Retail location and freight flow generation: proposition of a method estimating upstream and downstream movements generated by city center stores and peripheral shopping centers

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Abstract

This paper aims, via an analysis of the literature, to propose a first modelling and assessment framework to estimate the impact of retail location and characteristics on the environment. The contribution at this point remains conceptual and methodological, but the proposed framework is able to be applied if suitable assessment tools are available. The framework combines a freight trip flow and a shopping trip flow models for vehicle and transport distance estimation, and a life cycle analysis method to convert those vehicles and distances into environmental impacts, taking into account both direct and indirect impacts. First, an overview on retailing location and the motivation of the proposed framework is presented. Second, the general methodology is described. Third, the different modelling schemes are proposed, relating them to what is proposed currently in literature. Finally, future developments are presented.

Keywords: City center stores, peripheral shopping centers, freight flows, logistic movements, end-consumers' movements.

1. Introduction

The urban trade sprawl affects many cities in France (Desse, 2001; Dablanc and Rodrigue, 2016). For example, since the 1960s, the generalized urban sprawl in Paris had not only a consequence in logistics activities (Dablanc and Rakotonarivo, 2010), but also on retailing location with the deployment of peripheral retailers, mainly related to mass-market retailing, which lead to the loss of a part of the suburban clients but also a part of the Parisians which, from then, go to purchase in the peripheral shopping centers. However, "*because of their historic embeddedness and their accessibility, and due to the preservation of big volumes of resident population and employment, the retail stores and the private services managed to resist and stay in Paris"* (Fleury, 2010, p. 171) . This dichotomy between city-center and outskirts is already dedicated by several scholars addressing the issue, among others, of the daily and residential mobility. That debate, related to the one between density and urban sprawl, also takes place on the topic of the retail location. In this perspective, it seems interesting to estimate the consequences of the retail location in the periphery or in the city center.

Although some works deal with the effects of retailing, they are mainly focused on the shopping trip component (Kubis and Hartmann, 2005; Gonzalez-Feliu et al., 2010, 2012) or deal with behavioral issues (Russo and Comi, 2010; Barone et al., 2014; Nuzzolo and Comi, 2014) rather than spatial ones. Moreover, those methods have not been conceived to estimate the environmental impacts but only the transport flows, and only consider direct environmental impacts from transport. For that reason, a methodology that integrates both inbound and outbound flows, at and from retailers, and considers the spatial patterns of transport and location seems necessary. Moreover, this method should be developed on the main goal of estimating the environmental impacts of retailing, both direct and indirect and not only those related to transport direct gas emissions.

The aim of this paper is to propose the first step of a methodology that would, in fine, estimate the environmental impacts that are generated by urban retails accessibility. Indeed, upstream and downstream flows to the stores, whether they are located in the city-center or outskirts the city, generate pollutant emissions. This paper aims at representing both the upstream freight flows and downstream shopping trips that are generated by urban retailing in terms of kilometers, transport modes, types of road (urban road, highway, for example) to represent the responsibility of urban retailing in pollutant emissions that are linked to goods transportation in the city.

First we present a conceptual debate within which it suggests the integration of inter-establishments movements into the debate about urban retail location. Then, the proposed methodology is presented, focusing first on the evaluation of the environmental impacts of retailing development and the main determinants of those impacts related to goods distribution to the shop and the consequent transport to households, mainly via shopping trips. Then, the transport flow modelling framework is presented, detailing both freight distribution and shopping trip flows. The proposed framework is general and conceptual, and can be deployed in contexts or urban fields where suitable models and tools are available of applicable. However, it is important to deploy an integrated model when those tools are not available, so the paper will conclude by presenting the work in progress in the seek of developing that model.

2. City-center stores versus peripheral shopping centers: what about freight trips flows? A conceptual debate

The involvement of the local authorities in the organization of urban retailing allows thinking that they are interested for several reasons. One can think about the fiscal contribution of retail establishments as units inserted into the economic fabric of the city, but the intentions can go beyond. For Varanda (2005), the interventions targeted by local authorities are not strictly motivated by only urbanistic or commercial stakes. These considerations legitimize centrally-located retails, opposite to the peripheral shopping centers which emerged in France, in the 60s. To legitimate city center localization of retail stores, the assets of the city center retails that are often put forward are its animation capacities, the revitalization and even the contribution to neighborhoods safety (Petit et al., 2013). On another hand, the environmental pressures of retail stores are also reported: land pressure, urban roadways congestion and environmental pollution due to the freight trips towards the city-center retails in particular.

