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CARBON FOOTPRINT PRINCIPLES AND CHALLENGES IN TRANSPORT LOGISTICS

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Abstract: Logistic operators are under pressure from consumers and governments to reduce the carbon footprint impact. Operators need increased focus on reducing the carbon impact and calculating their actual carbon emissions. EU's Emissions Trading System comes into force from 2027 and works on the 'cap and trade' principle. A cap is a limit set on the total amount of greenhouse gases that logistic operators may emit. Therefore, there is a need to develop a roadmap and action plans to reduce emissions, which will drastically impact the logistic operators. The paper brings forward current standards, frameworks and principles as well as examples of carbon footprint calculations in last-mile transportation.

Keywords: Carbon Footprint Calculation, Digitalisation, Last Mile Delivery, Frameworks, Transport Planning

1 INTRODUCTION

Order management and transport planning of last-mile transportation is critical since it is expensive and can account for as much as 75% of the total transportation cost [1]. Freight distribution companies are focusing on improving routing efficiency and reducing the cost of their deliveries. The improvement today also needs to be reductions in externalities such as congestion [2], air pollution [3], and greenhouse gas emissions as well as noise and accidents [4,5].

The costs of fuel consumption represent over 50% of the total operating costs in last-mile transportation [6], especially when taking load, distance, speed, and time dependencies into consideration [7].

According to a recent literature review on last-mile deliveries [8] there is a growing interest in studying last-mile delivery operations from both academia and industry to identify the underlying challenges and possible solutions. In a recent literature review on last-mile strategies for urban freight delivery [9], 22 last-mile delivery strategies are identified. This is reflected by an increase in the number of publications related to last-mile deliveries [10]. Even though there is a growing body of literature addressing last-mile delivery operations, the authors found a lack of principles and methods for transport planning and calculating CO_2 emissions concerning transportation in last-mile deliveries.

The challenge is that freight distribution companies are faced with new and stronger requirements for documenttation and reporting. These new requirements drive a growing need for innovation and efficiency at freight distribution companies, which has not been seen before. Transportation companies must from 2027 be part of the EU's emissions trading system (ETS). The current EU requirements for the fulfilment and reporting of Greenhouse Gas (GHG), which follows ISO14083 will also be expanded with the new EU requirements (see section 2), which together with the EU's emissions trading system (ETS), will result in freight distribution companies being put in a very difficult situation.

The principle of the ETS is that there is a CO_2 quota allocated to companies in general, which will be continuously reduced to reach the climate targets that have been set.

GHG distinguishes between Scope 1, Scope 2 and Scope, where Scope 3 is the emission of CO_2 (e) from activities carried out by subcontractors. This is where freight distribution companies come into play when transporting goods to or from a company.

Customers who purchase transport services will focus on only "paying" carbon emissions for their share of the transport. This means that freight distribution companies are squeezed on their competitive edge partly because they have to buy CO_2 from the continuously reduced CO_2 quota in the ETS and partly because customers have to document and report on their GHG in scope 3. Transport companies will aim to reduce overall emissions by minimizing idle time and optimizing the utilization of payload as well as consolidating goods on different modes of transport.

The EU is currently working on introducing a digital product passport (DPP), which will help reduce environmental impact and support development towards a circular and sustainable future. The purpose of the DPP is also to help the customer make better decisions when buying, which is why it is expected that the DPP will also contain information about CO_2. DPP not only requires freight distribution companies to provide this data, but the product owner or the financially responsible company (e.g. distributor or retailer) is responsible for this data. A challenge for freight distribution companies is that both their own and the customer's calculation must be reported for the planned DPP.

Overall, there is a need for more data to document and report the calculations used. This includes principles and methods to be able to meet requirements from the EU as well as requirements from customers and for transport companies' own GHG reporting. To our knowledge, no previous studies have investigated this issue, as it is a quite new but challenging planning area, and there is a lack of guidelines to overcome these challenges.

