E-commerce last-mile in Belgium : developing an external cost delivery index

Reference:
Cardenas Barbosa Ivan Dario, Beckers Joris, Vanelslander Thierry.- E-commerce last-mile in Belgium : developing an external cost delivery index
Research in transportation business & management - ISSN 2210-5395 - 24(2017), p. 123-129
Full text (Publisher's DOI): https://doi.org/10.1016/J.RTBM.2017.07.006
To cite this reference: https://hdl.handle.net/10067/1444650151162165141

E-commerce last-mile in Belgium: developing an external cost delivery index

Abstract. The rise in online B2C sales resulted in a fragmentation of freight shipments. Logistics service providers are challenged to cope with high competition, a consumer-driven economy, failed delivery issues, reverse logistics and environmental measures taken by policymakers, which are all putting pressure on the costs. The last-mile of these deliveries, widely accepted as the most expense part of the trip, is a trade-off between internal costs, externalities and the density of deliveries. Little is known so far about the actual impacts of e-commerce on transport and logistics on society. In this paper, we first analyse the spatial distribution of e-commerce deliveries during a 4-month period in Belgium. Next, we propose a methodology based on the total vehicle-kilometres travelled to calculate the external costs per parcel at the national level. The results show that despite the high urbanization in the country, the e-commerce consumption per capita is higher in rural areas while the total number of kilometres travelled remains similar to that in urban areas. While urban areas undergo most of the disadvantages related to the e-commerce last-mile, the average external cost per parcel was found to be higher in rural areas.

Keywords: e-commerce, last mile, external costs, urban logistics.

1. Introduction

During the last years, e-commerce has been growing at a two-digit rate, and an increasing number of customers use the business-to-customer (B2C) e-commerce channel to order products online and have them delivered at home. However, this raises new challenges for logistics since the supply chain has to cope with the increased fragmentation to satisfy the needs of customers. High competition, a consumer-driven economy, failed delivery issues, reverse logistics and environmental measures taken by policymakers are factors that increase the costs of delivering online orders. The consequence is that the last mile is regarded as the most expensive section of goods distribution (Gevaers et al. 2014; Fernie et al. 2010). Because of the complexities present in the delivery of e-commerce goods, improving the availability, quality and affordability of delivery solutions has been identified as one of the objectives to stimulate e-commerce growth (European Commission 2013).

B2C e-commerce implies individual shipments, resulting in an increasing number of trips and kilometres (Taniguchi & Kakimoto 2004). The B2C channel represents around 30% of the e-commerce turnover (FTI Consulting 2011), and it generates 56% of all the e-commerce shipments (Copenhagen Economics 2013). While there is no general acknowledgement, estimates indicate that the volume of shipping worldwide is close to 31 billion parcels per year (Pitney Bowes 2016).

The negative impact of B2C e-commerce last-mile have raised interest from urban logistics researchers, transport and retail geographers as well as practitioners and public decision makers (Weltevreden & Rotem-Mindali 2009). The relevance of this discussion is that delivering the last mile is a trade-off between internal costs, externalities and the density of the deliveries. On the one hand, customer density is essential for achieving efficiency in the last-mile. Therefore, rural deliveries can be three times more expensive than urban ones (Boyer et al. 2009; Gevaers et al. 2014). In the urban areas, the density is higher and logistics carriers benefit from lower costs. However, the residents undergo more negative impacts such as congestion, noise, and emissions than rural areas (Zito et al. 2013; Holguín-Veras et al. 2008). At the end, the various stakeholders have to manage different externalities in different regions, which underlines the difficulties associated to the last mile.

Still, little is known about the effects e-commerce has on transport and logistics. An unresolved issue remains whether urban areas generate higher transport demand for transport than their rural counterparts. Recently, Boschma and Weltevreden (2008), who were analysing the evolution of the retail sector, mention the incubation hypothesis in e-commerce adoption, highlighting cities as early centres of innovation. However, Clarke, Thompson, & Birkin (Clarke et al. 2015) found that B2C e-commerce is expanding rapidly and conclude that at least for the UK, B2C e-commerce is not exclusively restricted to urban areas anymore.

Linked with this discussion is the observation that while urban areas are more sensitive to the negative impacts of transport, spreading the externalities can result in an even worse situation. For example, Dablanc & Rakotonarivo (2010) argue that the CO_2 emissions are increasing dramatically because of the geographical dispersion of e-commerce usage in Paris. The very complex nature of e-commerce deliveries and the fact that it is a relatively new phenomenon imply that neither the spatial distribution of B2C e-commerce nor its impacts on the society are fully understood.

The aim of this paper is threefold. Firstly, we shed light onto the spatial distribution of the demand of B2C deliveries by exploring where in Belgium the deliveries occur. Secondly, we propose a methodology to estimate the share of each region in the total amount of travelled kilometres to deliver B2C e-commerce goods. Finally, we quantify the negative impacts of the transport used to deliver in the last mile.

