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Effect of pick-up points and returns on CO_2 emissions in last mile parcel delivery networks

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Summary

The volume of the e-commerce segment of economy is growing fast in the Netherlands and overall in the world. E-commerce brings the convenience of shopping to the consumers' homes, however, it is also characterised by an increase of traffic nuisance and CO_2 emissions from the extra traffic in last mile parcel delivery networks. One of the promising ideas to alleviate these negative effects of e-commerce is a more widespread use of pick-up points, which may be used as the delivery address of the goods instead of the consumers' homes. If a parcel is delivered to a pick-up point, there is no need for the delivery vehicle to drive to the consumer's house. If many consumers opt for a delivery to the pick-up point, then with one stop at the pick-up point a larger number of stops in the district will be avoided. The use of pick-up points may increase traffic and emissions on the part of consumer mobility. However, how the consumers get to and from the pick-up points is not taken into account in this report.

This report provides first analytical considerations on how to assess the effect of pick-up points on CO_2 emissions from the last mile parcel delivery networks. We show that current carbon footprinting methods, such as derivatives of the EN 16258 standard, can be successfully used for assessment of the last mile network emissions. We also provide an approach on how to analytically assess the impact of a larger share of deliveries via pick-up points on CO_2 emissions in the last mile. With each additional parcel delivered via pick-up points the number of consumer home locations to be visited goes down, and so does the number of kilometres driven. We point out that on average, the distance between consumer home locations will increase as more parcels are delivered via pick-up points, thus the effect is more complex than a simple linear approach of location removal would suggest. An estimation example is provided to illustrate the effect of pick-up points on parcel-level emissions, where under some realistic assumptions, a shift of some 50% from home deliveries to the pick-up points will result in 17% less CO_2 emissions in the last mile network and 33% less CO_2 emissions in last mile for the parcels delivered via the pick-up points, compared to the situation when all parcels are delivered to the home addresses.

The carbon footprinting methods are shown to be adequate for properly stimulating the last mile networks with respect to CO_2 reduction by pick-up points. The methods work very well for the goals of the transport service provider, but are too aggregate to help the consumers make decisions in favour of the pick-up points. To help consumers make informed choices about delivery, a modification of the method would be necessary; the marginal accountancy technique seems to be the most promising in this context. Consumers can also be helped by a clear message on the effect of returns on emissions in last mile networks. The considered methods show that returns increase the overall network emissions independent from the exact method chosen on how to account for them.

Lastly, given the sheer volume of e-commerce and parcel networks, it is advisable to deepen the theoretical analysis with the construction of a simulation model that would better approximate the state of real-world last mile networks.

Even if a relatively small percentage of CO_2 emission reduction can be achieved by using the modelling outcomes, it would translate into substantial gains with respect to absolute CO_2 emission reduction, and would expectedly decrease the costs of last mile parcel networks.

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1   Introduction

E-commerce is a fast growing segment of the economy. The recent events related to the COVID-19 pandemic have further sped up the growth of this segment, easing consumer access to material products and bringing more comfort of shopping from home. The growth of e-commerce results in a growth of transport, especially in last mile delivery networks, which is the transport segment from the final hub or sorting centre of the service provider to the home locations or pick-up points. Last mile parcel networks create transport nuisance and emit substantial amounts of CO_2 emissions. Therefore, potential measures to reduce these negative effects, together with the methods to quantify those effects, need to be carefully considered. The set of improvement measures to reduce these negative effects includes a wider use of pick-up points and disincentivizing returns. This report elaborates on the effect of both of these measures on CO_2 emissions in last mile parcel delivery networks.

Parcel deliveries to pick-up points could potentially reduce the CO_2 emissions in last mile parcel delivery networks. Each parcel delivered through a pick-up point, removes[1] one address visited by the vehicle (one stop) from the home delivery network, thus generally decreasing the number of vehicle-kilometres driven for the deliveries. However, the exact impact of pick-up points on the CO_2 emissions of the last mile parcel delivery network and on the CO_2 emissions per parcel will depend on a number of factors that may have a complex way of impacting CO_2 emissions of last mile deliveries[2].