The purpose of this article is to shed light on the challenges of order management and transport planning with a focus on calculating CO_2 emissions regarding transport services. We particularly focus on the differences between pre-calculations, which are often based on offers as well as form the basis for agreements with customers, and the subsequent follow-up on the actual work carried out for the customer, also called post-calculation.

A variation and difference between pre-calculation and post-calculation have always existed, but the question is which of the parties will be exposed to this difference in terms of emissions and what significance it will have concerning the aforementioned documentation and reporting requirements in the future in the area of sustainability. A possible difference between the pre-calculation and post-calculation is expected to become the new and decisive competitive parameter for both the goods owner/customer but also transport companies in the future, which is why planning and optimization of transportation is expected to be an even more important factor in transport companies.

The authors hypothesise that, depending on which planning principles and methods transport in the last-mile is carried out, there will be differences in the amount of environmental pollution. This difference between the offer to the customer and the actual consumption of emissions and thus also the price will be the future challenge that needs to be clarified.

This environmental burden must be expected to be seen by the end customer, customs, public authorities, etc. via the new EU digital product passport. This may result in additional GHG costs for the product and not just the GHG reporting of the customer's business.

We search for answers to the following research questions:

- How will transport planning principles and methods affect the amount of greenhouse gases?
- How will this difference be handled by the supplier of transport services? and whom of the partners (customer vs. supplier) should bear this difference?
- How will competitiveness be affected by current and future reporting and documentation of emissions?

The paper is organized as follows: Section 2 covers the main emission frameworks (Greenhouse Gass Protocol, Global Logistics Emission Council Framework) and ISO's 14083 standard as well as EU's Digital Product Passports and EU's Emissions Trading System. Section 3 covers the elements of Transport Planning and Carbon Footprint and section 4 covers four different principles and methods of calculating the transport work and emission of 3 deliveries. Section 5 is a discussion and finally, section 6 is a conclusion.

2 FRAMEWORKS SUPPORTING EMISSION REDUCTION

In this section, we discuss frameworks supporting emission-reducing frameworks such as the Greenhouse Gass Protocol, Global Logistics Emission Council Framework and ISO's 14083 standard as well as EU's Digital Product Passports and EU's Emissions Trading System

2.1 Emission frameworks and standards, EU's Digital Product Passports and EU's Emissions Trading System.

The Greenhouse Gas Protocol (GHG) [11] is the global standard for corporate climate reporting. It distinguishes between scope 1, scope 2 and scope 3. Scope 3 is the emission of CO_2 (e) from activities carried out by subcontractors. For example, when transport of goods to or from the company is carried out by subcontractors for the company.

When it comes to the calculation and declaration of CO_2 (e) emissions for transport, a European standard, EN16258, was adopted in 2011. This standard has today been upgraded to an ISO standard, ISO14083 [12].

An industry initiative, the Global Logistics Emission Council Framework, also called the GLEC framework [13] (GLEC Version 3), is based on the principles described in ISO14083. In some areas, the GLEC framework differs from ISO14083. For example, GLEC only concerns CO_2 (e), i.e. reporting of energy consumption is not included.

The GLEC also contains minimum requirements for the content of the company's GHG reporting to external stakeholders (CSR reporting and ESG data). Here, it is important that a new EU requirement, the Corporate Sustainability Reporting Directive (CSRD), has been introduced. The new standard is called the European Sustainability Reporting Standards (ESRS) and contains all the requirements that must be followed when reporting to CSRD.

ISO14083 is primarily a standard for calculating energy consumption and CO_2 emissions. The standard follows the principles of the GHG protocol. A calculation/declaration according to ISO14083 will thus be following the GHG protocol. However, it is important to know, that reporting CO_2 (e) emissions following the GLEC framework will meet the requirements of ISO14083, whereas reporting according to ISO14083 will not necessarily meet the additional requirements of the GLEC framework.

Science Based Target Initiative, SBTi was established at the initiative of the UN, the Carbon Disclosure Project, the World Resources Institute and the WWF (World Wildlife Fund). The aim was to give companies common guidelines for how they should determine their targets for reducing CO_2 emissions in line with the objectives of the Paris Agreement. SBTi recommends that the GLEC framework forms the basis for the calculation of CO_2 emissions for transport chains.

