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TOPIC 29
COUNTRY STUDIES

PASSENGER AND FREIGHT DEMAND MODELS FOR THE ITALIAN TRANSPORTATION SYSTEM

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Abstract

The SISD is an integrated set of data-bases and simulation models for the national system, both passenger and freight, covering different aspects such as demand, supply, economic and external impacts. In the general architecture of the system, a central role is played by demand models simulating passengers and freight flows among traffic zones of Italy as well as other countries.

INTRODUCTION

A large integrated research project is currently under way in Italy, aimed at the development of a Decision Support System for transport policies (SISD). The project is being financed by the Italian Ministry of Transportation and by the National Research Council (CNR) in the 2nd Finalized Transportation Research (PFT2) Program.

The SISD is an integrated set of data-bases and simulation models for the national system, both for passengers and freight, covering different aspects such as demand, supply, economic and external impacts (Cascetta 1995). In the general architecture of the system, a central role is played by demand models simulating passengers and freight flows between traffic zones of Italy as well as between Italy and other countries. At this stage of the project, is possible to describe in detail the structures adopted and preliminary calibration results for some of the demand models to be included in the SISD.

This paper describes a system of disaggregate passenger internal demand models for average winter week-days, the designed aggregation procedure, a multiregional Input/Output model for level and distribution of freight demand and freight mode choice models.

PASSENGER DEMAND MODELS

Recently, full or partial behavioural systems of models describing intercity trips have been proposed, modifying the traditional approach based on partially or globally descriptive models.

One of the most complete systems of fully behavioural models is the Dutch LDTM model, used in different versions for transport demand forecasting in some European countries like The Netherlands, Norway and for the PBKA High Speed Rail project (Ashley and Baanders 1990; Ministry of Transport and Public Works 1992; TØI Institute of Transport Economics 1990). Both mobility and travel choices are simulated. In particular, the spatial distribution and modal choice levels are considered as conjoint, supposing that people make a joint evaluation of where and how to undertake the trip for a defined purpose. A similar approach was adopted for a nested logit model for intercity demand in Sweden (Algers 1994). While mobility choices, such as licence holding or car ownership, are not directly simulated, destination choice, primary, access and egress modal choices are considered in a nested logit structure in which the last two modal choices are calibrated by a partial information procedure while the rest by a full information one (Algers 1994). A nested logit structure was also used to simulate transport demand, for work and for other purposes in the U.S.A. In such a structure all the travel choice dimensions were considered except trip frequency which was treated with a statistical regressive model containing accessibility variables (Koppelman 1989). Similarly, also the traffic forecasting model set up for the Milan-Naples high speed rail corridor in Italy presents a descriptive trip frequency model while destination, modal and path choice models follow a nested logit structure (TECH.A.V.-TPL.A.V. 1993). Six different trip purposes were considered: work, study, business, tourism, leisure, other. A similar approach is also followed by other models used in two feasibility studies of high speed rail corridors in Italy (Ferrovie dello Stato F.S. 1988, 1993) and in a study on the intercity travel demand started by the European Community in the seventies (Ashley and Baanders 1990).

In the literature there are also many "partial" models dealing with single dimensions, typically mode choice, such as the model developed by Cascetta et al. (1989), Mandel et al. (1992) and Forinash and Koppelman (1994).

For a more detailed analysis of the literature, see Miller and Fan (1992) and Cascetta et al. (1994).

Model system architecture

The system of models developed in the context of the above mentioned research project simulates some mobility choices (driving licence holding and car ownership) and, for an average winter period, the frequency of extra-zonal tours, their distribution among the different zones within Italy, as well as their distribution among the different transport modes and services available for the different demand segments, in relation to pre-defined supply and socio-economic and territorial scenarios (see Figure 1).

