FRETURB V3, A Policy Oriented Software of Modelling Urban Goods Movement

Jean-Louis Routhier, Florence Toilier

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FRETURB V3, a policy oriented software tool for modelling urban goods movement

Jean-Louis Routhier*, Florence Toilier**

*research engineer, ** study engineer

jlrouthier@let.ish-lyon.cnrs.fr, toilier@entpe.fr

Laboratoire d'Economie des Transports, Lyon, France

(CNRS, Université Lyon 2, ENTPE)

14 avenue Berthelot, F-69363, Lyon

ABSTRACT

This paper presents a land use and tour-based model for urban goods movement simulation. Three modules interact each other: a "delivery-pick-up model" including transport of goods between all the economic activities in the city; a "town management module", (transport of goods and raw material for public and building works, urban networks maintenance and removals); and a "purchasing trips model", which concerns trips of consumers during their purchasing activities. This communication focus on the delivery-pick-ups model. Thanks to the results of thorough establishment surveys coupled with driver surveys, this model estimates, on a town zoning, the goods movements (road occupancy, just as by vehicle flows as by on-road parking vehicles) according to the logistic strategy of the shippers and of the haulers, the environment and the characteristics of the establishments and the urban land use. It is divided into four parts: methodology, description of the different components of the model, description of the functionality of the software and discussion of some results.

KEY WORDS

urban goods movement, freight modelling, tour-based model, decision making.

INTRODUCTION

The paper presents the third version of a model for urban goods movement simulation. It is developed in the framework of the French research program "Marchandises en ville" funded by the Transport Ministry and the French Environment and Energy Control Agency (ADEME). This program was initiated in 1993 in order to limit the environmental impacts of the urban goods movement in conjunction with a harmonious urban economic development.

It was noticed that the transport and logistics behaviour of the urban stakeholders was poorly known (Browne et al., 2007): the estimation of the urban goods vehicle traffic was as usual measured with the help of simple counts of vehicles or cordon surveys. It was inadequate to bring the knowledge of the mechanism of generation of the goods vehicles traffic: only heavy vehicles are identified by the counts; the cordon surveys give few information on the characteristics of the generators (shippers, forwarders, consignee) and are poor in the description of complex tours. Thus, from a long time, urban goods transport models were derived from large scale models of road trucks traffic (interurban flows at a national or international scale).

The main approach consisted in gravity functions of the commodity flows, according to the industrial GDP of the origin and destination areas and the impedance function being a generalised cost function. An O-D matrix of tons-kilometres was calculated and translated in vehicles-kilometres for the whole urban area (Ambrosini et al., 2004a).

There were two reasons of the failure of this approach: in urban areas, the distribution of goods traffic (in tons) is not the same as the vehicle distribution; the logistic choices are the result of a compromise between the aims of a lot of actors (shippers, haulers, city planners, residents) and cannot be summarised by the single minimisation of transport costs. For all those reasons, one of the first task of the research national program was to build simultaneously surveys and model in order to improve the knowledge and to help efficiently decision making on urban logistics. Urban freight transport is a system with numerous components as represented on the figure below.

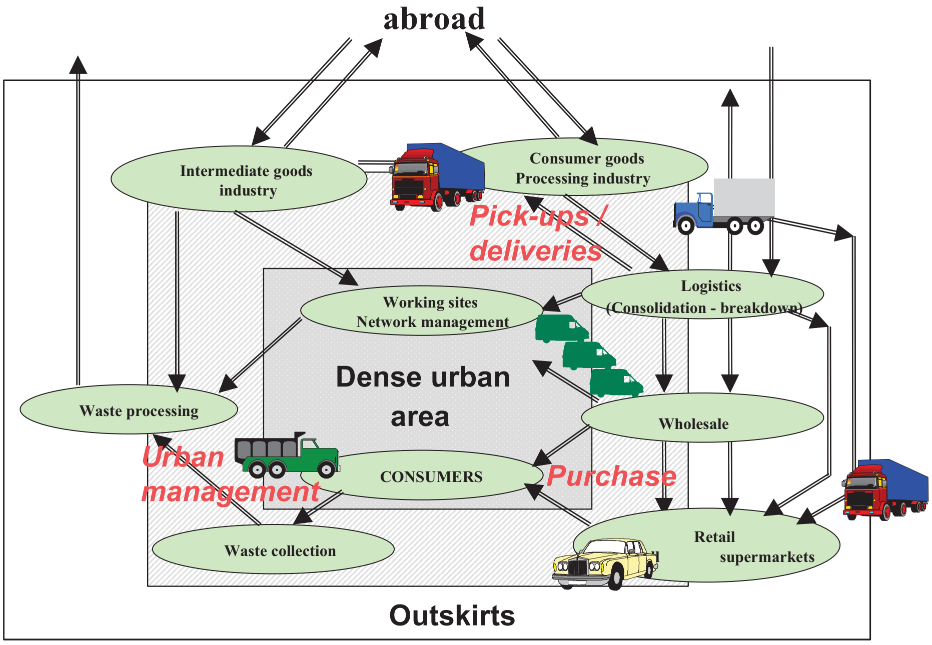


Figure 1: urban freight transport system

Three modules interact each other: a "pick-up and delivery model" including commodity flows between all the economic activities of a town (production, supplying by wholesale and retail like handcraft, services and offices); a "town management module", consisting of transport of goods and raw material for public and building works, urban networks maintenance (sewers, water, phone) and removals; a "purchasing trips module", modelling shopping trips by car, which represents the main last kilometre trips to consumers. This paper describes essentially the pick-ups and delivery model.

The software presented is a tour-based tool, modelling the commercial vehicle movements, according to various segments of activity. He may be compared with tour-based (with or without microsimulation) models such as WIVER orVISEVA-W (Meimbresse and Sonntag, 2000, Friedrich et al., 2003), the commercial travel model of TLUMIP (Donnelly, 2002) and Calgary Commercial Vehicle Movement Model (Stefan et al., 2005). The reader will find in Routhier et al. (2007) a thorough comparison between those modelling approaches and the FRETURB model.

METHODOLOGY

As the current modelling approaches are not efficient at the urban scale, it is may be why the underlying hypotheses do not fit. Considering urban goods transport analysis, data collection or modelling, we must have in mind three requirements: coherence, relevance and measurability. These three attributes are necessary conditions of the efficiency of the methodology. The coherence is no only a classical condition of non contradiction but also a consistence with the objectives of the approach. The relevance is necessary to reflect the actual situation. The measurability enable not only the assessment of the results but also the condition of verifiability (Bonnafous, 1989).

