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An emission model as an alternative to O-D matrix in urban goods transport modelling

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Abstract
This paper presents an alternative method to O-D matrix for estimating road occupancy of urban goods movement (UGM). The originality of the model arises on three elements. The first is that the modelling unit is the delivery operation, with all the elements that are associated to it. The second is that it follows an inductive approach, starting from a rich database, to define different generation functions without a priori applying a defined mathematical framework. The third is that the model is an emission one, i.e. we start generating the number of deliveries that are shipped by the different urban establishments, and not those attracted by them. First, the literature in the field is reviewed. Then, the main methodological elements are presented. We present here the delivery generation procedure and the route definition method. Finally, validation results for both parts of the model are critically discussed.

Keywords: urban goods modelling; category class model; delivery-based model; experimental analysis.

Un modelo de emisión como una alternativa a la generación de matrices O-D para modelar el transporte urbano de carga

Resumen
Este trabajo presenta un método alternativo a la matriz O-D para estimar los impactos del transporte de mercancías urbano. La originalidad del modelo está en tres elementos principales. La primera es que la unidad utilizada es la entrega. La segunda es que se sigue un enfoque inductivo, partiendo de una base de datos rica para definir las diferentes funciones generadoras sin utilizar a priori un marco matemático definido. La tercera es que el modelo es de emisión, es decir, se genera el número de entregas que envían los diferentes establecimientos urbanos, y no las que ellos reciben. En primer lugar, se realiza una revisión de la literatura para posicionar la investigación. A continuación, se presentan los principales elementos metodológicos usados, principalmente el procedimiento de generación de la entrega y método de definición de ruta. Finalmente, los resultados de validación para las dos partes del modelo se presentan y discuten críticamente.

Palabras clave: modelado de mercancías en medios urbanos; modelo de clasificación en categorías; modelo basado en la entrega; análisis experimental.

1. Introduction

Modelling is one of the main issues of city logistics. Although urban goods modelling is a research subject since 40 years [1,2], the subject is still of actuality nowadays. However, and opposing urban personal transport modelling, the classical four step model is not adapted to urban goods transport [3], so a multitude of approaches is proposed in literature [4-7]. We can therefore observe four main categories of models, related to the general sequential methodology they apply to estimate the impacts of urban goods transport: classical models with four steps, models with four steps adapted to urban goods transport and combined models, and category class models.

The first category (***classical four step models***) emerged in the 1970s. The aim of this first group of models was to characterise the transport demand of urban business and industrial zones to dimension infrastructures and promote the economic development of these areas [1-2, 8-9]. Other more exhaustive models included services, waste and construction [10-11]. Those models are built *using a logic very close to that of urban passenger transport*, using data from cordon line

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surveys, specific to each city and only focusing on the vehicle trip. The models follow the classical four-step procedure [12]: first, the number of vehicle trips for urban goods transport was generated by emission and attraction; second origin-destination pairs were obtained with a distribution model, generally using gravity or entropy minimisation methods; the third step (modal choice) is replaced by the choice of vehicle given the mono-modal nature of UGM. When necessary, traffic assignment (the fourth step) was implemented [13]. Several authors conclude that classical four step models are not adapted to the problem of UGM [3] because they do not take into account the LTL[1] nature of transport and other basic elements such as the type of and nature of goods, hence the interest of seeking new paths of reflection.

To deal with those limits, the second one adapts four-step models to the LTL nature of urban goods transport. This category, called ***adapted four-step models***, is closely linked to the distribution of business activities and thus transport for third parties. The main steps of this category of models are: (1) generation of needs for goods, (2) estimation of a goods O-D matrix, (3) construction of trip sequences, (4) estimation of a trip O-D matrix and (5) traffic assignment when necessary. For the first step, we therefore find econometric models that estimate the quantity of goods generated by an urban activity attracting goods then the quantity of goods emitted by each zone of influence in the city [14]. This quantity of goods is then distributed to obtain the first O-D matrix, which links the place of shipment and the place of delivery, mainly with gravity models [15]. Thirdly, routes are estimated from data obtained from specific surveys, by using discrete choice methods [16], route optimisation algorithms [14] or multi-agent simulation methods [17]. Then, on the basis of these routes, a second O-D matrix, for vehicle trips this time, is obtained. Finally, traffic assignment can be done by using classical algorithms [17].

