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DOI
10.1016/j.trpro.2016.02.026
Publication date
2016
Document Version
Final published version
Published in
Transportation Research Procedia
License
CC BY-NC-ND

Link to publication

Citation for published version (APA):
Spijkerman, R. (2016). Fashion consumer behaviour impact on the model of last mile urban area emissions. *Transportation Research Procedia*, *12*, 718-727. https://doi.org/10.1016/j.trpro.2016.02.026

Available online at www.sciencedirect.com
ScienceDirect
Transportation Research Procedia 12 (2016) 718 – 727
Transportation Research Procedia
www.elsevier.com/locate/procedia

The 9th International Conference on City Logistics, Tenerife, Canary Islands (Spain), 17-19 June 2015

Fashion consumer behaviour impact on the model of last mile urban area emissions

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Abstract

To enhance the validity of a mobility emission-effects model, a research is conducted on consumer behaviour. Consumer mobility preferences are the main determining factor in the proposed model that describes the kilometre and emission outcome under several scenarios. Motorized mobility of consumers buying fashion in shopping areas cause more kilometres in the network and subsequently more emission than when the fashion is bought online and the delivery is done by the parcel delivery services. The model provides an indication of best practice: if consumers change their shopping preferences they reduce emission and they also enable the PDSs to optimize their delivery operations.

Peer-review under responsibility of the organising committee of the 9th International Conference on City Logistics

Keywords: online; fashion; urban; parcel delivery services; emission model

1. Introduction

In the past two decades the growth of online shopping by consumers has led to a strong growth in the number of parcels shipped to consumer homes. This change is caused by new shopping patterns of consumers who buy goods online, which twenty years ago, would have been bought in shops. The percentage of online purchased articles ranges from 5% to 90%, depending on the type of article (Javelin Group, 2011, Cushman & Wakefield, 2013). This change has also led to a growth in parcels volume (Weltevreden and Rotem-Mindali, 2009, Ducret and DeLaitre 2013, Rotem-Mindali and Weltevreden 2013).

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Peer-review under responsibility of the organising committee of the 9th International Conference on City Logistics
doi:10.1016/j.trpro.2016.02.026

Cities experience traffic problems like congestion and pollution, such as CO_2, NO_x, PM_{10} and SO_2. In addition, motorized traffic of both the shopping public as well as parcel delivery services can cause dangerous situations and lethal accidents. In order to organize land use, transport routes and environment zones, policy makers in cities need specific information about mobility patterns in the towns. And, more precisely, information about mobility effects due to changes in consumer shopping patterns that change the kilometres travelled motorized. Parcel delivery services (PDSs) will benefit by optimizing their routes and enhancing the number of drops per stop. Using less fuel and less time for the process of delivery is beneficial for both the city environment and the efficiency of the PDS's (Weltevreden, 2008; Russo and Comi, 2012). The impact of the increase of online shopping on traffic by increasing home deliveries is unclear. Expectations range from less traffic due to a decrease of consumer shopping trips by car, to more traffic due to an increase of delivery trips by the PDSs.

2. Current state of the art

Dixon and Marston (2002) found that almost two thirds of the online buyers indicated that some or all of their online purchases replace an offline purchase in a town or city centre. This substitution effect is also partly expected in fashion purchasing, although researchers contradict in their conclusions about the substitution effect (Dixon and Marston, 2002, Krizek et al., 2005). Corpuz and Peachman (2003) suggested a substitution effect because 35% of their respondents would have made a physical shopping trip if they had not purchased their products online. Schellenberg, (2005) also found a substitution effect between online shopping and offline shopping, whereas Hernandez et al., (2001), Ferrel, (2004) and Farag et al. (2007) found a complementary effect. Moreover, approximately 45% of the substitution trips would have been made as a multiple purpose trip. Only 38% of all online purchases lead to a decrease in personal travel, 50% are multiple-purchase trips and 11% would have been undertaken when travelling from work to home (Esser and Kurte, 2005). Frequent online shoppers make as many trips to a physical store as infrequent online shoppers and the time saved from online shopping is spent on additional trips (Winslott Hiselius, Smidfelt Rosqvist and Adell, 2015). Functional motivated shoppers are often time pressured and therefore more inclined to shop online (Kaltcheva & Weitz, 2006, p. 112). The value of delivery time for a purchased book from an online bookstore to a consumer is approximately $0.53 per day, which means that a delivery delay can be expressed as an amount of money determining price differences between offline and online purchased products (Hsiao, 2009). But, according to Li, Kuo and Russell (1999) online buyers are not more price-sensitive than offline buyers.