This report aims to answer the following questions:

1)   What factors influence the CO_2 emissions of last mile parcel delivery networks and the CO_2 emissions per parcel delivery?
2)   How do these factors influence the CO_2 emissions per parcel?
3)   Is the current CO_2 footprinting method adequate for analysis of CO_2 reductions by the use of pick-up points? By 'the current CO_2 footprinting method' we mean the method derived from the EN 16258 standard, modified in accordance to suggested improvements in the FP7 COFRET project[3] and implemented in the BigMile^{TM} tool.
4)   Does the current CO_2 footprinting method stimulate the use of pick-up points as a measure to reduce CO_2 emissions in last mile parcel delivery networks?

Chapters 1 to 4 provide the answers to these questions for the forward moving parcels, i.e. the parcels that travel from the web shops to consumers.

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[1] Assuming one parcel per delivery address. In case of multiple parcels per address, they are considered as one parcel delivery in the context of this report

[2] Note that parcel deliveries to the pick-up points may influence CO_2 emissions made by the consumers, as it is possible that a part of them will come to pick-up points by car or public transport. This report considers these mobility-related emissions outside of the scope and concentrates on the emissions of last mile parcel networks of professional carriers.

[3] Davydenko, I., Ehrler, V., de Ree, D., Lewis, A., & Tavasszy, L. (2014). Towards a global CO_2 calculation standard for supply chains: Suggestions for methodological improvements. Transportation Research Part D: Transport and Environment, 32, 362-372. For more information on BigMile^{TM} we refer to the www.bigmile.eu website and technical documentation and https://www.bigmile.eu/sites/default/files/2020-02/bigmile_productrelease_3.0_nl.pdf

Chapter 5 looks into the situations with returns, and provides arguments for the same methodological treatment of returns as for the forward moving parcels. Therefore, the reasoning of chapters 1 to 4 applies to the return flows as well.

2   Factors that influence CO_2 emissions in last mile parcel delivery networks

A last mile parcel delivery network can be conceptualized as a number of vehicle journeys from a distribution centre (or depot). A journey can be considered as a number of linked segments, such as a segment from the depot to the first address (distance a_1 and a_3 in the illustration below), a number of segments along which the vehicle moves between the first delivery address and the last delivery address (with the average distance between delivery addresses being d^1 and d^2 respectively for the upper and lower route respectively in Figure 1 below) and the segment from the last delivery address to the depot (distances a_2 and a_4 respectively in the illustration of Figure 1 below).
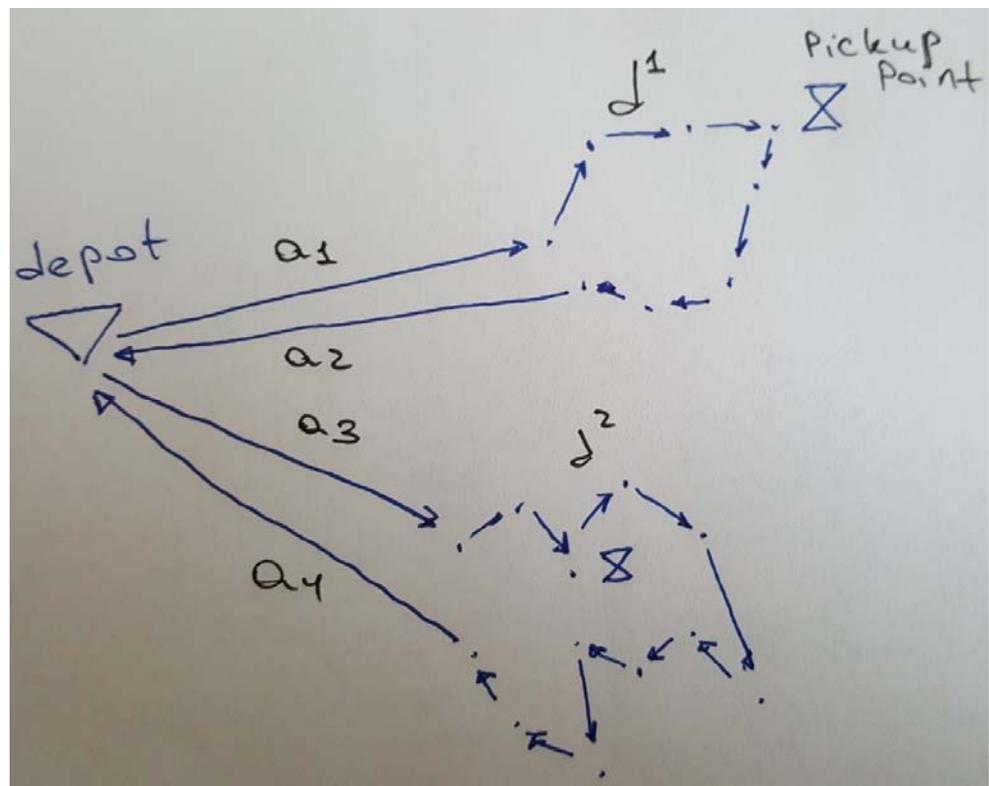
Figure 1: Conceptual representation of a last mile network.

