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Using E-fulfilment centres for direct last-mile parcel delivery: an activity cost based analysis

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Abstract

In the last few years, online shopping has been increasing rapidly. Optimising the sorting processes in E-fulfilment centres, combined with direct parcel delivery from the E-fulfilment centres to the close-by customers has not been widely studied in a quantitative manner. The main objective is to show whether E-fulfilment centres can generate a reduction in costs for parcel delivery. Two models are used to calculate the cost savings by using of an E-fulfilment centre. The volume of parcels has a crucial role in the calculation (and the competitiveness) of delivery costs. The time-driven performance reaches a break-even point for the volumes that can compete with the logistics providers. The impacts of directly delivering parcels from an e-fulfilment centre to nearby customers result in lower greenhouse gas emissions.

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Keywords: Type your keywords here, separated by semicolons ;

1. Introduction

In 2021, retail e-commerce sales amounted to approximately 5.2 trillion U.S. dollars worldwide. This amount is forecasted to grow by 56 percent over the next years, reaching about 8.1 trillion dollars by 2026 (Chevalier, 2022). E-commerce can be described in terms of purchasing and selling products or services through the channel of the internet (Grandon & Pearson, 2004). By that time, e-commerce has evolved from simple transactions over the Internet to selling, buying, logistics, or other management activities via the Internet. From different studies, it can be concluded that the business-to-consumer distribution of parcels accounts for 56% of all shipments in e-commerce. Also, last-mile delivery of online shopping is responsible for 32% of total energy consumption. The growth of online shopping also impacts congestion in the inner cities (Pufahl, et al., 2020). In different studies, the last-mile delivery is studied and

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compared with each other. Based on different cost and environmental components, all the different last-mile solutions such as reception boxes, collection point delivery and/or drones are studied and evaluated (Mangiaracina et al., 2019). From here, it can be concluded that each of the studies has identified its criteria to distinguish the different alternatives, however from a general perspective they all are summarised into a few important criteria.

Assessing criteria such as delivery costs, delivery time, emissions and customer satisfaction have been used multiple times in several studies. Combining the different alternatives and researching the possible benefits that could occur are suggested (van Duin et al., 2019). Different potential benefits can be achieved if different processes in or around parcel delivery are adapted (Van Loon et al., 2105). Combining (and transforming) the function of the E-fulfilment centres to act as a city hub (for delivery to nearby customers) has not been widely studied. However, internal processes of E-fulfilment centres are widely studied and optimised for first-mile delivery from the retail location (Leung et al, 2018). Studies show that combining an ‘integrated’ logistics system does improve the costs, customer expectations and reduce emissions. Furthermore, the challenges regarding omnichannel logistics are studied and where possible changes should be made for a transition of the E-fulfilment centre (Mena et al, 2016).

On the other hand, it can be concluded that parcel lockers have virtually no failed deliveries compared to home deliveries and that from questionnaires customers are willing to use a parcel locker if it fulfils their desires (Iwan, 2016). It is clear that parcel lockers solely or in combination with other alternatives as electric vans have the potential to impact traffic the most (van Duin et al., 2019). A quantitative study is proposed for future research, in similarity to the concepts of the Amazon hub lockers (Mangiaracina et al., 2019; Lunden, 2017).

To conclude, a quantitative study, with possible costs- and emission reductions, are not widely studied (yet) in a combination with direct parcel delivery. This can be achieved by modelling and computing, the combination of different alternatives such as restructuring E-fulfilment centre processes with parcel lockers and pick-up points. Moreover, in the proposed parcel delivery model, the parcel orders in different radius distances will be compared to the scenarios if the parcels are conventionally delivered to the end customer. This paper will experiment and study certain radius distances (to nearby customers) from the E-fulfilment centre to gain insights into the potential impacts of direct parcel delivery. Lastly, understanding and identifying the radius distances in combination with ‘sufficient’ volume to transport direct delivery is important to calculate the costs per parcel. Once, the volume scale is larger than the break-even point, the economies of scale and the cost advantages can be expressed. A visualisation of the problem statement and elimination of the sorting steps in the current parcel delivery process is shown in Figure 1. Elimination of the sorting steps is by depicted the red box in the visualisation.