Most simulations of mobility effects of online shopping lack the consumer behaviour parameters and are focused on either personal (consumer) travel changes or PDSs efficiency, but not both. (Barone, Crocco and Mongelli, 2014; Salomon, 1986; Visser. Nemoto and Browne, 2014). Research on car-free households suggests that taking goods from the shopping area back home is perceived "to be a major problem in everyday life" (Visser & Lanzendorf, 2003, p. 197). Visser. Nemoto and Browne, (2014, box 1, p.20) stated that "*The people in the Netherlands made approximately 3.4 billion trips to go shopping in 2011, 44.3 % of these were made by car.",* and estimated *"the total travel distance in 2011 for home delivery by vans on 670 million vehicle kilometres. The number of home deliveries is estimated on 100 million parcels in 2011 (based on OPTA, 2011). In case these 100 million deliveries substitute a movement to a shop, these 100 million (on 3.4 billion moves) represent 3% (in vehicle kilometres) of the total trips for shopping*."

Crocco, Eboli and Mazzulla (2013), found that online consumers tend to purchase computer hardware and software, while clothes are more purchased in-store. Even within one product group large differences exist. In fashion percentages between 10% and 40% of the total fashion purchases have been mentioned. Since fashion is a product group which, according to the consumers, is both a fun shopping experience (recreational motivation) as well as a need (functional motivation) (Mokhtarian, 2003), it is expected that consumers will show personnel strategies and choices in what to buy online. The product characteristics also influence consumer’s intentions to shop online (Lee, 2002). Fashion purchases are known to depend on the 'size fit' and the 'good looks', and therefore fashion consumers will have an ambiguous attitude towards buying online. Therefore, the fashion product group is well suited for a research of consumer preferences for online and offline shopping behaviour and mobility effects. Although the number of kilometres driven and the substitution effects are small as compared to total traffic movements, it is interesting to find out what the emissions are because environmental issues in dense population regions are at stake. Furthermore, since car use is often the best choice for offline purchases in the fashion product group, large emission effects are expected in urban areas when these purchases will instead be done online.

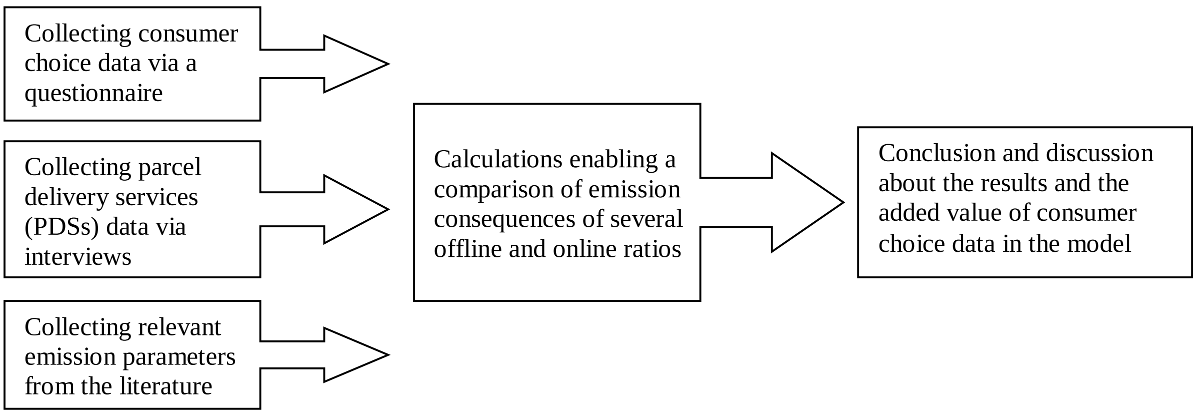
Only rough estimates were available to compare offline and online effects on the kilometres driven to deliver the fashion goods to the homes of the consumers (Spijkerman, 2013). A more precise estimation of the kilometres driven should be established in order to monitor mobility effects of online sales. Via simulations, with all main variables in the model, some progress is made in the validity of the models (Gonzalez-Feliu, Ambrosini & Routhier, 2012; Teo, Taniguchi and Qureshi 2012; Visser & Francke. 2013; Gevaers, VandeVoorde and Vanelslander 2014; Nuzzolo, Comi and Papa 2014; Taniguchi, Thompson and Yamada, 2014)). However, consumers' choices in terms of shopping trip modality have not been taken into account in these models.

