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SPATIAL REFINEMENT TO BETTER EVALUATE MOBILITY AND ITS ENVIRONMENTAL IMPACTS INSIDE A NEIGHBORHOOD

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HIGHLIGHTS

- An evaluation methodology for environmental and social impacts of mobility associated with a neighborhood development project is presented.
- The method is sensitive to the neighborhood project's program, layout and local mobility set-ups.
- It deals with the neighborhood in relation to the urban configuration of activities and the transport networks.
- The evaluation is easy to implement, based on GIS tools and standard transport simulation models.

ABSTRACT

A large share of a neighborhood project's environmental impacts is due to mobility. It either takes place inside the neighborhood, such as transit traffic or internal mobility, or is induced by it and exchanged with the rest of the urban area. A way to improve mobility impacts evaluation in the assessment of neighborhood alternative designs, is to refine traffic simulation models making them more sensitive to spatial design while keeping their sensitivity to local traffic conditions and associated energy consumption and pollutants' emissions.
This paper introduces a methodology relying on the classic four-step scheme for mobility demand modelling together with specific spatial refinement. The neighborhood is divided into fine sub-areas, with specific consequences for each step: first, trips are generated on the basis of sub-area land-use and activity data; second, the trips are distributed between all Traffic Analysis Zones (TAZs), enabling to identify internal short-range trips; third, the mode choice model takes into account the particular access conditions between sub-areas and transit stations or roadway nodes; fourth, traffic assignment involves finer TAZs and finer path description. Furthermore, a 5th step is added to deal with environmental evaluation, especially the allocation of mobility impacts to the project's sub-areas. These steps are presented and illustrated on the 'Cité Descartes' district case study, in Eastern Paris. Dividing its 1 km^2 area into about 100 sub-areas enabled us to depict the projects' program and spatial layout very finely, especially so in relation to the transit stops and stations location. Some limitations and needs for further research are also outlined.

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1. INTRODUCTION

1.1 Background and literature review

A large share of a neighborhood project's environmental impacts is due to mobility. It either takes place inside the neighborhood, such as transit traffic or internal mobility, or is induced by it and exchanged with the rest of the urban area. Thus, it is important to evaluate that part of the environmental impacts correctly in the assessment of alternative design options.

A literature review has been conducted on that issue along three different scientific streams. First, environmental evaluation is a mandatory part of global evaluation for transport and infrastructure projects in France (as described in Quinet, 2013). Spatial analysis can then be conducted by coupling transport demand models with pollutants' emission models to study the effect of regional-scale regulation and urban policies (such as applied in Mestayer, 2012 and IRSTV, 2017). Different modelling chain combinations, assembling micro, meso and macro transport, emissions and air quality models allow to evaluate local extent of air pollution (a review is presented in Fallah Shorshanni, André, Bonhomme, Seigneur, 2015). These evaluation methods pertain to the global regional scale.

Second, among transport, emission and air quality model combinations, developments in the direction of multi-agent models should be cited (e.g. Hülsmann, Gerike, & Ketzel, 2014) as they allow to improve population exposure modelling through a disaggregated individual-based approach (see also Beckx, et al., 2009). Spatial resolution of such models allows for a fine-level ambient conditions description, yet at the expense of computational burden. Being individual-centered they also do not aim at development project's evaluation.

Third, there is an ambition to cover a larger range of environmental impacts, considering transfers between different spatial and temporal scales and ecosystems in a global development project's assessment framework – the Life Cycle Assessment. Transport is then considered as one of the neighborhood's impacts contributors among others (for a recent review, see Lotteau, Loubet, Pousse, Dufrasnes, 2015). Transport's impacts are then usually treated in an aggregated, averaged manner ignoring local specificities. On the other hand, a transport-specific LCA allows to go into life cycle and urban context details (e.g. François, Gondran, Nicolas, Parsons, 2017) and mode-specific operational conditions (see De Bortoli, Féraille, & Leurent, 2016). Recent efforts also aim at combining the advantages of LCA and travel demand model's - based traffic evaluation (e.g. Mailhac et al., 2016).

1.2 Objectives

The present work aims at keeping a medium level of modelling complexity by focusing on the spatial refinement of a travel-demand model, incorporating individual behavior: purpose, mode and route choices. We intend to maintain the coherence between distribution, modal choice and assignment steps, by iteratively calculating traffic equilibrium. Our primary objective is to determine some important environmental impacts, namely air pollutants and GHG emissions together with energy consumption, but spatial refinement also provides an opportunity to improve the assessment of several socio-economic indicators.