2.2 Digital Product Passport

The European Digital Product Passport is an important initiative by the European Union towards sustainability and circular economy [14]. Introduced by the European Commission, this passport aims to provide valuable information about the environmental sustainability of products [15]. It is part of the broader efforts to promote sustainability and achieve the goals of the European Green Deal [5]. The objective of the European Digital Product Passport is to enhance the traceability of products and their components, thereby contributing to a climate-neutral and circular European economy [16].

The passport will enable easy access to information about a product's environmental attributes, such as durability, reparability, recycled content, and availability of spare parts [15]. By providing this information, consumers will be empowered to make more informed purchasing decisions [14]. Additionally, the European Digital Product Passport also supports the goal of reducing CO_2 emissions by 55% by 2030, as part of the Ecodesign for Sustainable Products Regulation [16]

This initiative is part of a comprehensive plan laid out by the European Commission in March 2022 to improve product sustainability within the European Union [11]. The Circular Economy Package released by the European Commission identified the Digital Product Passport as a key solution to enhance product traceability [14]. This passport will not only benefit consumers but also contribute to a more sustainable and circular economy by promoting the design of products with longer lifetimes and better recyclability [11].

By implementing the European Digital Product Passport, the European Union is taking significant steps towards achieving its sustainability goals and promoting a more transparent and eco-friendly marketplace [16]. The passport is expected to play a crucial role in the European Union's transition to a sustainable and circular economy [16, 17].

Additionally, DPPs could be relevant to industries as digital-based supply chain compliance tools for reporting duties such as GHG emissions, life cycle assessments or corporate social responsibility reporting. For example, they could provide detailed and recent information along the value chain to create the conditions for Scope 3 GHG reporting. Scope 3 emissions cover all indirect emissions, both upstream and downstream, that occur in the value chain of a reporting company [11].

At the moment the establishment of the data requirements for the EU digital product passports for each specific product category will depend on a process of industry-wide stakeholder consultation. The entire supply chain has to work together to specify the vital information that could stop a product from going to waste. Some of the data specifications have already been established.

2.3 Emissions Trading System

The Emissions Trading System (ETS) is a central element of the European Union's efforts to combat climate change and reduce greenhouse gas emissions. Implemented in 2005, the EU ETS is the largest carbon market in the world, covering various sectors such as power generation, industry, and aviation [18]. The EU ETS operates on the cap-and-trade principle, wherein a cap is set on the total amount of greenhouse gas emissions allowed by participating entities [19]. These entities are then allocated a certain number of emission allowances, which they can use, either for their internal emissions or trade with other participants [19]. This market-based approach creates incentives for companies to reduce their emissions, as those that exceed their allowances must purchase additional permits, while those with lower emissions can sell their excess permits [19].

Over the years, the EU ETS has demonstrated effectiveness in reducing emissions. According to the European Environment Agency, between 2005 and 2020, the ETS sectors achieved a 42% reduction in emissions, far surpassing the initial reduction target of 21%. [20]. This success has been attributed to the economic incentives created by the carbon market, encouraging innovation and emissions abatement measures within covered industries [21].

Key features of the EU ETS include its flexibility and gradual reduction of allowances over time. The system employs a linear reduction factor, which decreases the number of available allowances year by year, thereby progressively tightening the emission cap [20]. This approach ensures a steady decline in emissions while allowing for adjustments to economic circumstances and policy developments [18].

The environmental integrity of the EU ETS is maintained through strict monitoring, reporting, and verification requirements for participating entities [19]. The European Union's emissions registry, as well as independent third-party verifiers, ensure accurate accounting and transparency within the system [21].

The EU ETS has also taken steps to address potential carbon leakage, where companies may shift production to regions with lax emissions regulations. To prevent this, the EU has introduced the Carbon Leakage List, which identifies sectors at risk and provides additional allowances to mitigate the risk of carbon leakage [22].

