**European Research Studies Journal**  
*Volume XXIV, Issue 2B, 2021*  
pp. 860-870

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**Carbon Footprint Management within a Supply Chain – A Case Study**

Submitted 19/03/21, 1st revision 23/04/21, 2nd revision 13/05/21, accepted 30/06/21

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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 CO₂ 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 CO₂ emissions from distribution operations.

*Findings:* In practice the level of the CO₂ 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 CO₂ 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 CO₂ 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.

**Acknowledgement:** The publication fee is funded by internal grant of the Poznan University of Technology 0812/SBAD/4187.

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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 CO2 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 CO2 emissions. Das and Jharkharia (2018) define it 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 CO₂ 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 CO₂ 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 | CO₂ Factor (kg / unit) | CH₄ Factor (g / unit) | N₂O Factor (g / unit) | Units |
|--------------|------------------------|-----------------------|-----------------------|-------|
| 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

| Type       | Unit    | kg CO₂e | kg CO₂ | kg CH₄ | kg N₂O |
|------------|---------|---------|--------|--------|--------|
| 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 CO₂e | kg CO₂ | kg CH₄ | kg N₂O |
|------------|------------|------------|---------|---------|--------|--------|--------|
| 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 CO₂ 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 CO₂ 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**

| FROM       | DC Italy | DC Finland | DC Poland | DC Germany | DC Romania |
|------------|----------|------------|-----------|------------|------------|
| 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**

| FROM       | DC Italy [Road] | DC Finland [Road] | DC Finland [Ferry] | DC Poland [Road] | DC Germany [Road] | DC Romania [Road] |
|------------|-----------------|-------------------|--------------------|------------------|-------------------|-------------------|
| DC Italy   | 2.567           | 82                | 20.27              | 1.782            | -                 |                   |
| DC Finland | 2.567           | 82                | 13.12              | 2.120            | 2.019             |                   |
| DC Finland | 82              | 82                | 82                 | 82               | 82                | 82                |
| DC Poland  | 50,688          | 32,800            | 2,050              | 44,712           | 33,912            |                   |
| DC Germany | 891             | 2,120             | 82                 | 17,881           | -                 |                   |
| DC Romania | -               | -                 | 15,565             | -                |                   |                   |

**Source:** Own elaboration.
In US EPA methodology, the monthly amount of line-hauls between each location is multiplied by distance and CO₂ 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**

| From       | To       | DC Italy | DC Finland | DC Poland | DC Germany | DC Romania |
|------------|----------|----------|------------|-----------|------------|------------|
| DC Italy   |          | 2,318    | 17,726     | 1,358     | -          |            |
| DC Finland |          | 2,318    | 12,204     | 1,927     | 1,830      |            |
| DC Poland  |          | 44,315   | 30,510     | 39,090    | 34,020     |            |
| DC Germany |          | 779      | 1,927      | 12,036    | -          |            |
| DC Romania |          | -        | -          | 13,608    | -          | -          |

*Source: Own elaboration.*

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

| From       | To       | DC Italy | DC Finland | DC Poland | DC Germany | DC Romania |
|------------|----------|----------|------------|-----------|------------|------------|
| 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**

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**

![Diagram of supply chain process](image)

**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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