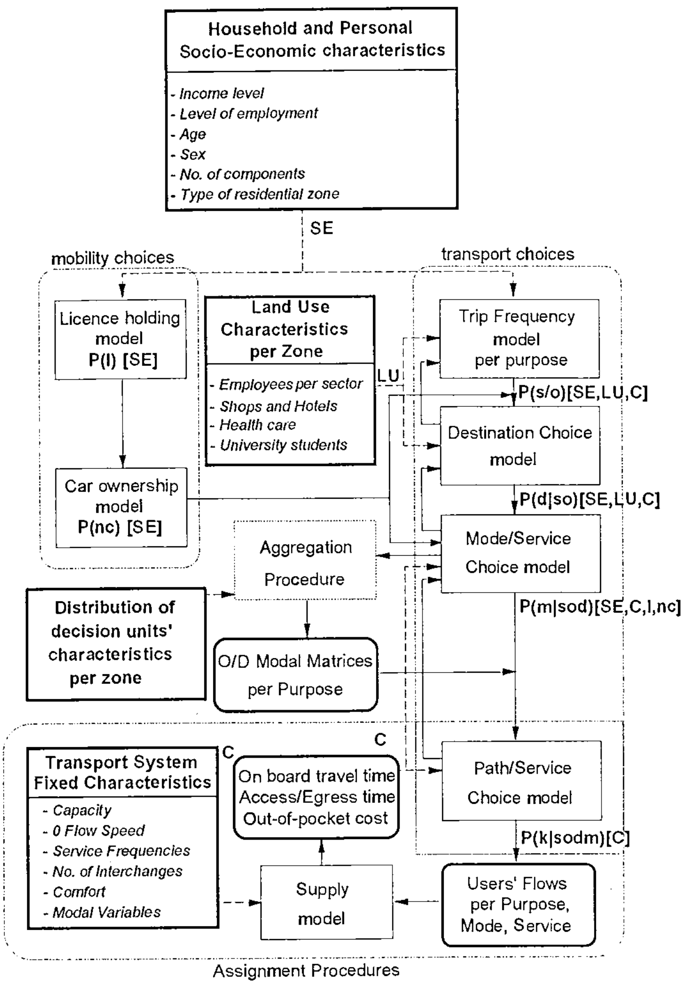

Figure 1 The general structure of the model system

Five tour purposes are considered: workplace commuting, work and professional business, university education, leisure and tourism, other purposes. For each purpose, frequency, distribution and mode/service choices are simulated considering six different modes: car, regional rail, intercity rail, sleeping-berth and wagon-lits train, airplane, bus.

The system of travel choice models has a tree logit structure with multinomial logit models for all the choice dimensions. Inclusive variables in the specifications of the alternatives take into account the influence of the lower choice stages on the upper ones. Consequently demand can be considered as elastic with respect to transport attributes over all choice dimensions, including the global "level".

A full presentation of the system of models is reported in CSST et al. (1993), CSST (1994) and Cascetta et al. (1994).

An extended survey was carried out aiming to obtain data for a significant calibration of all the models belonging to the mentioned system. The data base thus consists of 6011 families, interviewed by phone, equivalent to 10022 individuals, giving 3176 intercity trips divided into the five purposes mentioned.

Level of service attributes were obtained by a network model of the passenger transport system at the intercity level (Cascetta et al. 1994).

Some examples of model specification and calibration

The various models reported below were specified and calibrated separately (partial information estimation) by using standard Maximum Likelihood estimator as included in the package ALOGIT.

With regard to mobility choices, the probability of an individual *holding a licence* to drive is specified and calibrated through a binary logit model on the two alternatives of holding or not holding, whose variables are all dummies relative to socio-economic conditions, such as age bands also related to sex, employment status, income band, and land use type as the urbanization of the person's residence zone.

The results of the calibration show some interesting aspects (see Table 1). The positive value of the "urban zone" variable can be considered as an index of the reduced need to hold a licence for people living in urbanised areas due to a greater accessibility to public transport facilities. Also sex and age differences are evident, revealing how licence holding is more frequent for medium-aged males while women show a significant reduction factor linked to age-related socio-cultural factors. The positive coefficients of employment and income status link licence holding with car ownership as shown in the next point.

Table 1 Coefficient values for the licence holding model

ρ^2=0.437	18-24 aged	25-56 aged	empl.	inc. med.	inc. high	urb. zone	18-48 ag.fe.	48 ag. fem.	no lic.
licence	0.173	1.146	1.279	0.716	1.229				
t	*2.1*	*16.4*	*19.5*	*10.2*	*5.9*				
no licence						0.262	1.197	2.384	-1.022
t						*5.1*	*17.1*	*34.9*	*-16.2*

A multinomial logit model was specified and calibrated to simulate *car ownership* considering three alternatives: no car, 1 car and 2 or more car ownership. The adopted specification of the model takes into account socio-economic characteristics like the number of employed people and students and licence holders in the family, the average annual car use cost, the income and age dummy variables, and land use characteristics relative to the residence zone.

All coefficients show correct signs and statistical significance; in particular the "urban zone" variable reveals the disutility of multiple car ownership in accessible urban areas (Table 2). Furthermore, income variables show a similar ratio between the car ownership and licence holding models; these two variables and the positive value of the "number of licence" variable represent the linkage between the two dimensions.

