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Abstract. In this paper. we analyse interregional freight transport movements in Europe with a view on new spatial patterns based on transport economic scenarios for environmental sustainability. Two different approaches are compared. viz. the logit model and the neural network model.

The paper will essentially deal with a research experiment for the robustness of interregional freight flows by comparing the two above methodologies. Our results in this framework highlight the fact that the two models adopted. although methodologically different. are both able to provide a reasonable spatial representation of the interregional transport flows in Europe.

1. A New Scene for Europe

The western countries are going through a stage of structural transition. After the era of modernalisation - characterized by high economic growth. a strong population rise. a pervasive industrialisation process, the emergence of the modern welfare state and an unprecedented mobility growth - we are now witnessing the gradual emergence of a new stage in the history of western societies. Signs of this new era are stabilising demographic growth patterns, an orientation towards a service economy, imbalances on labour markets, increased female labour force participation. a trend towards socio - cultural heterogeneity. a strong individualisation trend. a higher environmental awareness and a transition towards regulatory and institutional reform.

The development of the European Union (EU) - marked by both a decline in the importance of the nation state accompanied by a rise in regional autonomy and identity and an internationalisation process with free exchange of goods. capital and labour - fits in this structural transformation process. But at the same time the EU is facing a major dilemma: more openness presupposes more mobility. while more mobility is at odds with the need for a high quality of life in Europe. For example. cross-border commodity transport has increased since the beginning of 1990s with some ten percent annually. thus causing a significant rise in social costs as a result of congestion. environmental pollution and accidents. Thus. there is a need to develop new transport policies in Europe which would charge the social costs related to externalities of the transport sector to the user. based on the ‘polluter pays‘ principle.

At the same time. it is also increasingly recognized that the predominant role of road transport for goods in Europe can no longer be maintained. Other modes of transport such as railways and **waterways.** which have for long been neglected. have to be considered as alternative means of transport. In the EU transport policy this awareness has led to the increased interest in intermodality. which seeks to exploit the benefits of combining different complementary transport modes while minimizing the overall environmental burden caused by the transport sector,

From the above sketched broad perspective. the present paper sets out to develop a methodology for analyzing the potential of the different modal choices for European freight transport. seen from the viewpoint of efficiency (i.e. cost minimization) and environmental sustainability (i.e. application of polluter pays principle). After a concise sketch of recent developments in interregional European commodity flows. few complementary methodological approaches. viz. a logit analysis and a neural network analysis. will be proposed as an operational analytical framework for assessing and forecasting interregional freight flows in Europe. Several empirical results based on an extensive database will be presented and discussed. while finally also various environmental cost strategies will be proposed and their implications for European freight flows will be analyzed.

2. Methodology

Given the previous observations the present paper aims to analyse interregional freight transport movements in Europe (108 regions) as well as to forecast resulting spatio-temporal flow patterns on the basis of new transport economic scenarios. For this purpose. a modal split analysis will be carried out by means of two statistical models. namely the logit model and the neural network model. A binary logit model will be discussed in Section 2.1. while a feedforward neural network model will be presented in Section 2.2.

2.1 Logit Analysis

A widely adopted approach for modal split analysis is the logit model (see e.g. Ben-Akiva and Lerman. 1985). Recent experiments using logit models / spatial interaction models in order to map out the freight transport in Europe have been carried out by Tavasszy (1996), who showed the suitability of logit models also for the goods transport sector (where data are more ‘fuzzy’ and incomplete compared to the passenger sector). Logit models are discrete choice models, which are used for modeling a choice from a set of mutually exclusive and exhaustive alternatives. It is assumed that the decision-maker **chooses** the alternative with the highest utility among the set of alternatives. The utility of an alternative is determined by a utility function, which consists of independent attributes of the alternative concerned and the relevant parameters.

Since in our case two discrete choices -rail (t) and road (c)- will be considered, a binary logit model is adopted. The variables ‘time’ and ‘cost‘ between the 108 regions for the two transport modes are considered (see Reggiani et al. 1996b).

2.2 Neural Network Analysis

Neural network (NN) analysis has in recent years become a popular analysis tool (see for reviews Himanen et al. 1997). NNs replicates human brain functions and are thus considered as ‘intelligent’, since they learn and generalize by examples (see e.g. Reggiani et al. 1997). NNs have been widely applied to the area of transport engineering, in particular in relation to traffic control problems and accidents (see Himanen et al. 1997). However, only a few experiments exists in the field of transport economics or transport route / mode / destination choice (see e.g. Nijkamp et al. 1996 and Schintler & Olurotimi 1997). Our experiments aim to explore also this novel research direction.

