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

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

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

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

20 **1. Introduction**

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

33 B2C e-commerce implies individual shipments, resulting in an increasing number of
34 trips and kilometres (Taniguchi & Kakimoto 2004). The B2C channel represents around
35 30% of the e-commerce turnover (FTI Consulting 2011), and it generates 56% of all
36 the e-commerce shipments (Copenhagen Economics 2013). While there is no general
37 acknowledgement, estimates indicate that the volume of shipping worldwide is close to
38 31 billion parcels per year (Pitney Bowes 2016).

39 The negative impact of B2C e-commerce last-mile have raised interest from urban
40 logistics researchers, transport and retail geographers as well as practitioners and public
41 decision makers (Weltevreden & Rotem-Mindali 2009). The relevance of this

42 discussion is that delivering the last mile is a trade-off between internal costs,
43 externalities and the density of the deliveries. On the one hand, customer density is
44 essential for achieving efficiency in the last-mile. Therefore, rural deliveries can be
45 three times more expensive than urban ones (Boyer et al. 2009; Gevaers et al. 2014). In
46 the urban areas, the density is higher and logistics carriers benefit from lower costs.
47 However, the residents undergo more negative impacts such as congestion, noise, and
48 emissions than rural areas (Zito et al. 2013; Holguín-Veras et al. 2008). At the end, the
49 various stakeholders have to manage different externalities in different regions, which
50 underlines the difficulties associated to the last mile.

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

59 Linked with this discussion is the observation that while urban areas are more
60 sensitive to the negative impacts of transport, spreading the externalities can result in
61 an even worse situation. For example, Dablanc & Rakotonarivo (2010) argue that the
62 CO₂ emissions are increasing dramatically because of the geographical dispersion of e-
63 commerce usage in Paris. The very complex nature of e-commerce deliveries and the
64 fact that it is a relatively new phenomenon imply that neither the spatial distribution of
65 B2C e-commerce nor its impacts on the society are fully understood.

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

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

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

85 2. Data and Methodology

86 2.1. Data Source

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

98
99 Predicting where the deliveries occur imposes some difficulties. The demand for B2C
100 e-commerce is not spatially contiguous and depends on socio-economic characteristics
101 such as age, income etc.(Clarke et al. 2015), two alternatives can be chosen to determine
102 the destination of deliveries. One alternative is identifying the role played by socio-
103 economic characteristics and indirectly predicting where the destination of the parcels
104 is. The problem with this method is that in addition to the normal uncertainty in the
105 predictions, many e-commerce deliveries do not occur at the home address (Gardrat et
106 al. 2016). In Belgium, around 30 per cent of deliveries occur in a different location than
107 where the customer lives (Comeos 2014). This percentage is even higher in other
108 countries (Morganti, Seidel, et al. 2014; Morganti, Dablanc, et al. 2014). A second
109 alternative is therefore to directly use data from the deliveries executed by the carriers.
110 This data provides a unique insight into the spatial pattern of deliveries.

111
112 The data is aggregated to the level of zip code. Therefore, the country is divided into
113 1,153 spatial units with an average area of 26.8 km². The costs of external impacts will
114 be calculated at this scale. For refinement of the external cost parameters, we attach the
115 geographical morphology to each zip code based on the definition by Luyten and Van
116 Hecke (2007). The authors identify Belgium's main urban agglomerations based on
117 population density. These agglomerations, together with the functionally related
118 suburban areas, form a city region. To ease international comparisons, these city
119 regions are identified as urban regions. The communities surrounding these city
120 regions, but tightly linked due to commuting flows, are classified as semi-urban. The
121 remaining areas fall under the rural category.

122

123 *2.2. Methodology*

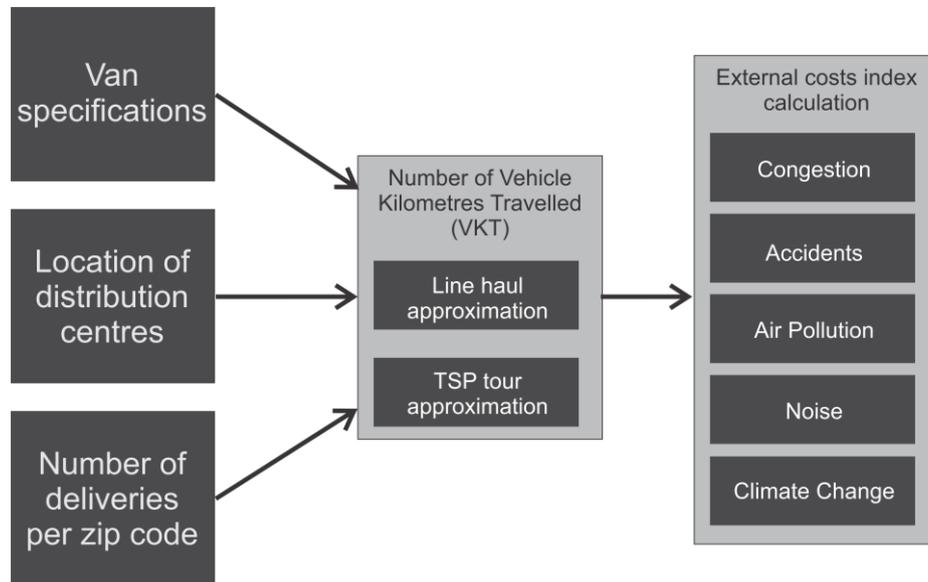
124 In this paper, we assess the external costs of e-commerce deliveries. The main objective
125 of the external costs calculation is to reveal the hidden costs in the cost structure of the
126 market. By monetizing the different impacts of transport, we can assess the external
127 costs as a transversal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