The analysis is performed based on data from a parcel delivery company in Belgium who will remain anonymous for privacy issues. Based on the data, we derive the number of vehicle-kilometres needed to deliver e-commerce goods. Moreover, values for external costs are assigned based on the total travelling distance and depending on the morphological characteristics of the regions. Because of the high urbanization present in the country, is important to distinguish between rural, semi-urban and urban areas and weight the impacts on these different types of areas.

This paper is organised as follows. Section 2 introduces the methodology, available data and the different parameters. Next, the approach used to derive the total vehicle kilometres travelled (VKT) from the original dataset as well as the external costs included in the externalities index are elaborated. Section 3 presents the results and discusses the key findings of the study and the externality index based on the calculation of external costs. Finally, Section 4 concludes on the research, and identifies directions for further research.

2. Data and Methodology

2.1. Data Source

To estimate the impacts of B2C e-commerce transport for Belgium, we face the challenge of estimating the routes used for delivering (Gonzalez-Feliu et al. 2012). Since this information is not easily available, those trips were estimated based on the location of parcel deliveries. The data used in this paper corresponds to the B2C deliveries at address level performed by a logistics carrier in a four-month time window in 2015 in Belgium. For each delivery address, the number of deliveries is known. In total, 1,143 parcels were delivered during this period. The data is assumed to cover a share of about 10% of the total delivery market. A spatial bias could nevertheless exist because of regional differences in e-commerce behaviour and, therefore, logistics carriers. Due to the unavailability of information from other logistics carriers, we consider the available data as a proxy for the total Belgian population.

Predicting where the deliveries occur imposes some difficulties. The demand for B2C e-commerce is not spatially contiguous and depends on socio-economic characteristics such as age, income etc.(Clarke et al. 2015), two alternatives can be chosen to determine the destination of deliveries. One alternative is identifying the role played by socio-economic characteristics and indirectly predicting where the destination of the parcels is. The problem with this method is that in addition to the normal uncertainty in the predictions, many e-commerce deliveries do not occur at the home address (Gardrat et al. 2016). In Belgium, around 30 per cent of deliveries occur in a different location than where the customer lives (Comeos 2014). This percentage is even higher in other countries (Morganti, Seidel, et al. 2014; Morganti, Dablanc, et al. 2014). A second alternative is therefore to directly use data from the deliveries executed by the carriers. This data provides a unique insight into the spatial pattern of deliveries.

The data is aggregated to the level of zip code. Therefore, the country is divided into 1,153 spatial units with an average area of 26.8 km². The costs of external impacts will be calculated at this scale. For refinement of the external cost parameters, we attach the geographical morphology to each zip code based on the definition by Luyten and Van Hecke (2007). The authors identify Belgium's main urban agglomerations based on population density. These agglomerations, together with the functionally related suburban areas, form a city region. To ease international comparisons, these city regions are identified as urban regions. The communities surrounding these city regions, but tightly linked due to commuting flows, are classified as semi-urban. The remaining areas fall under the rural category.

2.2. Methodology

In this paper, we assess the external costs of e-commerce deliveries. The main objective of the external costs calculation is to reveal the hidden costs in the cost structure of the market. By monetizing the different impacts of transport, we can assess the external costs as a transversal indicator of the negative impacts of transport. Through the calculation of the impacts, we are able to weigh properly the number of total vehicle-kilometres travelled in rural, semi-urban or urban areas. Moreover, this allows developing a sustainability index for the entire country.

Because of the wide range of transportation impacts, various external cost calculations can be identified in the literature (Durand & Gonzalez-Feliu 2012; Edwards et al. 2010; Collins 2015). The common denominator amongst them is calculating the total VKT since more kilometres almost always imply more externalities. However, VKT can bring more or less externalities, depending on the population density of the area where they occur. For this reason, we try to consider this effect by not only calculating the VKT but by weighting them based on the affected area. In this section, we therefore firstly present the framework depicted in **Figure 1** to calculate a cost index per parcel for different areas in Belgium.

2.2.1. Parameter Inputs

In the first stage, parameters form the characteristics of the vehicles are obtained via the logistics companies, mainly the capacity and the average duration of the tours. The capacity is fixed at 100 parcels per van per day, which is an appropriate estimation from daily operations of the company. Next, the distribution centres were located. While the location of distribution centres from the carrier is known, in order to not disclose the data provider indirectly and to broaden the generalisation of the analysis, distribution centres are assumed to be located in the centroid of regions similar to the distribution zones used in practice by various logistics carriers. Seven distribution centres are assumed to perform the delivery process in Belgium; this assumption is based on the current networks of different carriers. Finally, the addresses in the dataset were geo-located and a aggregated number of deliveries per zip code was obtained. Based on this, an expected number of deliveries per day was averaged.