Table 2 Coefficient values for the car ownership model

ρ^2=0.376	no car	num. empl.	35-65 aged	car an.c.	inc. med.	inc. high	num. stud.	urb. zone	num. lic.
no car	-1.332	-1.441	-0.735				-0.992		
t	*-13.5*	*-17.2*	*-7.2*				*-4.3*		
one car				-0.477					1.062
t				*-24.6*					*27.3*
2 + cars				-0.477	1.018	1.537		-0.557	
t					*12.4*	*6.1*		*-6.9*	

Concerning transport choices, the demand for inter-provincial tours originating in the zone of residence is simulated by the system of models:

$$d_{o,d}(s,m)_c = \sum_n N(o)_c n p(ns/o)_c p(d/s,o)_c p(m/s,o,d)_c \quad (1)$$

where:

$d_{od}(s,m)_c$ is the number of tours made from origin o to destination d for purpose s by mode m by category c users;

$p(ns/o)_c$ is the probability that a category c user makes n extra-provincial tours for purpose s from zone of origin o provided by the tour frequency model;

$N(o)_c$ is the expansion factor for category c users resident in the zone of origin

$p(d/s,o)_c$ is the fraction of trips departing from origin o for destination d for category c users provided by the distribution model;

$p(m/s,o,d)_c$ is the fraction of users who choose mode m to travel from origin o to destination d, provided by the modal distribution model.

All submodels have a multinomial logit specification and the sequence is a nested logit model insofar as at each level inclusive variables relative to the lower level are included

The adopted *tour frequency model* simulates the probability that a category c user makes n extra-provincial tours for purpose s from zone of origin o. Such a probability is computed by a logit model considering the alternatives "not to travel", "to make one tour" and "to make two or more tours" in the reference period (two weeks). The expansion factor depends on the aggregation procedure used: when the sample enumeration method is used, $N(o)_c$ is the factor of expansion for category c users for zone o. Appearing in the systematic utility are the socio-economic attributes of the user and his family and accessibility variables as inclusive variables of lower level choices in the nested model structure. One peculiar feature of the proposed specification is the "self attraction" variable of "number of employees in services and commercial branches (named empl.)" included in the systematic utility of the "no trip" alternative. This is to take into account the fact that the simulated tours are extra-provincial ones and the more work opportunities are present in the province of residence, the less is the probability of making extra-provincial tours. Systematic utilities contain family socio-economic characteristics, like income dummy variables and number of components and owned cars, and individual ones, like age band, employment status and level (comprising university student status), licence holding dummy variables; zone land use characteristics, like number of total residents, of employees (also divided into different sectors) and geographical location in the country; the accessibility variable is considered as the logsum term of destination choice $Acc = \ln\Sigma_d \exp(V^c_{od})$. Table 3 shows an example of the systematic utility function calibrated for the professional business purpose.

The results of the calibrations are globally consistent with coefficients of expected signs and statistically significant. The probability of making tours, for example, increases with the income levels particularly for the "business" purpose, the example given. The accessibility coefficient, that is the logsum function of the destination alternative utilities, has negative sign and does not lead to a nested logit model for such a tour purpose.

Table 3 Coefficient values for work and professional business purpose

ρ^2=0.7061	empl.	acc.	med. inc.	high inc.	male	high empl.	1 tour	2 tour
no tours	0.11	-0.14						
t	*4.8*	*-2.3*						
one tour			0.61	1.53	0.96	0.33	-4.80	
t			*5.3*	*7.2*	*4.9*	*10.2*	*-13.5*	
2 or + tours			0.61	1.53	2.34	1.47		-5.592
t					*4.9*	*11.3*		*-14.5*

It is also worth noting that some attributes like employment status and sex have a non-linear effect with a coefficient which is over twice as great in the "two or more tours" alternative with respect to the "one tour" alternative.

Distribution models providing the probability of choosing destination *d* for a trip departing from origin *o* for users of category *c*, are formulated as multinomial logit considering both inclusive variables for the mode choice dimension and size function variables as the attraction attribute of the destination zone. More specifically, the logsum variable of the systematic utilities connected to the different modes of transport available on relation *(o,d)*, as obtained by the mode/service choice models, has been used as an attribute of cost or of separation between the origin and the destination.

To take into account the (unknown) number of elemental destinations included in each aggregate zone (eg a province) "size functions" were used as attraction attributes of the zone (Daly 1982; Ben Akiva and Lerman 1985). The specification of the systematic utility function can be written as:

$$V^c_{od}=\beta_1\left(\log\sum_m \exp V^c_{od}\right)+\beta_2\left(X_{1d}+\log\sum_{k=3}^{Ks}\beta_k X_{kd}\right)+\sum_{k=Ks+1}^{K}\beta_k X_{kd} \qquad (2)$$

in which the first part is the cost term relative to the different available modes, the second is the size function of the considered aggregate zone while the third term is relative to all the linear attributes not included in the first two parts. Inside size function utilities, the number of employees in commercial and service sectors, of tourist businesses, of hotels and hospital beds are considered. To capture the greater attractiveness of the residential region, a dummy variable called "same region" is introduced.