From this perspective, the notion of compact city appears first in Netherlands in 1985, before being associated with that of "city of short distances", which emerges in Graz, Austria, and in Groningen, Denmark, with an aim of facilitating the access to local services by reducing the distances. Newmann and Kenworthy (2006) have also the opinion according to which the outer-urban installations are more generative of pollutant emissions than those in city-center.

Traditionally, households' shopping trips are taken into the account of urban mobility but freight flows are less often included in general urban transport flow estimations. Even if, since the 80s, urban mobility plans the inclusion of goods flows is compulsory for the urban areas of more than 100 thousand inhabitants (CERTU-ADEME, 1998), it is only from 2014 that the law on territorial action moderning and metropolization development "*Loi MAPAM*" places goods flows under the same ruling and funding authority than personal transport flows (Ministère de l'environnement, de l'énergie et de la mer, 2014).

The flows generated by shopping trips or inter-establishment movements depend on the distances covered, which depend on the retails location. So, what retail installation to consider in city-center or in periphery? Where is the border? Many scholars worked on that issue but it is still not easy to define precisely the borders between the center and periphery of a city. Bonnet and Tomas (1989) state that the concept of centrality is progressing: since the crisis of the early 70s, urban space is affected by many differentiations and the problem "center-periphery" may seem to be less central (Figure 1).

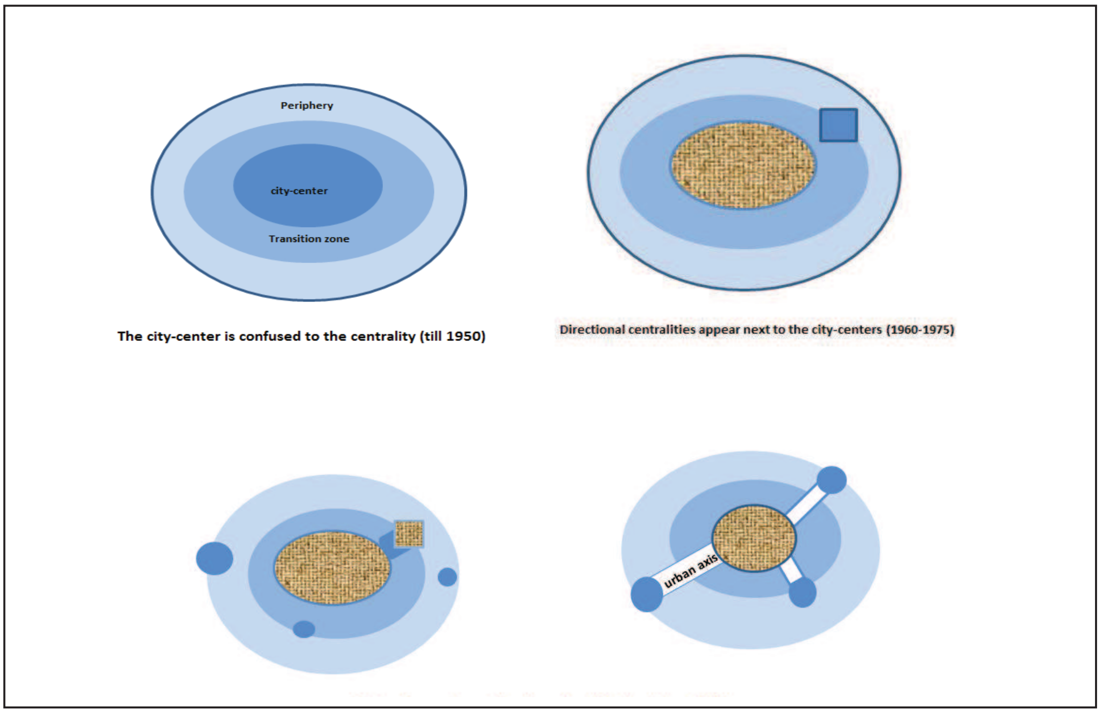

Figure1. The evolution of centrality (Adapted from Bonnet ant Tomas, 1989 p11).