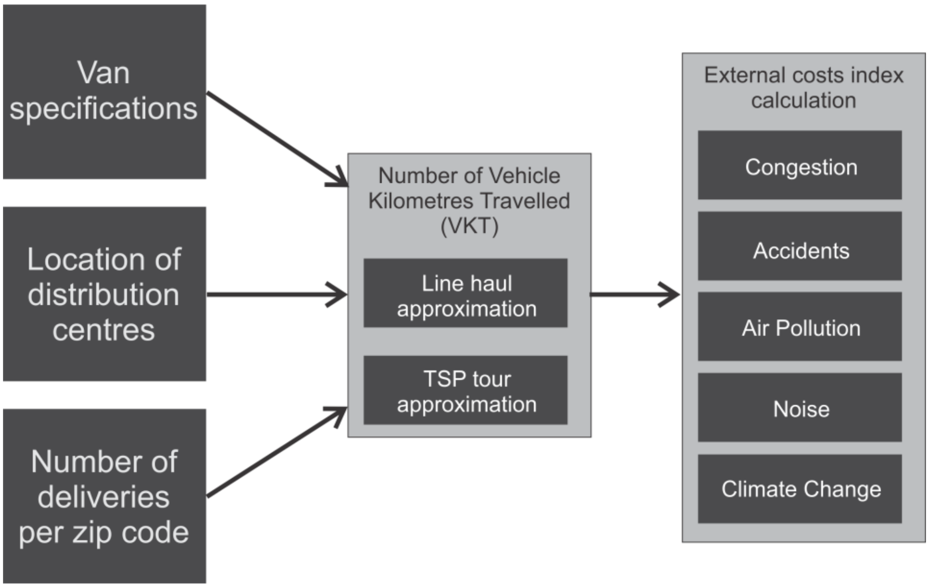

Figure 1. External costs index calculation framework
Source: Own Elaboration

2.2.2. Calculation of total vehicle-kilometres travelled

The purpose of this estimation is to distinguish among the travelled distances from delivery vehicles in rural and urban regions at the zip code level. The total distance to deliver parcels consists of two components: one is the distance from the depot to the customers, known as line-haul. This part of the tour is traditionally dealt with by the capacitated vehicle routing problem (CVRP). The other part is related to the distance between customers, which is traditionally related to the travelling salesman problem (TSP).

However, to estimate the distances over the entire study area, we opt for an aggregated distance estimation instead of simulating the actual routes. For this purpose, Daganzo (Daganzo 1984) proposes the following intuitive formula for calculating the length of the line-haul when the distribution centre is located outside of the customers' area:

$$d_{lh} = \frac{2rn}{Q} \tag{1}$$

Where
r = the distance between the distribution centre and the area
n = the number of customers to be served
Q = the capacity of each delivery van.

The number of vans is then represented by $\frac{n}{Q}$. Note that this expression is not necessarily an integer and $\left\lceil\frac{n}{Q}\right\rceil$ would be the correct expression. However, the aggregate number will be a close approximation to account for the total kilometres in the long run.

For the second component, approximations for the TSP can be found in (Beardwood et al. 1959). The authors demonstrate that the distance to travel between a set of points n in area A converges to $k\sqrt{nA}$, where A is the area containing the customers expressed in square kilometres. The constant term has been estimated at $k = 0.765$, assuming compact and convex shapes for the areas where the tour is circumscribed (Stein 1978; Figliozzi 2009).

2.2.3. Calculation of external costs

Several types of external costs can be distinguished among in the literature. However, the figures proposed by the authors differ significantly. The variations in the factors are caused by differences in methodology and input values. In the following sub-sections, we discuss the selection of values to be used in this calculation. We chose to include the external effects of congestion, accidents, air pollution and noise, since the scientific discussion around those costs is in a later stage providing better figures for using in this analysis.

2.2.3.1. Congestion Costs

Congestion costs represent the decrease in speed caused by every additional vehicle using the road (Blauwens et al. 2014). In general, the calculation of these costs is done based on the characteristics of the road, the value of time for users of the road, and the relation between the number of cars and the changes of their speed. Since these characteristics are specific for every road, Delhaye, De Ceuster, & Marivoet (2012) developed a cost calculation distinguishing among four different types of roads in Belgium.

The authors also distinguish among peak and non-peak periods, since the marginal impact by a single car will differ between these periods. Certainly, more detailed data is needed to capture the driving patterns of each van. When inquired about this topic, different carriers agreed that delivery routes start early in the morning, and resultantly high congestion is encountered in the line-haul. The delivery tours take place in off-peak periods during the day. This assumption is a major limitation on this study and should be addressed with detailed information on the average route timing and average speed statistics for the route.

2.2.3.2. Accident Costs

Accident costs account for the risks that society bears when a vehicle is travelling. The most widely used methodology is proposed by Lindberg (2006). The authors define the marginal costs of accidents according to equation (2).

$$MCA = r(a + b)(1 - \theta + E) + rc(1 + E) \quad (2)$$

In Equation (2), three different cost components can be discerned: the costs for the person exposed to the risk (a), the costs for the relatives and friends of the person exposed to the risk (b) and the costs for society such as police, medical and output losses costs (c). The term r considers the risk of a given vehicle to be involved in an accident calculated as the ratio between the number of accidents involving that vehicle and the number of VKT of that type of vehicle. The elasticity of the risk E estimates how much an increase in VKT will increase the risk. Finally, the parameter θ calculates which share of these costs are already internalised by the insurance. Delhaye et al. (2012) estimates the risk of accidents for vans in Belgium based on statistics of the BIVV (2010). The authors assumed an elasticity of risk of -0.25 and an internalisation ratio of 0.22 based on the calculations from (Lindberg 2006).

