ECONOMIC RESEARCH CENTRE

ROUND TABLE 58

REVIEW OF DEMAND MODELS

FORECAST/RECORDED TRAFFIC COMPARISONS FOR URBAN AND INTERCITY TRANSPORT

EUROPEAN CONFERENCE OF MINISTERS OF TRANSPORT

PARIS 1982

ECONOMIC RESEARCH CENTRE

REPORT OF
THE FIFTY-EIGHT ROUND TABLE
ON TRANSPORT ECONOMICS

Held in Paris on 25th and 26th June, 1981
on the following topic:

REVIEW OF DEMAND MODELS

FORECAST/RECORDED TRAFFIC COMPARISONS FOR URBAN AND INTERCITY TRANSPORT

EUROPEAN CONFERENCE OF MINISTERS OF TRANSPORT

The European Conference of Ministers of Transport (ECMT) was instituted by a Protocol signed at Brussels on 17th October 1953. It comprises the Ministers of Transport of the following 19 countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxemburg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom and Yugoslavia (associated countries: Australia, Canada, Japan, United States).

The purposes of the ECMT are:

— *to take whatever measures may be necessary to achieve, at general or regional level, the maximum use and most rational development of European inland transport of international importance;*

— *to co-ordinate and promote the activities of International Organisations concerned with European inland transport (rail, road, navigable ways), taking into account the work of supranational authorities in this field.*

Publié en français sous le titre :

BILAN DE LA MODELISATION DE LA DEMANDE
CONFRONTATION PRÉVISIONS/RÉSULTATS DANS LES TRANSPORTS URBAINS ET INTERURBAINS

* * *

ECMT publications are marketed by the Sale of Publications Department of the OECD, 2, rue André-Pascal, 75775 PARIS CEDEX 16, France.

TABLE OF CONTENTS

PASSENGER TRANSPORT

Olivier Morellet
Roger Marche
Xavier Godard
Institut de Recherche des Transports
94114 Arcueil
France

SUMMARY

INTRODUCTION

A transport project cannot be planned or assessed in terms of economic feasibility unless medium or long-term traffic forecasts are established, since the volume of traffic, while not the only criterion, is fundamental to any decision to invest or to operate in a particular way. It is accordingly essential to know the extent to which one can rely on the technical instruments used for a priori estimates of future transport demand.

These instruments are usually models incorporating a set of principles expressed in mathematical terms and relating the phenomenon under consideration to a certain number of explanatory variables.

The soundness of a model can be assessed "from inside", so to speak, by analysing the different options taken in building it and, for example, estimating a confidence interval for the findings. On the face of it, however, a more conclusive method is simply to test the model empirically and compare the findings relevant to a given project with the factual data recorded after its implementation.

What this amounts to, however, is to assess the relevance not only of the model, but of the forecasting exercise as a whole. In addition to the problems specific to the construction of the model, there are also those relating to both the choice of basic assumptions at an earlier stage and, subsequently, the ways in which the results of the calculations are interpreted and used. These three aspects vary in impact and importance according to the nature of the study under consideration.

Examples of studies carried out in France are set out in the following three chapters:

A. a nationwide forecast of a steadily rising demand for inter-city transport which may be examined in terms of a single mode: <u>private car traffic outside built-up areas</u>;

B. forecasting rapidly expanding demand on a network of inter-city routes which calls for a multi-modal approach: <u>passenger traffic on French domestic flights</u>;

C. forecasting urban transport demand on a particular route: <u>involving the opening of a number of new public transport</u> services.

These studies are not claimed to be representative of all the problems arising in connection with passenger transport demand models. They are simply intended to provide a basis for more general methodological consideration which offers the maximum possible specificity and diversity.

One point in particular will be recurring and deserves to be stressed: efforts should certainly be made to improve models, especially on the basis of what has been learned from comparing the results given by a model with the volumes of traffic which are in fact subsequently recorded, but however good the model, it can only be really effective if used correctly. Thus, in addition to making technical improvements to the instruments, it is also necessary to focus attention on the conditions under which these instruments are used.

A. A DEMAND MODEL FOR INTERCITY PRIVATE CAR TRAFFIC

(Olivier MORELLET)

INTRODUCTION

Studies for the purpose of forecasting intercity road traffic usually comprise two successive phases:

- <u>an analysis of demand based on the data available when the study is carried out</u>, which essentially consists of breaking down traffic flows by places of origin and destination of the vehicles by means of either road-side traffic surveys or traffic generation distribution models;
- <u>projection of this demand over the forecasting period</u>, which consists of estimating trends over time in volumes of traffic by origin and destination and differentiating between two types of growth:
  - "natural" growth, i.e. what would be observed if service conditions were unchanged;
  - "induced" growth, which is added to the above and is the product of improvements made in traffic conditions during the forecasting period.

While trends in induced growth are usually determined by applying a supply and demand model to each origin-destination route, natural growth is very often established globally for the whole network under consideration.

More specifically, the method consists of applying the same growth rate to the volume of traffic on each origin-destination route, the rate being estimated on the basis of a model designed to show the overall trend in intercity traffic. An instrument of this type was developed in about 1970 for the Highways and Road Traffic Directorate of the Ministry of Transport. In the following paragraphs we shall give a brief description of this model and then compare the results it gave with the traffic data recorded between 1970 and 1980. Lastly, an attempt will be made to explain the discrepancies between forecasts and recorded traffic, differentiating between two types of contributory factor: methodological errors and the choice of unsound assumptions.

I. BASIC PRINCIPLES OF THE MODEL

The 1970 approach is conventional in that it considers the growth of intercity private car traffic to be the product of two trends:

- the total number of cars in use;
- the average use made of each car.

It would be too lengthy to give a detailed account of the calculations made. Suffice it to say that:

- the percentage of households owning cars was projected by Cramer's method: the distribution of households by income is assumed to be lognormal and no given household buys a car unless its income exceeds a certain threshold which varies from one household to another, here too the distribution being lognormal; in addition, the concept of the spread of car ownership is applied insofar as the median income of the distribution of ownership thresholds falls slowly over time;
- the percentage of households with two or more cars was extrapolated in the shape of a parabolic curve fitted to past observations since 1958, which implicity assumed that the slowdown of the phenomenon would not be felt before 1985-90; in addition it was assumed that the distribution by income group would not change over time;
- the trend in the number of kilometres covered annually by each car in intercity traffic was assimilated to that of total average kilometrage per car, itself estimated according to a simple principle: each income group was given an average "first car" kilometrage and an average "second car" kilometrage on the basis of survey data obtained for 1967;
- finally, it was assumed that company cars always account for 5 per cent of the total number of cars and have an average annual kilometrage slightly higher than that of private cars.

II. THE FRAME OF REFERENCE FOR THE FORECAST

A description of the basic principles of the model does not suffice for the purpose of assessing the forecasts, since it is also necessary to define the general frame of reference established for these forecasts. In other words, what assumptions were made about trends in the various explanatory variables determining car ownership and mobility levels? The explanatory variables were:

- number of households, which was assumed to grow by 0.9 per cent a year. This figure was obtained from a none too recent demographic projection dating from 1964;
- disposable income per houshold, for which an annual growth rate of 4.5 per cent was applied, thus leading to a very high rate of increase of total household consumption (over 5 per cent a year) in line with the trend observed in the recent past (see Figure 1);
- motor fuel prices, which are a major influence on car use; no explicit assumption was made about the relevant trends, but price stability in constant value francs was inherent in the choice of a fixed kilometrage per income group. This implicit assumption in fact departed somewhat from past trends since at the time of the study the relative price of fuel had been falling steadily for more than 15 years (see Figure 1).

III. FORECASTS ESTABLISHED AND TRAFFIC IN FACT RECORDED

A model based on such assumptions concerning social and economic developments was hardly likely to produce forecasts which differed much from past trends and, in fact, the 1970 study showed a continuation of the trend observed over the preceding years, i.e. very slight exponential growth at a rate of 6.5 per cent a year (see Figure 2).

What actually happened?

A fairly accurate picture of the real trend in intercity traffic is given by an index calculated for the whole of the non-urban road network (major motorways and main roads outside built-up areas with populations of over 5,000). This index shows the trend from one year (n) to the next (n+1) in recorded flows of private cars on the infrastructures in service as at 1st January of year (n). Variations in this index over a long period are not an accurate reflection of the "natural" growth of intercity traffic, since such variations include both the diversion of main road traffic to motorways opened during year (n) and induced traffic or that diverted from minor roads to motorways already in service at the beginning of that year; this is a good example of the difficulty sometimes experienced in simply measuring the phenomenon to be modelled. These two factors fortunately tend to offset one another so that the index can be accepted as providing a fair first approximation of intercity traffic.

One needs only to look at the graph showing this index between 1970 and 1979 to see that the regular growth expected in 1970 did

Figure 1 **TRENDS IN GDP, HOUSEHOLD CONSUMPTION AND THE PRICE OF MOTOR-FUEL IN FRANCE**

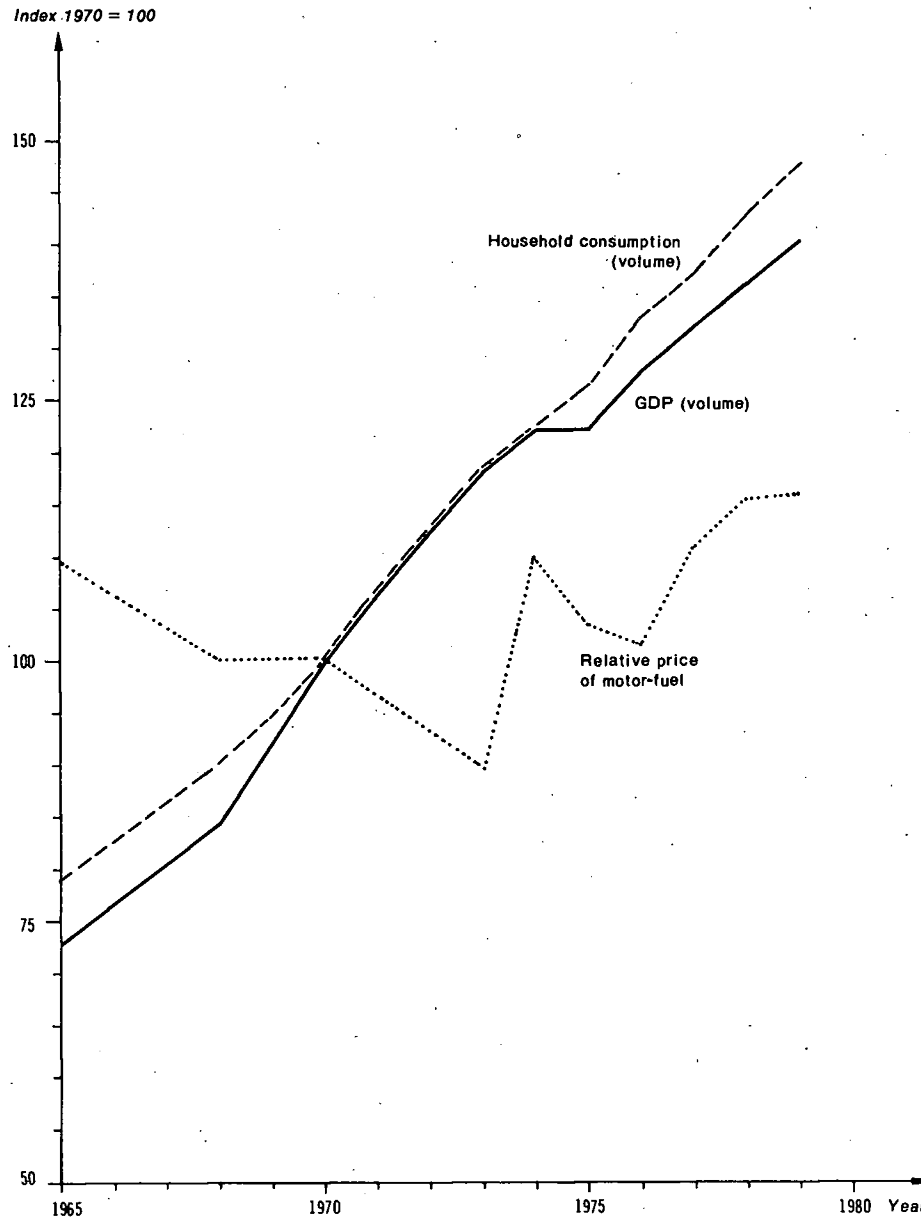
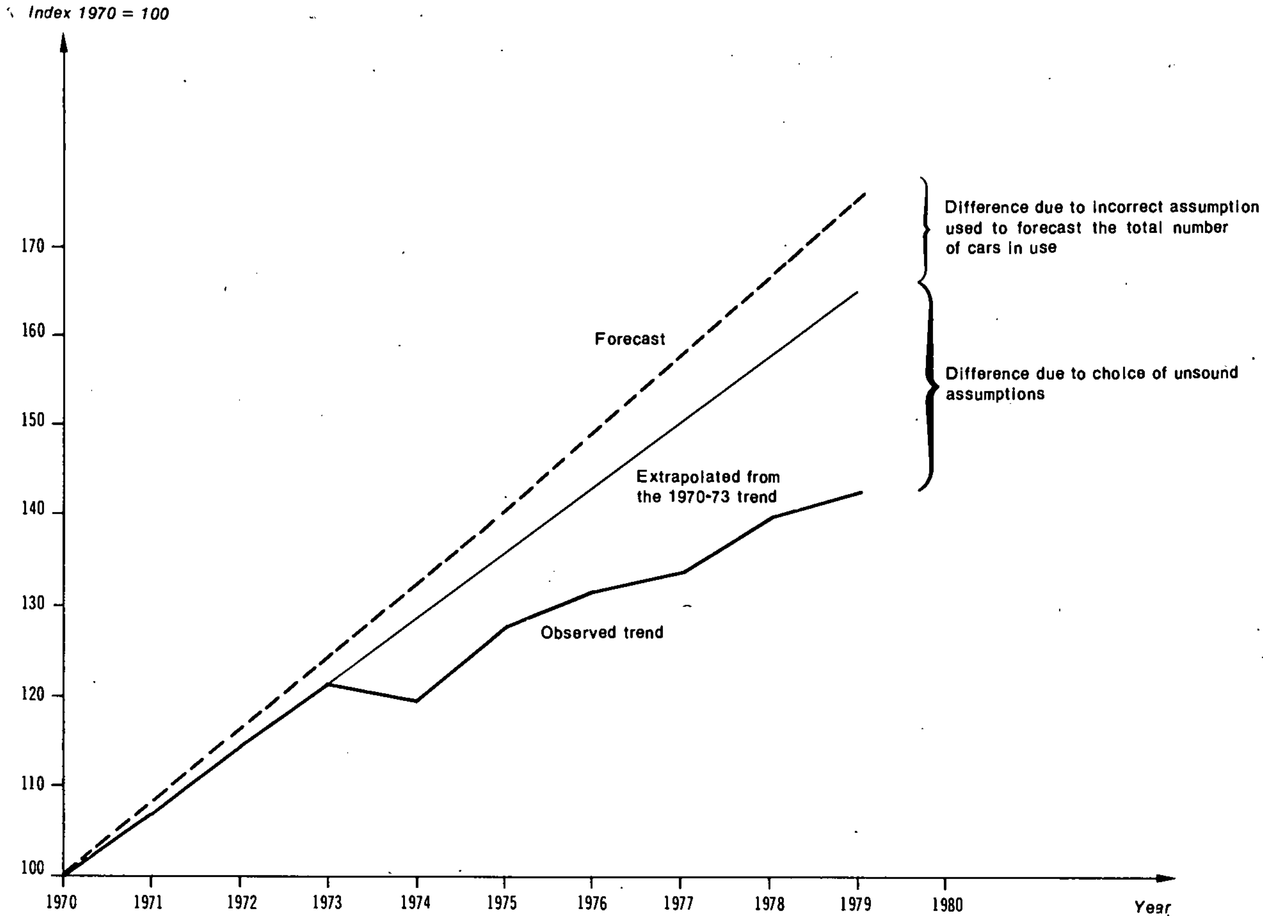


Figure 2 **INTERCITY PRIVATE CAR TRAFFIC**



not take place. After a period of sustained growth up to 1973, intercity traffic fell slightly between 1973 and 1974 and then began to expand again from 1975 onwards but at a much slower rate (3.6 per cent per annum as opposed to 6.5 per cent). This discrepancy between the forecast and the traffic in fact recorded is far from negligible and can be attributed to two sources:

- the method used;
- the basic assumptions.

IV. A CRITICAL ANALYSIS OF THE MODEL

The main methodological errors are to be found in the projection of the number of cars in use. The 1970 study forecast that by 1979, 75 per cent of households would have one car and 28 per cent two or more; in fact, the recorded figures were only 68 per cent and 17 per cent respectively and the discrepancies can certainly be largely attributed to faults in the method used:

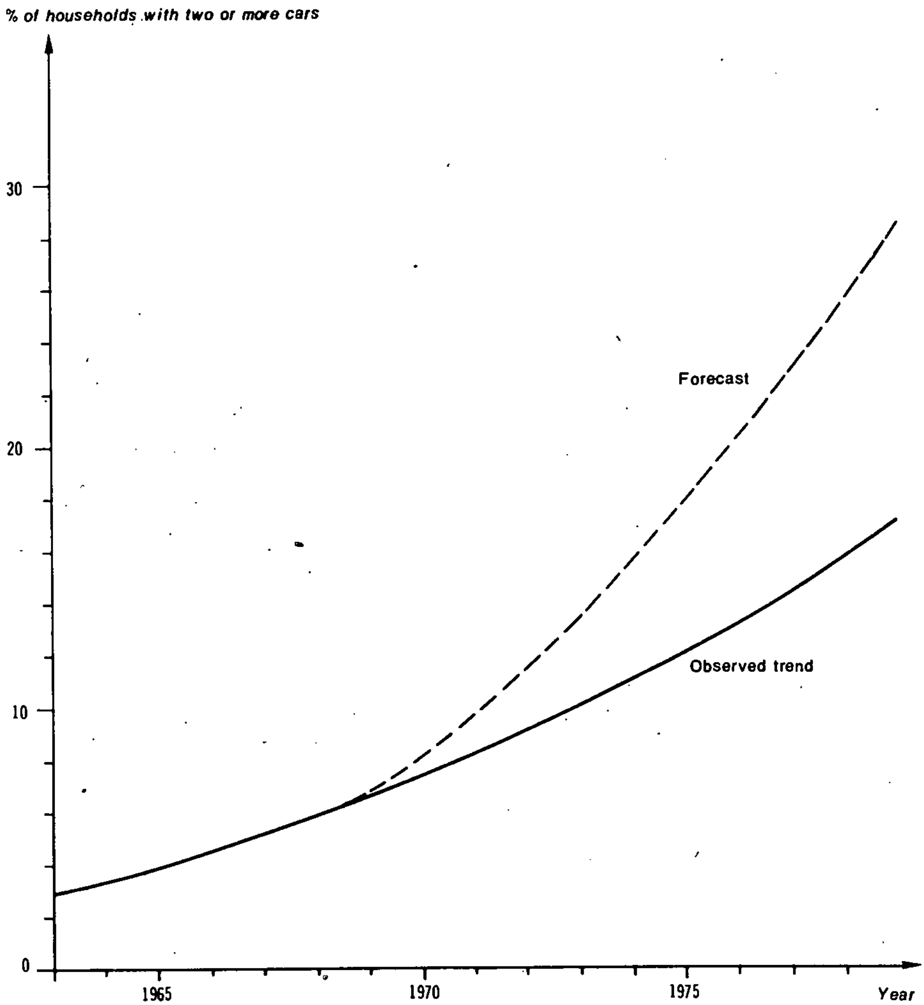
- the gradual decrease in the median income threshold for car-ownership was extrapolated linearly from the past trend, although in fact the spread of car ownership had slowed with the years, hence the fairly marked overestimate for car ownership in 1979;
- the phenomenon of the two-car household was certainly expanding rapidly around 1970, but it was somewhat risky simply to extend the parabolic growth curve fitted to past growth rates. Why extend this parabola and not some other function that could have been adjusted just as well? In any event, actual developments showed that the slope of the recorded growth curve for two-car households was not as steep as was expected in 1970 (see Figure 3).

An analysis of the methodological errors is not the main matter of concern here, however, as the work done on car ownership models since 1970 has mitigated such shortcomings and will continue to do so in the coming years.

V. A CRITICAL ANALYSIS OF THE ASSUMPTIONS

On the other hand, there will always be considerable uncertainty concerning the assumptions on which forecasts are based, namely the assumptions about trends in population, economic development and the cost of using a car. On these three points, in fact, the recorded data are not always consistent with the expectations of the 70s:

Figure 3 **PERCENTAGE OF HOUSEHOLDS WITH TWO OR MORE CARS**



- The estimated number of households in 1979 was 18.8 million as against the 17.1 million forecast in the study. The discrepancy is easily explained by the underestimation of a phenomenon which has marked the past 20 years, i.e. a reduction in the average sized household, which owes more to the earlier departure of young people from their homes than to a fall in the birth rate (3.19 persons per household in 1960, 3.1 in 1970 and 2.9 in 1979). It may be noted in passing that this oversight regarding the number of households is partly offset by the overestimate of car ownership, but not to such an extent that the forecast of the number of cars owned by households finally turned out correct (17.7 million vehicles expected as opposed to 16 million actually recorded). The slight overestimate of the growth in the number of cars quite adequately explains the discrepency between the forecast figures and what would have been forecast by extrapolating the real trend observed between 1970 and 1973 (see Figure 2);
- but, if there was to be a continuation of that trend , it would also have been necessary to maintain the growth rate which France had been experiencing for several years previously and which had prompted the experts' optimistic forecasts. In 1973-74, of course, came the upsurge in the price of imported oil and its two main consequences:
  - an immediate increase of almost one-quarter in the relative price of motor fuel, which had little impact on the total number of vehicles in use, but caused a fairly sharp drop in private car kilometrage;
  - in the longer-term, stable motor fuel prices over a long period and a slower rate of growth in the French economy (3 per cent per annum as compared with 6 per cent between 1960 and 1970). These two new trends influenced both the number of vehicles and their use and entirely account for the low growth rate of intercity car traffic.

Thus, virtually all the assumptions made in 1970 were invalidated 10 years later, usually proving over-optimistic. In the final analysis, it is this choice of unsound assumptions that is largely responsible for the discrepancy between the traffic forecasts for 1979 and traffic in fact recorded.

VI. POSSIBLE IMPROVEMENTS

In the light of the above retrospective analysis, it may be asked whether it is worthwhile, for the purpose of medium-term forecasting, to use a highly sophisticated explanatory model in conjunction with a set of assumptions which necessarily remain somewhat arbitrary and uncertain. Is not the quality of the instrument somewhat disproportionate to the quality of the data incorporated? In the case under consideration, for example, a simple model in which traffic elasticity is equal to 1 in relation to household consumption and minus 0.2 in relation to the relative price of fuel is enough to reconstruct the trend observed between 1970 and 1979 (see Figure 4).

Obviously, if any progress is to be made in this field, one cannot simply take the line of least resistance whereby the forecaster discards the sophisticated model because he is unable to put it to proper use. On the contrary, the aim should be to ensure that the frame of reference for the forecasts is more carefully selected.

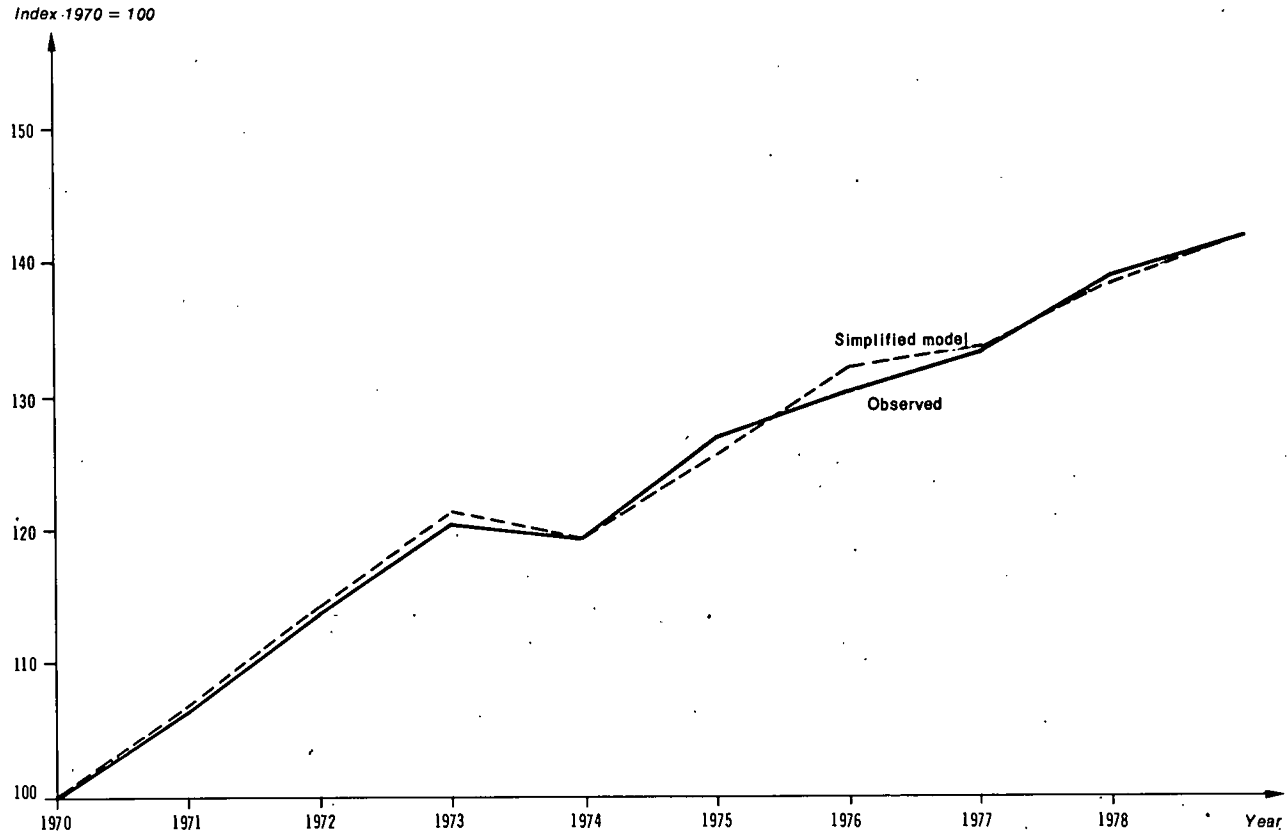
However, projections of demographic and economic trends, whether national or worldwide, can never be completely reliable. The approach to adopt would therefore seem to be to take account of several possible scenarios, each based on a particular set of assumptions. The fact that many different results are obtained will not of course make it any easier to interpret them or use them for decision-making, but they can at least help in two respects by showing:

- what lies within the bounds of possibility;
- what exogenous factor can significant influence the trend in demand under consideration.

The preparatory studies for the VIIIth Plan illustrated this new approach in that car traffic forecasts were established for each of four different scenarios and showed the following average annual growth rates for the period 1978-85:

	Scenario			
	Regulation in a favourable external environment	Regulation in an unfavourable external environment	Structural adjustment in a favourable external environment	Structural adjustment in an unfavourable external environment
GDP	2.9%	2.5%	3.2%	2.7%
Household consumption	3.6%	3.1%	3.8%	3.4%
Crude oil price	-	7 %	-	7 %
Motor fuel price	-	1.5%	2.9%	4.4%
Intercity traffic	3.6%	2.8%	3.2%	2.5%

Figure 4 TRENDS IN INTERCITY PRIVATE CAR TRAFFIC



B. RAIL VERSUS AIR AND DEMAND FOR FRENCH DOMESTIC AIR SERVICES

(Roger MARCHE)

INTRODUCTION

The first long-term domestic air transport demand forecasts for France were carried out in 1965 on the basis of an analysis of the 1963 situation. The study covered the period up to 1970 and, somewhat more cursorily, to 1975.(1)

There were three main reasons for this choice:

- a "multi-modal" model was used to establish air transport demand forecasts. Referred to succinctly as the "price-time-income" model, it was the first to introduce the air versus rail choice. The model was based on data from sample surveys among air and rail passengers in 1963, data which provided the basis for an analysis of the influence of demand factors;
- domestic air transport demand was growing very rapidly in the 1960s and major changes were expected in the supply situation, so the forecasting model had to be able to take accurate account of this very rapid growth;
- the forecast/recorded traffic comparison can be made over a very long period (1963-75), and it would be useful to extend the critical analysis up to 1980 by examining the improvements made to this first multi-modal model.

I. DOMESTIC AIR TRANSPORT IN 1963

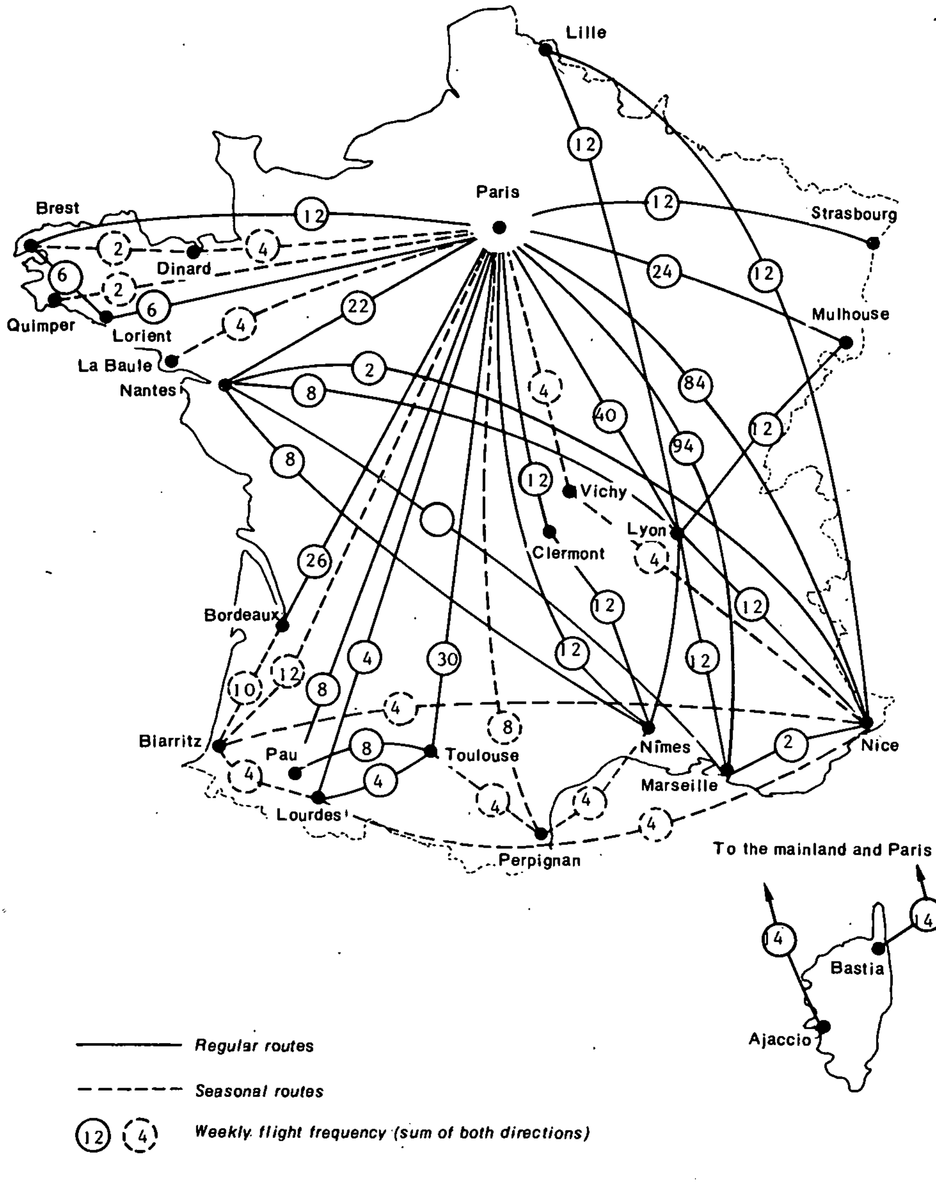
Before describing the demand analysis methods and the forecasting model, it is important to clarify the context of air transport in the base year (1963), in terms of both the structure of the air network and the volume of air travel in relation to total long-distance passenger transport.

I.1 The air network

Figure 1 shows domestic air links in 1963 with weekly flight frequencies:

- 35 regular links (year round operation): 16 with Paris, of which 8 relatively old-established (Nice, Marseilles, Bordeaux, Toulouse, Mulhouse, Strasbourg, Ajaccio and Bastia); 15 mainland links between provincial towns; 4 between the Mediterranean coast (Marseilles, Nice) and Corsica (Ajaccio, Bastia);

Figure 1 **DOMESTIC AIR NETWORK IN 1963**



- 14 seasonal links operated during the summer (in July and August, often in September and sometimes in June): 6 links with Paris, 8 between provincial towns.

It may be noted that the air network was already fairly extensive, but that the flight frequency exceeded 20 per week (i.e. approximately a minimum of 2 flights a day in each direction) on only 7 regular links with Paris, 5 of them relatively old-established (Nice, Marseilles, Bordeaux, Toulouse and Mulhouse) plus Paris-Lyons and Paris-Nantes.

Turbo-jet aircraft (Caravelle, Boeing 707, DC8) were already operating some of the services on the major links over relatively long distances (over all the older regular links with Paris, except Paris-Mulhouse) but the other links were flown by slower aircraft (turbo-prop or piston-engine machines).

I.2 Air transport demand

Approximately 1 million people (990,000 paying passengers) were carried on the domestic air network in 1963:

- 730,000 passengers on mainland links: 660,000 over links with Paris, 70,000 between provincial towns (the forecasts were concerned with these mainland links);
- 260,000 passengers on links with Corsica.

Over the mainland links, the average flight distance for the domestic air traveller was 590 km, a figure comparable with that of the European traveller departing from Paris (650 km).

