Effects of CO2e measures for the transport logistics sector

M. Sc. Kai Kindsgrab
Muenster School of Business (MSB), FH Muenster, Germany
kai.kindsgrab@fh-muenster.de

Prof. Dr. rer. pol. Michael Dircksen
Muenster School of Business (MSB), FH Muenster, Germany

Univ. Prof. Dr.-Ing. Hartmut Zadek
Institute of Logistics and Material Handling Systems, Otto von Guericke University Magdeburg, Germany

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Abstract
Nowadays logistic service providers (LSP) are facing more and more regulations and political measures concerning sustainability. This paper presents the first results and discussions of a simulation on environmental policy measures in the transport sector. The additional costs of these measures were calculated for two ideal truck models over the next four years. Besides higher fuel costs due to a gradual increase in certificate costs, which translates to additional costs of €6,949 or 4.9 cents per km for a EURO 6 truck with an annual mileage of 140,000 km, the new published truck toll costs for 2024 cause a high increase of additional environmental costs. All measures combined result in additional costs of €61,806 for a EURO 6 and €65,638 EURO 5 truck. The study also calculates the total cost of ownership (TCO) for a single truck and finds that the additional environmental costs would cause additional costs of 53.74% to 57.07% for the selected truck model. The study notes that the cost difference cannot be integrated in current transport prices due to an average profit margin of only 3,4% for LSP companies. Therefore, the authors point out the importance of an overall simulation model.

1. Introduction
In march 2023, the new IPCC report announced that the global temperature increase already reached 1,1°C compared to 1990 [27]. In the transport and traffic sector, greenhouse gas emissions have stagnated for years. In Germany, emissions in this sector amounted around 145 million tons of CO_2- equivalent (CO_2e) in 2020 [19]. In 2021 emissions already raised up to 148 Mio. tons of CO_2e [26]. The goal of a significant CO_2e reduction in this sector becomes tangible taking the year 2020 as an example: even with its Covid lockdowns only around 7% of greenhouse gases could be saved [10].
In addition, according to the "Verkehrsverflechtungsprognose 2030", freight transport performance is expected to increase to 838 billion ton kilometers by 2030, which means that an increase in emissions can also be assumed, irrespective of technical progress [8]. Furthermore, the long-term worldwide trend of increasing transport volumes due to growing trading demand must also be considered [5]. This indicates how ambitious the recently communicated cross-sectoral targets of 65% savings by 2030 in Germany and 55% within the EU are [16].
In January 2021, the Fuel Emissions Trading Act (BEHG) came into force in Germany, and a national emissions trading scheme (nEHS) was launched [22]. The price for a national allowance has been set to €25 per ton of CO_2e for 2021 and should gradually increase to €55 by 2025, after which it can be freely traded within a price corridor of €55–€65. For 2023, the increase of the national CO_2e price will be suspended and for 2024 and 2025 discounted to €35 and €45, respectively due to the increased energy costs and rising inflation [20]. In 2021, the German Emissions Trading Authority at the Federal Environmental Agency calculated a price increase of 7 cents per liter of diesel fuel as a consequence of the CO_2e price of €25 [11]. For currently €30 CO_2e price an impact of 10 cents per liter of diesel fuel is calculated. Besides, the EU Commissions announced in their Fit-For-55 strategy that they are planning to set up a second European emissions trading system (ETS2) for the transport and building sector by latest 2026 [7]. This trading scheme will also be implemented as an

upstream principle like the nEHS and come along with a CO_2e price between €45-€50 [7]. The current CO_2e price in the ETS1 scheme is €89.78 (ISIN: XC000A0C4KJ2, 01/30/2023). The maritime cargo sector will be already covered within the ETS1 in 2023 [15]. For the air cargo sector, the emissions trading system will be implemented in the ETS1, for all inter-European or non-CORSIA flights, starting in 2024. The rail cargo network is already covered indirectly through either the ETS1 (Electrical engine) or will be covered via the ETS2 (Diesel fuel engine). Besides the integration of transport sectors into the EU ETS, several other political instruments, including a change of the environmental component inside the truck toll, more rules concerning environmental reporting (CRSD) or a stronger fleet regulation to archive the national climate law, are currently discussed [30]. These effects inevitably lead to the following research question:

RQ: What is the financial impact of environmental policies on the cost of transport?