2.2.3.3. Air Pollution

Air pollution from freight transport activities is a major concern for society. Four types of pollutants can be distinguished among as the most harmful: particulate matter (PM), nitrogen oxides (NOx), sulphur dioxides (SO_2), and the toxic volatile organic compounds (VOC) (Korzhenevych et al. 2014). A number of studies have addressed the composition, emission, and dispersion of these particles; however, attempting to monetize the damage made by these emissions remains a challenge (Blauwens et al. 2014).

Costs for the different types of particles in euros per tonne are investigated by the NEEDS project (Preiss & Klotz 2008). As such, they include a larger number of countries in Europe and consider not only health effects but impacts on crops, biodiversity, and other materials as well. An important cost differentiator among countries is the density of the population since it means a different degree of exposure to the contaminants. Finally, to find unit costs, these values are combined with the typical emissions produced by a van. In this model, we use the values proposed by Korzhenevych et al. (2014). As for the calculations, we assume a standard diesel Euro V light goods vehicle and, as before, we differentiate based on the characteristics of the area (urban/semi-urban/rural) and assume motorways for the line haul.

2.2.3.4. Noise

Typically, noise costs represent the annoyance and, in situations where it exceeds 60dB, health damage for the people exposed to it (van Essen et al. 2011). In contrast to air pollution, limited research has been conducted on this subject. Even more, data about noise levels is also scarce, with most modelling efforts based on the NOISE database, which is built based on the statistics reported by European Member States. The total noise costs are calculated by multiplying the number of people exposed to noise by the costs per person. While values for this cost are not easily obtained, Delhaye et al. (2012) suggests 10 euros per person. Finally, the costs are assigned to the different modes of transport based on the share of the modes and assigning a weighting value proposed by van Essen et al. (van Essen et al. 2011).

2.2.3.5. Climate Change

The climate change costs represent the damage caused by greenhouse gas (GHG) emissions. In Europe, 23.2% of the GHG emissions were caused by the transport sector (European Commission 2016). Two different approaches can be used to estimate those costs. One is by calculating the total damage costs caused by the emissions, while the other is calculating the necessary costs to achieve a given reduction level. The problem with the former is that the effects of climate change remain unknown, like the effect of other initiatives to tackle the problem. The second approach, known as avoidance costs, aims at determining the least cost option to achieve a given climate change reduction goal (van Essen et al. 2011). Since these goals already exist, it is more practical to estimate the latter costs.

The estimation of the avoidance costs allows setting a "carbon price" (CO_2-equivalent). Once the carbon price is acknowledged for, similar calculations as for air pollution render the costs for the main pollutants (i.e. CO_2, CH_4 and N_2O). We use the values proposed by van Essen et al. (van Essen et al. 2011) using the central value of 90 euro / ton proposed by (Korzhenevych et al. 2014) based on the current goal required to stabilise the global warming at 2°C.

2.2.3.6. Other costs not included

It is worth mentioning that a number of external costs were not taken into consideration in this analysis. The up- and downstream processes and the costs to the infrastructure (Korzhenevych et al. 2014), the lack of benefits from active modes (Delhaye et al. 2012), the scarcity of space, the contamination of water and soil or the energy dependence costs (van Essen et al. 2011) are topics that are still in an early stage of research. For this reason, the absolute number of the total external costs can vary significantly from one study to the other.

2.2.4. External cost per delivery index

To analyse how the last mile of e-commerce deliveries impacts on the environment, we propose an index representing the average external cost to deliver a parcel in each zip code. Different characteristics, such as the density of inhabitants, the number of goods demanded and area's morphology, are considered when calculating the costs. The index corresponds to:

$$\frac{ec_m VKT_i}{n_i} \quad (3)$$

Where ec_m is an external costs coefficient based on the different costs for the each morphology m (i,e, urban, sub-urban or rural), VKT_i the number of kilometres travelled in the i-th zip code by the delivery van(s). The total costs of the tour are averaged by dividing by the number of stops/deliveries on each tour (assuming a delivery/stop ratio of 1:1).

3. Results and discussion

This section subsequently deals with the spatial distribution of B2C e-commerce deliveries, the VKT, and the externalities of B2C e-commerce transport, by applying the equations and using the data from section 2.

3.1. Spatial distribution of deliveries

Figure 2 displays the spatial distribution of the B2C e-commerce deliveries. At first glance, these deliveries seem to be concentrated in urban areas. As expected, the number of deliveries per zip code is highly correlated with the population per zip code. In fact, both variables show a correlation factor of 0.808.

