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Carbon Footprint Management within a Supply Chain – A Case Study

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Abstract:

Purpose: *The aim of this paper is to analyze the carbon footprint in a supply chain with the focus on distribution operations. We use the primary data from a case study conducted in the apparel industry.*
Design/Methodology/Approach: *Comparative studies of the results of two existing* CO_2 *measuring standards are presented for the same supply chain. We have chosen the apparel industry due to the fact that the returns in the apparel industry reach up to 40% and they contribute to the total level of* CO_2 *emissions from distribution operations.*
Findings: *In practice the level of the* CO_2 *emissions depend on the logistics parameters, like distance, load factor and transshipment schedule. The methods for the measuring of the carbon footprint do not fully reflect the real life needs. The reported level of* CO_2 *emissions depends on the used method for calculation. Thus, the choice of the calculation method should be carefully justified by a company.*
Practical Implications: *The case study method allows the application of US EPA and UK DEFRA carbon footprint calculation methods in real-world conditions .*
Originality/Value: *The papers on the* CO_2 *emissions in a supply chain management focus mainly on the manufacturing and sourcing operations. The studies on the Carbon footprint, which are related to the distribution operations are very limited. We contribute to this gap, by providing the empirical results.*

Keywords: *Low carbon supply chain, carbon footprint, supply chain management, distribution.*

JEL codes: *D30, L20.*

Paper Type: *Case study.*

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1. Introduction

Contemporary supply chain (SC) is a complex network of mutual interconnections. The environmental responsibility of participants of a supply chain is driven by the legal regulations, and a shift in expectations of the customers (Toptal and Çetinkaya, 2017). Companies in a supply chain can benefit by taking into account both the environmental concerns, and the operational excellence (Wojtkowiak and Cypik, 2020). The carbon footprint (CF) is recommended to measure the environmental performance of a supply chain (Sherafati *et al.*, 2020). The carbon footprint quantifies the impact of a product, process or activity in terms CO2 emissions (Patella *et al.*, 2019).

The policy makers worldwide aim for significant reduction of CO_2 emissions. The European Commission in the White Paper on Transport aims by 2030 to reduce greenhouse gas emissions in the transport sector by around 20% compared to 2008 levels. The Paris agreement signed in 2015 by 196 parties aims to minimize global warming effect and decrease average temperature by 1,5–2 degrees Celsius (UN, 2015). European Green Deal (EGD) proposes a legally binding target of zero net greenhouse gas emission by 2050 (EU, 2015). Current legal trends and policies oblige to take far-reaching measures to improve the measurability of greenhouse gas emissions in the supply chains (EU, 2019). The management of carbon footprint in supply chains shall be strategic imperative, as it helps not only the climate change issues but also fulfill the legislative requirements (Jabbour *et al.*, 2015; EC, 2006).

The aim of this paper is to analyze how the application of two different methods for carbon footprint (CF) measuring may influence the emissions value recognized in the supply chain. We present a case study of a global apparel company. We apply the case study approach, which allows exploring "what, "how" and "why" the analyzed phenomenon works (Yin, 2009). Meredith (1998) argues that that case studies are preferred to the more traditional rationalist methods (e.g., optimization, simulation, statistical modelling), as they allow for the conducting of an early stage explanatory investigation, even if variables are not fully understood. The main contribution of this study is the assessment of the emissions impact of transportation, which has not been well studied in the literature.

2. Literature Review

The concept of the low carbon supply chain (LCSCM) highlights the importance of measuring and reduction of the CO_2 emissions. Das and Jharkharia (2018) define is, as *"a strategy that integrates CO2 or CO2 equivalent or GHG emissions either as a constraint or as an objective in supply chain design and planning"*. The studies on the LCSCM are divided into two topic groups (Das and Jharkharia, 2018):

- the operational aspects of supply chain management (sourcing, production, distribution, network design and supply chain coordination);
- the accounting and conceptualization of carbon footprint.

In this article, we analyze the operational aspects of the supply chain (distribution and related transportation issues) by comparing two CF calculation methods, thereby merging these two (above) research strands. In this article, we contribute to the existing literature of LCSCM by providing empirical evidence on the problems of CF calculations.

According to the Greenhouse Gas Protocol (GGP, 2015), companies have to measure their emissions in response to a variety of business goals. The most significant challenge with regard to the CO_2 emission is data equality between SC participants (Sundarakani, 2008).