To enhance the validity of our model of mobility effects of online shopping in the fashion industry, we tried to find a justification of parameter values by conducting an analysis on consumer preferences. Consumer preferences are the preference to shop either online or offline, and the preference for the modality to travel to the shopping area being by foot, by bike, by scooter, by public transport (bus) or by car.

Determining better estimates (uncertainty reduction) is meaningful for city municipal policy design, regulation, congestion and quality of life and for optimization of delivery by PDSs.

In this study, both consumer travel behaviour as well as PDS urban logistics will be taken into account to identify and evaluate the potential impacts of the increased use of home delivery on the sustainability of cities. The main goal of this study is to test if the growth of online shopping leads to a growth or a reduction in the amount of kilometres, with regard to emission. Following Barone, Crocco and Mongelli (2014), the end user is in the role of the decision-maker in the last-mile. The question raised here is: How far does the last-mile freight transport substitutes for consumer shopping trips? The answer on this question offers a possibility to choose the suitable city logistic policies to promote efficient last-mile delivery in urban areas (Visser, Nemoto and Brown, 2014, p.19).

To obtain relevant data, the following structure is used:



3. Survey and data analysis

The data base that allowed the development of a model using reliable consumer choice parameters is built on data collected using a questionnaire. The survey was carried out between May and October 2014 (n=3835) by students of on the University of Applied Sciences of Amsterdam and students of TMO Doorn, both in the Netherlands.

Interviewees were contacted via email or on the street of the towns the students lived in, and interviewees participated in the survey voluntarily. The data from each interviewee’s answers was entered in SPSS within a week after the interviews. The questionnaire was divided into three parts.

- General questions such as gender, age, residence and income category,

- A part that deals with specific fashion related issues, such as what has been bought in shops during the last three months (categories), the price, and the same questions also for online fashion purchases.
- A part that specifically deals with mobility issues such as percentage of modality used, distance to a preferred shopping area and frequency of fashion shopping trips.

The first part recorded socio-economic data.

60% of the sample is made up of females and the remaining 40% of males. Interviewees have an average age of 30 years. For age groups analyses, three classes were made: 0 to 29 years (67%), between 30 and 49 years (19%) and older than 50 (14%). Regarding employment status, 31% of interviewees have full-time jobs (more than 32h p/w), 27% have part-time jobs (between 16 and 32h p/w), while the remaining 42% is made up of pensioners (4%) and students having small or no jobs (<16h; 39%).

Regarding the academic qualifications of interviewees, 48% said they had passed Secondary Education examinations, 22% completed an intermediate vocational education and 30% completed (or was busy with) a university college programme. The interviewees were asked to fill in a gross income per month indication: category < €1,000 (53%), €1,000 – 2,000 (18%), €2,000 – 3,000 (15%), €3,000- 4,000 (7%), €4,000 – 5,000 (4%) and >€5,000 (4%).

