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Measuring CO_2 emissions level for more sustainable distribution in a supply chain

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Abstract

The stakeholders put pressure on supply chain managers to provide the performance which is economically viable and also environmentally sound. The inclusion of environmental factors in the set of periodically measured KPIs, such as the carbon dioxide equivalent (CO_2e) becomes more crucial. The aim of this paper is to identify the challenges, which appear when measuring the carbon footprint in a supply chain. The emphasis is put on the direct emissions from distribution operations in terms of European perspective. Through literature review and two case studies conducted in the retailing companies we identify the factors which influence the CO_2 in the area of distribution in a supply chain. The result of the conducted research is of great importance for the creation of more sustainable and green distribution supply chains (GrSC). On the basis of surveys conducted among transport managers, the main factors determining the emissivity of the supply chain have been shown. Also the main challenges faced enterprises that want to measure and manage their carbon footprint of distribution processes were identified. The main contribution of this paper is to provide an actionable set of variables which shall be included by supply chain managers in their decision-making process in order to make the distribution operations more sustainable.

Keywords: Carbon footprint assessment, Sustainable supply chain management, Environmental approach within supply chain, GHG assessment methods

1. Introduction

The initial reason for measuring the carbon footprint (CF) is climate change, the effects of which are increasingly felt and noticed by humans around the globe [1]. Researchers and politicians are working together to reduce the impact of human activities on climate change around the world. The effect of this is cooperation within the Intergovernmental Panel on Climate Change [2]. Adoption of the Paris Agreements in 2015, or the acceptance of the Kyoto Protocol in 1997, assuming the reduction of carbon dioxide emissions of anthropological origin can be treated as an important milestones in the way of anthropogenic CF mitigating. The polices for carbon emission reduction usually take form of the following carbon policy regulatory mechanisms: Carbon cap policy (CCP), Carbon tax policy (CTP), Carbon cap-and-trade, policy (CCTP), and Carbon offset policy (COP) [2, 3]. Legislative changes, like for example ETS (European Union Emissions Trading System) put obligation on entrepreneurs from the energy generation sector and highly energy-intensive industries [4] to purchase additional CO_2 emission permits after using the allocated amount of emission allowances. Measuring the carbon footprint and striving to reduce it also affects the positioning of company on the market. An increasing number of customers make their purchasing decisions based on this factor [5]. The paper is organized, as follows: in the Section 2 are presented related studies. Section 3 describes research methodology and outline research questions. Section 4 concludes the case studies from retailing companies. The final conclusions are stated in Section 5.

2. Literature review

The impact of regulations on reducing emissions in supply chains directly affects their shape [6]. Carbon dioxide emission limits imposed by international organizations, such as the EU ETS shift the center of gravity of investor decisions towards an environmental perspective [7]. The growing importance of the concept of sustainable development in modern supply chains has forced the creation of appropriate mechanisms for measuring emissions and dynamically determining its mitigation [2, 3]. The environmental parameters are more often included in a fixed set of KPIs measured by leading enterprises to assess its effectiveness and to indicate the appropriate position on the market [8, 9]. According to Carbon Disclosure Project (CDP), which associates over 680 of the world's largest financial institutions, 95% of the affiliated companies indicate the use of environmental indicators or plan to implement them within the next two years [2]. In the CDP 2022 Disclosure Workshop Series survey, as many as 76% of the surveyed companies indicated measuring environmental factors and striving to limit them as a way to increase the competitiveness of their enterprise on the international arena. Appropriate process management and implementation of the SCM concept can help to significantly increase the profitability of the company and ensure its entry into the path of long-term development [10, 11]. Therefore, there are important prerequisites for measuring the carbon footprint of supply chains to become the norm for companies focused on maximizing the efficiency of their

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processes and caring for their sustainability. The research questions outlined in Section 3 of this paper correlate with Sureeyatanapas et al. research [12] however, in their research authors refer to manufacturing footprinting programme and verify its potential benefits. It was indicated that due to the limited possibility of verification on the level of return on environmental investments, small enterprises with a limited budget may not overcome financial barriers in order to reduce their carbon footprint. Research was based on example of Thai manufacturing companies, nonetheless this research doesn't reflect European transportation perspective in terms of mitigating supply chain's carbon footprint [12].