It addressed the fact that EU industries had been facing carbon costs from the European Emissions Trading System (ETS), unlike those in non-EU countries. This created a disadvantage for domestic producers. Although not currently expected to be in the current version, an EU CBAM could be used in the future to mandate that importers of regulated products pay a price based on the carbon footprint of their product before it is sold on the EU Single Market.

Going forward, the EU will therefore deploy an alternative policy instrument to avert emissions leakage: the Carbon Border Adjustment Mechanism, CBAM [23]. Supporting the EU ETS, this instrument will apply the carbon price faced by foreign producers to the emissions embedded in imports of some categories of products.

In the future, a DPP could be an important tool to disclose the carbon footprint of products. The need for reliable information throughout the whole product value chain is a key factor in calculating the carbon price through a CBAM

Furthermore, the EU ETS has evolved through time to address emerging challenges and align with the EU's climate ambitions. The system was revised in 2018 to strengthen its functioning and align with the goals of the Paris Agreement, including the introduction of the Market Stability Reserve to address potential surpluses or deficits in allowances [24]. The EU has also proposed expanding the scope of the ETS to include new sectors such as shipping, bringing further emissions under its jurisdiction. In 2027, the EU ETS will be further extended to cover CO_2 emissions from road transport [25].

3 TRANSPORT PLANNING AND CARBON FOOTPRINT

According to the Eurostat [26], empty backhauls represent about 20% of road transportation activities in Europe. This is 5% lower than reported in 2014 [27] alongside the average use of loaded trucks of 57% of their capacity. In light of the strong focus on reducing CO_2 emissions, improved filling rates of trucks is an area worth researching. Potential benefits of horizontal collaboration for logistics services providers are found in the literature, which reports cost savings from less than 10% up to 50% [28-32]. The cost savings are based on increased efficiency and productivity [33] and are further leading to decreased environmental impact [34].

The transport companies investigated in this paper, all plan transports manually, although domain-specific systems are used for decision-making such as moving transports from one route (truck) to another. Most order requests come from primary or secondary customers but the load are not known until a few hours before the truck starts its route, which makes efficient planning complicated. To utilize the capacity best possible, they make use of "buying or selling" casual transports from/to other transporters to fully utilize their trucks. This is, however, very time-consuming and is mainly based on a huge number of phone calls and, to some degree, emails. As a last option to level capacity, they make use of transport brokers such as Teleroute and Timocom. This is, however, not a preferred option due to limited control of the transport and the limited financial outcome [35-37].

In a previous study [38], we presented a concept to enable a dynamic plan to be used "on route" based on an agent-based approach aiming at supporting selling and buying transports to and from other transport companies. This includes a large number of constraints, as illustrated in Figure 1, to evaluate whether a request qualifies for manual decision-making. The main aim was to increase the truckload while at the same time smoothening the communication and admin processes.