For the computation of CO_2 emissions per parcel we need to determine the transport activity and the CO_2 emissions resulting from the vehicle journeys. The transport activity for parcel delivery networks is usually computed as $m^3.km_{GCD}$, where GCD is short for Great Circle Distance. The transport activity can be very accurately computed using depot and delivery locations and parcel volume data. Journey vehicle emissions can be estimated ex-ante using distances a_i and d^i.

For simplicity[4], assuming a constant fuel consumption (CO_2 emission rate) per kilometre travelled c, journey emissions can be determined as

$$E^j = a_i * c + d^j * (n^j - 1) * c + a_{i+1} * c \qquad (1)$$

Where
E^j are emissions of journey j
n^j is the number of delivery stops in journey j
a_i is the distance between the depot and the first stop
a_{i+1} is the distance between the last stop and the depot
d^j is the average distance between the stops in the district
c is a constant representing the CO_2 emissions per kilometre.

The number of delivery stops (n^j) is equal to the number of parcels delivered (p^j) minus the number of parcels shipped via a pick-up point[5] (z^j) plus one stop for the pick-up point itself.

$$n^j = p^j - z^j + 1 \qquad (2)$$

Journey level emissions can thus be re-formulated as follows

$$E^j = a_i * c + d^j * (p^j - z^j) * c + a_{i+1} * c \qquad (3)$$

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[4] Vehicle emissions can be modelled in much more detail, for instance, taking into account the start-stop cycle, different levels of fuel consumption per road type, etc. However, for this analysis such details will only complicate the things without clear benefit. A simulation model that is to be discussed later in the document, may take these complexity factors into account.

[5] This assumes, for simplicity, one pick-up point per journey j. Multiple pick-up points per journey can be included into a detailed simulation: in this report such addition would substantially increase the complexity of the reasoning without a clear benefit for the conclusions.

3 How do these factors influence the CO_2 emissions per parcel?

A naïve analysis of equation (3) could lead to the following conclusion: Under the assumption that the number of parcels delivered remains the same, each extra parcel delivered via a pick-up point (starting from the second parcel), reduces d^j kilometres driven and results in $d^j *c$ less CO_2 emissions. If all parcels are delivered via the pick-up point only the a_i and a_{i+1} distances will be driven. This can lead to very substantial reductions in CO_2 emissions.

However, the naïve approach has a number of deficiencies. It fails to consider the following aspects:

1) Each extra parcel[6] that is delivered via a pick-up point removes a stop from the route j and will **increase the distance between stops d^j**. In case of a higher use of pick-up points the vehicle will probably travel more kilometres per stop as the distance between the stops d^j will increase, but overall, the number of kilometres driven per parcel should generally decrease, as the sum of kilometres d^j made in the districts will decrease. If the network is dense (i.e. deliveries to neighbourhoods with a high concentration of high-rise buildings), the pick-up points will have a small effect on the network CO_2 performance and thus the CO_2 emission reduction from pick-up point deliveries will also be very small in this case due to a small value d^j of saved kilometres in a dense network.

2) **Capacity limitations related to the route will shift**. This will impact **the network organisation** and **the distribution routes**. A route can be limited by time or limited by the dimensions (maximum volume or weight) of the vehicle. This could lead to a different organisation of the distribution network. For example the use of other vehicle types or separate routes to pick-up points.

   a. If journey j is **time limited** by the working hours of the driver, or by the service timing (i.e. evening deliveries), then the vehicle capacity is not initially a limiting factor: the vehicle could take more parcels into the route. When more parcels are delivered via pick-up points instead of directly to home addresses, the total stop time for this route will decrease. In case of a time-limited route this means that the vehicle can deliver more parcels in the same route. As a journey will deliver more parcels in time-limited capacity, the total number of journeys will decrease due to a larger number of delivered parcels per journey. As a result of the decreased number of journeys, the number of segments to the first address (a_i) and the number of segments from the last address (a_{i+1}) will likewise decrease, thus further providing savings in kilometres driven and hence in CO_2 emissions.