Table 4 Coefficient values for the work and professional business purpose distribution model

ρ^2=0.3129	Y_{odc}	same reg.	serv. empl.	β_2
	0.334	1.787	1.000	0.913
t	*61.3*	*42.3*	---	*13.8*

In the reported example the number of workplaces in the service sector (with unit coefficient) was used within the size function as proxies of the number of elemental destinations. The coefficient of the size function is close to one, which is the value to be expected theoretically. Moreover, the value of the logsum variable shows a considerable correlation perceived by users among the available mode alternatives.

The *modal choice model* has a multinomial logit specification and includes six mode/service alternatives: car, bus, airplane, interregional train, intercity train, sleeping-berth/wagon-lit train. For each mode, generic attributes of time and cost (including access/egress) were considered; in particular in the utility functions, two different monetary cost coefficients were adopted for low and medium-high income households taking into account different cost perceptions and hence value of time in different income classes. Other levels of service attributes include the relative headway of service (ie the time headway divided by on board travel time, to take into account the reduced influence of time headway as the total travel time increases) and the number of transfers. Moreover, also the number of family cars available and dummy for licence holders variables are considered.

Great significance was shown by the difference in value of time (VOT) between low and medium-high income classes. In the example given, VOT is estimated at about 11,000 lire per hour for the low income class and 25,000 lire per hour for the other class (respectively about $7 and $16 per hour). For leisure and tourism and for other purposes the difference in VOT of the two classes is less evident: VOT for the medium-high income class is about more than twice the low income class value. The negativity of the coefficient relative to the type of destination variable ("dest. type") for leisure, business and other purposes, is probably due to the relevance of egress times and costs in destinations outside urbanised areas without significant public transport services.

Table 5 Coefficient values for leisure and tourism purpose modal choice model

ρ^2=0.758	time (h)	low inc cost (10000£)	m/h in cost (10000£)	car avail.	dest. type	transf. num.	time hea.	region sp.	interc. sp.	wl sp.	air sp.	bus sp.
car	-12.29	-11.43	-4.91	3.81								
interreg. rail	-12.29	-11.43	-4.91		-3.72	-0.97	-0.60	0.95				
intercity rail	-12.29	-11.43	-4.91		-3.72	-0.97	-0.60		-0.54			
wagon lits	-12.29	-11.43	-4.91		-3.72	-0.97	-0.60			9.96		
airplane	-12.29	-11.43	-4.91		-3.72	-0.97	-0.60				-1.62	
bus	-12.29	-11.43	-4.91		-3.72	-0.97	-0.60					-2.31
t	*-26.2*	*-5.4*	*-15.7*	*30.3*	*-18.0*	*-5.4*	*-24.0*	*-0.6*	*-4.4*	*3.6*	*-12.7*	*-14.4*

Aggregation procedure

The demand model system described in the previous section is intrinsically disaggregate. An aggregation procedure is thus needed to obtain aggregate estimates/forecasts of travel demand.

Among the various known aggregation procedures, the joint use of classification and sample enumeration represents the most flexible tool for aggregate application of disaggregate models.

While the classification procedure is necessary to take into account forecasts of demographic, socio-economic and land-use variables and to obtain future class weights in the population, sample enumeration gives rise to more precise choice probability expected values for each class, given the non linearity of probability functions with respect to perceived utilities (generalized cost). The probability of choosing an alternative over the entire population is the expected weighted value of the alternative class probability over all the classes.

In general, the stages in the application of aggregate forecasting can be summarized as follows:

1. class definition and evolution in future scenarios;
2. computation of class weights (or expansion factors);
3. sample enumeration and determination of total probability values.

With regard to point 1, it is worth noting the different aggregation level for classes involved in the mobility and travel models, and for classes used to design future scenarios. In general, the latter are more aggregated than the first; thus, a procedure is needed to compute model class weights starting from forecasting scenario class weights. Two procedures may be used to achieve this goal: a minimum least squares method or a proportional fitting procedure.