The efficiency of the method results from a balance between those three attributes. For example, if we try to detail the payload (nature, weight, volume, packaging,…) the high level of splitting of those elements needs a higher relevance in the theoretical statement of the problem. According to the urban goods movement modelling, the proposed method aims to examine two issues in order to satisfy the three previous requirements: whether to reduce the object of the investigation to the elements we consider as essential or to keep an ambitious object and to propose a methodological innovation.

If we try to focus our object, we can consider that the main question about urban goods movement is the road occupancy by the goods vehicles, which are in competition with the individual cars. Congestion and accessibility alike local environment for residents may be translated by road occupancy.

In the standard analysis of urban mobility, the aim is to reach a good understanding of the daily individual trips. The observation unit is naturally the trip identified by his origin, his destination, his reasons for being in any particular place, the social and economic determinants for the trips choice, etc. The four steps model is a reduction of the question but it fits on the target which is to forecast the road traffic or the attendance of public transport.

It is not possible to do so (i.e. to choose the commodity trip as observation unit) in the case of the urban goods transport. Therefore an origin-destination of goods has no meaning in term of transport: a ton of goods from *zi* to *zj* may be transported as a single payload in a direct trip with a heavy goods vehicle as well as hundred small parcels, some of them being delivered straightforward and some other delivered in complex rounds with light goods vehicles. It is therefore not relevant to observe the delivering and pick-up of the sending.

What is the most quantifiable observation unit? In order to observe the different ways of organisation on the road of a good vehicle, several statistical units may be considered: monitoring of *a street segment* during a defined period may provide the parking place and time and the moving of the goods vehicles working on this segment. Surveying the *routes* of goods vehicles provides a thorough description of the stops which make it up. Through surveying *the shippers* all the pick-ups and deliveries could be registered. Each of those observation units have drawbacks: the rules of sampling of street segment are difficult, the routes may not be settled into the land use characteristics, shipper surveys do not provide easily the routes characteristics.

The "movement of vehicle", in the sense of deliveries or pick-ups achieved in each establishment, was chosen as the statistical unit for the following reasons:

- A movement of vehicle may be considered through the road occupancy (as the trip and the on road parking time), that assure the measurability of the objective,

- The movements may be described through an establishment survey, in order to keyboard with a appropriate precision the useful characteristics of each movement. In particular, the space occupancy by the stationary vehicles may be precisely measured.
- In France the establishments registers "SIRENE" are easily accessible. It makes possible an a-priori stratified sampling of establishments according to their industry class and size.
- In order to explain and quantify the road occupancy when a vehicle moves from the depot to the delivery zone or between two delivery points, it is necessary to complete the establishment survey with a delivery-man survey. A self managed questionnaire is filled by the drivers who have visited the surveyed establishments. By this way, it is possible to recreate the route containing the movement initially surveyed.

If the size of the sample is sufficient, such a survey may give a accurate picture of the urban goods vehicles traffic. The traffic is considered in the general sense of road occupancy for both the trips and the parking on the road.
More generally, this surveying method satisfies the condition of measurability, according to the three objectives: knowledge of the urban goods movement, modelling in order to restore the urban goods transport activity and simulation of his possible evolutions under different hypotheses on exogenous variables.

A method of survey and modelling

A couple of nested surveys was carried out in three French towns (the city centre and his suburbs) Marseille of 1,1 Million, Bordeaux of 750,000 and Dijon of 240,000 inhabitants (LET, 1997, 1999).

- A survey among 4,500 establishments sample of all type of activity was carried out. A stratified sample is representative of the type of activity, location in the urban area, size of the establishments (number of employees). A thorough description of the deliveries and pick-ups for a week have been completed in each establishment, according to the type, packaging, weight and volume of the goods delivered, the type of transport operator (made by the forwarder, the consignee or by public transport), the type of vehicle involved (LGV (<3.5t.), rigid lorries, articulated trucks), and if the transport was made in a single trip or in a tour of various size.
- 2,200 drivers have been interviewed about their company, the description of their vehicle (PTAC, payload), the stops and the route (drawn on a map). Their timetable was also described.

Those two surveys are coupled in order to get the relationship between the spatial and economic behavioural data (activity of the establishments) and the operations of transport (vehicle choice, routing, scheduling,…). We call them Urban Goods Movement (UGM) surveys.

The main results of the surveys widely confirm the relevance of the statistical approach (Patier, Routhier, 1998). In addition, the following results are, in average, not significantly different from a town to another:

- In average, we observe about 1 delivery or pick-up per week and per employee. The type of activity and the number of jobs of an establishment have a significant effect on the number of deliveries and pick-ups.
- The number of delivered points in a route is 5 in average (and 13 if we consider only the rounds).

- The part of the deliveries and pick-ups realised in direct routes is in average of 25%.
- The part of the rounds among the vehicle-routes is in average of 25%
- The amount of the deliveries and pick-ups carried out by heavy articulated trucks is less than 15% of the total urban deliveries.
- 50% of the deliveries and pick-ups are made by LGV (<3.5t).
- The break down of the deliveries, according 8 categories of activities is the following:

Activity category	Share of deliveries/pick-ups
Retail (small)	25%
Wholesale	22%
Handcraft, services	17%
Supermarkets	3%
Industry (production)	16%
Transport (warehouses)	10%
Offices	7%

Table 1: Share of goods movement per activity category

- The road occupancy, measured in number of hours ∗ cars unit equivalent (CUE∗h)[1] is as follow:

	- 1 - On street parking (CUE∗h)	Distance In CUE∗km per week	Speed average	- 2 - Traffic duration (CUE∗h)	(1)/(1+2)
Whole town	41,600 h.	2,560,000	35 km/h	136,700 h.	23%
City Centre	18,000 h.	167,500 km	15 km/h	11,000 h.	62%

Table 2: road traffic and on road double parking in Bordeaux

The stops represent less than the quarter of the road occupancy on the whole town, but they represent the two third in the city centre. This is a validation of our choice of surveys based on the movements of vehicles for which the requirement of relevance and measurability are simultaneously validated.

The fundamental assumption follows from those results: the generation and the behaviour of the commercial vehicle flows is significantly and essentially dependent on the type of firms (activity, nature of premises and size of employment) where the goods are loaded or unloaded. They seem independent on the size and of the shape of the town.