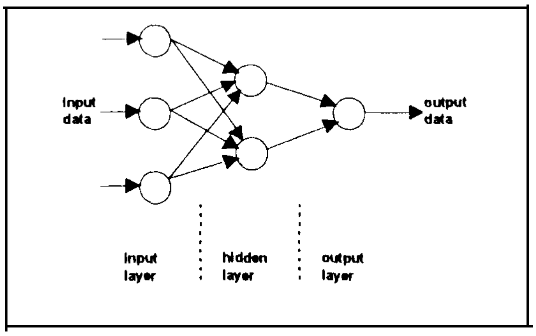

Figure 1 A Feedforward Neural Network architecture

Following the majority of applications on NNs. in this study a two-layer feedforward. totally connected NN will be used in order to analyse the freight transport modal split problem The methodological structure of the main steps related to the application of a feedforward NN is described in Reggiani and Tritapepe (1997) (see also Figure I). Concisely. it consists of three stages: a) definition of network architecture: b) learning phase: c) forecasting phase. It is necessary to define the right architecture of the network. i.e. the number of units on the relevant levels. Usually. the input and output units depend on the number of input and output variables which define the problem. In our application one possible NN architecture contains 4 input units which correspond to the attributes time and cost related to each transport mode (rail and road) and one output unit corresponding to the probability of choosing one mode' (e.g., the rail mode). In the past years we have witnessed an increasing acceptance of NN models in social science research. including transportation science. Section 3 will offer empirical results obtained by applying an NN model to European freight flow data.

3. Empirical Application

We will now present results from the experiments with the logit and the neural network approach. In Subsection 3.1 a concise description of the data set will be given and in Subsection 3.2. the findings from of the two alternative approaches will be compared and evaluated.

3.1 Data Set

The data set' contains the freight flows and the attributes related to each link between 108 European region? for the year 1986. The attributes considered are '*time* ' and '*cost* ' between each link (ij) with reference to each transport mode. In particular. each observation of the data set pertains to variables related to each link (ij). Furthermore, the flow distribution in the matrices concerned refers to one particular kind of goods. viz. food.

Since 108 areas have been considered. the data set should ideally contain 11664 observations (according to the previous remarks on our observations). However. our data set contains finally 4409 observations because of the following considerations (by analysing the data set):

- the intra-area freight flows are zero:

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[1] The choice probability of the other mode is just the complement.

[2] The data set has been kindly provided by NEA Transport Research and Training, Rijswijk.

[3] The map and list of regions is displayed in Reggiani et al.(1997b)

for each link. only the transport movements towards one direction i → j have been considered:

only the links where the flows and the attributes (of both road and rail) are different from zero have been considered (i.e.. empty cells are excluded).

The data set has been randomly subdivided into three sub-sets:

- a *training set* containing 2992 observations. i.e. about 68% of the data-set;
- a *cross-validation set* containing 447 observations. i.e. about 10% of the data-set:
- a *test* set containing 970 observations. i.e. about 22% of the data-set.

3.2 Comparison of Results from the Logit and Neural Network Approach

The logit model has been calibrated in order to estimate the unknown parameters in the utility function, For this purpose. a data set. which is the learning set combined with the cross-validation set. has been used. The NN model has been trained with the training set and the cross-validation set is used to cope with the overfilling problem (for details on the calibration/learning procedure. see Reggiani et al. 1997b).

By using the test set. which was not used for the calibration procedure. both the binary logit and the neural network model have been employed to predict the freight flows for link (ij). This performance has been evaluated using the statistical indicator ARV (Average Relative Variance):

$$ARV = \frac{\sum (y - \hat{y})^2}{\sum (y - \bar{y})^2} \qquad (1)$$

where y = the obsened transport flow using car. y = the transport flow using car. predicted by the adopted model and y = the average of the observed transport flow using car (see Fischer and Gopal. 1994). Table I shows the value of the ARV indicator for the adopted models.

Table 1. **Comparison of Logit and NN performance**

	ARV
NN	0.176
Logit	0.185

According to the ARV indicator. the NN approach for forecasting spatial flows performs overall slightly better than the logit approach.

4. Environmental Scenario Experiments

It goes without saying that freight transport causes high social costs. which from an economic perspective would have to be charged to the transportation sector. We will now investigate the consequences of varying the transportation costs for freight flows. A sensitivity analysis of the previous results based on some economic scenarios will now be carried out in this section by using again both the binary logit model and the NN model. Three policy scenarios based on different external costs assignments will be used: they will concisely be discussed here. Later on. we will present the results related to the sensitivity analysis for the logit and the neural network approach.

At present. because of severe problems on the road transport network (for example. congestion), governments are trying to reduce the road usage by imposing policy measures that serve to increase the cost of road usage (see Verhocf. 1996). An example of a Pigouvian policy for coping with environmental externalities is the recently increased tax on fuel in the Netherlands. In so doing. the usage of the road transport network is made less attractive than other transport networks. In the light of these recent developments. three scenarios have been developed and considered for an sensitivity analysis: these are based on the observations in the test set. In all three scenarios we assume that a uniform European tax policy for freight transport is adopted and that the cost attribute related to the road mode is increased for all links (ij) to reduce road usage. In Scenario 1 the cost attribute is increased by an 5% increase and in Scenario 2 by 10% If the high social costs of external effect (for example congestion, accidents, etc) would be included in the cost of road usage. the cost will significantly increase. So Scenario 3 is a draconian scenario with an assumed increase of an ecotax of 50%.