The adopted minimum least square procedure minimizes the differences between some target values, which are the forecasted scenario values (eg total population number), and the sum of the contribution of each class to the target (eg the sum of all the families multiplied by the relative number of components, which is the family contribution to the target). Such a minimization procedure is carried out also taking into account the fact that the weight must, at the same time, not differ too greatly from a vector of initial weight values. Formally:

$$x=\arg\min_{x}\left[w_j \sum_j (n_i c_{i,j} x_i)^2 + \sum_i (x_i-\overline{x}_i)^2\right] \quad (3)$$

where x is the vector of expansion coefficients x_i whose start values (naive) are the overlined ones; n_i is the number of observations sampled for class i; $c_{i,j}$ is the contribution of class i to target T_j; w_i is a "relative importance" weight factor relative to the j-th target. This GLS procedure is analogous to the one proposed for the national model system in the Netherlands (Ministry of Transport and Public Works 1992). Equation (3), can be read as the minimization of the expansion coefficients' estimation errors, with respect to naive values, subject to target constraints; in this case w_i are the Lagrangian coefficients of the minimizing problem. Such an approach gives rise to some problems due to the different magnitude both among targets and between the two terms of the sum in Equation (3). This second problem can be solved partially by using weight coefficients w_i but no systematic methods have been suggested until now in literature.

The "proportional fitting" procedure can be carried out by different sub-procedures of such a fitting; each sub-procedure is relative to a different kind of target. For example, if there are family targets and population targets, two different proportional fitting procedure must be performed. Starting from initial expansion coefficients determined by sample data, the method fits such coefficients to target values which refer to some marginal characteristics such as the number of components and the income for the family targets. In particular, if there are two considered characteristics (eg number of components and income), x_{ij} is the expansion factor of the class which contribute to the marginal targets determined by the i-th level of the first characteristic and the j-th level of the second. Then, x_{ij} is obtained as follows:

$$x_{ij}=k_i k_j \overline{x}_{ij} \quad (4)$$

where k_i and k_j are the fitting values of x_{ij} respectively for target $T1_i$ and $T2_j$, and their expression can be written as:

$$k_i=\frac{T1_j}{\sum_j k_j \overline{x}_{ij}} \qquad k_j=\frac{T2_j}{\sum_i k_i \overline{x}_{ij}} \quad (5)$$

For the time being, least squared method was performed by allowing for a fine classification which provided too large a number of classes. An extraction of 175 classes, with a 2% error on the total population, was then carried out to avoid excessive computation. The targets considered for the forecasts were relative to family (number of families with one, two, three, four, five, six or more components and number of families with high, medium, low income) and to population (total population number, total number of high and low qualificated people employed, total number of university students, total number of family components over 14 years old and different from the others considered above).

THE FREIGHT DEMAND MODEL SYSTEM

In the area of freight demand modelling different approaches have been proposed in the literature for various aspects of demand.

Level and distribution of freight demand can be modelled through statistical-descriptive models, network-based Spatial Price Equilibrium (SPE) models (Harker 1987) or multisectorial multi-regional macro-economic models based on Input-Output theory or its generalization into Computable General Equilibrium (CGE) theory (Roson 1994).

Various approaches are possible also for modelling freight mode-service choice including logistic-inventory based models and discrete choice/random utility models, for a recent review of modal choice models see Modenese Viera (1993).

In the Italian project a modelling architecture combining Spatial Input-Output models with random utility mode and path choice has been adopted for reasons of flexibility, data availability and internal consistency.

The overall structure of the model system is represented in Figure 2.