The second part recorded fashion purchases in the offline and online shops.

The percentage of online bought fashion items of the total purchases is 21% (Standard Deviation 4, range between 15 and 26), an outcome that supports a realistic ratio for 2014 of 80% offline and 20% online fashion purchases. In general, women buy more garments than men (1.9 / 1.0; www.modint.nl, 2004). This fact will also be visible in the number of online purchases. However, the ratios used in a comparison of offline/online are independent of this difference. No gender differences were found; women showed similar ratios to men.

Prices of fashion items bought online were, over all categories, lower than prices of fashion bought offline (mean difference is €7,28; range between €-3,03 (Sportswear; a higher price online) and €26,36 (Jackets; a lower price online)). This finding is in line with the conclusion of Hsiao (2009). Similar to the findings of Barone, Crocco and Mongelli (2014), the most important reason to go to offline shops for fashion purchases is the opportunity to touch and see goods (45%).

4. The model

The model is primarily designed to find out what fashion shopping choice is the most beneficial for emission reduction. The design is a contribution to an agent based model, in this case having only the fashion consumer as an agent. So there are no interactions with other agents in this model.

Starting point is that fashion deliveries at shops require just as much kilometres as the fashion deliveries at DCs of the PDSs'. The usage of this equality is based on the fact that the large fashion brands like H&M, Benetton, Levis, G-star, Mexx, Esprit as well as the largest home shopping firm in the Netherlands 'Wehkamp', and sports brands like Nike and Adidas most of the time have optimized full truck loads. Smaller brands and their smaller volumes are bundled by dedicated service providers or by the PDSs in full truck loads.

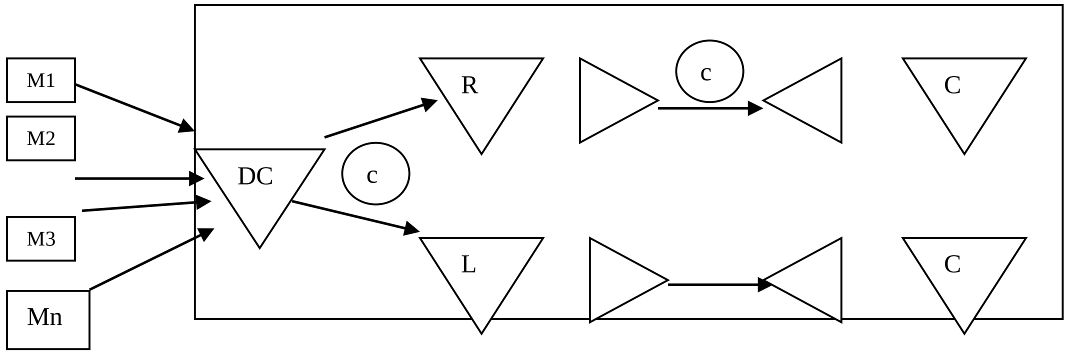
So, this research is about a comparison of kilometres made to get the fashion from shops or local DCs to the consumer home address; the last-mile.

There are three different situations to be evaluated in this last mile:

A) Consumers buy (and pay) in the shop and take the fashion home by themselves (consumer-kilometres).

B) Consumers buy fashion on a website and the delivery at their home address is carried out by the PDSs (PDS-kilometres). PDSs in the Netherlands are mainly PostNL, Selektvracht (DHL), DPD, TNT Express, GLS. PostNL is by far the largest provider (market share of about 62%) and Selektvracht is the second largest (market share of 14%).

C) A combination: the consumer buys a percentage online and a percentage offline (consumer and PDS-kilometres).