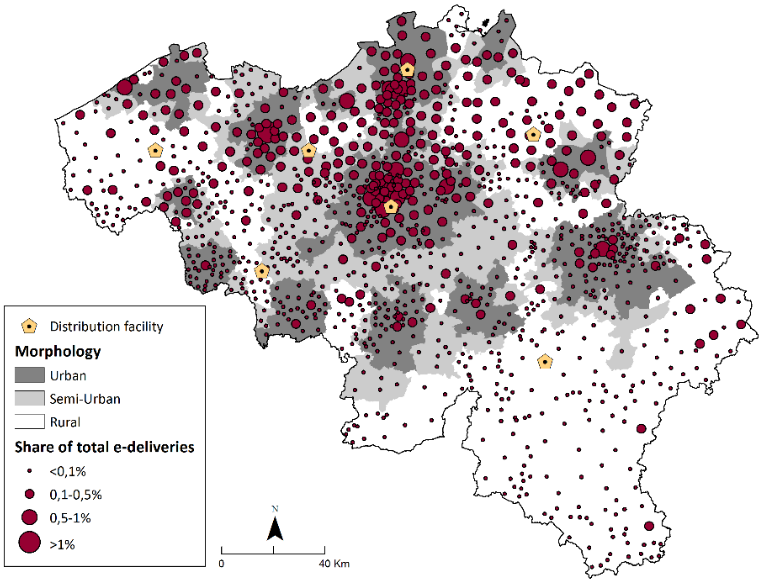

Figure 2. Spatial distribution of deliveries and location of simulated distribution centres

Source: Own Elaboration

Table 1 summarises the densities of population and deliveries according to the different morphological characteristics. Densities per square kilometre were calculated instead of absolute values to avoid the modifiable areal unit problem (MAUP) (Openshaw 1984). Note as well that these values correspond to the owner of the data and therefore reflect its market share. By comparing these values, it can be seen that the average urban delivery density is double that of the rural one.

Table 1. Densities of population and deliveries per square kilometre.

	Average population density (habitant/sq.-km)	Average delivery density per day (deliveries-day/sq.-km)	Average daily deliveries per capita (deliveries-day/ thousand habitants)
Urban	1299.17	0.43	0.33
Semi-urban	345.19	0.25	0.72
Rural	219.59	0.20	0.91

Source: Authors' elaboration

However, some question may arise. The nationwide share of urban deliveries is 56%, whereas urban areas are populated by 76% of the population. In **Table 1**, the calculation of deliveries per capita is also shown. This value indicates that while more deliveries flow to urban areas, it is only a consequence of more people living in urban areas since rural areas are characterised by a higher number of deliveries per capita. This evidence is in line with the observations of other authors such as Clarke (Clarke et al. 2015), who found high e-commerce usage in rural areas of the UK.

3.2. Vehicle kilometres travelled (VKT)

This section analyses the spatial distribution of the VKT. Two different scenarios can be expected a priori. One is that the urban deliveries may cause more VKT, because their higher amount. On the other hand, rural deliveries are more scattered and further from the distribution centres, causing a higher number of VKT as well. As mentioned, we decompose the total VKT in two different components. The first is a line-haul which is the leg from the distribution centre to the zip code. The second is a tour, which is the loop between customers.

The line haul results in **Table 2** show that the number of VKT in this leg of transport is significantly higher for the combined urban deliveries. One of the reasons behind this may be that the higher demand results in a higher number of vehicles, increasing the VKT.

Table 2. Line-haul VKT estimation

	Total VKT (km)	% of total
Urban	552.36	43%
Semi-urban	284.62	22%
Rural	432.86	34%

Source: Authors' elaboration

Another finding is that the regions with higher VKT are located in the east of the country (i.e. the border with Germany and Luxembourg). The number of VKT in these regions can be biased by the selection of the distribution centres. It is also relevant to note that for this reason, some companies may deliver to these regions from the neighbouring countries, which is not taken into account in our analysis.

The results of the VKT in the delivery tours are shown in **Table 3**. Higher distances for the rural tours were found, despite the many stops in urban areas. This is the result of the combination of a high demand but rather low density in rural areas, due to the large distances between addresses. The total distance of the rural tours thus outweighs the total distance of the shorter but more frequent urban delivery tours.

Table 3. Delivery tour VKT estimation

	Total VKT (km)	% of total
Urban	2327.64	36%

Semi-urban	1627.83	25%
Rural	2473.92	38%

Source: Authors' elaboration

The VKT of delivery tours largely exceed the VKT of the line-haul. In fact, for urban deliveries, the delivery tour represents around 80% of the total VKT. For semi-urban and rural deliveries, the share of the delivery tours reaches on average 85% of the total VKT. This only proves again the importance of the last mile, and how resource-demanding the final leg of transport is.

Finally, **Table 4** summarises the total VKT to deliver B2C e-commerce goods in the different regions of Belgium. The results show that there is almost no distinction between urban and rural VKT. A number of factors were considered in this analysis and both increasing and decreasing factors were encountered in urban and rural areas.

