

Freight transport in urban areas: an integrated system of models to simulate freight demand and passengers demand for purchase trips

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Abstract—The urban transport system is a complex system in which freight is moved in the same transport structure in which passengers travel. Given that in many cases urban transportation modeling treats passenger and freight transportation separately, this paper proposes a modeling system to simulate goods movements at an urban scale which combines urban personal travel and commodity flows (commodity flows are generated in order to support a given need). Demand forecast is extremely important for the analysis and the modeling of transportation systems because the planning of infrastructures and services of transports results from the necessity to satisfy the needs of mobility and its characteristics. The scientific literature about freight transportation provides fewer studies than the literature about passenger transportation. Regan and Garrido [20] proposed a comprehensive state of the art of freight demand models, which can be classified into gravity models (Hutchinson [11] List and Turnquist [12]; Taylor [28]; Fridstrom [3]; Russo and Comi [21]), input-output models (Harris and Liu [5]; Marzano and Papola [13]), models of spatial equilibrium of the prices (Oppenheim [19]; Nagurney [15]). A classification followed by many authors distinguishes commodity-based from truck-based models. In paper the results of an experimental survey conducted in a medium-sized city are presented. The collected data allowed a system of demand models to be developed to simulate consumer trips and goods movements at an urban scale.

Keywords— Urban goods movements, end-consumer, freight, purchase passenger trips, demand models.

I. INTRODUCTION

THE structure of production, distribution and transport is undergoing rapid changes. On the one hand, globalization, European integration, market liberalization and increased spatial interactions led to a general increase in demand for transport creating growing problems of traffic and congestion on networks. On the other hand the growth in new techniques of production, distribution and handling of goods have led companies to radically change their concept of logistics, generating an impact on the type and quality of freight services required.

Travels to bring products and services to final customers increase (since the speed of delivery is added value) as they

increase to replenish the supply chain more frequently, in the view of just-in-time. This structure has resulted in improved productivity and efficiency, better quality, less used space and in a procedure of elimination of any unnecessary activities that does not add value in the process of transformation of goods, leading to the use of shipping lots smaller, more frequently and with a lower level of inventory. However, it has led to increased traffic of goods vehicles and the resulting increase of congestion, accidents and pollution.

In the freight market, road transport has easily won the challenge with a competitive rail cargo sector unable to manage a global offer in terms of punctuality, reliability and security of service. The existing imbalance between modes of transport is still one of the most critical factors for sustainable growth of the transport system in Europe.

The road transport has many virtues (it's flexible, penetrating, safe, does not forces to breaking load) and also appears to be the cheapest on the middle distance, ignoring the "negative externalities" resulting.

As is well known this type of transport is the most polluting among all. Furthermore, given the fragmentation of supply, it is very difficult to control and optimize and therefore it is also expensive.

The centrality of freight for the European economy and quality of life implies the urgent need to address the challenges in efficiency, quality and sustainability.

A significant proportion of responses to a series of problems depends on freight transport: congestion, pollution, climate changes (transport of goods produces one third of total CO₂ emissions from transport), impact of rising energy costs and safety.

The absence of concrete and decisive measures lead inexorably to the final decline of urban areas, ideally designed as places where living and do economic, social and recreational activities.

The distribution of goods in urban areas affects also significantly over the city and traffic due to the amount and dimension of commercial vehicles, their frequent stops (often at the roadside), emissions of diesel engines subject to continuous accelerations and decelerations and noise of vehicles and handling of packages.

In view of urban areas more and more congested, it is necessary to define solutions on the basis of a careful examination of the mobility structural factors, specifically through the valuation of demand, rather than focusing exclusively on supply.

Freight demand models are one of the key components of the transport plans at the strategic, tactical and operative level. Local authorities need to predict future transport requirements both for passengers and freight so as to plan the development of infrastructures and related human resources. The private sector requires models to predict transport service demand in order to evaluate future needs. This applies both to transport service managers, producers of consumer goods and firms using transport services, as well as manufacturers of commercial vehicles (White Paper, 2001).

Over the last few years, the need to use mathematical models for analysing urban freight transportation system has increased. A better organization of the territorial logistics can have positive effects not only on regional economy but also on people quality of life, because it entails the reduction of traffic congestion and consequently of many problems such as air and noise pollution.

Observations on passengers mobility must be connected to the observations on freight transportation since only in an overall view, which takes in account both flows characterizing a determined area, it is possible to find effective solutions. The importance of considering both components (people and commodities) in every urban transport policy, is underlined in the Green Paper published in 2007 by the CCE.

The purpose of this paper is the development of a demand models system for medium cities that allows the local authorities to evaluate the passenger trips for purchases and the commodities movements, differentiating by type of good and considering as decision-maker the “family” or a family component (end-consumer).

II. STATE OF ART

The scientific literature about freight transportation provides fewer studies than the literature about passenger transportation.

Regan and Garrido [20] proposed a comprehensive state of the art of freight demand models, which can be classified into *gravity models*, similar to those used in the passenger analysis (Hutchinson [10]-[11]; Ogden [17]-[18]; List and Turnquist [12]; Taylor [28]; He and Crainic [6]; Fridstrom [3]; Gorys and Hausmanis [4]; Russo and Comi [21]-[22]-[23]; Nuzzolo, Crisalli and Comi [16]), *input-output models* (Harris and Liu [5]; Marzano and Papola [13]), *models of spatial equilibrium of the prices* (Oppenheim [19]; Nagurney [15]). A classification followed by many authors distinguishes commodity-based (e.g. Ogden [18]) from truck-based models (e.g. Taniguchi and Thompson [24]; Munuzuri, Larraneta, Onieva and Cortes [14]).