Modern supply chains are based on outsourcing solutions that benefit from the presence of independent third party service providers (LSPs) (Haffer, 2021). They link several participants in the supply chain, and transport and/or store goods on their behalf, therefore has an importance impact on the environmental performance of a SC (Bask *et al.*, 2018). Studies on environmental sustainability in SC management are mostly focused on the manufacturer perspective (Werner-Lewandowska and Golinska-Dawson, 2021). The studies on the distribution and transportation operations are underrepresented in literature. The papers often focus on sustainability of supply chain (environmental and/or social) but studies on the emissions-related issues of supply chain management are very limited (Das and Jharkharia, 2018).

Initiatives and methodologies for measuring CO_2 have been outlined worldwide (EC, 2015). Each of them focuses on different aspects of an emission within a supply chain or puts more attention to accurate tracking of specified factor or offers different way of sourcing data (Hervani and Marilyn, 2005). Table 1 presents key methodologies and standards implemented all over the world. Methods bolded in the below table are outlined in further part of this study (EU, 2015). Internationally recognized organizations such as United States Environmental Protection Agency (US EPA), and United Kingdom Department for Environmental Food & Rural Affairs (UK DEFRA) provides emission factors that can be used in calculations. Those are presented in Table 2, Table 3 and Table 4 below.

We do not include in this study European Trading Scheme Guidelines (EU ETS), as it’s a ‘cap and trade’ system dedicated for factories, its installations and flight operators (EU, 2015; EC 2009). EU ETS provides general guidelines to support organizations in defining their emission, and improving them but it doesn’t provide strict CF calculation method.

Table 1. *Presentation of major GHG reporting methods and initiatives worldwide*

Global	**Europe**	**North America**	**Asia-Pacific**
Carbon Disclosure Project	French Bilan Carbone	US Regional Greenhouse Gas Initiative	Japanese Voluntary ETS
WBCSD/WRI GHG Protocol	EU Emissions Trading Scheme	US Climate Registry General Reporting Protocol	Japanese GHG Reporting Scheme
IPCC 2006 GHG Workbook	**UK Department for Environment, Food and Rural Affairs (DEFRA) Guidelines**	USEPA GHG Rule	Australian Carbon Pollution Reduction Scheme
ISO 14064: 2006 (Parts 1 and 3)	UK Carbon Reduction Commitment (CRC)	US Securities and Exchange Commission (SEC) Guidance	Australian National Greenhouse and Energy Reporting Scheme
Climate Disclosure Standards Board (CDSB)	UK Climate Change Levy Agreement (CCLA)	Californian Climate Action Registry	
Enterprise Carbon Accounting	Dutch Energy Covenant	**US EPA Climate Leaders Inventory Guidance**	
International Local Government GHG Emissions Analysis Protocol	The Carbon Trust Standard	Environment Canada GHG Emissions Reporting Program	
Global Reporting Initiative		Chicago Climate Exchange	
API/IPIECA GHG Compendium*		US GHG Protocol Public Sector Standard	

Source: *Based on EC, 2015.*

Table 2. *Key emission factors provided by US EPA*

Vehicle Type	**CO_2 Factor**	**CH_4 Factor**	**N_2O Factor**	**Units**
	(kg / unit)	**(g / unit)**	**(g / unit)**	
Medium-and Heavy-Duty Truck	1,407	0,013	0,033	vehicle-mile
Passenger Car	0,341	0,009	0,008	vehicle-mile
Light-Duty Truck	0,464	0,012	0,01	vehicle-mile
Medium-and Heavy-Duty Truck	0,211	0,002	0,0049	ton-mile
Rail	0,022	0,0017	0,0005	ton-mile
Waterborne Craft	0,036	0,0116	0,0016	ton-mile
Aircraft	1,16	0	0,0357	ton-mile

Source: *US EPA 2020.*

Table 3. *Emission factors provided by UK DEFRA. Truck emission*

		100% Laden			
Type	Unit	kg CO_2e	kg CO_2	kg CH_4	kg N_2O
All HGVs	tonne.km	0,08820	0,08721	0,00001	0,00098
	km	1,17500	1,16178	0,00013	0,01308
	miles	1,89098	1,86970	0,00022	0,02106