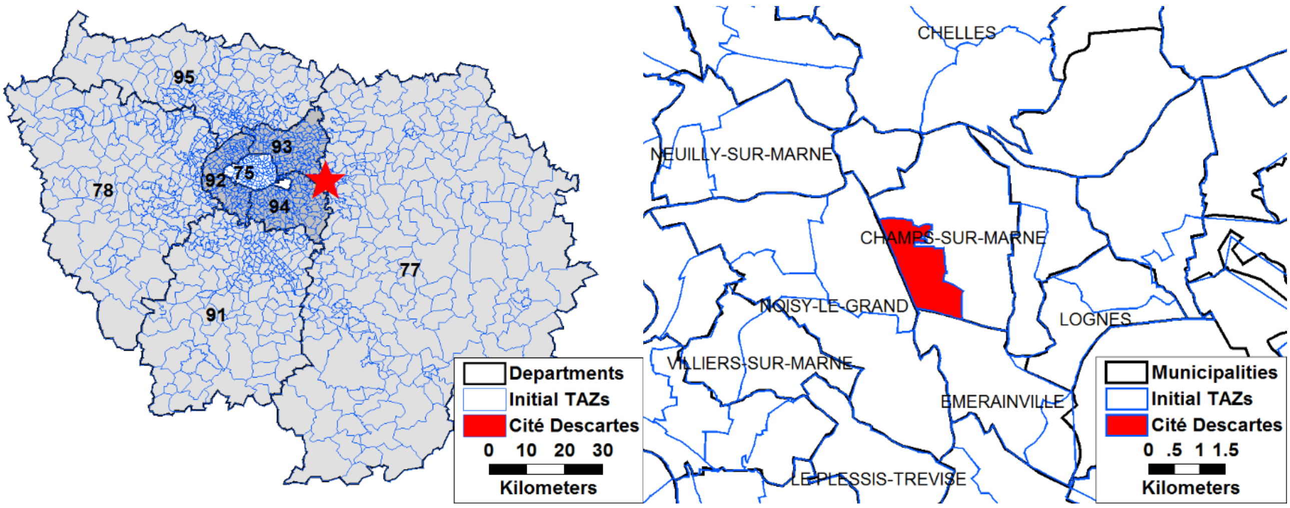
1.3 Methodology

The methodology developed in the present paper overcomes some of the above-mentioned shortcomings. It allows to quantify and qualify the mobility associated with a neighborhood by distinguishing specific conditions and functions of buildings within it. This methodology also enables quantifying environmental impacts of this mobility. It is based on common consultancy engineering tools, thereby allowing for easy replication and transferability.

Building on an available urban travel demand model at the city level (TDM), our main contribution is to spatially refine this model to better describe local mobility: identify and differentiate the mobility attributed to a given building within the neighborhood; quantify and characterize the neighborhood's mobility (in particular the internal mobility's share); analyze local mobility's impact on the ambient conditions inside the district (pollutants emissions, local congestion) and attribute external impacts to individual neighborhood's components. In order to achieve these objectives, several modifications and adaptations were brought to the original city-level model. The idea to spatially refine a city-level zonal model is not new (see Manout, Bonnel, & Ouaras (2017) for a recent review), we focus in our work on the pragmatic contributions of such spatial refinement for neighborhood-level project evaluation.

The model used in the present case study, MODUS (hypothesis presented in Simonet, 2012), covers the entire Ile-de-France region. It is a macroscopic, static, 4-step model (trip generation, trip distribution, modal choice and trips assignment), see Ortuzar and Willumsen (2011) for theoretical background. The first three steps can be seen as demand modelling, whereas the fourth step of user-equilibrium assignment pertains to traffic modelling. And a fifth step of environmental evaluation was added to complete this modelling framework.

The methodology was applied on a district located in the Eastern part of Greater Paris (Ile-de-France Region, France) – the Cité Descartes (CD) district, which extends over 1 km^2 (see Fig. 1 (b)). MODUS is a 'zonal' model in which the entire region is discretized into approximately 1300 Transport Analysis Zones (TAZs) to study aggregated flows exchanged between them. The CD district, one of the initial TAZs was further refined into nearly 100 sub-zones (see Fig. 2 (b)). In what follows we will refer to the initial aggregated TAZ - the CD aggregated TAZ, and the spatially refined district – the disaggregated CD district.



(a) (b)

Figure 1: Cité Descartes's position in the Ile-de-France region. (a) Ile-de-France region's TAZs and general CD location. (b) CD district's location at municipal scale.

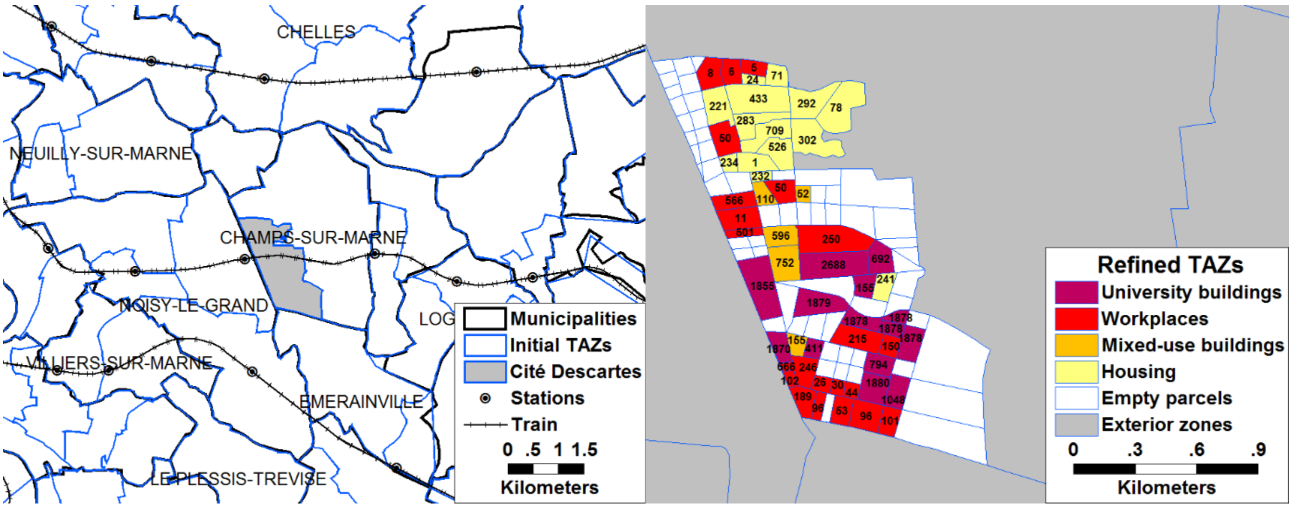
1.4 *Structure of the paper*

Section 2 presents spatial refinement adaptations of the model. In sections 3 and 4, the four modelling steps and their adaptations are described, grouped respectively into demand modelling and traffic modelling sections. Next, section 5 describes the additional step of environmental evaluation and how it was designed to attribute impacts to the neighborhood's individual components. Spatial refinement thus makes the neighborhood's mobility evaluation methodology sensitive to the project's layout and program. To conclude, section 6 synthesizes the contribution and points to topics for further research.