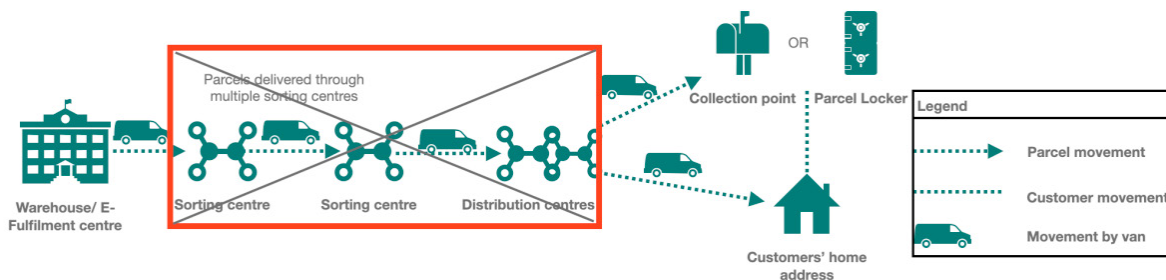


Fig. 1. Visualisation of problem statement

The research question that is answered in this paper is, ‘To what extent is it possible to perform direct parcel delivery from the E-fulfilment centre to nearby customers?’ The main objective is to show whether E-fulfilment centres can generate reduced costs in parcel delivery. To answer this question, firstly the identified parcel delivery models are elaborated. Then the research approach is discussed. This is followed by a presentation and discussion of the scenarios. The paper ends with the conclusions and recommendations for future research.

2. Two parcel models

Two main parcel delivery models are compared to each other: the current parcel delivery model and the proposed direct parcel delivery model. At this moment, in the first step of the sorting processes, the orders are sorted and processed for delivery from the E-fulfilment centre. Hereafter, the few largest logistics carriers as PostNL and DHL Parcel in the Netherlands use their parcel network for delivery of the parcels to the end customers (ACM, 2019). Figure 1 shows a simplified visualisation of the current parcel delivery model by neglecting the cross in the red box.

From other studies on innovation in parcel delivery (Mangiaracina et al., 2019; Van Duin et al., 2019; Slabinac, 2015) the four main criteria to be fulfilled are the delivery costs, the delivery time, emissions, and customer satisfaction. A more detailed emphasis on these criteria is explained hereafter.

Last-mile delivery of parcels is mainly dependent on the population density of areas, and the number of order quantities (Wang et al., 2014). Especially, in low customer density areas, the chances of missing home deliveries leads to extra miles driven. As a consequence, these related extra miles driven eventually lead to a growth in economic and environmental costs. Nonetheless, decreasing last-mile delivery costs is the most important objective for retailers, as these costs are still accountable for between 13% and 75% of the total supply chain costs (Gevaers et al., 2009). For these high costs, various underlying factors can be identified for the last-mile delivery costs. The three main factors are: (i) the probability of having failed deliveries, (ii) the customer density in the delivery areas, and (iii) the degree of automation of the process (Mangiaracina et al., 2019). These factors are also in line with the time spent processing the parcels and eventually the delivery time. Finding other options to reduce the driven kilometres and time driven of the parcels, the proposed direct parcel delivery model can be a potential solution that is partially derived from the omnichannel delivery theory. The omnichannel strategy is introduced, where customers choose the strategy and maintain the same level of customer satisfaction regardless of which channel they receive the parcel(s). So, for the direct parcel delivery model, the parcels will be directly delivered from the E-fulfilment centre to the end customers, instead of transporting them to the sorting and distribution centres. A visualisation of the proposed direct parcel delivery model is shown in Figure 1.

3. Research Approach

To find and explore the different possibilities for restructuring parcel delivery, via (in)direct delivery from the E-fulfilment centre and/or in combination with distribution centres and parcel lockers, different methods are used.