The rapid growth of domestic air traffic is illustrated by the following annual increases on links with Paris: 1960/1961: 39 per cent, 1961/1962: 36 per cent, 1962/1963: 37 per cent, and 1963/1964: 25 per cent. Growth was naturally slower over the main old-established links (averaging over the period 1959 to 1963, 24 per cent per annum for Paris-Nice and 29 per cent for Paris-Marseilles) than over the more recently opened links.

It is important to note the breakdown of the demand for domestic air transport between the two main categories, business and private travel. The relative shares of these two markets were ascertained by means of a fairly large sample survey (almost 6,000 questionnaires) carried out in 1963 on the initiative of the Ministry of Transport's Economic and International Affairs Service (Service des Affaires Economiques et Internationales - SAEI) and with the collaboration of the Air Inter and Air France airlines:

- this survey covered all the mainland Air Inter links except Paris-Nice (operated at the time on a pool system by Air France and Air Inter) and the flights operated by Air France on the Paris-Marseilles link;

- the survey procedure involved two steps: a sample of flights on each link and a sample of pre-selected seats (the survey covered passengers of over 14 years old occupying these seats);
- the flights were sampled during the period between May and November 1973 so as to provide a satisfactory picture of demand over the whole year; the findings of the survey were adjusted link by link (taking account of possible connecting flights) with a breakdown between two periods: summer (1st July to 15th September) and the rest of the year;
- the findings relate to a total of 400,000 passengers who may be considered to be representative of mainland domestic demand with the exception of Paris-Nice (490,000 passengers if the 240,000 on the Paris-Nice link are subtracted from the total of 730,000).

On the mainland domestic links, excluding Paris-Nice, business trips accounted for 77 per cent of the total:

Business trips:		
- work	71.0%	76.7%
- work and tourism	5.7%	
Private trips:		
- tourism	9.7%	23.2%
- visits to friends or relations	11.2%	
- other reasons	2.4%	

Finally, it may be noted that 13 per cent of the 400,000 passengers covered by the survey were resident abroad and 13 per cent of the trips were to a foreign destination.

I.3 Long-distance rail transport demand

The situation with regard to long-distance train trips (over 300 km) was estimated for 1963 on the basis of a SNCF sample survey of passengers in 1961.(2) Although the definitions for the two surveys differ (in the air survey, the passenger count on the domestic network takes account of possible onward flights on the network, whereas the train "passenger" count in fact relates to SNCF trips made on the same train, so that the same trip, on the outward or homeward journey, may give rise to two successive trips of over 300 km on different trains). Table 1 enables us to compare demand for air and rail travel (the air links are broken down according to the distances between SNCF stations).

Table 1

MAINLAND DOMESTIC AIR PASSENGERS AND SNCF JOURNEYS
(1963)

Distance	Millions of "passengers"				Air + 1st class rail	
	Air	Rail			Millions	% air
		1st class	2nd class	Total		
301 to 600 km	0.19(1)	7.0	15.1	22.1	7.2	3%
601 to 1000 km	0.29	3.4	9.3	12.7	3.7	8%
>1000 km	0.25	1.5	4.2	5.7	1.7	15%
Total	0.73	11.9	28.6	40.5	12.6	6%
% of business trips	75% approx	56%	23%	33%	57%	

1) Including about 5,000 passengers travelling less than 300 kms.

Thus, air transport demand in 1963 was very modest in comparison with rail transport demand, even for very long journeys (over 600 km):

- first-class SNCF travellers, who represented a potential demand for air travel for both business and private purposes, accounted for almost 12 million journeys. A more detailed analysis of points of departure and destination showed that the annual number of journeys (taking account of possible changes of train) over links where the air network might compete (links where air services existed or where such services could be opened in view of the distance and the size of the conurbations concerned) totalled about 8 million, approximately 6 million of which being on "home-destination" links within France;
- attention should also be drawn to the large number of second-class long-distance train journeys (more than 13 million journeys of over 600 km) which included short-stay personal trips by potential air passengers.

The modest growth of mainline SNCF traffic can be seen from the following annual increases in passenger-km: 1960/1961: 4.8 per cent, 1961/1962: 6.5 per cent, 1962/1963: 0.6 per cent, and 1963/1964: 0.9 per cent.

Further information on rail transport demand was provided by a sample survey carried out in 1963 on the initiative of the SAEI with the co-operation of the SNCF:

- the survey was conducted among first-class passengers on the main trains on the following five links: Paris-Lyons/Bordeaux/Toulouse and Lyons-Nantes/Mulhouse;

- it provided data for studying rail transport demand on these five links and also on the Paris-Marseilles and Paris-Nice links;
- it covered about 1,900 passengers, about 1,100 of whom travelled on the above seven links, giving a breakdown by stations of departure and destination;
- as the survey was carried out between the 23rd September and 23rd November, 1963, the findings tend to be more representative of the "non-summer" period, but were nevertheless applied to the 1963 traffic as a whole: a total of 2.35 million journeys on the seven links taken together.

Table 2 below:

- shows the demand for first-class train travel on the seven links and differentiates between "short" distances (home and destination in the same départements as the stations, Seine and Seine-et-Oise being considered as a single département) and "longer" distances (either the station of departure or destination in a neighbouring département);
- enables us to compare air and rail demand. On the main links, the air share is higher than in Table 1 and can be seen to increase with distance.

Table 2

NUMBER OF JOURNEYS BY AIR AND FIRST CLASS RAIL ON SEVEN LINKS (1963)

Link	No. of journeys ('000s)				Air share (%)
	Air	Rail Total(1)	1st class of which "short" distance	Air + rail	
Paris-Nice	238	430	270	668	36%
Paris-Marseilles	156	390	240	546	29%
Paris-Lyons	73	850	350	923	8%
Paris-Toulouse	53	170	130	223	24%
Paris-Bordeaux	38	450	250	488	8%
Lyon-Nantes	7	18	6	25	28%
Lyon-Mulhouse	7	39	12	46	15%
Total	572	2,347	1,258	2,919	20%

1) Départements included under the definition "longer distance" journeys:

- Nice: Basses-Alpes, Hautes-Alpes, Var
- Marseilles: Gard, Hérault, Vaucluse
- Lyons: Région Rhône-Alpes, minus Rhône
- Toulouse: Ariège, Aude, Gers, Tarn, Tarn-et-Garonne
- Bordeaux: Charente, Charente-Maritime, Dordogne, Landes, Lot-et-Garonne
- Nantes: Ile-et-Vilaine, Maine-et-Loire, Morbihan, Vendée
- Mulhouse: Bas-Rhin, Territoire-de-Belfort.

This survey showed that business trips accounted for 68 per cent of both the "short" and "longer" distance journeys on these seven links.

II. ANALYSIS OF DEMAND FACTORS

Demand analysis is a prerequisite for the construction of a forecasting model and in this case was carried out on the basis of the above-mentioned sample surveys of air and SNCF passengers.

These surveys provided some very interesting data on the nature of air and rail journeys:

- reason for travel: the analyses and the forecasting model obviously differentiate between the two separate markets for business and private travel;
- passenger's home: the analyses mainly covered travellers resident in France;
- duration of trip (length of absence from home);
- number of persons travelling together.

However, these surveys were primarily used to analyse the role played by socio-economic factors, i.e. the socio-economic characteristics of the passengers, with particular reference to:

- the influence of income;
- the possible influence of age, insofar as such influence should be interpreted as a "generation" effect in the demographic sense of the term.

This analysis focused on the influence of socio-economic factors on both air travel mobility and the rail/air modal split.

In addition, the "price-time-income" model enabled us both to:

- clarify the role of socio-economic factors in the rail/air modal split;
- highlight the comparative influence of transport supply characteristics.

II.1 Socio-economic factors relevant to air travel mobility

a) Definition of mobility

Mobility is defined as the number of journeys (a single leg of a round trip) per 1,000 persons resident in France:

- for private travel, mobility was calculated per 1,000 persons over 14 years old;
- the analysis of business travel was confined to men, who account for 95 per cent of air journeys;

  mobility was calculated per 1,000 gainfully employed men.

The principle of mobility analysis is simple: it simply calls for a comparison of the travel survey findings, broken down by income or age groups, with similar data for the whole population derived from statistics compiled by the National Institute for Statistics and Economic Studies (INSEE) (1962 census, income statistics, data from sample surveys of households).

A number of difficulties had to be resolved, however, and we shall return to them later:

- theoretical difficulties due to the fact that the socio-economic variables (income, size of family, age) are interrelated;
- practical difficulties mainly concerned with income measurement:
  - first, household income has to be interpreted differently according to the reason for travel: in the case of private travel and to give a better idea of a "standard of living", the income has to be converted into "income per unit of consumption", while in the case of business travel, household income is assimilated to the passenger's income, which assumes both that the passengers are mainly heads of households and that their income accounts for the bulk of the family income;
  - secondly, income data from different sources (surveys and overall population data) are not strictly comparable: gross (pre-tax) and net income, possible measurement errors.

b) The "lognormal" model for estimating income elasticities

It is a well-established fact that the distribution of households by annual income is approximately "lognormal" and will be defined by the two parameters of the corresponding normal distribution (statistical distribution according to the Napierian log of the income): mean m and standard deviation σ . The statistical distributions according to household income of persons not under 14 and gainfully employed men are also close to lognormal.

The distribution of air journeys (private journeys, business journeys for men) according to household income were found to be very close to lognormal, with the same parameter σ as for the corresponding population.

This last property (same standard deviation σ) indicates that the coefficient of elasticity is relatively constant, an assumption that is in fact readily verified by calculating mobility per income group, since it can easily be demonstrated that:

- given the assumptions: lognormal distribution (m, σ) in the population and constant elasticity of mobility a,

- the distribution of journeys according to income is lognormal $(m + a\sigma^2, \sigma)$.

It is therefore easy to estimate the income elasticity of mobility from the two cumulative income curves (population curve and journey curve). "Crude" elasticities, i.e. not corrected for the possible influence of other socio-economic factors were obtained:

- for private air journeys: a = 2.2;
- for business air journeys: a = 4.6.

The elasticities calculated in this way relate in principle to gross income (before deduction of income tax):

- which is satisfactory for business travel: the cost of labour is clearly related to gross income;
- but is less satisfactory for private travel: calculated in relation to net income, the elasticity would be about 3.

c) Assessment of the roles of the different factors

As regards private travel, it is important to:

- calculate a relevant income elasticity with due regard to the correlations between household income and the other socio-economic variables (size of household, age);
- show the specific influence of age on air travel mobility.

The method used to identify the separate roles of the different variables involved a series of approximations and can be described briefly as follows:

- by adjusting income elasticity around the crude value obtained as described above for sub-populations of households by size, it was found that a value between 2.5 and 3 was most commensurate with an approximate scale of units of consumption (1st adult = 1 unit, additional person = 0.6 unit);
- given this range of 2.5 to 3, the age effect could be clearly ascertained and showed air travel mobility decreasing after 45 by some 20 per cent for the 45 to 54 age group and 30 per cent for the 55 to 64 age group (beyond which the findings are very arbitrary). It may be noted in passing that women have about 15 per cent less air travel mobility than men in the same age and income groups;
- after eliminating the "sex" and "age" effects, the calculated mobility for each size of household led to an average income elasticity of 2.5 to 3, depending on whether the income was gross or net.

Where business travel is concerned, it is much more difficult to interpret the findings:

- the very high crude income elasticity indicates the relationship between income and the job held in the firm;
- the marked age effect (diminishing from 45 onwards) is also disrupted by the job structure;
- more knowledge about the role of these factors can primarily be acquired by comparing the data on air and first-class rail travel.

II.2 Socio-economic factors relevant to the air/rail modal split

a) Income elasticity of mobility

Crude mobility elasticities for rail travel were calculated as for air travel by using the lognormal model and assuming elasticity to be constant, a method that proved to be sound.

Table 3 summarises the results obtained.

Table 3

INCOME(1) ELASTICITY OF MOBILITY

(Crude data)

Results for each mode	Business travel(2)	Private travel(3)
Domestic air journeys (a)	4.6	2.2
First-class rail journeys on 7 links (b)	3.4	1.4
Train journeys over 300 km		
- 1st class (c)	4.2	1.7
- 2nd class (d)	1.5	0.2

1) Household income.
2) Mobility calculated per gainfully employed male.
3) Mobility calculated per inhabitant aged 14 and over.

Differences in elasticity between one mode and another are particularly interesting since they reflect the income elasticity of the ratio of the two demands. In the case of business travel, for example, (a and b) = 1.2 represents the elasticity of the D_A/D_T ratio (D_A = demand for air travel, D_T = demand for first-class train travel). It must be stressed that these elasticities of demand ratios (which can be calculated directly without adopting the assumption of the lognormal model) are estimated more accurately than mobility elasticities because they are based solely on the incomes declared in the 1963 surveys whilst the estimation of mobility elasticities is affected by the lack of comparability between revenues declared in the surveys and revenues pertaining to all households.

These results clearly show how income level influences passenger choice among air, first-class rail and second-class rail travel but, if they are used to forecast the comparative rates of growth in the different modes on the strength of increase in real incomes, two problems arise:

- first, the possibility of substitution involving three modes of transport (air, first-class rail and second-class rail) makes interpretation difficult;
- secondly, the overall results (for example, in terms of the seven links) relate to a by no means homogeneous set of links and this structural effect may introduce bias into the elasticities of demand ratios.

Accordingly, further analysis called for the construction of a "price-time-income" model with the dual aim of:

- introducing the different links separately; and
- "explaining" the income elasticities of the D_A/D_T ratio.

Before describing this model, it may be said that the rail survey data on mobility as a function of sex and age also provided a clearer picture of the generation effects.

b) The "price-time-income" model

This model is based on two simple principles:

First, the choice between rail and air travel is the result of a trade-off by the passenger between the time saved by air travel and the difference in fare. From the conventional standpoint of "generalised" individual cost ($\gamma = p + ht$) (p = price paid; t = door-to-door journey time; h = the value the traveller puts on one hour of his time), travellers choosing air transport are those for whom $h > (p_A - p_T)/(t_T - t_A)$.

Secondly, the individual value of h is correlated with income level.

To build the model, the principles adopted have to be set out mathemetically.

We know that the distribution of journeys as a function of income i is approximately lognormal, of parameters m and σ (mean and standard deviation in the normal distribution of nd i).

It was assumed that nd i and nd h follow a normal distribution with two variables. Therefore:

- the slope of the line of regression of nd h with respect to nd i is, as a first approximation, the coefficient of elasticity e of the mean value of h with respect to i;
- the "marginal" distribution of journeys according to h is also lognormal, of parameters m' and σ';

- letting σ_ϵ be the standard deviation of the distribution conditioning nd h, we have the simple equation: $\sigma'^2 = e^2 \sigma^2 + \sigma_\epsilon^2$.

Differentiating between business and private travel, we analysed the five ("short") links for which the supply of air services was relatively good and where the 1963 surveys provided data on demand for air and first-class rail travel (the links between Paris and Bordeaux, Lyons, Marseilles, Toulouse and Nice, the demand structure for the Paris-Nice link being estimated by analogy with the other links). The aim of these analyses was to test the model and estimate the numerical values of the parameters.

Figure 2, covering business travel, shows that the statistical distribution of the journeys (air plus first-class rail) according to the value of h is quite compatible with the assumption of a log-normal distribution. The value of σ' is 0.79, as compared with $\sigma = 0.55$. The picture is similar for private travel, with $\sigma' = 1.10$ and $\sigma = 0.75$.

Figure 3 shows the elasticity of D_T/D_A with respect to h for business travel, where e = 2.2. For private travel, the picture is similar with e = 1.4. It should be emphasized that the constant elasticity found is consistent with the assumptions: the normal distribution function followed by the statistical distribution of $D_T/(D_A + D_T)$ as a function of nd h is numerically close to a "logistic" distribution, and the property "nd D_T/D_A is a related function of nd h" is characteristic of the logistic distribution.
Let us note in passing that:

- the statistical distributions of the journeys (air plus first-class rail) in 1963 according to the value of h, give a median value of Frs.11 per hour for business travel and Frs.7 per hour for private travel, the mean values being higher and closer (Frs.13 to Frs.14 per hour);
- for air journeys, the mean values of h are considerably higher (Frs.30 to Frs.35 per hour).

As regards elasticities of h with respect to i, the expectation was:

- a value close to unity for business travel, since the hourly cost of time was expected to be related to the hourly cost of labour;
- a value considerably higher than unity for private travel, by analogy with consumer behaviour vis-à-vis goods or services which are not "prime necessities".

The elasticities were calculated in two ways on the basis of the surveys:

Figure 2 STUDY OF $D_T/(D_A+D_T)$ AS A FUNCTION OF $h = (p_A - p_T)/(t_T - t_A)$
(Business travel)

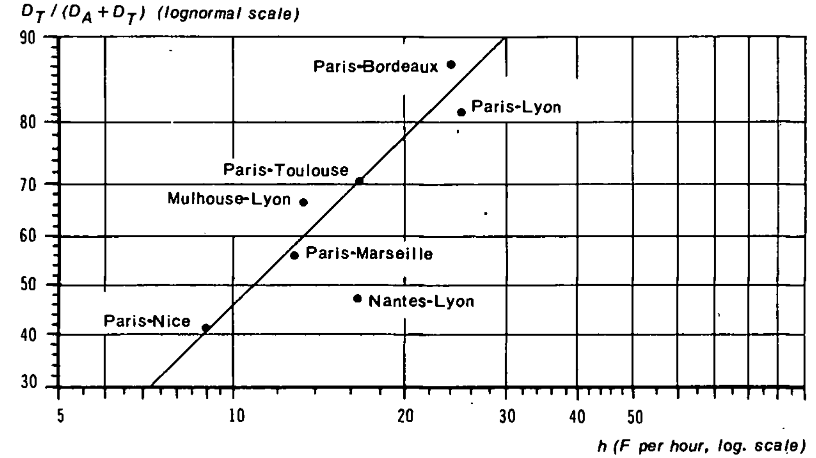
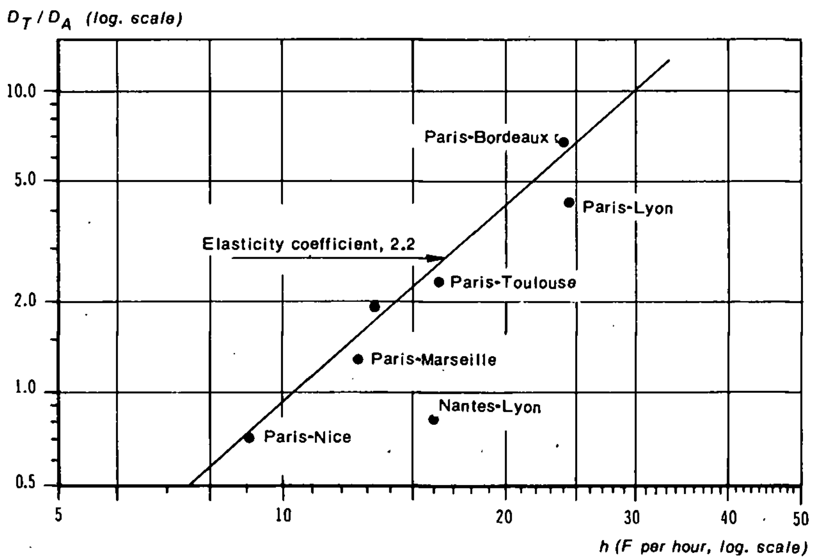


Figure 3 ELASTICITY OF D_T/D_A IN RELATION TO $h = (p_A - p_T)/(t_T - t_A)$
(Business travel)



- first by "disaggregating" the model according to certain classes of i;
- secondly, on the basis of the comparative values of σ and σ'; adopting reasonable assumptions in respect of σ_ϵ.

In short, these elasticities were estimated at 0.7 for business travel and about 1.4 (a not very precise estimation) for private travel. Taking into account the e elasticities (of D_A/D_T with respect to h), the following elasticities of D_A/D_T with respect to i were obtained:

- 1.5 for business travel, a value close to that obtained by the overall analyses [see paragraph II.2(a)];
- approximately 2.0 for private travel, a value higher than that obtained by the overall analyses.

It should be emphasized that, while the elasticities of D_A/D_T are close for the different links, this is not true of the elasticities of $D_A/(D_A + D_T)$, which depend on the market shares of the two modes.

II.3 The influence of transport supply

a) Experience acquired with the "price-time-income" model

The regression lines of nd (D_A/D_T) as a function of nd $[h = (p_A - p_T)/(t_T - t_A)]$ provided a means of examining the responsiveness of D_A/D_T as a function of the supply characteristics of air or rail transport: transport price p_A or p_T; journey time t_A or t_T.

It should be noted that the elasticities of D_A/D_T with respect to price and time:

- differ for business and private trips,
- differ according to the link,
- are not constant, given the considerable variations in price or time.

The same is true of the elasticities of $D_A/(D_A + D_T)$.

b) Other qualitative aspects of service

A "good" quality of service in air transport supply means a minimum of two direct flights per day in each direction at the beginning and end of the working day (so that a return trip can be made in one day) and the use of high-speed aircraft.

We saw that in 1963 such services existed on only a few links with Paris and that these "good" links provided the bases for the econometric analyses of the air/rail modal split. It is to be noted that in the study of D_A/D_T as a function of $h = (p_A - p_T)/(t_T - t_A)$, the links with a low service frequency, such as Lyons-Mulhouse and Lyons-Nantes, lie well below the regression line.

It was necessary to analyse the influence of the poor service frequency during the early years of operation and, more generally, the gradual effect of adapting demand to supply according to what may be called "the maturity level of the line". The analysis consisted of building a "development model for new lines", of the type:

$D_{ij} = K(x - x_o)\ D^o_{ij}$, where:

- D^o_{ij} represents the demand level on maturity of the line, reached in year x_o;
- the function $K(x - x_o)$ represents both the general trend (influence of the factors for lines which have reached maturity) and the "immaturity" effect (deviation from this trend for $x < x_o$).

This analysis led to the adoption of a function of the type $K(x - x_o) = e^{\alpha - e^{-\beta(x - x_o)}}$ (for $x < x_o$), i.e.: nd $K(x - x_o) = \alpha - e^{-\beta (x - x_o)}$. In fact:

- this function corresponds to a linear relationship between normal distribution of K and the annual rate of growth of K (or of D_{ij}): nd $K = \lambda - \mu \tau$ (λ and p being easily expressed as functions of α and β);
- after having calculated $K = D_{ij}/D^o_{ij}$, by estimating D^o_{ij} by means of a gravity model (as a function of the populations P_i and P_j of the conurbations i and j and distance d_{ij}), a good linear correlation was noted between normal distribution K and τ (the values of τ were calculated for the different links as an average over several years; for the old-established lines, two successive periods were taken into account);
- the parameters of the model were determined on the basis of this regression.

III. THE FORECASTING MODEL

III.1 Taking account of socio-economic factors

The aim was to estimate medium-term trends resulting from the influence of different factors:

- population growth and urban concentration;
- growth of real incomes;
- possible age and generation effects.

These last effects were found to be relatively weak, the generation effect being partly offset by changes in the age pyramid: an increase over five years of no more than about 1 per cent in both business and private trips.

As regards the other socio-economic factors, the information derived from the analyses prompted the use of two different models, one for business travel and the other for private travel.

a) Business travel in 1970

It was assumed that the choice between air travel and other modes was mainly limited to the choice between air and first-class rail.

The procedure consisted of:

- estimating the medium-term growth rate for all business travel (air plus first-class rail);
- taking account of the influence of real income growth on the air/first-class rail modal split.

Analysis of the trend of passenger-kilometres travelled by air and first-class rail showed:

- steady growth between 1960 and 1964 with an annual rate of increase of 8.6 per cent;
- that rates of growth for business and private travel should be quite similar.

On the assumption of a continuation of past trends in total population growth and urban concentration on the one hand and in real incomes on the other (annual rate of increase in per capital real incomes of 4 per cent), we obtained a growth rate of 8 per cent per annum in business travel.

By combining this assumption with that of an elasticity of 1.5 for the ratio D_A/D_S (obtained by the price-time-income model), applied to a 4 per cent annual increase in real per capita incomes, we obtained an annual growth rate of almost 14 per cent (13.7 per cent) in the number of business trips by air (general trend for mature services).

b) Private travel in 1970

The analyses showed that modal choice could not be limited to air and first-class rail travel, as "substitutions" between air and second-class rail or car travel were certainly important.

It was not possible to make accurate estimates of:

- first, past trends in overall demand for long-distance travel;
- second, elasticities of substitution between the different modes as a function of growth in real incomes.

Accordingly, the procedure adopted was:

- to take an income elasticity of demand for air transport alone: by applying an elasticity of 2.5 to an annual rate of increase in per capita real incomes of 4 per cent, we obtained an annual rate of increase in private air journeys of over 10 per cent (10.3 per cent) with a constant population;

- to assume an annual increase of some 2 to 3 per cent in the population of the large conurbations, allowing for an effect on the growth of private travel of about 3 per cent per annum.

In the last analysis it was found that, given the influence of socio-economic factors, the medium-term growth rate for private travel could be expected to be similar to that for business travel, i.e. about 14 per cent per annum.

III.2 Taking account of improvements in air transport supply

The forecasts were based on the assumption that the price terms of competition between air and rail would be unchanged: more precisely, it was assumed that fares would remain at the same level in real terms.

As regards changes in quality of service:

- no account was taken of improvements in train services;
- in the case of air transport, allowance was made for the gradual introduction of improved service (increased flight frequency, development of jet aircraft) on a link by link basis, but on a general basis for each link by means of the line development model discussed above.

III.3 Forecast traffic

The forecast traffic on mainland domestic flights for 1970 was 3.4 million passengers, i.e. traffic was expected to increase by 4.7 times during the period 1963-1970 (730,000 passengers in 1963). Of the 3.4 million passengers, 2.9 travelled on links existing in 1963, i.e. traffic increased almost four times, thus showing an annual rate of increase of almost 22 per cent - very much higher than the overall figure of 14 per cent - and providing a clear indication of the role to be played by improvement in supply.

For the period 1970-1975 an overall increase of about 13 per cent per annum was forecast, i.e. traffic was expected to increase 1.84 times over five years and 6.3 million passengers were forecast for 1975.

IV. FORECAST/RECORDED TRAFFIC COMPARISON

After comparing the figures, we shall undertake a critical analysis of the model and the basic assumptions.

IV.1 Statistical comparison

a) Overall demand

For 1970, Table 4 shows that:

- the forecast for total mainland domestic flights (3.4 million passengers) came very close to the figure recorded (3.3 million), but
- the demand for links with Paris was underestimated by 15 per cent (2.9 million actual passengers compared with 2.5 million forecast) and that demand for links between provincial airports was very much overestimated (0.4 million passengers as compared with almost 1 million forecast).

Figure 4 shows the annual increases in the number of passengers on the mainland domestic air network:

- up to 1966 growth was almost exponential, with an annual rate of increase close to 35 per cent (34.9 per cent for the period 1960-1966);
- from 1967, the rate of growth slowed and entered an approximately linear phase of development, slackening off in 1974-75 following the economic downturn and the first oil crisis. There was an average annual increase of 473,000 passengers over the whole period 1969-1978, but an increase of 536,000 a year from 1969 to 1972, 288,000 from 1972 to 1975 and 595,000 from 1975 to 1978.

The forecast for 1975 (6.3 million passengers) was an overestimate. It was based on an average annual rate of increase of 13 per cent over the period 1970-75, whereas the actual rate was only 10.3 per cent. It should be noted that this forecast lies on the extended linear trend line for the period 1969-72.

b) Reasons for travel

It should be borne in mind that, on the basis of the analyses made, the forecasts assumed the same rate of growth for business and private travel, an assumption that was in fact confirmed since business trips accounted for:

- about 75 per cent of passengers in 1963, taking the Paris-Nice link into account;
- 73 per cent of passengers in 1968, according to survey data obtained by the Air Inter Company in 1968-69.(3)

Table 4

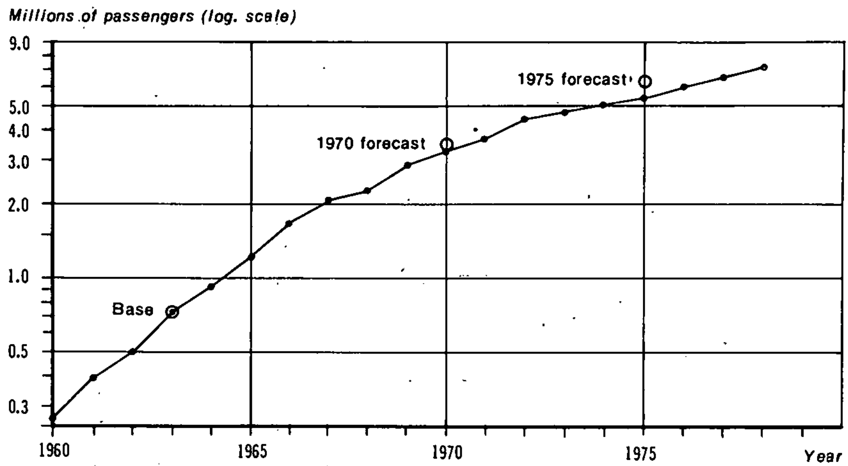
FORECASTS AND RECORDED FIGURES

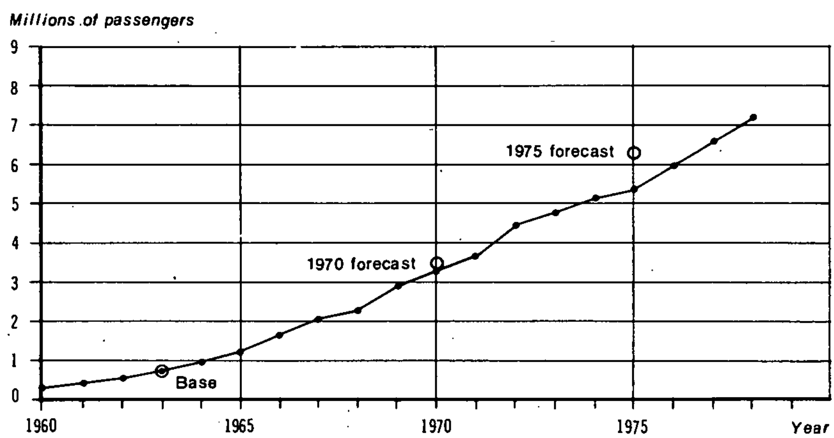
(Annual number of passengers on mainland domestic flights)

Type of link	1963 '000 journeys	1970 Forecast '000 journeys	1970 Forecast % per annum 1963-1970	1970 Recorded figures '000 passengers(1)	1970 Recorded figures % per annum 1963-1970	Forecast / Recorded figure
<u>With Paris</u>						
Links existing in 1963	660	2,400	20.3 %	2,570	21.4 %	0.93
New links	-	60		340		0.18
Total	660	2,460	20.7 %	2,910	23.6 %	0.85
<u>Between provincial airports</u>						
Links existing in 1963	70	500	32.4 %	180	14.4 %	2.78
New links	-	470		210		2.24
Total	70	970	45.6 %	390	27.8 %	2.49
<u>Total</u>						
Links existing in 1963	730	2,900	21.8 %	2,750	20.9 %	1.05
New links	-	530		550		0.96
Total	730	3,430	24.7 %	3,300	24.1 %	1.51

1) Passengers who change aircraft on the domestic network are counted twice (1 journey = 2 passengers). This differerence in definition influences the comparison slightly.

Figure 4 **INTERNAL CONTINENTAL AIR TRAVEL - COMPARISON OF FORECAST AND RECORDED DEMAND**





IV.2 A critical analysis of the assumptions

a) The socio-economic context

It will be recalled that the forecasts were based on the assumption of a 4 per cent annual increase in real incomes per capita.

This assumption turned out to be:

- realistic for the period 1963-70, per capita GDP having increased by an average of 4.5 per cent per annum in real terms;
- an overestimate for the period 1970-75, the real growth in per capita GDP being only 3.2 per cent per annum, which at least partly explains why the forecast for 1975 proved to be too high.

b) Air transport supply

The forecasts were also based on the assumption that air and rail fares would follow the general trend of prices.

In order to calculate precise indices for air and rail fares, a special study would be required, particularly for the 1970s when substantial changes were made in both air and rail fare structures.

According to rough calculations:

- during the period 1963-70, there was a slight increase (between 5 and 10 per cent) in real air and rail fares;
- during the period 1970-75, average revenue per passenger kilometre, in real terms, remained at the same level for air travel and fell by about 10 per cent for rail travel, which helps to explain the discrepancy between forecast and recorded traffic figures for 1975.

As regards the geographical structure of the network, we have seen that the 1974 forecasts:

- underestimated demand for links with Paris (both light-traffic links in 1963 and new links). In fact, only two new links had been planned (with Grenoble and Montpellier) whereas there was substantial demand on a number of other links in 1970 (with Chambéry, Lille, Metz, Nancy, Rennes and Toulon);
- overestimated demand between provincial airports, both for links existing in 1963 and new links.

Any attempt to explain these discrepancies in terms of the quality of service offered would call for a lengthy process of reconstruction of flight frequencies, link by link, for the period 1965-70,

IV.3 A critical analysis of the model

For links that were already relatively important in 1963, the model proved useful for forecasting general trends in demand under the influence of socio-economic factors and improved transport supply.

As already indicated, the trends for the other links would have to be examined link by link if, in explaining the discrepancies, we wished to determine:

- first, the influence of the quality of service supplied: in particular, demand assumed to be met by direct links may be met by flights involving changes if there are not enough flights on direct links;
- secondly, the soundness of the estimate of demand for links reaching "maturity", which was probably too high for "cross-country" links since, owing to the concentration of administrative functions in the Paris area (both public services and private firms), gravity models based on the population of conurbations and essentially adapted to radial links are bound to overestimate demand for "cross-country" links.

V. IMPROVEMENTS TO FORECASTING MODELS

V.1 Improvements to the multi-modal model

The "price-time-income" model for forecasting demand for air transport, based as previously on competition between air and first-class rail, has been gradually improved by the Civil Aviation Services and Air Inter:

- the increased mobility ("induced traffic") due to the reduction of "generalised cost" or "generalised time" was taken into account in a more explicit way in 1969(4);
- the daily flight frequency F was taken into account by means of a time equivalent λ /F in 1970-71(5);
- these models are periodically updated by the Civil Aviation Administration and by Air Inter as the recorded data on traffic enable improvements to be made to the "base year" of the model.