Source: *Based on UK DEFRA, 2020.*

Table 4. *Emission factors provided by UK DEFRA. Cargo ship emission*

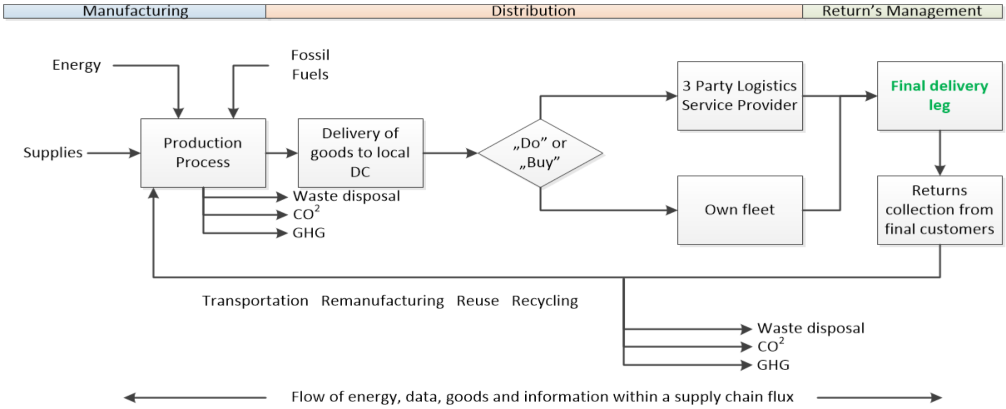
Activity	Type	Size	Unit	kg CO_2e	kg CO_2	kg CH_4	kg N_2O
Cargo ship	Vehicle transport	4000+ CEU	tonne.km	0,03245	0,03200	0,00001	0,00044
		0–3999 CEU	tonne.km	0,05840	0,05760	0,00002	0,00079
		Average	tonne.km	0,03858	0,03805	0,00001	0,00052

Source: *Based on UK DEFRA, 2020.*

3. Case Study

The analyzed company is a global apparel retailer with own Distribution Centers (DC) and cross-docks, which are located in many countries across Europe. We consider the Central and East Europe market. In order to ensure undisturbed goods flow in a timely manner to their customers, location of each DC has been configured based on: center of gravity method, graphic method and median method (Tao *et al.*, 2018). Thus, we can assume that locations of pick-up and delivery points is optimized and at this stage no more action can be taken to minimize a carbon footprint in terms of their geographical locations. Each DC size is adequate to the actual cargo volume flow in designated area. Figure 2 presents the logic of flow of materials in the analyzed SC.

Figure 2. *Supply chain before optimization. Major points of CO_2 emissions*

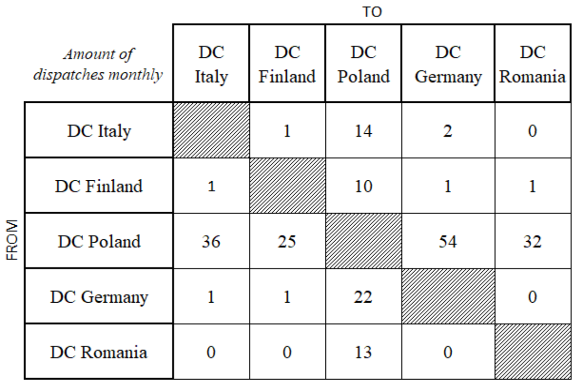


Source: *Own elaboration.*

Supplies are delivered via various transportation channels. Stock replenishment partially comes by road from Turkey, as this is the quickest way of refilling the supplies into DCs. The supplies are predominantly delivered by sea from manufacturers located in Asia (Taiwan, India and China). Urgent replenishment for High Value Low Volume (HVLV) goods can be arranged by air (rarely used due to high costs).

Total CO_2 emission within analyzed SC is calculated using both US EPA and US DEFRA standards. In order to present both results in the same format, the same distance and truck types were used for all calculations. The same conditions were adopted for calculation i.e. Truck total average weight – 40 tons, ferry linkage distance from port of Helsinki to port of Tallinn average value of 82 km has been chosen. For this study purposes actual locations are described by the country name only. Table 5, Table 6 and Table 7 contains data used for calculation.

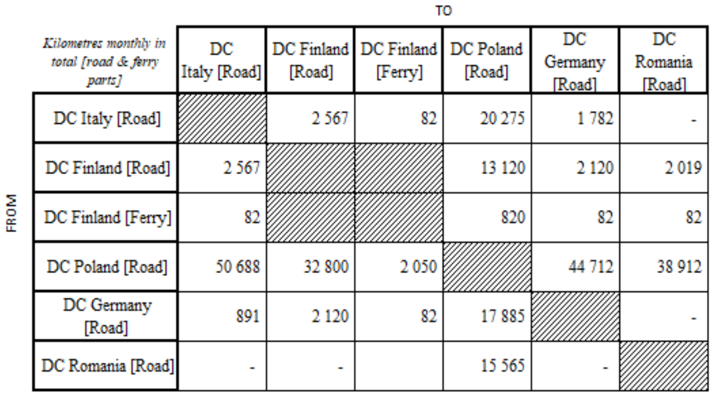
Table 5. *Average amount of line-hauls between each DC on monthly basis*