Designing the scenarios. In collaboration with the experts of the E-fulfilment centre the scenarios are designed by analysing the data and using the input given by the stakeholders. The reason for collaboration and involvement of these parties is preferred, is because of their broad experiences in delivering large numbers of parcels and route planning of both parties. The approach of designing the scenarios for the quantitative analysis is performed through a systematic approach. In the first phase, possible scenarios requirements and relevant components are described. These will be derived from the main criteria and stakeholder analysis. Hereafter, the approach for analysing the volume data and organising a workshop session to formulate different scenarios. In total, the construction of the scenarios for direct parcel delivery consists of two main phases. Firstly, this involved an analysis of the current parcel delivery and data analysis regarding the volume of the E-fulfilment centre. Secondly, the geographical chances and the possible radius distance options towards direct delivery are researched and discussed.

Data analysis. A data file was provided containing the following information: (i) the order numbers, (ii) attached six coded postal codes for the Netherlands and postal codes for international orders, (iii) the moment of the year the order (2020) has been fulfilled. The complete information on the street and house level of the orders could not be provided due to privacy reasons. However, analysing the opportunities to which options of radius distance(s) direct delivery is possible, the six coded postal codes are sufficient. In the next step, to include the parcel lockers and collection points in the surrounding areas, the six coded postal codes are clustered. Hereafter, the data is analysed to see the yearly pattern (2020). Analysing the yearly pattern provides the lowest number, the average number and the highest number of parcels handled by the E-fulfilment centre in the year 2020.

Postal codes radius model. In order to create scenarios, a postal code radius model is introduced. This model filters all the orders in the postal codes of the chosen radius distance. Initially, all the postal codes for each radius distance

from the E-fulfilment centre are categorised.

By combining the aforementioned information, the scenarios of researching the different possibilities are dependent on the different radial distances. In this research, four linear distances are chosen for the scenarios, 20, 25, 30 and 35 kilometres. The linear distances are chosen, due to the average on and off-driving distance from sorting depots to the end customers. These discrete distances are based on the practical experiences of experts. Also, this research focuses on gaining insight into business opportunities, rather than looking at the exact radius distances and the prices based on the volumes.

Evaluating the scenarios. Assessing direct delivery is based on the crucial objectives of the main stakeholders. The costs/parcels are the most important and interesting challenge that could be undertaken by direct delivering the parcels in a certain radius distance with attached parcel volumes. Evaluating the scenarios financially requires the computed/assumed output of possible parcel delivery routes as an input for the cost model. Therefore, to analyse and to answer the research question the following two main assessing methods are chosen: a freight transport route planner and a costs analysis.

Delivery route planning software. To simulate and define the variables for the cost model, a delivery route planning software package SmartRoute is used (Devari et al., 2017). It calculates the routes among the nodes by Dijkstra's algorithm, i.e. the shortest paths between nodes are searched in a graph, where the nodes may represent the stops of the parcels (Bast et al., 2015). The model is used for parcel delivery to home addresses based on the postal codes and the delivery to the fictive manned pick-up points or unmanned parcel lockers. The generated routes will be used for the cost calculation of the different scenarios.

Cost analysis per parcel shipped. The quantitative analysis, for comparing the costs, is performed by Activity Based Costing (ABC) and Cost-effectiveness Analysis (CEA). CEA is a comparative analysis that calculates the costs per unit of product. As a first step the costs for all the activities for the base case, also known as the current parcel delivery model, are researched and divided. Hereafter, the activity costs for each scenario are summed up individually and compared to the base case. Lastly, the outcome of the total costs is divided by the number of units, in this case, the parcels (Newcomer et al., 2015.). For this research, a combination of ABC and CEA will be used that calculates the delivery costs per parcel. The reasons for performing an ABC are due to gain insights into the costs per parcel which form the core insight values of this research. As mentioned the CEA provides the ability to compare the possible scenarios, and determines if the new designs are justified compared to the costs of the current parcel delivery model.