Another research outline relationship between sustainable energy sourcing and economic dynamics [13]. Correlation between various energy sourcing solutions and economic indicators refers to carbon emission what provides an excellent environmental approach within a research. Analysis were based on the three ASEAN countries - Malaysia, Indonesia and Thailand. Results are presented in traditional panel regression and compared in terms of GDP growth. Despite valuable findings useful for industry experts, researchers, and various stakeholders research doesn't provide an answers to research questions related to challenges and important factors related to management of carbon footprint within distribution processes [13].

Quantile on Quantile regression and Granger causality in quantile methods used in empirical analysis of carbon dioxide emissions resulting from textile and clothing (T&C) manufacturing [14]. Conducted analysis provides valuable information about asymmetric relationship between textile industry and environmental degradation within China, India, Pakistan and Indonesia economies. A recommendation based on conducted research refers to introduce proper incentives for more green manufacturing [14]. However research doesn't provide a complete view for major challenges and factors of carbon dioxide emission accounting within distribution processes.

Interesting research conducted by Muhammad et al. [15] refers to correlation between various political, market, economic indicators and carbon dioxide emissions. Outcome of analysis published by researchers is based on data sourced from World Bank. Novelty of proposed approach refers not only to relationship between environment and political freedom, but takes into account CO_2 emission. A scope of this research is related to ASEAN countries in terms of financial development and mitigation of overall economic carbon footprint. Researchers outlined analysis difficulties related to limited data availability, nonetheless it doesn't refers to distribution specificity and supply chain CO_2 emission management [15].

The goal of this paper is to identify the factors which are influencing the measurement of the CO_2 emissions in area of distribution in a supply chain. We summarize the findings from critical literature review and 2 case studies which were conducted by us at retailing companies in a food and apparel sector. The contribution of this paper is the set of crucial factors which shall be monitored in order to properly measure and mitigate the level of CO_2 emission in distribution activities.

The carbon footprint is "a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product" [16].

The carbon footprint is becoming more often measured KPI parameter in both service and production companies. This is directly related to the growing awareness of entrepreneurs about the risks arising from failure to meet the environmental standards of their services and products. Simultaneously there is a desire to minimize the impact of their services on the environment. Companies therefore decide to measure the carbon footprint of their processes to [8, 17, 18]:

- Identification of the most energy-consuming processes,
- Determine how to optimize them and reduce energy consumption,
- Define the level of emissions so that the obtained results can be compared with competitors in their business sector.

The state-of-art on reducing carbon footprint in a supply chain is classified, as [19]

- Low carbon operational aspects of supply chain management (sourcing, inventory management, transportation);
- Low carbon SC design (network design and SC coordination, SC collaboration);
- Carbon management (the accounting and conceptualization of carbon footprint).

In this paper we will focus on the carbon footprint accounting in the context of distribution activities. Additionally specificity of Central and Eastern Europe has been considered.

3. Research methodology

The following research questions are stated in this paper:

RQ1: What are the challenges of the current approaches in the CO_2 measuring (accounting) in a supply chain?

RQ2: Which factors contribute in practice to the CO_2 accounting from distribution activities?

The research methodology is presented in Figure 1.