2 SPATIAL MODELLING

2.1 *Zone system refinement*

On average, the area of each sub-zone is roughly 1.5 ha (appx. 120 m x 120 m), close to the building block scale. The largest sub-zone's area is 9 ha (appx. 300 m x 300 m), which would take 4.5 minutes to cross on foot. Each TAZ in the region, including the sub-zones, is characterized by four land use variables: working and non-working population, number of jobs and number of available places in the education institutions. The sub-areas in the CD district are almost exclusively mono-functional (see Fig. 2 (b)): housing, university building, offices, etc… while mixed-use occupations are also described using an appropriate mix of the four land-use variables. This spatial refinement enabled to finely depict the projects' program and spatial layout.



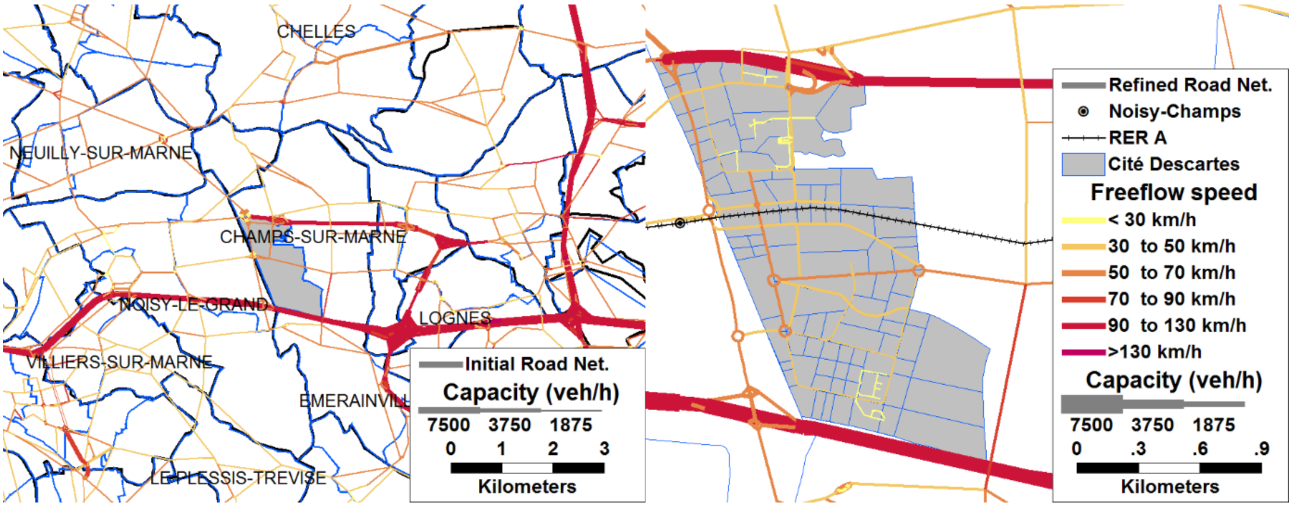
(a) (b)

Figure 2: Refining the Transport Analysis Zones inside the Cité Descartes district. (a) Initial aggregated CD TAZ. (b) Disaggregated CD district. *Source: Emilie Vanhille (2015)*

2.2 *Network refinement*

The sub-zones' relation to the transport network was also specified through network refinement and creation of specific connectors. In the initial city-level MODUS model, the road and transit networks are simplified – their precision matches that of the TAZs' description. In order to analyze and

accurately represent local mobility, internal to the CD district, the simplified network was locally replaced with a detailed description including secondary access roads inside the district (see Fig. 3). The initial transit network, although simplified, was not modified as all of the transit stations and stops are exhaustively represented and accurately located within the district.
Once the sub-zones are created and the network refined, it is necessary to connect them. To do so, centroids, representing each zone's access point and virtually collecting its population and jobs, are located at each sub-zone's center and then linked, using connectors, to both road and transit networks. Each sub-zone's specific access conditions are therefore finely described.



(a) (b)

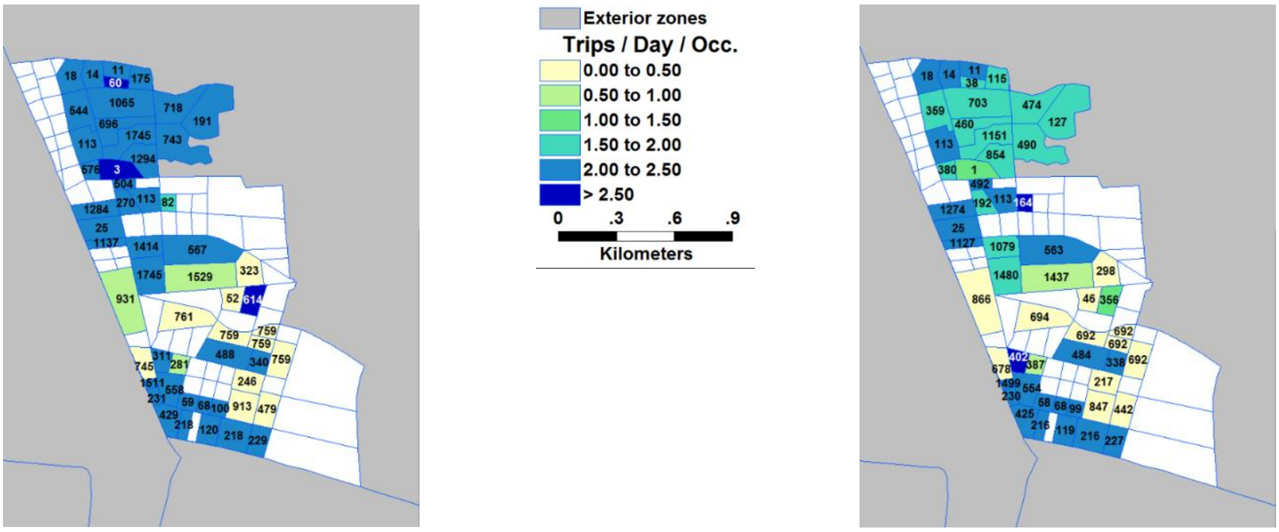
Figure 3: Local road network refinement. (a) Initial road network around CD. (b) Locally refined road network inside the CD district. *Source: Emilie Vanhille (2015)*