The third category (***combined models***) is more difficult to define, as they combine two or more approaches. Ogden [18] was the first to make a distinction between goods O-D (commodity flow) and vehicle O-D (vehicle trip). . Sonntag [19] proposed using the Savings method frequently used for optimising rounds. In this way each round is built without knowing the quantity of goods. Hunt and Stefan [20] proposed a method based on a set of specific surveys to characterise mods of organisation, and used a discrete choice model to build the rounds. These methods do not comprise the generation of a goods O-D matrix rather they pass from generation to building rounds directly. A limit of that category of models arises on the fact all sequences of trips are rounds, i.e. that the point of departure and destination is the same, as several surveys have shown that this mode of operation only covers part of the trips made to transport urban goods. Another approach by Holguin-Veras et al. [21], started by generating goods O-D (generation and distribution) and then converting them into the stops of a round, to which were added returns and empty first legs, generated specifically. Routes were then built using discrete choice methods. A third group proposes the route as unit of generation. Generation is ensured in a way similar to that of the previous group, by using vehicle stops as the working unit. Each stop is then assigned to a round.

The fourth category is that of ***category class models***, that consist on dividing the entire set of establishment into classes then affecting a generation function. Then, different distribution functions can be assigned. A first group of models propose to generate deliveries using a category class model [22], focusing on generation at destinations, and then explore the origins, without necessarily coming to the definition of transport flows. A second group [23] aims to produce an estimation of travelled kilometres from a category class model based at destinations (so in attraction). This model proposes a method to estimate road occupancy issues based on transposition of survey adjustment coefficients and average values of route characteristics, always following category class approaches. Then, a distribution method can be used to obtain finally O-D matrices [24].

As seen in this synthetic overview (Table 1 presents a synthesis of those 4 categories), and to the best of our knowledge, urban goods movement models attempt to estimate flows by adapting and completing classical four-step models, sometimes introducing sound methodological innovations, but all of them produce O-D matrices to estimate then road occupancy impacts. Moreover, they start by generating attracted quantities of goods then affecting them to emission zones. Taking as goal to estimate road occupancy impacts, for city planners and in an aggregated way (i.e., by zone or by city) for an entire urban area (i.e. for a higher territory than a city centre), we can question the mono-approach viewpoint that supposes using only O-D matrix

Table 1.
Synthesis of main demand UGM models

Reference	Category	Unit	Implementation issues
[8] [1] [2]	Classical Four steps	Trip	Easy to assess, strong approximation
[9] [21] [10]	Classical Four steps	Delivery	Easy to assess, strong approximation
[25] [11] [26]	Classical Four steps	Trip	Easy to assess, strong approximation
[14] [17]	Adapted Four steps	Commodity	Difficult to assess, city (context) dependent
[3]	Adapted Four steps	Delivery and commodity	Operational tool used for local planning
[27]	Adapted Four steps	Trip	Strong object reduction due to lack of data
[28] [16] [30]	Adapted Four steps	Commodity quantity and trip	Model remains theoretical
[18] [29] [21]	Combined models	Trip and commodity	City (context) dependent
[19] [20]	Combined models	Round	Takes into account routes
[31] [25] [22]	Category class	Delivery-commodity	Easy to assess, context dependent
[23]	Category class	Delivery	Needs very detailed data

Source: Authors ‘elaboration from the literature review presented above.