The aim of the research is to develop a decision model, which can reflect the effect of different governmental measurements like CO_2e pricing or additionally CO_2e truck toll for different HGV-models to calculate a sustainable transport price, which covers also the additional environmental costs or a flexible floating system to pass the costs to value chain partners. Furthermore, the model should show first ideas of how additional carbon pricing costs can be forwarded inside the value stream, as well as to calculate when a swapping point is reached to invest in a different HGV-model.
Initial calculations have already been carried out in the two ILM research projects "Logistics Emissions Trading System for Green Optimization (LETS GO)" and "Combined Emission Controlling Instruments for Road Freight Transport (COMECON)". Various scenarios were used to determine how additional costs would behave as a result of the downstream principle, the upstream principle or an energy tax [9] [24] [39]. At the time of the research projects, a final political decision on the introduction of ETS2 certificate trading had not yet been made. Accordingly, it also had not yet been investigated how this would affect transport prices in concrete terms with higher CO_2e prices and in combination ("instrument mix") with other measures such as the HGV toll. This is especially true when considering alternative engine systems such as the battery electric truck (BEV). Initial approaches to the total cost of ownership (TCO) of different engine technologies, considering such an "instrument mix", have recently been published in a study by the German Federal Environment Agency (Umweltbundesamt, UBA). However, this study did not take different CO_2e price paths or individual cost units into account [40] [31]. There are already numerous frameworks in the literature for calculating individual cost units. The number of cost units and their values vary widely [25] [36] [35]. In summary, it can be said that individual calculation models already exist that show the effects of single environmental policy measures, also for the individual logistical sub-services. However, the research gap of a comprehensive model that also shows the interaction of the individual measures has not yet been closed. This is the aim of the author's doctoral thesis. In this paper the general approach and first calculations of individual measures are presented. Therefore section 2 briefly describes the used methods for this research. In section 3 the major results will be presented and discussed. In the last section 4 limitation and conclusion of my research will be described.

2. Methods or experimental part

The calculation model has been developed based on the VDI 3633 standard "simulation of systems in materials handling, logistics and production". The steps are:

1. initial situation,
2. target description,
3. task definition,
4. system analysis,
5. data collection,
6. model formalization,
7. data preparation,
8. implementation,
9. experimentation and analysis,
10. documentation.

They are processed sequentially [23]. The steps 2) goal description, 4) system analysis, and 5) data acquisition will be exemplarily described in detail in the following chapters.

2.1. Goal description

The calculation of transport costs is based on the cost model of the "Bundesverband Gueterkraft-verkehr Logistik und Entsorgung (BGL)" with 24 cost units, which are re-weighted at regular intervals by a quantitative survey of the BGL, thus providing a neutral and generally valid basis. The total transport costs, including a profit margin or risk surcharge, can then be offered as a transport price on the transport market (secondary market). This is usually referred to as the cost-plus method. On the other hand, transport prices can also be influenced on the market side by an increased demand for transport resulting from an increased

