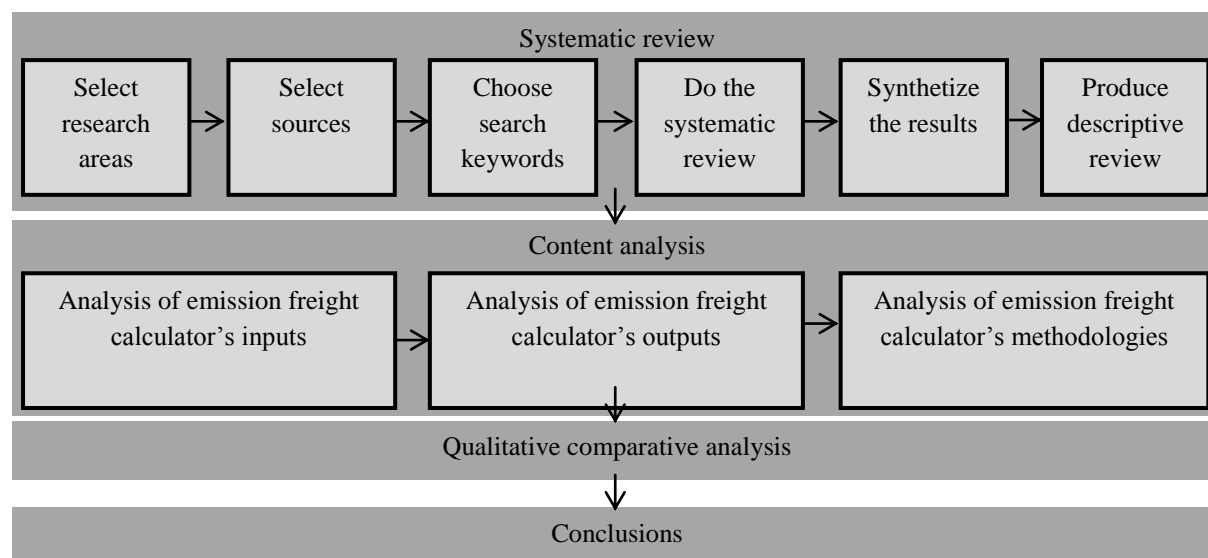


Figure 2 Processing procedure

The research areas were as follows: “For what transport modes can the emission calculators be used?” and “What inputs, outputs, and methodologies use the freight transport emissions calculators?” The method of systematic review was used to search freight transport emissions calculators. The Google search was used by two independent researchers in January 2019 using the following keywords “emission calculator” and “emission freight calculator”. Subsequently, the first ten freight transport emissions calculators were selected based on their position in the search engine. The content analysis of inputs, outputs and methodologies of the freight transport emissions calculators was used by three independent researchers in February 2019.

4. Results

Analysed freight transport emissions calculators selected based on their position in the search engine, were: no. 1 - CO₂ emission calculator - EECA Business [48], no. 2 - Emission calculator and carbon offset - SAS [49], no. 3 - Emissions Calculator - Cargolux [50], no. 4 - Business CO₂ emissions calculator - ClimateCare [51], no. 5 - Freight Emissions Calculator [52], no. 6 - Emission Calculators | Sustainable Freight [53], no. 7 - EcoTransIT World - Calculation [54], no. 8 - Van Donge & De Roo calculator [55], no. 9 - OOCL Carbon Calculator [56], no. 10 - Carbon Calculator | cn.ca [57]. The results of content analysis of the freight transport emissions calculators are presented in Table 1.