In business practice, gaining data for individual activity costs is not always public or not accessible due to contractual agreements. Therefore, the completion of these values is based on the experts' experiences, perspectives and/or similar reports (McEwan, 2012). In the model, total time driven (T) and distance (D) by the driver(s) are the most important components for the cost calculations. In the new direct parcel delivery from the E-fulfilment centre model, different steps in the logistics chain can be avoided. With this information and the scoped situation, the cost formula for direct parcel delivery from the E-fulfilment centre can be designed (Gevaers et al., 2014) and (Blauwens, et al., 2010).

The current parcel delivery model contains the sorting costs, transport costs from the E-fulfilment centre to the sorting centre, sorting cost at the sorting centre, sorting centre to the distribution centre, sorting cost at the distribution centre and the cost for the last mile delivery. The following formula (1) is applied for the calculation of the total costs of the parcels via the current delivery and sums up to €3.52 per parcel.

$$[SH] + \frac{(T_h \cdot t + D_h \cdot d \cdot v)}{Q_h} + [SC] + \frac{(T_c \cdot t_c + D_c \cdot d \cdot v)}{Q_c} + [SD] + \left(\frac{(T \cdot t + D \cdot d \cdot v)}{\left(\left(\frac{STOP}{w} \right) \cdot ip \cdot ad \cdot cp \cdot Q \right)} \cdot (1 + r) \right) + ((lc + ht) \cdot r) + (ip \cdot pc) \quad (1)$$

where

Symbol	Variable	Value	Unit
SH	Sorting costs current situation at Fulfillment centre	0.17	€/ parcel
T_h	Time of transport from fulfillment centre to sorting centre	1.5	hours

D_h	Distance of transport from fulfilment centre to sorting centre	120	kilometres
Q_h	Number of parcels transported from sorting centre to distribution centre	900	-
SC	Sorting costs current situation at sorting centre	0.17	€/ parcel
T_c	Time of transport from sorting centre to distribution centre	2.96	hours
D_c	Distance of transport from sorting centre to distribution centre	236	kilometres
Q_c	Number of parcels transported from sorting centre to distribution centre	900	-
SD	Sorting costs current situation at distribution centre	0.17	€/ parcel
t	Time coefficient	30	€/ hours
T	Duration of route(s)	48	hours
D	Distance of route(s)	300	kilometres
d	Distance coefficient	0.22	€/ kilometres
v	Vehicle type coefficient	1	-
$STOP$	Number of stops per delivery route per driver	820	-
w	Time window coefficient	1.4	-
ip	First-time hit rate coefficient	90	%
ad	Area density coefficient	1.41	-
cp	Collection point coefficient	1	-
Q	Parcel multiplication coefficient	1.2	-
r	Return logistics coefficient	10	%
lc	Logistics handling costs per parcel	0.17	€/ parcel
ht	Handling costs (for return delivery) per parcel	0.07	€/ parcel
pc	Parcel compensation for retailer per parcel	0	€/ parcel

Direct parcel delivery model. In the direct parcel delivery model, where the parcels will be directly delivered, different steps in the logistics chain are reduced. Therefore, only the sorting costs at the E-fulfilment centre and last-mile delivery costs are taken into account for calculating the costs per parcel. A large difference in costs is the small increase in sorting costs if the parcels are directly sorted. In the current parcel delivery, automation is widely used on a larger scale, whereas with direct delivery less automation is expected in the first stages. This formula is shown in Equation 2.

$$[SHD + \left(\frac{(T \cdot t + D \cdot d \cdot v)}{\left(\frac{STOP}{w}\right)} \cdot (1 + r) \right) + ((lc + ht) \cdot r) + (ip \cdot pc) \quad (2)$$

where

Symbol	Variable	Value	Unit
SHD	Sorting costs direct situation at Fulfillment centre	0.25	€/ parcel
t	Time coefficient	30	€/ hours
T	Duration of route(s)	Variable per scenario	hours
D	Distance of route(s)	Variable per scenario	kilometres
d	Distance coefficient	0.22	€/ kilometres
v	Vehicle type coefficient	1	-
$STOP$	Number of stops per delivery route per driver	Variable per scenario	-
w	Time window coefficient	1	-
ip	First time hit rate coefficient	90	%
ad	Area density coefficient	1.41	-
cp	Collection point coefficient	1	-
Q	Parcel multiplication coefficient	1	-
r	Return logistics coefficient	10	%
lc	Logistics handling costs per parcel	0.17	€/ parcel