The general structure of commodity-based models is based on a sequential approach similar to that used for the analysis of

passenger mobility, not estimating the number of trips but the quantity moved between two traffic areas. These models study the relationship $d-w$ (retailers-wholesalers). They consists of a generation model (in quantity), a distribution model (in quantity), a choice of mode/service model (from quantity to vehicles), an assignment model. An alternative to this approach is to summarize into a single step the first three steps. An equilibrium model of urban passenger travel and goods movement was proposed by Oppenheim [19], in which commodity flows are generated by the need to support a given generic urban activity undertaken by individual travellers, which involves consumption of a given commodity. Travellers are assumed to maximize their utilities, through their joint choice of an activity site and travel route to it. Activity suppliers also maximize their utilities through their joint choice of commodity suppliers and freight shipping routes.

Input-output models and models of spatial equilibrium of the prices are typically commodity-based or monetary-based models.

The truck-based models, however, directly estimate the movement of commercial vehicles.

It's possible to identify, even in this case, two subcategories: a sequential approach and an direct estimation approach.

Ambrosini, Routhier, Sonntag and Meimbresse [2] propose an overview of freight demand models in urban areas in the European scene, starting from the results of BESTUFS and describing some models developed in Germany, Italy and France.

Many of the models in the literature, however, do not take into account the integration of freight movements with other components of urban mobility. They focus on the movements between firms (producers) and distribution centers on a wide scale. They seldom consider the possibility of combining freight and passenger flows, and representing the interacting behavior of commodity consumers and commodity suppliers/shippers/retailers. Such models are thus unsuitable for forecasting the impacts and simulating the effects of transportation measures on a small scale.

In Russo and Comi [21] is the first formulation of a system of models to simulate passengers shopping trips and to determine the flow of commercial vehicles used to carry goods on the urban network.

Russo and Comi [22] classify freight demand models on the basis of six elements, namely the following criteria:

- modeling structure, which concerns partial share or direct/joint models to simulate explicitly or otherwise, and sequentially or simultaneously, the mean characteristics of the freight transport system;
- reference unit, which can be the commodity or the vehicles;
- distribution channel, which can be pull or push;
- aggregation level, which regards the data aggregation used for both specification and calibration of the model and for its application;
- user behavioural assumptions, which refers to the use of

behavioural or descriptive model;

- level of integration with passenger models.

In recent years the interest of researchers has been directed toward *urban freight platforms*. This urban freight platform, called Urban Distribution Center (UDC), requires particular models in order to define the optimal size and location, as well as assess the impacts of their introduction. The concept of logistic terminals (multi-company distribution centers) has been proposed in Japan to alleviate traffic congestion and reduce environmental, energy and labor costs (Taniguchi and Thompson [24]).

Finally, in order to analyze the *stakeholder behaviour* related to some measures, a methodology for evaluating city logistics measures considering the behaviour of several stakeholders associated with urban freight transport is proposed by Taniguchi and Tamagada [27]. They consider five stakeholders: administrators, residents, shippers, freight carriers and urban expressway operators. In the urban areas of NYC a survey was carried out and the results are discussed by Holguin-Veras and Patil [8]. The study shows the great complexity and nuances that exist in commercial deliveries. A similar initiative was developed in the United Kingdom by G. Allen, Tanner, Browne, Anderson, Christodoulou and Jones [1].

The interactions between the freight agents at urban scale were studied by Wisetjindawat, Sano, Matsumoto and Raothanachonkun [30] who proposed a micro-simulation model for urban freight movement in which the behaviour of freight agents and their interactions in the supply chains are incorporated. Application to the Tokyo Metropolitan Area is also described. Holguin-Veras and Wang [9] developed a hybrid micro-simulation modeling framework in order to construct commercial vehicle tours that satisfy a known commodity flow origin-destination matrix in an urban freight market.

The proposed modeling framework is applied to an 84-node test case and shows that several variables have significant impacts on the choices of destination location and the decision whether or not to return to base on each tour.

For recent developments on urban freight methods and models, the reader can refer to Thompson and Taniguchi [29].

III. PLANNING AND DESIGN OF THE DATA COLLECTION SURVEY

In order to specify and calibrate a system of models to analyze simultaneously the mobility of passengers for purchases and to estimate the amount of different types of goods handled in urban areas, it was necessary to design a campaign of surveys aimed at building a database to highlight the explanatory variables.

Following the definition of the geographical areas identified in the conurbation Cosenza - Rende - Castrolibero, the research has started from a careful analysis of the commercial structure of the study area and then to focus on the analysis of consumption of resident families for different product

categories and characteristics of movements related to them.

The study area was divided into 32 uniform traffic areas that represent the whole choice of destination, although an effective and practical attraction is attributable to the seven areas with the highest commercial density.

The division of the territory in homogeneous traffic areas was carried out by aggregating census particles, that is the basic territorial units used by Istat (the Italian National Institute of Statistics) at the general population census, to ensure uniformity of socio-economic attributes (resident population, working population, etc.) within each area. In this way, the boundaries of traffic areas are coincident with the



Fig. 1 the study area

boundaries of census parcels that compose it.

The bundling of census sections was performed taking into account spatial homogeneity, comparing the indices of population density, the number of employees in different work sectors of each section, the physical homogeneity whereas any physical division element between different areas, the transport uniformity, by combining sections whose accessibility is ensured by the same infrastructure of the transport system.