In the same perspective, let's revisit the hypothesis of the theory of central places with Huriot & Perreur (1995), who stated that this theory is based on postulates which do not take into account the local peculiarities that can explain the location of economic activities. Those postulates are five:

- The geographical space is considered as perfectly homogeneous for both physical and human features.
- Every individual is aimed to maximize his utility.
- The prices are fixed for all individuals.
- For consumers, purchased goods transport implies a cost which increases with the distance.
- Economies of scale in the production of the central goods make that the average of production costs decreases when the produced quantity increases.

According to this, the city center can be defined as the place of the big scale economies characterized by a strong human concentration, in terms for example of density of the housing environment. For, if the peripheral shopping malls can also constitute scale economies areas, they will at least, lake of housing environment density, making the city a system with two complementary sub-systems, one related to center and another for peripheries. However, a third zone, called intermediary or transition zone, can be defined (Huriot and Perreur, 1997).

Gonzalez-Feliu et al, (2012) join this spirit of a concentric representation of Lyon urban area growth by using the zoning proposed in Nicolas et al. (2011), i.e. dividing the urban area into 34 macro-zones. Authors declined the area in three big crowns which are the center zone formed by Lyon and Villeurbanne, a less dense intermediate crown constituted by the bordering municipalities of the center zone and the third crown constituting the periphery (Gonzalez-Feliu et al., 2012). As it can be seen on Figure 2, the realities of the urban population density of the Lyon urban district in 2005 do not contradict such a distribution.

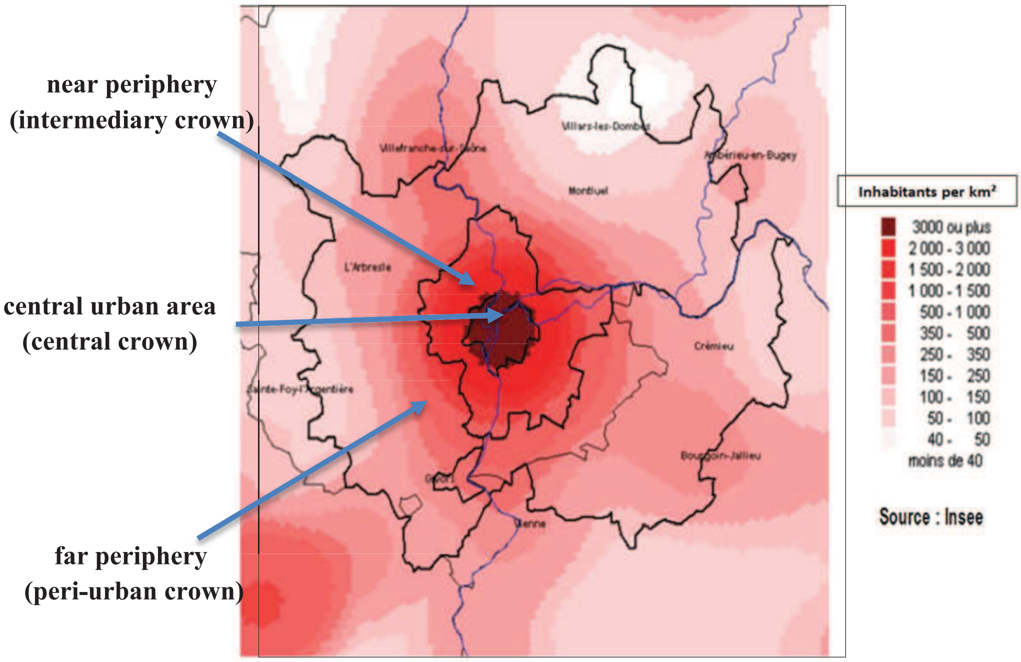

Figure 2. Population density in Lyon urban area in 2005. (Adapted from Monchabert, 2011, relating it to the urban space zones of Gonzalez-Feliu et al., 2012)

3. Methodology

3.1. Goal definition and scope of the study

The first stage is to define the system under study and the parameters that will be taken into account. Our final aim is to compare the pollutant emissions due to both freight flows and shopping trips respectively generated by a city center located and a peripheral shopping center, within the life-cycle-assessment methodology.