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[6] Starting from the second parcel delivered to the pick-up point. The first parcel at the pick-up point can be considered as an address change from home address to a pick-up point address. Such a change will not impact the aggregate CO_2 emissions of the last mile delivery network. Note that the total number of delivered parcels stays the same, the reasoning applies to a shift from home deliveries to pick-up point deliveries.

b. If the capacity is **limited by the dimensions of the vehicle**, (i.e. by the maximum volume of the vehicle, which is the typical situation in parcel networks, or by the weight, which may also happen), then there will be no reduction of journeys and also no reduction of kilometres related to the segments to the first address and from the last address in the delivery route.

The reduction of kilometres is in this case only related to a decreasing number of kilometres driven in the district. Theoretically, for visiting the n_j locations with an average distance between the stops of d_j, a total distance of $D = (n_j - 1) * d_j$ kilometres should be driven.
A removal of 50% of the locations to visit will increase the distance between the locations to visit by the factor $\sqrt{2}$ (~ 1.414, see Figure 2). The total distance travelled will then become
$D' = (n_j/2 - 1) * \sqrt{2} * d_j$, so $D' \sim \frac{\sqrt{2}}{2}D = \frac{D}{\sqrt{2}}$.
This means that the total distance travelled in the district is decreased by a factor of $(1 - \frac{1}{\sqrt{2}})$ or 29%.
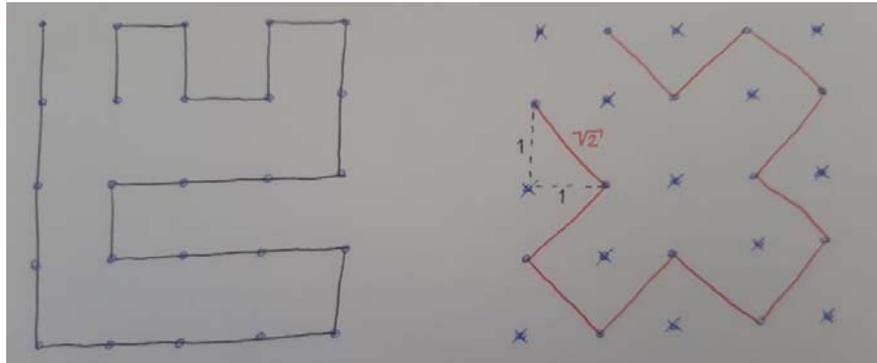

Figure 2: Example to illustrate an increase in distance per stop by a factor $\sqrt{2}$ in case of a decrease in the total number of stops by a factor 2.

4 Does the current CO_2 footprinting method stimulate the use of pick-up points as a measure to reduce CO_2 emissions in last mile parcel networks?

The current carbon footprinting method will provide a very good assessment of the CO_2 emissions of the last mile network. The reductions of CO_2 emissions due to the use of pick-up points will be visible (measurable at the network level), thus the service providers running the network will see reductions in fuel use and in CO_2 emissions. The carbon footprinting method will incentivise them to increase the share of parcels delivered to the pick-up points. See item 2) of the previous section for the considerations why CO_2 emission savings will occur and a very rough estimation of them.

At the level of consumers[7], who take decisions on whether to deliver to their house address or to a pick-up point, the current carbon footprinting method will not show any structural[8] difference between pick-up points and home deliveries. In other words, when presented with a choice between home delivery and delivery to a pick-up point, the consumers will see no significant difference in CO_2 emissions between these two options. This means that the current carbon footprinting method provides no incentive for consumers to choose for delivery via a pick-up point instead of a home delivery.

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[7] The consumers may be presented with a number of delivery options at the checkout page of a web shop. For each delivery option, the consumer can be presented with CO_2 emissions related to the choice.

[8] For each individual parcel there will be a difference in CO_2 emissions between home delivery and delivery to a pick-up point. This is due to the fact that the CO_2 emissions of a parcel are computed as CO_2 emissions per $m^3.km_{GCD}$ multiplied by the volume of the parcel and the great circle distance between the depot and the delivery location. For each parcel the distance between the depot and the pick-up point and between the depot and the home address will not be equal. The difference in distance has an equal chance to be positive or negative. However, for a large sample of parcels, there will be no statistical difference in distances.

5 Which alternative CF options can stimulate the use of pick-up points as a measure to reduce CO_2 emissions in last mile parcel networks?