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

140 *2.2.1. Parameter Inputs*

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

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Figure 1. External costs index calculation framework

Source: Own Elaboration

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2.2.2. Calculation of total vehicle-kilometres travelled

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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).

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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:

172

$$d_{lh} = \frac{2rn}{Q} \quad (1)$$

173

Where

174

r = the distance between the distribution centre and the area

175

n = the number of customers to be served

176

Q = the capacity of each delivery van.

177

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

182
183 For the second component, approximations for the TSP can be found in (Beardwood
184 et al. 1959). The authors demonstrate that the distance to travel between a set of points
185 n in area A converges to $k\sqrt{nA}$, where A is the area containing the customers expressed
186 in square kilometres. The constant term has been estimated at $k = 0.765$, assuming
187 compact and convex shapes for the areas where the tour is circumscribed (Stein 1978;
188 Figliozzi 2009).

189 *2.2.3. Calculation of external costs*

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

197 *2.2.3.1. Congestion Costs*

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

205
206 The authors also distinguish among peak and non-peak periods, since the marginal
207 impact by a single car will differ between these periods. Certainly, more detailed data
208 is needed to capture the driving patterns of each van. When inquired about this topic,
209 different carriers agreed that delivery routes start early in the morning, and resultantly
210 high congestion is encountered in the line-haul. The delivery tours take place in off-
211 peak periods during the day. This assumption is a major limitation on this study and
212 should be addressed with detailed information on the average route timing and average
213 speed statistics for the route.

214

2.2.3.2. Accident Costs

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

218

$$219 \quad MCA = r(a + b)(1 - \theta + E) + rc(1 + E) \quad (2)$$

220

221 In Equation (2), three different cost components can be discerned: the costs for the
222 person exposed to the risk (a), the costs for the relatives and friends of the person
223 exposed to the risk (b) and the costs for society such as police, medical and output
224 losses costs (c). The term r considers the risk of a given vehicle to be involved in an
225 accident calculated as the ratio between the number of accidents involving that vehicle
226 and the number of VKT of that type of vehicle. The elasticity of the risk E estimates
227 how much an increase in VKT will increase the risk. Finally, the parameter θ calculates
228 which share of these costs are already internalised by the insurance. Delhayé et al.
229 (2012) estimates the risk of accidents for vans in Belgium based on statistics of the
230 BIVV (2010). The authors assumed an elasticity of risk of -0.25 and an internalisation
231 ratio of 0.22 based on the calculations from (Lindberg 2006).

232

2.2.3.3. Air Pollution

233

234 Air pollution from freight transport activities is a major concern for society. Four
235 types of pollutants can be distinguished among as the most harmful: particulate matter
236 (PM), nitrogen oxides (NO_x), sulphur dioxides (SO₂), and the toxic volatile organic
237 compounds (VOC) (Korzhenyevych et al. 2014). A number of studies have addressed
238 the composition, emission, and dispersion of these particles; however, attempting to
239 monetize the damage made by these emissions remains a challenge (Blauwens et al.
240 2014).

241

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

252

253

2.2.3.4. *Noise*

254 Typically, noise costs represent the annoyance and, in situations where it exceeds
255 60dB, health damage for the people exposed to it (van Essen et al. 2011). In contrast to
256 air pollution, limited research has been conducted on this subject. Even more, data
257 about noise levels is also scarce, with most modelling efforts based on the NOISE
258 database, which is built based on the statistics reported by European Member States.
259 The total noise costs are calculated by multiplying the number of people exposed to
260 noise by the costs per person. While values for this cost are not easily obtained, Delhaye
261 et al. (2012) suggests 10 euros per person. Finally, the costs are assigned to the different
262 modes of transport based on the share of the modes and assigning a weighting value
263 proposed by van Essen et al. (van Essen et al. 2011).