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[1] Less-than-truckload, i.e. the organization of transport into routes having one origin and two or more destinations, opposing to TL (full truckload), where the transport goes directly from an origin to a unique destination, typical of inter-urban distribution [7]

estimation to then estimate road occupancy issues.
This question arises on two points: the first is that, if we get a zoning of a city and we can estimate routes entering the zone, we can, with empirical methods, estimate road occupancy issues without passing through the approximation of estimating O-D matrices with four-step models (whose errors and limits are clearly set in Ortuzar and Willumsen [12]. The second is that O-D matrices are able to estimate road occupancy by running vehicles, and work well when dealing with aggregated approaches at a city (or urban area level). However, those approaches make abstraction of the routes nature and are public-policy oriented.

As city logistics has been developed on an optimisation logic [32], it is important to relate it also to supply chains and to private carriers management issues [33]. Moreover, private carriers are more and more integrated into city logistics projects, and organizational issues become now as important as public policy actions. Indeed, in a first time, city logistics was mainly related to public decision support [34-36], but in the last years we show a highly increasing implication of private companies, mainly with an aim of optimization [37-39]. But in terms of modelling, all approaches are "public decision support" oriented or derive from frameworks related in a first time to public policy making. For that reason, we think it is important to propose a model that estimates urban freight transport demand from carriers' perspectives. Moreover, and since ITS and optimization methods in urban logistics need a good knowledge of demand [40] and the relations between territory and logistics are starting to be studied [41], it is important to develop data production methods that are not expensive and need few computational and financial efforts to support decisions in urban logistics management.

This paper aims to propose an alternative methodology to estimate road occupancy issues without generating O-D pairs. This methodology does not propose a new mathematical framework but aims to adapt and existing modelling methods to generate, non O-D matrices but deliveries at their origin, then routes which lengths and stop duration are first defined without a spatial assignment then related to the zones. The novelty is that the proposed model is an emission one, i.e., the generation is made at the goods origin, and then routes are associated to those deliveries using statistical approaches. First, the main methodological elements are presented. Then, calibration results are presented to show the suitability and the validity of the proposed model. Finally, as a conclusion, the model's main applications are described.

2. Methodology

2.1. Hypotheses, definitions and model structure

Before presenting the methodology, it is important to define the main targets, definitions and hypotheses behind the proposed model, to motivate it and introduce its main methodological choices. Although having spatial information is extremely important in planning, the main constraints of integrating urban goods in urban transport and mobility plans resume to identifying road occupancy issues, by zone, since such plans are established in a long term horizon and lead with general impacts on transport. In such plans, the aim is to make a diagnosis of current and future flows, both for personal and commercial transport (including goods), as well as to estimate the impacts of envisaged actions such as access limitations, infrastructural changes or the creation of logistics platforms or parking areas. In that context, road occupancy issues and other impacts such as pollution or GHG emissions, can be made without necessarily estimating O-D pairs, since the needed results are global indicators, aggregated by zone but do not necessarily need to assigned to a road network.

To do this, we need first to collect enough data, of enough quality and in a coherent way. Then we need to be sure such data are representative of the situation we aim to estimate. The choice of the modelling unit is then fundamental to ensure the model suitability. For that reason, we aim to whose not the trip or the quantity of freight, but the movement, intended the pickup or delivery operation at a location, as the observation and modelling unit, to have a coherence between data collection (surveys, described in [42]) and modelling. The movement is then not only a trip origin or destination, but a route stop, to which is associated a quantity of freight (here not considered, but being possible to consider as on [43], an operation (pickup, delivery or combined pickup and delivery), a type of establishment, nature of freight and loading unit.

Then, the model structure is defined. First, the number of deliveries of each establishment is generated at its origin, i.e. at the shipper's location. In parallel, those deliveries are empirically converted into routes, making abstraction of freight quantities in a first time (freight quantities will be able to be added further). Finally, to those routes, a travelled distance is estimated to finally obtain road occupancy rates by running vehicles.