<i>ht</i>	Handling costs per parcel	0.07	€/ parcel
<i>pc</i>	Parcel compensation for retailer per parcel	0	€/ parcel

Validation and verification of the model. The model results of the delivery planning as well as the cost models are verified by the transport experts from Izipack¹. These results are in line with the real values that are used in the parcel delivery field. For this research, three main different techniques are used for validation: (1) conceptual model validation and face validity, (2) comparison to other models, and (3) extreme condition tests. In the condition tests, changes are made to the adaption of the number of parcels delivered per stop, lower labour costs) and the delivery of parcels every other day. These changes result in much lower delivery costs, when delivering the parcels directly for this specific E-fulfilment centre.

4. Results

Results first alternative (base). In the costs analysis, the delivery costs of the direct parcel delivery scenarios via the E-fulfilment centre are compared to the estimated current parcel delivery costs. From the E-fulfilment centre, delivery costs €3.50-€4.00 per parcel are estimated. Exact delivery costs from practice are not made available due to contractual agreements. However, when compared with direct parcel delivery, this range of values is sufficient. For direct home parcel delivery, the radius of 25 kilometres offers the lowest delivery costs and shows possible competitiveness with the current delivery costs. By radius when the distance is lower than 25 kilometres the delivery costs are higher than the upper limit of the current delivery costs. Also, by radius distances of 30 and 35 kilometres, when a higher volume is reached, the costs are still higher than the upper limit of €4.00 per parcel. Due to the long time and distance driven, it is not affordable to enlarge the radius distance by more than 25 kilometres as shown in Figure 2.

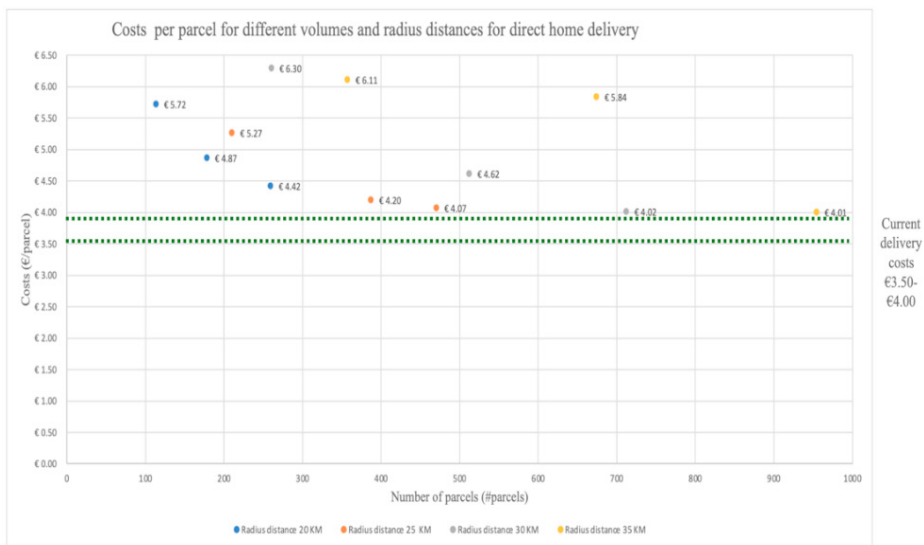


Fig. 2. Comparison costs of direct home delivery with current delivery costs

Results second alternative (unmanned pickup delivery). The second alternative, with only (un)manned pick-up delivery results, also showed competitive results in the radius distance of 25 kilometres. In the high-demand scenario in a radius of 25 kilometres, a price range of €2.19-€2.26 is reached. Due to clustering, each stop has multiple parcels delivered, which decreases the delivery costs per parcel. For this alternative, it is possible to enlarge the radius, but the costs will be higher than the aforementioned €2.19 - €2.26 per parcel. However, with radius distances of more than 25 kilometres, the delivery costs will be lower than the cost of current delivery as shown in Figure 3.