3 TRAVEL DEMAND MODELLING

3.1 Generation

Trip generation modelling aims at quantifying daily incoming and outgoing flows for each zone. Spatial disaggregation then enables simulating flows emitted and received by each building or group of buildings, attributing to each micro-zone its share of the overall district's demand (Fig. 4). This mobility demand is segmented according to trip purpose (6 purposes are distinguished in the MODUS model) and individuals' characteristics (captive or non-captive of public transportation).
MODUS deals with individual trips (as opposed to daily activity programs or tours) yet in a statistical, macroscopic way. Its trip generation sub-model is based on zone land use characteristics (the 4 variables mentioned above) and relies on regionally calibrated production and attraction rates, further specified by sub-regional average segments characteristics (captive vs non-captive users). An imbalance of incoming and outgoing trips can be noted, particularly for residential areas. This is due to regionally calibrated attraction and emission rates aiming at a global balance for mixed-use TAZs. The CD aggregated TAZ and the disaggregated CD district share the same overall land-use characteristics – total working and non-working population, jobs and places in the education institutions. The resulting

total mobility demand is then the same whether the district is spatially aggregated or divided into sub-zones, since the generation model's formulation is linear.
As the micro-zones exhibit higher functional specialization, there could be an additional opportunity to describe more specifically sub-zones' jobs and populations. However, MODUS is not presently calibrated finely enough for such specializations. A re-calibration would therefore be necessary to take into account the disaggregation of job types and population segments (e.g. mobility behavior of students at the CD might differ significantly from that of an average non-working person in the Ile-de-France region).



(a) (b)

Figure 4: Aggregated daily flows for all purposes entering or exiting CD sub-areas. (a) Total daily attractions and per occupant attraction rates. (b) Total daily trip emissions and per occupant emission rates. *Source: Emilie Vanhille (2015)*

3.2 Distribution

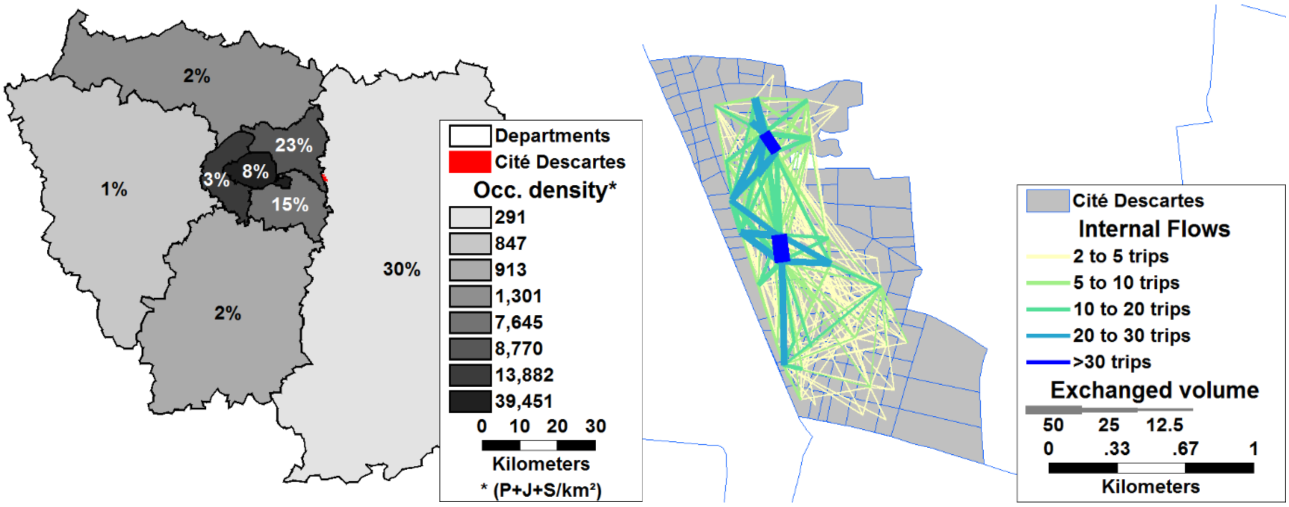
The distribution step allows pairing origin and destination zones of the travel demand, representing users' destination choice. In the MODUS model this choice is based on two aspects. First, on the utility of a destination zone for a given trip purpose, thus reflecting the spatial configuration of activities at the regional level. And second, on the multimodal disutility of the destination zone with respect to the given origin zone, depending on the regional multimodal network.
Spatial refinement of a district has a twofold modelling impact on the trip distribution step: first concerning trips taking place inside the district, and second, concerning trips exchanged with the rest of the territory.
Concerning internal trips, spatial refinement leads to an individualization of intra-district micro-zones, specifying multi-modal access conditions between them. We can thus explicitly model and represent short trips inside the district, as shown in Fig. 5 (b). Thus, internal trips are not only quantified but also spatially located, establishing explicit relations between district's buildings.
This modelling representation also modifies the external versus internal flow ratio. Although overall numbers are the same, internal flows are lower in the disaggregated configuration where daily internal flows are approximately 4 700 trips versus 8 400 trips in the aggregated configuration. This observation can be explained by the fact that the initial MODUS model (at least its academic

implementation in the commercial tool TransCAD) does not take into account intra-zonal impedance while modelling internal trips which leads to overestimating internal trip flows. Spatial disaggregation of the district, reintroduces this internal impedance in the model.