- Sources; Inventory or stock: load and unload; choice
- Manufacturers (M1-Mn) deliver at brand DCs (DC);
- Consumer decides to purchase in a retail shop (R) and chooses the modality to and fro the shopping area, and delivers at home stock (C). (=situation A)
- Consumer decides to purchase online (L = DC of LSP or PDS) and the PDS chooses the most efficient van or truck and delivers at home stock (C). (=situation B)

Fig. 1. The service network of fashion home deliveries

5. The input for the model

5.1 Consumer data per record

n_c = number of fashion shopping trips per month.
a_c = average distance to preferred shopping area in km.
$na_c = n_c * a_c * 2$ (to and fro) in km/month.
m_{ci} is an array of percentages of modality choice per respondent (always added up to 100%).
Emission per respondent if 100 % has been brick-shopping is calculated:

$$E_{ci} = \frac{na_c * \ m_{ci} * e(s,i)}{Y(i)}$$

And the total emission is given by $\sum E_{ci}$.

5.2 Parcel delivery services data

The average number of 80 parcel addresses that PDSs told us to do per route, including a second route for 'not at home' is used, leading to 96% first time right. PostNL and Selektvracht are able to organize their deliveries as efficient as possible. In the case of the PDSs route length, the estimation comes from personal communication with PDS drivers and management, and common sense. However, van Duin (2015) found that this estimate is too high and a 90%, if neighbour deliveries are added, is more realistic.
n_f = number of fashion items ordered by consumers.
avg_p = average number per distribution trip (e.g. 100 to deliver at 80 addresses).
a_p = average route length for PDP's (70% carried out in suburbs; 30 % towards rural areas).
n_p = number of required trips per month; is n_f / avg_p.
$n_{ap} = n_p * a_p$ km/month.
The total emission if all respondents order all fashion on the web and delivery done by PDSs: $E_p = n_{ap} * e(s,i)$

5.3 Environmental parameters

The environmental effect parameters used are derived from studies conducted in the Netherlands (Boer, Brouwer and Essen, 2008, Klein et al., 2014). Also the average occupancies are derived from these studies. In table 1, the specific emission per modality is stated in g/km.

Table 1. Environmental effect parameters

	environment effect				
	CO_2	NO_x	PM_{10}	SO_2	
modality	g/km	g/km	g/km	g/km	occupancy
scooter	59	0.049	0.039	0.002	1
avg cars	130	0.291	0.014	0.004	1.58
bus	62	0.605	0.020	0.001	16
van	251	1.030	0.100	0.004	80
small truck	449	5.190	0.315	0.007	120

5.4 Emission Model Notations:

$i \in \{small\ truck, van, bus, car, scooter, bike, walk\}$ is the index of the type of the mobile modality.
s ∈ {CO_2, NO_x, PM_{10}, SO_2} is the index of the chemical substance.
e(s,i) = average emission of a substance (s) per kilometre attributed to a modality type i.
Y(i) = average number of users (occupancy) of a certain modality per trip (car = 1.58, bus = 16, scooter = 1).

6. Results

When consumers buy all their fashion offline, they will travel n fashion shopping trips per month * 2 (to and fro) * average distance to preferred shopping area in km per respondent.

The emission generated by a respondent is $E_{ci} = na_c * m_{ci} * e(s,i) / Y(i)$. The motorized part of the mobility of consumers buying fashion in shopping areas is 116,251 km per month, an average of 30 km/month. The total emission is given by $\sum E_{ci}$. (11,866 kg CO_2, 43.48 kg NO_x, 2.09 kg PM_{10} and 0.12 kg SO_2, see the upper part of table 3).

PDSs transporting all fashion bought online will have to deliver all items to the home addresses of the consumers. Brands offer parcels at the PDSs and the PDSs tend to avoid cooperation with other PDSs, leading to multiple trips to one consumer. Of course more than one item is distributed in one parcel, leading to an average number of 80 parcels to be delivered at 80 addresses per PDS distribution trips to suburbs in towns.

The average route length (a round trip) for PDSs in the Netherlands is 90 km. For the distribution to rural areas the route length is longer (140 km) and the parcels delivered in a certain time span is smaller (60). Estimated is 70% towards suburbs and 30 % towards rural areas. These estimations lead to a calculation of a total of 15,341 kilometres per month for a realistic e-fulfilment scenario. [na_p (urban) + na_p (rural) = $n_{pu} * a_{pu} + n_{pr} * a_{pr}$ km/month]

If the PDSs need more kilometres for their route and will deliver less parcels in time - a worst case scenario - the kilometres will be 22,690 per month. (See table 2).