Thanks to those surveys, a lot of indicators on the logistics behaviour of the shippers, hauliers and drivers have been obtained, which build up the specification of the model. Thus the inputs of our model are both a national French establishment's register (SIRENE data) and the lessons of the specific surveys as shows the figure 2:

[1] CUE : car unit equivalent, i.e. *v1:* LGV=1.5 cars, *v2:*rigide lorries=2 cars, *v3:* HGV articulated vehicles=2.5 cars.

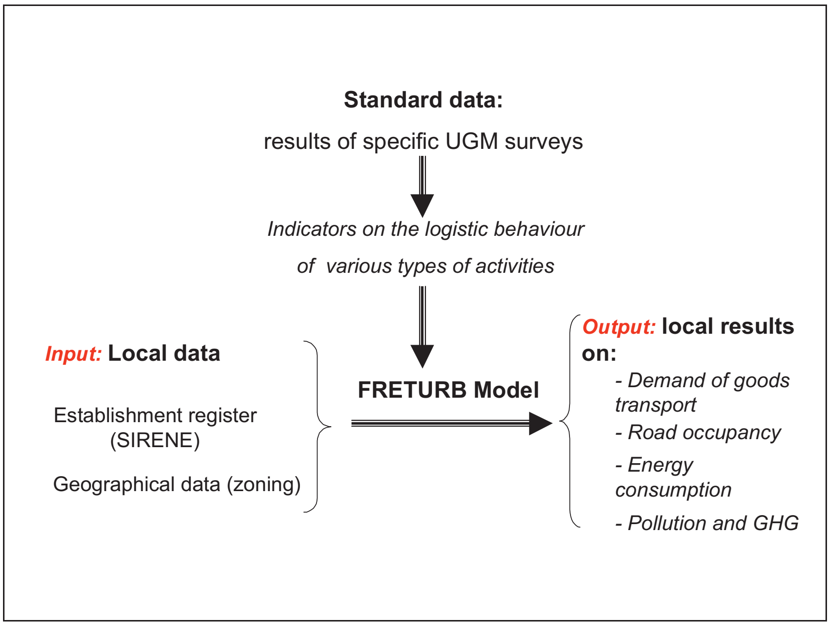


Figure 2: FRETURB : a model built on empirical data

THE MODEL STRUCTURE

The analyse of the results of the UGM surveys provides indicators on the logistic behaviour of various types of activities: a segmentation into 116 types of establishments, according to activity and size, allows to formalise the various urban logistics behaviour of the urban aera.

At this urban scale, the knowledge of the different activities is better than the knowledge of the amount and the nature of the payloads. As shown in the previous section, it is possible to have a precise description of each establishment of the city (accounting location, type of activity, size, nature), while the commodity flows are easily measurable and relevant only at a regional or national level.

Our main hypothesis is that the quantities of goods of various nature forwarded or delivered in an establishment depends on its activity (NACE), its size and its nature.

The model is thus based on the nature of the generators (shippers, forwarders, consignees) and the transport choices by the latter.

Generation of movements

Remind that a *movement* is the operation of transport which describes a delivery or a pick-up, by a type of vehicle in a given establishment. The relevant characteristics which explain the relationship between the urban activity and the deliveries and pick-ups generation are as following:
a: industry category (45 types),
p: nature of the premises (store, warehouse, office, headquarter),
o: number of jobs class (0, 1, 2-5, 6-9, 10-19, 20-49, 50-99, 100-199, 200-299,…)
The average number of movements is a function of the characteristics of the establishments *a, p, o*.

$$n_e=\varphi(a,p,o)$$

where n_e is the number of movements (deliveries, pick-ups and mixed operations) carried out each week for the establishment *e*.

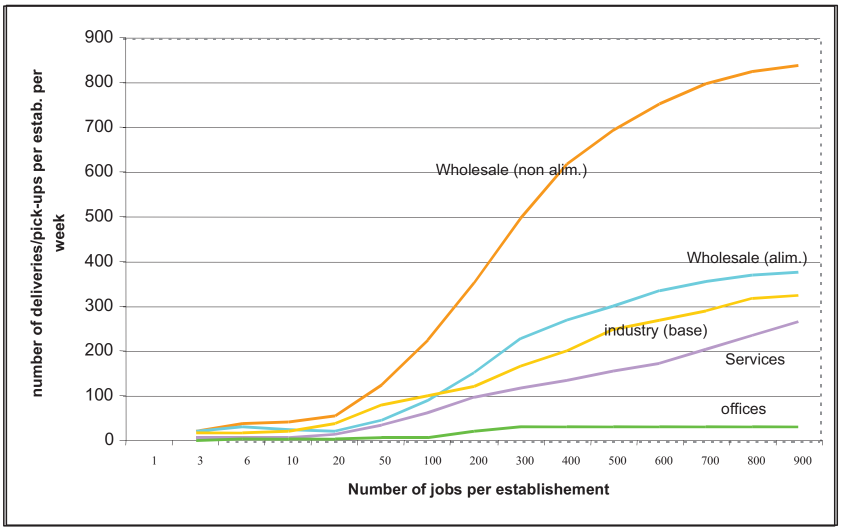


Figure 3: Some examples of curves of generation of pick-ups and deliveries according to the industry category. (number of movements of vehicles per establishment each week)

The curves shown above are an interpolation of the survey data according to the number of jobs. With the help of the national public registers of establishments, each zone is informed on the various types of generators according to its size (number of jobs) and its industry category. The number N_z of movements in a zone z is given by:

$$N_z = \sum_{e \in z} n_e\,(a,p,o)$$

According to the results of the surveys, a typology $\varepsilon(a,p,o)$ of 116 types of establishments (different industry category, with a decomposition according to the size and the nature of the premise) is built through the analyse of the surveys. This typology accounts for 30% of the variance of the whole number of movements.

The model calculates the breakdown of N_z according to the following types of transport services:

- three types of vehicles *v* (LGV<3.5t, rigid lorries and articulated vehicles).
- three modes of management of the transport *m* (third party, forwarder, consignee)
- two types of routes *r* (direct route, (often a full payload), round).