2.2. Generation model

The generation model we present here is based on emission and not attraction. In other words, and opposing previous literature in which deliveries are generated at destination, we start by generating the demand at their origin, i.e. starting at a depot or warehouse, after which the potential destinations are assigned to that demand. Thus the generation methods used are not new (they derive from [41]), but they are applied differently (to demand emission at shipment origin and not to demand attraction at shipment destination). In other words, the aim of the model proposed is to generate urban goods flows by focusing on shippers and not on receivers. To do this, we considered an establishment e of an urban area. This establishment is defined by an activity class ae (i.e. the type of premises, in 35 categories). Moreover, a premise is defined by its number of employees emp^e. The number of deliveries dele that establishment e ships are then defined by (1):

$$del^e = f(emp^e, a^e) \qquad (1)$$

As shown in Holguin-Veras et al. [41], some categories of establishments have a generation function that depends on employment rates, but others have a constant generation function at destination. Moreover, a^e is a class variable.

Consequently, we proposed an index category class model for generating deliveries at origin. This therefore led us to partition a set of all premises into 34 categories[2] (according to the French Institute of Statistics and Economics, INSEE, in its classification at level 2):

$$\Pr = \{\Pr_1, \Pr_2, \ldots \Pr_i, \ldots \Pr_n\} \tag{2}$$

such that, $\forall e \in E_i$:

$$\begin{cases} del^e = f^{ae}(emp^e) & \text{if } a^e \text{ is employment dependent} \\ del^e = K^{ae} & \text{if an invariant can be demonstrated} \\ del^e = r^{ae} & \text{elsewhere} \end{cases}$$

where f^{ae} is a function (linear or not) of the employment, defined for each employment-dependent category *ae*;

K^{ae} is a constant, also defined for each corresponding category a^e;

r^{ae} is a random value, following a probability distribution (Normal or Rayleigh), also defined for each corresponding category a^e.

The choice of the probability distribution in non-invariant categories which are also not employment-dependent depends on the standard error s. If s>3*Average, we define a Rayleigh distribution (ref.) in order to avoid negative values. Elsewhere, a Normal distribution will be able to good approximate the probability distribution of the number of deliveries.

2.3. Route construction model

The proposed model generated the number of deliveries at each origin, for all establishment of a city or urban area. Opposing to other models, and for reasons of data needs, we aim to propose a model that do not need a big quantity of data in input, so with only generation inputs (at emission) and standard data inputs, the model has to be able to simulate freight transport routes in urban contexts.

When speaking about urban freight transport between two establishments, we observe three main modes of management of those transport flows. The first is that of third-party transport, i.e. the transport is carried out by a transport carrier; the second is that of shipper's own account, i.e. the transport is carried out by the shipper and made by his own vehicles and resources; the third is that of receiver's own account, i.e. the receiver goes himself by his own vehicle to pick up directly the freight from the shipper or an intermediary platform. The composition of those three modes of management in terms of percentage is different for each category. Moreover, the composition of the transport in terms of route length (in number of stops) is also related to both the category and the mode of management [25].

In this section we propose an empirical route construction procedure that assigns to each delivery generated a set of destinations and constructs a realistic route taken into account the composition of the urban delivery system, using data from the French Surveys on Urban Goods Transport [42]. The procedure is divided into 4 stages:

1. Definition of rates of own and third-party account to each category.
2. Definition of types of routes and characterisation of each category in terms of routes.
3. Empirical route construction procedure: Matching to cover all activities of the city.
4. Travel distance estimation: definition of an average first trip/last trip length and an average intermediary trip length.

One of the main characteristics of urban goods transport is the importance of own account transport (about 56% of the total traffic of goods transport in Bordeaux [42]. Since the fact establishments need to be delivered seems to remain invariant with respect to the city or the economic context [42], we can use the data of the French surveys (3 cities) to obtain average ratios that characterize the parts of own account transport for each category of establishments. In other words, given establishment *e* belonging to category *ae* and having a number of deliveries at origin in establishment *e*, noted del^e, we define P_m^{ae} the percetage of deliveries of each establishment of category *ae* that follow a mode of management *m*. We define three modes of management: third party transport (TPT); shipper's own account (SOA) and receiver's own account (ROA). Since the sum of deliveries made by each mode of management must be the total number of deliveries del^e, the following condition needs to be met:

$$P_{TPT}^{ae} + P_{SOA}^{ae} + P_{ROA}^{ae} = 1 \tag{3}$$

Assumming that each establishment *e* belonging to category *ae* has the same proportion of own account and third party transport, the number of deliveries del_m^e made by mode *m* are defined as:

$$del_m^e = P_m^{ae}.del^e \tag{4}$$

Then, we need to build routes. Given the category of establishment *ae* and the proportion of routes P_m^{ae} made by mode *m*, we define the average composition of routes extending the findings of Gonzalez-Feliu and Morana [45] to define the average characteristics of a route (in terms of number of deliveries, truck size and traveled distances).

3. Validation results

The generation model was calibrated on the basis of the Urban Goods Transport Survey of Bordeaux (France), performed in 1995 [42], although the data is not new, the results of that survey still appear coherent [44, 46]. Moreover, this survey presents a richness that was not

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[2] Categories are obtained from NAF codes (the French declination of European NACE codes) in an aggregation in 34 categories. For more information, see http://www.insee.fr.

Table 2
Main variant characteristics of the two measurements considered (significant results in bold)

			Linear regression results			Dispersion analysis		
Category	**Name**	**Sample**	**Coef-ficient**	**Adjusted R^2**	**Critical value of F**	**Average**	**Standard error**	**Retained model**
1	Agriculture	15	0.270	**0.810**	**1.593E-07**	2.800	3.802	Employment dependent
2	Craftsmen	17	4.058	0.217	0.025	14.882	54.167	Rayleigh
3	Industry-Chemical	21	0.016	-0.047	0.799	32.476	**2.770**	Constant
4	Industry-Intermediary	54	0.117	0.109	0.007	16.037	49.272	Rayleigh
5	Industry-Manufacturing	37	0.024	0.326	**8.590E-05**	3.081	2.597	Rayleigh
7	Intermediary distribution	57	0.446	**0.429**	**1.047E-08**	8.298	10.073	Employment dependent
8	Wholesalers-Non food	38	4.315	**0.424**	**3.142E-06**	42.526	107.539	Employment dependent
9	Wholesalers-Food	33	0.050	0.009	0.253	10.030	11.134	Rayleigh
24	Tertiary-Services	24	0.026	0.032	0.184	1.792	2.265	Rayleigh
25	Tertiary-Other	21	0.007	-0.046	0.735	2.650	5.373	Rayleigh
34	Heavy Industry/Construction	15	0.028	0.346	0.009	2.000	1.961	Rayleigh

Source: Authors ‘elaboration of the results of both linear regression and dispersion analysis presented above

exploited in precedent works, which were more focused on a global vision of the city and not on that of shippers. A sample of 454 representative establishments is surveyed, and each operation was surveyed for a week. Since the sample is small, and for reasons of statistical representativeness [47], only categories with more than 15 individuals in the sample are selected for the model calibration. In this way, the sample has been reduced to 332 establishments belonging to 11 categories of shippers. The categories non present in the analysis contain establishments that are receivers, but not shippers. This does not exclude the fact some shippers can also be receivers, but show, as seen in table 2, which categories are at the origin of freight transport flows: agriculture, craftsmen, industry, intermediary distribution (including logistics and transport operators when moving freight by themselves), wholesalers, construction and tertiary activities. On the basis of these data, two modelling approaches are applied: the first is a linear regression approach to study the relations between the number of deliveries generated and the workforce of the establishment, the second is a mean-standard error estimation to study the potential of applying constant generation rates.