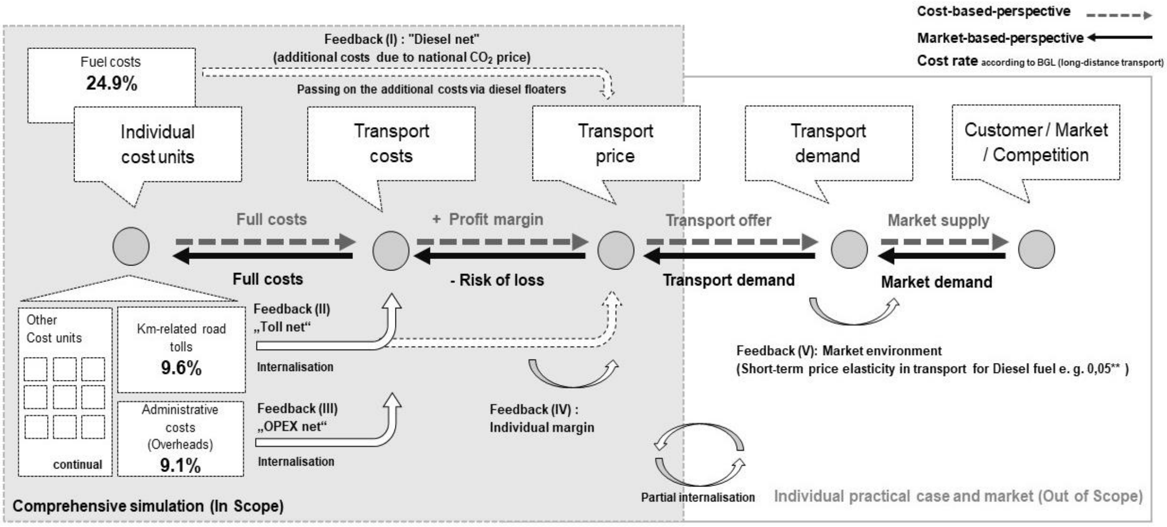

Figure 1: Impact of transport cost calculation; Own visualization with data from [3] [13]

volume of trade on the primary market. Also due to insufficient publicly available data on price elasticities in the transport market, the simulation model should focus on internal transport costs (see grey area in figure 1).
Within this internal cost calculation, the following cost items should be focused on

- fuel costs,
- kilometer-based road tolls, and
- administrative costs

as these alone account for 40% of all costs. Therefore, the first effects of environmental policy measures on these cost types can be identified. The fuel and toll costs can be passed on to the customer in individual cases via a variable system separated to the actual transport price. This additional margin from a diesel floater system has already been analyzed for the entire German road transport industry under the new indicator "diesel net", which is described as the difference between the "price index for road haulage, removal transport (WZ 2008:49.4)" and the corresponding diesel price for large consumers [28].
In order to simplify the complexity of individual business cases and to show the maximum effect of environmental policy measures, this floating system should be omitted in a first step in the model. The effects of two selected environmental policies are analyzed in more detail in the next section.

2.2. System analysis

Two major environmental policy measures are often analyzed in more detail in the literature under the term "instrument mix". These are the national or upstream CO_2e certificate price and the