For each establishment category $\varepsilon(a, p, o)$ three parameters are calculated: the share of *v* types of vehicles (LGV, HGV - rigid and articulated); *m* operators (third party and own account - forwarder and consignee -); and *r* direct routes and of various size rounds (the latter consist of starting, ending trips and connecting trips). The number of goods movements balances the number of trips ensuing from the transport logistic behaviours defined above for each category, so that:

$$N_z = \sum_{\varepsilon,v,m,r} N_{\varepsilon,z}\,.\,f_{v,m,r}\,(\varepsilon)$$

where $f_{v,\,m,\,r}$ is the frequency of $(v,\ m,\ r)$ for the category ε and $N_{\varepsilon,z}$ is the number of movements generated by the establishments of category ε in the zone z.

Discussion: This calculation for the model was made possible, because the analyse of the surveys showed that the geography, the size and the shape of the town do not significantly affect the calculation of $f_{v,m,r}$. This is the reason why the number and the main characteristics of the movements generated by each activity is not significantly different from a town to another.

Those results confirm the hypothesis:

The urban logistic behaviour of the establishments is essentially steered by economic factors. The local factors (geography, network, location strategy of the firms inside the town) must be considered of second rate.

Trips generation

In an itinerary , three types of stops and trips are distinguished:

- for a direct route there are generally two stops (*dr*=2*;* one single loading, one single unloading), and two direct trips (*dt*=2; go and return).
- In a round:
  - the main loading/unloading point (position *p*=2 realised in the establishment where the vehicle is loaded for the delivery tours or unloaded for the pick-ups tours). Two trips are connected to this position, named starting and ending trip (*se*=2). Generally, one of those trips is unladen;
  - the ordinary delivery or pick-up positions (*dp* points) are touched by a connecting trip (*c* trips) or by a starting or ending trip. Thus *c* = *dp*-1

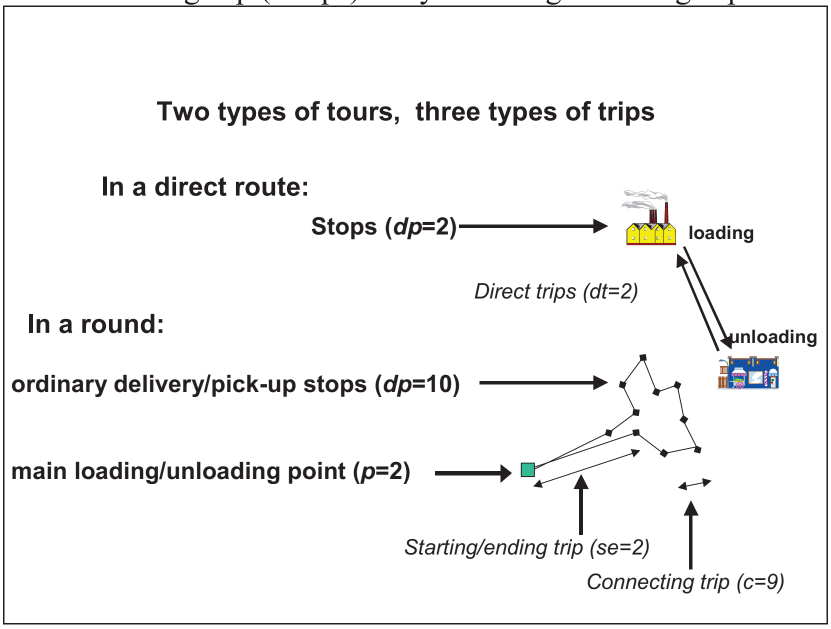


Figure 4: description of the routes

In a round with $n+1$ points, the last point is generally also the starting point *p* and the last trip is the go back of the vehicle to *p*. the number of trips *t* is therefore such as $t=n$.

The number of goods vehicle trips t_z generated in the zone *z* depends on the number of tours and on the number of deliveries and pick-ups in the zone.

$$t_z = 2 * dr_z + 2 * p_z + (dp_z - p_z)$$

where

dr_z is the number of direct rounds starting in *z*

p_z is the number of main loading or unloading points in *z*,

dp_z is the number of deliveries or pick-ups realised within a round in the zone *z*.

It is also: $t_z = dt_z + se_z + c_z$

where dt_z is the number of direct trips realised in *z*,

se_z is the number of starting and ending trips in *z*

c_z is the number of connecting trips beginning in the zone z.

Discussion:

The hypothesis for the calculation of the type of route choice are as following:
- the logistic and transport choice in an urban area is determined by several factors, like just in time, to minimise stocking up, to improve security for the goods and the vehicles, all factors related to the company strategy.
- apart the direct trips, the origin and destination of goods are distinct from the origin and destination of vehicles (see previous section). Thus, the optimisation of the itinerary by the hauler is performed according to non traffic references:
    - the type of available vehicle by the hauler,
    - the location of the main loading point and the length and time spent covered in the starting trip.
    - the nature of the payload (built up of each sending in the tour) and the time for loading/unloading at each point,
    - the opening schedules of each delivery point (different time windows according the activity, the location etc.),

For all those reasons:
- the urban freight modelling cannot follow the current inter-urban freight transport modelling approach (gravity model of commodity flows, with a simple linear payload factor in the vehicle traffic calculation).
- The real path and the way of the itinerary cannot be modelled, as soon as the modelled routes are not recreate.
- The length of each trips making up the route is calculated.

Distance generation

The number of covered kilometres is calculated according to the three types of trips.

i/ Modelling the length l_{dt} of the direct trips (*dt*)

Among the direct trips, the most discriminating variable is the type of vehicle. Next comes the size of the town (distance average weighted by the number of TD movements in each zone). Finally the mode of management of the transport (third party, forwarder and consignee) is also important:

o

Vehicle *v*	***dt* length average (km)**
<3,5t	8.7
Rigid lorry	14.1
Articulated truck	23.6
***wr*(*T*), Weighted radius of the Town (km)**	***dt* length average (km)**
Marseille (568 km2): 8.8	18.2
Bordeaux (928 km2): 6.3	11.7
Dijon (161 km2): 3.6	5.1
Operator	***dt* length average (km)**
Third party	18
Forwarder	12.9
Consignee	8.6

Table 3: determination parameters of the lengths of the direct trip

According to the type of vehicle used, the relationship between activity category and *dt* distances is not significant.

The equations for the direct trips length are following:

$$l_{dt}\,(v) = \alpha_v * wr(T) + \beta_v$$

vehicle *v*	*dt* length (km)	average (km)
<3,5t	$l_{dt} = 1.35 * wr + 0.24$	8.7
Rigid lorry	$l_{dt} = 1.82 * wr + 1.44$	14.1
Articulated truck	$l_{dt} = 2.84 * wr$	23.6

Table 4: characteristic function of length of the direct trips

Where: l_{dt} = direct trip length,

wr = radius of the town *T* weighted by the number of *dt* trips

The analyse of the residues of the l_{dt} model shows that they are independent on the mode of management and that the distance of the zone to the city centre may be integrated into the equation of the *dt* trip distance calculation.