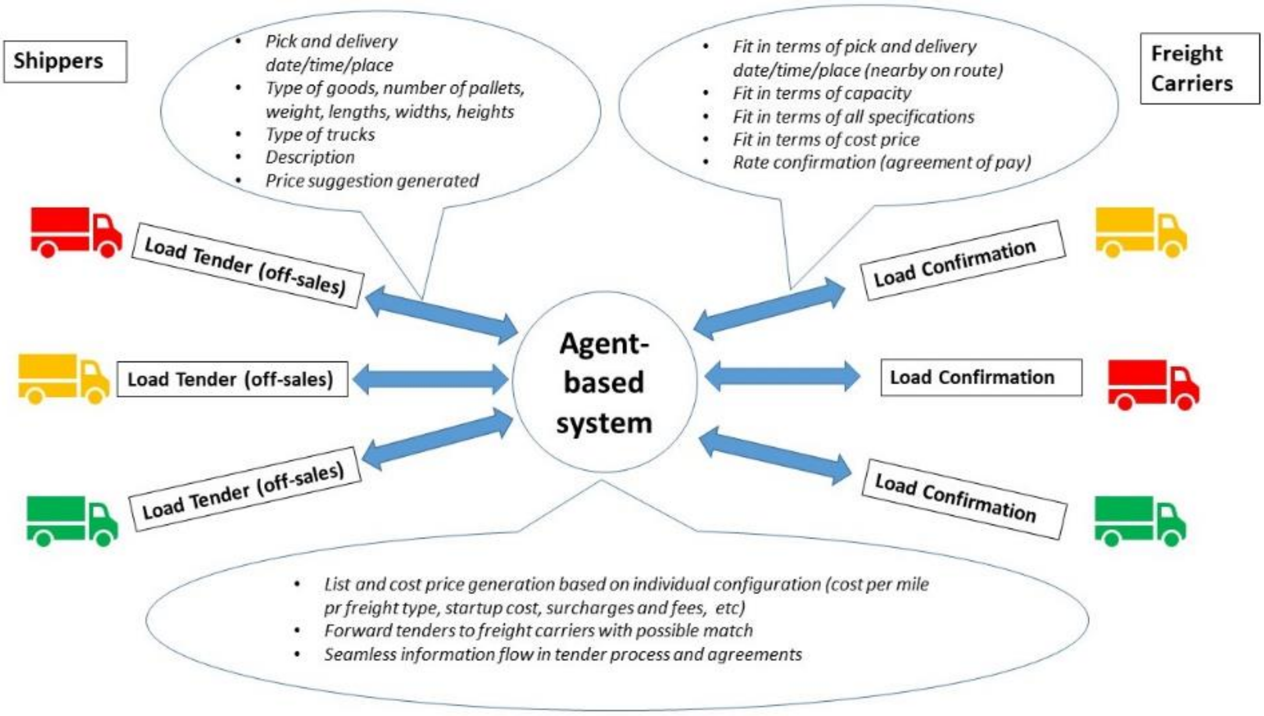

Figure. 1. Conceptual illustration of tenders, requests, constraints and business model [38]

In the next section, we will delve into the methods and factors used to determine carbon emissions in the context of last-mile goods transport.

3.1 Carbon Footprint

Due to the increased focus on reducing the Carbon Footprint impact, transport companies experience that more and more customers ask for a declaration of the carbon footprint on the invoice. Further, some customers are asking for a carbon footprint estimate in their request alongside the cost. In the near future, caps on carbon footprint usage will be introduced. This leads to a situation where most or all customers will ask for a carbon footprint quotation and not just an estimate. By then, the carbon footprint will be just as important as the cost quotation.

The challenge for many transporters is, that costs and carbon footprint are difficult to estimate before you have a full truckload, as well as a full picture of which types of energy the customers are willing to pay for such as traditional fuel, bio-fuel, electro-fuel, electricity etc. A truckload with a variety of customer-specific fuel "conditions" will either be a nightmare or require flexible customers accepting that goods on average are transported according to the fuel customers pay for, meaning that their specific goods may not be transported as environmentally friendly as they pay for. This will also depend on the future rules for calculating the carbon footprint as input for the digital product passport as discussed in section 2.

The starting point for calculating the emissions is the distance, the weight, the road conditions and the mode of transport:

1. **Distance**: The total distance covered during the transport operation is a fundamental factor. This includes each leg of distance travelled by different modes of transport—road, rail, water, or air—including detours or intermediate stops.
2. **Weight**: The weight of the goods being transported significantly impacts the energy required titled pay-load. The total weight, including the cargo and pack-aging, should be considered when calculating the transport work. Heavier loads require more energy for transportation.
3. **Road Conditions**: The terrain and road conditions, including inclines or declines, affect the energy needed for transport. The additional work required to overcome slopes or rough surfaces should be factored into the calculations.
4. **Mode of Transport**: Different modes of transport have varying energy efficiencies and associated work requirements. Road transport, for example, may have higher energy demands compared to rail or water transport. Considering the specific mode of transport involved in each leg of the journey is crucial.