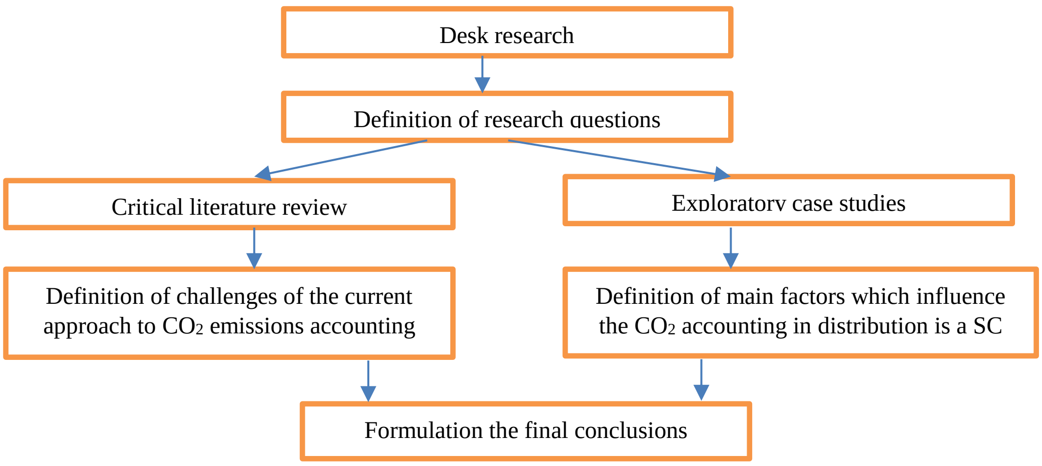

Figure 1 Research methodology

4. Findings/Case studies

The carbon footprint accounting derives from LCA (life-cycle assessment) concept and it estimates the GHGs emitted (and embodied) at each identified step of the product's (or service) life cycle. Most of the carbon footprint accounting covers direct emission (so called scope 1) and indirect emissions (scope 2 - embodied emissions in purchased energy & scope 3 - other indirect emissions). In the context of a supply chain a carbon footprint might be measure with:

- Top-down using the Input-Output Framework for corporate or regional CF accounting [20] or
- Bottom up approach with LCA approach (or hybrid IO-LCA) for product level CF accounting [21, 22].

The accounting of carbon footprint covers [23, 24], as follows:

- Selection of GHGs to be included in calculations (direct and indirect);
- Setting organizational & operational boundary using equity approach and stakeholder analysis;

4.1 Collection of GHG emission data

Companies measure CF usually at the aggregate level, because they struggle to allocate the data to the individual product or service in a SC [25, 26] so structural decomposition analysis and structural path analysis are applied to identify the main areas for emissions [8], which required a significant work load and dedicated resources.

One of the most important issues related to measuring the carbon footprint of enterprises is the data collection. Srividya and Tripathy in their research [27] draw attention to this problem by describing more broadly the essence of proper information gathering within Big Data and pointing to their important role in the context of managing the entire sustainable supply chain. Thanks to the use of modern technologies and the inclusion of sustainable development elements within the shared supply chains, it is possible to the map the whole supply chain in mathematical model along with all its participants [28, 29]. Relevant data might be collected through real-time measurements, or through estimations based on emission factors and models [24]. The choice of appropriate method is determined by the mandatory or voluntary character of carbon footprint calculations, as well as feasibility (costs and capacity). Specific emission factors are used often from general databases on consumption of fuels, energy, and other inputs. That situation might result in differences in the carbon footprint calculations.

4.2 Selected carbon footprint schemes and guidelines

There are common guidelines for accounting of carbon footprint like ISO 14067:2018, DEFRA 2010, PAS 2050 and Greenhouse Protocol. Accademia contributes also to carbon foot print accounting by presenting conceptual models [18] measurement and benchmarking methods [8, 30] which are dedicated for a SC. Despite the variety of presented above approaches there is a gap with regard to standard guidelines for the supply chain CF accounting which is actionable for reliable and feasible calculation of CF from the logistics processes.

Measuring the carbon footprint and reporting emissions as part of an industry association of producers, or to a organizations such as Lean & Green or the Carbon Disclosure Project, helps to find a benchmark for determining the level of processes efficiency.
In this section we compare the selected popular schemes and guidelines for carbon footprint accounting and reporting. The analyzed approaches and their diverse nature indicate the multilevel nature of the issue of measuring the carbon footprint. The Table 1 presents the selected initiatives. In order to categorized each method, we compare different schemes and guidelines based on the same set of criteria (Table 1). The brief characteristics of the analyzed approaches is presented below.

4.2.1 Carbon Disclosure Project (CDP)

CDP provides universal tools for determining the level of the carbon footprint. The organization publishes lists indicating the CFs of associated companies. The international nature of the project and the parameterized method of measuring the level of greenhouse gases (GHG) emissions at each stage of the SC make the method more credible and popularize it among the world's largest producers. Its biggest advantage is its universal character and great investor confidence in the results presented by the organization. The main challenge is to guarantee the quality of the input data to perform the complex analysis [31].

Table 1 Selected schemes and guidelines for assessment of GHG emissions.