The "price-time-income" model was extended to all modes (air, rail, car) and all inter-regional journeys (business and private) in 1973 under the auspices of the SAEI by the TRIP (Inter-regional Passenger Transport Working Party). This model simulates individual behaviour on the basis of journey samples:

- it simulates the influence of quality of service on modal choice and mobility by means of individual generalised times;
- these generalised times take account of the comparative advantages and drawbacks of the different modes (from the passenger's standpoint) by means of probability functions;
- seven modes of transport are differentiated: "air", four "rail" modes (distinguishing between first and second class and day and night trains), two "car" modes (with or without the use of toll motorways);
- the frequency and time slots of public transport timetables are taken into account by simulating passenger choice on the basis of discrepancies between preferred and offered times;
- in order to determine the traffic "potentials" of conurbations (the "emission potential" of the conurbation where the traveller resides, "reception potential" of his destination conurbation) an "intensity" of interchange is used, which varies according to the reciprocal function of the conurbations in the regional framework.

This multi-modal model was developed and first applied to business travel between the Paris conurbation and the large provincial conurbations in the period 1973-76(6)(7) on the basis of surveys carried out in 1968-69.(3) The IRT (Transport Research Institute) has undertaken to modify the model (to give better internal coherence in relation to a car ownership development model) in order to be able to apply it to new crude data which will shortly be available (surveys carried out among rail, car and air passengers on the Paris-South East corridor and the "Transports 1981" survey carried out by the INSEE on a national-wide sample of households).(7)

V.2 Scope for forecast recorded traffic comparisons

The comparisons given here for the period 1963-70 and, more briefly, for the period 1970-75, could be extended to the present time by examining the more recent models mentioned above, but this would involve a great deal of work in the critical analysis of these models and in the collection of data.

CONCLUSIONS

The initial "price-time-income" model, which was used during a period of rapid development of domestic air transport in France, was found to be valid for long-term forecasting (to 1975 on the basis of the 1963 situation). Its deficiencies, which have been offset in more recent models, relate mainly to its application to "new" links and "recent" links with a low demand in the base period and have two separate causes:

- an intensity of interchange which varies according to the reciprocal function of conurbations in the regional framework;
- the importance of the quality of service of the air transport supply (flight frequency and time schedules).

REFERENCES

1) "Place du transport aérien intérieur dans les transports de personnes en France" (Aéroport de Paris - SETEC, in collaboration with Air Inter and the SNCF) - 1965.

2) "Etude des voyages 1961" (SNCF - SETEC).

3) Surveys 1968-69 (SNCF, Air Inter, roadside) carried out in preparation for the VIth Plan.

4) Claude Abraham, Thierry Baumgart and Jean-Didier Blanchet - "Un modèle de trafic aérien intérieur" - Revue du SGAC - No. 136 - 15th November, 1969.

5) SGAC - "Schéma directeur de l'équipement aéronautique" - November 1972.

6) TRIP study: "Modèles d'offre et de demande" (SAEI - SETEC) - November 1977.

7) Roger Marche - "Pour mieux comprendre les déplacements interrégionaux de voyageurs : un modèle multi-modal de demande" - Cahiers Scientifiques de la Revue Transports - Nos. 2 and 3, 1980.

C. URBAN PUBLIC TRANSPORT DEMAND MODEL

(Xavier GODARD)

INTRODUCTION

In the case of public transport systems, which are the prime concern of this paper, demand forecasts essentially serve two types of function: first, as an aid for project design and, more particularly, as a basis for decision-making through socio-economic feasibility studies; secondly, as a means of fine tuning of the operating procedures of a transport system (station facilities, service frequencies, interchanges, etc.) and the restructuring of the surface network when a dedicated infrastructure comes into service.

Forecast/recorded traffic comparisons can be made here as there are many cases in which such comparisons may be meaningful. Examples will here be taken from the Paris region as well as from the Lyons and Frankfurt metros.

It will however be seen that this rather crude comparison of forecasts and recorded traffic does not obviate the need to analyse the modelling process itself. In particular, it will be found that certain ambiguities as regards the specific status of traffic forecasts have to be resolved since this is the only means of improving methods of establishing and using forecasts in decision-making.

I. SOME CASES OF DISCREPANCIES BETWEEN FORECASTS AND RECORDED TRAFFIC

In examining overall traffic forecasts for new public transport lines, a few cases will be reviewed in some detail - Lyons and Frankfurt metros, the Paris Regional Express Network and the junction of metro lines 13 and 14 - while some other Paris projects will be touched upon. It will be seen that, although the scale of discrepancies between forecasts and recorded traffic varies greatly, such discrepancies are invariably due to the fact that the forecasts are on the high side.

I.1 Lyons metro

As regards Lyons metro line 2, which entered service in May 1978, two types of forecast are considered: those made in 1970 for an inter-ministerial working party studying the advisability of this investment, i.e. forecasts to be used as aids to decision-making, and those made in 1978 just before the line was opened, which were mainly to assist the operating authorities. The following table shows the relevant main forecasts and recorded traffic:

	Daily traffic Line A	Public transport network(1)	% of journeys involving metro-bus interchanges
1970 forecast of 1975 traffic	140 000	520 000	57%
SEMALY 78 Estimate	123 000	430 000	36%
Jan 79 Recorded traffic	118 000	453 000	52%
Mar 80 Recorded traffic	137 000	-	-

1) These journeys could therefore involve several interchanges between one section of the public transport network and another.

I.1.1 The 1970 forecasts

The 1970 forecasts were established to provide data for a multi-criteria feasibility study for the Lyons metro. The modelling procedure used was greatly simplified in the modal split phase(1) where pre-determined coefficients were used. It should also be noted that these coefficients were conceived both as forecasts and as modal split objectives, as it was in fact considered that many factors external to the project itself, but which would influence these coefficients, depended on the policy to be adopted by the local authority as regards fares, the public transport image, constraints on car-use, etc.

These coefficients were thus considered to be the result of an overall policy for the promotion of public transport, which included the metro project.

A forecast/recorded traffic comparison shows that the forecasts were slightly high, with the scale of the over-estimate depending on the terms of the comparison. A few months after the opening, the over-estimate is about 20 per cent, but after 18 months of operation - thus, as seems more reasonable, allowing time for the new equilibrium to be established - the over-estimate is insignificant.

1) Instead of using a conventional model based on generalised costs, modal split was determined according to a simplified matrix of percentage utilisation of public transport, distinguishing between type of journey (within city centre, centre-periphery, periphery-periphery), the hour of day and, of course, metro services to the areas in question.

It should however be noted that the original time horizon for the forecasts receded owing to delays in deciding to go ahead with the project, which meant that it was completed at least three years later than originally planned. By and large, therefore, it may be said that, while there was an over-estimate, it was within reasonable bounds and can unequivocably be attributed to over-optimistic assumptions about modal split.

I.1.2 <u>The 1978 forecasts</u>(1)

The model used for the 1978 forecast is one specially designed for analysing public transport traffic. It is a uni-modal (public transport) growth factor type model based on marginal changes (in populations of zones) and elasticities of demand in relation to generalised time with reference to traffic recorded at the time of the study.

This model explicitly assumes that the bulk of the users of the new public transport infrastructure will be already public transport users (relatively few modal switches away from the car are expected).

A forecast/recorded traffic comparison shows that the total traffic of the network was under-estimated as a result of an under-estimation of surface network traffic in conjunction with an over-estimation of metro traffic. Closer analysis of the recorded traffic reveals the source of these discrepancies: firstly, induced traffic (in particular increased mobility) turned out to be greater than expected and, secondly, there were fewer route changes (switches from bus to metro) than expected.

It will also be noted that forecasts were made for each station. The discrepancies were greater here and involved both under- and over-estimates. As would be expected, the greater the degree of disaggregation of the forecast, the greater the discrepancies are likely to be. Conversely, errors in the component parts of aggregated forecasts can offset one another, which may therefore make such forecasts more reliable.

I.2 <u>Frankfurt metro</u>(2)

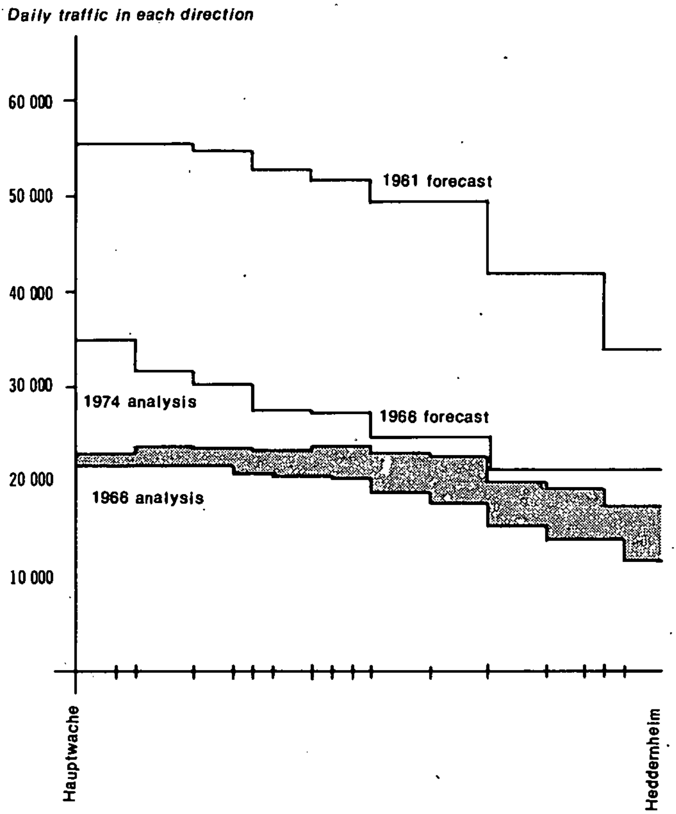
The Frankfurt metro entered service in 1968. We shall examine the forecasts made in 1961 and the traffic recorded in the 1970s.

The 1961 forecasts are seen to have been much too high as the 1968 traffic amounted to only about one-third of the forecast figure (see graph). The 1968 forecasts were also too high

1) Based on a Note by the SEMALY (the company operating the Lyons metro) of June 1979.

2) This section is based on a paper delivered by Dr. H.P. WEBER at the Grainau Conference "Fourth International Conference on Travel Behaviour Modelling" (July 1979) which provided data on the Frankfurt metro obtained from a study by the Battelle Institut.

FRANKFURT METRO TRAFFIC FLOWS BETWEEN HAUPTWACHE AND HEDDERNHEIM



Source : Dr. Hans Peter Weber.

but closer to the recorded traffic figures. Aside from the rather unsophisticated nature of forecasting models in 1961, two main factors explain the very large over-estimate:

- the population forecasts, showing an increase from 665,000 inhabitants in 1960 to 790,000 in 1990, were widely off the mark, as the population would seem to be falling rather than rising and the current forecast for 1990 is around 600,000 inhabitants. The pattern of migration from city centres toward peripheral dormitory suburbs was not foreseen and assumptions about population trends obviously have a direct effect on traffic forecasts;
- the modal split assumptions were also apparently over-estimates and the data available in 1968 and 1971 seemed to indicate a slight fall in the percentage utilisation of public transport, a development that was probably attributable to the road investment policy pursued elsewhere in the conurbation which facilitated the use of the private car (and no doubt encouraged migration away from the city centre).

The latter point highlights a problem central to any forecasting, namely the definition of the environmental conditions, that is to say the state of the system when the project is being implemented. At the time the forecast is made, one has to assume that these conditions will remain more or less unchanged, but this is clearly unlikely since decisions that will have a major influence on traffic forecasts will be taken elsewhere.

I.3 Paris Regional Express Network (RER)

The Paris Regional Express Network is a global project comprising a number of sub-projects which can be considered independently and have come into service at different times. Forecast/recorded traffic comparisons can be made for each section on the basis of official documentation, although in many cases several forecasts have been made, sometimes by different bodies.

The following features will be noted, though a more detailed analysis would be necessary to determine the causes of the discrepancies observed:

- new sections always come into service several years after the date on which the forecast is based, since it seems that there are invariably delays in the implementation of transport projects;

RER TRAFFIC
(evening rush hour, average day)

RER Section	Year of Study	Forecast	Recorded	% error
Nanterre - La Défense	1967	1970: 22 to 25 000 1975: 25 000	1977: 12 000	+ 100%
Nation - Boissy St-Léger	-	1970: 22 000 1975: 25 000	1977: 14 000	+ 80%
Auber - Nation	1970	1975: 31 500 to 33 800	1977: 22 500 1979: 27 000	+ 50%
Marne-la-Vallée Branch	1971	1975: 27 500	1978: 21 500 1979: 24 300	+ 30%
St-Germain Branch	1970	1975: 29 800	1978: 14 500 1979: 16 600	+ 100%
Sceaux - Châtelet Line	1971	1975 - Châtelet - Luxembourg 14 400 1975 - Denfert - Cité 27 500	1977: 10 000 1979: 20 000	+ 50% + 30%

- the traffic forecasts for all RER sections were much too high (from 30 to 100 per cent);
- there would at first sight seem to be two main reasons for the over-estimates:
  . first, the assumptions about urbanisation on which the forecasts were based subsequently had to be revised downward: delays in the implementation of major projects (La Défense, Marne-la-Vallée, etc.), a slowdown in overall urban development in the Paris Region.
  . secondly, fewer passengers than expected have switched routes. The forecasting models paid too little attention to the difficulty of access to the RER and the consequent disincentive effect: long descent below the ground, the obligation to walk considerable distances in the corridors of many interchange stations. This aspect has in fact been taken into account in improvements made to the model by the RATP (Paris Public Transport Authority) whereby access to the RER is one of the factors explicitly included, thus providing a sounder basis for certain forecasts.

It is accordingly always necessary to take account of the interdependence between the lines in a network, since traffic switches from one line to another. In other words, planning cannot be based on the traffic on any one line, since the traffic over the whole network has to be taken into account, although this is really only practicable in the case of relatively small networks and is a very uncertain proposition where Paris is concerned.

I.4 Paris metro lines 13 and 14

In 1976, there were several modifications to Paris metro lines 13 and 14 within a short space of time in that a junction was created and the lines were extended northwards to St. Denis and southwards to Montrouge(1).

	Year of Study	Forecast	Recorded Traffic	% error
Junction of the two lines	1970 1976	1975: 10 200 1977: 16 500	15 600 (rush hour 2nd Class)	- 40% + 5%
Saint-Denis extension	1971	1975: 3500 additional rush hour passengers	1979: 2000 additional rush hour passengers	+ 75%
Montrouge extension	1972	1975: yearly traffic 21 million	1979: 14 million	+ 50%

The table shows that the initial forecasts fell very short as regards the junction of the two lines, but were far too high for the North and South extensions.

Further forecasts were made shortly before the projects were completed and came much closer to recorded traffic.

When the reasons for the forecasts/recorded traffic discrepancies were analysed, reference was made to a number of different factors: over-estimated population growth in the southern suburbs; over-estimation of bus feeder services; poor analyses of route changes (traffic switching from one line to another) within the metro network.

Here, too, it will be noted that the forecasts tend to become more accurate as the date of a project's completion and entry into service approaches.

I.5 The Paris region "carte orange"

The Paris Region "carte orange" warrants at least a brief mention. Introduced only very recently, this monthly ticket gives unrestricted access to the region's public transport system (though the initial price varies according to the number of covered zones).

1) See the RATP documentation based on highly detailed surveys (log books) of a user sample before and after the lines were extended to the suburbs. RATP "Jonction des lignes 13 and 14 et prolongements ... Bilan d'ensemble" - December 1979.

Before the decision to introduce this ticket was made in 1975 (?), the forecast was that there would be about 500,000 users, whereas the number of tickets sold in fact reached 700,000 within the first few months and rapidly passed the million mark.

In seeking to explain such a large discrepancy between the forecast and tickets sold, two sets of reasons must be offered:

- first, the forecasts simply tried to ascertain the minimum number of users who would be interested, so the model in question adopted price advantage as the only criterion for the user's choice between a regular ticket and "carte orange". Grounds for this approach were found in the negotiations with the Ministry of Finance whose main concern was to ensure that the Paris public transport deficit did not increase as a result of this change in the fares system. Accordingly, the transport system authorities tended to minimise the potential impact of the decision;
- secondly, it was hard to predict how the public transport users would respond to this entirely new ticket. There was no way of using the existing situation as a guide and little was known about the psychological factors determining attitudes to this type of ticket. The fact that its success has been much greater than expected has created a number of operational problems for bus services which have experienced an unexpected increase in ridership. Taking advantage of the marginal benefit of their "free pass", many people now take the bus for short distances they used to walk.

II. GENERAL ANALYSIS OF REASONS FOR DISCREPANCIES BETWEEN TRAFFIC FORECASTS AND RECORDED TRAFFIC

On the basis of the examples already given and earlier studies on the utilisation of traffic forecasts, we shall now try to ascertain the reasons for discrepancies between forecasts and recorded traffic by differentiating between two types of cause: one direct (where did the discrepancy come from?) and the other more "institutional" (how was this kind of discrepancy able to arise?). First, however, it may be useful to draw attention to a number of difficulties involved in defining the concepts employed in forecasting, which may themselves help to create such discrepancies.

II.1 Definition of homogenous traffic indicators

Traffic indicators may relate to different time periods: annual traffic, daily traffic, peak hour traffic (which are used for calculating an infrastructure's dimensions). They may concern journey or passenger counts (an important distinction when dealing with a network which may involve interchanges: a single journey may be counted several times if the passenger uses several lines in making it).

Indicators cannot be defined without specifying the method of recording or calculation involved.

While the concept of annual traffic appears to have a clear enough purpose, the concepts of daily and peak hour traffic are artificial constructs (though, of course, useful).

The concept of daily traffic involves a somewhat mythical "average day" which is supposed to be a distillation of daily reality and its diversity, since any transport operator knows that daily traffic is subject to variations, sometimes seasonal, sometimes according to the day of the week, sometimes arbitrary and inexplicable. Determining the average of all these variations certainly has some significance, but there would be no point in saying that it can lay claim to any precision.

The same is true of the peak-hour concept which, while set more or less arbitrarily within a specific time range - e.g. between 17.30 and 18.30 hours - nevertheless varies from one day to another together with the volume of traffic. All this goes to show how fragile the definition of these indicators really is. They should, moreover, be considered in terms of probabilities which would put them on a sounder basis.

One method of calculating these indicators(1) - where the volume of traffic is to be estimated over a given period - involves sampling and the indicator obtained is then a range of estimated traffic with a certain probability of error.

It should be noted that sampling methods are found necessary once sight-check tickets (season tickets) are in general use since, on many networks, such tickets leave no indication that a user has made a journey. As this subject is not our main concern here, suffice it to say that:

- the concepts of average day and peak hour are not precise and their accuracy depends on the method of calculation used, which may vary from one network to another and from one year to the next;
- there is some uncertainty about recorded traffic owing to variations in this traffic over time and the inadequacy of the recording methods;

1) The other method consists of counting, either on a regular basis by means of tickets (the RATP network uses magnetic tickets) or periodic counts with the sole aim of estimating traffic. These methods do not necessarily give the true traffic figure owing to possible recording errors.

- the cumulative effect of these uncertainties is a source of imprecision in traffic estimates which may partly account for discrepancies between forecasts and recorded traffic while not necessarily invalidating the forecasting method.

It must in fact be recognised that the knowledge of past or present phenomena may itself be a source of bias, and not only in forecasts (for example, the volume of traffic on the Lyons bus network was over-estimated for several years and the basis of the calculation had to be changed: the error stemmed from over-optimistic estimates of average mobility in the case of sight-check tickets). After these cautionary remarks, we can resume the analyses of reasons for discrepancies between forecast and "recorded" or, more precisely, "estimated" traffic.

II.2 Analysis of direct causes of discrepancies

The above examples provide a basis for a number of conclusions about the reasons for discrepancies between forecast and recorded traffic (which are almost always over-estimates). We shall examine the direct causes first.

Structure of models

A technical discussion of models is beyond the scope of this paper. The structure of models, i.e. determination of the variables to be taken into account and the factors influencing them, is in fact open to criticism, especially as regards the forecasts made in the early 1970s, but progress has since been made and will probably continue. This is not the main problem. However, the structure of models may be criticised for reproducing existing behavioural mechanisms and not really being able to take account of breaks in the trend of behaviour. This may explain the equality of short-term forecasts in contrast to long-term forecasts which very often prove to be much too high.

Models must in fact change in order to adapt both to ways in which problems are presented and changes in life-styles and ensuing patterns of behaviour. However, the basic problem would not seem to relate to the quality of models and the people who use them, since even good models, properly used, can produce inaccurate forecasts.

The forecasting of parameters external to the model

Once the structure of a model is accepted (and the parameters are adjusted to an observed situation), the forecasting process then calls for the input of a number of external variables which are generally estimates up to the end of the forecasting period: e.g. growth rate of car ownership, socio-occupational categories of a given area, value placed on time, population and employment in a given area, individual mobility, etc.

The estimates based on such parameters, which may themselves be produced by specific models or else be fixed more or less arbitrarily by specialists or policy-makers, are of course subject to uncertainty and are often the prime cause of discrepancies between forecasts and recorded traffic. Among these factors, assumptions about urban development are of particular importance.

Urban assumptions

Assumptions about population and employment in the areas served by a project clearly influence traffic forecasts since any errors in this connection are reflected directly. Urban development forecasting is by no means easy, especially as public transport investment projects are accompanied by large-scale town planning operations which are spread over many years and thus subject to numerous imponderables.

In almost all the examples given, it can be seen that unsound urban development assumptions were the main cause of over-estimates in the traffic forecast. Town planning projects are abandoned or do not proceed at the expected rate (e.g. La Défense and the new towns in the Paris region) or trends are reversed (e.g. Frankfurt).

Changes in project specifications

The transport project itself is usually modified to a greater or lesser extent between the planning decision on basic outline stage, and its final implementation. Such modifications may relate to the routing, location of stations, service frequency, quality of interchange facilities and feeder services.

It is rare, moreover, that the target date for completion of the project is met since in many, if not all, cases there is a lag of some years owing to the negotiations involved in the decision-making process and this time-lag is certainly indicative of the difficulties and ambiguities associated with the forecasting process itself, a point that we shall return to further on.

Changes in project specifications and the measures necessarily entailed clearly partly explain discrepancies between forecasts and recorded traffic in many cases. On the other hand, delays in implementing a project tend to have the reverse effect.

Implicit assumptions about the environmental conditions external to the project

Traffic forecasts for a project always involve a number of assumptions - seldom explicit - about the external environmental conditions which are very often simply assumed to remain in a stable state or to be implicitly favourable to the project: accompanying measures to curb the increase in car traffic, public transport fares policy, ancillary schemes to improve the public transport image, etc.

In the case of the Frankfurt metro, for example, it was seen that substantial investment in roads, which was not taken into account in the forecasts, meant that metro traffic fell considerably short of expectations.

This category of external environmental conditions should perhaps include the influence of public transport infrastructures on changes in the socio-occupational groups of populations living close to stations where rising property prices tend to increase the proportion of the more comfortably off who are more likely to own cars and use public transport less frequently. It is too difficult, at least as matters now stand, to incorporate this type of process into traffic forecasts.

II.3 Analysis of indirect causes of discrepancies

The previous section lists a number of causes of discrepancies between forecast and recorded traffic and identifies the variables which may underlie such discrepancies. The fact is, however, that this analysis certainly does not in itself suffice to explain the discrepancies and has to be taken a step further by examining the process of determining the assumptions on which forecasts are based.

A fundamental point which has to be stressed is that, whatever the validity of the model itself and the competence of those who use it, any forecasting model incorporates many assumptions about parameters of an uncertain character. The forecast therefore stems from one set of plausible assumptions selected from among a number of equally plausible sets of assumptions. What governs the choice of these assumptions? It is not merely a matter of chance or the intuition of the specialists constructing the model. The choice also conforms to an institutional logic.

It should first be borne in mind that the concepts of "forecast" and "objective" are not entirely separate but tend to overlap to some extent. In a field such as transport, project design does not simply follow the logic of "demand" but also depends on an overall policy which takes account of interactions between transport modes and between the transport system and the process of urban development. Accordingly, some parameters are just as much objectives as forecasts, since they are the product of political will.

Such is the case, for example, for assumptions about urban development, which are a key factor in traffic forecasts. It is understandable that, given a wide range of assumptions about urban development, the choice will fall on the one consistent with planning policy objectives, though experience shows that such objectives are not always achieved.

This could equally be the case with modal split parameters where the policy is specifically to re-establish a balance by promoting public transport, or with mobility norms when the aim is to improve travel conditions for disadvantaged users (captive riders, etc.).

The most important thing to recognise, however, is that traffic forecasts - and, more generally, all project-related studies - are weapons in the hands of the institutions negotiating the project in question(1). Traffic forecasts, directly or indirectly, serve to justify the validity ("public utility") of a project and it is quite normal that, given many possible sets of assumptions which on the face of it are equally plausible, an institution defending a project will choose the set most favourable to it.

Moreover the selection of assumptions is not usually a conscious process. Thus, in a period of economic growth, as was the case in 1970, there is a tendency to plan in terms of continued growth through such parameters as urban development, incomes, mobility, etc. The forecasts merely give expression to a general state of mind about the development of society, which may well prove to be mistaken in practice.

All that has been said in this section points to the concept of a study that argues in favour of a project. While such an approach may seem undesirable in certain respects, it throws an interesting light on possible explanations of discrepancies between forecasts and recorded traffic.

III. CONCLUSIONS AND RECOMMENDATIONS

Three types of conclusion can be drawn from the above analyses:

- Where models for traffic forecasting are concerned, there is still room for improvement but, owing to the inherent uncertainties about urban development and life-styles there will never be any guarantee of fully reliable forecasts.
- An initial improvement in traffic forecast planning and presentation would be to explore different sets of assumptions rather than a single one. This could be done by means of parameter sensitivity studies or by establishing different scenarios to be considered simultaneously. It cannot be denied that this method, useful and necessary as it may be,

1) Such is the analysis of the study group on urban transport economics /Groupe de Réflexion sur l'Economie des Transport Urbains - (GRETU)7 cf.: "Une étude economique a montré ..." Editions Cujas, Collection GRAL, 1980.

comes up against difficulties which indicate its limits: it is not possible to vary all parameters simultaneously, as this would lead to far too great a volume of output through the combination of all possible variants.

However, this approach could at least gain acceptance for the presentation of upper and lower limits instead of the single forecast figure generally found at present.

- A second improvement concerns the use made of traffic forecasts. It must be recognised that models cannot give forecasts in the nature of a scientific truth which has to be accepted by all, but can produce plausible forecasts on the basis of plausible assumptions. If this were to be understood and explicitly admitted by decision-makers, it would avoid some of the misunderstanding about the role of forecasting studies, which might be more appropriately called "simulation studies".

FREIGHT TRANSPORT
AN EVALUATION

Drs. Jan van Es
Transport Economic Adviser
Oisterwijk
The Netherlands

SUMMARY

SUMMARY

INTRODUCTION

Freight demand-supply modelling is a rather new field of interest for both researchers and policy makers on different political levels (urban, regional, national and international). In most countries its development and application has always been behind passenger transport modelling. Transport planners are little acquainted with the fundamental characteristics of the freight transport markets, as standardized approaches such as developed for passenger transport, are lacking. Recently, however, there has been a growing awareness of the importance of freight transport as part of the national economy. Its essential role in the functioning of the economy, its complete dependency on limited available liquid fuels, its impact on the environment, its influence on infrastructure usage, etc., are separate reasons why governments are and should be more and more interested in freight transport and its developments. However any transport policy design and its implementation should be based on a thorough insight into the structural relations within the transport sector and between the transport sector and other economic activities.

This growing awareness has lately initiated some freight transport studies in Europe, of which the recently completed EC-freight transport study is the most comprehensive one. Research institutes are also experimenting with new modelling techniques to increase the policy sensitiveness of freight models. There is also a growing tendency to develop and use freight transport demand and supply models for transport policy areas other than infrastructure. Examples are the market observation system being developed by the EC and a transport policy information system being developed by the Dutch Ministry of Transport.

This paper will review some interesting developments in freight transport modelling and its application for transport policy purposes (section A). Of the few available freight models, some recently developed and interesting ones will be evaluated and, as far as possible, compared (section B). At the end of this paper all results are summarised in a special section.

Section A

SOME BASIC CONCEPTS FOR FREIGHT TRANSPORT MODELLING

1. POLICY ORIENTATION OF FREIGHT DEMAND AND SUPPLY MODELS

1.1 The policy making process

Freight demand modelling or rather demand and supply modelling has to be reviewed according to the ways it can contribute to the design of transport policy. Otherwise an evaluation and comparison of results of different freight models becomes less useful.

First of all the contribution of freight transport demand and supply analysis to the process of policy formulation should be clear. One could say that a freight transport model forms the cornerstone of a broader policy information system to support policymakers in taking the right decisions. In this context a freight model consists of data, transport economic variables and transport economic (structural) relations, describing in a quantitative way the relationships between the data and the transport economic variables. The data consists of variables or elements which can be influenced politically and variables which cannot. The former belong to the policy instruments which can be used by policymakers to achieve certain aims. The policy aims consist of certain transport economic variables for which values (at least in a quantitative model) are specified *a priori*. The essence of the transport policy process is to find the best policy to achieve the aims by selecting the optimal number of instruments (type and usage), taking into account possible boundary conditions for the actual usage of the instruments.

Freight transport analysis (demand and supply) can contribute to this process in various ways, its main task being the specification of the structural relationships between the transport economic variables and the data involved. Those relationships specify the ways in which the economic subjects adapt themselves to changes in the data. This adaption process or transport behaviour is represented by the equations which together form the transport model.

However, it cannot contribute to the choice of aims and, to a lesser degree, to the choice of instruments to be used. Those elements, although belonging to the transport policy formulation process, are exogenous to freight transport analysis and the resulting transport models.

In summary the freight transport policy process consists of three different stages:

Stage 1: defining the policy aims and the type of instruments to be used (political-choice process)

Stage 2: specifying the structural relationships between the aims and the instruments (modelling process)

Stage 3: finding the optimal policy, expressed in the number of instruments, to achieve the policy aims (policy-evaluation process).

It is quite easy to see that a whole family of freight models can be developed depending on the policy problems (aims and instruments) involved /a model defined as a set of equations describing the structural relationships between the endogenous (policy aims) and the exogenous (instruments) variables/.

The degree in which freight transport models can support transport policy decision-making depends on:

a) the degree to which the policy problems, expressed in aims and instruments, can be translated into the equations and the variables of the models; and
b) the degree to which the structural relationships, representing the behaviour of the economic subjects, can be specified in a reliable theoretical and statistical way.

These two elements determine the policy sensitivity of a freight transport model.

Although different models can be formulated, depending on the transport policy problems involved, they should be based on a common and generally accepted transport demand and supply theory. Whereas transport is one of the economic sectors, it is quite logical to apply existing economic theories (micro and macro) to this sector, taking into account its special characteristics of which the spatial element is the most complicated one.

1.2 Policymakers: their aims and instruments

Policymakers do need information to define their objectives, to select the most efficient instruments and to evaluate the consequences of different courses of action, before they can decide on the most optimal and desirable policy. The type of information needed depends of course on the category of policymakers involved in the transport process. Three broad categories of actors can be distinguished, that is the shippers, the transport firms and the government bodies. The demand-supply equilibrium of freight markets is influenced by decisions taken by all three categories.

The demand for transport, its size and structure, is highly influenced by a large number of decisions taken by the shipping industry, like production decisions (levels and production techniques), plant location decisions, physical distribution decisions, mode of transport decisions, etc. Many of them are directly or indirectly influenced by the level of service of the transport services offered by the transport industry. The type and quality of the transport services offered on the transport markets are directly influenced by a number of individual decisions taken by the transport industry, such as decisions on equipment, scheduling, tariffs, etc. In the market equilibrium process the volume of shipments for the different modes of transport is determined on the various transport markets, together with the equilibrium values of the level of service variables.

This demand-supply equilibrium process is influenced by governments in different ways. First of all, the government acts as a supplier of transport services (or part of it) by offering the main part of the physical transport infrastructure. By doing this it influences to a great extent the type, the quality and the costs of the transport services offered by the private transport industry. So infrastructure policy is one of the main areas of concern to the various government institutions (local, national and international).

It is generally accepted that governments should have a certain regulatory role in the freight transport markets, given the specific characteristics of those markets and the complementary role of the transport sector to the rest of the economy. In other words, the expected outcome of the equilibrium process on the freight transport market without government intervention, will diverge from what is seen as the most desirable outcome. This divergence between the "actual" situation and the "most desirable" situation forms the criterion for a transport policy and leads to the formulation of government goals and government actions.

Because the demand for freight transport is highly determined by factors which cannot directly be influenced by the transport industry or by a government's transport policy, transport policy is almost always aimed at influencing the supply side of the transport markets, leaving the transport firms and the government institutions as the main direct policymakers for this sector. As both groups of policymakers have the possibility to influence the supply of transport services each in their own way, they often need the same kind of information for their policy-making, but in different degrees of detail.

Although it is not the purpose of this paper to deal in depth with the various policy objectives and the available policy means, it is important to understand the relationship between this part of the freight transport policy process and the second part, the transport modelling phase. The second part can only be carried out in an efficient and useful way if aims and instruments are formulated in advance.

Government institutions

In general the most global and therefore abstract aim of a regional, national or international transport policy is formulated as the maximum contribution to income and welfare, taking into account other areas of policy interest (traffic safety, environment, land-use, pollution, energy, economic growth, etc.). In economic terms it implies the most efficient use of production factors allocated to this sector. Because it is a very global policy objective, it should be translated by what is known as a number of operational objectives by a procedure of iterative steps. At every step the objectives have to be further dissected into more operational objectives. At the end the derived operational objectives should be formulated in such a way that:

a) direct relationships can be established between the objectives and the available instruments; and
b) the objectives can be quantified in such a way that they can be compared with the output of the instruments (the output is defined as the effect an instrument has on a certain objective).

This type of policy objective analysis is already used in some countries for different policy areas and an example is given in Figure 1. The prime objective is dissected into the ultimate operational-level objectives, which are directly related to the available government instruments and activities.