		TO				
	Amount of dispatches monthly	DC Italy	DC Finland	DC Poland	DC Germany	DC Romania
FROM	DC Italy	▨	1	14	2	0
	DC Finland	1	▨	10	1	1
	DC Poland	36	25	▨	54	32
	DC Germany	1	1	22	▨	0
	DC Romania	0	0	13	0	▨

Source: *Own elaboration.*

Table 6. *Total monthly distance of road in each DC*



		TO					
	Kilometres monthly in total [road & ferry parts]	DC Italy [Road]	DC Finland [Road]	DC Finland [Ferry]	DC Poland [Road]	DC Germany [Road]	DC Romania [Road]
FROM	DC Italy [Road]	▨	2 567	82	20 275	1 782	-
	DC Finland [Road]	2 567	▨	▨	13 120	2 120	2 019
	DC Finland [Ferry]	82	▨	▨	820	82	82
	DC Poland [Road]	50 688	32 800	2 050	▨	44 712	38 912
	DC Germany [Road]	891	2 120	82	17 885	▨	-
	DC Romania [Road]	-	-		15 565	-	▨

Source: *Own elaboration.*

In US EPA methodology, the monthly amount of line-hauls between each location is multiplied by distance and CO_2 emission factor adequate to the truck type. Same logic is used by the ferry routes (to and from Finland). In this stage of calculation truck's total average weight and distance has been taken into consideration.

UK DEFRA methodology takes into consideration a filling grade of a truck. This approach allows checking how truck capacity and level of filling of a trailer impact emission. All distance values are converted from kilometers to miles where needed using conversion ratio 0.621371 (Ambler, 2008) and rounded to whole numbers. Outcome of those calculations is presented in Table 7 for US EPA and table 8 for US DEFRA. The differences in calculation of emission are related to different approach and factors structure in each methodology. In UK DEFRA method assumption is made, that the vehicle is fully loaded. US EPA methodology doesn't take this factor into consideration and it is based on truck type only. Values of carbon footprint are presented in Figure 3.

Table 7. *Total CO2 emission monthly US EPA calculation methodology*

		TO				
	tCO2e US EPA approach [kg/monthly] Road and ferry parts calculated	DC Italy	DC Finland	DC Poland	DC Germany	DC Romania
FROM	DC Italy	▨	2 318	17 726	1 558	-
	DC Finland	2 318	▨	12 204	1 927	1 839
	DC Poland	44 315	30 510	▨	39 090	34 020
	DC Germany	779	1 927	15 636	▨	-
	DC Romania	-	-	13 608	-	▨

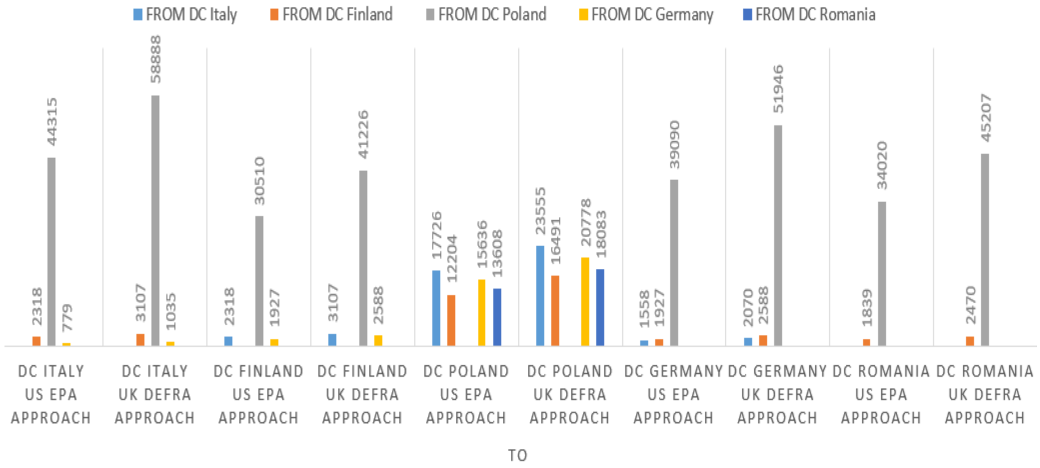
Source: *Own elaboration.*

Table 8. *Total CO2 emission monthly UK DEFRA calculation methodology*

		TO				
	tCO2e UK DEKRA [kg/monthly] Road and ferry parts calculated	DC Italy	DC Finland	DC Poland	DC Germany	DC Romania
FROM	DC Italy	▨	3 107	23 555	2 070	-
	DC Finland	3 107	▨	16 491	2 588	2 470
	DC Poland	58 888	41 226	▨	51 946	45 207
	DC Germany	1 035	2 588	20 778	▨	-
	DC Romania	-	-	18 083	-	▨