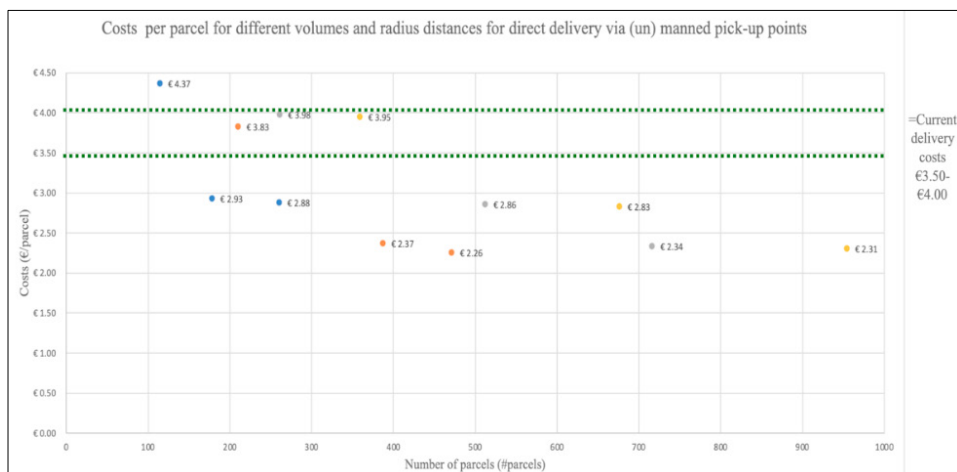


Fig. 3. Comparison costs of direct (un)manned delivery with current delivery costs

5. Conclusions & discussion

The results of this study show that omitting the sorting processes and delivering the parcels directly from the E-fulfilment centres to the end customers is sustainable and financially possible. By omitting the sorting processes in the conventional delivery processes, it results in the volume attached to the distance and time driven having a crucial impact on the determination of the delivery costs. In the first base scenario, the delivery costs for the home delivery in a radius distance of 25 kilometres, achieve costs €4.07 per parcel. To become more competitive, volumes must increase (e.g. via additional demand, collecting demand for more than 1 day into one route, etc.). In the second alternative, adding the (un)manned pick-up delivery the costs could be reduced to €1.50 - €2.00 per parcel. Thus, by increasing the volumes compared to the current chosen one-day delivery, the volumes have a crucial role in the calculation of the delivery costs and can compete with the large logistics providers such as PostNL or DHL Parcel. The impacts of directly delivering the parcels are expected to result in lower Greenhouse Gas Emissions between the sorting and distribution centres and in the last-mile parcel delivery. By merging the parcels, fewer vehicles for parcel delivery are needed which could also lead to a reduction in (city)congestion.

For looking into strong business propositions and possible (future) implementation of delivering parcels directly, future research is desired. Ideally, researching the possibilities with the geographical parcel network infrastructure instead of using assumed (un)manned pick-up points. The density of the population, as well as the number of (un)manned pick-up points in another geographical context, could lead to other results due to environmental factors. Furthermore, the high peak tensions on the automated sorting processes from the large Logistics Service Providers (LSP) could be reduced and a positive impact regarding sustainability for city congestion can be achieved. Studying the possibilities and sustainability impacts are proposed for follow-up studies. Lastly, looking into the next step of online shopping are the return delivery processes, and how these could be integrated with the process of direct delivery, without the sorting processes. Designing and exploring this way of modelling and computing the costs via an activity based cost approach is insightful. It can also be interesting to add this function to (new) hubs and urban consolidation centres.

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