The total distance *Ldt* generated by the traffic of *dt* in a zone *z* (km) is:

$$Ldt(v,z) = \sum_{\varepsilon,v} N_z \,.\, f_{\varepsilon,v}(dt) \,.\, l_{dt}(v) \qquad (1)$$

where $f_{\varepsilon,v}\,(dt)$ = frequency of the direct trips among the total of movements per category of establishment ε, for the type of vehicle *v*.

Discussion: The l_{dt} model shows the role of the size of the town on the direct trips distances. It shows also that, as regards *dt* (in that case, the goods trip are the same as the vehicle trips), the gravity factor of generalised cost between the origin and destination of the goods seems not relevant.

ii/ The length of the starting/ending trips

The main discriminating variable is the distance of the generator from the centre. A linear function adjusts the length of the starting trip according to the distance of the zone to the centre of gravity of the town (weighted by the number of movements):

The equation is as following:

$$L_z = \alpha * dc(z) + \beta$$

Where L_z: length of a starting/ending trip in *z,*

dc(z): "as the crow flies" distance of the zone *z* from the city centre

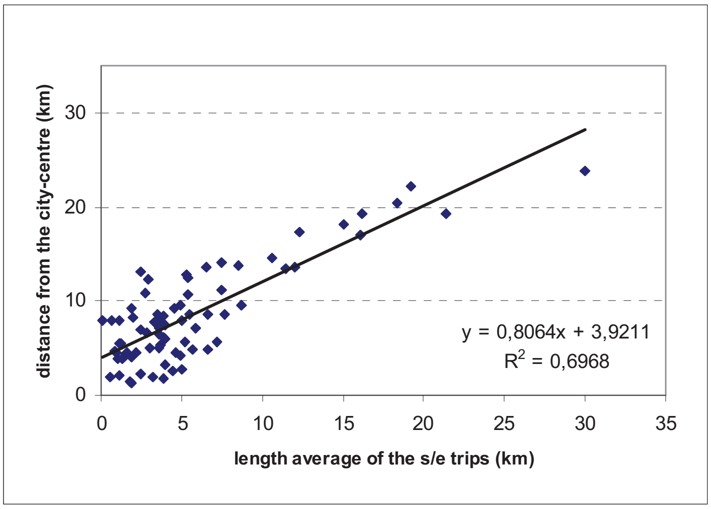


Figure 5: length average of the starting/ending trips according to the distance from the centre (distance between the centroïds).

The analyse of the residues of this starting/ending trips model shows that:

- it is efficient to distinguish between the basic sector (industry, wholesales, warehouses, agriculture) and the proximity activity (offices, handcraft and services, small retail, super- and hyper-markets).
- the starting/ending trip distances of third party, forwarders and consignees are different.

$$L_{z,\,m} = \alpha_m * dc(z) + \beta_m$$

Activity category	Mode *m* of management	α_m	p-value (*T* test)	β_m	p-value (*F* test)
Proximity activity	Consignees	0.54	1.3 E^{-04}	2.1	*0.1**
	other	0.54	1.1 E^{-05}	4.3	1.7 E^{-05}
Basic sector	Third party	0.81	1.5 E^{-7}	4.6	1.6 E^{-7}
	Forwarders	0.64	2.E^{-6}	5.7	2.E^{-6}
	Consignee	0.81	0.02	4.5	*0.22**

Table 5: determination parameters of the distances of the starting/ending trips (basic sector / proximity activities)

There was not enough observations to have a good estimation of the constant parameter for the consignee L_z-model.

The breakdown of the starting/ending trips among the total movements by rounds is not significantly different from a surveyed town to another. It is the reason why the following table is used in the model:

Category of activity *a*	Third party	Forwarder	Consignee
Services and handcraft	1%	11%	14%
Industry	10%	36%	34%
Wholesale	5%	19%	46%
Super / hyper-markets	5%	21%	0%
Retail (small shops)	1%	10%	87%
Offices	3%	20%	1%
Transport / Warehouses	72%	75%	100%

Table 6: Part of the *se* trips among the trips realised in rounds per activity category and mode of management ($=SE\%_{m,,a}$)

The total distances of *se* trips generated by the zone *z* is:

$$Lse(z) = \sum_{m,r,a,z} L_{m,z} \,.\, N_{m,r,a,z} \,.\, SE\%_{m,a}$$

Discussion: The determination of the length of the *se* trips depends on the mode of management. It is coherent with the fact that the part of the latter in movements in each activity category is very variable (see table above). The type of vehicle is not distinguished at this level, but it is possible to measure as follow the number of trips for each type *v* of vehicle:

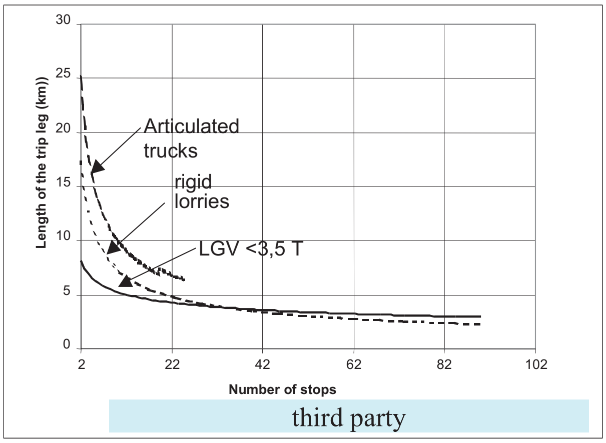
$$Lse(v,z) = \sum_{m,r,a,z} L_{m,z} \,.\, N_{v,m,r,a,z} \,.\, SE\%_{m,a} \qquad (2)$$

Where: $N_{v,m,r,a,z} = \sum_{\varepsilon \in a} N_{\varepsilon,z} \,.\, f_{v,m,r}\,(\varepsilon)$

iii/ The length of the connecting-trips

According to the results of the surveys, the main discriminating variables of the length *l* of a connecting-trip are:

1. the number of stops *s* in the round (more stops, more delivery-time and running time, therefore more short trips),
2. the type of vehicle *v* (light goods vehicles make especially express deliveries, with trips shorter than heavy goods vehicles),
3. the mode of management *m*, (round-trip distances of the third party operators are smaller because their trading areas are denser as the own account one's)