As a consequence, the additional 'external' trips observed in the disaggregated configuration take place mostly in the vicinity of the CD district: internal micro-zones of the district are competing with zones closest to the CD. The distribution model should be re-balanced by introducing internal impedance for the remaining, unchanged TAZs, in the rest of the territory. At the same time, flows internal to a micro-zone should vanish as the size of the micro-zone becomes smaller and closer to that of an actual building.

It should be reminded that, since MODUS deals with individual trips, it does not allow to take into account activity chains inside a district and therefore the effects of functional diversity of the neighborhood on the travel demand for trips outside the district.

Concerning the impact of spatial disaggregation on trips exchanged with the rest of the territory, two main aspects stand out: spatial disaggregation leads to a specialization of micro-zones compared to the aggregated representation (for example, some micro-zones contain exclusively jobs and no population), this leads to a specialization of associated travel purposes and has repercussions on the destination choice (first-order effect, modifying flows exchanged with an external zone up to 100%); additionally, disaggregation allows specifying networks access conditions for each micro-zone, modifying, compared to the aggregated configuration, accessibility to the rest of the territory and therefore destination choices (second-order effect, modifying flows up to 10%).



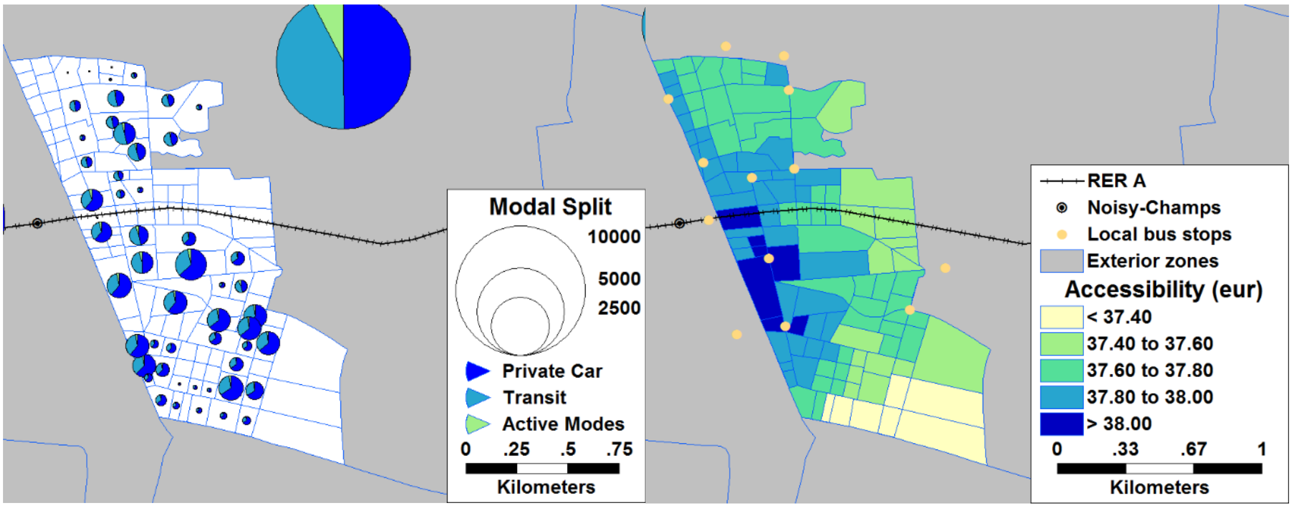
(a) (b)

Figure 5: Distribution of the disaggregated CD district's daily mobility demand. (a) Overall flows' share exchanged with CD's exterior territory. (b) Distribution of internal CD's flows. *Source: Emilie Vanhille (2015)*

3.3 Mode choice

The mode choice step enables to split the users' trip flow between an origin and a destination zone of a given demand segment among available transport modes. The mode choice model confronts modes based on their generalized cost, including weighted time and cost variables. The weighting coefficients

were calibrated for each demand segment of the Ile-de-France region using the household mobility survey, EGT 2009 (Enquête Globale Transport, a Household travel survey for the Ile-de-France region). MODUS comprises three transport modes, described with several modelling limitations: active modes (in fact limited to walking); private car (excluding parking search time and parking costs, or the possibility to combine it with public transport); transit, covering several sub-modes (train, suburban train, metro, tram and bus) integrated in a transit network (accessed on foot exclusively).
As mentioned in the Generation step, working at a finer micro-zone level calls for a finer demand segmentation which, in turn, would require a recalibration of the mode choice behavior model. For instance, describing 18 and older students predominant at the CD as a specific demand segment would be preferable to aggregating individuals aged 6 to 25 in their study-bound travel behavior. Additionally, working with a refined local network could also enable to improve transit feeder modes' description and modelling. Furthermore, similar to the Distribution step, the effects of grouping activities into activity chains are neglected, simplifying the mode choice. In fact, mode choice for trips made within the same activity chain are interdependent, covering the entire day dynamics. These aspects leave room for further developments.
Despite the above-mentioned limitations, spatial refinement allows to tackle two major issues in neighborhood-scale transport modelling. First, specifying, for each micro-zone, on foot access conditions between the access point (micro-zone centroid) and the transport networks. Second, distinguishing, for each micro-zone, its modal travelling conditions in relation to its origin or destination zones. This, in turn, leads to differentiated mode choices. These aspects are important improvements on the initial aggregated model, representing the neighborhood as a homogeneous zone.