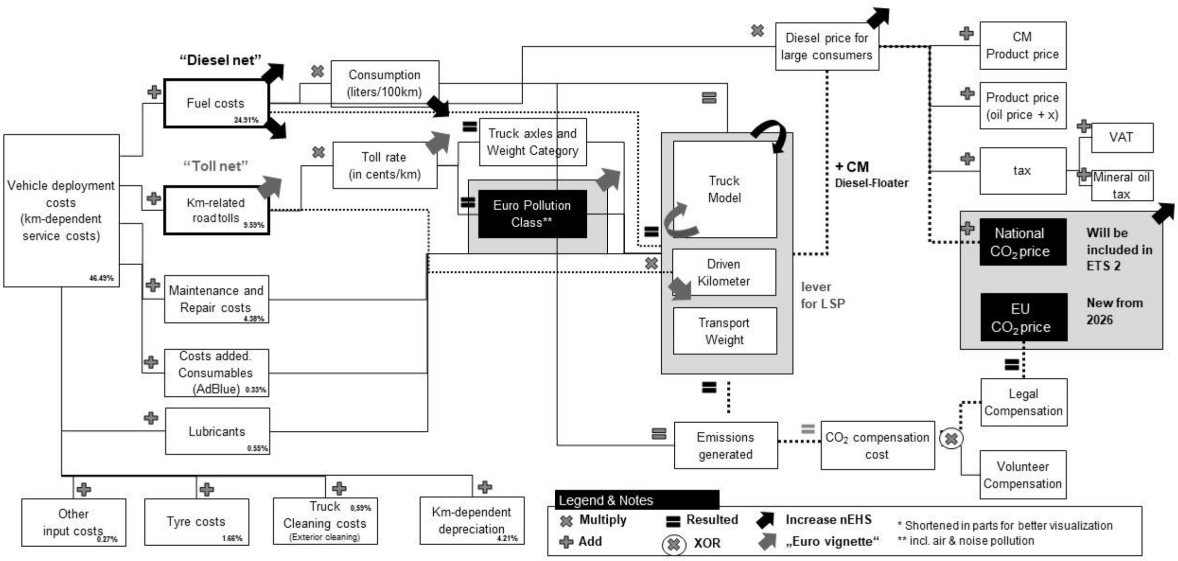

Figure 2: Effect of environmental policy measures; Own visualization with data from [3][2]

extension of the truck toll to include a separate CO_2 component [40]. Since the focus in this study is on land transport, which accounts for the largest share of greenhouse gases of CO_2 the term CO_2 equivalent is not used further [33].

Looking first at the options of setting a price for CO_2, there are different approaches used around the world [37]. The two most prominent are a CO_2 or energy tax and a CO_2 certificate trading system [38]. In Germany, the BEHG was introduced in 2021 and will be integrated into the European ETS2 certificate trading system in 2026 [34]. Both systems operate according to the so-called upstream principle, which means that the distributor of the fuel must purchase a CO_2 certificate for every ton of CO_2 generated during the production of this substance (nEHS). In the case of diesel, the certificate price forms the new diesel price, in addition to fuel tax, VAT, the price of crude oil and the manufacturer's profit margin. An increase in the price of CO_2 certificates is therefore only indirectly perceived by the consumer through an increase in the price of diesel since the consumer of the fuel does not have to purchase his own certificates for his individual CO_2 emissions any longer [34].

Truck tolls in Germany currently consist together of three components:

1. infrastructure costs,
2. noise pollution costs,
3. air pollution costs.

The individual cost rates for these three components depend on the selected truck model with a specific number of used axles, a defined pollutant class and a maximum weight load of the HGV. In the new version, valid from January 2023, these cost rates vary from the current 19 cents per kilometer (EURO 6, 4 axles, >18 tons) to 35.4 cents per kilometer (EURO 0 & 1, 4 axles, >18 tons). Trucks under 7.5 tons and battery electric vehicles (BEVs) are currently exempt from the toll. In Germany, EURO 6 and EURO 5 HGVs accounted for 99% of the toll kilometers driven, with EURO 6 trucks accounting for the much larger share (90%) [1].

These toll rates are changed periodically by the German government. One of the most important influencing factors is the result of the "Road Cost Report" [6]. In Addition, the EU Directive 1999/62/EC obliges its member states to introduce a CO_2 component into their national toll systems in due course. Under the "Euro-vignette-directive", additional toll costs of between 8 and 16 cents per km for a diesel truck (EURO 6, 4 axles, >18 tons) are currently being discussed in Germany [4]. In March 2023 the German government decided to add a CO_2 component to the national toll system of €200 per ton of emitted CO_2 and included trucks with a maximum weight above 3.5 tons. This leads to additional cost of €0.158 (EURO 6, 4 axles, >18 tons) and €0.160 (EURO 5, 4 axles, >18 tons) [14]. An increase in both types of costs would have a steering effect on the investment decision of an individual HGV or the strategic composition of a vehicle fleet (summarized in figure 2 as a truck model) [2]. In order to represent the exact amount of additional costs in a later TCO model, different data sources have to be used. Section 2.3. summarizes the data collection and scenario building process.

2.3. Data acquisition

For this paper, CO_2 prices from the current legal norm of the BEHG and the current truck toll from the BMVI were chosen (see table 1).