Using the policy objective analysis, the above mentioned global policy objective can be translated into more concrete objectives, such as:

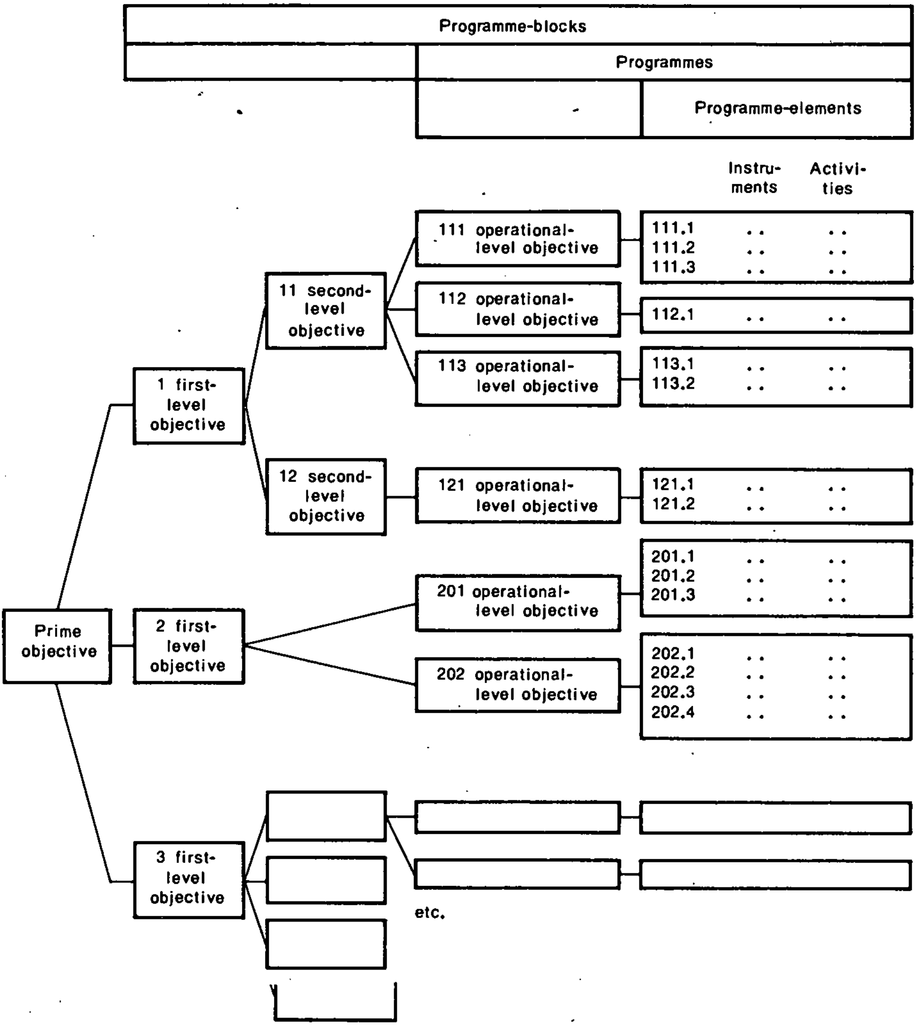
- the maintenance of balanced demand and supply relations or conditions on the various transport markets (rail, road, inland waterways);
- the promotion of a transport system of a high technological and commercial standard;
- the attainment of equal competitive conditions for the different modes of transport;
- the attainment of cost-based tariffs for the different modes of transport;
- the attainment of desirable income and labour conditions in the transport sector, etc.

This process should continue until the aims are attained and measures can be found to quantify them. As aims are by definition transport-economic variables a priori quantified, these aims can easily be accepted by the freight transport modelling process.

Defining the policy objectives in an operational way is only half of the work to be done. The second part concerns the available

Figure 1

THE STRUCTURE OF A POLICY-OBJECTIVE PROGRAMME



instruments. Two types of policy means can be distinguished, that is quantitative and qualitative means. Qualitative means are used to change the structure, while quantitative means are used to adapt the transport sector to small and frequent changes in some of the data. An example of a qualitative means is the improvement of the labour conditions for the inland waterway sector; an example of a quantitative means or instrument is a temporary tonnage stop in the same sector. Or in terms of the freight transport models qualitative policies are aimed to change the structural relations between the transport-economic variables and the data, while quantitative policies, leaving the structural relations unaltered, only influence some of the data in the structural relations. The quantitative and qualitative instruments can be grouped into five broader categories of policy areas, as follows:

a) infrastructure policy;
b) capacity policy;
c) pricing policy;
d) competition policy;
e) other policies of various kinds, mostly derived from other government objectives (energy, environment, safety, social, etc.).

Without going into further detail, it is understandable that a lot of instruments, if used, do influence more than one policy aim. To evaluate instrument effectiveness, it is necessary to determine the quantitative relationships between the instruments and the policy aims, which can be achieved by the explicit definition and empirical development of a freight transport model.

Transport industry

While the governments by their actions influence the equilibrium on the freight transport markets mostly in an indirect way, the transport industry is one of the main direct actors. It is understandable that their policy objectives are more direct and less abstract than the government objectives. Given the demand for transport, the individual transport firms, through their instrument policy, equipment usage policy, pricing policy, etc. determine to a large extent the actual developments in the freight transport markets. To develop their strategies they need detailed information on a micro-business level (costs, prices, profitability of individual contracts, marketing, budgeting, rentability, etc.). Besides that there is a need for general information about future economic and technological developments to develop medium-term strategies for their own firms. Here the transport industry organisations can play an important role by supplying information about those developments to the individual firms, who can use them in setting their own goals and developing their own market strategies to achieve these goals. This type of more general information has the same degree of detail as the information needed by governments to design their transport policy. It concerns, for example, information on such topics as future demand developments, government policy and the way it is supposed to influence the demand-supply equilibrium process on the various transport markets, technological changes on both sides of the markets, infrastructure developments, etc.

Thus the conclusion is that governments and transport industry to a large extent need the same kind of information to design their policies. Governments use this information to define their objectives and to evaluate different policies to achieve those objectives. Once the objectives are defined and the policy strategies chosen, the expected effects on the equilibria in the freight transport markets are of great importance for the policy strategies of the individual firms. It is hardly necessary to say that the same freight transport models have to be used to supply both actors with consistent information about their present and future policy strategies.

2. FREIGHT-DEMAND SUPPLY THEORY

2.1 The demand-supply equilibrium

The purpose of this part is to develop some basic theoretical concepts for the development of freight transport models. These basic concepts are independent of the size or type of geographical area to be studied such as urban areas, regions, countries or groups of countries. The main hypotheses about transport can be highlighted in a very simple demand-supply equilibrium model:

$$\left.\begin{array}{ll} \text{Demand function:} & V = F(A,L) \\ \text{Supply function:} & S = G(T,L) \\ \text{Equilibrium:} & V = S \end{array}\right\} \quad L_o,\ V_o,\ S_o)$$

$$\text{Reduced functions:} \quad V_o,\ L_o,\ S_o = H(A,T)$$

V : volume of transport flows

S : supply of transport services

A : activity pattern

L : level of services expressed in a generalised way (generalised cost or time)

T : the available transportation system.

In this simple demand-supply model two groups of variables are exogenous to the equilibrium process, that is the activity pattern and the available transport system. The activity pattern is the pattern of production and consumption activities, that is to say its level, its composition and its geographical distribution. The transport system consists of all transport options open to the shipper (all transport modes, all facilities, etc.).

Because both exogenous variables A and T can only be defined in a spatial way, the endogenous variables V, S and L are spatially determined too. Spatially determined in a practical way means on a region-to-region or a zone-to-zone basis. It implies, too, that all variables can be seen as matrices, the individual elements measured on a region-to-region basis, i.e. the variable V_o is the equilibrium freight flow pattern of a certain area.

As the variables A and T can only be specified usefully within a spatial context, every policy-oriented freight transport analysis should take the freight flow as its research object. The core of any freight transport analysis is the determination of or the prediction of changes in the freight flows. More precisely, the freight flows between region A and region B can be seen as a distinct transport market with its own demand and supply conditions. All individual freight transport markets are highly interrelated by the mechanism of substitution factors working on both the demand and the supply sides: industries can change the destinations of their produced commodities, carriers can change their transport equipment from one market to another.

From this simple presentation of the demand-supply equilibrium process, more detailed modelling concepts can be derived - concepts which are aimed to specify the spatial demand and supply functions in a more detailed and operational way.

2.2 The freight transport demand factors

As already stated, the demand for freight transport is directly influenced by the level, composition or structure and the geographical distribution of production and consumption activities,(1) as can easily be seen at the level of the individual production firm. The individual shipper takes a lot of decisions which influence the actual demand for transport in a direct or indirect way. His long-term strategic decisions concern the commodities to be produced, the production techniques to be used and the location of the plant(s). The first two decisions directly influence the composition of the incoming and outgoing freight flows of the firm, while the third decision already predetermines to a large extent the geographical distribution of those flows. His location decisions will be influenced especially by the present (or future) transportation system. His medium-term decisions concern production levels, geographical markets (sales and supplies), and his own transport facilities. All these medium-term decisions will be influenced by the available

1) Refs. 13), 14).

physical transport systems and the level of services offered by the transport industry.

His short-term decisions concern consignment weights, transport units, transport modes, distribution frequency, etc. Here the type and quality of the transport services offered to him will shape the ultimate actual demand for freight transport.(1) Because of the often limited impact transport supply factors have on the aforementioned long- and medium-term decisions of the individual firms, the development of transport demand is to a large extent exogenous to the transport sector. This is of course particularly the case within the Western developed economies, which already have a high-quality transport system available.

How does all this affect the freight transport modelling process? First of all, freight demand modelling and forecasting cannot take place without a detailed picture of the present and future activity patterns. Details are necessary for the production and consumption structure (level, composition, geographical distribution). The production and consumption activities are very diversified in our developed economies due to the high degree of specialisation. Every activity has its own very specific transport requirements. Consequently the incoming and outgoing flows vary a great deal from one activity to another, as regards:

- transport volume per time period;
- commodity categories;
- type of load;
- consignment size;
- geographical distribution of the flows;
- physical distribution systems;
- seasonal and conjunctural dependencies;
- quality of service expected, etc.

Normally this problem of diversification can be solved by differentiating the total volume of transport between commodity classes. For every commodity class a separate demand function or model can be developed. This is, however, only allowed if the volumes of freight transport by commodity class are modelled in an interrelated way. This can clearly be seen by taking a simple example: if, for example, the steel industry increases its output of steel products, the volume of various other commodities will also increase in relation to the output increase of steel products, such as volumes of iron ore, coal, energy, etc. The interrelationships between the volumes of the different commodity groups can be taken into account by using an economic production-structure model, e.g. an input-output model on a national, regional or interregional scale. In fact the production levels of the different production sectors are determined by

1) Ref. 8).

the final demand components, and the resulting transactions between the sectors on an interregional basis, form the real base for the derivation of interregional freight flows.

In other words, the structural and spatial relations between the production and consumption activities are the necessary input to interregional freight demand modelling. If in practice, due to a lack of data, second-best approaches have to be followed, those relationships should as much as possible be preserved in a more indirect manner, because the above-mentioned demand factors are the main determinants of the observable freight flow patterns. Fluctuations and structural changes in the activity pattern have immediate strong impacts on the resulting freight flow pattern.(1)

The second group of demand factors form the level of service variables derived from the supply functions of the various transport services. Shippers will respond to changes in these variables in different ways depending on the type of decision to be taken. Such changes will have a much more direct impact on modal choice decisions than on plant location decisions, as the adaption costs involved in the latter group of decisions are much higher than in the former. The main level of service variables to be taken into account are:

- transport costs (door-to-door);
- transport times (door-to-door);
- loss and damage;
- reliability;
- minimum shipment size.

The way those variables will be derived from the supply models will be discussed in the next section.

2.3 The freight transport supply factors

The supply models are of equal importance to the demand-supply modelling process and the policy-making process. They not only provide the possibility to specify in detail the level of service variables necessary for the development of the freight transport models, but they also offer the possibility to translate the transport policy options into this group of demand related variables. As we have already seen, the main policy actors in the policy-making process are the government institutions and the transport industry. Their policies are aimed to alter the supply conditions in order to influence the outcome of the demand-supply equilibrium process on the freight transport markets. In other words their control lies on the supply side. Supply models must explicitly incorporate, directly or indirectly, all elements which can be influenced by the policymakers.

1) Ref. 20).

Each of their options must be translated via the supply models in the resulting level of service variables mentioned in section 2.2.

The vector of level of service variables, too, should be determined in a spatial way, that is to say for every type of transport service on every geographically determined transport market. The number of vectors depends on the number of commodity groups and regions taken into account.

The level of service elements are in principle determined by two main categories of exogenous variables: the available transport infrastructure and the production functions used by the transport firms, primarily because government institutions often have a great influence on the actual value of the individual elements.

The available transport infrastructure, its size, type and quality directly influences the type of transport services offered on the various transport markets and, to a large extent, the corresponding transport times, too. Via the derived transport times, transport costs are influenced in an indirect way, as transport times form a basic input to the cost functions. Both supply elements, costs and time, should be based on a door-to-door basis, taking access and egress, handling costs and time into account, because individual shippers will base their decisions on the door-to-door values.

The operating costs and times of the transport industry depend on the production techniques selected: from the supply models derived, transport costs and time models offer the possibility of analysing the consequences of altered supply conditions caused by various policy options. If the transport tariffs are cost-based, which is often the case for the medium- and long-term, the effects of altered supply conditions on the demand-supply equilibrium can also be analysed in detail.

The supply models and the derived transport costs and time models should be rather detailed, if they are to express the consequences of all kind of changes in the supply conditions, such as:

- general prices (labour, capital, energy);
- quality of infrastructure;
- technology;
- productivity;
- social conditions;
- government regulations, etc.

The more detailed they are, the deeper can be the evaluation of these policy actions and their consequences for the achievement of the objectives.

3. BASIC FREIGHT TRANSPORT MODEL STRUCTURES

In line with the basic freight transport modelling concepts mentioned in section 2, only spatially determined model structures will be reviewed. In principle two main interregional (or interzonal) modelling approaches are used to build interregional freight transport models. The first one, the classic and probably more accepted one, is an approach which takes a certain freight flow between two regions as the unit of observation. Although such a freight flow can be very specific, such as the flow of a certain commodity group for a certain mode of transport over a certain period of time, all these individual flows consist of an aggregation of a number of individual consignments sent by a group of firms in region A to a group of firms in region B, hence a large number of demand and supply factors have to be used as averages. This is the main reason for typifying such approaches as aggregated modelling exercises.

This expression however is misleading, because interregional freight flow models can be very disaggregated in their flows, although they will never reach the point of individual consignments. The second type of main approach is called disaggregate because it is based on the analysis of individual consignments. Models of this type are called disaggregate models. The development of this approach started about ten years ago in the passenger transport sector caused by mixed feelings about the performance of aggregate passenger transport models in the transport policy field. Recently some disaggregated freight (sub) models were developed and it appears that in the near future this approach will be more fully explored.

Although in principle both methods are based on freight modelling concepts, they differ in the way the technical and structural relations are derived from observed transport data. This is partly caused by the differences between the type of data used and partly by some differences in the applied general demand theory. In the next part of this section these model approaches will be briefly examined.

3.1 The disaggregated modelling approach

The disaggregated demand-supply approach is based on the choice-behaviour of the individual production firm (industry, staples, etc.). The demand for transport consists of a number of individual consignments, each with its own characteristics, for which the individual shipper has to take a number of transport-related decisions. Every decision is seen as a choice made from a set of alternatives. There are a number of interrelated choices to be made for every individual consignment, e.g. a transport of x tonne at a time t of commodity k with transport mode m from origin i to destination j implies already six identifiable choice situations:

- the choice of commodity k
- the choice of origin i
- the choice of destination j
- the choice of amount x
- the choice of time t
- the choice of mode m

It is not very difficult to dissect the transport of an individual consignment into an even larger number of interrelated choice situations. As seen from the following sequence of choices, some kind of hierarchy in the decision-making process is already introduced, in accordance with the already mentioned distinction between long-, medium- and short-term decisions (see section 2.2).

To model the different choice processes in a sequential or simultaneous way, a choice-based demand theory is developed. The following equations illustrate the demand theory.(1)

1) $U_{it} > U_{jt}; \; i,j \in A_t$

2) $U_{it} = u_{it} + \varepsilon_{it}$

3) $P(i : A_t) = \text{Prob}\left[U_{it} > U_{jt}\right] \; ; \; i,j \in A_t$

4) $P(i : A_t) = \text{Prob}\left[\varepsilon_{jt} - \varepsilon_{it} < u_{it} - u_{jt}\right] \; ; \; i,j \in A_t$

5) $P(i : A_t) = \dfrac{e^{U_{it}}}{\sum_{j \in A_t} e^{U_{jt}}}$

U_{it}, U_{jt} : the utility of alternative i or j for shipper t.

A_t : the set of alternatives, shipper t can choose from

u_{it} : the common (for all shippers of type t) statistical definable part of the total utility of alternative i

ε_{it} : an by shipper t additional and subjective attached amount of utility to alternative i, seen as the random part of the total utility of alternative i

$P(i : A_t)$: the probability that shipper t chooses alternative i out of the set of alternatives A_t.

Equations 1 to 4 explain the choice behaviour process of shipper t facing a set of alternatives, which is seen as a utility maximising process.(2)

1) Refs. 1), 2), 5), 9).

2) Note that the use of utility theory here differs from the utility theory used in micro-economic theory to derive demand functions.

Equation 5 is the demand function which is formalised by an assumption about the distribution of the random variables ε_{it}. By assuming a log normal distribution, equation 5 is the expression of the well-known multinominal logit model.

The structure of the demand models, which implies the interrelations between the probabilities of the different choice situations depends on the assumptions made about the dependency and simultaneousness of the choice decisions to be taken, which lead to three basic structures.

Take as an example the determination of the probability of (f) shipments by period (week, month, year), for commodity k with mode (m) in consignment size (q) to destination (d) from a given origin i. This leads to:

6) $P^k(f,q,d,m)_t$; $fqdm \in (FQDM)_t$

where:

$(FQDM)_t$: the set of alternatives open to shipper t for frequency f: (F), consignment size q: (Q), destination d: (D) and mode m: (M).

From 6) the following structures can be derived.

7) <u>independency</u>:
$$P^k(f,q,d,m)_t = P(f)_t \cdot P(q)_t \cdot P(d)_t \cdot P(m)_t$$

8) <u>dependency and sequential, e.g.</u>
$$P^k(f,q,d,m)_t = P(f)_t \cdot P(d/f)_t \cdot P(q/f,d)_t \cdot P(m/f,d,q)_t$$

9) <u>dependency and simultaneous</u>
$$P^k(f,q,d,m)_t = P^k(fqdm)_t$$

where:

$P^k(f)_t$: the probability of shipper t choosing f consignments per period

$P^k(q)_t$, $P^k(d)_t$, $P^k(m)_t$: the probabilities of shipper t choosing respectively consignment size q, destination d and mode m

$P^k(d/f)_t$: the probability of shipper t choosing destination d, if he chooses frequency f (this is a conditional probability)

$P^k(q/f,d)_t$: the probability of shipper t choosing consignment size q, if he chooses f and d

$P^k(m/f,d,q)_t$: the probability of shipper t choosing mode m, if he chooses f,d and q

$P^k(f,q,d,m)$: the total probability of shipper t choosing the combination fqdm out of the set alternatives (FQDM).

The independency alternative will not exist because of the influence of the level of service variables on the different structural probabilities.

The choice between a sequential or simultaneous structure will depend on an analysis of the actual choice behaviour. The sequential structure, which is the easiest to model, is often found in aggregate transport demand models for both passenger and freight transport (generation, distribution, modal split).

The specification of the various probability functions is the next step in arriving at a freight demand-supply model, that is to say, the determination of all variables which influence the outcome of the choice process in every choice situation. However the choice-based demand theory does not give indications of the variables to be used, which implies that the model specification has to follow a trial and error procedure.

If we restrict ourselves again to the specification of the $P^k(f,q,d,m)_t$ freight demand model, the following categories of choice variables can be assumed to have influence on freight demand:(1)

a) the characteristics of the various transport services such as (V)
   - transport tariffs or costs;
   - transport times;
   - reliability;
   - damage and loss;
   - minimum consignment size, etc.

b) the characteristics of the commodities to be transported such as (G)
   - type of product;
   - volume/weight ratio;
   - value/weight ratio;
   - perishability;
   - inventory system;
   - ownership, etc.

c) the characteristics of the markets (sale and supply) such as (M)
   - relative prices;
   - firm size;
   - available loading and unloading facilities for customers;
   - infrastructure facilities (connection with), etc.

d) the characteristics of the shipping firm such as (B)
   - production level;
   - sales prices;
   - plant location;
   - available infrastructure facilities;
   - storage policy and costs, etc.

Substituted in the general demand model (6) the following specification can be derived:

1) Ref. 10).

10) $P^k(f,q,d,m)_t = F(V_{fqdm}, G_{fqdm}, M_{fqdm}, B_{fqdm}) : fqdm \in FQDM$
where:

V : the vector of level of service variables for all combinations fqdm
G : the vector of attributes of commodity k
M : the vector of attributes of the commodity markets
B : the vector of attributes of firm t at location i
F : the demand function (simultaneous or sequential)

This demand model estimates the probability that shipper t chooses alternative fqdm out of the set of alternatives FQDM. By multiplying these probabilities with the frequency values, a volume model can be derived (measured in consignments), that is

11) $V^k_{idqm(t)} = \sum_{f \in F} P^k(f,q,d,m)_t \cdot f$

The transformation in tonnage can be accomplished by multiplying V^k_{idqm} with the average consignment size.

12) $T^k_{idqm(t)} = V^k_{idqm(t)} \cdot \bar{Q}^k_{qm}$

or

13) $T^k_{idm(t)} = \sum_{q \in Q} V^k_{idqm} \cdot \bar{Q}^k_{qm}$

where:

$\bar{Q}^k_{qm}$: the average consignment size of class q for mode m
$T^k_{idqm(t)}$: transport volume in tonnage from region i (origin) to region d (destination) for consignment class q by mode m for shipper t
$T^k_{idm(t)}$: idem for all consignment classes q together, being the total volume of transport for commodity k by mode m from origin i to destination d for shipper t.

In other words

14) $T^k_{idm(t)} = \sum_{q \in Q} \sum_{f \in F} \cdot P^k(f,q,d,m)_t \cdot f \cdot \bar{Q}^k_{qm}$

$V^k_{idqm(t)}$ resp. $T^k_{idqm(t)}$ can be seen as the transport volume (consignments resp. tonnage) expressed demand model $P^k(f,q,d,m)_t$.

Equation 10 the demand model is very complex due to the large number of alternatives in the choice set FQDM and the large number of variables to be specified per alternative fqdm (the vectors V,G,M,B).

This model can be simplified by using a sequential demand structure (see e.g. equation 8).

At the present time the development of complete disaggregated demand models is restricted for many reasons. First of all, the underlying demand theory is not explored in enough detail to develop a complete freight demand-supply equilibrium model according to the basic concepts (see section 2). Secondly, the properties of the choice-based demand theory are questionable in part, e.g. the property of equal cross-elasticities for all alternatives (e.g. modes of transport).(1) Thirdly, it is doubtful if a complete disaggregated freight demand-supply model system according to the above-mentioned concepts can be developed. This is especially true where the integration between the economic activity models and the derived freight demand functions is concerned. Fourthly, the specification of the freight demand models (choice variables and sets of alternatives) still cannot be solved by the choice-based demand theory itself. Finally, the data on individual consignments are not collected by the statistical offices, which implies collection by special surveys, which is a costly affair.

On the other hand, disaggregated demand analysis - even applied on a small scale - offers distinct possibilities for policy sensitive research. Because of its high degree of detail and its use of non-averaged demand factors in the demand equations, it offers greater possibilities to describe the transport behaviour of the economic subjects in a satisfactory way.

3.2 The aggregated modelling approach

In contrast with the development of disaggregated model approaches, which up to now has taken place only in a rudimentary way, mainly due to a lack of data, aggregated approaches are much more developed and have already been applied on a number of occasions. To avoid misunderstanding it should be repeated that the term aggregated only refers to the type of statistical observations used for the model development, that is freight flows instead of individual consignments.

Although not essential for the approach as such, most spatial models have a sequential structure, explaining and predicting the volume of the specific freight flows in a step-by-step process. Special procedures take care of the internal consistency of the various submodels. According to the line of thinking developed in section 2 a freight demand-supply model normally can be subdivided into the following main submodels:

i) a multi-sectoral economic model
ii) a spatial economic model
iii) a freight production and attraction model
iv) a freight distribution model
v) a freight modal split model
vi) a freight traffic production model

1) Refs. 3), 4), 7).

vii) a set of freight supply related models
- transport time models
- transport tariff models
- transport costs models

viii) an equilibrium model
- transport infrastructure (assignment)
- transport industry

The interrelationships between the various submodels are shown in Figure 2.

The models i) and ii) are economic models, which of course can also be combined into one spatial, multi-sectoral economic model. The output of the economic models forms the main input to the freight demand models iii) to v). The freight demand models determine the freight flows by commodity group and by mode of transport for each pair of origin and destination, measured in tonnage. Model vi), the traffic production model, transforms the freight flows (in tonnage) into traffic flows measured in all types of vehicle movement (truck, ship and wagon movements).

The group of submodels vii) are the level of service models derived from the supply models, followed by the last submodel, the equilibrium model.

The whole model system can be defined in a general way by the following set of equations:

i) <u>the multi-sectoral economic model</u>

15) $P^g = \sum_h P^{gh} + FC^g + BI^g + E^g$ $\qquad g,h = 1,\ldots, G$

16) $P^{gh} = \beta^{gh} \cdot P^h$

17) $\bar{P} = \left[B\right] \cdot (\bar{FC} + \bar{BI} + \bar{E})$

18) $\left[B\right] = \left[I - A\right]^{-1}$

P^g : total supply of sector g (gross output of commodity g)

P^{gh} : delivery of sector g to sector h

FC^g : final demand of sector g, excluding investment and export

BI^g : brute investments originating in sector g

E^g : export of sector g

β^{gh} : technical coefficient describing P^{gh} as a fixed proportion of P^h

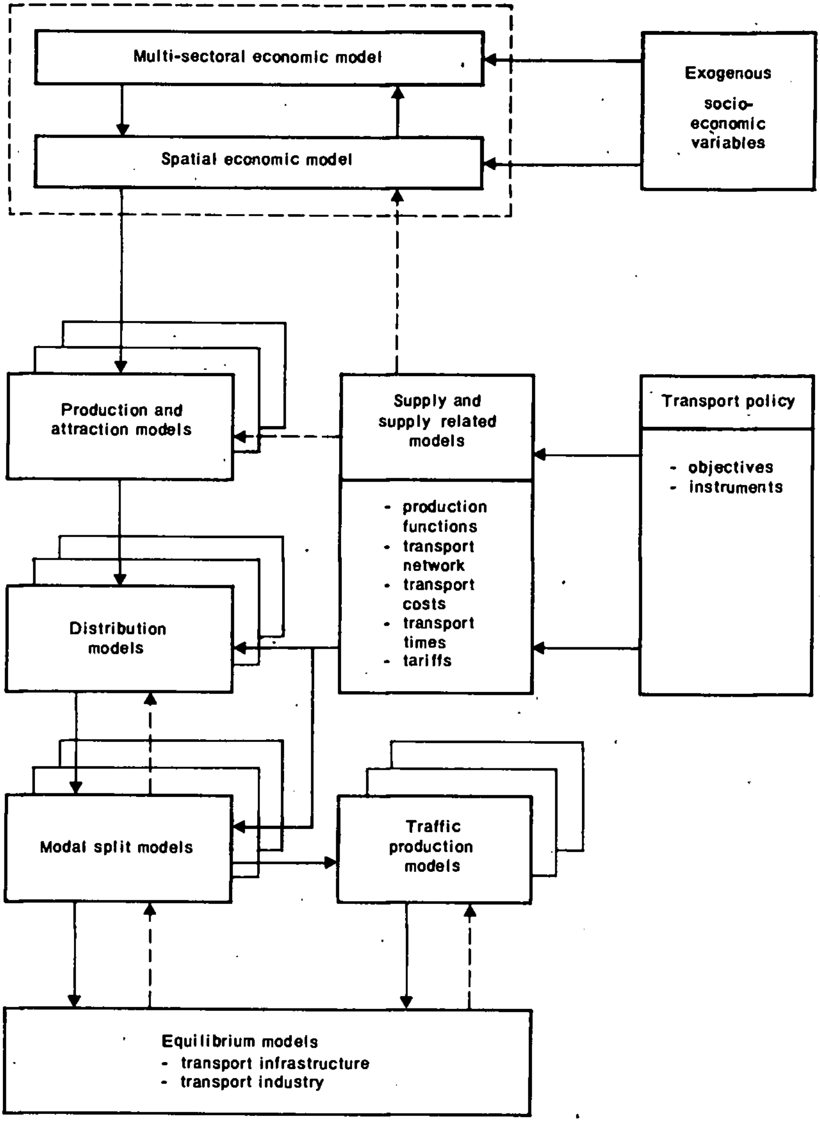
$\bar{P}$: vector of the supply levels for G sectors

$\left[I - A\right]^{-1}$: the leontief-inverse matrix

g,h : number of sectors c.q. commodity groups (g,h = 1,..., G)

Figure 2

THE INTERNAL STRUCTURE OF THE DEMAND-SUPPLY MODEL



The multi-sectoral economic model is based on the so-called transaction table described in equation 15. There is one equation for every sector or commodity.

Finally the gross output of all sectors is related to the final demand components for each industry (equation 17). The B-matrix may be multiplied by any level and composition of final demand in order to derive the levels of gross output for each industry. Besides the gross output levels, the levels of a number of other macro-economic variables can be derived, such as employment, value added and import per sector. In most countries transaction tables have been constructed for recent years, so that the practical application of such models is quite feasible. Although other sector growth models exist, the input-output model is the most robust.

ii) <u>a spatial economic model</u>

19) $P^g_{io} = \delta^g_{io} \cdot P^g$ $\qquad g = 1, \ldots, G$

20) $\sum_i \delta^g_{io} = 1$ $\qquad i = 1, \ldots, I$

21) $\delta^g_{io} = \dfrac{L^g_i}{\sum_i L^g_i}$

P^g_{io} : Gross Domestic Product of sector g in region i

δ^g_{io} : regional supply coefficient

L^g_i : the employment of sector g in region i (e.g. manyears)

i : number of regions $\qquad$ i,j = 1,..., I)

This is of course a very simple regional supply model, which does not take the interregional interdependencies into account. The factor L can be substituted by other factors or weighted combinations of it. However it does not solve the problem of interregional interactions.

i and ii) <u>a spatial multi-sectoral economic model</u>

To overcome the weakness of the multi-sector economic model as a tool for spatial analysis and prediction, it should be transformed explicitly into a spatial model.

22) $P^g_{io} = \sum_j S^g_{ij} \cdot P^g_{oj}$ $\qquad g,h = 1, \ldots, G$

23) $S^g_{ij} = \dfrac{P^g_{ij}}{P^g_{oj}}$ $\qquad i,j = 1, \ldots, I$

24) $P^g_{oj} = \sum_h P^{gh}_{oj} + FD^g_{oj}$

25) $P^{g}_{io} = \sum_{j} S^{g}_{ij}(\sum_{h} P^{gh}_{oj} + FD^{g}_{oj})$

S^{g}_{ij} : trade coefficient for commodity g between region i and j

FD^{g}_{oj} : total final demand of sector g in region j

By solving this system of equations in the same way as indicated under i) the regional gross output per sector will be determined by the final demand components of all sectors in all regions. Because of the lack of data few models have been used for estimating the regional production levels. Besides which, the trade coefficients S^{g}_{ij}, which are fixed values, are not very stable over time. They will be influenced by the level of service of the available transport system, for example.

Because of this, one often has to use a two-step regional forecast procedure as described under i) and ii).

Before presenting the actual freight demand models one could ask why these economic models are so important for freight demand-supply predictions.

Why not use a more simple procedure, e.g. start with an a priori defined growth rate for Gross Domestic Product (GDP), and dissect it into sectorial growth figures using a stepwise procedure? There are two important reasons for not using such simple prediction methods.

First of all, the same expected increase in Gross Domestic Product can be caused by various combinations of growth rates of the individual sectors. The actual combination depends on the interrelations between the sectors expressed in the production structure of an economy. The composition of the gross output levels are of special importance for the derivation of the demand for freight transport. Any change in final demand, e.g. export, implies production increases in almost all sectors of the economy.

Secondly, satisfying the above-mentioned internal consistency criterion is conditional to a freight demand-supply model, where a market segmentation procedure is implied, that is to say total freight demand is segmented into freight demand volumes by commodity group, and independent prediction procedures are used for every commodity group. This is only allowed if the input into these models (sectoral production levels) is internally consistent, which can only be achieved by using a multi-sectoral economic model. As we will see later, existing freight models do not take this consistency condition sufficiently into account, which can have serious drawbacks for the calculated prediction figures and the usage which can be made of these models. The same kind of remark can be made concerning the internal regional consistency of production levels. However drawbacks there are much less pronounced than in the first case.

iii) <u>the freight transport production and attraction model</u>

26) $V^g_{oo} = f_{g^1}(P^g_{oo})$ $\qquad g = 1, \ldots, G$

27) $V^g_{io} = f_{g^2}(P^g_{io})$ $\qquad i,j = 1, \ldots, I$

28) $\sum_i V^g_{io} = V^g_{oo}$

29) $V^g_{oj} = f_{g^3}(P^g_{oj})$

30) $P^g_{oj} = \sum_h b^{gh} P^h_{oj}$

31) $\sum_j V^g_{oj} = V^g_{oo}$

V^g_{oo} : total transport volume of commodity g

V^g_{io} : generated transport volume of commodity g by region i

V^g_{oj} : attracted transport volume of commodity g by region j

P^g_{oo} : total production of sector g

P^g_{io} : production of sector g in region i

P^g_{oj} : composite demand factor for commodity g

b^{gh} : cumulated production coefficient for sector g

$g = 1, \ldots, G$: number of sectors resp. commodity groups

$i,j=1, \ldots, I$: number of region

Equation 27 is the regional freight transport production function which relates the total transport volume of commodity g originating in region i directly to the gross-output level of sector g in region i, determined by the economic models i) and ii) (the number of sectors equal the number of commodity groups, while the classification of the sectors is commodity based).