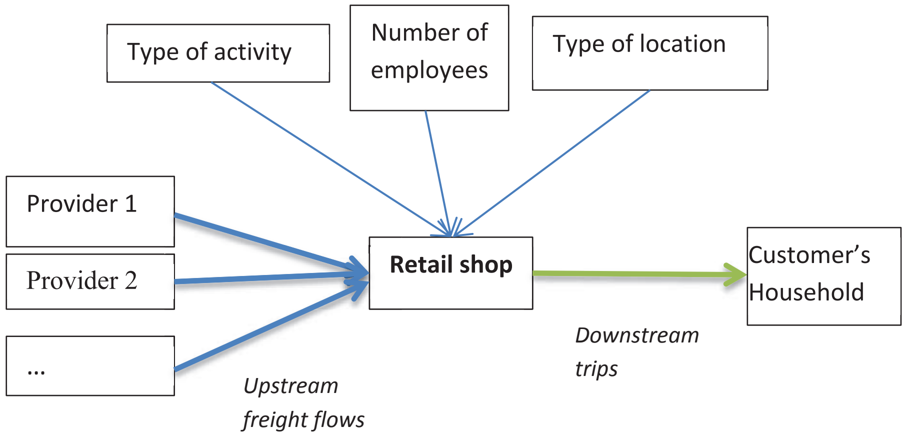

Figure 3. Representation of the system under study

3.2. Which functional unit to choose? The meter-square of store, the Euro turnover or the ton of products sold?

A common functional unit must also be defined to compare the two systems under study as recommended by the ISO 14040 international normalization. According to this norm, "*the functional unit defines the quantification of the identified functions (characteristics of performance) of the product*". A functional unit needs to be related to a reference to which inputs and outputs are connected. In LCA, the comparability of the results is crucial for the evaluation of various systems to make sure that these comparisons are made on a common base (ISO 14040, 2006, p. 13). LCA has recently applied to urban mobility (Le Féon et al., 2012; Gondran, 2015), and also to urban freight transport but on a logistics viewpoint (Andriankaja et al., 2015). In those works, the functional units are mainly related to vehicles. However, in retailing there are other elements that impact the environment and although freight transport is

For retailing-based LCA, different functional unit may be chosen in this case: as for example one euro of turnover, one ton of products sold by unit of time, or an average transaction. One euro of turnover seems to be interesting for comparing the businesses generally speaking, but it depends largely on the unit price of products and such a functional unit can be lacking relevance and comparability between various types of stores as it is linked to the flow that is generated, which is what we are studying in fine. For a luxury store for example, the turnover can rise very quickly even for very small packages.

The ton of sold products can also be relevant as functional unity. This parameter is indeed associated with the volume, which determines the loads of vehicle for the supply of the businesses for example. For that reason, we assume that the ton of product sold is interesting to choose as functional unit (FU).

3.3. Methodological approach

To estimate the environmental impacts that are caused by the freight generated by the shops, it is necessary to estimate the number of kilometers that is covered by different categories of vehicles. To approximate this, the first step is to estimate the number of movement in the direction of the trade upstream as downstream, and the vehicles used.