	Carbon Disclosure Project (CDP)	**EU Emissions Trading Scheme (EU ETS)**	**UK DEFRA Guidelines**	**Japanese Voluntary ETS (J-VETS)**
The area of influence	Global	EU	EU	Asia
Complementary method for calculation of overall emission	No	Yes	Yes	Yes
Provides a calculation method?	Yes	Yes	Yes	Yes
Emission Trading Scheme	No	Yes	No	Yes
Uses another method of GHG assessment	Yes	No	No	No
Covers a whole SC emission	Yes	Yes	Yes	Yes
Recognized internationally policy	Yes	Yes	Yes	Yes
Financial penalties for non-compliance	No	Yes	No	Yes

4.2.2 European Union Emissions Trading System (EU ETS)

EU ETS is an emission permit system within European Union, which allows for assigning CO_2 emission limits to individual member states and contribute to “Fit for 55” Policy”. The emission allowances can be traded on the common exchange. In the long-term perspective, countries investing in renewable energy sources can resell their emissions to countries that use fossil fuels and require increased emission permits. The main challenge is lack of a commonly available tool supporting the calculation of the carbon footprint. The concept allows for the calculation of the carbon footprint on the basis of other validated methodologies which, however, may differ from each other [32].

4.2.3 UK Department for Environment, Food and Rural Affairs (DEFRA) Guidelines

The unquestionable advantage of the method is that it provides precise indicators that enable the calculation of GHG emissions on the basis of fuel consumption of various means of transport. Including road, rail, air and intermodal transport. The total carbon footprint of the distribution can be calculated from the fuel consumption parameter, the number of kilometers and the specific vehicle type according to the Gross Vehicle Mass class. The method also makes it possible to determine the carbon footprint resulting from energy consumption of processes expressed as kWh. The final result is presented as CO_2 equivalent - kg CO_2e, and its structure can be presented in a more complex way, taking into account the composition of methane, carbon dioxide and nitrogen oxide. The main challenge of this approach is the very elaborate way of measuring the final emissions. Published emission factor tables require precise parameterization of own processes to enable precise determination of the carbon footprint level.

4.2.4 Japanese Voluntary ETS (J-VETS)

The functional scope of the method is very close to the EU ETS. Its main assumptions are aimed at imposing restrictions on GHG emissions among the main issuers and the trading of emission allowances between them. The method is the first cap & trade type scheme in Japan. The main challenge of this scheme is its regional character [33].

4.3 Reducing the carbon emissions from distribution

In the context of distribution in a SC, the mitigation of the carbon footprint from freight is noticeable trend [34]. Transportation is the major sources of GHG emissions from distribution in a supply chain. For this reason we focus in this paper on the direct CO_2 emission from transportation in distribution operations in a SC.

The summary of the dominant operational approaches to reduce the CO_2 emissions from the distribution in SC is presented in Table 2.

Table 2 Operational approaches to reduce the CO_2 emissions

Operational approaches to reduce CO_2 emissions from distribution	Source
Fleet renewal & electrification	[35, 36]
Demand consolidation	[37]
Pooling for last mile delivery	[38]
Full truckload strategy	[39]
Mode selection	[3, 40]

Seeking opportunities to implement consolidation, increase the load rate ns of transport used and changes in customer purchasing trends, thanks to which it will be possible to significantly reduce the carbon footprint left during the distribution [3, 37].

4.4 Case studies

In this section we present the quantitative and qualitative results from 2 exploratory case studies. Based on market data, a comparison of two logistic models and the carbon footprint related to its functioning was made. In the case of company A, the main goal was to demonstrate possible differences related to the adopted calculation methodology. At the same time, on the example of data from company B, further attempts were made to identify the key factors determining the quality of the results obtained. Their indication also outlined potentially further areas for research. Thanks to the possibility of analyzing market data, it was possible to verify the research and scientific approach. Information from real enterprises allows for the adoption of a broader horizon in the undertaken research and the validation of the obtained results. Due the space limitation only the main findings are summed up.