264

2.2.3.5. *Climate Change*

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

275

276 The estimation of the avoidance costs allows setting a “carbon price” (CO₂-
277 equivalent). Once the carbon price is acknowledged for, similar calculations as for air
278 pollution render the costs for the main pollutants (i.e. CO₂, CH₄ and N₂O). We use the
279 values proposed by van Essen et al. (van Essen et al. 2011) using the central value of
280 90 euro / ton proposed by (Korzhenevych et al. 2014) based on the current goal required
281 to stabilise the global warming at 2°C.

282

2.2.3.6. *Other costs not included*

283 It is worth mentioning that a number of external costs were not taken into
284 consideration in this analysis. The up- and downstream processes and the costs to the
285 infrastructure (Korzhenevych et al. 2014), the lack of benefits from active modes
286 (Delhaye et al. 2012), the scarcity of space, the contamination of water and soil or the
287 energy dependence costs (van Essen et al. 2011) are topics that are still in an early stage
288 of research. For this reason, the absolute number of the total external costs can vary
289 significantly from one study to the other.
290

291 *2.2.4. External cost per delivery index*

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

297
$$\frac{ec_m VKT_i}{n_i} \quad (3)$$

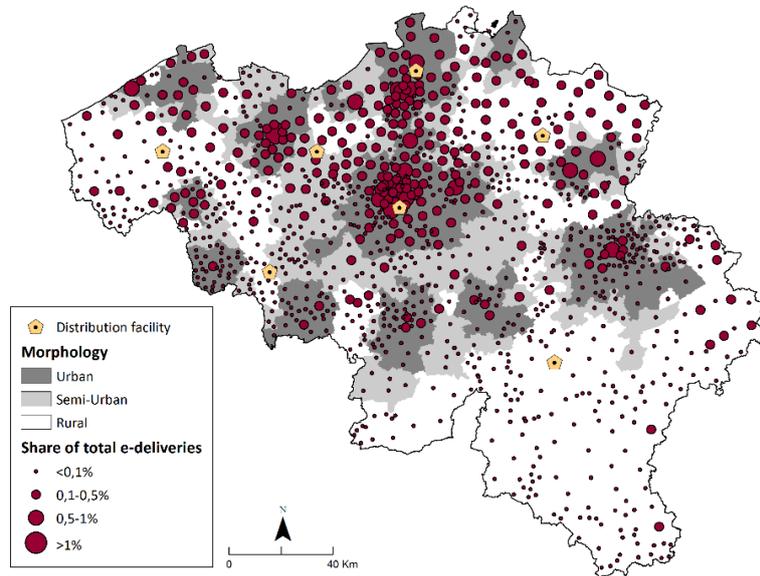
298 Where ec_m is an external costs coefficient based on the different costs for the each
299 morphology m (i.e, urban, sub-urban or rural), VKT_i the number of kilometres travelled
300 in the i -th zip code by the delivery van(s). The total costs of the tour are averaged by
301 dividing by the number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

303 **3. Results and discussion**

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

307 *3.1. Spatial distribution of deliveries*

308 Figure 2 displays the spatial distribution of the B2C e-commerce deliveries. At first
309 glance, these deliveries seem to be concentrated in urban areas. As expected, the
310 number of deliveries per zip code is highly correlated with the population per zip code.
311 In fact, both variables show a correlation factor of 0.808.
312



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314

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

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Source: Own Elaboration

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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.

325

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

326

Source: Authors' elaboration

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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

331 flow to urban areas, it is only a consequence of more people living in urban areas since
332 rural areas are characterised by a higher number of deliveries per capita. This evidence
333 is in line with the observations of other authors such as Clarke (Clarke et al. 2015), who
334 found high e-commerce usage in rural areas of the UK.

335 3.2. *Vehicle kilometres travelled (VKT)*

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

343
344 The line haul results in **Table 2** show that the number of VKT in this leg of transport
345 is significantly higher for the combined urban deliveries. One of the reasons behind this
346 may be that the higher demand results in a higher number of vehicles, increasing the
347 VKT.
348

349 **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

350
351
352 Another finding is that the regions with higher VKT are located in the east of the
353 country (i.e. the border with Germany and Luxembourg). The number of VKT in these
354 regions can be biased by the selection of the distribution centres. It is also relevant to
355 note that for this reason, some companies may deliver to these regions from the
356 neighbouring countries, which is not taken into account in our analysis.
357

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

363 **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

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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