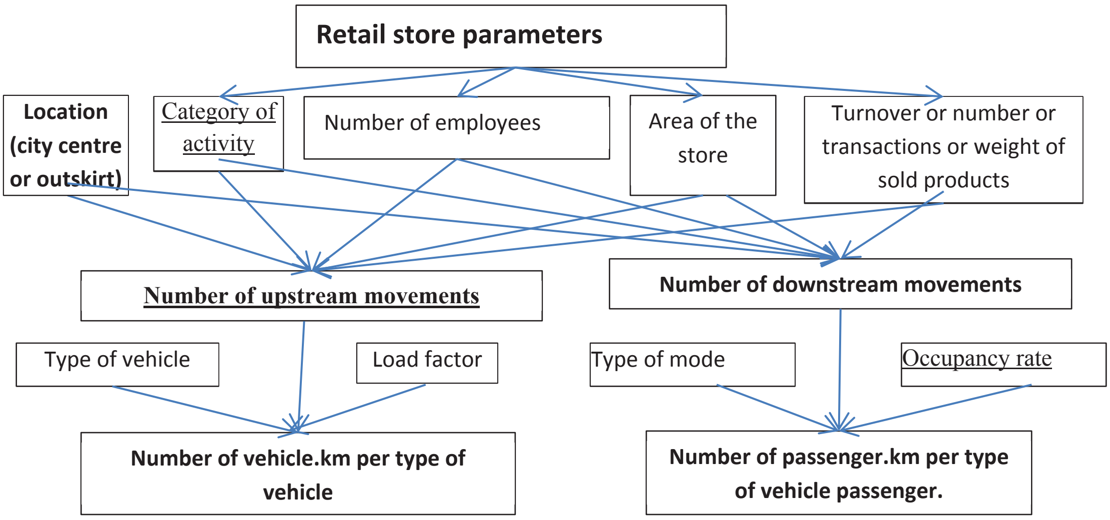

Figure 4. Representation of the proposed methodology

In the following, we propose a conceptual declination of the methodology, relating it to existing works. Although the aim of this research is to propose an integrated assessment framework of urban retailing environmental impacts, the transport flow estimation will be made by adapting and eventually completing and extending existing frameworks in order to make a unified framework able to be adapted to any context and modelling tools. Indeed, some fields have their own tools so it will be easier to adapt them to the proposed framework, completing them when necessary with suitable procedures. When no tools are used, we would propose an integrated and operable model for flow estimation. In any case, the general methodological structure will be the same, and is presented in the following subsections.

3.4. The transport flow estimation model: from employees to distances.

The proposed modelling framework consists in first estimating separately the freight trips for inter-establishment and shopping trips then calculating their associated distances respectively, and this for city center stores and for peripheral located shopping centers. In a second time, those distances and integrated and compared. To do this, it is important to choose a modelling schema for each type of flows based on the same units and on comparable assumptions.

3.4.1. Freight trips flows of inter-establishments movements.

For freight trip flows, traveled distances will be generated in three stages. The first is to generate the tours, the second is to characterize them and the third consists in deducting the trips distances by estimating the average length of a route for a category of establishment.

i. Generation of the tours

The first phase of the freight transport flow model is freight trip generation (FTG). Several authors dedicated a strong importance to FTG, being the category class models those predominant (Holguin-Veras et al., 2011, 2013; Bonnafous et al., 2014; Gonzalez-Feliu et al., 2014). However, two approaches are mainly used: the classical constant-based generation (Aubert and Routhier, 1999; Holguin-Veras et al., 2012; Bonnafous et al., 2014; Gentile and Vigo, 2013) and the heterogeneous category class generation (Holguin-Veras et al., 2011, 2013; Gonzalez-Feliu et al., 2014; Sanchez-Diaz et al, 2016a,b). Since the limits of constant trip rate generation have been proved in Holguin-Veras et al. (2011) and heterogeneous category class generation is nowadays a unified methodology, we will follow this second group of approaches.

Following those statements, we propose a general formulation for FTG derived from works cited above. We assume a model of tours that can take a constant or linear form, as stated in Holguin-Veras et al. (2011, 2013) and Sanchez-Diaz et al. (2016). This model will therefore be expressed for each category of establishment by the following expression:

$$T_i = a \times Emp + b$$

Where T_i is the number of tour;

Emp is the number of employees;

a and b are constants to be found but can be null:

- If a =0, then the number of turns is constant and will be a characteristic of central tendancy (arithmetic mean, median or standard deviation)

- Else, a linear regression model of the distribution enables us to obtain either $T_i = a \times Emp$, or, $T_i = a \times Emp + b$

In order to assess the suitability of each model, we will estimate the mean quadratic error (RMSE) of the three alternatives and the model of tours will be that which has the least RMSE, following the same methodology than on Gonzalez-Feliu et al. (2016) but generating freight trip attraction (FTA, i.e. the number of trips at shopping destination) and freight trip production (FTP, i.e. the number of trips at origin) separately[1].

ii. Characterization of tours

Once the number of trips generated by each establishment is generated it is important to construct the transport routes, or tours. We find in literature three main approaches. The first is that of estimating first the trip O-D matrices then to link them to reproduce routes (Sonntag, 1985; Eriksson, 1997). This is only possible when data on O-D matrices is available. If not, suitable O-D matrices can be estimated (Routhier and Toilier, 2007; Muñuzuri et al., 2009) but the validity of the results depend on collecting other non-O-D data aiming to estimate a general shape of routes.

The second is that of estimating commodity O-D matrices (Holguin-Veras et al., 2010; Gentile and Vigo, 2013) then constructing routes mainly using vehicle routing problems (Crainic, 2008; Cattaruzza et al., 2015). The main critical points to this issue is that routes do not always reproduce the reality, and are in general too much optimized. Other ways of estimating routes can be to link them to behavioral models including empty trips (Holguin-Veras et al., 2010), to behavioral models integrated into distribution chains (Nuzzolo and Comi, 2014) or to multi-agent simulation models (Wisetdjindawat et al., 2005).