4.5 Company A

Company A is a big size international apparel retailer with own distribution network. The scope of our study covers the distribution operations in a SC for Central and East European market. The analyzed network in this study is optimized by the center of gravity method [7]. The detailed description of this case study can be found in our previous research [41]. Due to the space limitation we present here the comparison of the carbon emissions with use of two approaches, namely using US EPA and US Dekra emission factors for the main logistics DC. In Figure 2 is presented the scheme of distribution network.

The assumptions for both methods are made, as follows:

- The same distance, truck types & weight (40 tonnes),
- Distance for ferry from Helsinki to Tallinn is 82 km,
- Current network design is optimized & fixed.

Table 3 presents the data which was used for calculations.

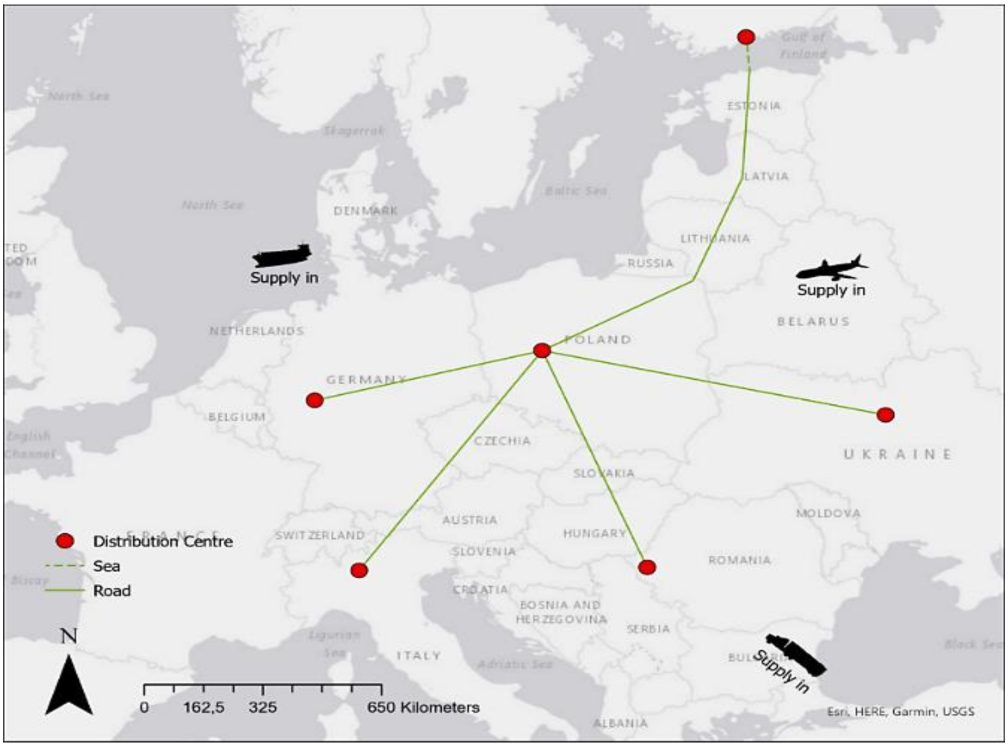

Figure 2 Analyzed distribution network

Table 3 Data for calculation adopted from Dubisz and Golinska research [41].

Point of origin		Total monthly distance [km]	No of shipments per month
DC Italy		20275	14
DC Finland	Via road	13120	10
	via ferry	820	10
DC Germany		17885	22
DC Romania		15565	13

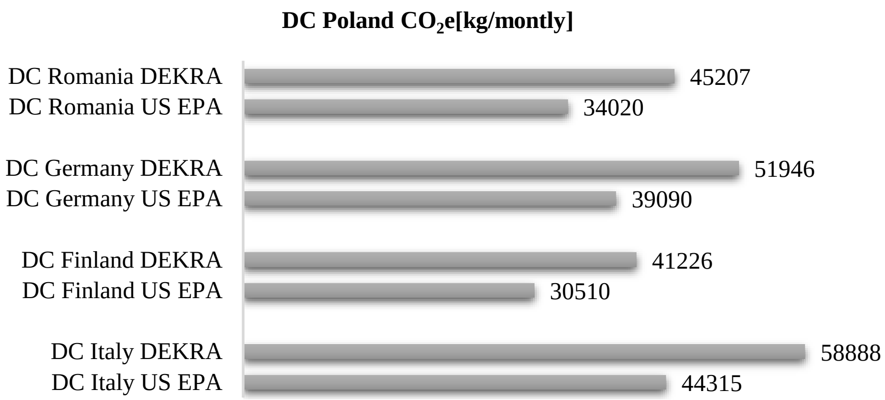

Figure 3 Comparison of the results

The example, which is presented in Figure 3 shows that the selection of a calculation method might impact the results even by 25%. For that reason a second case study (Company B) was conducted to identify the potential crucial factors which shall be taken in consideration when managing the CO_2 emissions in the distribution in a supply chain.