Based on the considerations presented in Chapter 3, the conclusion is that the current carbon footprinting (CF) method is useful for the organisation of the network and that it incentivises deliveries to the pick-up points from a service provider perspective. The current CF method does not incentivise consumers to choose pick-up point delivery over home deliveries.

For the consumers, a modification of the CF method might be useful. At this moment, two approaches seem to be worth considering:

1)   Using analytical considerations (e.g. marginal accounting) to provide evaluations of CO_2 emissions for home delivered parcels and for parcels delivered to the pick-up points. The analysis should be done on the data of the current CF method implementation. An example of this analytical approach is given in paragraph 5.1;

2)   Treat deliveries to pick-up points and deliveries to home addresses as different parts of the network, i.e. as different Transport Service Categories (TSCs). Treating home deliveries and deliveries to pick-up points as different TSCs allow computing CO_2 emissions separately for these TSCs. Such approach has an advantage that no marginal accounting methods are necessary, but the approach is complicated by a challenge that both TSC shipments often travel within the same vehicle. This document will not further elaborate on this approach, but it is worth checking its applicability when a simulation model is constructed.

Each of the two approaches has advantages and disadvantages. Therefore, it is important to analyse these further. In an ideal situation, a realistic simulation model for the last mile deliveries should be constructed. This model will not only create clarity on the impact of pick-up point deliveries on the CO_2 emissions, but will also provide data on the traffic nuisance (as, for instance, such a model can compute indicators on the number of kilometres driven in the districts and show the impact of pick-up points on the reduction thereof) – no less important issues in the city environments.

5.1   Fictive example on the application of an analytical approach

The following example will illustrate a possible analytical approach. Suppose that in "Situation 1"[9] 100 parcels are delivered to home addresses in a single delivery journey. The total CO_2 emissions related to the roundtrip are 30 kg CO_2, implying an average emission of 300 grams of CO_2 per parcel.

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[9] Situation 1 can be considered as the current scenario or business as usual scenario.

In "Situation 2", 49 parcels will still be delivered to the home addresses, and the remaining 51 will be delivered to a single pick-up point[10].
Suppose further, that in Situation 1 the distance from the depot to the first address (a_1) plus the distance from the last address to the depot (a_2) is 40 km (corresponding to $a_1 + a_2$ in equation (3)). In Situation 1 the average distance driven between addresses is 500 meters, roughly corresponding to 50 km driving in the district. Suppose further, that in Situation 2, the distance to the first address a_1 and the distance from the last address a_2 stay the same. The total distance of the roundtrip in Situation 1 is 90 km (= 40 km + 50 km) and the total CO_2 emissions related to this roundtrip are 30 kg CO_2, so the constant c in equation (3) is equal to 0.33 kg/km (= 30 kgCO_2 / 90 km).

In Situation 2, the total number of stops has decreased by a factor 2, so, as illustrated in Figure 2, this implies that the average distance per stop (d) is increased by a factor $\sqrt{2}$ and the distance driven in the district decreases by a factor $\sqrt{2}$ and is now 35 km. The constant emission factor (c) in kgCO_2/km in Situation 2 is the same as in Situation 1 and is equal to 0.33 kg/km. An overview of Situation 1 and Situation 2 is provided in Table 1.

Table 1: An overview of Situation 1 and Situation 2.

	Equation (3)	Situation 1	Situation 2
Total number of parcels	p	100	100
Number of pick-up point parcels	z	0	51
Distance to first and from last address	$a_1 + a_2$	40 km	40 km
Average distance per stop	d	0.50 km	0.71 km
Total distance in district	$(p-z)*d$	50 km	35 km
Total distance of roundtrip	$a_1 + a_2 + d$	90 km	75 km
Total emissions	E	30 kg	25 kg
Emission factor in kgCO₂/km (derived)	c	0.33 kgCO₂/km	0.33 kgCO₂/km