Table 4. Total VKT estimation

	Total VKT (km)	% of total
Urban	2880.00	37%
Semi-urban	1912.45	25%
Rural	2906.78	38%

Source: Authors' elaboration

As intended form the beginning of this paper, the VKT itself only measures the distance travelled but the main concern lies on the negative impacts of transport. The next sub-section therefore checks how these impacts are different among urban and non-urban areas.

3.3. Impact of B2C e-commerce transport on externalities

As shown in previous sub-sections, urban agglomerations attract the majority of deliveries, and therefore, it would be plausible to infer that higher negative impacts from transportation occur in those areas. However, during these analyses, we included additional considerations resulting in an indication that e-commerce deliveries are not limited to urban areas but are dispersed around the country, resulting in an equal share of VKTs for urban and rural deliveries.

In this last step of the analysis, we construct an index to quantify the negative impacts in each zip code. This index represents the external cost per delivery of the data provider, per zip code. The results of this index are shown in Figure 3. The map shows that the negative impacts of e-commerce deliveries surprisingly tend to be more significant in the southern part of the country, which have a lower density of inhabitants.

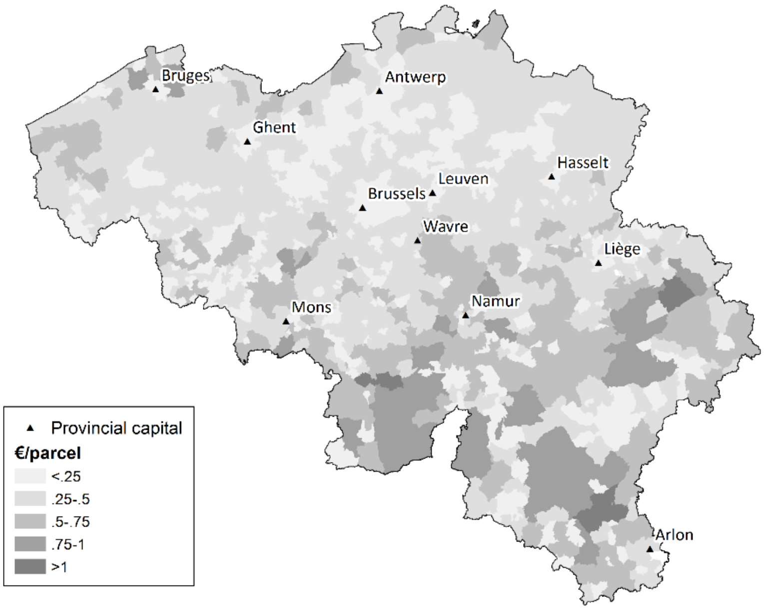

Figure 3. Total external costs of e-commerce per parcel delivered
Source: Authors' elaboration

If we assign a cost factor to represent the external costs based on the morphology of the different regions, the results indicate that the relative shares change considerably compared to when we consider VKT alone. Table 5 shows that the urban areas account for 50% of the total external costs caused by the deliveries of B2C e-commerce. The average costs per parcel and the share of the total external costs for each type of morphology indicate that, at least in terms of external costs, due to the economies of scale, the burden of delivering a parcel is higher in rural areas than in urban areas. These results can be useful for decision makers to estimate the negative impacts caused by a single delivery and to know where to focus the efforts to reduce negative impacts.

Table 5. External costs estimation

	Average cost per parcel (Euro/parcel)	Share of total costs
Urban	0.26	50.07%
Semi-urban	0.33	20.39%
Rural	0.37	29.54%

Source: Authors' elaboration*

4. Conclusions and further research

In this paper, data from B2C e-commerce deliveries in Belgium are examined to estimate the negative impacts of transporting those goods. We develop an external costs index to check the relation of externalities caused by the transport used to deliver e-commerce goods and the places where those deliveries occur. The geographical analysis of our data shows that urban areas still absorb most of the e-commerce freight transport. More than half (56%) of the total deliveries in the country occur in urban areas and, according to our estimations, 50.07% of the total external costs derived from e-commerce for the country arise in urban areas. Therefore, the analysis shows that, at an aggregated level, urban areas are the most problematic place, in terms of external costs for e-commerce deliveries. Besides the exception of some border areas, most regions with a high sum of external costs are located near the largest cities.

Our results also show that the e-commerce consumption per capita is higher in rural areas. In other words, people living outside the city buy more online. At the same time, the total VKT in rural areas are comparable with urban ones, contrasting the hypothesis that rural areas will have considerably more kilometres due to their peripheral location. However, urban areas can also contribute to the VKT due to higher volumes and especially when they are not close to the distribution centres.

Finally, according to the index proposed in this paper, the higher external costs per stop occur in rural areas (Table 5). This result reveals that even when the external costs per kilometre are lower in rural areas, the amount of VKT in rural areas, due the low density, will cause a higher negative effect. It is important to note the evolution of the spatial distribution of e-commerce deliveries since greater imbalances between urban and rural deliveries may shift the majority of the impacts to the latter regions.