Table 2 presents the main calibration results. From the French survey on Urban Goods Transport in Bordeaux we extract the 332 establishment from which we have complete records for transport emissions (i.e. shipments or routes having an origin at the surveyed establishment). We report in Table 2 respectively the sample size, the results of the linear regression and the results of the variance analysis. Finally, we reported which model was chosen for each category (either a constant rate or a linear function of the employment). Concerning linear regression, the model is considered robust if the critical value of F is lower than 1/1000. Moreover, this model is chosen if the R^2 is higher than 0.4 and the variance analysis does not show a strong invariance. Concerning variance analysis, we consider that a constant rate is suitable if the standard error is less than 10% of the average. We observe 3 robust employment-dependent models (categories 1, 7 and 8) and one robust constant rate model (category 3). For the rest of the categories, if the standard error is less than 1.3 the generation pattern can be seen as a random generation following a normal law (knowing both the average and standard error and assuming that the probability distribution follows a normal law). This is applied to categories 3, 4, 9, 24 and 34. Finally, 3 categories do not show a clear model that seems more robust than the others, while other possibilities exist for (categories 2, 4 and 25). We report in Table 3 the percentages of own account and third party transport in each retained category. Those results are extracted from the generalization of the Survey of Urban Goods Transport in Bordeaux (France). We observe a high predominance of third party transport (i.e., more than 2/3 of routes are third party managed) in four categories: chemical industry, intermediary industry, non-food wholesalers, and heavy industry. The other manufactory, tertiary and distribution activities present third party rates between ½ and 2/3 of the total. Only agriculture presents a lower rate (about 47%). For the report between shipper's and receiver's own account, receiver's own account (the most difficult part of transport to optimize) is usually lower than shipper's, except in chemical, intermediary industry and non-service tertiary activities. In any case, receiver's own account is present, as well as shipper's own account. With those results, we can state that classical models, based on LTL routes made by professionals (in general, the three first categories presented in section 1), will at their best underestimate transport flows (since third party transport is better optimized than own account transport) but also the number of routes.

Table 3.
Rates of own account and third party transport for delivery emission in the retained categories

Category	Name	P^{ROA}	P^{SOA}	P^{TPT}
1	Agriculture	39.72%	13.05%	47.23%
2	Craftsmen	53.42%	21.40%	25.17%
3	Industry-Chemical	10.60%	15.57%	73.83%
4	Industry-Intermediary	5.40%	17.96%	76.65%
5	Industry-Manufacturing	24.11%	12.81%	63.09%
7	Intermediary distribution	24.14%	9.26%	66.61%
8	Wholesalers-Non food	16.16%	14.00%	69.84%
9	Wholesalers-Food	36.83%	8.03%	55.15%
24	Tertiary-Services	22.33%	14.96%	62.71%
25	Tertiary-Other	23.51%	25.77%	50.72%
34	Heavy Industry/Construction	13.24%	2.86%	83.90%

Source: Authors' elaboration from French urban goods surveys 1995-1997

Table 4.
Average and standard error of the number of delivery stops for each route category

	Average number of delivery stops		
Route size category	TPT	SOA	ROA
TL routes (1 delivery)	1.00	1.00	1.00
2 to 10 deliveries	6.47	6.48	3.47
11 to 20 deliveries	15.49	15.69	11.03
21 to 30 deliveries	24.70	24.94	-
31 or more deliveries	45.95	30.49	-
	Standard error of number of stops		
Route size category	TPT	SOA	ROA
TL routes (1 delivery)	0.00	0.00	0.00
2 to 10 deliveries	2.37	2.19	1.83
11 to 20 deliveries	2.79	2.81	0.58
21 to 30 deliveries	2.58	2.34	-
31 or more deliveries	12.23	6.43	-

Source: Adapted from [45]

We report in Table 4 a synthesis of the results obtained from surveys concerning routes composition. We show the average and standard error of the number of delivery stops, aggregated for each category of route. We observe that TPT and SOA routes (i.e. third party transport and own account carried by shippers have a very similar behaviour for categories of route size up to 30 deliveries. The main difference arises in the weights mobilized as shown in [23], but for road occupancy issues the composition of the routes (before spatializing them) are very close. However, the spatial component shows an important role, and the first analyses of data surveyed show a significant difference in terms of travelled kilometres [42].

Receiver's own account (ROA) has its particularities, since it shows routes until 20 deliveries, which are collection routes (i.e., the receiver does not deliver goods but goes to shippers' locations to collect them). Those routes are less loaded than TPT and SOA delivery routes so less optimized [42].