Since in Situation 2 the total distance has decreased to 75 km (= 40 km + 35 km), the total CO_2 emissions related to this roundtrip are decreased to 25 kg CO_2 (= 75 km * 0.33 kgCO_2/km). This means that in Situation 2 some 17% less CO_2 is emitted in the delivery journey compared to Situation 1. The fact that 5 kg CO_2 are saved can be attributed to the use of the pick-up point. Using marginal accounting principles the CO_2 emission reduction of 5 kg is attributed to the 51 parcels that are delivered at the pick-up point while the CO_2 emissions attributed to the 49 parcels that are delivered at home will stay the same as in Situation 1, namely 300 gram per parcel. The home delivered parcels account for a total CO_2 emissions of 14.7 kg (= 49 parcels * 0.300 kg/parcel). The remaining CO_2 emissions of 10.3 kg (= 25 kg – 14.7 kg) are assigned to the 51 parcels that will go to the pick-up point in Situation 2. This corresponds to 0.202 kg CO_2 per parcel (= 10.3 kg CO_2 / 51 parcels), which represents some 33% CO_2 savings per parcel that is delivered to the pick-up points, instead of an average 17% (=5kg/30kg) savings per parcel for all parcels.

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[10] Note that the use of a pick-up point introduces an extra stop in the network. For the simplicity of a 50/50 split between the parcels going to home addresses and pickup points, we assume that 51 parcels will go to the pick-up point and 49 will be delivered to the home addresses, thus reducing the number of stops by a factor 2.

The example above is an illustration on how some basic ideas related to marginal accounting can be used to estimate the effects of the use of pick-up points at the level of individual parcels. The estimations are sensitive to the assumptions and in practice will depend on the specific properties of the service areas. An application of a simulation model can verify these assumptions and improve the assessment of the effects. It can be expected that a simulation model can provide estimations for the effect of pick-up points depending on the area under consideration (e.g. large city, rural, suburban, etc.). The data from simulations can be used for influencing of the consumer behaviour with respect to the delivery options for parcels.

6 Effect of returns on emissions and adequacy of CF method for the returns

The returns in e-commerce are the previously purchased products that are sent back to the retailer by customers, who in turn receive a refund on the original form of payment. The possibility to return unneeded or unsatisfying products greatly increases attractiveness of e-commerce to the customers, and allows some e-commerce segments like apparel to gain a substantial market share. On the other hand, returns create extra transport volumes, especially so as one return creates two transport orders, first in the form of a forward transport order from the shop to the consumer, and second in the form of a transport order from the consumer back to the shop. These extra transport volumes lead to additional CO_2 emissions, while a returned product does not create a sale. At this moment, carbon footprinting of the returns is not sufficiently developed and incorporated into decision support tools. Moreover, returns create contradictory effects related to carbon efficiency of transport networks, which makes it even more important to get these effects right. Likewise, the consumers[11], who essentially determine the volume of returns in e-commerce networks, should be made aware of the negative effects of returns on transport and logistics emissions, while the complexity of network effects should be aggregated into easily understood numbers that encourage behaviour leading to emission reductions. This section looks at the effect that returns have on emissions in last mile parcel networks and assesses the adequacy of the CF methods for encouraging decisions related to reduction of the emissions.

There are indications[12] that at this moment the flow of returns follows the same network as the parcels going in the "normal" direction from the shops to consumers. The majority of forward parcels are delivered to home addresses, and the majority of returns are returned via the pick-up points as the vehicles that bring parcels to these locations take returns back to the depots. In the context of logistics flows, these parcels cannot be distinguished from the parcels sent by private persons or smaller web shops via retail pick-up points of the carriers. In case the flow of returns does not fit into the current set of vehicle journeys, additional roundtrips might be used to transport these parcels. This is equivalent to additional roundtrips that are added in case extra forward parcels do not fit into the current roundtrips. Both additional returns and additional forward parcels will increase the total transport activity in the network, which could both lead to additional CO_2 emissions due to extra roundtrips.

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[11] The returns policies of shops have an effect on the volume of returns, as for instance "free" returns may encourage consumers making "riskier" choices with respect to buying decisions, as the products can be freely returned. However, free returns are a part of competitive efforts by the shops to attract consumers, who may prefer a shop that offers free returns over those that do not offer them.

[12] GET RID OF RETURNS project, TNO report *Analyse van retouren van online aankopen in fashion en schoenen en verkenning van oplossingsrichtingen*, Gerwin Zomer en Elisah van Kempen (TNO), juli 2019, TNO 2019 P11 074

It is worth discussing that since returns increase transport activity[13], the CO_2 emissions per transported activity (e.g. $m^3.km_{GCD}$) could still decrease as the transport activity would generally increase more than corresponding emissions related to the extra transport activity. This will result in an "improved" network CO_2 efficiency indicator (kg CO_2 per $m^3.km_{GCD}$), while absolute emissions will go up. This can be seen as a side-effect of "wasted" transport activity, avoidance of which should be stimulated.