The activities have been, as follows:

- home surveys at 939 families residing in the conurbation Cosenza - Rende - Castrolibero;
- destination surveys addressed to 663 consumers living in the conurbation Cosenza - Rende - Castrolibero at major shopping centers located in the study area.

The campaign of surveys among families allowed to define, for each household interviewed and for different product categories, socio-economic data (area of residence, household income, household members, education level and employment status of the interviewed, number of owned cars, driver's licenses number) and informations on quantities consumed, movements for purchase made, modes of transport used, favorite days, timeframes, preferences in the choice of places for purchases and size of each purchase.

The destination interviews allowed to analyze user behavior in the purchase of different product categories, in terms of time taken to the purchase, number of people of the group who went at the market, mode of transport used, size and influence of good characteristics such as price, brand, warranty, delivery of

Table. I commodity types analyzed

Non durable (with daily replacement)	Non durable (with weekly replacement)	Durable
Dairy products	Water	Herbalist's products
Bread	Sparkling drinks	Pharmaceuticals
Egg	Fruit juices	Tobacco
Fruit and vegetable	Alcoholic drinks	Ironmongery products
Meat	Coffee	Electric materials
Pastries	UHT milk	Chemical products
	Pasta and rice	Flowers and plants
	Sweets	Toys
	Fresh fish	Books, magazines and newspapers
	Deep-frozen food	Stationery products
	Canned products	Music products
	House cleaning products	Optical products
	Personal care products	Jewellery
		Sport products
		Clothing
		Footwear
		Household appliances

goods on the preference of the product.

Regarding the studied categories, 19 types of non-durable goods and 17 types of durable goods have been distinct (Table I). In particular, for non-durable goods a further distinction has been made between non-durable goods to daily replacement (e.g. bread, milk, fruits, vegetables, etc.) and non-durable goods in weekly replacement (e.g. pasta, UHT milk, frozen products, etc.). Instead, with regard to durable goods, reference is made to the ATECO 2002 classification (Code of Economic Activities).

IV. THE SYSTEM OF MODELS

In the system of models proposed three different approaches are characterized: a *trip-based* approach, a *quantity-based* approach, a *purchase-based* approach (Fig. 2).

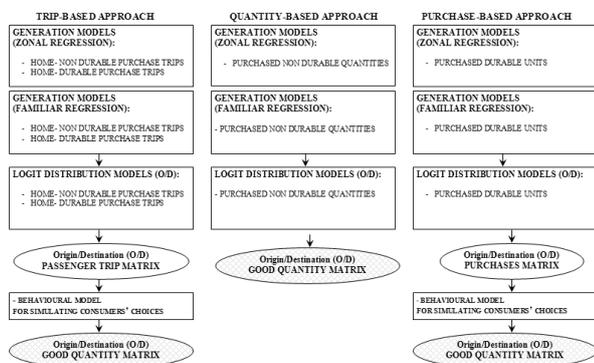


Fig. 2 the system of models

Generation models allow to estimate for every type of non durables and durables in Table I:

- the number of daily trips for purchases originated from the zone o for the commodity type k (trip-based approach);
- the quantity of non durable of type k that every day is attracted (consumed) from o (quantity-based approach);
- the number of durable daily purchases originated from every zone o for the commodity type k (purchase-based approach).

Distribution models for non durable goods with daily replacement, for non durable goods with weekly replacement and for eight groups of durable e non durable goods have been specified, calibrated and validated. For every approach, different specifications have been formulated, diversified for typology of commodity, considering as attributes of choice: the air distance among the centroids of the zones; the number of retailers (trip-based) and the number of retail shops (quantity-based and purchase-based) of goods of type k in the zone d ; a dichotomous variable that is equivalent to 1 if a shopping center is present in d ; a dichotomous variable that is equivalent to 1 if the trip from o to d has been gone by auto; a dichotomous variable that is equivalent to 1 if the net annual income of the family is superior to 40.000,00 €; spatial dominance variables.

At a third level, some logit models simulating the choices of the size of purchased goods are proposed, in which consumer socio-economic characteristics (income, number of family members, number of people making the purchase) and product characteristics (price, assistance, instalment) are introduced as attributes in the utility function. Purchased product units are then converted into quantities of goods. Models of choice of the purchase dimension allow to convert, in the trip-based approach, the trips in quantities and, in the purchase-based approach, the units purchased in quantities.

V. GENERATION MODELS

The generation models enable to assess:

- the number of daily shopping trips issued by area o for the product category k (trip-based approach);
- the quantity of commodity type k that is attracted (consumed) every day from the area o (or quantity-based approach);
- the number of daily purchases generated by each area o for the product category k (purchase-based approach).

The estimates were obtained as a function of both number of households and number of residents in the area of traffic o considered. The k categories considered are:

- non-durable goods with daily replacement: dairy products, bread and pasta, eggs, fruits and vegetables, meat, fresh pastries;
- changed weekly non-durable goods: water, soft drinks, fruit juices, carbonated non-alcoholic beverages, coffee, UHT milk, pasta and rice, sweets, fresh fish, frozen products, canned food, household products, products for

the person;

- durable goods: herbal products, pharmaceuticals, tobacco products, hardware and metal products, electrical equipment, chemicals, plants and flowers, toys, books, newspapers and magazines, stationery, music, optics and accessories, sporting goods, textiles and clothing, footwear, household appliances.