The brainstorming with the SC managers in the analyzed company A, has allowed to identify the action crucial for mitigating the emissions from the distribution activities, as follows:

- Increasing load factor of truck;
- Consolidating the shipments between distribution centers;
- Managing of returns at regional level in each DC (as it was identified, as s significant source of additional shipments between DCs);
- Outsourcing of transport activities to the logistics service providers, as they can provide fleet with lower emission levels;
- Implementing a new KPI for monitoring the load factor of shipments.

The findings are consistent with the previous research, as presented in Table 2.

4.6 Company B

Company B is a big size retailer in food industry in Poland. Daily deliveries are performed from regional distribution centers to hundreds of small size shops on daily bases. The exploratory case study was conducted with the supply chain managers in order to identify the factors which are crucial for accounting in carbon emissions in their distribution network. First during brainstorming session 3 main construct (decision making areas) were identified:

- Demand for fleet (related to the fleet characteristics and cargo characteristics);
- Energy consumption;
- Road conditions.

In the second step of the brainstorming session the variables (control parameters) for decision making were defined (Figure 4).

	Construct		
	Fleet	**Energy consumpt.**	**Road**
Control parameters	• Truck type • Engine size • Fuel type • Truck body type • Tyre type & size • Cargo weight & volume	• Fuel efficiency • Age of vehicle • Fuel type &quality	• Distance • Weather conditions • Topography of route • Road type

Figure 4 The decision making matrix.

In this case study the managers have identified more variables than are included in the current existing methods for the calculation of the CO_2 emissions. As the results a dedicated calculator was elaborated. However the access to the reliable data for calculation of all of the variables is difficult. Further expert research will be continued in order to investigate the reference values and importance of each parameter, in order to create a more universal tool.

5. Discussion and conclusion

Despite of the fact that a lot has been done in recent years to improve CF levels in various business sectors, there are still gaps to be filled up. The standardization of the way in which CF is measured in a SC worldwide is needed. In this paper we contribute to the existing research gap by searching answers to the two research questions.

First in RQ1 we search for the challenges of the current approaches in the CO_2 measuring (accounting) in a supply chain. We identify that the access to the comprehensive and reliable data is a main challenge. Moreover the existing approaches for the bottom-up CF calculation in a SC relay strongly on the LCA methodology which is time- and resource-intensive. Our results are consistent which the findings of Das and Jharkharia [19], which identify the problems with the indentation of the scope, boundaries and data for LCA. Thus, a more actionable approach is needed.

Searching the answer for the RQ2, we have conducted 2 exploratory case studies in retailing sector. Through the brainstorming with the SC managers we have identified factors, which in practice contribute to the CO_2 accounting from distribution activities.

The limitations of this paper result from the limited expert selection (2 companies). In the further research we will focus on the definition of the reference values of the identified variable (operational) and on verification of the factors with a broader expert's panel. On the basis of the collected data, further research can be carried out to verify the degree of dependence between individual parameters of the sustainable supply chain and the increase in greenhouse gas emissions. Precise definition of the key factors determining the level of efficiency of the supply chain will help to identify its important elements determining a significant increase in the efficiency of processes. On the basis of further research, sets of guidelines for logistics operators may be developed, which will be used to minimize the carbon footprint resulting from distribution processes. Recommendations for distribution companies based on the results of surveys, basic research and resulting from analyzes of transport processes of existing companies will be of a very high and useful nature, enabling their implementation in real market conditions.

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7. References

[1] Guo Y, Zhu L, Wang X, Qiu X, Qian W, Wang L. Assessing environmental impact of NO_X and SO_2 emissions in textiles production with chemical footprint. Sci Total Environ. 2022;831:154961.