Table 2. Kilometres made by Parcel delivery services if 100% is bought online

parcels	van kms (x 1.1)	parcel stops	kms	total km				
9376	50	80	6446		optimum of PDSs			
9376	60	80	7735					
9376	70	70	10314					
9376	70	80	9024					
9376	80	70	11787					
9376	80	80	10314					
9376	90	70	13260					
9376	90	80	11603	8122	realistic	urban	70	percent
9376	100	60	17189					
9376	120	60	20627	14439	worst case	urban	70	percent
9376	140	60	24065	7220	realistic	rural	30	percent
9376	160	60	27503	8251	worst case	rural	30	percent
Realistic		scenario		15341	km p/month by PDSs			
Worst case		scenario		22690	km p/month by PDSs			

Starting point in table 2 is the number of parcels that should be delivered (=9376). Driven kilometres as well as the number of stops may vary (column 2 and 3). In column 4 the total number of parcels is divided by the number of stops and multiplied by the estimated kilometres driven having a extra drive for 10% (not first time right). The kilometres driven by PDSs for delivery is calculated using a 70/30% split in the route length for both a realistic scenario as for a worst case scenario.

The total emission, if all respondents order all fashion online and delivery is done by PDSs, is given by: $E_p = na_p * e(s,i)$, having 70% vans and 30% small trucks. The result of the emission calculations is stated in the lower part of table 3.

Table 3. Emissions of chemical substances per month for 3835 fashion consumers in the Netherlands

	scooter + bus + car (avg)				
	CO_2	NO_x	PM_{10}	SO_2	
	11866	43.48	2.09	0.12	kg
	van and small truck				
	CO_2	NO_x	PM_{10}	SO_2	
Realistic	4762	34.95	2.52	0.08	kg
Worst c.	7131	82.43	5.00	0.11	kg

In column 2, 3, 4 and 5 the emission of gases is calculated by multiplying the numbers from table 1 by the amount of kilometres per modality.

CO_2 emissions by consumer movements, which are mainly caused by cars, clearly are more numerous as compared with CO_2 emissions by PDSs, both in the realistic scenario as in the worst-case scenario (11,866 kg versus 4,762 kg and 7,131 kg). However, the NO_x and SO_2 emission are very close, and the PM_{10} emission (having fine dust) is higher for PDSs (2.09 kg versus 2.52 kg and 5.00 kg).

In the case of a development towards more fashion web sales, the total emission changes relative to the emission of the consumer and PDSs modalities used. Emissions of consumers and PDSs are added in table 4.

Table 4. Emissions for different percentages of online shopping of 3835 consumers.

	Emission in kg per month				
	CO_2	NO_x	PM_{10}	SO_2	
0% web	11866	43.5	2.1	0.12	kg
20% web	10445	41.8	2.2	0.11	kg
30% web	9735	40.9	2.3	0.11	kg
40% web	9024	40.1	2.3	0.10	kg
50% web	8314	39.2	2.3	0.10	kg
60% web	7604	38.4	2.4	0.09	kg
70% web	6893	37.5	2.4	0.09	kg
80% web	6183	36.7	2.4	0.08	kg

In column 1 the percentage of on-line sales is stated. In column 2, 3, 4 and 5 the emission of gases is calculated by adding the relative contribution of consumers and PDSs.

7. Conclusion

The motorized mobility of 3835 consumers buying fashion in shopping areas cause more kilometres in the network (116,251 km/month) than when the fashion is bought online and the delivery is done by the PDSs (22,690 km/month in a worst case scenario or 15,341 km/month in a realistic scenario). And subsequently more Carbon dioxide emission (11,866 kg CO_2/month versus worst case 7,131 kg CO_2/month or realistic 4,762 kg CO_2/month). The comparison of the NO_x, MP_{10} and SO_2, all gases that directly influence the air quality citizens experience, shows a decrease from 45,7 kg/month to 39,2 kg/month.