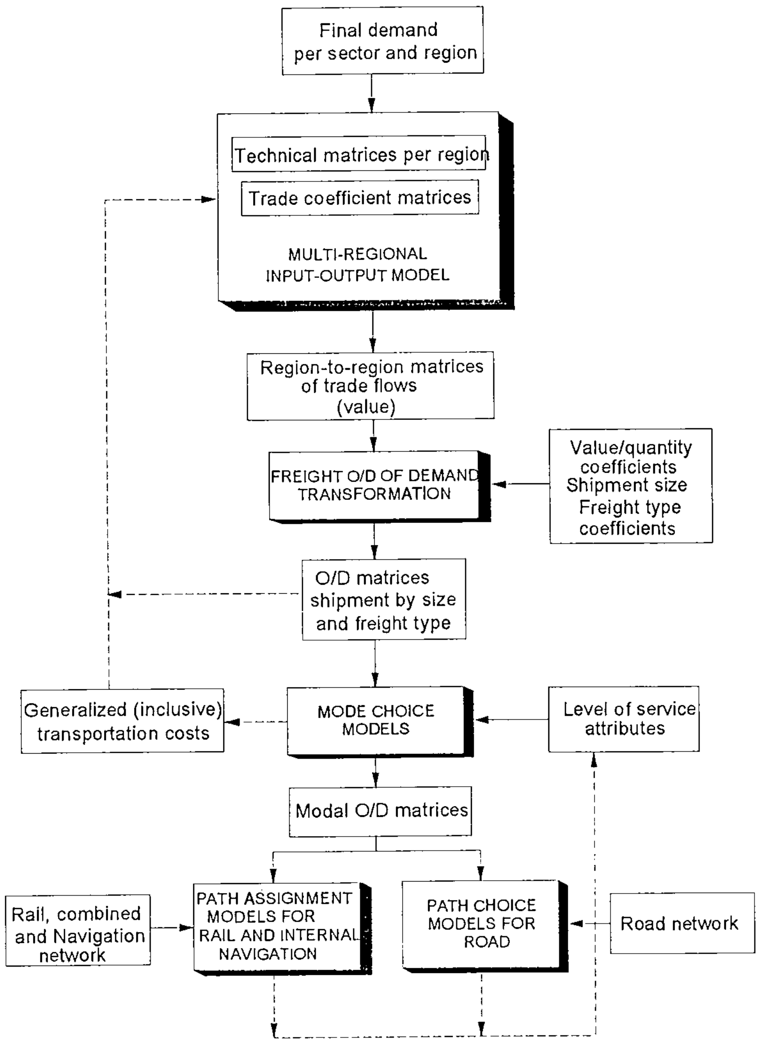

Figure 2 Freight demand model system

The spatialized I-O model produces region-to-region trade flows matrices for each economic sector using final demand vectors, technical coefficient matrices for regional economies and inter-regional trade coefficients which are elastic with respect to generalized transport costs. These matrices expressed in monetary terms are transformed into Origin-Destination matrices of freight quantities and split among sub-zones (provinces) belonging to each region following a gravity model. O-D matrices are subsequently disaggregated with respect to freight types and shipment dimensions through a fixed (exogenous) coefficient and split among available mode/services by discrete-choice models. Finally modal O/D matrices are assigned to networks following normative (rail) and random utility (road) path choice models. Consistency among different models is achieved through aggregation/disaggregation procedures and inclusive variables (dotted lines in Figure 2).

In the next two sections some further elements will be given for elastic trade coefficients in a multiregional Input-Output model and mode choice models.

Multiregional input-output model and trade flows

The level and geographical distribution of freight demand is simulated by taking account of production-consumption of different sectors of the Italian economy and their mutual interdependences through a Chenery-Moses Multiregional Input-Output model.

The system of equation formally describing the model is the following :

$$x = TAx + Ty - m \tag{6}$$

and

$$x = (I - TA)^{-1} (Ty - im) \tag{7}$$

where

x ($n_R \cdot n_S$ x1) is the vector of total production for each sector in each region;

y ($n_R \cdot n_S$ x1) is the vector of final demand relative to each sector and region. Final demand is assumed made up of final consumption (of both households and collectivity), investments, stock variations, exports;

im ($n_R \cdot n_S$ x1) is the vector of imports from other Countries per sector and region;

A ($n_R \cdot n_S$ x $n_R \cdot n_S$) is the block-diagonal matrix made up of n_R blocks, each being a regional technical coefficient matrix ($n_R \cdot n_S$);

T ($n_R \cdot n_S$ x $n_R \cdot n_S$) is the trade matrix made up of diagonal matrices, one for each region pair, with elements *t(s,o,d)* (inter-regional trade coefficients) expressing the fraction of sector *s* production consumed in region *d* and purchased in region *o*.

In this application the twenty administrative regions in Italy (n_R=20) were considered while the 92 sectors of the national Input-Output table were grouped into 17 sectors (11 producing goods and 6 services).

Two options are available for trade coefficients. The first is to use fixed coefficients estimated on the present inter-regional trade pattern (traditional multiregional I-O model). The second option is to express trade coefficients through a multinomial logit model

$$t(s,o,d) = \frac{\exp(V^s_{od})}{\sum_{o'} \exp(V^s_{o'd})} \tag{8}$$

with a systematic utility V^s_{od} including a "size-function" relative to overall region "o" production in sector s, average generalized transportation cost (combination of inclusive values from mode choice models of different freight types when relevant) and average price levels. This "elastic trade coefficients" version of the model is currently being calibrated.

Once regional productions have been obtained through Equation (7), region-to-region trade flows (in monetary terms) can be obtained by:

$$C = T \cdot A\langle x \rangle + T\langle y \rangle \tag{9}$$

where

C $(n_R \cdot n_S \times n_R \cdot n_S)$ is the inter-regional trade flows matrix with elements $c(s_1, s_2, r_1, r_2)$ expressing trade flows from sector s_1 of region r_1 used in sector s_2 of region r_2;

$\langle x \rangle, \langle y \rangle$ are $(n_R \cdot n_S \times n_R \cdot n_S)$ diagonal matrices obtained from vectors x and y previously defined.