The regression model for estimating of the number of shopping trips N_o^k takes two different formulations that take into account the number of resident households (1) or number of residents (2) in the traffic zone o :

$$N_o^k = \beta_{fam}^k \cdot N_{o,fam} \tag{1}$$

$$N_o^k = \beta_{res}^k \cdot N_{o,res} \tag{2}$$

where N_o^k is the number of trips of type purchases, made for the purchase of generic goods of type k required in the area o [movements/day], β^k is the coefficient for the type of commodity k , $N_{o,fam}$ is the number of families living in each area of traffic o , $N_{o,res}$ is the number of residents in each traffic area o .

The regression model for estimating the quantities of goods consumed Q_o^k takes two different formulations that take into account the number of resident families (3) or the number of resident people (4) in the traffic zone o :

$$Q_o^k = \beta_{fam}^k \cdot N_{o,fam} \tag{3}$$

$$Q_o^k = \beta_{res}^k \cdot N_{o,res} \tag{4}$$

In the case of durable goods (*purchase-based approach*), the generation model provides, for each type, the number of daily purchases generated by each traffic area o :

$$Acq_o^k = \beta_{fam}^k \cdot N_{o,fam} \tag{5}$$

$$Acq_o^k = \beta_{res}^k \cdot N_{o,res} \tag{6}$$

In Table II the results obtained from the calibration models are reported, differentiating by commodity type and approach.

All the models prove largely the statistical tests on the overall goodness of the estimate, in particular ρ^2 ranges in a minimum of 0.8943 for the category metals and hardware (*purchase-based approach*) and a maximum of 0.9974, achieved for the model related to the pasta category (*quantity-based approach*).

Table II Generation models

Commodity type	Trip-based approach			Quantity-based approach			Purchase-based approach		
	β_{fam}^k	t	β_{res}^k	β_{fam}^k	t	β_{res}^k	β_{fam}^k	t	β_{res}^k
Dairy products	0,395	19,4	0,107	19,4	0,63	29,0	0,172	30,1	
Bread	0,477	31,9	0,130	33,0	0,51	32,1	0,139	38,9	
Egg	0,151	36,4	0,041	34,0	0,08	24,8	0,023	22,4	
Fruit and vegetable	0,281	21,3	0,041	21,0	0,68	30,4	0,183	25,9	
Meat	0,188	37,7	0,051	36,3	0,33	19,7	0,090	19,3	
Non-durable (with daily replacement)									
Pastries	0,057	31,3	0,016	36,3	0,05	34,8	0,014	36,8	
Water	0,138	29,4	0,038	33,7	2,37	28,7	0,646	31,2	
Sparkling drinks	0,107	21,8	0,029	22,7	0,34	25,4	0,092	25,8	
Fruit juices	0,103	29,1	0,028	28,8	0,23	33,7	0,062	35,0	
Alcoholic drinks	0,082	32,7	0,022	30,2	0,19	40,4	0,053	36,5	
Coffee	0,188	37,7	0,020	71,5	0,09	27,1	0,024	30,8	
UHT milk	0,105	22,0	0,029	21,1	0,24	36,6	0,066	34,3	
Pasta and rice	0,120	26,8	0,033	29,5	0,43	65,0	0,116	55,3	
Sweets	0,117	46,2	0,032	60,7	0,16	89,2	0,043	70,2	
Canned products	0,107	75,5	0,029	58,7	0,14	42,1	0,038	35,4	
Deep-frozen food	0,102	40,1	0,028	46,6	0,16	60,8	0,043	58,6	
Fresh fish	0,104	27,2	0,028	23,7	0,12	46,3	0,034	41,0	
House cleaning products	0,082	48,3	0,022	33,3	0,16	53,2	0,044	57,1	
Personal care products	0,075	40,3	0,020	38,2	0,07	29,7	0,019	29,8	
Durable									
Herbalists products	0,025	37,7	0,007	53,9			0,068	30,5	0,019
Pharmaceuticals	0,107	34,0	0,014	30,8			0,133	37,5	0,036
Tobacco	0,255	25,9	0,006	23,5			0,336	67,6	0,119
Ironmongery products	0,013	28,8	0,003	26,5			0,022	27,1	0,006
Electric materials	0,013	39,7	0,004	36,9			0,046	40,4	0,013
Chemical products	0,006	30,3	0,002	28,0			0,029	34,2	0,008
Flowers and plants	0,024	71,8	0,006	44,9			0,036	39,1	0,010
Toys	0,008	34,5	0,002	34,9			0,010	37,0	0,003
Magazines and newspaper	0,295	34,9	0,080	30,4			0,431	30,9	0,117
Stationery products	0,021	37,6	0,006	34,6			0,147	35,8	0,040
Music products	0,007	28,8	0,000	30,0			0,011	37,7	0,003
Optical products	0,011	23,5	0,003	21,7			0,016	33,5	0,004
Jewellery	0,003	50,6	0,001	36,4			0,004	51,3	0,001
Sport products	0,007	31,5	0,002	27,3			0,029	32,2	0,008
Clothing	0,011	46,4	0,003	38,1			0,046	43,6	0,013
Footwear	0,007	34,4	0,002	34,3			0,026	32,7	0,007
Household appliances	0,003	29,2	0,001	32,3			0,004	24,0	0,001

Using more disaggregated categories, made possible by the high number of information gathered from sample surveys, allowed to specificate, calibrate and validate family regressions, according to socio-economic variables such as the size of the household (number of components of the familiar nucleus) (DF), the level of annual net income (MLA) and the car availability (DA) are used to estimate: the daily trips N_i^k made by the generic family i residing in the traffic area o to purchase goods of the product category k , in the *trip-based* approach (7); the Q_i^k daily amounts of non-durable goods of k category, in the *quantity-based* approach (8) and the number of purchases of durable goods of category Acq_i^k generated by a generic family residing in o , in the *purchase-based* approach (9).