The input in the model of the consumers' choice where to purchase (online or offline), together with the estimations of PDSs operations consequences, offers more detailed information about the impact of online fashion shopping on the emission levels in urban areas. The model provides an indication of best practice: if consumers change their shopping preferences they reduce emission and they also enable the PDSs to optimize their delivery operations.

8. Discussion

In politics, blogs and news-papers in the Netherlands, it is argued that vans of the PDSs cause traffic problems like congestion and pollution in the suburbs. This argument mainly emerges due to the visibility of the vans in the suburbs during daytime. People tend to forget all their neighbourhood car movements that are decreased. (44% of the modality used to do the fashion shopping is the car). Since fashion shopping is done for fun and heavily depends on fit of the product, consumers will not stop shopping in the shopping areas.

NO_x, PM_{10} and SO_2-emissions, that are responsible for the local air quality, decreased significantly since 1980 (Moorman & Kansen, 2011). In this study we found a slight though relevant decrease that could be attributed to consumer choice in online or offline purchases of fashion.

Reduction of CO_2 is globally important, and the ambitious goal for 2030 to have an almost CO_2-free urban distribution (European Commission, 2011), can only be met by a few options for more sustainable home delivery (after Visser. Nemoto and Browne, 2014, p23):

1) Extending low emission zones forcing investment by PDSs in electrical vans and small trucks in urban areas. 2) Organizing parcel deliveries local, enabling more consolidated delivery trips by DPSs (horizontal cooperation) and enabling profitable investments in more environmental friendly vehicles. 3) By far the most effective option according to this study, would be to discourage consumers to use their car for fashion shopping trips.

With our approach, taking real choices of individual fashion shoppers as input for the data of the environmental pressure calculations in the model, we think that the outcome is more realistic than in former studies on mobility effects of online shopping.

The model used, contains quite simple arithmetic calculations. The first discussion point about the model is that the model doesn't account for temporary undeliverable parcels, causing extra drives, and return collection procedure with extra kilometres either by consumers or by PDSs since data are not available. Furthermore, there are some estimates made, mainly by taking the average (in car emission) or a percentage (in the division of percentage urban and rural). These choices are arbitrary by nature when empirical date (per respondent) are lacking. The questionnaire also didn't provide relevant data to analyze substitution effects versus complementary effects between online shopping and offline shopping of fashion.

The most arbitrary choice in the model is the absence of estimation of multiple purpose trips, due to the lack of insight intp the consumer's choice. Multiple purpose trips could be multiple item shopping trips (e.g. electronic devices, food, and fashion) and multiple goal trips by car (e.g. children to school, to work, afterwards to shopping area and then home). Both multiple purpose trips don't necessarily reduce travel time or distance (Visser & Lanzendorf, 2003). Clearly respondents will optimize their shopping trips cost as much as possible.

Since there is a possibility for the parcel delivery services (PDSs) to enhance their operational activities by loading trucks and vans more efficient, and by making more efficient routing and bundling, the ratios even tend to grow in favour of the PDSs for the mobility process (Visser & Hassall, 2005). Boyer, Prud'Homme & Chung (2009) showed that more deliveries per trip reduces the number of vehicle kilometres per delivery. So, consolidations within a PDS also make home delivery more efficient. Optimizing freight transport by combining deliveries of different companies or by combining deliveries and return flows is also a possibility for PDSs (Visser & Lanzendorf, 2003, p. 200-201). When it comes to the comparison of the environmental pressure, the PDSs in the Netherlands are dedicated to choose for electrical trucks. This choice will even have a greater impact on the air quality especially when the car-driving consumer buys online.

Follow up studies should incorporate return rates and modality used as well as multiple purpose trips of consumers and a substitution effect or a complementary effect in the model.

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