(a) (b)

Figure 6: Multi-modal access conditions at the CD micro-zone level. (a) Modal split of daily home-work trips to and from the CD. *Source: Emilie Vanhille (2015).* (b) Accessibility for the non-constrained, home-to-work segment.

Figure 6 (a) illustrates the model sensitivity to location within the neighborhood. It shows modal split for home-work purpose trips on a daily basis: in the Northern part of the CD district, users favor transit modes whereas in the South of the district the private car share is more important. These modelling results are consistent with the transport network configuration: the South part has a privileged access to the motorway network whereas the Northern part is further away from it but benefits from a shorter access to the train station facilitated by the presence of a feeder bus service. Accessibility indicator evaluation, shown in Fig. 6 (b) for the home-to-work purpose and non-constrained demand segment, is also improved and spatially refined showing a greater sensitivity to the location of transit modes' stations in the neighborhood. The Hansen formula was used for the accessibility indicator as follows:

$$A_z = \frac{1}{\theta}\ln\left(\sum\nolimits_d O_d \exp(\theta U_{MM})\right)$$

Where A_z is the accessibility indicator, equal to the monetary value per trip and per day of access to jobs and educational places using transportation networks; O_d is the number of opportunities at a destination zone; U_{MM} is the multimodal utility of a trip between zone z and the destination zone d, it equals to: $U_{MM} = \frac{1}{\theta}\ln(\sum_M \exp(\theta U_M))$.

4 TRAFFIC MODELLING

The assignment model confronts transportation offer (transport networks and services) and demand (trip flows) for a given period of the day (typically MPP – morning peak period or EPP- evening peak period). First, the daily demand is scaled down to the peak periods, using average sub-regional, mode-specific ratios, then resulting peak demand is assigned. The assignment model provides (MPP and EPP) quality of service characterization for all origin – destination pairs, resulting from each segment's route choices. This quality of service characterization is iteratively used in the distribution and mode choice steps. The MODUS model assigns vehicles and transit passengers' flows respectively to road and transit networks' links, whereas active modes, although quantified, are not assigned to the road network. Therefore, spatial refinement has twofold consequences: on private car and transit modelling quality.

4.1 Private car assignment

MODUS allows to specify auto ridership for each origin – destination pair, based on sub-regional average observations. Thus, vehicle flows can be deduced from travelers' flows obtained at the mode choice step. Congestion is represented by flow-delay relationships. And, since MODUS is a macroscopic model dealing with aggregated flows rather than individual vehicles, average congestion conditions are determined for each link. MODUS is also a static model, the congestion hyper-peaks and their consequences are therefore smoothed out.

Once congested travel times are determined for all network links, through an iterative assignment process, demand flows are assigned on the shortest paths between the origin and the destination zones. The criterion to determine the shortest path is a tradeoff between travel time and travel cost, translated into the generalized cost of a path.

Private car assignment step provides vehicles' flows, congestion level (w.r.t. link capacity) and average vehicle speed at the link level. Aggregation along chosen routes provides total travel times for each O-D pair. Then, quality of service characterization follows.

Spatial refinement of the CD district allows identifying flows exchanged between the buildings inside the CD district, and also assigning them onto a refined local network. As a consequence, secondary road links bear their share of traffic, whereas in the simplified network description only major arteries were loaded.

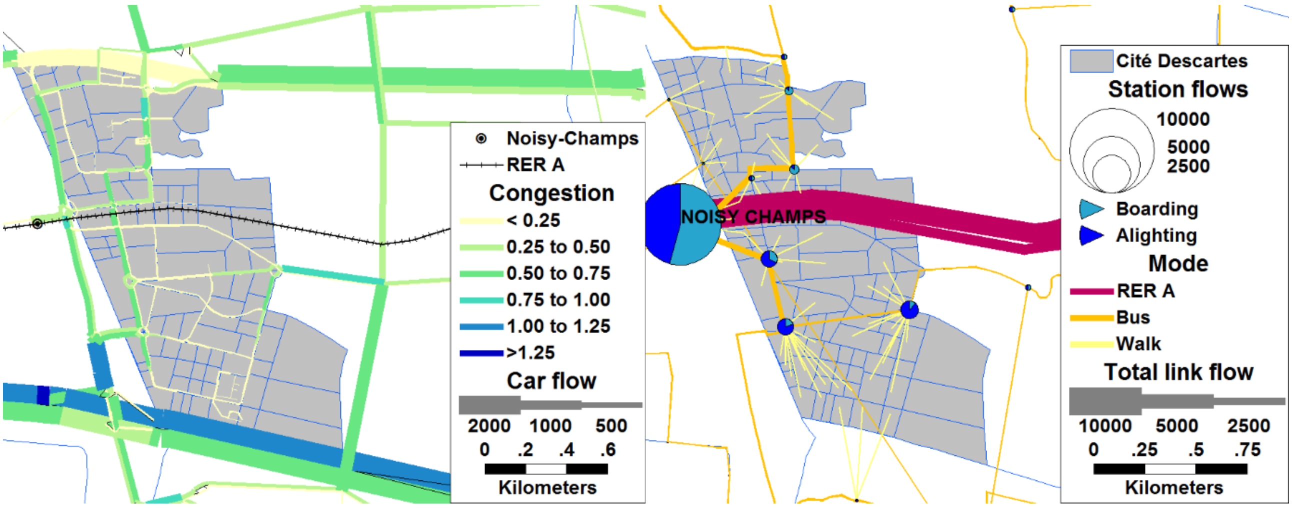
Figure 7 (a) represents private car assignment results for the CD district during the EPP, the most problematic period for the private car. It should be noted that the motorway flows are visually diminished (they are in reality approximately 3500 veh/h in each direction). The figure shows local traffic contributing to ambient conditions, noise and pollution levels. The motorway and its access ramps' congestion in the Southern part of the district can be noted, whereas the major road in the Northern part of the district is under-used. As expected, the congestion levels in the neighborhood itself are rather low, with the exception of the major North-South axis and secondary East-West transit itinerary.