Methodologically this means that the return parcels can be treated in the same way as the forward parcels going through the network, namely, by considering return parcels as transport orders no different from forward parcels. This implies that considerations provided in chapters 1 until 4 equally apply to the return flows. In other words, whether a stop at a certain location[14] is caused by a "normal" forward parcel or a return there is no difference with respect to CO_2 emissions in last mile networks. CO_2 emissions at the level of a parcel and at the network level can be determined using the same methods and the impact of pick-up points will be the same, independent from the direction of the parcels.

Therefore, the expected effect of a larger number of return parcels on emissions in last mile networks is that the overall network emissions will probably increase, but the CO_2 emissions per parcel (or per $m^3.km_{GCD}/ton.km_{GCD}$) transported in the network will decrease. At the same time, the returns will increase CO_2 emissions per definitely sold parcel (i.e. the parcel that will never be returned). This creates an interesting context, where emissions per transported parcel decrease, while per sold parcel the emissions increase. Nota Bene, this expected effect of a decrease of CO_2 emissions per parcel transported is per one-way parcel movement. A consumer who sends the parcel back would be responsible for approximately twofold CO_2 emissions: the first time when the parcel was travelling from the web shop to the consumer, and the second time when the parcel was travelling back to the web shop. As the decrease in parcel-level emissions due to returns is expected to be smaller than twofold, consumers who send back their parcels will increase real world emissions associated with their actions. The current carbon footprinting method will account for these emissions properly: first assigning CO_2 emissions to the parcel travelling to the consumer, and second assigning CO_2 emissions to the parcel travelling back from the consumer.

The current carbon footprinting methods will remain effective in the estimation of CO_2 emissions and as a means to control or reduce them. From the consumer point of view, if a parcel is to be returned, there will be associated emissions with such an action. The amount of CO_2 emissions of the parcel to be returned will be equal or close to the amount of CO_2 emissions related to the "forward" transport of the parcel in the last mile network. This is valid under the condition that the same method is used for the "forward" delivery as for return, i.e. that the parcel is sent back from the same pick-up point, or the parcel is returned from the home address where it was delivered.

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[13] Note that a return create on average double transport activity that of a forward parcel, which will not be returned. A return consists of two transport assignments, first as a forward parcel, and second as a parcel from consumer to the shop.

[14] The term "location" is equally applicable to the home addresses and pick-up points.

In case the parcel was received at home and sent back via a pick-up point, the amount of CO_2 emissions can differ and the points discussed in the sections above will apply[15].

The carbon footprinting method provides a solution to increase consumer awareness and stimulate emission-avoidance behaviour. For instance, at the check-out page of a web shop, the consumer can be shown CO_2 emissions related to their purchase as two numbers: one number for the case if the purchase is definite (e.g. will never be returned) and a second number for the case the purchase is returned. The consumer can be attended to the fact that in case of a return, the associated emissions would be made without any positive result for retailer and consumer. This information will change behaviour of a certain share of consumers.

The above-described method, however, is not the only possible one for dealing with returns. An example of a second approach can be found in the carbon footprinting guidelines published by Connekt. In these guidelines, all CO_2 emissions, including those caused directly or indirectly by the returns, are allocated to the transport activity of all 'forward' parcels. The flow of return parcels is not included in the calculation of the transport activity and return parcels do not get any allocation of CO_2 emissions. This means that someone who orders and keeps one pair of shoes will 'pay' the same amount of CO_2 emissions as his neighbour who orders and returns one pair of shoes. However, if this neighbour orders five pairs of shoes, returns four pairs of shoes and keeps one pair, the neighbour will pay a five-fold of CO_2 emissions, since the allocation is proportional to the volume of the parcels. In this approach the total number of return parcels does not directly influence the CO_2 emissions per parcel. This solves the possibly counterintuitive fact that more returns in a parcel network decrease the CO_2 emissions per one-way-trip[16] of a parcel (since the same CO_2 emissions are allocated to a larger amount of transport activity). However, in case additional trips are needed to handle return flows, these additional emissions are allocated to the forward parcels, which will lead to higher CO_2 emissions per parcel for all forward parcels in the network. This means that the one-way parcels are also 'paying' for the additional CO_2 emissions related to returns. These considerations show that a balancing act must be performed between the methodological purity on the one hand, and a broader understanding and acceptability of the method for calculation of the carbon footprint of parcels and returns on the other hand, as well as the effectiveness of the result of the calculation as an incentive for improving sustainability.