The results from this paper contribute to raising the awareness of managing the negative impacts of e-commerce logistics in urban and rural areas. Decision makers need to be aware of the importance of urban areas for both logistics carriers and population. The results of this analysis contribute to the assessment of different practices aiming at a more sustainable/efficient organisation of logistics in cities. The results also give an indication, based on the hypothetical growth of rural deliveries (Clarke et al. 2015), on how the impacts of rural deliveries will evolve in the future.

For business practice, the findings in this paper show potentials to reduce negative externalities of e-commerce goods transport. The evidence from this paper show that the majority of negative externalities are taking place in urban areas. Specifically in the last mile which is average, according to our results, 83.6% of the total VKT of a tour. Nonetheless, the urban last mile also offers the possibility of aggregating and consolidating demand via alternatives such as delivery or pick-up points reducing in this way the total VKT. To this end, the composition and current practices of the market seem to merit special attention, because the high pressure on delivery costs the market is experiencing.

To estimate the externality impacts, we followed a bottom-up approach based on distance approximations at a zip code level. This can be a more efficient alternative to estimate the length of tours when only the origin and destinations are available. We also discussed the selection of the external cost factors to be used. Significant research must be undertaken to have a "standard" source of external costs for transport. Another interesting question remains about the mismatch between the deliveries and the current customers. If customers receive their parcels at work or at a delivery point, the deliveries will not follow the demographics. This may result in an even larger share of the deliveries going to the urban areas as attractors of additional e-commerce deliveries demand.

Limitations of this research should be addressed in future academic exercises. The discrepancies between the distance approximations used in this paper and the real distances travelled should be further investigated. Assumptions on the congestion levels can significantly affect the external costs factor; data from traffic at both, regional and local level is needed to overcome this limitation. At the same time, a higher level of detail can be achieved by selecting a smaller spatial unit of analysis than the zip code level. The coupling with analysing alternatives for delivery such as reception at proximity points (Gonzalez-Feliu et al. 2012; Durand & Gonzalez-Feliu 2012), bike deliveries (Anderluh et al. 2016; Maes & Vanelslander 2012; Schliwa et al. 2015), off-hour deliveries (Holguín-Veras et al. 2005; Li 2015; Holguín-Veras et al. 2014), or electric vans (Margaritis et al. 2016; Roumboutsos et al. 2014) would provide more insights for managing e-commerce logistics in cities.

References

Anderluh, A., Hemmelmayr, V.C. & Nolz, P.C., 2016. *Synchronizing vans and cargo bikes in a city distribution network*, Springer Berlin Heidelberg.

Beardwood, J., Halton, J.H. & Hammersley, J.M., 1959. The shortest path through many points. *Mathematical Proceedings of the Cambridge Philosophical Society*, 55(4), p.299.

BIVV, 2010. *BIVV Observatorium voor de Verkeersveiligheid*,

Blauwens, G., De Baere, P. & Van de Voorde, E., 2014. *Transport Economics* 5th ed., Antwerp: De Boeck.

Boschma, R.A. & Weltevreden, J.W.J., 2008. An evolutionary perspective on Internet adoption by retailers in the Netherlands. *Environment and Planning A*, 40(9), pp.2222–2237.

Boyer, K.K., Prud 'homme, A.M. & Chung, W., 2009. the Last Mile Challenge: Evaluating the Effects of Customer Density and Delivery Window Patterns. , 30(1), pp.185–202.

Clarke, G., Thompson, C. & Birkin, M., 2015. The emerging geography of e-commerce in British retailing. *Regional Studies, Regional Science*, 2(1), pp.370–390.

Collins, A.T., 2015. Behavioral Influences on the Environmental Impact of Collection/Delivery Points. In B. Fahimnia et al., eds. *Green Logistics and Transportation*. Springer International Publishing, pp. 15–34.

Comeos, 2014. E-commerce Belgium. , pp.4–94.

Copenhagen Economics, 2013. *E-commerce and delivery*,

Dablanc, L. & Rakotonarivo, D., 2010. The impacts of logistics sprawl: How does the location of parcel transport terminals affect the energy efficiency of goods' movements in Paris and what can we do about it? *Procedia - Social and Behavioral Sciences*, 2(3), pp.6087–6096.

Daganzo, C.F., 1984. The Distance Traveled to Visit N Points with a Maximum of C Stops per Vehicle: An Analytic Model and an Application. *Transportation Science*, 18(4), pp.331–350.

Delhaye, E., Griet, D. & Sven, M., 2012. *Internalisering van externe kosten van transport in Vlaanderen*,

Durand, B. & Gonzalez-Feliu, J., 2012. Urban Logistics and E-Grocery: Have Proximity Delivery Services a Positive Impact on Shopping Trips? *Procedia - Social and Behavioral Sciences*, 39, pp.510–520.