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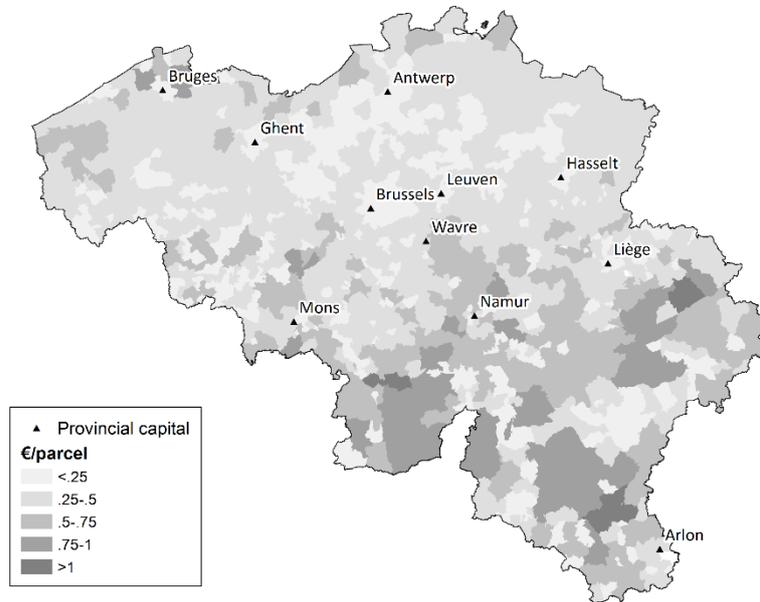
As intended from the beginning of this paper, the VKT itself only measures the distance travelled but the main concern lies on the negative impacts of transport. The next sub-section therefore checks how these impacts are different among urban and non-urban areas.

384 *3.3. Impact of B2C e-commerce transport on externalities*

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

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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.



399

400

Figure 3. Total external costs of e-commerce per parcel delivered

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Source: Authors' elaboration

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403

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.

411

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%

412

Source: Authors' elaboration*

414 4. Conclusions and further research

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

426
427 Our results also show that the e-commerce consumption per capita is higher in rural
428 areas. In other words, people living outside the city buy more online. At the same time,
429 the total VKT in rural areas are comparable with urban ones, contrasting the hypothesis
430 that rural areas will have considerably more kilometres due to their peripheral location.
431 However, urban areas can also contribute to the VKT due to higher volumes and
432 especially when they are not close to the distribution centres.

433
434 Finally, according to the index proposed in this paper, the higher external costs per
435 stop occur in rural areas (Table 5). This result reveals that even when the external costs
436 per kilometre are lower in rural areas, the amount of VKT in rural areas, due the low
437 density, will cause a higher negative effect. It is important to note the evolution of the
438 spatial distribution of e-commerce deliveries since greater imbalances between urban
439 and rural deliveries may shift the majority of the impacts to the latter regions.

440
441 The results from this paper contribute to raising the awareness of managing the
442 negative impacts of e-commerce logistics in urban and rural areas. Decision makers
443 need to be aware of the importance of urban areas for both logistics carriers and
444 population. The results of this analysis contribute to the assessment of different
445 practices aiming at a more sustainable/efficient organisation of logistics in cities. The
446 results also give an indication, based on the hypothetical growth of rural deliveries
447 (Clarke et al. 2015), on how the impacts of rural deliveries will evolve in the future.

448
449 For business practice, the findings in this paper show potentials to reduce negative
450 externalities of e-commerce goods transport. The evidence from this paper show that
451 the majority of negative externalities are taking place in urban areas. Specifically in the
452 last mile which is average, according to our results, 83.6% of the total VKT of a tour.
453 Nonetheless, the urban last mile also offers the possibility of aggregating and
454 consolidating demand via alternatives such as delivery or pick-up points reducing in
455 this way the total VKT. To this end, the composition and current practices of the market
456 seem to merit special attention, because the high pressure on delivery costs the market
457 is experiencing.

458

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

469
470 Limitations of this research should be addressed in future academic exercises. The
471 discrepancies between the distance approximations used in this paper and the real
472 distances travelled should be further investigated. Assumptions on the congestion levels
473 can significantly affect the external costs factor; data from traffic at both, regional and
474 local level is needed to overcome this limitation. At the same time, a higher level of
475 detail can be achieved by selecting a smaller spatial unit of analysis than the zip code
476 level. The coupling with analysing alternatives for delivery such as reception at
477 proximity points (Gonzalez-Feliu et al. 2012; Durand & Gonzalez-Feliu 2012), bike
478 deliveries (Anderluh et al. 2016; Maes & Vanelslander 2012; Schliwa et al. 2015), off-
479 hour deliveries (Holguín-Veras et al. 2005; Li 2015; Holguín-Veras et al. 2014), or
480 electric vans (Margaritis et al. 2016; Rouboutsos et al. 2014) would provide more
481 insights for managing e-commerce logistics in cities.

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