$$N_i^k = \beta_{DF_i}^k \cdot DF_i + \beta_{DA_i}^k \cdot DA_i + \beta_{LRD_i}^k \cdot LRD_i \tag{7}$$

$$Q_i^k = \beta_{DF_i}^k \cdot DF_i + \beta_{DA_i}^k \cdot DA_i + \beta_{LRD_i}^k \cdot LRD_i \tag{8}$$

$$Acq_i^k = \beta_{DF_i}^k \cdot DF_i + \beta_{DA_i}^k \cdot DA_i + \beta_{LRD_i}^k \cdot LRD_i \tag{9}$$

In Table III the results of the calibration models for each approach and for each commodity type under investigation are reported. All the presented models prove the statistical tests on the overall goodness of the estimate, in particular ρ^2 ranges in a minimum of 0.2654 for the category optical and accessories (*trip-based approach*) and a maximum of 0.9239 for the category products for the individual in the *trip-based* approach).

Table III Family regression models

Commodity type	Trip-based approach			Quantity-based approach			Purchase-based approach		
	$\beta_{DF}^k(t)$	$\beta_{DA}^k(t)$	$\beta_{LSD}^k(t)$	$\beta_{DF}^k(t)$	$\beta_{DA}^k(t)$	$\beta_{LSD}^k(t)$	$\beta_{DF}^k(t)$	$\beta_{DA}^k(t)$	$\beta_{LSD}^k(t)$
Dairy products	0.087 (15.8)	0.072 (2.99)	-	0.168 (57.4)	-	-	-	-	-
Bread	0.101 (19.6)	2.7*10 ⁻⁶ (5.3)	-	0.127 (27.5)	1.1*10 ⁻⁶ (2.5)	-	-	-	-
Egg	0.023 (12.4)	0.035 (7.0)	5.1*10 ⁻⁷ (3.1)	0.014 (8.2)	0.018 (2.4)	3.9*10 ⁻⁷ (2.5)	-	-	-
Fruit and vegetable	0.035 (17.6)	0.063 (7.3)	-	0.109 (11.2)	2.9*10 ⁻⁶ (3.3)	0.187 (4.6)	-	-	-
Meat	0.035 (17.6)	0.063 (7.3)	-	0.069 (14.8)	0.041 (2.1)	9.9*10 ⁻⁷ (2.4)	-	-	-
Pastries	0.006 (4.8)	0.063 (3.5)	4.9*10 ⁻⁷ (4.4)	0.008 (6.1)	0.012 (2.3)	3.4*10 ⁻⁷ (2.3)	-	-	-
Water	0.021 (8.5)	0.029 (2.8)	8.9*10 ⁻⁷ (4.1)	0.454 (13.2)	-	1.8*10 ⁻⁵ (5.3)	-	-	-
Sparkling drinks	0.0148 (7.3)	0.038 (4.9)	5.6*10 ⁻⁷ (3.1)	0.074 (12.8)	-	1.9*10 ⁻⁶ (3.3)	-	-	-
Fruit juices	0.018 (10.1)	5.3*10 ⁻⁷ (3.3)	0.0237 (3.1)	0.061 (41.7)	-	-	-	-	-
Alcoholic drinks	0.014 (9.0)	-	7.2*10 ⁻⁷ (4.4)	0.053 (38.1)	-	-	-	-	-
Coffee	0.024 (5.5)	0.011 (10.9)	3.4*10 ⁻⁷ (3.7)	0.024 (34.5)	-	-	-	-	-
UHT milk	0.018 (7.3)	0.043 (4.0)	-	0.048 (9.3)	0.075 (3.3)	-	-	-	-
Pasta and rice	0.022 (16.3)	0.037 (6.2)	-	0.103 (33.9)	0.055 (4.2)	-	-	-	-
Sweets	0.023 (13.5)	0.035 (4.7)	-	0.042 (42.8)	-	-	-	-	-
Canned products	0.016 (10.1)	0.056 (8.2)	-	0.027 (14.5)	0.045 (5.5)	-	-	-	-
Deep-frozen food	0.014 (11.9)	0.029 (5.6)	6.1*10 ⁻⁷ (5.6)	0.034 (21.6)	0.039 (5.7)	-	-	-	-
Fresh fish	0.009 (6.3)	0.042 (6.4)	7.9*10 ⁻⁷ (5.8)	0.020 (9.6)	0.023 (2.5)	7.7*10 ⁻⁷ (4.1)	-	-	-
House cleaning prod	0.013 (17.8)	-	9.1*10 ⁻⁷ (12.2)	0.030 (33.8)	0.041 (11.0)	3.8*10 ⁻⁷ (4.8)	-	-	-
Personal care prod	0.013 (15.5)	0.012 (3.2)	5.8*10 ⁻⁷ (7.3)	0.026 (22.0)	0.025 (4.9)	-	-	-	-
Herbalist's products	0.003 (7.9)	-	3.5*10 ⁻⁷ (8.2)	-	-	0.013 (6.2)	-	5.9*10 ⁻⁷ (2.9)	-
Pharmaceuticals	0.005 (6.7)	0.026 (8.2)	1.9*10 ⁻⁷ (2.9)	0.025 (14.2)	-	8.6*10 ⁻⁷ (4.8)	-	-	-
Tobacco	0.051 (8.1)	-	2.0*10 ⁻⁶ (3.3)	0.119 (29.7)	-	-	-	-	-
Ironmongery prod	0.002 (10.9)	0.004 (4.7)	-	0.005 (12.2)	-	1.1*10 ⁻⁷ (2.6)	-	-	-
Electric materials	0.001 (6.7)	0.002 (2.8)	1.5*10 ⁻⁷ (8.1)	0.008 (15.6)	-	4.2*10 ⁻⁷ (8.0)	-	-	-
Chemical products	0.0009 (7.0)	-	8.0*10 ⁻⁸ (6.5)	0.006 (15.7)	-	9.7*10 ⁻⁸ (2.4)	-	-	-
Flowers and plants	0.002 (4.5)	-	4.3*10 ⁻⁸ (8.1)	0.005 (7.3)	-	4.7*10 ⁻⁷ (6.6)	-	-	-
Toys	0.001 (8.1)	-	9.8*10 ⁻⁸ (7.1)	0.002 (7.3)	-	1.4*10 ⁻⁷ (6.5)	-	-	-
Magazines and new	0.017 (3.1)	-	6.4*10 ⁻⁶ (11.5)	0.042 (5.6)	-	7.7*10 ⁻⁶ (10.3)	-	-	-
Stationery products	0.004 (7.5)	-	2.1*10 ⁻⁷ (4.2)	0.031 (14.4)	-	9.7*10 ⁻⁷ (4.5)	-	-	-
Music products	0.0006 (2.9)	-	1.4*10 ⁻⁷ (6.6)	0.001 (4.2)	-	1.9*10 ⁻⁷ (6.5)	-	-	-
Optical products	0.003 (18.4)	-	-	0.001 (2.4)	-	3.7*10 ⁻⁷ (7.8)	-	-	-
Jewellery	0.0003 (7.3)	-	7.0*10 ⁻⁸ (20.0)	0.0003 (6.8)	-	8.0*10 ⁻⁸ (16.2)	-	-	-
Sport products	0.0011 (18.2)	-	8.7*10 ⁻⁷ (14.7)	0.006 (18.1)	-	1.9*10 ⁻⁷ (5.6)	-	-	-
Clothing	0.0006 (5.7)	0.003 (4.9)	1.7*10 ⁻⁷ (15.5)	0.007 (14.6)	0.01 (4.6)	5.1*10 ⁻⁷ (11.2)	-	-	-
Footwear	0.0008 (16.7)	0.003 (12.6)	5.8*10 ⁻⁸ (12.5)	0.006 (28.4)	-	8.3*10 ⁻⁸ (3.9)	-	-	-
Household appliance	0.0002 (7.4)	-	6.4*10 ⁻⁸ (23.4)	0.0004 (7.6)	-	7.7*10 ⁻⁸ (16.2)	-	-	-