The attracted transport volume of region j can only be explained by using a composite demand factor based on the cumulated production coefficients from the economic models.

iv) <u>the freight transport distribution model</u>

32) $V^g_{ij} = f_{g^4}(V^g_{io}, V^g_{oj}, R^g_{ij})$

33) $R^g_{ij} = f_{g^5}(\overline{TK}^g_{ij}, \overline{TT}^g_{ij}, \overline{TZ}^g_{ij})$

34) $\overline{TK}^g_{ij} = f_{g^6}(TK^g_{ij1}, \ldots TK^g_{ijk})$

35) $\overline{TT}^g_{ij} = f_{g^7}(TT^g_{ij1}, \ldots TT^g_{ijk})$

36) $\overline{TZ}^g = f_{g^8}(TZ^g_{ij1}, \ldots TZ^g_{ijk})$

$$37)\ \sum_j V^g_{ij} = V^g_{io}$$

$$38)\ \sum_i V^g_{ij} = V^g_{oj}$$

V^g_{ij}	: transport volume of commodity g between the regions i and j
R^g_{ij}	: transport resistance for commodity g between the regions i and j
$\overline{TK}^g_{ij}$, $\overline{TT}^g_{ij}$, $\overline{TZ}^g_{ij}$	: respectively the average transport costs, transport time and average other level of service factors for commodity g between the regions i and j (weighted by the shares of the various modes of transport on the i,j relation)
TK^g_{ijk}, TT^g_{ijk}, TZ^g_{ijk}	: respectively the transport costs, transport time and other level of service factors for commodity g and transport mode k between the regions i and j
$g = 1,\ldots, G$	: number of commodity groups
$i,j = 1,\ldots, I$	: number of regions
$k = 1,\ldots, K$	: number of transport modes

The freight transport volume between region i and region j, according to equation 32, is determined by the total supply and demand of commodity g in, respectively, the region of origin and the region of destination and some transport resistance value. The transport resistance depends on the different level of service variables of the available modes of transport, such as costs, time, etc., used as weighted averages.

v) <u>the freight transport modal split model</u>

$$39)\ V^g_{ijk} = (TK^g_{ij1}, \ldots TK^g_{ijk}; TT^g_{ij1}, \ldots TT^g_{ijk}; TZ^g_{ij1}, \ldots TZ^g_{ijk})$$

$$40)\ \sum_k V_{ijk} = V^g_{ij}$$

V^g_{ijk}	: transport volume of commodity g by transport mode k between region i and j
$g = 1,\ldots, G$	: number of commodity groups
$i,j = 1,\ldots, I$	: number of regions
$k = 1,\ldots, K$	: number of transport modes

Equation 39 described a set of modal split functions for g commodity groups and k modes of transport. The main modal split factors are transport cost and transport time, both measured on a door-to-door basis. Equation 40 restricts the shares of the modes to 1.

In the next submodel, the freight traffic production model, tonnages are transformed into vehicle movements.

vi) <u>the freight traffic production models</u>

41) $VPB^{g}_{ijk} = V^{g}_{ijk} / \overline{ACW}^{g}_{ijk}$

42) $\overline{ACW}^{g}_{ijk} = f_{g}10 \, (V^{g}_{ijk}, D_{ijk}, C_{k})$

43) $VPB^{g}_{ijkl} = \alpha^{g}_{ijkl} \cdot VPB^{g}_{ijk}$

44) $\sum_{l} \alpha_{ijkl} = 1$

45) $VPB_{ijkl} = \sum_{g} VPB^{g}_{ijkl}$

46) $VPL_{ijkl} = f_{kl} \, (VPB_{1Okl}, \ldots VPB_{IOkl}; TK_{j1kl}, \ldots TK_{jIkl})$

47) $VPB_{iokl} = \sum_{j} VBB_{ijkl}$

48) $VP_{ijkl} = VPB_{ijkl} + VPL_{ijkl}$

VPB^{g}_{ijk}	: number of loaded traffic movements for commodity g by mode k between the regions i and j
$\overline{ACW}^{g}_{ijk}$	: average consignment weight for commodity g by mode k between the regions i and j
VPB^{g}_{ijkl}	: number of loaded traffic movements for commodity g by mode k in loading capacity class l between the regions i and j
VPB_{ijkl}	: total number of loaded traffic movements by mode k in loading capacity class l between the regions i and j
VPL_{ijkl}	: number of empty traffic movements by mode k in loading capacity class l between the regions i and j
VBP_{iokl}	: supply of consignments in region i for mode k in loading capacity class l
VP_{ijkl}	: total traffic movements by mode k in loading capacity class l between the regions i and j
D_{ijk}	: transport distance by mode k between the regions i and j
C_{k}	: technical constraint on loading capacity size
α^{g}_{ijkl}	: loading capacity class coefficients
g = 1,... G	: number of commodity groups
i,j = 1,... I	: number of regions

$k = 1, \ldots K$: number of transport modes
$l = 1, \ldots L$: number of loading capacity classes

The number of loaded traffic movements by capacity class is described by the equations 41 to 45, with the average consignment weight as the main variable.

Equation 46 describes the number of empty movements for the different modes of transport, while equation 48 is the description of the total traffic movements by mode of transport and loading capacity class.

vii) <u>the supply-related models</u>

Input to the above-mentioned model equations are the level of service variables derived from the supply models of the various modes.

49) $TK^g_{ijk} = f_{gk} (\overline{ACW}^g_{ijk}, D^g_{ijk}, TT^g_{ijk}, \varepsilon^g_{ijk}, \gamma^g_{ijk}, HK^g_{ijk})$

50) $TT^g_{ijk} = g_{gk} (\overline{ACW}^g_{ijk}, D^g_{ijk}, \varepsilon^g_{ijk}, \gamma^g_{ijk}, HT^g_{ijk}, IQ_{ijk})$

51) $TZ^g_{ijk} = d_{gk} (\overline{ACW}^g_{ijk}, D^g_{ijk}, IQ_{ijk})$

TK^g_{ijk} : transport cost for commodity g by transport mode k between regions i and j
TT^g_{ijk} : transport time for commodity g by transport mode k between regions i and j
TZ^g_{ijk} : other level of service variables for commodity g by transport mode k between region i and j
ε^g_{ijk} : average utilisation degree of transport equipment
γ^g_{ijk} : ratio of loaded and empty kilometres
IQ_{ijk} : quality of physical infrastructure and transport services offered
HK^g_{ijk} : handling cost for commodity g and mode k
HT^g_{ijk} : handling time for commodity g and mode k

The equations 49 to 51 are reduced form equations derived from the different supply models for the various modes of transport. Changes in the supply conditions will be expressed in the reduced form equations via these supply models.

viii) <u>an equilibrium model</u>

The general equations mentioned in this section thus far together form a complete spatial freight demand model, which can be specified in a more detailed way depending on the policy problems involved and the degree of detail of the available data. The outputs of the various submodels can also immediately be used as input for other specific models, such as energy demand models, fleet capacity models, cost-based tariff models, cost-benefit models, etc.

However, the model system is still incomplete when viewed in the context of a demand-supply equilibrium system. Assigning the ultimate traffic flows to the infrastructure networks, recalculating the resulting transport times and costs, refeeding them into the demand functions until those values are in equilibrium, that is having the same ultimate values for all model parts, is only half of the equilibrium solution. There is an equilibrium as far as the supply of the infrastructure networks is concerned, but not for the supply of the transport services delivered on those networks. To achieve this explicit equilibrium, separate supply functions of transport services are needed, while demand and supply should be measured in the same units. Taking a partial equilibrium as an example, the following functions can be defined.

52) Reduced demand function from equation 26 to 40, measured in tonnage

$$V^g_{ijk} = F_{gk}(P^g_{io}, P^g_{oj}; TK^g_{ij1}, \ldots, TK^g_{ijk}; TT^g_{ij1}, \ldots, TT^g_{ijk}; TZ^g_{ij1}, \ldots, TZ^g_{ijk})$$

$g = 1, \ldots, G$

$k = 1, \ldots, K$

$i,j = 1, \ldots, I$

under the restrictions:

$$\sum_k V^g_{ijk} = V^g_{ij}$$

$$\sum_j V^g_{ij} = V^g_{io}$$

$$\sum_i V^g_{ij} = V^g_{oj}$$

$$\sum_i V^g_{io} = \sum_j V^g_{oj} = V^g_{oo}$$

Taking the tonne/hour as the general production unit in which all individual transport services can be measured, the following general demand and supply functions can be defined:

53) $DU_{ijk} = \sum_g TT^g_{ijk} \cdot F_{gk} (V^g_{ijk}) = \overline{\overline{TT}}_{ijk} F_k (V_{ijk})$

54) $SU_{ijk} = H_k (TK_{ijk}, PK_{ijk}, TT_{ijk})$

55) $DU_{ijk} = SU_{ijk}$ (long-term equilibrium)

where:

DU_{ijk} : demand for transport measures in tonne hours for mode k on transport market i, j

TT^g_{ijk}	: transport time for commodity g and mode k on transport market i, j
F_{gk} (V^g_{ijk})	: reduced transport demand function for commodity g and mode k on transport market i, j
$\overline{TT}_{ijk}$	: average transport time for mode k on transport market i, j
F_k (V_{ijk})	: total reduced demand function for mode k on transport market i, j
SU_{ijk}	: supply of mode k, measured in tonne loading capacity hours on transport market i, j
PK_{ijk}	: production costs for mode k on transport market i, j
TK_{ijk}	: transport costs (tariffs) for mode k on transport market i, j

This is only a partial equilibrium which has to be extended to all markets, the equilibrium values of all markets being interdependent.

Section B

A COMPARISON OF VARIOUS FREIGHT TRANSPORT MODELS

1. THE EUROPEAN COMMUNITY FREIGHT MODEL

1.1 Introduction

The most recently developed freight demand model is that by the Netherlands Institute of Transport for the EC-area and Spain on behalf of the European Community.(1) In the terms of reference it was stated that this freight demand model should support

> "The preparation of estimates of Community infrastructure requirements for merchandise traffic on principal routes (road, rail and inland waterway) in the years 1985 and 2000".

In order to achieve this primary objective three distinct secondary objectives were defined:

i) to construct a data bank of existing freight transport statistics and associated economic statistics;

ii) to develop a freight simulation model based upon the data bank and calibrated against it;

iii) to use the simulation model to produce forecasts of future freight flows given various scenarios for economic development.

As far as freight transport is concerned the whole forecasting system is shown in Figure 3. The ultimate aim of the system is to predict transport and traffic flows from one region to another in as detailed a manner as possible.

Because of differences in the explanation of the freight flows, a distinction has been made between domestic transport per country and international transport between countries. The study area for which the transport flows have to be predicted consists of the nine members of the European Community, - Belgium, Denmark, France, United Kingdom, Ireland, Italy, Luxembourg, The Netherlands and the Federal Republic of Germany - and one non-EC member of the ECMT, Spain.

For domestic transport in these countries different levels of stratification into regions were used, depending on their geographical surface and on available statistics, while for international transport the existing EC regions were used. The modes of transport were

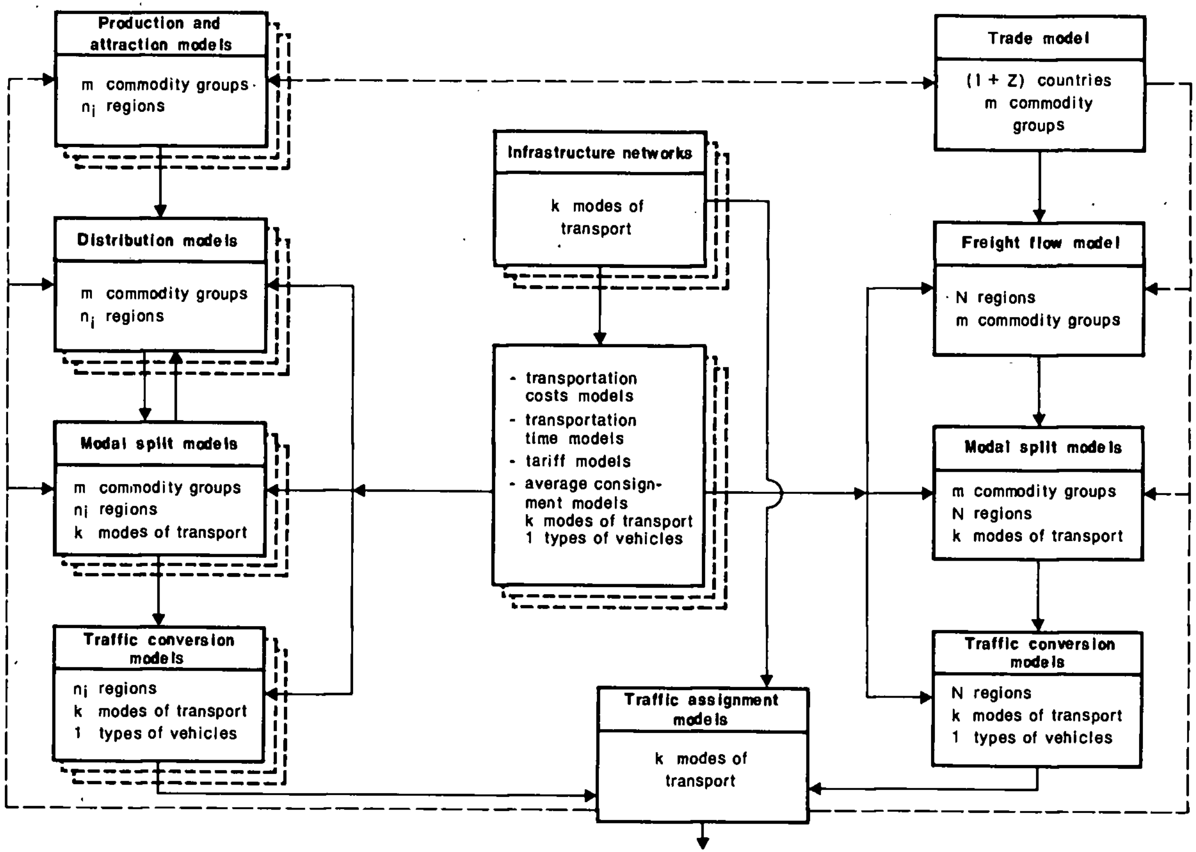
1) Ref. 14).

Figure 3

THE TRANSPORT MODEL

DOMESTIC FREIGHT MODELS
Country i (i = 1. . . . . J)

INTERNATIONAL FREIGHT MODEL



restricted to the so-called "land" modes, rail transport, road transport and inland waterway navigation. Transport by pipelines and sea shipping was omitted.

Because the developed freight model system for the EC follows to quite an extent the aggregated freight demand-supply model structure high lighted in section A-3.2, the description of this comprehensive model system is held verbally.(1)

1.2 Model development

The data base for model development

Each of the submodels of which the freight transport model consists, is estimated on a transport and traffic data base for the years 1973 (domestic transport) and 1974 (international transport). The necessary data were provided by the different countries of the study area and some international organisations such as the OECD and the Statistical Bureau of the Community in Luxembourg.

The freight data bank compiled describes the transport and traffic flows for the basic year in detail. For domestic and international freight transport the following information for each origin and destination pair is available:

1. Zone of origin,
2. Zone of destination,
3. Commodity group m(m = 1, - 2, ... 14),
4. Total tonnage transported per commodity group,
5. Tonnage transported per commodity group by mode of transport (rail, road, inland navigation),
6. Average consignment weights (differentiated as point 5),
7. Number of loaded vehicle movements per mode of transport,
8. Number of empty vehicle movements per mode of transport (excluding rail transport),
9. Distribution of loaded and unloaded vehicle movements over loading capacity classes per mode of transport (for inland waterway transport: six classes, for road transport: six classes and rail transport excluded).

In addition to this information the data bank contains a full description of the available infrastructure networks for rail transport, road transport and inland navigation, tariffs (rail, road and inland navigation), transport times and transport costs (road and inland navigation) on an origin and destination basis, time series of transport and socio-economic variables together with foreign trade figures on a country-to-country basis for 14 commodity groups and for the period 1965-1976.

1) Ref. 14).

Development of the domestic freight models

The need to include the domestic transport of each country was very obvious given the ultimate aim of the study and the importance of domestic freight traffic in the use of the transport infrastructure. It implied the development of a separate domestic transport model for every country in the study area.

Unfortunately, due to the lack of sufficiently detailed geographical data, no domestic model could be estimated for Belgium and Luxembourg. There are some differences in the degree of statistical reliability of the estimated models between the different countries related to the quality and the degree of detail in which the basic data were provided.

The domestic freight models developed consists by country of:

1. A production and attraction model by commodity group,
2. A distribution model by commodity group,
3. A modal split model by commodity group,
4. A traffic conversion model by mode of transport,
5. A traffic assignment model, for domestic and international freight traffic for each mode.

The production and attraction models explain the existing relationships between the demand for transport by commodity group and the level and structure of the economic activities. For statistical reasons the models could not be regionalised, so they consist of a number of relationships explaining total domestic transport by commodity group based on the level of certain basic economic sectors. In the second phase of the production and attraction models those national totals were regionalised on the basis of exogenous information concerning regional economic development.

For the transport of two commodity groups, solid fuels and crude petroleum, no econometric relationships were used in the forecasting procedure; in those cases direct transport scenarios were built for 1985 and 2000.

After determining total transport by commodity group and region for all countries, distribution models are used to divide total transport over all available origin and destination pairs. The distribution models, one per commodity group, explain the transport volume by geographical transport relation as a function of total transport generated by region of origin, total transport attraction by region of destination and the value of the transport resistance between the regions. The value of the transport resistance depends on the level of transport costs and transport times, measured as door-to-door values, of the available modes of transport. The cost and time variables used were calculated as weighted means, with the shares of the modes of transport as weights.

This implies that the distribution and modal split models are interrelated or, in other words, the transport volume by geographical transport relation depends on the modal split on that relation and vice versa. In the forecasting procedure these interrelationships were taken into account.

The detailed estimation results of the distribution models for the different countries give rise to the general conclusion that there exists a basic similarity between the models found for the different countries.

It is interesting to note that for all countries and all commodity groups, the distribution pattern is highly influenced by transport costs and for most countries also by transport time. The resulting elasticities are highly significant, while the values of the elasticities vary in a logical way with the commodity groups concerned.

For the future the relative distribution pattern can change due to:

a) differences in regional transport growth (production and attraction);
b) changes in the real transport costs by mode of transport;
c) changes in the required transport time by mode of transport;
d) changes in modal split.

Transport costs and times not only change due to various price developments (energy, wages, etc.), but also due to changes in the quality of the infrastructure networks, on which the calculations of both these variables are based.

The third sub-model, the modal split model, distributes the geographically determined transport volumes over the available modes of transport, depending on the competitive position of each mode in each geographical transport relation.

In the theoretical specification of the modal split models, the differences between the competitive positions of the different modes of transport are described as transport cost and transport time ratios. The commodity classification used eliminates to a large extent all other modal split factors of a qualitative nature such as reliability, damage, etc.

In evaluating the modal split models estimated for the different commodity groups and for the different countries, the general conclusion that there exists a number of similarities in the results could be drawn. In all countries for all commodity groups the most important factors which influence the modal split are:

1. The level of transport costs of the different modes of transport;

2. The level of transport times of the different modes of transport; their modal split influence is primarily via the influence on transport costs;
3. The (volume) - scale of the transport market in which the modes compete with each other.

There is one indirect modal split factor which has not been mentioned, that is the consignment weight in which the commodities are transported. The consignment weight does influence the level of transport costs and/or tariffs and transport times. In general the larger the consignment weight, the lower the transport costs per unit. However, the influence of the consignment weight on transport costs decreases with increasing magnitude.

The average consignment weight depends in the model on the volume to be transported and the transport distance. Thus modal split is influenced by transport volume in two ways. First of all, for all commodity groups an increase in the transport volume leads to an increase in the average consignment weight (by mode of transport), which leads to a decrease in real transport costs, affecting different modes in different ways. The resulting changes in the real transport cost ratios influences the modal split. Secondly, for some commodity groups an increase in total transport volume favours the use of modes which can offer transport means with a relatively high technical capacity. So even a general increase in total transport volume, leaving the relative transport cost structure unaltered, does in principle influence the transport volume by mode of transport.

In reality, however, the influence of all modal split factors on the toal transport market is diminished by the simple fact that, for large parts of the domestic freight market, no real competition between the modes of transport exists. This is particularly true for short distance transport which is nearly all carried by road and forms a very large part of the total transport market.

The last group of models needed prior to the traffic assignement are the so-called traffic conversion models. In principle the traffic conversion model for each mode of transport consists of two parts. The first part deals with the conversion of tonnage into loaded movements by capacity class, while in the second part the necessary empty movements, also by class, are determined. In all empty vehicle models the volume disequilibrium in the geographical transport markets and transport distance form the explanatory variables. Unfortunately, for rail transport only the first part of the traffic conversion model could be developed, without the inclusion of a distribution of wagon movements over different types.

Assigning the traffic movements by mode of transport to the infrastructure networks, in order to compare traffic intensity with traffic capacity, is carried out by means of assignment models. Using the minimum cost criterion, routes between all origin and destination pairs are determined, to which the traffic can be assigned. The assignment models also combine the traffic movements originating from the domestic and the international transport models.

The development of the international freight transport

In addition to the domestic freight models a complete model for international freight transport has been developed. Some components of the international model are comparable with the domestic freight models, for example, the modal split and traffic conversion models; other parts have been developed in a theoretically different way.

To achieve the necessary consistency with the economic developments in the different countries, which give rise to international transport betwen those countries, an international trade model was developed, which formed the basis for forecasting the volume and structure of international freight movements. So the first part of the international freight model consists of a country-to-country trade model where, as well as the ten countries of the study area, eleven other countries or groups of countries are distinguished. To retain consistency with the available transport data, the trade model was also developed for the same 14 number of commodity groups.

The data on which the trade model is developed were derived from the OECD trade statistics and cover the period from 1963 to 1975. Using origin and destination tables trade functions were estimated, which explain the volume of trade by commodity group and by origin and destination pair. The trade between an exporting country and an importing country is explained by a production variable for the exporting country, an attraction variable for the importing country and a trade resistance or trade facility variable, expressed in different dimensions, such as distance and membership of preferential trade arrangements, like EC, Benelux and EFTA, expressed by dummy variables. After analysing and evaluating the development of the trade pattern in time the estimation of the trade models was based on a pooling of statistical data for the period 1963 to 1972.

Because of the significant EC - effect on the development of the trade volumes between countries belonging to the EC, it can be expected that, for the future, new members will be confronted with an extra increase in their trade with the already existing members of the EC. Those effects have been incorporated in the international freight forecasts for the years 1985 (United Kingdom, Denmark and Ireland) and for the year 2000 (Spain).

The trade flows measured in tonnes have to be translated into freight flows. Because of the transit, mainly by seaports, the international freight flows differ from the international trade flows. The conversion process took place on a country-to-country basis. Afterwards the resulting international freight flows were expanded to region-to-region flows for the 14 commodity groups distinguished. The regions used are the so-called EC regions (84 including Spain). The volume of the trade and freight flows depends in the model system on:

- the socio-economic development in the countries concerned (scenario);
- the assumed distribution of transit amongst the sea-ports in the study area;
- the assumed internal origin and destination by country.

The derivation of the modal split for international freight transport is based on the same variables as used in the domestic modal split models. The most important modal split factors found are the tariff or transport cost variables of the different modes of transport and a market scale factor. As could be expected, given the structure of the international freight transport market, the cost elasticities found are in general higher than the same elasticities for domestic transport, implying that the international modal split structure is more sensitive to changes in transport costs and transport times than the domestic modal split models.

The traffic conversion models for international freight transport have the same structure as for domestic transport. These models determine in principle the number of loaded and unloaded vehicle movements per loading capacity class per mode of transport.

Finally, as previously mentioned, the derived international freight traffic movements together with domestic freight traffic were simultaneously assigned to the infrastructure networks for road transport, rail transport and inland waterway navigation.

The scenarios

A scenario is defined as a plausible and coherent simulation of a future economic situation. The scenarios used in this study are trend scenarios, i.e. they are attempts to extrapolate the long-term trends as they appear from past developments. The basic assumptions relate to the rates of growth of the Gross Domestic Product at constant prices for the various countries covered by the study.

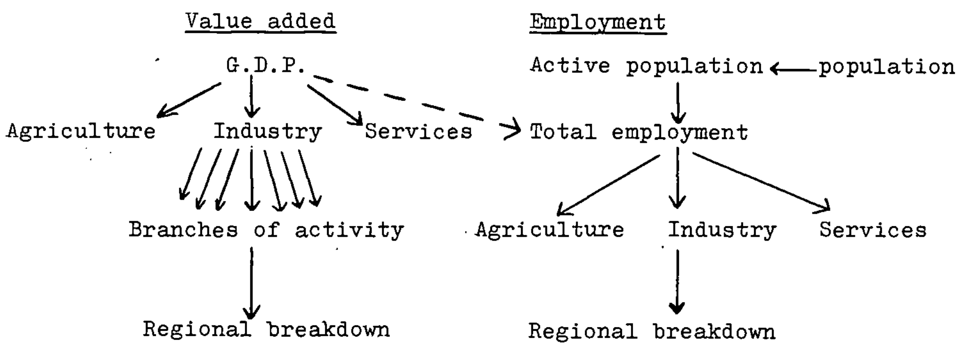
The horizon years are 1985 and 2000. For the period 1975-1985, only one hypothesis, specific to each country, was made about the growth path of Gross Domestic Product, whereas for the period 1985-2000 two possible growth paths were assumed and applied to all the countries (average yearly growth rates of 2 per cent and 5 per cent).

The method used to prepare these scenarios consists of a progressive breaking down of the aggregate growth figures into their various components.

1. National level
   a) the GDP was broken down into value added in the three head sectors (agriculture, industry, services);
   b) value added of industry was broken down into eight industrial branches.
2. Regional level
   Whenever the available information allowed, the value added in each of the industrial branches was disaggregated by regions.

When the necessary information was available, employment was deduced from the GDP on the basis of certain hypotheses concerning the development in productivity.

DIAGRAMMATIC REPRESTATION OF THE SCENARIO FORMULATION



The value added figures were used as exogenous variables for the freight model, i.e. as explanatory variables which determine the endogenous transport variables.

The strategies

The model is intended to be capable of simulating the effects of a wide range of variations in the determinants of freight traffic. These determinants include not only the socio-economic developments contained in the scenarios but also major transport policy strategies.

A strategy is defined as "a coherent and co-ordinated body of major decisions affecting the transport system and aimed at achieving fairly long-term objectives".

Strategy tests are intended to fulfil two purposes:

1. To identify and quantify the real value of a strategy. As all policy measures entail both costs and benefits, the results of the strategy test should indicate the nature and magnitude of the costs and benefits that could occur;
2. To examine the alternative methods of achieving the stated objectives in an attempt to determine the most efficient means.

The formulation of strategies comprises three main stages:

1. The definition of a number of primary objectives to be included in the strategy;
2. The selection of operational means of achieving these objectives;
3. Translation of these "operational means" into terms acceptable as inputs to the model.

In principle the model can take account of four categories of instrument variables or combinations of them:

- factors affecting transport costs (e.g. labour and energy costs);
- factor influencing journey times (e.g. speed limits, driver's working conditions);
- organisational factors (e.g. licences and permits, technical controls);
- infrastructure.

Within the timetable and budget of the present study it was only possible to carry out sensitivity tests of instrument variables and an examination of the "status quo" strategy. The "status quo" situation is the basis for any strategy study, as it serves as the "bench mark" or point of comparison for the evaluation of all other strategies. It assumes the continuation of existing policies into the future. However, it does not assume that there will be no changes, but that the changes which do occur will follow the lines already laid down in government policy.

1.3 Projection of European freight demand

The growth of total freight transport

During the forecasting period total transport in the study area will increase by 78 per cent according to scenario 2000/(2 per cent) and by 185 per cent according to scenario 2000/(5 per cent). So an enormous difference exists between the freight transport consequences of both scenarios. Within the total forecast, international freight transport is always increasing faster than domestic transport, independent of the formulated scenarios. In 1974 its share is about 5 per cent, which increases to a maximum of about 13 per cent for the 2000/(5 per cent) scenario. Those developments are presented in Table 1. It is evident that the high scenario for the year 2000 implies a strong acceleration in growth over time. Given the economic situation of today and the prospects for the medium-term, the reality of this scenario can be doubted. But at least it shows the sensitivity of the freight transport forecasts to the assumed economic developments of the countries concerned.

In absolute figures the total freight transport volume for the study area increases from 8.6 thousand million tonnes to about 15 thousand million tonnes for the 2000/(2 per cent) scenario and more than 24 thousand million tonnes for the 2000/(5 per cent) scenario. International freight transport grows from 400 million tonnes to more than 1,200 million tonnes (low-growth scenario) or 3,000 million tonnes (high-growth scenario) for the year 2000. Looking at the individual country level, the growth rates for domestic freight transport differ, as can be seen from Table 2, due to variations in the assumed economic development of the different countries.

In Table 3 the development of international freight transport is further differentiated into ingoing and outgoing transport by country. As international freight transport is based on the development of international trade between the countries, the EC - trade effect for the new members of the Common Market (the United Kingdom, Ireland and Denmark) finds expression in the accelerated growth of their ingoing and outgoing freight transport volume. The same happens for Spain after 1985. In particular the volume of outgoing transport for Belgium and the Netherlands is also growing faster, compared with the average development, because of their position as transit countries for a large part of the study area.

Finally, in Table 4 the development of trade per commodity group is given for the period before and after 1974, together with the development of Gross Domestic Product of the study area. From those figures it can be concluded that the development of international trade and therefore of international freight transport is in general consistent with the past and expected growth of the Gross Domestic Product of the study area.

The growth of freight transport by commodity group

Because of the different assumptions concerning the development of the various economic sectors in the countries of the study area, the composition of freight transport demand in terms of commodity groups is changing during the forecast period. With a few exceptions, those developments are a continuation of structural changes in the production structure of Western Europe already started some time ago. These assumed continued developments have a strong influence on the structure of freight transport demand, implying a further shift to the transport of medium and high valued commodities (see Tables 5 and 6). For domestic freight transport in the study area the share of low valued commodities decreases from 52 per cent in 1974 to 42 per cent in the year 2000 (5 per cent scenario). For international freight transport this decrease is more pronounced than for domestic transport. Here the same share decreases from

Table 1

TOTAL FREIGHT TRANSPORT IN THE STUDY AREAS
(in million tonnes; 1974 = 100)

Category	1974		1985		2000/(2%)		2000/(5%)	
	Absolute	Share	Absolute	Share	Absolute	Share	Absolute	Share
Domestic Transport								
Absolute	8,168	95	11,383	94	14,020	92	21,336	87
Index	(100)		(139)		(172)		(261)	
International Transport								
Absolute	400	5	716	6	1,256	8	3,067	13
Index	(100)		(179)		(307)		(767)	
Total Transport								
Absolute	8,568	100	12,099	100	15,276	100	24,403	100
Index	(100)		(141)		(178)		(285)	

Table 2

THE DEVELOPMENT OF DOMESTIC FREIGHT TRANSPORT PER COUNTRY
(in million tonnes, index 1974 = 100)

Country	1974	1985	2000/(2%)	2000/(5%)
Belgium	391 (100)	524 (134)	648 (166)	941 (241)
Denmark(1)	14 (100)	21 (150)	28 (200)	47 (336)
France	1,974 (100)	3,136 (159)	3,919 (200)	5,946 (301)
United Kingdom	1,939 (100)	2,664 (137)	3,350 (173)	5,638 (291)
Ireland	92 (100)	127 (138)	148 (161)	214 (233)
Italy	1,099 (100)	1,484 (135)	1,736 (158)	2,591 (236)
Luxembourg	20 (100)	24 (120)	31 (155)	43 (215)
The Netherlands	422 (100)	535 (127)	652 (154)	934 (221)
F.R. Germany(1)	557 (100)	636 (114)	872 (157)	1,388 (249)
Spain	1,659 (100)	2,232 (135)	2,636 (159)	3,595 (217)
Total Study Areas	8,167 (100)	11,384 (139)	14,020 (172)	21,337 (261)

(1) The freight transport figures for Denmark are not complete, while for F. R. Germany freight transport under 50 km is not recorded.

Table 3

TOTAL TRANSPORT (EXCLUDING SEA TRANSPORT) OUTGOING AND INGOING PER COUNTRY WITHIN THE STUDY AREA
(in million tonnes; base index 1974 = 100)

	Belgium	Denmark	France	United Kingdom	Ireland	Italy	Luxembourg	The Netherlands	F.R. Germany	Spain	Total Study Area
Ingoing											
1974	80.9 (100)	1.9 (100)	59.5 (100)	2.0 (100)	0.2 (100)	19.0 (100)	12.0 (100)	77.0 (100)	144.8 (100)	2.3 (100)	399.7 (100)
1985	144.3 (178)	6.3 (325)	116.0 (195)	6.5 (324)	1.6 (872)	36.7 (193)	12.9 (107)	128.2 (166)	258.2 (178)	5.7 (248)	716.2 (179)
2000/(2%)	250.0 (309)	11.8 (607)	203.4 (342)	11.8 (592)	3.6 (1,988)	60.1 (317)	17.8 (148)	195.7 (254)	456.2 (315)	15.0 (649)	1,225.8 (307)
2000/(5%)	605.7 (749)	30.8 (1,591)	536.2 (902)	35.5 (1,778)	11.2 (6,255)	152.5 (803)	32.6 (270)	418.2 (543)	1,203.1 (831)	41.2 (1,787)	3,066.9 (767)
Outgoing											
1974	66.3 (100)	3.2 (100)	76.0 (100)	1.0 (100)	0.2 (100)	11.1 (100)	8.6 (100)	126.8 (100)	103.3 (100)	3.2 (100)	399.7 (100)
1985	128.2 (193)	7.8 (245)	137.7 (181)	4.2 (416)	1.1 (594)	24.8 (224)	11.8 (137)	237.7 (187)	156.2 (151)	6.8 (215)	716.2 (179)
2000/(2%)	226.5 (341)	13.2 (415)	219.0 (288)	8.0 (785)	2.5 (1,341)	38.5 (347)	18.4 (215)	445.3 (351)	239.3 (232)	15.6 (494)	1,225.8 (307)
2000/(5%)	551.3 (831)	29.5 (927)	492.5 (648)	25.9 (2,556)	7.2 (3,782)	110.2 (995)	37.6 (439)	1,227.6 (968)	549.5 (532)	35.6 (1,128)	3,066.9 (767)

about 52 per cent in 1974 to a maximum of 26 per cent in the year 2000. The relative decrease in the transport volume of low valued commodities, mostly transported in bulk cargoes, does of course influence the future modal split structure, as will be seen later on.