Table 1 The results of content analysis

No.	Transport modes	Inputs	Outputs	Methodology
1	Unspecified	Fuel type, Amount consumed, Units	Tonnes of CO ₂ e, Energy content (GJ)	Emission factors of the Ministry for the Environment

2	AiT	From, To, Cargo weight (kg), Aircraft type	Great circle distance, Revenue ton kilometre; Kilograms of CO ₂ , NO _x , CO, HC, Particles, SO ₂ ; CO ₂ offset	Not specified
3	AiT	From, To, Shipment weight (kg)	Kilometres, Tonnes of CO ₂	Not specified
4	RoT, AiT, MaT, RoRo	Transport type, Distance (km, miles) / Hours (AiT), Freight weight (t)	Tonnes of CO ₂ , CO ₂ offset	AiT - Aviation Emissions and Offsets; RoT, MaT - UK Government conversion factors
5	RoT	Shipment weight (lbs), Shipment distance (miles)	Tonnes of CO ₂	U.S. Department of Energy
6	MaT, RoRo	Ship type, Distance (km), Total cargo (t)	Kilograms of CO ₂ , Comparison with another ship	CEFIC - Guidelines for Measuring and Managing CO ₂
7	RoT, RaT, AiT, MaT	Weight (t, TEU), Net weight (t/TEU), Type of state, Ferry routing, Origin, Destination, Transport mode, Vehicle type, Fuel type, Emission standard, Traction, Load factor, Empty trip factor, Speed reduction	Primary energy consumption (MJ, kWh, diesel equivalents); GHG emissions (CO ₂ , CO ₂ e, NO _x , SO _x , NMHC, Particles); Distance (km); Comparison of transport modes	Methodology Report (EcoTransIT World Initiative)
8	MaT	Port of Loading, Port of Destination, Volume, Type of CCWG emission factor	Tonnes of CO ₂ , Distance (km)	Clean Cargo Working Group (CCWG)
9	MaT	Origin, Destination, Cargo volume (t, TEU)	CO ₂ Index (kg CO ₂ /TEU-km or kg CO ₂ /t-km, Total distance (km), CO ₂ emissions	Clean Cargo Working Group (CCWG)
10	RoT, RaT, MaT	Units (miles/km, t), Shipment weight (t), Vehicle type, Port of Origin, Port of Destination	Tonnes of CO ₂ e	Transport and Environment Database System

Notes: RoT - road transport, RaT - railway transport, AiT - air transport, MaT - maritime transport, RoRo - Roll-on/roll-off ships, NMHC - Non-methane hydrocarbons, GHG - greenhouse gas

The first research area was “For which transport modes can be used emission calculators?” Analysed freight transport emissions calculators can be used for the following modes of transport: six of them for the maritime transport, four of them for the air and road transport, two of them for the railway transport and two of them for the RoRo transport. The RoRo transport is a specific type of maritime transport provided by vessels designed to carry wheeled cargo, such as cars, trucks, semi-trailer trucks, trailers, and railroad cars. A comprehensive multimodal emission calculator has not been found within the analysed calculators. If a user needs to calculate emissions of multimodal transport, transportation must be divided into sections according to the different transport modes. Subsequently, the user has to add the emissions from the individual sections.

The second research area was “What inputs, outputs, and methodologies use the freight transport emissions calculators?” Basic input data of most analysed freight transport emissions calculators was the same or similar, for example: from/origin/port of loading, to/destination/port of destination or direct entry of distance/shipment distance/flight time.

Further data is generally related to the weight of the shipment/cargo, weight/freight weight/volume/cargo volume or the net weight. Some freight transport emissions calculators allow the user to enter additional specific input data, for example: fuel type and amount consumed, type of means of transport (aircraft type/ship type/vehicle type etc.), type of goods (light/average/heavy), cargo type (bulk/liquid/other), ferry routing, type of traction, load factor, emission standard, empty trip factor and speed reduction. Most calculators allow the user to choose from several units (km/miles/hours, kg/t/lbs/TEU etc.). All analysed calculators contain output data on CO₂ emissions (calculators differ only in units). Some calculators also included the following output data: energy consumption; amount of CO, HC, NO_x, SO_x, NMHC, particles; the possibility of offsetting emissions; total distance and comparison of transport modes.