the crow flies (in km) between centroid of traffic areas (Cod); a dichotomous variable (CC_d^k) which is 1 if in the destination zone of displacement there is a shopping center, 0 otherwise; the number of employees in trade of goods for the product category k in the d area (Add_d^k), a dichotomous variable ($Modo_{od}$) which is 1 if the movement between the origin area o to destination d was carried out by car, 0 otherwise; a dichotomous variable (LRD) which is 1 if the net annual income of the household is greater than € 40,000.00, € 0 otherwise. Dom_d is a strong degree of dominance of an area (alternative) d , that is the number of zones d for which the following conditions occur simultaneously:

- (a) d' has a number of employees at firms for goods of category k greater than d ;
- (b) the distance of d' from the residence of the consumer ($dist_{od}'$) is less than the distance of d ($dist_{od}$)
- (c) d' is along the path to reach the point of purchase starting from the place of residence of the consumer o . In this case d is an intervening opportunity along the way, or set of paths to d' (Stouffer [31]).

The concept of dominance has been used in the context of the methods of comparison of alternative projects on transport systems (Haines and Chankong [32]) and introduced for the first time by Cascetta and Papola [33] for the simulation of the set of choice in case choice of destination for unsystematic trips (shopping, sports, entertainment, etc.).

In many contexts of choice, as the one of destination choice, we can observe that some alternatives are not considered as “dominated” by others.

The simulation of the perception of an alternative occurs through dominance attributes defined by the rules listed above, to be included in the utility function of the model as attributes of availability/perception.

To each alternative is assigned a dominance variable and, therefore, will be defined a ranking of alternatives, where the place occupied by each one is pointed out by the number of alternatives that dominate them. The first places will be filled by alternatives with more domination and, therefore, the model will give them less probability to belong to the set of choice; latest places will be filled in areas with fewer domination and thus by the ones better perceived by the user. The ranking can be used as an attribute of dominance in the specification of the utility function, realizing the degree of perception of an alternative.

The proposed methodology allows to bypass the problem of the exclusion a priori of alternatives from the set of choice, since they are all perceived at the same time, but with a different level of perception. This approach avoids problems of incorrect model specification (Cascetta et al [34]).

In Table V the results of the best calibrations and validations obtained for each group of goods categories surveyed are reported.

VI. DISTRIBUTION MODELS

The study area identified in the conurbation Cosenza-Rende-Castrolibero, has been divided into 34 uniform traffic areas that represent the full range of choice of destination, although an effective and practical power of attraction is attributable to seven zones with higher commercial density.

Distribution models have been specified, calibrated and validated for non-durable goods with daily replacement, non-durable goods with weekly replacement and for other six groups of categories of durable goods, grouped by similar characteristics:

- $G I$: non-durable goods with daily replacement;
- $G II$: non-durable goods with weekly replacement;
- $G III$: herbal and pharmaceuticals products;
- $G IV$: tobacco products, books, newspapers, magazines, stationery and music products;
- $G V$: hardware, metal products, electrical equipment, chemicals, plants and flowers;
- $G VI$: optical and accessories, watches, silverware, gold and crystals;
- $G VII$: sporting goods, textiles, clothing and footwear;
- $G VIII$: toys and appliances.