If a simulation model is to be constructed, the model can take into account the capacity of the vehicles, as well as the storage capacity of the pick-up points. Given the half a billion of parcels that were sent through the Dutch parcel delivery networks every year in 2018[17], even a modest reduction in CO_2 emissions per parcel will result in a substantial reduction of absolute CO_2 emissions.

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[15] In the current carbon footprinting method, the amount of CO_2 emissions of a return is approximately the same as the amount of CO_2 emissions for the delivery of a parcel. This implies that a consumer who is returning a parcel will be accounted for twice as much CO_2 emissions compared to a consumer who is not returning a parcel.

[16] Note that in such formulation, the CO_2 emissions of a returned parcel (two-way) will be higher (approximately two-fold) than the CO_2 emissions of a 'normal' parcel (one-way).

[17] https://www.logistiek.nl/distributie/nieuws/2019/08/acm-504-miljoen-pakketten-vervoerd-in-2018-101169190

Only a proper simulation can point out the most effective ways to stimulate networks for CO_2 emission reduction through for example technical measures (electric vehicles), logistics organisation and stimulating favourable consumer behaviour.

7   Conclusions

This report looked at the effect of pick-up points on the CO_2 emissions in last mile parcel delivery networks. It formulates a parameterized model that allows a conceptual analysis of the impact of pick-up points on CO_2 emissions in last mile parcel deliveries. It can be concluded that the pick-up points have a potential to reduce CO_2 emissions in the network of a transport service provider by reducing the average number of kilometres driven per delivered parcel, and hence reducing the CO_2 emissions. This CO_2 emission reduction does not account for a possible increase in emissions due to the actions of the receivers of the parcels, such as for instance, those related to visits to the pick-up points by car – these actions are outside of the scope of this report.

As more parcels go via pick-up points, the expected emission reduction in last mile parcel delivery networks can be attributed to the two following effects. Firstly, if the vehicle is not volume or weight limited, but time limited due to e.g. working time regulations or delivery time windows, pick-up points allow more parcels to be transported in one journey. Emissions related to the distance driven from the depot to the first delivery location and the distance driven from the last delivery location to the depot will be allocated to a larger number of parcels, thus reducing the CO_2 emissions per parcel and the total network emissions. Secondly, due to the fact that less addresses have to be visited, the number of kilometres in "the district" will be decreased, as well as the CO_2 emissions. The report presents a conceptualization of the model and provides some basic estimations on the effect of pick-up points.

The current carbon footprinting methods are well suited to determine the effect of pick-up points on CO_2 emissions in last mile parcel delivery networks.
By application of the carbon footprint method, the transport service provider will get an accurate ex-post account of emissions and emission volume per parcel delivered. However, the current footprint method is too aggregated to show the effect to the consumer, who may decide to receive the parcel at home, or to let the parcel be delivered to a pick-up point. We provide some considerations on how to make a computation for the consumer, of which a marginal accounting method might be the most feasible.

The behaviour of consumers to order many items and then return some, causes some additional transport activity, and hence emissions. The returns often fit into the forward networks of the carriers, but in some cases require extra transport, and thus causing additional CO_2 emissions. The effect of returns can be determined by the current carbon footprinting methods, either as "an overhead" that somewhat increases emissions of all forward parcels, or can be treated separately and assigned to the consumer that returns the product. Both ways of emission computation will discourage returns, presenting consumers with two numbers of CO_2 emissions related to a definite sale and a return will probably have a stronger impact on emission awareness. There are further ways for discouraging returns by the shops, for instance, by avoiding offering free returns when their competitive environment permits it.

This report provides conceptual theoretical considerations related to the effect of pick-up points and returns on CO_2 emissions in the last mile parcel delivery networks. Given the sheer volume of parcel networks, a continuing growth of the e-commerce segment and the resulting emissions, it is considered to be worth to construct a simulation model for the last mile parcel delivery networks. If such a model helps reducing 10% of emissions in last mile networks, the real-world savings can be counted in tens of thousands of tons of CO_2 only for the Dutch parcel market. Furthermore, the logistics service providers may be able to re-organize the networks for more efficiency and for alleviation of bottlenecks, such as congestion in the cities and the (possible) shortages of drivers and zero-emission vehicles.

8 Signature

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TNO

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