The third one is related to characterize those trips then estimating distances without actually constructing a route or transport chain, but based on average characteristics (Bonnafous et al., 2014) or on probabilistic procedures (Gonzalez-Feliu et al., 2014; Gonzalez-Feliu and Morana, 2014). In those procedures, for each category of establishment, it will be necessary to specify the mode of management (shipper's own accounts, receiver own account or third party transport), then the vehicle's size (light commercial vehicle, single truck, semi-articulated vehicle) and finally the number of stops and which are the main activities delivered at those stops. With all those information, a tour classification that includes the specificities of retailers will be proposed. Then, each trip will be associated to a category using a matching procedure, in order to estimate realistic tours.

iii. Estimation of distances

To estimate the distances covered, the total distance of tours ought to be known. To do this, If routes are generated and spatialized (which is the case when O-D matrices are known) as well as the vehicle type, distances are calculated directly from those routes. When not, an alternative estimation is needed. In this case, the distance generation model proposed in Gerardin et al.

[1] In Sanchez-Diaz et al. (2016b), trips are generated without knowing if the location is an origin or a destination.

(2000) can be adapted. This model expresses the average length of routes as a function of the number of routes (**r**), the vehicle used (**v**), for a mode of management (**m**) and for a density class of operation per week (D_w): under 1000 per week, between 1000 and 5000 or more than 5000 per week, i.e. following the relation: **L= f(r, v, m,** D_w **).**

The function needs then to be defined according to available data.

3.4.2. Shopping trip flows of end-consumer movements

The proposed shopping trip framework consists in first modelling the number of shopping trips. Second, the trip chains where those shopping trips are included will be characterized, for each zone by type of movement and by the transport mode used. The third step will consist in generating the travel distances.

i. Generation process

According to different authors (Cubukcu, 2001; Russo and Comi, 2010; Durand and Gonzalez-Feliu, 2012), two main modes are predominant in shopping trips: car and foot, but many models focus only on car-based trips. According to the general shopping trip rate generation framework (Cubukcu, 2001), we propose a shopping trip generation (STG) formulation based on a linear relation (Gonzalez-Feliu et al., 2012) that takes the following form:

$$T_i = (\alpha_i + \beta_i) \times Men_i + \sum_k [(\alpha'_i + \beta'_i) \times Com_{i_k}]$$

where

Ti is the number of movement chains,

$\alpha_i$and α'_i being constants relative to car use movement

β_i and β'_ibeing constants relative to movements by foot

Men_ibeing the number of households by zone

Com_{i_k}being number of retailers of each type ***k.***

A multilinear regression will be made to determinate the parameters and eliminate those which are not import ant, according to the data (Household Trip Survey of Lyon, 2006). The model will then be validated by comparing the value of the R^2 and of the F-test after grouping the zones in three as defined above: city-center, intermediate crown and the periphery.

ii. Shopping trip chains characterization

After obtaining the STG rates, it is important to estimate the characteristics of those trips. In order to make a coherent model that is comparable with the freight flows one, we propose to group shopping trips into chains, as shown by Gonzalez-Feliu et al., (2012) those trips are not independent but making part of more complex trip rounds. However, those works are now at an initial stage, most shopping trip models being based on single trip O-D matrix estimation (Russo and Comi, 2010; Nuzzolo and Comi, 2014). However, a categorization can be made by type of urban zone (Gonzalez-Feliu et al., 2012), mode (car and pedestrian) and type of retailer (small retailers, stores, megastores). This categorization will be made with the same types of methods than for freight flows. Moreover, four main types of shopping trips are identified: Home-purchase, purchase-home, work-purchase and store-store. Those types of trips can be combined to define more complex trip chain.

iii. Covered distances estimation

Once the trip chain categories are defined, we can, as for freight trips, estimate the distances. However, there is not, to the best of our knowledge, an equivalent formulation for shopping trip distance estimation. We are currently working on the development of this relation.

4. Conclusion

This paper is the first part of a whole work intending to estimate the polluting emissions of the urban goods movement flows. We suggest here a methodology showing, in a proof of concept perspective, that it is possible to estimate both the upstream inter-establishment movement and the downstream shopping trips. These two types of traffic generation seem interesting to take into account simultaneously in the perspective of the study of environmental impacts of urban mobility.

The perspective of this study is to validate this methodological proposition on statistical data concerning the case of a French city, as for example Lyon urban area or Saint-Etienne conurbation (which includes both urban and rural spaces).

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