For each of the three approaches have been made different specifications, differentiated for type of commodity.

In the *trip-based* approach, the distribution model allows to estimate the number of trips to purchase goods of category k directed in d coming from o . The functional form of the proposed model is of a Multinomial Logit and the utility function has the following expression:

$$V_{d|ok} = \beta_{dist}^k \cdot C_{od} + \beta_{add}^k \cdot Add_d^k + \beta_{cc}^k \cdot CC_d^k + \beta_{dom}^k \cdot Dom_d + \beta_{LRD}^k \cdot LRD \quad (10)$$

where were considered as attributes of choice, the distance as

Table IV Trip-based approach: distribution patterns

Specificazioni Logit	G1	GII	GIII	GIV	GV	GVI	GVII	GVIII
β_c	-1,431	-1,214	-1,279	-0,5832	-0,6384	-0,3992	-0,3859	-0,1108
(t-student)	(-50,3)	(-34,6)	(-23,9)	(-26,3)	(-25,6)	(-8,9)	(-11,6)	(-2,6)
β_{sat}	0,0018	0,00060	0,1239	0,0179	0,02	0,0668	0,0132	0,0320
(t-student)	(19,2)	(4,3)	(23,4)	(39,9)	(27,3)	(23,7)	(26,5)	(22,3)
β_{cc}	1,579	2,077	1,198	0,8035	0,1747	1,0990	2,120	1,852
(t-student)	(42,4)	(48,7)	(18,3)	(17,8)	(4,5)	(16,1)	(38,6)	(29,2)
β_{mod}	0,7771	1,422	0,903	0,6495	0,3043	0,5538	0,5003	1,0630
(t-student)	(13,6)	(20,4)	(4,9)	(7,1)	(3)	(2)	(3,5)	(16,6)
β_{dom}	-0,4559	-0,3170	-1,233	-0,3203	-0,3293	-1,386	-0,8266	-1,0680
(t-student)	(-14,8)	(-7)	(-10,1)	(-9,7)	(-5,9)	(-15,6)	(-16,8)	(-19)
β_{LRD}		0,7595			1,252	0,8416	0,4249	
(t-student)		(2,2)			(3,4)	(4,4)	(2)	
N. osservazioni	5001	3885	1803	3115	3110	1534	2688	1918
log-likelihood	-17635,3	-13699,9	-6358,1	-10984,6	-10966,9	-5409,4	-9478,9	-6763,6
log-likelihood(b)	-8143,7	-5825,7	-1780,2	-4962,5	-4936,2	-1771,4	-3512,7	-2510,9
LR(0)	18983,4	15748,3	9155,7	12044,3	12009,1	7276,0	11932,4	8505,2
ρ^2	0,5382	0,5748	0,7200	0,5482	0,5499	0,6725	0,6294	0,6288
$\rho^2_{varianza}$	0,5379	0,5744	0,7192	0,5478	0,5494	0,6716	0,6289	0,6280
% Right	48,71	56,43	72,23	60,50	56,20	56,80	63,58	55,40

The evaluated coefficients have a sign consistent with the meaning of the variable associated with them for all models and the t-Student test has been extensively checked for all the coefficients at a significance level of 95% ($t > 1.96$). Even the statistics LR , ρ^2 and the % RIGHT test gave satisfactory results.

It should be noted that, although the 34 alternative of choice, an effective and practical power of attraction is, in fact, attributable to higher-density commercial areas that correspond to the zone 10, 12, 15, 20, 25, 28 and 23. In traffic areas 10, 20, 28 and 23 are also present shopping centers that have a significant role in terms of attracted traffic, as gravitate by consumers that buy, but also people that goes on this places for recreational purposes only.

In the quantity-based approach, the quantity of goods of type k purchased in d and consumed in o can be calculated using a distribution model whose utility function has the following expression:

$$V_{d/ok} = \beta_{dist}^k \cdot C_{od} + \beta_{neg}^k \cdot Neg_d^k + \beta_{cc}^k \cdot CC_d^k + \beta_{mod}^k \cdot Mod_{od} + \beta_{dom}^k \cdot Dom_d \quad (11)$$

In the purchase-based approach, the number of purchases of durable goods of type k made in d and decided in o can be estimated using a distribution model whose utility function has the following expression:

$$V_{d/ok} = \beta_{dist}^k \cdot C_{od} + \beta_{neg}^k \cdot Neg_d^k + \beta_{cc}^k \cdot CC_d^k + \beta_{mod}^k \cdot Mod_{od} + \beta_{dom}^k \cdot Dom_d + \beta_{LRD}^k \cdot LRD \quad (12)$$

Compared to the specification (10) in (11) and (12) the attribute Neg_d^k is present, defined by the number of stores selling goods of category k in the area d.

In Table V the results of the best calibrations and validations obtained for each group of product categories under survey are reported.