4.2 Transit assignment

Transit flows are also assigned to the shortest paths, determined on the uncongested transit network. Indeed, MODUS model does not take into account transit capacity limitations potentially leading to longer travel times. The interactions between road traffic and transit operation, such as road congestion impact on buses that do not benefit from reserved lanes, are also neglected.

Transit assignment provides passenger flows per sub-mode at the link level and boarding/alighting flows at the station/stop level. Then aggregation on multimodal transit routes between an origin and a destination provides travel time including waiting, access and transfer times. This, in turn, results in transit quality of service characterization.

Spatial refinement allows distinguishing transit use according to land use and location within the district relative to transit stops. Figure 7 (b) shows the results for the CD district during the MPP, when residents leave for work and workers arrive to their workplace. The contrast is easily seen between North and South of the neighborhood: flows are predominantly boarding in the Northern, residential, part of the district while they are mainly alighting in the Southern part, concentrating the district's jobs.



(a) (b)

Figure 7: Assignment at the micro-zone level. (a) Private car assignment on the local road network, EPP veh/h. (b) Transit assignment, MPP pax/h. *Source: Emilie Vanhille (2015)*

5 ENVIRONMENTAL IMPACT EVALUATION

5.1 Average sub-mode environmental impacts calculation hypothesis

Since MODUS neglects congestion for transit modes, private car and public transportation were treated differently. For private car global impacts, such as fuel consumption and CO_2 emissions were considered as well as local pollutants emissions of PM_{10} and NO_X. Link-level emission factors were considered to depend on several factors: traffic conditions (represented by the average speed on the link, resulting from the assignment step) and fleet composition (regional average composition was used). Emission functions were taken from the relevant technical note issued by the French administration (Sétra, Cété de Lyon, & Cété Normandie-Centre, 2009), based on the COPERT IV methodology, which could further be updated.

Transit modes were further subdivided into electric sub-modes and buses. Electric sub-modes include train and suburban train, metro, tram. Their traction electricity consumption was calculated. It represents approximately 75% of operation energy. Associated CO_2 emissions, considering French production mix was also calculated (53g/kWh). Average consumption was calculated at the link-level, ignoring its dependence on inter-station distance, actual load and speed.

For buses the set of environmental impacts calculated was taken similar to that of private cars: fuel consumption, CO_2, NO_X and PM_{10} emissions. Average emission factors, neglecting speed and load dependence could be found in the literature and combined, using the fleet composition provided by the RATP (main transit operator in greater Paris) to obtain emission factors for the average regional bus. Then, multiplied by the actual vehicle flow (also resulting from the assignment step) and link length, total impacts produced at the link level are determined, for each sub-mode.

5.2 Demand-related environmental impacts

First, per person impacts are calculated at the link level by dividing total impacts produced by the vehicles of a sub-mode by the ridership of this sub-mode, in other words by the passenger or traveler flow on this link (resulting from the assignment step). These link-level per-person impacts are then aggregated along the routes connecting origin and destination zones providing individual impact for an O-D pair. Finally, the individual impacts for the O-D pair are multiplied by the actual demand flow exchanged between this origin and this destination to produce total impact per O-D pair.

5.3 Zone-level impacts attribution

Several attribution schemes were proposed and discussed in a related article presented at the 2016 European Transport Conference (Kotelnikova-Weiler, Leurent, & Poulhès, 2016). Here we summarize the zone-level attribution scheme.

In an attempt to build an attribution scheme that avoids possible overlapping (and double counts) when evaluating several neighborhoods in the same territory and guarantees transferability to any development project, whatever the program, the attribution scheme proposed relies on two main principles:

- Any trip whose extremity (origin or destination) is located within a zone is associated with this zone without a priori on what purposes should be associated with what types of building programs;
- To avoid double counts, 50% of a trip's impacts are attributed to the origin zone and 50% are attributed to the destination zone.

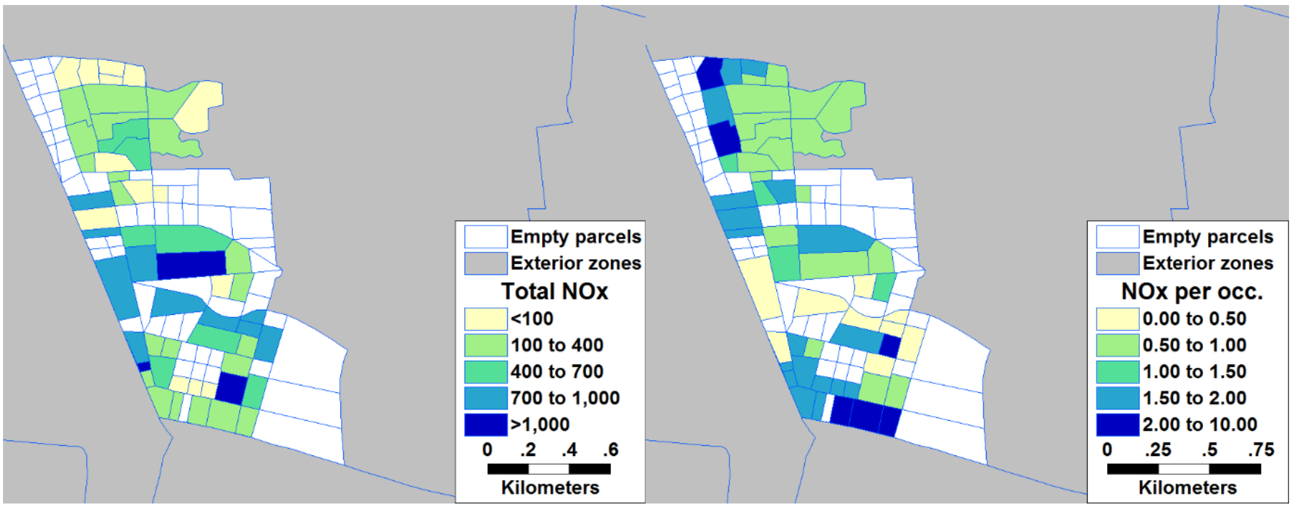
Pragmatically, these principles result in the following formula enabling to calculate environmental impacts of a zone:

$$Q_z = \frac{1}{2}Q_z^{or} + \frac{1}{2}Q_z^{dest}, \text{where } Q_z^{or} = \sum_{d \in D} Q_{zd} \text{ and } Q_z^{dest} = \sum_{o \in O} Q_{oz}$$

It reads that the total impacts of a zone z, Q_z, equal 50% of total impacts of all the trips that have the zone z as origin and 50% of total impacts of all the trips that have the zone z as destination.
Based on this attribution scheme, several impacts were calculated for the micro-zones of the CD district: total energy consumption, total CO_2 emission (combining private car, bus and electric modes' contributions), total NO_x and PM_{10} emissions (combining bus and PC contributions). For illustration purposes, reflecting particular peak traffic conditions experienced by the neighborhood users, figure 8 (a) shows total morning peak hour NO_x emissions generated by each micro-zone. Elevated NO_x emissions might indicate higher transport demand and/or poor access to public transportation. Educational institutions' buildings in the district center thus have a high impact whereas housing and office buildings on respectively North and South periphery of the district have relatively low contributions. To better understand impacts' structure, a different indicator can be useful: total impacts divided by total occupation parameter (population + jobs + places in educational institutions). It is presented in the Fig. 8 (b) and tells a different story: indeed, per occupant contribution, contingent to the settled urban function, is very low for educational buildings and high for residential and office buildings. This dual approach helps identifying potential for improvement: either zones where incremental improvement might produce high impact reduction or zones requiring structural modifications of the transport offer. To get a more physical sense of the environmental impacts, daily emissions can also be computed: both peak period and off-peak period simulations need to be performed, then corresponding hourly emissions can be combined in the following formula, to obtain daily emissions:

$$Q_z^{day} = aQ_z^{MPP} + a'Q_z^{EPP} + bQ_z^{OP}$$

where for private car a=2h, a'=3h and b=10h, and for transit a=1.5h, a'=2.5 and b=11h (Paris values).



(a) (b)

Figure 8: CD mciro-zones as generators of NOx emissions at the regional level combining private car and buses' contributions, morning peak hour. (a) Total NO_x per zone (g). (b) NO_x per occupant (g/occ.). *Source: Emilie Vanhille (2015)*

Remind that the emission of pollutants is only one factor of local air quality among other factors that include the background pollution, spatial and temporal propagation of pollutants and their chemical transformation. However, our methodology is aimed to evaluate the contribution of a neighborhood project to the regional emissions of atmospheric pollutants.

6 DISCUSSION AND FURTHER RESEARCH

The present article puts forward a pragmatic methodology to evaluate some social and environmental impacts of a neighborhood's mobility. Despite methodological limitations, among which the necessity to improve model's segmentation and calibration, it allows to achieve our main goals:

- Provide a finer description of the network's topology;
- Simulate internal traffic on the local road network;
- Provide a finer localization of local emissions inside the neighborhood;
- Thus, paving the way to a more specific evaluation of local exposures inside the neighborhood as both the emitting links and the receiving micro-zones are refined. Yet a complementary air quality model would be required;
- Allocate more specifically the environmental impacts of mobility at the regional level to generating micro-zones inside a development project for a finer assessment.

These contributions make the evaluation method sensitive to both building's function and location, and to heterogeneous multimodal transport conditions inside the district.

Our evaluation method is therefore applicable to a neighborhood development project, as it is both sensitive to the project's program and layout allowing to compare several design options. Additional transport-specific design alternatives can also be implemented and their impact evaluated: creation or modification of a transit line, such a as a feeder bus service, or layout and capacity dimensioning of local road network, what-if motorization scenarios can also be tested.

The method is also sensitive to regional-level context such as activities spatial distribution in the territory and networks configuration impacting regional accessibility. It is therefore mandatory that long-term project's simulation rely on sound regional development scenarios, both in terms of urbanization and transport networks evolution. Additionally, as environmental evaluation is also performed based on fleet composition and energy production mix, their future evolutions need also be hypothesized.

This methodology can be deployed in major urban agglomerations, for which transport demand models are available and have been calibrated. The treatments presented here were implemented using basic features of a commercially available transport-oriented GIS tool, TransCAD, making them replicable.

An original framework for joint road and transit impacts evaluation is provided. As well as an original proposal of attribution methodology at the micro-zonal level. It could further be discussed and improved. Indeed the 50-50 attribution scheme adopted here does not reproduce well the hierarchy of activity purposes in the daily program. Indeed, consider a secondary activity performed 'on the way' to or from a main activity. It is often true that the main rather than secondary activity determines the distance to be travelled (secondary activity would not motivate in itself a long trip), the mode to be used (given the accessibility of the main activity's location) and sometimes the reason to make the additional secondary activity (since the person is out of home, they can do both activities). So a major direction for further research is the implementation and adaptation of this evaluation methodology for tour-based or activity-based travel demand models.

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