The final steps involve the aggregation of trade flows to obtain overall trade flows for freight-producing sectors and conversion into quantities (tons).

Freight modal choice model

A "random utility" behavioural model was used in order to simulate mode choice for each shipment (Nuzzolo and Russo 1995) with a systematic utility, that is function of attributes which may be divided into three groups:

A) characteristics of sender firms;

B) characteristics of the freight to be shipped;

C) characteristics of modal alternatives (level of service attributes).

The full set of attributes used, is reported in Table 6.

Table 6 Attributes of modal choice model

Shipment characteristics:
- weight (tonn.)
- weight > 30 t (0/1)
- specific value of shipment, (value weight ratio)
- full load (0/1)
- shipment between factories of the same firm (0/1)
- shipment towards a final market (0/1)
Firm characteristics:
- number of own lorries
- number of lorries under contract
- own rail siding (0/1)
Level of service attributes:
- travel time (road, rail, combined, shipper) (h)
- travel cost (road, rail, combined, shipper) (Lire • 10^6)

Multinomial logit or nested logit models (Ben Akiva and Lerman 1985) were calibrated using Maximum Likelihood method, by using the ALOGIT package.

The maximum disaggregate choice set is defined by:

- own lorry
- lorry of carrier called for a single shipment directly by the firm or lorry of carrier under contract;
- traditional rail service by single car or group;
- combined rail (container, swap-bodies or semi-trailers)
- shipper "by road" (mode chosen by firm);
- shipper "by rail" (mode chosen by firm);
- shipper with mode chosen by himself.

Moreover it was assumed that modal choice is conditioned by the type of goods; these were divided into perishable, consumer and capital goods.

Data bases for the calibration and values of the attributes relative to sender firms and shipments were obtained through a survey carried out nation-wide in Italy (Nuzzolo *et al.* 1993). Level of service attributes were evaluated for each single transport mode, using road, rail and combined service network models.

For multinomial logit models, two choice sets were examined. In the maximum disaggregation hypothesis all the seven alternatives described above were considered. By contrast, the hypothesis of maximum aggregation considered only three combined alternatives: road haulage, train and combined. Furthermore, different specifications were tested varying in the number of shipment and firm attributes taken into account. In the following, only the most significant results are described. Further details and analyses are contained in Nuzzolo and Russo (1995).

In particular the following results are reported :

A) multinomial logit models with seven alternatives and a small number of attributes [all types of goods (A1), perishables (A2), consumer goods (A3) and capital goods (A4)] (Table 7).

B) multinomial logit models with seven alternatives and a larger number of attributes [all type of goods (B1), perishable (B2), consumer goods (B3) and capital goods (B4)] (Table 8).

C) multinomial logit models with three aggregated alternatives, for all type of goods (C1) and (C2) (Table 9).

D) nested logit model (D1) (Table 9).

With regard to the cost (or price) attribute, all calibrations gave satisfying results; ie significant parameter with the expected negative sign.

With regard to time, calibrations with mode-specific attributes were largely superior to the ones with a generic time attribute, thereby confirming some results reported in the literature.

Mode-specific time attributes were generally significant with correct signs. Furthermore values of time (VOT) derived from the models are highly acceptable both across modes and freight types. Also mode-specific attributes are rather stable across model specifications and reproduce a modal hierarchy varying with freight type.

Table 7 Freight modal choice type A: multinomial logit models, seven alternatives, limited number of attributes

Attribute	Alternative	Unit	All types A1	Perishable A2	Consumer goods A3	Capital goods A4
Train	Tt	0/1	-0.35	0.21*	-2.14*	1.19*
Train shipper	Ts	0/1	-2.27*	Δ	-3.82*	-0.29*
Combined	C	0/1	-2.85	-5.47	-3.26	-4.98
Road by own lorry	Ro	0/1	-1.08	0.11*	-0.63	-1.17
Road shipper	Rs	0/1	-1.15	-1.41	-0.13*	-1.96
Shipper	S	0/1	-1.56	-2.37	-1.50	-1.29
Train/Combined Time	T/C	hours		-0.07	-0.01	-0.06
Train time	T	hours	-0.05*		-0.01*	
Combined time	C	hours	-0.11*			
Road time	R	hours	-0.13	-0.17*	-0.03*	-0.11
Cost	G	Lit/10^6	-1.02	-1.15	-1.29	-0.94
Weight	Ro	ton		-0.07	-0.02	
Weight > 30 tons	Tt	0/1	0.34*			0.45
Perishables	Ro	0/1	0.34*			
Consumer goods	T	0/1	-0.32*			
n. observations			625	168	168	291
rho2			0.25	0.31	0.25	0.27

Notes:
* t, not significant at 5% level; alternative not present.
Tt= traditional train; Ts= train shipper; T= generic for train services; C= combined; Ro= road by own lorry; Rc= road by carrier; Rs= road by shipper; R= generic for road alternatives; S= shipper "tout court"; G= generic for T,C,R,S alternatives.