Table V Quantity-based approach and purchase-based approach: distribution patterns

Specificazioni Logit	G1	GII	GIII	GIV	GV	GVI	GVII	GVIII
β_c	-1,471	-1,242	-1,531	-0,5085	-0,6481	-0,5701	-0,3721	-0,1210
(t-student)	(-51,9)	(-35,3)	(-31,8)	(-21,2)	(-21,2)	(-12,9)	(-11,1)	(-2,7)
β_{neg}	0,021	0,0334	0,1495	0,01818	0,0823	0,0987	0,0133	0,0303
(t-student)	(28,6)	(23,2)	(32,8)	(44,5)	(31,5)	(19,0)	(26,3)	(22,0)
β_{cc}	1,957	2,270	1,239	0,9387	1,077	0,5047	2,133	2,007
(t-student)	(51,9)	(49,2)	(18,9)	(19,9)	(25,6)	(8,8)	(38,7)	(33,2)
β_{mod}	0,401	0,3507	0,939	0,5478	0,3435	0,8620	0,4710	0,7771
(t-student)	(6,5)	(4,9)	(5,1)	(6,0)	(3,7)	(3,4)	(3,3)	(12,6)
β_{dom}	-0,307	-0,1722	-0,8582	-0,4430	-0,4176	-2,491	-0,8585	-1,068
(t-student)	(-9,7)	(-3,5)	(-10,8)	(-10,9)	(-8,1)	(-10,2)	(-17,4)	(-17,6)
β_{LRD}			0,9004			1,752	0,8210	0,5408
(t-student)			(2,7)			(4,2)	(4,3)	(2,6)
N. osservazioni	5001	3885	1803	3115	3110	1534	2688	1918
log-likelihood	-17635,3	-13699,9	-6358,1	-10984,6	-10966,9	-5409,4	-9478,9	-6763,6
log-likelihood(b)	-7889,4	-5825,7	-1776,4	-4929,8	-5075,9	-1862,4	-3500,6	-2622,5
LR(0)	19491,9	15748,3	9163,3	12109,6	11782,2	7094,16	11956,5	8282,2
ρ^2	0,5526	0,5748	0,7206	0,5512	0,5372	0,6557	0,6307	0,6123
$\rho^2_{varianza}$	0,5524	0,5744	0,7197	0,5508	0,5367	0,6546	0,6302	0,6114
% Right	50,20	56,43	72,10	56,50	51,10	53,00	66,90	59,30

The proposed models satisfy the statistical tests on the overall goodness of the evaluation.

VII. CONCLUSION

The motivation behind this work is the belief that the study of processes of change in demand plays a key to the analysis and modelling of transportation systems, since infrastructure and transport services are justified by the necessity to meet the mobility requirements and their characteristics.

Even nowadays, concerning transport of goods, distribution in urban areas in many contexts has no systematic organization. This is a “material” mobility that remains anchored to the initiatives of individual businesses, defining a strong negative impact on the territory in terms of external costs and quality of services offered to consumers.

The continuous traffic growth, which occurs at higher rates than the annual growth of the economic system, whose effects are more marked in urban areas, justifies the action by Public Authorities to regulate the different forms of mobility with the aim of reducing external costs (or negative externalities: environmental pollution and noise, congestion, energy consumption, risk of accidents, degradation of the urban areas, etc.) caused by the movement of people and goods. It is happening, in fact, that those planning one or more movements of goods, as well as of people, only takes into account the internal costs in the production process related to the purchase and/or use of some used productive inputs.

In economic terms, the external costs are not reflected on the market price for those who buy or sell a mobility service, but are outside the economic transaction and are borne by society. The cost of congestion, however, is the only externalities reflected in the production process and production costs of mobility service, which is supported by all road users, as directly increasing their travel time and inconvenience they have incurred in. From this framework comes the legitimacy of public intervention and the need for interventions that are not left to chance, but planned using appropriate decision support tools.

Freight mobility in urban areas should not be considered just a problem of traffic or environment, but a management problem of an articulated socio-economic system, ensuring the survival of the urban system. In fact, it is necessary to

underline that the urban transport of goods, contributing significantly to the process of distribution of goods to final consumers, plays an essential role in the maintenance of urban functions related to trade and social life in terms of economic power, quality of life, accessibility and attractiveness of a city. This means that a transport system efficient and “friendly” for the environment is essential for economy and health of a city. It is important to distinguish the possibilities arising from technical approaches (vehicle technology, telematics, etc.), organizational (cooperation, etc.), operating (route planning, etc.), and political (time span, limitation of load for vehicles, etc.).

The attention of Public Authorities should not be focused only on cargo handling, but it should be also addressed to regulate harmoniously the entire traffic, rather trying to reduce interference and conflict between spatial and temporal flows of people and freight.

The urban transport system is a complex system in which goods are moved on the same network of passengers. Research in the field of transport has been, over the past three decades, extensive and detailed, but the literature in the field of freight is not yet as developed as in the case of passenger transport. Even today, research in this area is limited by lack of data, lack favoured by the specific peculiarities of the transport of goods.

Data collected in the experimental survey conducted allowed to specify, in addition to zonal regression models, generation model with very disaggregated categories such as families. The deterministic models and behavioural models, which analyze the behaviour of the decision-maker, are characterized by the breakdown level reached, which allows specific predictions for various categories.

The models developed are an important decision support system (DSS) for local governments and authorities allowing to estimate freight and passenger demand and plan, for example, measures of “city logistics”. For example, data on number of consumers who gravitate in a traffic area allow to estimate, in the planning stage, parking demand and to take strategic measures (demand management) to avoid congestion of that area. Furthermore, the models developed allow a control of the forecasts by comparing the results of the three different approaches (Fig 2).

Future researches could involve specification, calibration and validation models to convert handled quantities in vehicles, between origin and destination zones. New survey campaigns could be aimed to collect data related to flows between retailers and suppliers to develop choice models of the type of supply, choice models of vehicle type and models of allocation for the urban freight traffic. Although the results obtained confirm the fairness of the system of models proposed, it would be important to make an application to a real test network to compare the results obtained with the proposed models with those of other current formulations in literature.

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