By considering these factors, transport work can be calculated using established formulas by estimating emissions associated with last-mile goods transport. Carbon dioxide equivalents, CO_2 (e), are commonly used as a unit of measurement. Calculating emissions involves several extra factors:

1. **Fuel Consumption**: The type and quantity of fuel consumed by each mode of transport play a significant role in emission calculations. Different fuels, such as diesel, gasoline, or aviation fuel, have different carbon intensity values that need to be accounted for when estimating emissions.
2. **Emission Factors**: Emission factors represent the amount of emissions produced per unit of fuel burned. These factors are specific to different modes of transport and fuel types and are usually available from standardized emission databases.
3. **Mode-specific Considerations**: Each mode of transport has specific CO_2 emission factors (as well as methane, nitrous oxide, etc).

By multiplying the transport work with the CO_2 emission factor, emissions for the last-mile transport can be estimated. Carbon footprint calculators and emission inventory methodologies provided by organizations like the International Panel on Climate Change (IPCC) and emission databases by governmental bodies can assist in these calculations as well as companies like EcoTransIT [39] which has specialised in not only developing emission models but also collecting information on types of fuel used globally on ships and trucks.

4 TRANSPORT WORK AND EMISSIONS

In this section, we present 4 ways of calculating emissions for 3 deliveries from a distribution centre (DC) to customers.

- Delivery 1 consists of 8 tonnes and the distance from the DC is 5 km (10 km in total).
- Delivery 2 consists of 4 tonnes and the distance from the DC is 7 km (14 km in total).
- Delivery 3 consists of 6 tonnes and the distance from the DC is 9 km (18 km in total).

The calculations follow current guidelines by the organisation “Danish Freight Forwarders” [40] based on two factors.

- The total driving distance forms the basis for determining energy consumption and emissions.
- The payload is used to calculate transport work for distributing emissions among customers.

Quotations to the transport customer are for one trip at a time. Emissions can be differentiated into 2 types: *well-to-tank* and *tank-to-wheel*. Well-to-tank (WTT) emissions; referred to as energy provision GHG emissions and tank-to-wheel emissions (TTW), are referred to as operational GHG emissions. Jointly, these two add up to the well-to-wheel (WTW) emissions and they build the emissions of an entire transport chain element (TCE). In the following calculations, WTW emissions are used in the case examples.

The values for the emission factors used must be calculated following EU guidelines [19] and guidelines by GLEC [3] and ISO14083 [6]. The trucks drive on average 3.8 km. per litre of diesel (5% biodiesel) and the WTW emission is 3.17 kg CO_2 (e) per litre. The WTW emission is therefore 3.17/3.8 = 0,834 CO_2 (e) per km. The payload is not included in the emission calculations[40].

In the following, a pre-calculation and 3 different ways of conducting post-calculations are presented.

4.1 Pre-calculation.

Each customer inquiry is based on a pre-calculation. At the time of the quotation, it is unknown whether you will manage to get a return trip. Therefore, the pre-calculation is based on an empty return trip and orders are processed one by one. As the calculations entirely are based on transport distance, there is no emission contribution to the transport company, as it will be distributed among the individual shipments in a weighted ratio. Empty driving, repositioning without load and other driving without payload, which consumes energy and emits emissions, is distributed among the customers.

The CO_2 (e) emission (WTW) pre-calculations of the 3 deliveries are as follows:

(1): 10 Km * 0,834 Kg CO_2 (e) = 8.342 kg CO_2 (e).

(2): 14 Km * 0,834 Kg CO_2 (e) = 11.679 kg CO_2 (e).

(3): 18 Km * 0,834 Kg CO_2 (e) = 15.016 kg CO_2 (e).

given the above conditions where shipments are carried out one at a time. The truck will drive 42 km in connection with carrying out shipments, of which 21 km without a load. The total emission is 35.04 kg CO_2 (e) as it is the measured fuel consumption that is the basis for calculating the CO_2 (e) emissions post-calculation.

4.2 Post calculation, case 1.

In this case, orders are processed one by one according to the pre-calculation, but the emission is based on a weighted allocation of the transport work (Km * Tonnes).