Table 1: Cost rates for the calculation

Year/ Truck Model	**CO_2 price & expected diesel price**		**Truck Toll [cents / l]**	
	CO_2 price [to]	**diesel price [l]**	**EURO 5**	**EURO 6**
2023	€30	€1.84	22.9	19.0
2024	€35	€1.85	38.9	34.8
2025	€45	€1.88	38.9	34.8
2026	€65	€1.93	38.9	34.8

In chapter 3, the results of the simulation with these cost rates are simulated for an ideal EURO 5 and EURO 6 truck with an average diesel consumption of 29.8 liters per 100 km (EURO 5) and 28.6 liters per 100 km (EURO 6), and an annual mileage of 140,000 km [18] [17].

3. Results and Discussion

The environmental policy measures described in chapter 2.2 and quantified in chapter 2.3 were calculated for two ideal truck models for the next four years. Table 2 shows the additional costs for the three measures. These additional costs can then be added to the already existing individual vehicle costs.

3.1. Additional costs or strategic potential

The largest cost block is accounted for the increased fuel costs, which, with an initial diesel price of €1.84 per liter, rises to a final price of €1.93 in 2026 through a gradual increase in the certificate costs to €65. Since a liter of diesel emits emissions amounting to 267 grams per liter (Tank-to-wheel), an allowance price of €65 per ton of CO_2 corresponds to a price premium of 0.17 cents per liter of diesel. Transferred to a EURO 6 truck with 28.6 liters per 100 km, this results in additional costs of €6,949 or, with an annual mileage of 140,000 km, an average of 4.9 cents per km.

Table 3: Vehicle Data

Measures (Assumptions)	National / EU CO_2 price over diesel fuel		Increase of the CO_2 component in the national truck toll (80% of the annual mileage)		Sum of additional costs (Per year, per HGV)	
	EURO 5	**EURO 6**	**EURO 5**	**EURO 6**	**Euro 5**	**Euro 6**
Starting 2023	€3,342	€3,207	€3,136	€627.2	**€6,478**	**€3,834**
From 2024	€3,899	€3,742	€14,336	€14,157	**€18,235**	**€17,899**
From 2025	€5,013	€4,811	€14,336	€14,157	**€19,349**	**€18,968**
From 2026	€7,241	€6,949	€14,336	€14,157	**€21,577**	**€21,106**
Sum	**€19,494**	**€18,709**	**€46,144**	**€43,098**	**€65,638**	**€61,806**

In addition to these increased fuel costs, there are additional costs of €627.2 for the increase in the HGV toll from 18.3 cents to 19 cents for a EURO 6 HGV in 2023. For 2024 up to 2026 an additional increase from 19 cents to 34.8 cents is calculated. If one puts these in relation to possible additional costs for an existing EURO 5 truck, one obtains a cost difference of € 3,831 or on average €957.75 per year. However, this cost difference is largely dependent in the first year on the difference in diesel costs and the different diesel consumption of the selected HGV models and the basic diesel price. In the following years, the high increase in truck tolls compensates for this difference. If one adds up the additional costs for all two environmental policy measures, one obtains additional costs of €65,638 for a EURO 6 (see table 2).

Table 2: Summary Impact BEHG, Truck toll and CSRD

Parameter	**Unit**	**Value**
Mileage truck	km / Year	140,000
Working days	Tag /Year	245
Vehicle purchase price	Euro	135,924.13
Period of use	Year	5
Remaining value	Euro	20,000
Toll share of the mileage	%	80

The additional costs for a first-time CRS reporting in 2025 due to the implementation of the CSRD regulation in Germany are estimated up to €2,666 or 4 consulting days in the first year and €1,333 or 2 consulting days in the second year, assuming a cost of €1,000 per consulting day and an average fleet number of 1.5 trucks. These costs are not included in the calculation as they are independent from the chosen truck model and should more considered in future TCO calculations.