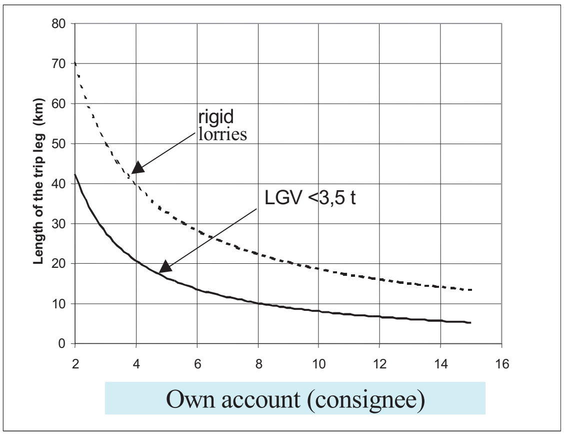


Figure 6: length of the connecting trips and discriminating variables

In order to take into account the spatial effects, two significant variables are added:

- the size of the town *T* (measured by the radius weighted by the number of movements *wr(T)*),
- the density of movements δ_z realised in the zones *z* (more dense are the zones, smaller are the round-trips, because of congestion and more trading opportunities)

$$l = \varphi(v, m, s, wr(T), \delta_{i,j})$$

Three classes of density δ were identified. The general function has this form:

$$l_{v,m,\delta}(s,T) = \alpha_{v,m,\delta} * log(s) + \beta_{v,m,\delta} * wr(T) + \gamma_{v,m,\delta} \quad (3)$$

Where $\alpha < 0$,

With three types of vehicles *v*, three modes of management *m*, three classes of density δ, a great number of relations was to estimate. In some situations, there was not enough observations to have a good estimation (R^2 too small, p-value of the coefficients too high), a more simple formulation was adopted. Finally, a system of 17 equations of type (3) was estimated, according to *v,m* and δ (Toilier et al., 2005a**).**
The total distances generated in the zone *z* by the connecting trips is:

$$Lc(v,z) = \sum_{m,r,a,z} l_{v,m,\delta}(s,T) . N_{v,m,r,a,z} . (1 - SE\%_{m,a}) \quad (4)$$

The total distance D_z (veh.km) generated by the activity of the zone *z* is as (1), (2), (4):

$$D_{z,v} = Ldt(v,z) + Lse(v,z) + Lc(v,z)$$

In order to justify the effect of the size of the vehicles in the congestion, it is useful to have a calculation of the traffic in car unit equivalent[1]:

$$D_z = 1.5 * D_{z,v1} + 2 * D_{z,v2} + 2.5 * D_{z,v3}$$

<u>Discussion :</u> The distance generated by the activity of each zone is calculated without having to assign the traffic on the network. The function which accounts for the resistance to the traffic is a density function. This approach is coherent with the fact that the length of the trips which make up the tours is modelled on the basis of the various types of transport logistics behaviour.

Calculation of the duration of parking for loading or unloading

As showed previously, an important factor of congestion in the dense areas is the double parking of the delivery vehicles. This is the reason why a model of parking time was developed.
According to the results of the surveys, the main discriminating variables of the duration of stops in a round-trip are:

- the type of vehicle, (e.g. the weight volume and size of packaging),
- the type of stop (*dt*, *se*, *c*),
- for the rounds, the number of stops *s*:

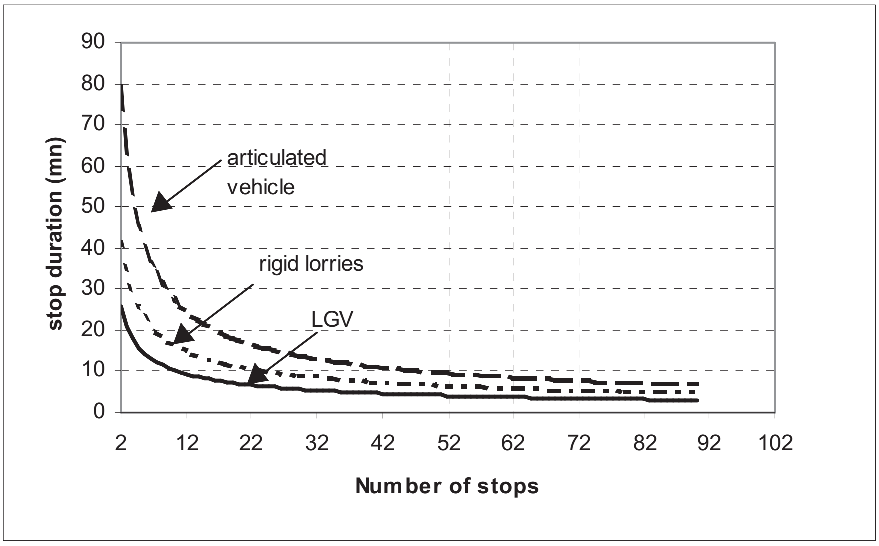


Figure 7: parking time according to the number of stops of the vehicle tour

$$t_{s,v} = \varphi(s, v)$$

- a density parameter of the zone (according to the density of inhabitants δp_z and the density of movements δm_z). It justifies the easiness for loading/unloading and parking facilities). It is a synthetic indicator of the available on road parking space.
- the type of activity delivered, (type of packaging, size of commodities, frequency of sending),

The parking may be realised in four situations:

- double parking on the road, which is the more frequent in dense areas,
- forbidden parking,
- on the street authorised parking,
- on private parking space.

As it is the main source of congestion, we focus on the double parking:

The total time for double parking in a zone *z* is:

$$Tdp_z = \sum_{s,v,m,r} t_{s,v} \,.\, dp_z\% \,.\, N_{v,m,r,z}$$

Where:

$t_{s,v} = \varphi(s, v)$ is the time average for delivering goods (Figure 7)

$N_{v,m,r,z}$ is the number of movements characterised by *v, m, r* in the zone *z*
$dp_z\ \% = \psi\ (\delta p_z, \delta m_z)$ is the part of deliveries realised in double parking in the zone z:

$$dp_z\ \% = \alpha * \delta p_z + \beta * \delta m_z + \gamma$$

The estimation of this function is such as:

$$\alpha = 0.00002;\ \beta = 0,00001;\ \gamma = 0,10013 \qquad \text{with } R^2 = 0.76$$

Discussion : as it was observed on the surveys, the double parking time is significantly dependant on the density of the trips emission zone. The weight of the population is twice the weight of the movements. The part of double parking is always above γ (10%).