The total emission is similar to the pre-calculation, which is 35.037 kg CO_2 (e) and the total transport work is 8 * 5 + 4 * 7 + 6 * 9 = 122 Tonnes-Km. The post-calculations of the 3 deliveries' emissions are as follows:

(1): 8*5/122 * 35,037 kg CO_2 (e) = 11.487 kg CO_2 (e)

(2): 4*7/122 * 35,037 kg CO_2 (e) = 8.041 kg CO_2 (e)

(3): 6*9/122 * 35,037 kg CO_2 (e) = 15.508 kg CO_2 (e)

In total 35,037 kg CO_2 (e) is allocated for deliveries, and zero kg for the transport company.

4.3 Post-calculation, case 2

In this case, the deliveries are consolidated as one trip instead of 3. This means that the total distance travelled in kilometres is reduced from 42 to 18 and with more cargo. All in all, a better filling rate and less empty driving. Further, both the outbound and inbound emission is distributed among the 3 deliveries according to transport work [40].

The post-calculation of the 3 deliveries' emissions are as follows:

(1): 8*5/122*18 *0,834 kg CO_2 (e) = 4,9223 kg CO_2 (e)

(2): 4*7/122*18 *0,834 kg CO_2 (e) = 3,3446 kg CO_2 (e)

(3): 6*9 /122*18*0,834 kg CO_2 (e) = 6,646 kg CO_2 (e)

In total 15.02 kg CO_2 (e) is allocated for deliveries, and zero kg for the transport company.

4.4 Post-calculation, case 3

In this final case, the deliveries are consolidated as one trip, similar to case 2. However, the emissions are distributed differently, as the outbound emission is distributed among the 3 deliveries according to payload [40] whereas the inbound emission is put on the transport company.

The post-calculation of the 3 deliveries' emissions are as follows:

(1): 8*5/122*9 *0,834 kg CO_2 (e) = 2,462 kg CO_2 (e)

(2): 4*7/122*9 *0,834 kg CO_2 (e) = 1,723 kg CO_2 (e)

(3): 6*9 /122*9*0,834 kg CO_2 (e) = 3,323 kg CO_2 (e)

(R): 9*0,834 kg CO_2 (e) = 7,508 kg CO_2 (e) for the inbound (return) trip

The results are summarised in Table 1, illustrating the huge difference between the different ways of calculating CO_2 emissions and raising a flag in terms of the importance of the chosen quotation strategy for transport companies in the coming years.

Table 1 illustrates 4 ways of calculating CO_2 (e) emissions of 3 deliveries. **Pre-calc**) a pre-calculation based on individual deliveries. **Post-calc 1**) a post-calculation based on individual deliveries. **Post-calc 2**) a post-calculation of consolidated deliveries. **Post-calc 3**) Similar to Post-calc 3, except that the customers are not "claimed" for the return trip

Case	Delivery	Tonnes	Km outbound	Km inbound	Tonnes*Km In truck	Tonnes*Km delivery	Tonnes*Km distribution	CO2 (e) distribution	Emission efficiency
Pre-calc	1	8	5	5	40	40		8,342	0,209
	2	4	7	7	28	28		11,679	0,417
	3	6	9	9	54	54		15,016	0,278
	Sum		**21**	**21**	**122**	**122**		**35,037**	
Post-calc 1	1	8	5	5	40	40	0,328	11,487	0,287
	2	4	7	7	28	28	0,230	8,041	0,287
	3	6	9	9	54	54	0,443	15,508	0,287
	Sum		**21**	**21**	**122**	**122**	**1,000**	**35,037**	
Post-calc 2	1	8	5	9	90	40	0,656	4,923	0,123
	2	4	2		20	28	0,459	3,446	0,123
	3	6	2		12	54	0,885	6,646	0,123
	Sum		**9**	**9**	**122**	**122**	**2,000**	**15,016**	
Post-calc 3	1	8	5	0	90	40	0,328	2,462	0,062
	2	4	2	0	20	28	0,230	1,723	0,062
	3	6	2	0	12	54	0,443	3,323	0,062
	Return	0		9	0	0	0	7,508	na
	Sum		**9**	**9**	**122**	**122**	**1**	**15,016**	

5 DISCUSSION

Order management and last-mile transport planning are challenging. Minimizing the difference between pre-calculation and post-calculation is even more important since CO_2 emission now needs to be documented and reported to the customer and authorities, based on a measurement of the transport service.