Source: *Own elaboration.*

Figure 3. *Measuring Methodology Matrix. Compare of US EPA and UK DEFRA*



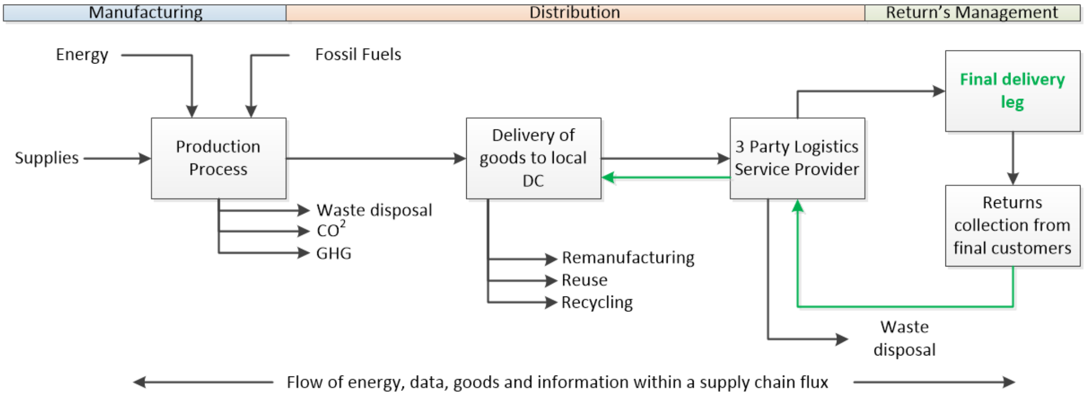
Source: *Own elaboration.*

Grey graph bars are for replenishment of the deliveries from the main DC located in Poland, and those values are related to the actual sales levels. Optimization of returning routes marked as a colored graph bars should be developed in terms of its number and frequency. It can be achieved by re-configuration of distribution operations in terms of return's management. An improved return's management can be expressed through an improved shipment consolidation process. DC located in Poland is a main distribution center, responsible for arranging the replenishment routes to each regional DC. All other routes are inter-location stock movement or movements of empty pallets between locations. All inbounds to DC located in Poland are for returned products, or empty pallets. In order to minimize carbon footprint in this particular supply chain following steps are recommended:

- Decrease level of returning routes by refurbishing or disposal of returned items in each DC regionally.
- Implementation of outsourced rented loading unit system.
- Consolidate goods where possible (Fewer trips).
- Increase the participation of the LSP.
- Implement a new process indicator (KPI) for measuring capacity and filling grade of trucks.

LSPs implement the solution to lower the CO2 emissions and environmental impact of logistics operations (Abbasi and Nilsson, 2016). In the analyzed company the distribution operations with regard to return's management shall be outsourced to logistic service provider (LSP). LSP is able to reduce the carbon footprint by the adoption of a Full Truck Load, and by consolidating the shipments (Berling and Eng-Larsson, 2016). According to Hoen *et al.* (2014) in such cases, the carbon footprint is reduced, as there will be fewer trips. In addition, LPS usually uses a newer fleet to better manage the choice of transportation methods.

Figure 4. *Improvement proposal*



Source: *Own elaboration.*

4. Conclusions

In practice, the level of the carbon footprint depends on the parameters related to the distribution organization, like distance, load factor and transshipment schedule (Rudi *et al*., 2016). The presented results of calculation indicate, that the methods for the measuring of the carbon footprint do not fully reflect the real life needs. The reported level of CO2 emissions depends on the used method for calculation.

Thus, the choice of the calculation method should be carefully justified by a company. In order to maintain a proper CO2 tracking level within a supply chain it is crucial to define "how?" and "why?" we wish to track them. The data availability is a common problem when choosing the Carbon footprint calculation method (Acquaye *et al*., 2014). For example, in the presented UK DEFRA methodology, a precise calculation of a load factors is required. Thus, each company shall assess data availability and choose sufficient method and tools to track their emissions within SC.

Further research will include the development of the method for identification and integration of the data regarding the CO2 emissions from the supply chain participants.

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