Peak hours

The urban goods movement peak-hour is calculated from the breakdown of the deliveries type along the day according to the different activity types. Here we observed through the surveys that the hours of delivery and pick-ups are mainly function of the activity and few sensitive to the size and geography of the town. It is thus possible to define the peak hour in a town-model and to measure the goods traffic during and out of the passenger peak hours.

Trips distribution

As the model generates distances directly from the behaviour of the establishments and from the shape of the town, it is possible to throw of the step of origin-destination distribution matrix of the traffic to estimate the UGM flows (km) generated by each zone. It is thus possible to estimate the total traffic in a zoning of the town, according to a lot of characteristics: the different industry (116 types), the modes of management, three types of vehicles. This stage of the development of the model was performed in the version 2 of the software. (Routhier et al., 2002a). Several simulations have been realised with the model (Ambrosini et al., 2004b): location changes of the establishments - come back of commercial activities in downtown - Urban Distribution Centre.

However, several problems can't be solved if the distribution of the flows are not performed. As it is not possible to assign the traffic, the effect of new infrastructures cannot be measured, the spotting of the roads the most taken by goods traffic is not possible, the conflicts in using the roads between passenger traffic and goods traffic cannot be measured.

Different current methods used to carry out the distribution of the urban goods traffic proved to be inefficient. (Routhier et al., 2007). As the path of the goods in the urban areas are different from the path of the goods vehicles (75% of the deliveries are made in rounds with multiple delivery stops), the commodity flow distribution models seem not efficient. In other words, origin/destination of goods modelling is not useful for traffic modelling inside an urban area, under the hypothesis that the proximity of the consignee is not the main determinant for the industry location (the price of the ground, the accessibility to the interurban infrastructures are more important), the gravity model seems not efficient too.

For all those reasons, and in the light of the previous results, a probabilistic method for traffic distribution of the commercial vehicles between each area is carried out.

In the previous sections, the model calculates in each zone the breakdown of the deliveries and pick-ups, according to different factors, modes of management, mode of organisation (direct trips, starting/ending trips of a round, size of the round, types of vehicles), different industry categories. For those factors, the length average of the trips is calculated.

Except for the direct trips, an emission of goods (consignment) does not coincide with the emission of the vehicles. It is so not possible to build an oriented distribution matrix. Our aim is therefore to build a non oriented trips distribution matrix.

The distribution model calculates:

- the distance between two adjacent zones,
- the average speed between i and j
- the route choice.

With d_{ij} = "as the crow flies" distance between i and j,

The average rectilinear distance RD_{ij} from the zone i to the adjacent zone j

if $d_{ij} = 0$ then $RD_{ij} = 0$
if $d_{ij} > 20$ km then $RD_{ij} = d_{ij} * (1.21)$
otherwise:
$RD_{ij} = d_{ij} * (1.1 + (0.3 * e^{(-dij / 20)}))$
(ref: Gallez, 2000)

Speed is a decreasing function of a density indicator Δ_{ij}.

Δ_{ij} is the harmonic mean of the density of population and of the density of movements:

$$\Delta_{ij} = \frac{((Pop_i + Pop_j) + (Nz_i + Nz_j))}{(Surf_i + Surf_j)}$$

Where *Pop* is the population, *Nz* the number of movements, *Surf* the surface of the zone *z*

$$s_{ij} = \varphi(\Delta_{ij}) \text{ where } \varphi \text{ is a decreasing non linear function}$$

Actually, it is observed that the speed average on a small road is such as (Toilier, Routhier, 2005a):

$\Delta_{ij} < 2000$: s_{ij}=30 km/h
$2000 <= \Delta_{ij} < 8000$: s_{ij}=20 km/h
$\Delta_{ij} >= 8000$: s_{ij}=10 km/h

According to the fastest type of road linking i and j, the speed becomes:

small roads : $s_{ij} * 1$
fast lanes : $s_{ij} * 1.5$
highways : $s_{ij} * 2.5$

This rough calculation is efficient to obtain routes choices from a zone to another:

Route choice

The selection of the neighbouring zones is systematically carried out. A table of the go through zones is performed. In order to build the total distance between z_i and z_j, a macro-network is performed between the centroïd of the adjacent zones. The time average $Ŧ_{ij}$ to run from z_i to z_j is obtained by:

$$Ŧ_{ij} = (RD_{i1}\ / s_{i1} + RD_{12}\ / s_{12} + \ldots + RD_{nj}\ / s_{nj})$$

The choice of the "best" route is finally obtained by the "fastest path" Dijkstra algorithm applied on the macro-network:

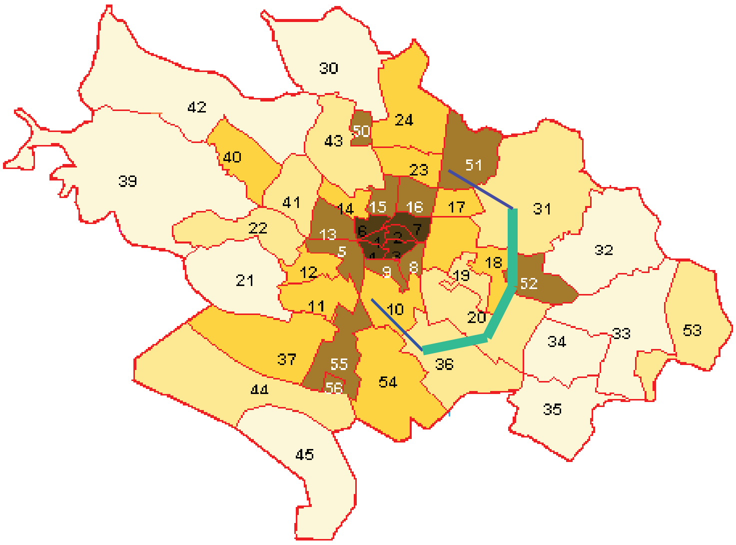


Figure 8: The fastest path from z $_{10}$ to z$_{51}$ *(city of Dijon, a 240,000 inh. Town in France)*

A typology $\{\tau\}$ of trips is performed according to the type of vehicle, the type of trip (*dt, se, c*), the mode of management *m* (third party, own account by forwarder or consignee) and the number of delivery stops in the routes. According to this typology (25 types), the beginning of each trip of type τ which touches the zone z_j, matches with the movements of type τ generated in z_i. As shown previously, a distance average of trip is allocated to each type of movement.