Table 4

GROWTH FACTORS OF TRADE PER COMMODITY GROUP 1963-1972 AND FORECASTS 1974-1985, 2000/(2%), 2000/(5%)

Period of Growth	1963-1972	1974-1985	1974-2000/(2%)	1974-2000/(5%)
	%	%	%	%
1. Agricultural	14.53	5.67	3.78	6.72
2. Foods	10.00	5.90	4.20	6.89
3. Fertilizers	1.37	2.59	1.69	3.09
4. Minerals	8.99	6.55	4.51	7.44
5. Ore and metal residues	0.32	- 1.37	0.47	2.49
6. Chemical products	17.96	13.56	9.00	14.32
7. Products of metal industry	7.57	3.93	3.76	7.37
8. Other agricultural products	5.48	5.86	4.04	6.48
11. Oil products	16.59	8.38	6.45	11.19
12. Cement, lime	7.90	5.13	3.51	5.94
13. Other fabricated building materials	9.79	8.26	5.63	9.41
14. Other articles	12.55	9.19	6.26	10.14
Total all commodities (excluding 9 and 10)	9.86	7.15	5.37	9.44
Gross Domestic Product	4.56	3.84	2.78	4.51

Table 5

STRUCTURAL CHANGES IN THE COMPOSITION OF DOMESTIC FREIGHT TRANSPORT IN THE STUDY AREA

(in percentages)

	1974	1985	2000/(2%)	2000/(5%)
Low valued commodities (I, III, IV, V, VIII)	52%	49%	47%	42%
Medium valued commodities (VI, VII, XI, XII, XIII)	26%	27%	28%	30%
High valued commodities (II, XIV)	22%	24%	25%	28%

Table 6

STRUCTURAL CHANGES IN THE COMPOSITION OF INTERNATIONAL FREIGHT TRANSPORT IN THE STUDY AREA

(in percentages)

	1974	1985	2000/ (2%)	2000/ (5%)
Low valued commodities (I, III, IV, V, VIII)	51.6%	41.9%	35.0%	26.3%
Medium valued commodities (VI, VII, XI, XII, XIII)	32.0%	39.1%	46.2%	56.2%
High valued commodities (II, XIV)	16.4%	19.0%	18.8%	17.5%

The more specific developments of freight transport by commodity group in the study area are given in the Tables 7 (domestic transport and 8 (international).

The growth of freight transport by mode of transport

Because of the increases in the transport volumes of each commodity group and the resulting changes in the composition of total freight transport demand as far as the commodity groups are concerned, some further changes in the modal split structure will occur for the forecast period.

As it is assumed that price developments in the different cost categories (e.g. energy, wages) will not give rise to changes in relative real transport costs, the foreseeable shifts in the modal split structures are only caused by transport volume effects.

An increasing transport volume can affect the modal split structure for each commodity group in two ways. Firstly an increasing volume may be accompanied by an increasing consignment weight. This effect varies with the commodity groups and the modes of transport. Secondly, an increasing transport volume can favour, by its scale effect, the use of transport modes with relatively high technical transport capacity means. This effect also varies by commodity group.

Completely separately from the above-mentioned effects, the share of each mode is influenced by changes in the composition of the freight transport demand in terms of commodity groups due to economic developments.

The changes in the modal split structure in domestic freight transport resulting from the scenarios are presented in Table 9, while those in international transport are presented in Table 10.

Table 7

DEVELOPMENT OF DOMESTIC TRANSPORT PER COMMODITY GROUP WITHIN THE STUDY AREA
(in million tonnes, 1974 = 100)

	1974		1985		2000/(2%)		2000/(5%)	
	Absolute	Index	Absolute	Index	Absolute	Index	Absolute	Index
1. Agricultural	354.9	100	444.0	125	495.3	140	623.8	176
2. Foods	805.4	100	978.7	122	1,125.9	140	1,445.4	179
3. Fertilizers	155.5	100	174.8	112	184.4	119	213.9	138
4. Crude and manufactured minerals	3,030.5	100	4,274.7	141	5,149.3	170	7,174.5	237
5. Ore and metal residues	239.1	100	225.5	94	254.3	106	306.9	128
6. Chemicals products	223.5	100	345.6	155	449.9	199	692.2	310
7. Products of metal industry	371.5	100	540.4	145	700.7	189	1,162.1	313
8. Other agricultural products	244.3	100	297.7	122	340.5	139	432.5	177
9. Solid fuels	379.5	100	389.3	103	253.9	67	378.5	100
10. Crude petroleum	6.6	100	6.1	92	6.1	92	6.1	92
11. Oil products	496.1	100	883.4	178	1,303.0	263	2,512.0	506
12. Cement, lime	219.2	100	282.3	129	319.8	146	408.1	186
13. Other fabricated building materials	688.7	100	919.7	134	1,078.7	157	1,526.7	222
14. Other articles	952.9	100	1,620.6	170	2,363.4	248	4,453.4	467
Total	8,167.8	100	11,382.8	139	14,020.2	172	21,336.0	261

Table 8

DEVELOPMENT OF INTERNATIONAL TRANSPORT PER COMMODITY GROUP WITHIN THE STUDY AREA
(in million tonnes, 1974 = 100)

	1974		1985		2000/(2%)		2000/(5%)	
	Absolute	Index	Absolute	Index	Absolute	Index	Absolute	Index
1. Agricultural	22.9	100	40.0	175	58.5	255	110.4	481
2. Foods	24.9	100	45.9	185	69.9	281	134.7	542
3. Fertilizers	11.5	100	14.3	124	16.3	141	22.1	192
4. Crude and manufactured minerals	79.6	100	155.6	195	242.7	305	477.2	599
5. Ore and metal residues	63.9	100	63.5	99	82.7	130	147.9	232
6. Chemical products	30.9	100	110.7	358	252.4	816	808.8	2614
7. Products of metal industry	45.9	100	64.8	141	108.3	236	246.6	537
8. Other agricultural products	9.8	100	16.2	165	23.0	234	40.1	408
9. Solid fuels	35.0	100	24.9	71	14.3	41	29.2	83
10. Crude petroleum	0.6	100	0.6	100	0.6	100	0.6	100
11. Oil products	27.2	100	69.8	257	160.7	592	567.2	2088
12. Cement, lime	5.4	100	7.9	146	10.0	185	14.3	265
13. Other fabricated building materials	7.1	100	16.8	235	28.9	404	69.7	976
14. Other articles	34.9	100	85.2	244	157.4	952	298.1	1142
Total	399.6	100	716.2	179	1,255.8	307	3,066.9	767

Table 9

THE DEVELOPMENT OF DOMESTIC FREIGHT TRANSPORT PER MODE OF TRANSPORT UNTIL 2000 FOR THE WHOLE STUDY AREA
(Inter-Regional Transport only, in million tonnes; 1973 = 100)

	1973		1985		2000/(2%)		2000/(5%)	
	Absolute	Share	Absolute	Share	Absolute	Share	Absolute	Share
<u>Rail Transport</u>								
Absolute	573	20	777	19	951	18	1,514	18
Index	(100)		(136)		(166)		(264)	
<u>Road Transport</u>								
Absolute	2,014	72	3,018	74	3,862	75	6,232	75
Index	(100)		(150)		(192)		(309)	
<u>Inland waterway navigation</u>								
Absolute	233	8	302	7	381	7	548	7
Index	(100)		(129)		(163)		(235)	
<u>Total inter-regional transport</u>								
Absolute(1)	2,820	100	4,097	100	5,194	100	8,294	100
Share	(100)		(145)		(184)		(294)	
Total Domestic Transport	7,894 (100)		11,383 (144)		14,020 (178)		21,336 (270)	

(1) Luxembourg excluded

As far as domestic transport is concerned, one should bear in mind that the modal split dealt with in the study is the modal split for inter-regional transport. The division between intra-regional and inter-regional transport is of course some what arbitrary and highly influenced by the number of regions distinguished in each country. For the whole study area only 36 per cent (1973) to 39 per cent [2000/(5 per cent)] of total domestic transport is defined as inter-regional transport. The intra-regional transport volume is for almost all countries transported by road.

Within the domestic inter-regional transport a further decrease of the shares of rail transport and inland navigation in the study area as a whole is foreseen during the forecast period, while the share of road transport increases. The relative decrease of rail transport and inland navigation differs per country, while for some commodity groups in some countries rail transport and inland navigation even increases due to the scale effects: these effects however, are counterbalanced by a slower growth of the commodity groups concerned compared with the total growth of domestic transport. Table 10 shows the same kind of developments for international transport, although the extent of the relative changes differs from domestic transport. Rail transport here decreases from a share of 23 per cent in 1974 to a share of 15 per cent in the year 2000 (5 per cent scenario), while the share of road transport increases from 29 per cent in 1974 to 37 per cent in the year 2000 (5 per cent scenario). The share of inland navigation stays constant for the whole period.

Table 10

DEVELOPMENT OF INTERNATIONAL TRADE AND TRANSPORT WITHIN THE STUDY AREA (in million tonnes, index 1974 = 100)

	1974	1985	2000/(2%)	2000/(5%)
1. International trade, excluding crude petroleum and solid fuels	395.9 (100)	896.4 (214)	1,545.3 (390)	4,133.7 (1044)
2. International transport, all commodities	399.4 (100)	715.9 (175)	1,225.4 (307)	3,066.4 (768)
3. International rail transport	91.2 (100)	124.9 (137)	191.5 (210)	454.2 (498)
Share in total	23%	17%	16%	15%
4. International road transport	117.3 (100)	263.7 (225)	466.0 (397)	1,121.5 (956)
Share in total	29%	37%	38%	37%
5. International inland waterway Shipping	190.8 (100)	327.4 (172)	567.9 (298)	1,490.6 (781)
Share in total	48%	46%	46%	48%

The growth of tonne/km production in international transport

Based on the tonnage transported per geographical transport relation, the corresponding total amount of tonne/km for international transport could be calculated.

From Table 11 it can be seen that for rail transport and road transport the tonne/km production increases faster than the amount of tonnage to be transported. This implies an important growth in the average distance per transport. In particular for rail transport the relative importance of transport under 500 km decreases rather fast, while especially transport above 1000 km will become more and more important. It has been calculated that the average transport distance for rail transport increases from about 500 km in 1974 to more than 625 km for the 2000/(5 per cent) scenario.

The same kind of development will occur for international road transport, although to a lesser extent. Here also the volume transported under 500 km decreases, while above 500 km there will be a relative increase in the transport volume. The average transport distance will increase from about 450 km in 1974 to about 525 km for the 2000/(5 per cent) scenario.

Although there will be some shift in the distribution of tonne/km over distance classes for inland navigation, this is of lesser importance compared with the other modes of transport.

The average transport distance hardly changed during the forecasting period. Two conclusions can be drawn from Table 11 and the related evidence.

Firstly, an increasing part of international transport will be transported over long distances (above 500 km), which among other things is caused by an extra increase in international trade between the original members of the EC and the new ones. Secondly, as a consequence, rail transport in particular will be faced by a quickly increasing average transport distance and a relatively large increase in the number of tonne/km.

1.4 Evaluation

The EC freight model developed by the NVI is a first attempt to model freight transport on a European scale. Although the model development was aimed to support infrastructure policy in the Community, other transport policy areas were not neglected.

The model structure used, follows to a great extent the basic modelling concepts of the aggregated inter-regional flow approach (A-3.2). As far as transport is concerned the model system is comprehensive, taking into account the main structural relationships within the transport sector itself. The degree of detail of the model system depends of course on the aim of the model (infrastructure) and the detail of the available statistical data.

Table 11

TONNES AND TONNE/KM BY MODE OF TRANSPORT FOR INTERNATIONAL TRANSPORT
(1974 = 100; tonnes in millions, tonne/km in thousand millions)

	1974		1985		2000/(2%)		2000/(5%)	
	Absolute	Index	Absolute	Index	Absolute	Index	Absolute	Index
Rail transport								
Tonnes	91.2	100	124.9	137	191.5	210	254.2	498
Tonne/km	46.9	100	72.4	154	116.8	249	287.2	612
Road Transport								
Tonnes	117.3	100	263.7	225	466.0	397	1,121.5	956
Tonne/km	53.5	100	128.0	239	233.2	436	596.3	1115
Inland waterway navigation								
Tonnes	190.8	100	327.4	172	567.9	298	1,490.6	781
Tonne/km	66.1	100	114.3	173	198.9	301	531.7	804

However the relationships between freight transport and the other economic activities show a certain structural weakness due to the type of economic scenario formulation approach used. (B-1.24). This type of approach can only be followed if no important structural changes in the economies are expected. If such changes do occur, the internal consistency of the production levels of the different economic sectors amongst the countries is doubtful.

Such structural changes however can be expected for the next decades. The forecasting system can remarkably be improved if at least explicitly formulated economic multi-sector models for the countries involved will be used to preserve the necessary consistency between the individual commodity freight forecasts.

A lot of equations were specified and quantified. It is difficult to judge the reliability of all these coefficients, but for international freight model choice some calculations of elasticities were made and evaluated.

As can be seen from Table 12, the derived price arc-elasticities look reasonably well compared with the results of other studies. Besides that it shows the sensitiveness of the international freight transport markets to real transport cost changes. Changes which can be induced by transport policy actions.

The strong sensitiveness of freight demand for the growth of the economic activities is shown by the results of the different applied economic scenarios. The 2 per cent annual growth of GDP until the year 2000 leads to an increase of total domestic transport of 80 per cent, while the 5 per cent growth alternative leads to a growth of 185 per cent in transport volume. For international freight transport the increases are even higher, ranging from about 200 per cent for the 2 per cent growth of GDP to about 650 per cent for the 5 per cent annual growth of GDP, implying in particular the trade-dependency of economic growth in the countries concerned.

Because growth in a dynamic context is accompanied by structural changes in the economies, the composition of freight demand to commodity groups is changing too, altering the demand for freight transport in a structural way. Such induced changes in the composition have led already to alterations in the shares of the various transport modes.

The results of the EC-freight model can be used for a first evaluation of future infrastructure needs for freight transport. Such evaluations will of course become more meaningful if passenger traffic is taken into account too.(1) Principal routes of Community interest can be studied in detail via cost-benefit analyses.

---

1) This is being done by the EC in combining the EC freight model and a recalibrated Cost 33 passenger model.

While the model system is primarily aimed at infrastructure evaluation, the direct application to other transport policy areas is somewhat restricted. For those areas the system is only a demand-related prediction model, missing a demand-supply equilibrium mechanism as far as the transport industry is concerned.(1) In other words the present EC-freight model predicts traffic flows which, after some feedbacks, can be brought into equilibrium with the supply of infrastructure, on the assumption that the supply of the transport industry will follow demand. This assumption can reasonably be made for a long-term infrastructure study, but it is less valid for medium- or short-term developments on the freight transport markets, which are of a particular interest to other transport policy areas. In such cases the present system should be extended with proper specified supply and price functions.

The forecast results presented in the NVI study can only be seen as working examples of the developed model system. The European Commission is preparing a new set of scenarios more adapted to the expected economic development of today. The resulting transport and traffic flows within the European Community will be available in the second half of 1981 and will be used in combination with long-distance passenger transport to identify future infrastructure bottlenecks.

Table 12

PRICE-ELASTICITIES FOR INTERNATIONAL FREIGHT TRANSPORT

Elasticities	30% increase in real road transport cost	30% increase in real rail transport cost
Direct price elasticities		
Road	-0.41	
Rail		-0.83
Cross elasticities		
Road		+0,25
Rail	+0.80	
Inland navigation	+0.02	+0.12

2. THE FREIGHT MODEL USED IN A RECENT CHANNEL STUDY

2.1 Introduction

Recently an extended cost-benefit evaluation of a fixed link across the Channel was undertaken by Coopers and Lybrand and

1) Ref. 15).

SETEC Economie on behalf of the EEC.(1) As part of the cost-benefit assessment economic scenarios were defined for 1985 and 2000 and, based on that demand, forecasts for passenger and freight transport have been made. The forecast of freight transport is derived from the expected future volume of trade flows by branches between the United Kingdom and the Continent using a single base railway tunnel connecting the SNCF and BR railway networks. From total freight, mostly bulk carried by sea, a part is diverted to the fixed Channel link. This type of traffic, carried by road vehicles or railway wagons is referred to as "unitised traffic". The "unitisation rate" was estimated for the base year 1976 and forecasted for the years 1985 and 2000.(1)

2.2 The trade-transport model

The forecasts of the trade-transport flows were mainly based on a four-step-model:

- forecasts of total imports and exports;
- forecasts by product group;
- forecasts by exporting or importing country;
- forecasts by country and product group.

The formulation of the model is as follows:

1) $Q_j = K_j \, (P_j)^{bj} \qquad j = 1,\dots,J$

2) $Q_j^k = K_j^k \, (Q_j)^{e_j^k} \qquad k = 1,\dots,K$

3) $$V_{ij}^1 = V_i^1 = \frac{V_{ij} \left(\dfrac{P_j^1}{P_j} \right)^{b_j}}{\sum\limits_{k \neq i} V_{ik} \left(\dfrac{P_k^1}{P_k} \right)^{b_k}}$$

1) Ref. 19), 21)

4) Combination of submodel 2 and 3 to determine: $V_{ij}^{k}(1)$

Q_j : total trade volume of country j

i,j=1,...J: number of countries (14)

P_j : Gross Domestic Product (GDP) of country j in year N

Q_j^k : trade volume of sector k for country j (export <u>or</u> import)

V_{ij}^1 : trade volume between country i and country j for year (N+p)

V_{ij} : trade volume between country i and country j for year N

P_j^1 : GDP of country j in year (N+p)

b_j : total country trade elasticities

e_j^k : branch-trade elasticities

The models described above determine the freight flows by branch on a country to country base. Those flows are corrected by the effects of price alterations in the following way

5) $(V_{ij}^k)_T = V_{ij}^k \cdot (r_{ij}^k)^{C_{ij}^k}$

$V_{ij_T}^k$: actual derived trade flow between country i and country j for branch k

r_{ij}^k : price factor

C_{ij}^k : export price-elasticity for the i,j relation and branch

until the model describes the trade flows in constant dollar terms. In a following step the trade flows in constant money terms are transformed into tonnage terms by introducing price/quantity ratios or unit values by branch.

The unit value of a product group is defined as the value at constant prices of one tonne. The unit value is expected to increase for the future, which indicates a shift to more sophisticated products with a higher added value figure.(2)

---

1) Not described in detail in the report, but carried out using an iterative procedure.

2) This is not explicitly introduced in the economic scenarios.

For the forecasting period increases varying from 1.0 to 3.0 per cent a year are assumed.

Although not explicitly mentioned some constraints had to be introduced to satisfy the internal consistency of the various sub-models because the trade volume (export plus import) is determined by equation 1, while the other equations step-by-step sub-divide total trade into trade flows.

The choice of mode and route process for freight traffic is not mentioned in detail. However the choice model used is a probability model, which attributes to each choice of mode or route a certain probability. The impedance is a function of the generalised cost, i.e. of the cost and the total transport time. All costs and time elements are introduced, such as transport times, terminal times, waiting times etc. The models were calibrated for the year 1977, given 3.4 pence per hour per tonne (1979 prices) as the derived value of time.

2.3 Evaluation

The forecast results for trade and transport with the United Kingdom are presented in Table 13. The growth rates for international trade are relatively high due to the high total country trade elasticity of the United Kingdom (2.53 for the EC-six, see also Table 14). The growth rates for transport are somewhat lower due to the assumed future increases of the unit values for the various branches.

Table 13

GROWTH RATES OF INTERNATIONAL TRADE AND TRANSPORT OF THE UNITED KINGDOM
1976 = 100

	Low Scenario		High Scenario	
	1976-1985	1985-2000	1976-1985	1985-2000
GDP United Kingdom	1.5%	2.0%	2.8%	3.5%
Trade in constant dollars:				
Imports	3.7%	3.9%	6.0%	6.6%
Exports	3.8%	4.2%	6.3%	7.0%
"Unitised" trade in tonnes:				
Imports	2.4%	2.8%	4.2%	4.8%
Exports	3.7%	4.2%	6.3%	6.6%
Total trade in tonnes:				
Imports	2%	3.7%	3.3%	3.8%
Exports	2.5%	3.0%	4.1%	4.9%
Year	1985	2000	1985	2000
Total trade	in mill. of tonnes			
Tonnage	44.6	65.2	50.6	95.7
Index (1976 = 100)	(122)	(179)	(139)	(262)

1) Trade and transport with countries that are of interest for the fixed Channel link.

The assumed growth of the GDP has of course a great influence on the trade-transport volume development but some of the estimated and used elasticities (period 1970-1975) look a little bit high to be realistic. Such high trade elasticities are often found if the endogenous (total import plus export) and the exogenous (Gross Domestic Product) variables are too aggregated (e.g. see the unused total export and import elasticities of the EC freight study).

Table 14

TOTAL COUNTRY TRADE ELASTICITIES
(Import + Export Together)

Country	Elasticities
F.R. Germany	2.04
Austria	1.73
Belgium/Luxembourg	2.04
Spain	1.58
France	1.61
Italy	2.09
Netherlands	1.71
Switzerland	1.90
Total	1.49
EEC(Six)	2.53

As a matter of fact the whole trade-transport model is too aggregated for the derivation of structural equations. The main volume variable (total import plus export) is only related to Gross Domestic Product. Both variables are very heterogenous and their composition will change over time, altering their quantified relationship. So the elasticities will probably not stay stable over time when the structure of the economy is changing, as can be expected.

Secondly the total trade volume of a country is only related to its own Gross Domestic Product, excluding the foreign economic developments. In reality, production and consumption developments in the various trading countries will determine together the trade volume between those countries.

The other sub-models are "share"-models, dividing total trade over export and import by branch and country pairs. Their results do not influence the total trade by country.

Because of the simplicity of the trade-transport model the economic structures of the various countries are not well related to each other by the assumed trade relations. Even small structural changes will probably change the values of the coefficients used in the trade-transport model. However, because the results were used in a cost-benefit analysis, where various alternatives were evaluated, the absolute figures are of course less important.

As the international trade-transport model used here covers the same period as the EC freight model, some comparison of the results can be made. Detailed comparisons, however, are hindered by a lack of commonly used classification criteria. The two main differences between the SETEC and the EC-trade forecasting systems are:

a) SETEC: trade volume for the United Kingdom, (total and per branch) only related to growth of the Gross Domestic Product of the United Kingdom. Afterwards a breakdown to trade relations is made.

EC: trade volume per branch between two countries is related directly to sectorial developments in both countries (imports and exports are dealt with separately).

b) SETEC: trade volume is measured in constant dollar terms, which implies that the results have to be converted in tonnage terms.

EC: trade volume is directly measured in tonnage terms, which implies no extra conversion to transport.

The trade forecasts of SETEC can only be compared with the EC results in a global way, because of the differences in the applied commodity classification.

Further, the scenarios used in the SETEC study are not the same as those in the EC Freight Study. As far as total United Kingdom trade to and from the "Six" is concerned a comparison of results could be made.

a) Scenarios United Kingdom (growth in GDP by year)

SETEC		EC	SETEC		EC	
low	high		low	high	low	
1.4%	2.4%	3.4%	2%	3.5%	2%	5%

b) trade volume (1974 = 100; 1974 estimated)

	1985			2000	
b.1) SETEC scenario,	low		high	low	high
SETEC model	156		193	290	535
(constant dollar terms)	(4.1%)		(6.2%)	(4.2%)	(6.7%)
b.2) EC scenario,		256	592		1629
SETEC model		(8.9%)		(6.7%)	(11.3%)
(constant dollar terms)					
b.3) EC scenario,		270		485	1500
EEC model		(9.4%)		(6.3%)	(11.0%)
(tonnage terms)					
(%) : annual growth rates					

Comparing the b.1) and b.2) figures one can see that the resulting increase in trade volume is completely different, mainly due to differences in the scenario assumption about the United Kingdom's GDP. For the year 2000 the low SETEC scenario b.1) gives an annual growth figure of 4.2%, while the low-EC scenario filled into the SETEC model (b.2) gives a figure of 6.7 per cent.

Comparing b.2) and b.3), one can see that the same EC scenario used in the two different models gives more or less the same growth figures (total trade only) for trade in constant dollar and in tonnage terms.

Next to the differences determined in annual growth due to the use of different scenarios, measured in constant dollars, the consersion from constant dollars into tonnage by SETEC causes another important difference in the growth of trade in tonnage terms. That is the use of a separate price/quantity index in this conversion process which is assumed to increase annually by 1 per cent to 3 per cent, according to the branch. However no significant statistical proof for this particular development could be found, neither was it explicitly included in the economic scenario formulation.

By applying this assumption however the growth of international trade in tonnage terms was brought back by 1 per cent to 3 per cent a year. It should be clear that the EC freight model is avoiding this difficult conversion process, although if one deals with both measures (dollars in constant prices and tonnage) some small changes in the price quantity ratios can be expected for the future.

So both models are using trade flows to derive international freight flows. The trade model, relating the various economies to each other, is more structurally developed in the EC-freight study than in the SETEC study. However, in both cases the relationships between the sectoral economic developments of the different countries are of a weak nature (see B-1), and less useful for the derivation of international freight flows under changing economic conditions.

3. SOME DISAGGREGATED FREIGHT DEMAND MODELS

3.1 <u>Freight demand forecasts for the West-Coast corridor study (USA)</u>

In 1978 results of a freight demand forecast study for the Pacific Region in the United States were reported by Cambridge Systematics, Inc. For part of this study a disaggregated demand approach was followed. Although model development was partly hindered by the lack of enough detailed data, it shows possible directions for further work in this area.(1)

1) Ref. 12).

The aim of the study was to produce freight forecasts for the manufactoring sector with a detailed commodity breakdown between about 25 large regions situated in California, Washington and Oregon, separately for road and rail transport (inland waterways were omitted).

The freight model developed uses a national input-output or transaction table in relation to reported production activities on a regional level, to estimate the regional consumption and production levels of the various sub-branches c.q. commodities. Those figures can be interpreted as the margins of a two-dimensional array of freight flows. To calculate freight flows, however, it was necessary to convert the production and consumption figures from dollars (the units used in transaction tables) to tonnes. The conversion figures (dollars per tonne) were derived from national figures.

After converting dollars to tonnes, first of all it was necessary to determine the flows between the regions for every commodity group (T^{g}_{ij}). This procedure was carried out by a simple gravity model to obtain an initial solution which, however, was not improved afterwards. The models were developed for the year 1972 and applied to 1995. No allowance was made for technological changes that could influence the relationship between the inputs and outputs.

The model share analysis was based on a model of binary choice between rail and truck. The model takes the form of a logistic curve:

$$1) \qquad R_{ijk} = \frac{\exp(U_{ijk})}{1 + \exp(U_{ijk})}$$

where:

R_{ijk} : rail share of commodity k between region i and j

U_{ijk} : linear-in-parameters difference between the utility of rail and truck transport

$$2) \qquad U_{ijk} : C_0 + C_1 D_{kj} + C_2 T_{ijk} + C_3 V_k$$

where:

C_0 : constant

C_1, C_2, C_3 : estimated parameters

D_{ij} : straightline distance between i and j

T_{ijk} : annual tonnes of commodity k moving between i and j (tonnes/year)

V_k : value per tonne of commodity ($/tonne)

The values of the parameters used came from a previously estimated modal choice model for the North-Eastern United States. That model was adapted to the prevailing conditions in the Pacific region. The theory of model transferability used implied the adaption of the constant term C_0 to incorporate the influence of changes in unobserved variables between the two data sets. The value of the parameters used were: $C_1 = 1.52$; $C_2 = 0.888$; $C_3 = -0.941$; C_0 has different values for the different States.

The authors themselves are aware of the limitations of the derived model, mainly due to data shortage and recommend a lot of improvements before any future application can take place. Although the various sub-models are rather preliminary in their specification, it shows a direction in which the aggregated inter-regional flow and the disaggregated approach can be combined. This possible combination will be discussed in more detail later on.

3.2 Disaggregate Model of modal choice in produce transportation (USA)

The second study is a commodity specific study (produce transport) dealing only with the modal choice part in a disaggregated way. In its specification it follows the disaggregated modal choice specification highlighted in section A-3.1.(1). The study carried out gives special attention to the attributes of modal choice such as market commodity and, receivers attributes, and level of service factors. The specification of the cost functions is based on inventory theory. The model estimated is a disaggregated behavioural modal choice model using a multi-nominal logit model to estimate the coefficients.

In the approach it is hypothesised that individual shippers choose among potential alternatives by minimising their total purchase and logistic costs. Logistic costs are defined as ordering, transport and storage costs, capital carrying costs in transit, safety stock carrying costs, loss and damage costs, etc.

The variables used in the model specification are:

$SSCC_j = \sigma_j \cdot UPV$

$CCCLD_j = LD\%_j + CLPR_j \cdot UPV \cdot IT_j$

$CCT_j = MTT_j \cdot UPV$

$TRANSCOS_r = Rate_r$

$Trancos_t = Rate_t \cdot SHWT$

where:

σ_j : standard deviation of transit time for alternative j (in days)

MTT : transit time for alternative j (in days)

$Rate_j$: freight charges for alternative j (dollars/Ib)

1) Ref.18).

$LD\%_j$	: percentage of loss and damage for alternative j (%)
$CLPR_j$	: probability of claim for alternative j (%)
IT_j	: investigation time for alternative j (days)
UPV	: Unit produce value (dollars/Ib)
SHWT	: shipment size (Ib)
SSCC	: safety stock carrying cost
CCCLD	: capital carrying cost tied up with a loss and damage claim
CCCT	: capital carrying cost in transit
TRANSCOS	: additional charges such as refrigeration, handling, etc.

The modal estimate was used to calculate elasticities of demand for the two alternatives (rail and truck). This was carried out by computing the demand elasticities for each observation (1275) in the sample and aggregating them to the overall market elasticities. Those elasticities are tabulated in table 15.

Table 15

AGGREGATE DIRECT AND CROSS ELASTICITIES OF DEMAND

Aggregate Direct Elasticities of Demand:			
Rail	rate		- 2.63
	transit time		- 1.26
	standard deviation of transit time		- 0.92
Truck	rate		- 1.25
	transit time		- 0.25
	standard deviation of transit time		- 0.12
Aggregate Cross Elasticities of Demand:			
Rail with respect to truck		rate	4.24
		transit time	1.08
		standard deviation of transit time	0.53
Truck with respect to rail		rate	0.68
		transit time	0.30
		standard deviation of transit time	0.22

The smaller elasticities for the truck alternatives can be expected because of the large share of the motor carriers in the market (four times that of rail). In other words a larger change in trucks attributes is needed to attract an extra per cent of the market. This is in accordance with the derived elasticity values. The model was used to compute the impact of some major policy changes in the model attributes. The impacts are presented in Table 16.

With the exception of the expected increase of the rail market due to a 20 per cent truck-rate increase (+11.9 per cent) and the relatively high elasticities, the calculated results look intuitively acceptable. As far as comparisons are allowed, the rail market share increases, calculated in the sensitivity analysis of the EC freight study, are of the same order of magnitude (international freight transport of corresponding commodities).

Table 16

IMPACT OF SOME POLICY CHANGES

Policy change	Predicted Rail Market Share (base = 21.8%)	Predicted Change in Rail Market Share
- 20% rail transit time reduction	25.3%	+ 3.5%
- 30% rail standard deviation of transit time reduction	25.7%	+ 3.9%
20% truck rate increase	33.7%	+11.9%
40% reduction in loss and damage for rail	22.8%	+ 1.0%
15% reduction in rail rate	27.3%	+ 5.5%

The model approach shows in particular the possibilities of including more variables than the usual ones, such as transport costs and transport times. The deviation-of-transit-time factor is of special interest, because it represents the reliability of transport to the shippers. Such factors however can only be introduced if a disaggregated consignment approach is chosen, rendering the modal split model more sensitive to policy making in this particular case.

4. SOME URBAN FREIGHT DEMAND MODELS

4.1 Introduction

Although there are hardly any theoretical reasons why urban freight demand modelling should differ from inter-urban or inter-regional modelling as described in the foregoing, in practice other methods are followed.

Because transport planners are often faced with the need to estimate the level of commercial vehicle movements as part of an urban transportation study, for which no standardised models (such as for passenger transport) are available, simple direct forecasts of the number of commercial vehicles are made. In this section two examples will be given, one which highlights the often followed procedure in the United Kingdom and other European Countries and one which is representative for the United States.