[2] Intergovernmental Panel on Climate Change (IPCC). Climate change 2014: mitigation of climate change. Working group III contribution to the fifth assessment report of the intergovernmental panel on climate change. New York: Cambridge University Press; 2014.

[3] Lin N. CO_2 emissions mitigation potential of buyer consolidation and rail-based intermodal transport in the China-Europe container supply chains. J Clean Prod. 2019;240:118121.

[4] Karlsson I, Rootzén J, Johnsson F, Erlandsson M. Achieving net-zero carbon emissions in construction supply chains-a multidimensional analysis of residential building systems. Developments in the Built Environment. 2021;8:100059.

[5] Halim S, Gan SS, Oentoro JM. Identifying factors that influence customers' interest in buying refurbished smartphones: an Indonesian context. Asia Pac J Sci Technol. 2022;27(4):1-11.

[6] Xu B, Xu R. Assessing the role of environmental regulations in improving energy efficiency and reducing CO_2 emissions: evidence from the logistics industry. Environ Impact Assess Rev. 2022;96:106831.
[7] Tao Z, Zheng Q, Kong H. A modified gravity p-Median model for optimizing facility locations. J Syst Sci Inf. 2018;6(5):421-34.
[8] Acquaye A, Genovese A, Barrett J, Lenny Koh SC. Benchmarking carbon emissions performance in supply chains. Supply Chain Manag. 2014;19(3):306-21.
[9] Hervani AA, Helms MM, Sarkis J. Performance measurement for green supply chain management. Benchmarking. 2005;12:330-53.
[10] Abdullah MI, Sarfraz M, Qun W, Javaid N. Drivers of green supply chain management. Logforum. 2018;14(4):437-47.
[11] Wojtkowiak D, Cyplik P. Operational excellence within sustainable development concept-systematic literature review. Sustainability. 2020;12(19):7933.
[12] Sureeyatanapas P, Yodprang K, Varabuntoonvit V. Drivers, barriers and benefits of product carbon footprinting: a state-of-the-art survey of Thai manufacturers. Sustainability. 2021;13(12):6543.
[13] Jermsittiparsert K. Examining the sustainable energy and carbon emission on the economy: panel evidence from ASEAN. Int J Econ Finance Stud. 2021;13(1):405-26.
[14] Haseeb M, Nasih M, Haouas I, Mihardjo L, Jermsittiparsert K. Asymmetric impact of textile and clothing manufacturing on carbon-dioxide emissions: evidence from top Asian economies. Energy. 2020;196:117094.
[15] Haseeb M, Wattanapongphasuk S, Jermsittiparsert K. Financial development, market freedom, political stability, economic growth and CO_2 emissions: an unexplored nexus in ASEAN countries. Contemp Econ. 2019;13(3):363-74.
[16] Wiedmann T, Minx J. A definition of ‘carbon footprint’. In: Pertsova CC, editor. Ecological Economics Research Trends. Hauppauge: Nova Science Publishers; 2018. p. 1-11.
[17] Moufad I, Jawab F. A methodology for measuring the ecological footprint of freight transport in urban areas: a case study of a Moroccan City. Proceedings of the International Conference on Industrial Engineering and Operations Management; 2018 Mar 6-8; Bandung, Indonesia. Southfield: IEOM Society International; 2018. p. 3220-7.
[18] Montoya-Torres JR, Gutierrez-Franco E, Blanco EE. Conceptual framework for measuring carbon footprint in supply chains. Prod Plan Control. 2015;26(4):265-79.
[19] Das C, Jharkharia S. Low carbon supply chain: a state-of-the-art literature review. J Manuf Technol Manag. 2018;29(2):398-428.
[20] Munasinghe M, Jayasinghe P, Ralapanawe V, Gajanayake A. Supply/value chain analysis of carbon and energy footprint of garment manufacturing in Sri Lanka. Sustain Prod Consum. 2016;5:51-64.
[21] Rugani B, Vázquez-Rowe I, Benedetto G, Benetto E. A comprehensive review of carbon footprint analysis as an extended environmental indicator in the wine sector. J Clean Prod. 2013;54:61-77.