Some freight transport emissions calculators do not specify the calculation methodology used. Other freight transport emissions calculators are based on the following approaches: Emission factors of the Ministry for the Environment; Aviation Emissions and Offsets; UK Government conversion factors; U.S. Department of Energy; CEFIC - Guidelines for Measuring and Managing CO₂; Methodology Report (EcoTransIT World Initiative); Clean Cargo Working Group or Transport and Environment Database System.

5. Discussion

After evaluating all the analysed freight transport emissions calculators, the use of EcoTransIT World calculator can be recommended, because that is the most comprehensive freight transport emissions calculator. The EcoTransIT World calculator allows choosing between standard and extended versions. The calculator can be used to calculate emissions from the following modes of the freight transport: road transport (truck), rail transport (train), air transport (airplane), sea and maritime transport (sea ship and barge). The EcoTransIT World calculator also allows specifying a large number of input variables and generates a large number of output variables in tabular and graphical form. This calculator distinguishes the type of output emissions (Well-to-Wheel, Well-to-Tank and Tank-to-Wheel). It transparently refers to the used methodology - Ecological Transport Information Tool for Worldwide Transports: Methodology and Data Update 2018 developed by IVE mbH - Ingenieurgesellschaft für Verkehrswesen mbH Hannover, Infras AG -Consulting, Analysis and Research and ifeu - Institut für Energie - und Umweltforschung Heidelberg GmbH.

Some analysed freight transport emissions calculators are available for one mode of transport only (usually for air transport and maritime transport); some calculators do not have a transparently specified methodology for emissions calculation. Most calculators do not allow specifying input variables sufficiently. Nine out of ten freight transport emissions calculators do not distinguish the approach to measuring emissions (Well-to-Wheel, Well-to-Tank and Tank-to-Wheel) as the output variable.

The big problem is the fact that the analysed freight transport emissions calculators do not allow the user to easily calculate the emissions of the multimodal transport, because multimodal transport consists of several modes of transport. If a user needs to calculate emissions of multimodal transport, transportation must be divided into sections according to the different transport modes.

The limit of the research is the number of freight transport emissions calculators studied, because only ten emission calculators were studied. Therefore, all conclusions are valid only for these ten freight transport emissions calculators. On the other hand, it is necessary to emphasize that these freight transport emissions calculators are the best positioned in the Google search engines after entering defined keywords.

6. Conclusion

The issue of the freight transport emissions is a very actual issue. This issue is addressed not only by researches but by companies, as well. Some companies are profiled as a socially responsible and in the context of their business activities take into account environmental and social aspects of their activities, products and services. Companies integrate environmental and social aspects into the decision-making processes at strategic and tactical-operational levels and use appropriate management tools to support the decision-making processes. Emission calculators can be included as logistics planning tools. Their use helps companies to reduce the negative environmental impact of logistics processes. The public and other stakeholders (business partners, employees, the state, etc.) are interested in this issue.

Nowadays, the largest companies have their own emission calculators, but most other companies use freely available emission calculators. This was one of the reasons for the analysis. The aim of the article was to analyse the approaches used in free available emission calculators arising from the freight transport. The focus was on the transport modes that calculators include, input data, output data, and methodologies used to calculate emissions. Use of EcoTransIT World calculator is recommended due to its transparency, complexity, structure of inputs and outputs and user-friendliness. On the other hand, it would be very beneficial to create a similar freight multimodal emission calculator that will be comprehensive and will cover all the emissions resulting from the implementation of multimodal transport. The results of the analysis could also be used to create new types of emission calculators. In the future, emission calculators should become a commonly used logistics planning tool, not only in logistics companies, but also in all the small, medium and large companies, regardless of the business branch. Appropriate tools should also be used at the level of the state administration and local governments as a support to the decision-making processes. The use of these tools could contribute to changing the approach to logistics planning, both within companies and supply chains, as well as within cities, conurbations and regions.

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