3.2. TCO for a single truck

Many different data sources and measurements from scientific and non-scientific sources are available in the literature for calculating TCO costs. As a first step, the following publicly available data from DVZ and DEKRA were used to calculate the TCO costs of a EURO 6 HGV [12] (see table 3). Based on this information, TCO costs of €172,835 per year were calculated with the BGL cost scheme and compared to the additional environmental costs. It is noticeable that these would cause additional costs of between 2.2% (€3.834 in 2023) and 35.76% (€61.806 in 2026) for the selected truck model. With reported TCO costs of only €115,000, these would even cause additional costs in 2026 of up to 53.74%. Assuming the same TCO costs of
€115,000 for a EURO 5 HGV we would have in 2026 additional cost of 57.07% (€65,638).
The overall profit margin (EBIT/Sales) for national transport companies was calculated to an average rate around 3.4% [29]. This means that if environmental policy measures are implemented as calculated or if there is a significant increase in diesel prices, logistics service providers will be forced to recalculate their transport prices in order to avoid the risk of making losses.
In addition to the active use of a diesel floater, consideration should also be given to externalizing the costs, especially the very high increased truck toll, of environmental policy measures, either by means of a floating system or by passing them on in the value chain.

4. Limitations and Conclusion

The expected research results allow the conclusion that the necessary decarbonization measures of the federal government and the EU will lead to a cost increase within the road transport sector and especially within the distribution logistics.

The current scenarios in this article still assume rather low costs for these environmental policies. However, it can be assumed that as climate change progresses, social pressure on policymakers will increase, leading to stricter measures or higher costs for logistics providers. Therefore, in the future it will be even more important to plan the fleet management strategically and to include CO_2 pricing measures in investment decisions and transport cost calculations.

4.1. Limitations

The simulation is only carried out on a simulation model basis using two representatively selected truck models in long-distance transport. If the simulation model is to be used for other modes of transport networks such as local or regional transport, the underlying cost structures must be adapted. Furthermore, only national decarbonization measures are currently priced in. However, if there is a need to map European or even international supply chains, further environmental policy measures would have to be included.

Furthermore, at the moment the simulation model does not contain future scenarios as different CO_2 pricing values or additionally CO_2 truck toll components. In order to allow a better strategic planning of a fleet, these best case and worst-case scenarios should be added to the simulation.

In addition, also the possibility to have different diesel prices through different transport roads in Europe would be interesting to see, as we are currently facing the problem of “grey emission imports” inside of the EU, as not all of the EU member states already implemented a CO_2 price on their fuels.

4.2. Conclusion and further search

From this paper we can conclude first ideas of how big the financial impact of environmental policies on the costs of transport are and how important it is to find European or even global standards for these measurements like CO_2 pricing in order to allow a decarbonization of the transport sector without preventing an unfair market situation for these transport companies, which are included in the ETS2 market and those ones, which are not.

But in order to get a deeper understanding on the financial impact some further research and model improvements are needed. Therefore, future research should investigate first whether CO_2 compensation costs should be completely included in transport costs or whether they could be passed on to the customer or value chain partner as it is currently happening with a floating system for fuel costs.

Secondly, the carbon balance in general should be further investigated. Up to now, it is not fully clear if and to which amount logistic service providers will have to cover their emissions as separate scope 1 emissions in there CSR(D) reporting or if their emissions are already covered and paid in scope 3 of the production company.

Thirdly, future research should examine whether investment decisions regarding new trucks could be made more attractive to carriers with Carbon Contracts for Difference (CCfD). Along with fuel costs, other cost carriers should be evaluated. For example, one can assume that administrative costs will increase due to additional corporate sustainability reporting (CSR) obligations [3]. For example, the “act to strengthen nonfinancial reporting by companies in their management and group management reports” will be discussed on a national level [21]. Should this directive come into force, companies that fulfill at least two of the three characteristics (i.e., balance sheet total ≥ €20 million, turnover ≥ €40 million, or number of employees ≥ 250) will have to prepare a sustainability report. This seems to be another challenge in the logistics industry, as McKinnon’s and Toelke’s recent study indicates, that only about 22% (N = 811) of the freight forwarders in Europe can calculate their CO_2 emissions at all [32].

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