Table 8 Freight modal choice type B: multinomial logit models, seven alternatives, large number of attributes

Attribute	Altern	Unit	All type B1	Perishable B2	Consumer goods B3	Capital goods B4
Train	Tt	0/1	-1.49*	-0.06*	-1.40*	-0.80*
Train shipper	Ts	0/1	-2.67*	Δ	-1.58	-1.05*
Combined	C	0/1	-1.65*	-4.60*	-3.33	-4.51
Road by own lorry	Ro	0/1	-0.40	0.63*	-0.19*	-0.41*
Road shipper	Rs	0/1	-0.33	-0.69	0.45	-1.05
Shipper	S	0/1	-0.74	-1.65	-0.91	-0.38
Train/Combined time	T,C	hours		-0.06	-0.04*	-0.04
Train time	T	hours	-0.03*			
Combined time	C	hours	-0.11*			
Road time	R	hours	-0.12	-0.16*	-0.10*	-0.08*
Cost	G	$Lit/10^6$	-0.99	-0.85*	-0.80*	-1.46
Weight	Ro	ton		-0.79		
Weight > 30 tons	T	0/1	0.79*		2.21*	1.40*
Perishables	Rd	0/1	0.49			
Consumer goods	T	0/1	-0.60*			
Full load	Rc	0/1	1.62	1.24	1.76	1.61
Own rail siding	Tt	0/1	2.40	1.49*	2.75*	2.30
Lorries under contract	Rc	n. lorries	0.04	0.03*	0.02*	0.03*
Own lorry	Ro	n. lorries	0.11	0.34	0.06	0.15
Value/weight	Tt	0/1 (v/w < 4000 $/ton)	0.01	0.09*		0.04
Value/weight	Ts	0/1 (v/w < 4000 $/ton)	-0.01			0.01*
n. observations			625	168	168	291
rho^2			0.31	0.35	0.31	0.35

Notes:

* t, no significative at 5% level; Δ alternative not present.
Tt= traditional train; Ts= train shipper; T= generic for train services; C= combined; Ro= road by own lorry; Rc= road by carrier; Rs= road by shipper; R= generic for road alternatives; S= shipper "tout court"; G= generic for T,C,R,S alternatives.

Table 9 Freight modal choice type C: multinomial Logit with aggregate (three) alternatives and nested logit

Attribute	Altern	Unit	multinomial		nested
			C1	C2	D1
Train	Tt	0/1	0.29*	-1.48*	-2.78*
Combined	C	0/1	-3.34	-3.22	-3.65
Road by own lorry	Ro	0/1			-1.37
Train time	T	hours	-0.06*	-0.05*	-0.04*
Combined time	C	hours	-0.12	-0.12	-0.13*
Road time	R	hours	-0.15	-0.14	-0.18*
Cost	G	$Lit/10^6$	-1.47	-1.60	-0.68
Weight > 30 tons	T	0/1	1.20*	1.57*	2.41*
Perishables	R	0/1	0.86*	0.83*	
Consumer goods	T	0/1	-0.64*	-0.88*	
Full load	Rc	0/1			
Own rail siding	Tt	0/1		2.09	2.68
Truck under contract	Rc	n. lorries			0.09
Own truck	Ro	n. lorries		0.01*	0.12
Value/weight	Tt	0/1 (v/w < 4000 $/ton)		0.01	
Value/weight	Ts	0/1 (v/w < 4000 $/ton)			0.01
Logsum					0.84
n. observations			440	440	625
rho^2			0.76	0.76	0.44

Notes:

* t, no significative at 5% level; Δ alternative not present;
Other abbreviations as for Table 8 above.

As regards the weight attribute, the best results for consumer goods and capital goods were obtained by considering a non-linear influence by means of a dummy variable for shipments over 30 tons.

Preliminary calibrations with a nested Logit structure were also carried out. Four alternatives were considered (own lorry and carrier road haulage), traditional train and combined transport) divided into two groups: road only and rail. The model specification assumed a single scale parameter for logsum variables of both groups with a value (0.844) consistent with its behavioural derivation; all other parameters had correct signs.

Models with a larger number of shipment and firm-specific attributes showed, as expected, an improvement in goodness of fit statistics and explicative power. In particular, unitary values of shipped goods, the availability of railway sidings for the shipping firm and the number of own lorries led to significant improvements.

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