4.2 The European experience

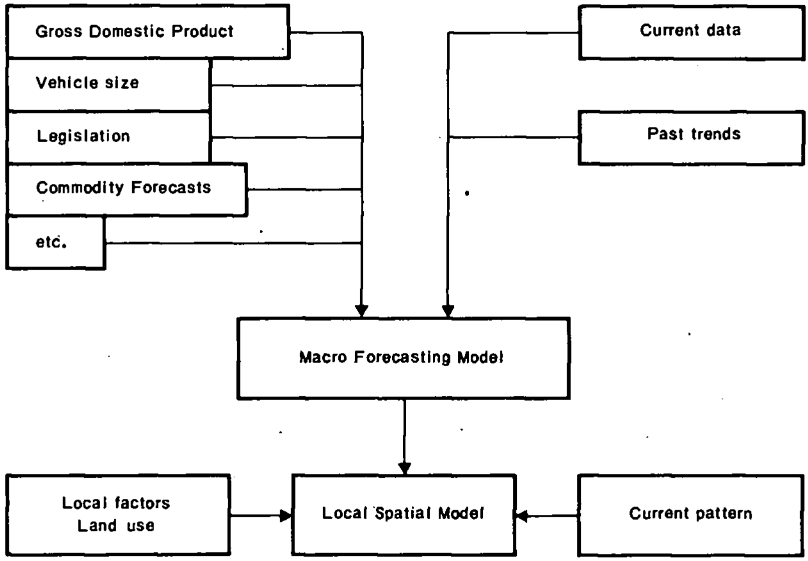
Although there is definitly no single approach in Europe, most of them have a lot in common. To summarise those approaches as far as their basic elements are concerned, the United Kingdom experience is taken as an example. This section relies to a great extent on an excellent paper written by C.R. Eastman for the 1979 PTRC-Conference in the United Kingdom, entitled "Freight Modelling - Which Way Now?" This paper summarises the experiences over 10-15 years with freight demand modelling in the United Kingdom, mostly in an urban context, its criticism and its prospects(1).

The basic model structure used by many transport planners is described in figure 4.

The macro forecasting model used in the United Kingdom by the Department of Transport is a trend-based partial forecasting system for commercial vehicles (number and tonne km).

Figure 4

BASIC MODEL STRUCTURE



Using a GDP/tonne-km relationship to forecast the number of tonne-km. Deduct tonne-km by other modes (rail, water, pipeline). extrapolate past trends in average carrying capacity of the vehicles and past trends in average load factors and calculate therefrom the future vehicle-km. From an assumed annual km per vehicle the future number of vehicles is calculated. To produce the corresponding figures for vans, a constant proportion of the goods vehicle fleet is used. Without going into detail it is obvious that such an approach is not very useful, and is unlikely to produce reliable answers to policy questions. It was then officially concluded that "the uncertainties in the various parts of this forecasting process are so great that the final results can be little better than guesses".

1) Ref. 16).

In the meanwhile a revised forecasting procedure is proposed, which starts forecasting tonnage produced by industry and splits total tonnage between the different modes before producing vehicle fleet numbers and tonne-km.

It is nevertheless still based on the extrapolation of aggregated past trends (national totals) and does not include any spatially disaggregated estimates. National totals are used as control figures for particular urban or regional commercial vehicle forecasts.

As far as local spatial studies are concerned, so-called direct commercial vehicle trip models are used. In the more extended approaches the forecasting of commercial vehicle movements follows the well-known urban passenger transport modelling approach, based on zone-to-zone flow data. It follows the sequence of trip generation and distribution by a gravity type of model.

The trip generation model is particularly hindered by a lack of parameters to describe commercial trip generation and attraction on a zonal level (such as number of firms, firm size, physical distribution, number of commercial vehicles owned, etc.).

All efforts have been made to relate vehicle trips directly to one or more zonal factors. However, results were such that they could not be used with confidence as a predictive tool. The experience of other countries shows the same kind of results.

To avoid all the problems involved in developing commercial vehicle trip models, often growth factor procedures are used. These start with the construction of a base year matrix by a journey log survey or by a partial matrix approach (screenline, survey method). In both cases the survey results have to be extended to the whole area. Next, growth factors have to be defined which could be either a simple overall factor or factors based on a zonal growth procedure (based on populations, employment, etc.).

All those models are not explanatory which implies the necessity to apply a further overall factor in order to bring the total matrix in line with previously calculated control totals, e.g. the totals from the macro forecasting model.

C.R. Eastman ends his summary of the United Kingdom freight modelling experiences with some concluding remarks which, as far as urban transport is concerned, are self-explanatory and applicable to the experiences of many countries.

1. "There are few, if any, truly explanatory projective techniques in the field of "(urban)" freight modelling and all forms of local model need to rely on a externally derived, macro forecasting model. Those macro models tend to be too simplistic".

2. "At the level appropriate for highway transport planning there is little opportunity to develop a satisfactory trip end model (spatial models)".

3. "In overall terms the field of "(urban)" freight modelling is still in its infancy".

A more detailed description of a spatial vehicle trip generation model within an urban context is given in the next section.

4.3 Commercial vehicle trip generation (USA)

The analysis of the commercial vehicle trip generation relationships in the Chicago region, described here, is a typical example of an often applied urban freight modelling approach. The relationships are estimated based on land use characteristics, taking into account different sizes of trucks (light, medium and heavy trucks). The analysis is compatible with the conventional urban transport planning models for passenger transport.(1)

The analysis carried out is aggregative as it deals with zonal sub-areas of the region rather than with individual firms. Relationships are developed between the volume of truck traffic generated (or attracted) by these zones and various measures of the activities located there. The land use categories defined are: residential, manufacturing, commercial public building, public open space, transport-communications-utilities and other developed land.

Within each category, land area and employment are taken as measures of activity. The truck data are provided by a specific commercial vehicle survey (1 per cent overall sample of all registered commercial vehicles in the Chicago area).

Separate regression models were formulated for each truck type and for total trips to the sub-regions; the main results are presented in Table 17.

Total trips to all land uses, TTOT, is best explained by total district employment. After stratifying the truck trips to vehicle type, total employment still yields the best results as an unstratified land use measure.

The results will improve if truck trips are stratified by type of land use (see equation 1 to 4 for total truck trips). Within the vehicle categories the same improvement will be achieved, although the results overall are less good than the total truck model results.

From the results it can be concluded that the type of activity measured in employment is the best explanatory variable in such trip generation models. Better results however were obtained with the total truck models than with the various vehicle type models.

1) Ref. 17).

Table 17

VARIOUS TRUCK MODELS

Model Type	N	R^2	F
Total Truck			
1) TTTOT = 4573.0 + 33.8 TOTEMP	62	.50	59.2
2) TTRES = 1078.6 + 56.5 RESLU + 11.7 DU	64	.54	36.0
3) TTMAN = 730.6 + 9.7 MANEMP	64	.58	85.4
4) TTCOM = 2252.7 + 23.7 CONEMP	62	.50	59.0
Light Truck			
1) LTTOT = 2427.9 + 11.92 TOTEMP	62	.32	27.3
2) LTRES = 188.8 + 35.38 RESLU + 2.86 DU	63	.55	36.3
3) LTMAN = 163.4 + 96.16 MANLU	50	.58	38.8
4) LTCOM = 1112.2 + 9.76 CONEMP	61	.31	27.0
Medium Truck			
1) MTTOT = 2117.6 + 17.65 TOTEMP	62	.41	41.3
3) MTMAN = 257.6 + 5.11 MANEMR	61	.51	69.9
4) MTCOM = 2492.1 + 3.60 COMEMP	64	.34	32.6
Heavy Truck			
1) HTTOT = 835.2 + 3.1 TOTEMP	62	.20	14.6
3) HTMAN = 271.6 + 2.3 MANEMP	61	.54	70.6
4) HTCOM = 305.7 + 2.2 COMEMP	62	.18	13.5

Note: All models are significant at 99 per cent by the F-test.

Definition of variables

TTTOT = Total truck trips to the district

TTRES = Total truck trips to Residential land uses in the district

TTMAN = Total truck trips to Manufacturing land uses in the district

TTCOM = Total truck trips to Commercial land uses in the district

LTTOT = Light truck trips to the district

LTRES = Light truck trips to Residential land uses in the district

LTMAN = Light truck trips to Manufacturing land uses in the district

LTCOM = Light truck trips to Commercial land uses in the district

MTTOT = Medium truck trips to the district

MTMAM = Medium truck trips to Manufacturing land uses in the district

MTCOM = Medium truck trips to Commercial land uses in the district

HTTOT = Heavy truck trips to the district

HTMAN = Heavy truck trips to Manufacturing land uses in the district

HTCOM = Heavy truck trips to Commercial land uses in the district

RESLU = District Residential land area (100 acres)

MANKU = District Manufacturing land area

MANEMP = District Manufacturing employment (in 100 employees)

COMPEMP = District Commercial employment

TOTEMP = District Total employment

DU = Number of Dwelling Units in the district (in hundreds)

Overall, however, the results are not very promising because of the large coefficient of variation of the regression models.

SUMMARY

1. Basic concepts

i) Spatial analysis

Freight demand-supply analysis is a spatial exercise, implying that the explanation, the determination and the prediction of freight flows between regions or zones must form the corner stone of successful freight modelling.

ii) Contribution to transport policy evaluation

If freight demand-supply modelling is used to support policy-making in the transport field, it must be seen as part of a broader policy evaluation process. This evaluation process consists of three stages:

a) definition of policy aims and policy instruments to be used;
b) the specification of the structural relationships between the aims and the instruments;
c) finding the optimal policy in the number and usage of the available instruments;

The main contribution of freight transport analysis is to stage b). Efficient freight transport modelling, however, can only be achieved if the policy objectives and the policy instruments are defined a priori in an operational way: operational in the sense that the policy objectives can be translated into transport economic variables and the instruments into the data of the transport markets. The definition of operational objectives is an especially difficult task in which the transport analyst should assist the policy makers.

iii) The main policy actors

Due to the derived character of freight transport demand the main policy makers - transport industry and government - can only try to influence the outcome of the freight transport markets by changing the supply conditions.

Government institutions mainly influence the supply of transport services in a indirect way by their infrastructure policy and their various kinds of regulatory policies, while transport industry decisions have a direct influence on the type, quality and level of the transport services offered. Both policy-actors need, however, general interrelated information about economic developments, freight demand developments and technological developments. Here general models can provide the necessary answers (general in contrast to micro-models needed by individual or groups of transport firms).

iv) A generally accepted freight demand-supply theory

Although different models have to be specified, depending on the policy problems involved, they should all be based on a common and generally accepted freight demand supply theory. From a simple demand-supply equilibrium theory it can be argued that the activity pattern and the available transport system form the main groups of variables influencing the equilibrium of the transport markets.

Because both the activity pattern and the transport system can only be defined in a spatial way, the endogenous variable, being the actual freight demand, is also spatially determined, that is to say on a region-to-region or zone-to-zone basis.

v) The economic activity pattern

The activity pattern, being the most important determinant for the demand for freight transport, is characterised by its levels, its composition or structure and the geographical distribution of the production and consumption activities.

All the various elements of the activity pattern are interrelated and form together the main input to the freight demand models.

vi) The supply of transport services

The transport system, consisting of all the various types of transport services offered, determines the supply conditions of the freight transport markets. The way shippers will respond to changes in those conditions depends on the type of decisions they have to make, taking into account the adaption costs and times involved. The supply conditions, expressed in level of service variables (including costs), are influenced by the physical transport infrastructure and the production functions used by the transport firms. As already stated, transport policy is almost always aimed at altering the prevailing supply conditions, which emphasises the great importance of the right specification of the supply functions and the derived level of service variables.

vii) Aggregated versus disaggregated approaches

Based on basic theoretical concepts, freight demand modelling has been developed in two different directions, that is into a disaggregated consignment and into an aggregated-freight-flow model approach, the main difference being the choice of the statistical research unit. The disaggregated approach is described in section 3.1, while the more common and more developed aggregated-flow-approach is described in section 3.2.

viii) The advantages of the aggregated-freight-flow approach

The great advantages of the aggregated-flow-approach lie in the data availability, at least in Western Europe, and in the possibilities to integrate general economic developments with freight demand-supply developments.

The data needed for the model development are, as the EC freight study has shown, normally collected by the statistical bureaux of the various countries on a yearly basis.

The economic models are used to forecast the main input to the freight demand-supply models - the expected pattern of economic activities - dealing with economic sectors (groups of firms) and regions. The level of the individual firm will never be used, except probably for detailed micro-study.

Here the correspondence with the two types of freight modelling becomes clear. A multi-sector economic model and an aggregated freight-flow model deal both with relationships between groups of firms, while the disaggregated approach (economic and freight) deals with relationships between individual firms. If the commodity and the sector classification are adjusted to each other, a statistically and theoretically consistent set of interrelated economic and freight (sub) models will exist.

ix) The advantage of a disaggregated-consignment approach

The main disadvantage of aggregated-flow modelling, which is at the same time the main advantage of disaggregated modelling, is its limited sensitivity to shippers' behaviour faced with changes in supply conditions. There are two reasons for this: the use of aggregated values of the explanatory variables and the limited number of variables which can be introduced. Disaggregated-consignment models are not hindered by the above-mentioned limitations (see section A.3.1) and will be more policy-sensitive than aggregated freight-flow models(1).

x) Synthesis between aggregated and disaggregated modelling

To overcome this problem a synthesis should be found between both approaches, which implies a combination of both model types depending on the degree of sensitivity of shippers' behaviour to supply conditions.

---

1) Ref. 6), 11).

xi) Short-term and medium-term freight models

For a short- and medium-term freight demand-supply model the following combination is most likely:

I Aggregated-freight-flow-approach
- multi-sectoral economic model;
- spatial economic model;
- freight production and attraction models;
- freight distribution models.

II Disaggregated-consignment-approach
- freight modal split models;
- freight traffic production models;

III Supply models
(These models are already based on individual observations)

IV Equilibrium models.

In a freight demand-supply model of such a structure, transport policy alternatives can be translated into the supply elements of the model system, while the consequence for the (transport economic) objectives can be determined through well structured behavioural equations for both shippers and transport firms.

xii) Long-term freight models

As far as long-term models are concerned, probably complete aggregated freight-flow approaches can be applied, as only the main developments are of importance, e.g. for long-term infrastructure planning it can be assumed that supply will follow demand taking into account the expected technological developments and some global transport policy alternatives. For such developments aggregated-freight-flow models have shown to be sensitive enough (see the EC-freight study).

2. Recent freight transport modelling

To compare freight transport models in detail is difficult because they are often specific and developed for solving a particular transport policy problem. However, they can be judged on more objective criteria such as:

a) the general assumptions made about the demand-supply equilibrium process on the freight transport markets;
b) the way the various demand-and supply functions are explicitly specified; and
c) the results in relation to the policy objectives of the models.

2.1 Aggregated-freight-flow approaches

Two aggregated-freight-flow models - the EC freight model and a Channel study freight model - were analysed in detail. The main difference between the two is that the EC freight model development was an exercise in itself, while the rather simple freight model used in the Channel project was developed only as part of a larger cost-benefit evaluation system.

i) The EC freight model

The EC freight model, being the first attempt to model freight transport on a European scale, follows to a great extent the basic modelling concepts of the aggregated-flow approach described in section A.3.2. The model is comprehensive and deals with national as well as international transport.

With the exception of the economic models, all submodels are well specified, within the possibilities of an aggregated-flow approach, while the empirical results for those models show a lot of similarities between the various countries. It implies that the chosen model specification could be satisfactorily applied to countries with different economic structures.

Some sensitivity tests were made by applying different growth scenarios for the future and calculating the price-elasticities for the international modal split model. The price-elasticities look acceptable, showing policy-sensitiveness for altering supply conditions on the international freight transport markets.

The use of a low- and high-growth economic scenario confirms the existing strong sensitivity of freight demand to developments in the econmic activity pattern (production, consumption and geographical distribution). Not only the total volume of freight demand, but also its composition to commodity groups and the distribution over modes of transport is highly influenced by economic growth, even if the supply conditions do not change.

Because of that it is a pity that no consistent multi-sectoral economic model could be used to forecaset the production levels of the various economic sectors.

However, such a model was not available and the scenario formulation followed only allowed for inconsistent sector developments, making the commodity forecast results less reliable.

The model system was aimed to support infrastructure policy on an EC-level. To accomplish this, freight flows between all regions were translated into detailed traffic flows which could be assigned to infrastructure networks to evaluate future infrastructure bottlenecks.

The EC freight model is a typical long-term demand-supply model, because it is conditional to the assumption that the supply of the transport industry will in principle follow demand developments. This is a reasonable assumption if some long-term technological developments and some general transport policies are also taken into account. The equilibrium process is based on an iterative calculation of the equilibrium values of infrastructure-related variables, such as transport times and costs.

New forecast results, including the identification of future infrastructure bottlenecks, will become available at the end of 1981, based on a set of scenarios more adapted to the expected economic development of today. The results will combine freight transport and long-term passenger transport.

ii) The Channel study freight model

The freight model used in this cost-benefit study deals with international freight transport. As in the EC freight model, international freight flows were related to the development of trade flows by branch between the countries of interest (14), from which a trade-transport model was developed. Although this model is too aggregated in some of its parts, it shows, as does the trade-transport model in the EC-freight model system, that modelling the interrelations between the economies by first using a trade model offers the best opportunity for forecasting international freight, an approach which is in accordance with the basic concepts mentioned in section A.

Similarly to the EC-freight model project, this study also suffers from the lack of a structural economic multi-sector model to produce consistent economic scenarios. In the case of expected structural changes, the results will probably be doubtful.

Although both studies use different economic scenarios, some global comparisons could be made, showing few differences in the outcome if the same scenarios are used. However, because of a separate assumption made about the price/quantity development in the Channel study, the ultimate growth of international trade in this study is less than in the EC-freight study. An assumption which looks somewhat doubtful, given the statistical evidence.

This study, too, is a long-term study. No specific equilibrium mechanism is used as far as supply is concerned. Much more so than the EC-freight study, the results are demand-related assuming that both the supply of infrastructure and transport industry will follow demand.

2.2 Disaggregated-consignment approaches

Although there are only a limited number of studies available, some of them show some interesting directions for further work. Real disaggregated demand modelling is seriously hindered by lack of data, which have to be collected specially by shippers-surveys.

The first study shows an attempt to combine an aggregated-freight-flow approach, partly based on input-output tables, and a disaggregated modal choice model. The various models are rather preliminary in their specification, mainly due to a lack of more specific data. In any case it shows a promising combination of both modelling approaches. The second study is of interest because it shows the extra possibilities to incorporate more specific modal choice factors in a disaggregated approach. In contrast with aggregated-flow-modal split models, where often only transport cost and transport time variables can be introduced, the modal choice model specifies two extra variables, that is a loss-and-damage and a transport time-reliability variable. The modal choice model estimate was used to calculate arc-price-elasticities of demand and to simulate the impact of some major policy changes in the model attributes, showing its policy sensitivity.

Both model attempts support the idea of synthesis between the aggregate and disaggregate modelling approach for short- and medium-term demand-and-supply models with the emphasis on a greater policy-sensitivity of the total model system.

2.3 Urban freight modelling

Urban freight studies show that freight modelling in urban areas is still in its infancy.

The methods used are very global, not structural, and their outcome has often to be adapted with some externally calculated control totals. The main failure can be due to direct modelling of commercial vehicle trips, instead of starting with the economic relations between the various zones of an urban area. There is no reason to believe that the basic concepts of freight demand modelling mentioned in section A are in principle inapplicable to micro situations like urban areas. There is of course a lack of data, but in such cases disaggregated model techniques based on data samples, offer firm possibilities for model development. The same has happened in the field of passenger transport. At the moment if freight transport in urban areas - the micro-economic-life-system - gets the same attention from policy makers as passenger transport enough resources will come available to collect, just as for passenger transport, the necessary data for model development.

REFERENCES

1) "Behavioural Travel-Demand Models", Peter R. Stopher and Arnim H. Meyburg; Lexington Books, 1976.

2) "Urban Travel Demand, A Behavioural Analysis", Thomas A. Domencich and Daniel Mc.Fadden; North-Holland/American Elsevier, 1975.

3) "The Demand for Travel, Theory and Measurement", Richard E. Quandt; Heath Lexington Books, 1972.

4) "Some Considerations with respect to Disaggregate Modelling", J. van Es and R. van der Kindt; N.V.I., 1978.

5) "Structure of Passenger Travel Demand Models", Moshe E. Ben-Akiva; M.I.T., 1973.

6) "Modal Choice in Freight Transport", J. van Es and C.J. Ruijgrok; International Conference on Transportation Research, 1973.

7) SIGMO study, Dutch Ministry of Transport, part 2 and 4; Projectbureau I.V.V.S., 1977 (C.S.I and N.V.I).

8) "Industrial Demand for Transport", B. I. Bayliss and S. L. Edwards; H.M.S.O. London, 1979.

9) Gedesaggregeerde modellen voor Verkeer en Vervoer; N.V.I., 1977.

10) "Freight Demand Modelling: A Policy Sensitive Approach", M. N. Terzien, M. Ben-Akiva and P. O. Roberts; the 47th National Operations Research Society of American Meeting, April 1975.

11) "Urban Goods Movement: Behavioural Demand Forecasting Procedures", P.O. Roberts and B.C. Kullmans C.S.I.; Resource paper for the Third International Conference on Behavioural Travel Modelling, 1977.

12) "Freight Demand Forecasts for the West Coast Corridor Study"; C.S.I., 1978.

13) "Demand for Freight Transport", report of the 20th Round Table; Paris, 1972.

14) "A Freight Transport Simulation System for the European Community and Spain", Parts 1 and 2; N.V.I., 1978, plus Annexes.

15) "Potential Markets for Combined Transport in 1985; Summary of Results", N.V.I., 1979.

16) "Freight Modelling - Which Way Now"? C. R. Eastman, P.T.R.C. 1979.

17) "Commercial Vehicle Trip Generation in the Chicago Region"; Zavaterro and others, T.R.B. 1980.

18) "Disaggregate Model of Modal Choice in Produce Transportation"; M.I.T., 1980.

19) "The Nature and Extent of Possible Community Interest in the Construction of a Fixed Link across the Channel"; EC 1979/1980, internal document; Coopers and Lybrand Associates and SETEC Economie.

20) Studies of factors determining the demand for freight transport; E.C.M.T. Round Table 16.

21) Etude de l'interêt communautaire d'importants projects d'infrastructure de transport; rapport de phase 2, août 1979; SETEC Economie.

SUMMARY OF THE DISCUSSION

1. INTRODUCTION

Modelling is a relatively old-established practice in the field of economics, but was fairly slow to be applied to the transport sector, where its first form was the forecasting of purely physical phenomena. This is why, at the moment, an evaluation of models by comparing forecasts with real figures is simply a matter of determining how operational are the models that forecast passenger and freight traffic.

Such forecasts are particularly necessary now because in the present economic context it is no longer possible just to monitor phenomena and to expect past trends to go on, and yet - precisely because of the changes of the recent past - modelling is becoming increasingly difficult just when these very changes make the need for it more vital than ever. This clearly underlines the importance of any exercise aimed at testing the reliability of models for the use that may be made of them, as the quality of the projections depends on the quality of the models.

A retrospective examination(1) is particularly enlightening for evaluating the quality of the forecasting models used in the transport sector; lessons can be learned and the study of past errors will hopefully lead to improved reliability in the instruments used. In such studies however, gaps between forecast and outturn should certainly not be considered solely as a criticism and from a purely negative or faultfinding standpoint. Judgments should be relativised because:

- the concept of recorded traffic is itself not very precise; in surveys carried out to estimate actual traffic there are

1) Characteristic of this type of approach is the work of I. Mackinder who carried out a forecast/outturn comparison for 44 urban transport studies carried out in the United Kingdom between 1962 and 1971. On this subject see:

- Mackinder, I.H.: "The Predictive Accuracy of British Transport Studies - A Feasibility Study". Department of the Environment, Department of Transport, TRRL Report SR 483, Crowthorne 1979.
- Evans, S.E. and Mackinder, I.H.: "Predictive Accuracy of British Transport Studies". Transportation Models and Analysis, PTRC Proceedings July 1980. London 1981.

serious problems of reliability so that these traffics are still poorly quantified;

- there are also difficulties as regards the horizon the studies apply to: the terms of comparison change with the year of reference.

This being borne in mind, a careful study of past transport demand modelling applications and forecast/outturn comparisons show that the errors which have been made are of two main types:

- one connected with defects in the models used;
- the other resulting from mistakes in the incorporation of exogenous variables.

These two types of error will be examined in turn and on the basis of a rapid survey of past difficulties encountered in this respect an effort will be made to draw a number of conclusions likely to improve the future performance of transport demand forecasting instruments.

2. DEFECTS IN THE MODEL

Mistakes made in the past inherent in the model itself stem from two main causes:

- estimation of parameters: this is an extremely technical problem which will not be discussed more fully here except to point out the uncertainty caused by estimating parameters too frequently on the basis of spot rather than interval data, though certain doubts about probability approaches are still justified;
- the internal structure of the model: while a retrospective review shows that errors of this type have not always been the most spectacular, the fact remains that substantial improvement can be envisaged in model construction under at least three headings:

2.1. The analytical phase

Before attempting to put a phenomenon into the form of a model, a thorough understanding of the phenomenon is necessary. Models are no more than the expression of a certain degree of knowledge of a sector. Apart from the modelling phase proper and the synthesising phase - i.e. forecasting - it is therefore necessary to develop a fully-fledged analytical phase including, in particular, the study of the sensitivity of demand to different variables.

In the course of this exercise which precedes the construction of any model, it is particularly important not to rely on appearances and over-hasty analyses. The correlations between variables therefore need to be interpreted with subtlety. Income elasticities, for example, are often extremely important, but leaving things at this simple statement may mean erroneous interpretation and hence inoperative models because, in reality, as only in-depth study can show, income acts not so much as such but as a characteristic of a certain social function.

This analytical phase should give rise to a certain interaction between the model and the studies which precede its construction. Developing the analysis along these lines should help to avoid constructing models erring on the side of optimism - all too frequently the case with traffic forecasts in the past through inadequate appraisal of phenomena associated with the spread of the car - because of the lack of analysis, the models used at the time disregarded, among other things, the fact that diffusion always tapers off with time. Another typical example of the errors which can result from inadequate analysis and hence knowledge of the sector studied - referred to by R. Marche in his introductory report - relates to French air traffic forecasts which overestimated the need for provincial intercity links. A thoughtful preliminary study would no doubt have helped to correct these forecasts by showing that there are in fact different levels of transport need according to the hierarchy of functions in the town concerned and the town's place in the space-time structure.

The organisation of markets is a very important factor in the analysis and must be incorporated in the models; but market phenomena, like sociological factors, cannot be so incorporated without a full-scale analysis of markets and their behaviour. In this field there are many similarities between passenger and freight transport markets, though the peculiar characteristic of the latter is the absence of "pure" or "perfect" competition in their organisational structures: observed results are not the sum of non-organised decisions but depend on strategies which themselves may vary over time. Hence the evident need in freight transport - just as in passenger transport - for a thorough analysis of the demand sector before any attempt at modelling. Market surveys are thus a vital preliminary, though they do not have to aim too high. Indeed the first essential is just to take a concrete, not overcomplicated, look at the market concerned, product by product and try in this way to arrive at some very simple elasticities or observations. The analyst can then hope to understand what really happens in the case of a particular product, and possibly see how modal split is determined in practice in relation to distance covered, weight to be transported, etc., and over what ranges the different modes compete for a given product.

Similarly, an in-depth examination of carriers' production and cost functions and the way to allow for them when constructing forecasting instruments could probably improve our understanding of the transport phenomena finally observed.

In addition, the transport sector is not hermetically sealed; it cannot be analysed in isolation but has to be seen in the context of the economic exchanges of which it is a reflection. This stresses the need for a better understanding of transport and for a fine analysis of economic structures and behaviours, changes in which can have very significant repercussions on the demand for passenger and freight transport.

The preceding arguments show clearly that the model must not be an end in itself. Indeed, planning processes need to be modified by enlarging the universe studied by the analyst, not limiting planning solely to models representing only part of a broader evaluation process comprising at least three phases:

- definition of the objectives and the instruments to be used at the policy level - careful examination of this point is a prerequisite for any study;
- definition of the structural relationships between the objectives and the means by which they can be achieved;
- determination of the best path to follow.

It is thus important to incorporate the forecasts in a broader decision-making process. This is why the preliminary analysis phase should also study the decision-making processes because a proper understanding of these is essential for results to be reliable. To this end, it would be useful to study how they actually worked in the past and to bring out the way in which such and such a decision was actually arrived at.

All these observations about the different factors which need particular analysis prior to any attempt at modelling directly raise the question of the relationships to take into account when constructing models, i.e. the difficulties associated with the actual specification of the model.

2.2. Improving model specifications

A. The technical reason why the planner is recommended to give particular attention to the specification of models, i.e. the nature of the relationships they include, is so as not to overlook any of the factors likely to exercise an influence on the results of the forecasts these instruments are to be used to make.

- A first example applies to transport policy factors. As pointed out above, transport demand generation models are one of the aids or instruments playing a role in a complex and interactive decision-making process; the forecasts therefore need to be incorporated in this broader process and this requires interactive forecasting, the use of scenarios by no means doing away with the need for such interactivity. For this reason, it is necessary for the models to be built in such a way as to include the variables on which the decisions are to be based and in particular the instruments through which the authorities take action, often known as "instrumental variables". Infrastructures and tariffs - not only from the cost aspect but also in terms of journey time - are examples of transport policy levers prompting reaction on the part of users and carriers which in turn causes the authorities to introduce new measures. Consideration of user or consumer reaction to decisions that relate to transport policy (creation of infrastructures, etc.), or affect supply, is necessary for all models including those in the form of scenarios. This will bring out the difference between these models and the "passive" forecasting models, unfortunately all too often used in the past, which, because they forecast traffic flows independently of decisions affecting the market, are in fact illogical and of little help. Estimating demand without at the same time considering the effects of possible measures is assuredly a pointless exercise.

- The same applies to other variables, generally known as <u>supply variables</u>, to which users on the transport market react. It is impossible to model transport demand without at the same time studying supply: infrastructures, operating methods used by transport firms, etc. Air traffic estimates, for example, will clearly be affected by companies' decisions about additional routes.
- The inclusion of supply variables is particularly necessary in the case of freight transport which will be studied here in a little more detail to make the point. Clearly it would be advantageous for freight movement forecasts to have variables in the models relating to types of market, production and distribution because these structural data are not without effect on modal split. A production organisation based on the co-operative system will influence modal choice. Similarly, when drawing up the specification of a model it is necessary to take into account the logistic policy into which any firm's transport strategy fits. Allowing for supply variables is admittedly difficult. In particular, there is the problem of gaps in freight transport statistics. Furthermore, when the modelling experts want to build spatial aspects into their forecasts, space variable/type of product cross-tabulation

proves very difficult and in any case gives no really significant results. The fact is that, because of its very complexity, the economic logic of the generation function at regional level is frequently difficult to establish; according to region and product the explanatory variables may be very different and there is no general logic from which a global model can be derived.

This difficulty of the satisfactory inclusion of supply variables in forecasting models explains why:

- the demand approach has been preferred in the past because the analysts hoped it would yield some indications as to modal split. It has to be admitted, however, that such a method cannot but fail because the problem of strategic variables cannot be satisfactorily treated with this type of approach;
- in the case of certain products, priority has been switched from models to more empirical market approaches based on surveys. On the basis of such one-off analyses, it has been possible to bring the technical substitution phenomena into clearer focus and, as a function of firms' policies, to draw certain conclusions as to modal split.

The contribution of such analyses is not denied and one of the problems facing forecasters is certainly how to incorporate the results of these concrete approaches, which constitute a useful preliminary to the modelling exercise, into their models. However, the inadequacy and purely preliminary nature of such approaches is obvious and therefore, despite the difficulties encountered, model builders will have to make an effort to improve the specification of their instruments so that they embrace not only supply and demand but also the processes by which equilibrium between supply and demand is achieved in order to introduce a dynamic perspective into their work.

B. During the actual construction of models, two particular points need to be borne in mind as they can make substantial improvements:

- As in energy studies, and unlike past practice characterised by a marked tendency to use static models for transport, the <u>distinction between the short and the long term</u> should be clearly made in specifications for transport demand forecasting instruments. There are in fact very few markets which regain equilibrium immediately - certainly not in the transport field. From this standpoint, some of the transport demand modelling equations currently employed therefore need careful reappraisal, otherwise in the absence of any dynamic perspective there is considerable risk - and the past offers ample evidence - of seeing, for example, such mistatements as the conclusion that the price or cost instrument is not very effective in transport policy. Taking short-term elasticities as a basis for decisions which will have long-term consequences is a real danger. This is particularly true in the case of commuter travel which is very inelastic in the short term whereas over a longer period there may perfectly well be a modal switch or a change in the departure and destination centres. It is therefore necessary to avoid a purely static specification of the modelling equations which should include short- and long-term reactions and be based on dynamic demand functions.

- Many sources of information are left out of present models. It would therefore be appropriate to open up traditional transport demand forecasting instruments and to include the results of the very detailed short-term or ad hoc concrete analyses and surveys mentioned above. In this respect it is useful to look at analogous model methods in the market research field which have added to the value of traditional econometric models by the input of "panel" findings. In addition, improving the models also implies the correct incorporation of behaviour, if need be in the form of scenarios, which cannot be done without establishing a real dialogue between sociologists and econometricians. Finally, models must not only be built so as to accept all existing sources of information, but must also be capable of periodical up-dating in the light of the latest available data.

The above comments again highlight the absolute necessity for thorough analysis prior to the actual modelling, which - as must unfortunately be admitted in the present state of the art - is not always possible, due to the inability to include all the essential variables when the model is being specified.

2.3. Need for a certain degree of disaggregation

A number of the errors seen in forecasting exercises of the past spring from insufficient disaggregation in the models used. This explains in particular the fact that many studies make no reference either to the structure of the car population, which is nevertheless a vital factor for correctly estimating road traffic, nor to the different reasons for travelling even though the logic of business travel is very different from that of private travel.

Indeed, one of the major difficulties encountered in forecasting is the multidimensional nature of the variables. It is therefore necessary to determine the appropriate level of aggregation for any forecast and to find out where the mesoeconomic optimum lies in the construction of models. Incidentally, it should be noted that a change in the level of the model (e.g. from macro to micro) implies a change in the variables taken into account, the transfer of macro variables as they stand to micro models being a major cause of errors.

The optimum level of disaggregation really depends on the problem concerned and is thus connected with the proposed end-use of the model. This is why it is essential for the expert to know what his forecasting instruments are to be used for before he makes them. This purpose needs to be clearly defined, in particular through an exchange of views between econometricians and model users during the preliminary analysis phase. It would be ridiculous to envisage a single model for all transport problems; the need for different models has to be admitted. This does not mean, however, that the theory underlying these models should not be the same, but simply that different levels of disaggregation are necessary according to the problem studied.