Overall, we have found the following answers to the 3 research questions.

It has been shown with the 4 cases, that differences between pre- and post-calculation are likely unless freight quote agreements are more flexible and contain an agreement on how an emission difference is to be distributed between the partners. To minimize this emission difference, it is important to use and maintain good key figures for planning, as they will be decisive for the size of the difference.

Generally, last-mile deliveries are less energy-efficient (with a higher fuel consumption) than long-haul freight, due to frequent stops, a higher share of idle time per trip, multiple delivery points per trip, a higher frequency of deliveries, different drop-off times, and nonoptimal rescheduling, due to the absence of recipients [41,42].

Emission-driven KPIs for last-mile deliveries will be largely based on empty driving, the utilization rate of payload and the distance travelled versus time unit ratio, as optimization of these will result in the lowest emissions for a transport unit, which will probably also become an important competitive parameter between freight distribution companies.

Documentation and reporting requirements for freight distribution companies are changing, especially when it comes to the new requirements for emissions and sustainability described in section 2.

Goods owners will have an increasing focus on the emission of their goods, not at least driven by the upcoming DPP. Customers expect minimum emissions related to their delivery. Also, the company's reporting requirements for GHG in scope 3, means that freight last-mile delivery in particular will be challenged as complexity is high and in terms of planning challenging.

Transport quotes will probably develop and adapt but it may have negative consequences for transparency. The partners may, according to the agreement, distribute the emissions between each other, which will be reported on the GHG annual statement, even if it is higher than expected.

The challenge in terms of transparency will probably be that the product owner does not want the actual emission to be disclosed on the planned digital product passport, precisely because it is agreed how the emission is to be distributed. It will be an important competitive parameter for the product owner that the product has the lowest emission printed on the digital product passport, as the customer can see this and will probably use this to decide on product selection. The problem we see is that even if the emission deviation results in a contribution to the transport company's envelope, the real emission will not be disclosed in the digital product passport, as the owner of the goods wants the agreed emission disclosed. Based on this, we believe we have answered the 3 research questions.

6 CONCLUSION

Accurately calculating transport work and emissions for last-mile freight distribution is crucial in understanding the environmental impact of transportation activities. Advancements in data collection, standardized methodologies, and technology-driven solutions can further refine these calculations, leading to better-informed decisions and a more sustainable future.

By considering factors like distance, weight, mode of transport and emission factors, businesses and policymakers can gain insights into the energy requirements and associated emissions of transporting goods. This information can improve decision-making, encourage more sustainable transport choices, and minimize the environmental impact of last-mile freight distribution.

Freight quotes based on a customer's inquiry are by nature a pre-calculation and a challenge in itself as the the remaining transportation tasks are more or less unknown at the time of the quotation. The current guidelines for freight forwarders, where all emissions are distributed to the customers and thus no emissions to the transport company, are under pressure, as this is not fair for the customers. In the future, customers may not accept an actual carbon footprint usage that is way higher than the quote provided by the transporter in advance. This leaves the transporter in a dilemma as the actual carbon footprint usage depends on which other customer orders they manage to get and how they can combine the total load in their truck planning.

The freight quotes agreement is expected to adapt to deal with this issue, which we expect the transport market will do, but the question remains whether the digital product passport will require the actual CO_2 emissions or it will accept the calculated CO_2 emissions related to the freight quotes agreement when entering into the transport agreement.

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8 DISCLAIMER

This paper is unrelated to one of the author's employment at the International Monetary Fund (IMF) and is undertaken in his capacity. The views expressed in this paper are those of the authors and do not necessarily represent the views of the IMF, its Executive Board, or IMF management.

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