For each type of trips, in order to find the zones eligible to have a link with z_i, a two sided confidence interval of each average distance is calculated, in order to build a "ring" of zones open to be touched by such trips, as represented on Figure 9:

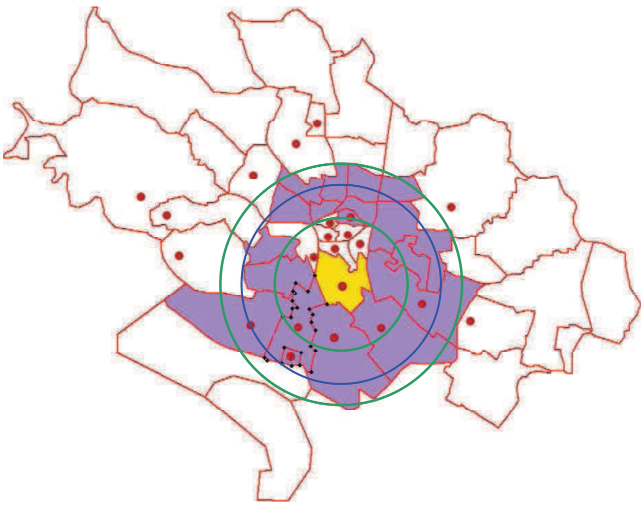


Figure 9: Example of the eligible zones for receiving the trips issued from the zone z_{10} *(Dijon, France)*

The distribution matrix is:

$$T_{ij} = [t_{ij}] = \sum_{v} [t_{ij}(v)]$$

Where t_{ij} is the sum of direct trips (go and return), starting, ending and connecting trips of tours from z_i. to z_j.

It is controlled that the eligible zones are able to host the trips emitted by the zone z_i. If the capacity of those zones is insufficient, the ring is widen in order to do eligible the bordering zones until having enough capacity.

An iterative probabilistic method is carried out for the distribution of the trips between z_i. and the host zones. Three rules are enforced:

- For each type τ, the zones z_i distributed first are those where the number of establishments of type τ is the most important,
- the host zones closer to the average distance are filled first,
- the breakdown of the movements per industry class (handcraft and services, industry, wholesale, great distribution, small retail, offices, transport and warehouses) is controlled.

The method is convergent and fulfils the following conditions:

$$t_{i,j}(v) = \sum_{m,r,a} N_{v,m,r,a,i} \,.\, f_{i,j}(\tau)$$

where f_{ij} is the factor of distribution of the τ trips from i to j

$$\mu_i(v) = \sum_{j} t_{i,j}(v)$$

where $\mu_i(v)$ is the number of movements realised in the zone i with a vehicle v.

This distribution model permits to feed a network distribution model. It may be calibrated on the basis of counts and cordon surveys. The first tests realised show that the results are coherent with the traffics observed on the main roads. A model on energy consumption and external effects (greenhouse effect gas, pollutant emissions) is also working on the same bases (Segalou et al., 2004, Toilier et al., 2005b)

DECISION MAKING AND SIMULATION EFFICIENCY

On that theoretical basis, a relevant software for decision-making aid is available. The results are essentially based on the road occupancy by the commercial vehicles. They are presented on a zoning, for each type of activity, with a distinction between the sizes of vehicles, third party or own account, direct trips or rounds. It is therefore possible to display an estimation of the number of deliveries and pick-ups, the number of kilometres and the number of hours for double parking. According to the type of vehicle, the type and the location of delivered activity and the density of each zone, a speed average is estimated as well as the energy consumption, greenhouse effect gas and pollutant emissions.

It is also a tool for local authorities, in order to simulate the freight transport in urban areas and to measure the impact of particular measures on the traffic, the energy consumption and environmental effects. Through the decomposition of the number of deliveries and pick-ups according to vehicles, shippers and routes, it is possible to simulate the effects of the following changes in the economy and land use:

- location and changes of the various industry activities, new urban logistics areas,
- business strategies (e.g. little units vs. supermarkets, co-operation between the firms).
- sensitivity to the logistic organisation (size of the vehicles, own account vs. third party),
- sensitivity to regulation (heavy vehicles ban, clean vehicles).

We can illustrate this chapter by the following results (Ambrosini et al., 2004b): in Lyon, a medium size city, the impact on the traffic flows of the relocation of seven urban distribution centres (UDC) is simulated. It was assumed that 20 % of the delivered weights in the central zones are capable to pass through a UDC. The traffic is estimated by the model as follows:

- considering only the relocation of UDC, we note a very small decrease in the travelled distances (- 0.6% of the total urban goods traffic in the reference scenario);

- considering the relocation with a co-operation between the stakeholders (aiming at an optimal restriction of the trading area of each UDC), the decrease is much more attractive: the saving reaches 384,000 km per week (-7% of the total urban goods traffic in the reference scenario).

Scenarios	Total km per week	Average km/trip LGV< 3.5 t)	Average km/trip rigid lorries	Average km/trip articulated vehicles	Average km/trip (all vehicles)
Reference	5,729,000	6.6	7.9	16.3	8.1
UDC	5,694,000	6.5	7.8	16.2	8.0
UDC + co-operation	5,345,000	5.9	7.4	15.8	7.5

Table 7: an example of results of a policy-oriented scenario

CONCLUSION

The reader can understand that the FRETURB model is yet a developing tool. Nevertheless, owing to its present performances it is used by the local authorities of two dozen of French cities. The main use of this software is to carry out a diagnosis of UGM for their Transport Master Plans. The city planners can have a better knowledge of the weight of the different economic stakeholder in goods, vehicles and trip length generation. The road occupancy by parking and running vehicles (in number of ~~hours*~~CUE*h per zone) is a good indicator of congestion and the matrix of distribution of three different sizes of delivery goods vehicles is an important outcome for feeding the current assignment traffic models. The current version of this software is coupled with the existing vehicle fleet according to their oldness in order to provide an appraisal of the environmental local (emissions of pollutants) and global impact (energy consumption and greenhouse gas) and to simulate the effects of policy. The main improvements of the model are therefore boosted by the demand coming from its users. Some of them are directly appointed by the weakness of the present version. The most important is due to the nature of available data: we only got cross-section data with the three surveys on three different cities. The new version will be based on more dynamic specifications, but we need for that time series data and consequently new surveys will be necessary.

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