The conditional predictions for the three Dutch regions are presented in Tables 2 and 3 for the binary logit and the neural network model. respectively. The relative prediction error (see Tables 2 and 3) is defined as the difference between the predicted flow and the real flow as a percentage of the real flow. These tables indicate that the binary logit model is relatively more sensitive to changes in the cost attribute than the NN model. The NN model estimates appear to give the lowest prediction error.

Table 2. **Results of the environmental policy experiments with the logit model**

	Food Transport Flows					Rel. Pred. Error			
From NL to Europe Regions	real flow	pred. flow test set	+ 5 %	+10%	+50%	test set	+ 5 %	+10%	+50%
Breda	181032	170981	169463	167754	146312	-3.6%	-6.4%	-7.3%	-19.2%
Eindhoven	968534	904321	897087	889200	799023	-6,6%	-7.4%	-8.2%	-17,5%
Maastricht	264424	252429	251264	249984	234094	-4,5%	-5.0%	-5.5%	-11,5%
TOTAL	1413990	1327732	1317814	1306938	1179428	-6.1%	-6,8%	-7,6%	-16.6%
From Europe to NL Regions									
Breda	15922	15837	15801	15759	15175	-0,5%	-0,8%	-1.0%	-4,7%
Eindhoven	119772	121918	121464	120957	114382	1.8%	1,4%	1,0%	-4,5%
Maastricht	59880	59550	59359	59147	56365	-0,6%	4.9%	-1,2%	-5.9%
TOTAL	195574	197304	196624	195864	185921	0,9%	0,5%	0,1%	-4,9%

Table 3 Results of the environmental policy experiments with the neural network model

	Food Transport					Rel. Pred. Error			
From NL To Europe Regions	real flow	pred. flow test set	+ 5%	+10%	+50%	test set	+ 5%	+10%	+50%
Breda	181032	176781	176369	176221	175011	-2,3%	-2,6%	-2,7%	-3,3%
Eindhoven	968534	945732	944253	943657	938761	-2,4%	-2,5%	-2,6%	-3,1%
Maastricht	264424	255930	255699	255588	254723	-3,2%	-3,3%	-3,3%	-3,7%
TOTAL	1413990	1378443	1376321	1375465	1368495	-2,5%	-2,7%	-2,7%	-3,2%
From Europe to NL Regions									
Breda	15922	15634	15620	15615	15572	-1,8%	-1,9%	-1,9%	-2,2%
Eindhoven	119772	122434	122313	122262	121873	2,2%	2,1%	2,1%	1,8%
Maastricht	59880	60010	59939	59912	59699	0,2%	0,1%	0,1%	-0,3%
TOTAL	195574	198078	197871	197789	197143	1.3%	1,2%	1.1%	0,8%

It is interesting to note that in the particular case of inflows from Europe to the Netherlands. the two models generally show -in the mean value- a slight increase of flows. despite the cost increase (the only exception being the case of +50 % in the cost for the logit model). This result may be plausible by taking into account the increasing amount of interaction among regional flows as a result of increased efficiency. It would certainly be relevant to compare these results with more updated data in order to better evaluate the 'forecasting' analysis of the two models. since we have used -as a starting point- a test set related to the year 1986.

However. the above results may be considered valid. in the absence of updated data that would be able to test our hypothesis of the increases in the costs. given the good performance of the calibration / test phase. Moreover. these results may offer a 'range of values' to policy actors aiming to evaluate the impact of cost changes on flows. given the intrinsic limits of the models adopted in the analysis..

We may remark here that on the one hand. the large amount of data at an aggregate level. hampers a behavioural perspective inherent in logit models and that on the other hand. the type of architecture adopted in NN models seems critical for the validity of the results. Consequently. the results of our model may be used as a benchmark for the results of other models. by offering a range of plausible output results to those involved in transportation planning.

Comparing the results of the two approaches related to Scenario 3 in Tables 2 and 3. it seems that the Logit models predicts a strong effect of the cost on the freight flows. while the NN model predicts only a slight change in the freight flows.

5. Retrospect and Prospect

The analysis undertaken in our study aimed to map out freight transport flows in an interregional European setting. Based on an extensive data set. various estimates of the impacts of costs on transport movements have been made. The test results show that both the logit and the NN approach are giving fairly favourable results. In general. NN models seem to perform slightly better by confirming previous results of NNs applied to transport data (see Nijkamp et al. 1996. 1997 and Reggiani et al. 1997). After this exploratory comparative study of two modelling approaches. it is certainly opportune to investigate more thoroughly the differences in background of these two research paradigms. It is well known that the logit model is a particular spatial interaction model that has its roots in social behaviour of actors. The NN model is based on similarity of learning experiments and has certainly a behavioural adjustment potential, but is less easily interpretable from social science motives. even though recent results show a compatibility between feedforward NNs and binary logit models (see Schintler & Olurotimi 1997), feedforward NNs and spatial interaction models (see Fischer & Gopal 1994) and feedforward NNs and logistic regression models (see Schumacher et al. 1996). Given its predictive ability, more research is needed to better investigate the behavioural roots of NN models. We may conclude that a blend of behavioural models and complex systems' models (such as neural network models) seems to offer a promising methodology for a proper mapping of spatial freight flows in Europe.

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