Finally, we report in Table 5 the results of an application of the model on the standard dataset of Bordeaux (France) used in the Urban Goods Transport Survey. We selected a significant sample from the survey and adjusted it using the different survey's adjustment ratios. Then, we applied the proposed generation model on each category. The table can be read as follows. The two first columns show each retained category; the third column represent the total number of deliveries shipped for all establishment of each category, per week, obtained directly from the survey; the fourth column presents the generation results of the model, i.e. the same measurements but estimated using the proposed approach; the fifth column presents the gap between the two results (model vs. survey, so in percentage with respect to survey results).

We observe significant gap differences in each category, going from less than 1% (Non-food wholesalers) to about 35% (other tertiary activities), in absolute values. Most results are about 10 to 25% with respect to the surveyed data (in absolute values), which are, according to [12], good results in terms of approximation, taken into account the difficulty to collect data (data is declared by shippers and receivers, and no automatic measurement can be defined nowadays to survey the pickup and delivery operations' description), the adjustment errors and the data sampling bias [47].

Table 5.
Model application on a surveyed sample

Category		Weekly number of deliveries		
		Surveyed	Estimated	Gap
1	Agriculture	109	118	+8.8%
2	Craftsmen	376	357	-5.2%
3	Industry-Chemical	146	170	+17.0%
4	Industry-Intermediary	1232	1507	+22.3%
5	Industry-Manufacturing	654	560	-14.4%
7	Intermediary distribution	1401	1249	-10.8%
8	Wholesalers-Non food	681	687	+0.7%
9	Wholesalers-Food	311	407	+31.2%
24	Tertiary-Services	271	326	+20.3%
25	Tertiary-Other	923	1249	+35.4%
34	Heavy Industry/Construction	381	289	-24.1%

Source: Authors' elaboration (surveyed data is obtained from French urban goods survey, 1995-1997, estimated data using the proposed model).

4. Conclusion and further developments

This paper presented an emission model to estimate the impacts of urban goods transport. After a literature analysis, the methodology of the model has been presented, as well as details on its mathematical framework. Then, validation results have proposed.

We observe that urban goods transport present different particularities that classical O-D approaches do not represent accurately. Moreover, validation results complete those of [41] by confirming their findings (generation rates are not homogeneous and each category has different determinants in the generation of urban goods deliveries). Moreover, the alternative proposed by an emission model that generates global impacts instead of O-D pairs seems robust and can be used for different purposes, as for example in urban mobility plans (to include freight flows) or in the definition and assessment of new urban distribution schemes, mainly for setting an initial situation, among others.

However, this approach is exploratory and the route construction procedure is empirical and not still related to the space. However, using complementary procedures (as freight quantity generation models like in Gonzalez-Feliu et al. [48], and route spatial construction methods like in [45], this model can be a good tool to propose realistic VRP instances for city logistics problems, which are needed by the scientific community who uses for the moment theoretical instances [49,50].

Moreover, from survey data, a parking time can be associated to obtain road occupancy rates by stopped vehicles. This should be done in a similar way than the rest of the modelling approaches, i.e., in an inductive way in order to find the best relation between parking time, category of establishment and/or vehicle, mode of management and eventually freight quantity. We insist in the fact that using averages can be interesting at an aggregate level (or macroscopic), for example to obtain road occupancy issues at the level of an urban area, but when dealing with street planning (parking issues or retailing location issues in terms of delivery needs), or on logistics management (in terms of route needs) it is important to produce more information than an average, as for example a mathematical relation (either linear or not), a distribution probability or, for practical issues, a suitability range (i.e., a min-max range within which the generated ratios must be included, to complete the average value).

Further developments of the model include improving the route construction procedure to provide an analytical framework able to be adapted to any context, and the completion of the model by adding road occupancy issues by stopped vehicles, which will be obtained from surveys' data and associated to each delivery of each route by a similar generation-assignment procedure as the number of deliveries or goods quantities.

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