[22] Wiedemann S, McGahan E, Murphy C, Yan MJ, Henry B, Thoma G, et al. Environmental impacts and resource use of Australian beef and lamb exported to the USA determined using life cycle assessment. J Clean Prod. 2015;94:67-75.
[23] Chen JX, Chen J. Supply chain carbon footprinting and responsibility allocation under emission regulations. J Environ Manage. 2017;188:255-67.
[24] Pandey D, Agrawal M, Pandey JS. Carbon footprint: current methods of estimation. Environ Monit Assess. 2011;178(1):135-60.
[25] Guajardo M. Environmental benefits of collaboration and allocation of emissions in road freight transportation. In: Zeimpekis, V, Aktas E, Bourlakis M, Minis I, editors. Sustainable freight transport. Cham: Springer; 2018. p. 79-98.
[26] Valderrama CV, Santibanez-González E, Pimentel B, Candia-Vejar A, Canales-Bustos L. Designing an environmental supply chain network in the mining industry to reduce carbon emissions. J Clean Prod. 2020;254:119688.
[27] Srividya V, Tripathy BK. Role of big data in supply chain management. In: Perumal K, Chowdhary CL, Chella L, editors. Innovative Supply Chain Management via Digitalization and Artificial Intelligence, Studies in Systems, Decision and Control. Singapore: Springer; 2022. p. 43-59.
[28] Divya Zion G, Tripathy BK. Comparative analysis of tools for big data visualization and challenges. In: Anouncia SM, Gohel HA, Vairamuthu S, editor. Data Visualization. Singapore: Springer; 2020. p. 33-52.
[29] Lee YH, Golinska-Dawson P, Wu JZ. Mathematical models for supply chain management. Math Probl Eng. 2016;2016:1-4.
[30] Roibas L, Elbehri A, Hospido A. Carbon footprint along the Ecuadorian banana supply chain: methodological improvements and calculation tool. J Clean Prod. 2016;112:2441-51.
[31] Riantono IE, Sunarto FW. Factor affecting intentions of Indonesian companies to disclose carbon emission. Int J Energy Econ Policy. 2022;12(3):451-9.
[32] Quemin S. Raising climate ambition in emissions trading systems: the case of the EU ETS and the 2021 review. Resour Energy Econ. 2022;68:101300.
[33] Herrador M, de Jong W, Nasu K, Granrath L. Circular economy and zero-carbon strategies between Japan and South Korea: a comparative study. Sci Total Environ. 2022;820:153274.
[34] Werner-Lewandowska K, Golinska-Dawson P. Sustainable logistics management maturity-the theoretical assessment framework and empirical results from Poland. Sustainability. 2021;13(9):5102.
[35] Ku AY, de Souza A, McRobie J, Li JX, Levin J. Zero-emission public transit could be a catalyst for decarbonization of the transportation and power sectors. Clean Energy. 2021;5(3):492-504.
[36] Woody M, Vaishnav P, Craig MT, Lewis GM, Keoleian GA. Charging strategies to minimize greenhouse gas emissions of electrified delivery vehicles. Environ Sci Technol. 2021;55(14):10108-20.
[37] Mei Q, Li J, Ursavas E, Zhu SX, Luo X. Freight transportation planning in platform service supply chain considering carbon emissions. Int J Prod Econ. 2021;240:108241.
[38] Olsson J, Hellström D, Pålsson H. Framework of last mile logistics research: a systematic review of the literature. Sustainability. 2019;11(24):7131.
[39] Rudi A, Frohling M, Zimmer K, Schultmann F. Freight transportation planning considering carbon emissions and in-transit holding costs: a capacitated multi-commodity network flow model. EURO J Transp Logist. 2016;5(2):123-60.
[40] Thibbotuwawa A, Nielsen P, Zbigniew B, Bocewicz G. Factors affecting energy consumption of unmanned aerial vehicles: an analysis of how energy consumption changes in relation to UAV routing. Proceedings International Conference on Information Systems Architecture and Technology; 2018 Sep 16-18; Nysa, Poland. Cham: Springer; 2019. p. 228-38.
[41] Dubisz D, Golinska-Dawson P. Carbon footprint management within a supply chain-a case study. Eur Res Stud J. 2021;XXIV(2B):860-70.