Edwards, J.B., McKinnon, A.C. & Cullinane, S.L., 2010. Comparative analysis of the carbon footprints of conventional and online retailing: A "last mile" perspective. *International Journal of Physical Distribution & Logistics Management*, 40(1/2), pp.103–123.

van Essen, H. et al., 2011. External Costs of Transport in Europe Update Study for 2008. *CE Delft, INFRAS, Fraunhofer ISI*, (September), p.161.

European Commission, 2013. *COMMUNICATION FROM THE COMMISSION A roadmap for completing the single market for parcel delivery Build trust in delivery services and encourage online sales /* COM/2013/0886 final */*,

Fernie, J., Sparks, L. & McKinnon, A.C., 2010. Retail logistics in the UK: past, present and future. *International Journal of Retail & Distribution Management*, 38(11/12), pp.894–914.

Figliozzi, M.A., 2009. Planning Approximations to the Average Length of Vehicle Routing Problems with Varying Customer Demands and Routing Constraints. *Transportation Research Record: Journal of the Transportation Research Board*, 2089(1), pp.1–8.

FTI Consulting, 2011. *Intra-community cross-border parcel delivery*, London, UK.

Gardrat, M. et al., 2016. How can the impact of new practices for supplying households be quantified in urban goods movements ? In *ILS 2016, 6th International Conference on Information Systems, Logistics and Supply Chain*. pp. 1–9.

Gevaers, R., Van de Voorde, E. & Vanelslander, T., 2014. Cost Modelling and Simulation of Last-mile Characteristics in an Innovative B2C Supply Chain Environment with Implications on Urban Areas and Cities. *Procedia - Social and Behavioral Sciences*, 125, pp.398–411.

Gonzalez-Feliu, J., Ambrosini, C. & Routhier, J.L., 2012. New trends on urban goods movement: Modelling and simulation of e-commerce distribution. *European Transport - Trasporti Europei*, (50).

Holguín-Veras, J. et al., 2005. Off-Peak Freight Deliveries: Challenges and Stakeholders' Perceptions. *Transportation Research Record*, 1906(212), pp.42–48.

Holguín-Veras, J. et al., 2014. The New York City Off-hour Delivery Project: Lessons for City Logistics. *Procedia - Social and Behavioral Sciences*, 125, pp.36–48.

Holguín-Veras, J., Thorson, E. & Zorrilla, J.C., 2008. Commercial Vehicle Empty Trip Models With Variable Zero Order Empty Trip Probabilities. *Networks and Spatial Economics*, 10(2), pp.241–259.

Korzhenevych, A. et al., 2014. *Update of the Handbook on External Costs of Transport*,

Li, Z.A.N., 2015. The E ciency of O -peak Deliveries in Stockholm City The Efficiency of Off-peak Deliveries.

Lindberg, G., 2006. *Marginal cost case studies for road and rail transport Deliverable D 3, GRACE*, Leeds.

Luyten, S. & Van Hecke, E., 2007. *De Belgische stadsgewesten 2001*,

Maes, J. & Vanelslander, T., 2012. The Use of Bicycle Messengers in the Logistics Chain, Concepts Further Revised. *Procedia - Social and Behavioral Sciences*, 39, pp.409–423.

Margaritis, D. et al., 2016. Electric commercial vehicles: Practical perspectives and future research directions. *Research in Transportation Business and Management*, 18, pp.4–10.

Morganti, E., Seidel, S., et al., 2014. The impact of e-commerce on final deliveries: alternative parcel delivery services in France and Germany. In *International Scientific Conference on Mobility and Transport*.

Morganti, E., Dablanc, L. & Fortin, F., 2014. Final deliveries for online shopping: The deployment of pickup point networks in urban and suburban areas. *Research in Transportation Business & Management*, 11(February 2012), pp.23–31.

Openshaw, S., 1984. *The modifiable areal unit problem*, Norwich.

Pitney Bowes, 2016. Parcel Shipping Index.

Roumboutsos, A., Kapros, S. & Vanelslander, T., 2014. Green city logistics: Systems of Innovation to assess the potential of E-vehicles. *Research in Transportation Business & Management*, 11, pp.43–52.

Schliwa, G. et al., 2015. Sustainable city logistics — Making cargo cycles viable for urban freight transport. *Research in Transportation Business & Management*, 15, pp.50–57.

Stein, D.M.., 1978. An Asymptotic , Probabilistic Analysis of a Routing Problem. *Mathematics of Operation Research*, 3(2), pp.89–101.

Taniguchi, E. & Kakimoto, Y., 2004. Modelling effects of e-commerce on urban freight transport. In E. Taniguchi & R. G. Thompson, eds. *Logistics Systems for Suistanable Cities*. Elsevier, pp. 135–146.

Weltevreden, J.W.J. & Rotem-Mindali, O., 2009. Mobility effects of b2c and c2c e-commerce in the Netherlands: a quantitative assessment. *Journal of Transport Geography*, 17(2), pp.83–92.

Zito, P. et al., 2013. *Framework for Assessing Indicators of Environmental Impacts in the Transport Sector*,