The freight transport sector, like passenger transport, is highly diversified. To work, the models used in this field certainly need some degree of disaggregation since too global an approach hides the phenomena of substitutability and complementarity essential for a proper understanding of transport phenomena. Excessive disaggregation, however, is a trap to be avoided; this type of approach, strongly developed in recent years, has not advanced research on forecasting very much. Exaggeratedly disaggregated models, whose cost is high in both money and time, are not always necessary. It is often better to use simpler models which can be handled more surely. For certain decisions of a fairly global nature, relatively aggregated models may be sufficient, the total volume transported being the determinant variable. Despite this warning against exaggerated segmentation, the fact remains that because of the very complexity of the phenomena studied, transport demand generation models should always include, with more or less detail according to the case, a minimum of disaggregation by sector, region, motivation, transport mode and social group.

The first reason why a measure of disaggregation in transport models is necessary is that it is an analytical requirement because the primary virtue of the segmentation exercise is that it obliges econometricians to be much more precise as to the explanatory factors governing demand generation. These factors could not be correctly read at too high a level of aggregation; they <u>cannot</u> be purely macro-economic because these are the variables with the highest degree of uncertainty. There is in fact an undeniable correlation between the danger of injecting exogenous hypotheses and the model's level of aggregation. A model with too high a level of aggregation includes a large number of variables which are only "apparent" and a number of implicit hypotheses which a disaggregated approach is precisely capable of bringing to the surface. It should also be noted that it is not at the macro-economic level that determinants of human choice (sociological, regional, etc.) can be introduced and yet there can be no question of neglecting these as influences. In this connection, significant examples of the difficulties caused by an aggregated approach are global elasticities which are often "apparent" (i.e. embracing both diffusion and substitution phenomena) or by estimates of general urbanisation trends. Finally, disaggregation in hypotheses helps to counterbalance the subjectivity of their choice.

While macro-economic (global) forecasts (general trends in car ownership, say) may have their use in providing a general framework for local studies, thus avoiding any hiatus between local and national scales, the models used to this end should, following the above logic, preferably be based on a certain breakdown. Transport flows are derived flows; any decision relating to transport, and hence in the first place to the resulting traffic, is in fact the outcome of a series of conditional choices which are difficult to model but which need to be carefully segregated: car ownership levels, degree of use, length of trip, etc. It is by proceeding in this fashion that the very important phenomenon of substitution and its consequences can be studied as well as the relationships between transport phenomena or decisions and the other factors governing them: spatial structure, economic organisation, etc. Only in this way is it possible to bring out geographical movements, the transport phenomenon finally being spatialised and thus linked with land use and location of activity models. A certain minimum disaggregation is also essential on the one hand to study the effect of service quality and other supply side factors which, as stressed above, have to be taken into account to make the model operational, and on the other hand to quantify modifications in behaviour (return to cycling, walking, etc.) and the evaluation of service frequencies and routes.

The segmentation process is particularly justified in the study of freight transport which in fact requires a twofold approach:

- The first is from the global standpoint and includes a small measure of disaggregation by sector so as to bring out the changes over the past few years in national production structures, which would be hidden at too high a level of aggregation. In this regard, there is considerable risk of falling into the error mentioned above of exaggerated segmentation; it is necessary to know when to stop (a maximum of 10 to 20 sectors) in order to work with large numbers and find the sectors that are important. One of the main difficulties encountered by this type of disaggregation is that the classifications used for transport are different from those used in industry and are not well suited to the requirements of the most recently developing sectors. In addition, there is no system of "materials" accounting between industries which makes it impossible to construct inter-industrial input-output tables.

- The above approach is nevertheless insufficient for valid forecasts; it needs to be supplemented by an approach with the firm as the starting point because each enterprise's transport policy is part of an overall logistic policy covering aspects like inventory, marketing, etc. significantly affecting modal choice. It is in fact the whole transport chain and the resulting necessary disaggregation which needs to be taken account of in the models. It is obvious in this respect that there is a close relationship between disaggregation problems and those referred to that are caused by the introduction of supply variables. This highlights the complexity of modelling and disaggregation operations in the case of freight transport, where extremely detailed typologies of market organisations and logistic structures are required. This explains why transport modelling is no doubt much more difficult for freight than for passenger transport.

3. INCORPORATING EXOGENOUS VARIABLES

Economists have always distinguished between endogenous variables - i.e. those to be forecast, e.g. traffic flows, etc. - and exogenous variables. Among the latter, those concerning the socio-economic environment and those relating to the nature of the service offered (price and quality of service) are of particular interest for transport demand projections. It is therefore essential that they be allowed for in demand generation models.

The equilibrium between these two types of variable within the model is very important, however. The fact is that, despite appearances, a large number of exogenous variables does not make forecasting any easier and certainly does not make forecasts any more reliable. All it does really is to displace the problem because ultimately the analyst has to forecast these variables with all the risks inherent in this kind of exercise. A model with too many exogenous variables therefore loses in value.

While including too many exogenous variables is to be avoided, the fact remains that, as shown by the above considerations relating to the analysis phase, the transport sector is not self-contained, so it has to be placed and studied in its context and any analysis has to allow for some exogenous variables. This is not without risk as is shown by the forecast-outturn comparisons of transport models used during the past two decades.

3.1. Errors found

A. Errors in assumptions

One of the main causes of the errors found in past transport forecasts lies in the exogenous assumptions introduced into the models and in particular those concerning trends in the socio-economic context. Extrapolations made in this area during the past 20 years err on the side of over-optimism, this resulting from the state of mind of the decision-makers and econometricians of the time as manifest both in the exogenous assumptions and the construction of the models.

This optimism was expressed particularly in a virtually universal tendency to project assumptions of very vigorous economic growth following the logic of the constant increase in GNP recorded up to that time. Such a choice necessarily affected evaluations of household consumption, one of the most important parameters in transport demand forecasting models. Similarly, models used up to the first oil crisis all included an implicit assumption of fuel price stability. Everybody knows how very different the real economic and energy situations have turned out and there is no point in commenting further on this self-evident point.

Thus, while the construction of the models, as shown by the arguments in Chapter 2 of this report, itself explains some of the shortcomings found in past forecasting attempts, an examination of modelling attempts over the past 20 years shows beyond doubt that in many cases the discrepancy between forecast and outturn was mainly the fault of the assumptions for exogenous variables. It is not sufficient, however, simply to observe that the assumptions made were wrong. It is necessary to carry the analysis somewhat further and find out why such or such an assumption was chosen, because there is necessarily a certain coherence in these choices and, no doubt, an underlying logic. Part of the answer to this question is certainly supplied by the very nature of the studies, their purpose often being to argue a particular case.

B. The risks involved in case-arguing studies

A posteriori examination reveals that the purpose of certain past studies has really been to argue a case(2). It is in fact this concealed objective which frequently led, particularly in the case of studies accompanying transport investment projects, to an overestimation of expected traffic. It unfortunately has to be admitted that in all investment projects it is in the interest of the body responsible for forecasts to choose among all plausible assumptions those most consistent with the project they wish to implement.

This observation does not imply, however, that it is the model itself which is at fault but it does highlight the risk of error implicit in the planner/decision-maker relationship and in the institutional environment surrounding the model. Nor is this danger surprising because no model can be any more than one representation of reality. It therefore seems difficult to prevent a measure of subjectivity in the choice of assumptions. It needs to be limited, however, and at very least be brought out into the open.

Finally, it turns out to be fairly easy to trace certain errors recorded in past forecasting exercises back to the inappropriate and over-subjective manner in which exogenous variables were taken into account. Because of the very scale of the errors there can hardly be any argument about them. It is, on the other hand, much more difficult to derive any indication from the analysis of past transport planning about how to improve the process of incorporating exogenous variables into the model in future. This exercise is essential however. Because of the scale of the errors which have resulted from incorrect integration of exogenous data into the models in the past, those concerned with designing or using these forecasting instruments in the transport sector must make every endeavour in this direction.

C. Possible improvements

In order to remedy the major source of error implicit in the inclusion of exogenous variables in transport demand forecasting models, two main lines of research merit particular attention.

a) Better knowledge of the variables

Transport demand is not an isolated but a derived phenomenon which has to be seen in the reality of the economic interrelations which it reflects. Perfect integration of the hypotheses determining the main transport flows is therefore necessary, and this has not

2) Cf. GRETU: "Une étude économique a montré..., Mythes et réalités des études de transport", Editions Cujas, Paris, 1980.

always been the case in the past, far from it. Through lack of satisfactory knowledge of exogenous variables, many sectoral models have been inadequately and incorrectly supplied with general hypotheses relating to macro-economic data and future possibilities.

In conjunction with the preliminary analysis phase, the necessity for which was stressed above, it is therefore important to work towards a better knowledge of exogenous variables. Here great care needs to be taken to ensure that macro-economic hypotheses (general trends, increases in income, sectoral trends, etc.) should exactly tally with the latest information from the organisations responsible for this type of projection (planning bureaux, international organisations, etc.). Clearly any over or underestimate here will inevitably affect specific forecasts in the field of transport. The uncertainties inherent in "unsettled" periods, such as the present time, will of course affect the degree of reliability of traffic flow forecasts, but the precise determination and explicit indication of that degree of reliability should incline decision-makers towards cautious and flexible policies.

In this seeking of better knowledge of exogenous variables, it would be useful to give particular attention to population forecasts which play a vital role in the projections particularly because they have a very important effect on space use, which cannot as such be included as an exogenous variable in the models. Demographic data are therefore valuable indicators whose quality requires constant monitoring.

b) Conditional forecasts

Whilst, as pointed out in the discussion of model structures, it is necessary to shift from passive forecasting to an interactive approach, it is also necessary to avoid non-objective forecasting methods that give results in the form of a single figure. In this respect, conditional approaches based on scenarios and projections on the basis of clearly-defined assumptions are no doubt well worth developing. They lessen the risk inherent in the introduction of assumptions concerning exogenous variables and in the institutional environment which tends to transform studies into mere justifications. Nevertheless, the somewhat over-hasty enthusiasm recently generated among forecasting specialists by this type of approach needs to be tempered somewhat by a preliminary warning: conditional forecasts have certain limits which, if not properly understood, are bound to give rise to vain hopes.

- The fact is that the scenario approach cannot be regarded as a miracle cure to solve all the problems of including exogenous variables.

First, there is a considerable danger when using multiple projections of arriving at results which have too broad a range and too extensive a choice of scenarios which are little use to decision-makers. With forecasting exercises of this kind, the outcome is likely to be a sad lack of real synthesis; in addition, having numerous sets of assumptions can only send up the bill.

Even with scenarios, the risk of a case-arguing study is by no means eliminated. Faced with a broad range of possible situations and results, decision-makers will always try to find out which, according to the author of the scenarios, is the most desirable and most plausible. It is never really possible to prevent this kind of technical advisor from having his own point of view, which once again points out the importance, even with modelling in the form of scenarios, of choosing people responsible for making the forecasts who are and can remain independent.

Nor does the probability approach seem capable of answering the decision-maker's problem of selecting among different scenarios. Great caution is necessary on the technical level with regard to the introduction of probabilities into the likelihood of the different scenarios and indeed in any work in the field of maximum probability. In any probability model there is in fact a whole set of hypotheses (usually seven or eight) and for each probability stated there is a probability that ... etc. But none of these probabilistic hypotheses is capable of being economically verified because the samples on which they work are unique in time. The hypothesis of normality, in particular, seems very rarely capable of verification. It is therefore necessary in this area to avoid being over-optimistic about the econometric results. By applying scientific methods to non-verifiable data there is a considerable risk of merely stepping out of one illusion into another.

- Despite these undeniable limits, the scenario approach, to the extent that it is not passive but interactive (i.e. really translates states of the world), presents obvious advantages favouring the development of conditional models.

  Models necessarily involve some degree of uncertainty and risk. The uncertainty is due to the stochastic elements inherent in any econometric model, the risk is due to the hazards involved in forecasting purely exogenous variables. To improve the quality of the projections, these two factors need to be made explicit, being estimated and brought to the fore in the presentation of the calculated results. In this context, one of the advantages of the scenario approach is that it gives decision-makers a means of assessing the degree of uncertainty and risk associated with the economic and social benefits of the projects envisaged. Scenarios enable the realm of the possible to be distinguished and its limits and frontiers drawn, so to speak. They bring the policy-maker face to face with his responsibilities. Thanks to scenarios, the decision-maker can get some idea of the scope of the different measures and their consequences, which is extremely valuable for taking policy decisions. In addition, scenarios constitute an effective instrument for improving and clarifying relations between those commissioning the studies and those constructing the models. It should be possible through them to establish an iterative relationship between technical advisors and decision-makers in order to arrive at hypotheses which actually do determine the results and pose a real problem because, in the final analysis, it is the policy-maker who has to commit himself on these hypotheses. As already pointed out, it is certainly necessary to avoid being over-optimistic. Despite the undeniable contribution of the conditional forecast technique, the difficulties inherent in making a choice between different scenarios remain and there is still a real risk of a case-arguing study. On the other hand, however, there is no need to go to the other extreme and paint a blacker picture than necessary. Firstly, in many cases some of the possible variants may reasonably appear more likely than others. Secondly, it must not be forgotten that in periods as unsettled as the present it is no doubt necessary above all to choose among all possible variants the "flexibility scenario" and hence favour scenarios based on successive decisions. Investment in the transport sector runs into particularly large amounts and it is clearly very desirable to be able to halt implementation without too drastic consequences. In a world characterised by great uncertainty, the criterion of reversibility is bound to weigh heavily with policy-makers. Thus the very weight of this criterion may quite naturally provide an answer to the tricky question of choosing between the different scenarios implicit in the conditional approach to forecasting.

An excellent way to appraise uncertainty and risk and to develop a scenario approach of real relevance to decision-makers, would appear to be to follow in the path already taken by certain United Kingdom studies(3), i.e. to carry out a detailed post mortem on the

3) Mackinder, I.H.: op. cit.

transport models which flourished in the sixties and seventies. Researchers now have available a veritable data bank of transport studies and a systematic forecast/outturn comparison would certainly be most instructive. Those responsible for constructing and presenting models would learn volumes from such an exercise, particularly as regards the origins and relative importance of the forecasting errors made in the past. This exercise would make it possible to find the assumptions made at the time and the results they led to, and to define the climate in which choices were made. Very useful lessons could no doubt be learned from this kind of historical analysis and could help improve the incorporation of variables affecting transport flows in future models.

An additional consideration argues in favour of the systematic study of previous forecasting and modelling exercises in the transport sector. As pointed out, a substantial proportion of the shortcomings noted in the use of these models is explained by unexpected changes in the socio-economic environment and their unfortunate results both as regard exogenous variables and the structure of the model itself. In view of this failure, one attitude might be to write off forecasting altogether. It would appear more effective, however, to react on the basis of the simple observation that in the statistical data there is now more "variance" and less "colinearity" because of the present crisis situation where certain developments are no longer in the line of the trend. The fact is that this offers an opportunity which should be seized and which should bring some advance in knowledge because it is no doubt easier now to distinguish between the two main types of error connected with the logic of the model itself (inclusion of incorrect implicit assumptions) and with the introduced assumptions (exogenous variables) and, for example, to resolve the difficult problem of apparent elasticities. Analysts now find themselves, in fact, in circumstances identical to those of 1929, characterised by greater variance. Analysts at that time took advantage of the opportunity and modern econometrics was born. As in the great crisis of the war period, the situation of the eighties, as a result of the breaks in the trend lines, constitutes a challenge to the understanding of phenomena and seems in its turn a period favouring substantial progress in economics and econometrics.

4. CONCLUSIONS

The aim of this document was to make an assessment of the attempts made since the early sixties to model passenger and freight transport demand. As the expected traffic flows did not in the majority of cases materialise it has to be recognised that results are disappointing if the models are considered as forecasting instruments. Faced with such a negative assessment, it is reasonable to ask whether it will ever be possible in the field of transport demand to undertake anything other than fairly mechanical forecasts for concrete and marginal phenomena coming under the heading of "traffic engineering". It may in fact be asked whether it is possible to make projections taking into account the complete socio-economic environment as required for accurate forecast of demand in the transport sector. The difficulty in this respect stems mainly from the fact that transport demand is derived from a number of phenomena that develop upstream and hence are difficult to record and even mor difficult to forecast; an accurate projection of transport demand means analysing extremely complex behavioural relations and solving a great many simultaneous equations virtually impossible to handle.

Despite the failure of models as regards forecasting and the weaknesses of the probability approach when applied to time series, the analyst should not fall victim to over-pessimism. In the first place, two paths are still open to those who want to forecast the future:

- more "heuristic" research approaches upstream of modelling such as those concerning mobility; these in fact stem directly from the criticisms levelled at models;
- data analyses, the direct exploration of the data leading to excellent and frequently counter-intuitive results, something that cannot be done through the modelling approach.

Secondly, the lack of success of modelling as a forecasting technique does not mean for all that that models are without interest. In the past there has been a tendency to overemphasize the forecasting dimension of the models and to neglect their analytical character, whereas they are of incontestable didactic and pedagogic value. Even though they founder on the basic problem of measuring long-term elasticities which are as yet very poorly understood, there generally being some confusion between short- and long-term elasticities, the models are nevertheless of obvious interest as an explanatory tool because they oblige the researcher to synthesise the different components of a process. While no miracles are to be expected on the forecasting level, models prove very useful for analysis because they impose a certain discipline making it possible to identify the relative weights of the demand-determining factors and to understand the phenomena underlying the creation of this demand. This does not mean, however, that the use of models should be limited to mere intellectual comprehension exercises. Through their analytical contribution and their explanatory value, well-constructed models should also make it possible to measure the impact of the different variables, showing decision-makers the likely consequences of the measures envisaged and determining the probability of attaining a certain financial objective, thus making the risks explicit for the policy-maker and facilitating the choice between probable scenarios.

Using models has the other advantage of promoting a certain "integrity" in the use of statistics. One of the most positive aspects of modelling is no doubt that this approach means that the statistics have to be as homogeneous as possible which leads in the long run to the need for data banks of coherent time series. Efforts to improve the effectiveness of models inevitably lead to proposals to improve statistics in order to reduce residual variances. There is in fact the risk of introducing very marked bias, at least comparable with that resulting from sampling procedures, at the data level and in this respect the quality of statistics relating to freight transport is an undeniable problem because they are all too often manipulated by pressure groups. Models can be no better than the statistics they use and for this very reason the reliability of these inputs must be given particular attention.

The big advantage of models is thus to rationalise thought, but by their nature such instruments simplify and it is therefore necessary to bear constantly in mind the field of reality not covered by such a representation. While it is necessary to have reliable data to understand the field properly, the data do not come solely from the statistical field, which immediately poses the question of the surveys needed to identify attitudes, choices, etc. In the present state, however, these surveys are not carried out in a satisfactory manner. Obtaining better results from modelling in the future means thinking not only about the methodology of the models themselves but also about ways in which to improve the surveys aimed at capturing actual behaviour.

Finally, models turn out to be the essential framework for integration, firstly in the case of knowledge of certain reactions on the transport market and secondly in the organisation of statistical information. Examination of the past performance of models shows that it is no good asking them to produce more than they were really designed for. Contrary to an ideal all too prevalent during the last two decades, models must neither be considered as a prerequisite nor serve to establish ex abrupto forecasts. It is necessary to integrate them into broader decision-making processes and to use them in particular as an instrument for achieving coherence, showing, among other things, whether the objectives in view are realisable at the simple level of accounting balances.

To fulfil this role properly, models can no longer be passive, and this first of all requires active treatment of the variables in the different scenarios. Models should be transparent, logically constructed and simple enough to allow them to be fully understood. In this respect it is essential that their structure be explained as clearly as possible and above all that however complex they may be the logic should remain fairly simple as it is mainly on this factor that decision-makers will judge them; the policy-maker in fact needs to know not the detail of the calculations but the internal logic on which he will base his decision. To make the models more operational it is therefore essential to demonstrate the coherence and internal logic of these instruments and show how they compare with the facts; that is how to prove their validity.

5. SUMMARY

The main lessons which can be drawn from a close examination of past attempts at modelling transport demand can be summarised as follows:

1. Transport demand generation models are in fact aids in a complex and interactive decision-making process. For this reason they need to include all the variables on which these decisions have to be based. This applies to infrastructure and tariffs which are the transport policy instruments to which demand reacts. Including them in models should enable these models to be contrasted with purely "passive" forecasting models which are illogical precisely for this reason.
2. Models necessarily involve a certain degree of uncertainty and risk; the uncertainty is due to the stochastic elements inherent in any econometric model, the risk is due to the hazards involved in forecasting the exogenous variables. These two factors need to be estimated and incorporated in the presentation of the calculated results. In this context, one of the advantages of the scenario approach is that it gives decision-makers the means of assessing the degree of uncertainty and risk associated with the economic and social benefits of the projects envisaged.
3. An excellent way to appreciate uncertainty and risk is to strip down the transport models which flourished in the sixties and seventies. Those responsible for constructing and presenting models learn volumes from such an exercise, particularly as regards the origins and relative importance of the forecasting errors made in the past.

4. Models always include a certain degree of disaggregation by sector, region, motive and transport mode. Below a certain level, disaggregation necessitates more precision in the explanatory factors which cannot be purely macro-economic as they are precisely the variables where the uncertainty is greatest. In addition, it is not at the macro-economic level that factors of personal choice (sociological, regional, etc.) can be introduced and these cannot be neglected as influences. Disaggregation in assumptions can help to counteract subjectivity of choice.

5. Given the high technical content of models, particular attention should be paid to their specification, i.e. to the nature of the relationships they include. This applies to the transport policy elements mentioned above; it also applies to other variables to which users react, generally known as "supply variables". In this respect the model should provide a framework into which all the available analytical elements can be fitted; not only should a model incorporate them wherever possible but it should be interpreted in their light. It thus becomes an excellent instrument for organising statistical information.

6. While macro-economic projections may have their uses (funds available, general trends in car-ownership, etc.) models should preferably be based on a certain level of breakdown. Traffic is in fact the outcome of a series of conditional choices which should be carefully isolated: cars/head of population rates, utilisation rates, trip lengths, etc. The substitutions that are so important and geographical movements are studied at this level, since "transport" is, at bottom, a spatial phenomenon and thus linked with land-use and location of activity models. It is also at this level that other factors operate, such as quality of service and other demand-side factors as well as modifications in behaviour (reversion to cycling, walking, etc.) and the evaluation of service frequencies and routes.

7. Market organisation is a very important point which has to be fitted into models. The fact is that there are many similarities between the passenger and freight transport markets, but the latter are more characterised by organisational structures which are not perfectly competitive. The results observed are not the sum of unorganised decisions but stem from strategies which can themselves be variable over time. Hence the necessity in the case of freight transport, and for passenger transport as well incidentally, for a prior analysis of the demand sector. The inclusion of studies of carriers'

production and cost functions will probably improve understanding of the "transport" phenomenon as finally observed.

8. A distinction needs to be made in the models between the long and the short term. In the past there has been too much inclination to use static models for transport studies. In this connection it would appear essential to recast certain equations in transport demand models, otherwise there is a considerable risk, for example, of wrongly concluding that the price or cost instrument is ineffective.

9. Very many sources of information are available, but they are badly incorporated in models. Models should contain access points where such information can be introduced. Traditional transport models in particular need opening up so that, when used, the results of detailed analyses and surveys of intentions or short-term improvements can be entered. It would be helpful in this regard to look at analogous model methods in the market research field since these are adding to the value of traditional econometric models by the input of "panel" findings. Transport models need to be constructed in such a way that they can digest all new information and be reassessed periodically in the light of the available data.

10. Another necessity is the accurate integration into transport models of the hypotheses determining major traffic flows. Here great care needs to be taken to ensure that macro-economic hypotheses (general trends, increases in income, sectoral trends, etc.) should exactly tally with the latest information from the organisations responsible for this type of projection (planning bureaux and international organisations). Clearly any over- or under-estimation here will inevitably affect specific forecasts in the field of transport. The uncertainties inherent in "unsettled" periods, such as the present, will of course affect the degree of reliability of traffic flow forecasts, but its explicit indication ought to incline the decision-makers towards cautious and flexible policies.

11. Finally, transport demand forecasting models should be transparent and logical in their construction. Their structure should be clearly explained. Even when complex, they should still display a fairly simple logic and it is on this that policy-makers will judge them. The planner in fact needs to know not the calculations but the internal logic on which he will base his decision. It is therefore important to demonstrate the coherence and internal logic of models and to show how they compare with the facts; that is how to prove their operational validity.

LIST OF PARTICIPANTS

Professor J. PAELINCK — Chairman
Director
Nederlands Economisch Instituut
Burgemeester Oudlaan 50
3062 PA ROTTERDAM (Netherlands)

Mr. Roger MARCHE — Rapporteur
Institut de Recherche des Transports
2 avenue du Général Malleret-Joinville
94114 ARCUEIL Cedex (France)

Mr. Olivier MORELLET — Rapporteur
Institut de Recherche des Transports
2 avenue du Général Malleret-Joinville
94114 ARCUEIL Cedex (France)

Mr. Xavier GODARD — Rapporteur
Institut de Recherche des Transports
2 avenue du Général Malleret-Joinville
94114 ARCUEIL Cedex (France)

Drs. Jan van ES — Rapporteur
Transport Economic Adviser
56 Hoevenseweg
5062 KE OISTERWIJK (Netherlands)

Mr. A. AURIGNAC
Ingénieur principal adjoint
Direction des Etudes Générales et de la Recherche
Département Recherches et Planification
S.N.C.F.
17 rue d'Amsterdam
75009 PARIS (France)

Mr. Z. BAUER
Hećimovićeva 11
4100 ZAGREB (Yougoslavie)

Professor A. BONNAFOUS
Directeur du Laboratoire d'Economie des Transports
Université de Lyon II
16 Quai Claude-Bernard
69007 LYON (France)

Mr. W. BRÜG
Director, SOCIALDATA
Institut für Empirische Sozialforschung GmbH
Hans-Grässel-Weg 1
8000 MÜNCHEN 70 (Germany)

Mr. M. DELLO SCHIAVO — Observer
Capo Divisione 33
Ministero Trasporti
Direzione Generale MCTC
Via Tronto 2
ROME (Italy)

Mr. V. DEMARELOS
University of Thessaloniki
92 Tsimiski Street
THESSALONIKI (Greece)

Professor F.X. DE DONNEA
Université Catholique de Louvain
Institut d'Administration et de Gestion
16 avenue de l'Espinette
1348 LOUVAIN-LE-NEUVE (Belgium)

Mr. T. ERIKSEN — Observer
Planning Department
Ministry of Transport
Frederiksholms Kanal 27
1220 KØBENHAVN K (Denmark)

Mr. FERRY
Ingénieur au Centre d'Etudes des Transports Urbains
Ministère des Transports - Ministère de l'Environnement et du Cadre de Vie
8 avenue Aristide Briand
92220 BAGNEUX (France)

Dr. M. GULLÓN
Ingeniero de Caminos, Canales y Puertos
Dirección General de Carreteras
Ministerio de Obras Públicas y Urbanismo
Paseo de la Castellana
MADRID 3 (Spain)

Mr. S. HANSEN
Vice President, Economic Research & Planning Division
NORCONSULT A.S.
Kjoerbuveien 20
1300 Sandvika
OSLO (Norway)

Professor C. HEIDEMANN
Institut für Regionalwissenschaft
Universität Karlsruhe
Kaiserstrasse 12
Postfach 6380
7500 KARLSRUHE (Germany)

Mr. H. McGEEHAN
Economist, Department of Regional Planning
Córas Iompair Eireann
14-19 Crow Street
DUBLIN 2 (Ireland)

Mr. I. MACKINDER
Director, Public Sector Management
228, London Road
READING RG6 1AH (United Kingdom)

Mr. A. MORENO
G.E.P.T.C.
Ministry of Transport
Rua da Alfandega 170
1100 LISBON (Portugal)

Professor A. NADDEO
Istituto di Statistica
Facoltà di Economia y Commercio
Via del Castro Laurenziano, 9
ROME (Italy)

Professor Dr. W. NONNEMAN
Universitaire Faculteiten Sint-Ignatius (UFSIA)
Studiecentrum voor Economisch en Sociaal
Onderzoek (SESO)
Prinsstraat 13
2000 ANTWERP (Belgium)

Mr. C. REYNAUD
Service d'Analyse Economique et du Plan
55-57 rue Brillat-Savarin
75013 PARIS (France)

Mr. A. RÜHL
Planning Director
Ministry of Transport and Public Works
Plesmanweg 1-6
THE HAGUE (Netherlands)

Mr. G. SAVENSTEDT
Department of Transportation Research
University of Umeå
S-90147 UMEA (Sweden)

Mr. O. SCHIØTZ
Road Directorate
Ministry of Transport
Postbox 2169
Havnegade 23
DK-1058 KØBENHAVN K (Denmark)

Mr. A. TALVITIE
Tie je Vesirekennushallitus TVH/Tt
PL 20
00131 HELSINKI 13 (Finland)

M. Dipl. Ing. D. ZUMKELLER
INTRAPLAN Consult GmbH
Klosterstrasse 35
D-4000 DÜSSELDORF 1 (Germany)

Secretariat:

Messrs. G. BILLET
A. DE WAELE
A. RATHERY

ECMT

ECONOMIC RESEARCH CENTRE

FORTHCOMING PUBLICATIONS

- Round Table 59: Transport and telecommunications.
- Round Table 60: Short-sea shipping in the economy of inland transport in Europe.

- Ninth International Symposium on Theory and Practice in Transport Economics

"TRANSPORT IS FOR PEOPLE"

Topic 1: Assessment of Society's Transport Needs

(Foreseeable trend, taking into consideration external factors such as environment, land use planning and energy)

1 (a) Mobility of Persons

1 (b) Goods Transport

Topic 2: Management of Firms to satisfy Transport Needs

(With emphasis on labour force and financing problems, as well as constraints caused by energy and environmental problems)

2 (a) Goods Transport by Road

2 (b) Inland Waterway Goods Transport

2 (c) Urban and Regional Passenger Transport

2 (d) Railways

OECD SALES AGENTS
DÉPOSITAIRES DES PUBLICATIONS DE L'OCDE

ARGENTINA – ARGENTINE
Carlos Hirsch S.R.L., Florida 165, 4° Piso (Galería Guemes)
1333 BUENOS AIRES, Tel. 33.1787.2391 y 30.7122
AUSTRALIA – AUSTRALIE
Australia and New Zealand Book Company Pty, Ltd.,
10 Aquatic Drive, Frenchs Forest, N.S.W. 2086
P.O. Box 459, BROOKVALE, N.S.W. 2100
AUSTRIA – AUTRICHE
OECD Publications and Information Center
4 Simrockstrasse 5300 BONN. Tel. (0228) 21.60.45
Local Agent/Agent local :
Gerold and Co., Graben 31, WIEN 1. Tel. 52.22.35
BELGIUM – BELGIQUE
LCLS
35, avenue de Stalingrad, 1000 BRUXELLES. Tel. 02.512.89.74
BRAZIL – BRÉSIL
Mestre Jou S.A., Rua Guaipa 518,
Caixa Postal 24090, 05089 SAO PAULO 10. Tel. 261.1920
Rua Senador Dantas 19 s/205-6, RIO DE JANEIRO GB.
Tel. 232.07.32
CANADA
Renouf Publishing Company Limited,
2182 St. Catherine Street West,
MONTRÉAL, Que. H3H 1M7. Tel. (514)937.3519
OTTAWA, Ont. K1P 5A6, 61 Sparks Street
DENMARK – DANEMARK
Munksgaard Export and Subscription Service
35, Nørre Søgade
DK 1370 KØBENHAVN K. Tel. +45.1.12.85.70
FINLAND – FINLANDE
Akateeminen Kirjakauppa
Keskuskatu 1, 00100 HELSINKI 10. Tel. 65.11.22
FRANCE
Bureau des Publications de l'OCDE,
2 rue André-Pascal, 75775 PARIS CEDEX 16. Tel. (1) 524.81.67
Principal correspondant :
13602 AIX-EN-PROVENCE : Librairie de l'Université.
Tel. 26.18.08
GERMANY – ALLEMAGNE
OECD Publications and Information Center
4 Simrockstrasse 5300 BONN Tel. (0228) 21.60.45
GREECE – GRÈCE
Librairie Kauffmann, 28 rue du Stade,
ATHÈNES 132. Tel. 322.21.60
HONG-KONG
Government Information Services,
Publications/Sales Section, Baskerville House,
2/F., 22 Ice House Street
ICELAND – ISLANDE
Snaebjörn Jönsson and Co., h.f.,
Hafnarstraeti 4 and 9, P.O.B. 1131, REYKJAVIK.
Tel. 13133/14281/11936
INDIA – INDE
Oxford Book and Stationery Co. :
NEW DELHI-1, Scindia House. Tel. 45896
CALCUTTA 700016, 17 Park Street. Tel. 240832
INDONESIA – INDONÉSIE
PDIN-LIPI, P.O. Box 3065/JKT., JAKARTA, Tel. 583467
IRELAND – IRLANDE
TDC Publishers – Library Suppliers
12 North Frederick Street, DUBLIN 1 Tel. 744835-749677
ITALY – ITALIE
Libreria Commissionaria Sansoni :
Via Lamarmora 45, 50121 FIRENZE. Tel. 579751/584468
Via Bartolini 29, 20155 MILANO. Tel. 365083
Sub-depositari :
Ugo Tassi
Via A. Farnese 28, 00192 ROMA. Tel. 310590
Editrice e Libreria Herder,
Piazza Montecitorio 120, 00186 ROMA. Tel. 6794628
Costantino Ercolano, Via Generale Orsini 46, 80132 NAPOLI. Tel. 405210
Libreria Hoepli, Via Hoepli 5, 20121 MILANO. Tel. 865446
Libreria Scientifica, Dott. Lucio de Biasio "Aeiou"
Via Meravigli 16, 20123 MILANO Tel. 807679
Libreria Zanichelli
Piazza Galvani 1/A, 40124 Bologna Tel. 237389
Libreria Lattes, Via Garibaldi 3, 10122 TORINO. Tel. 519274
La diffusione delle edizioni OCSE è inoltre assicurata dalle migliori librerie nelle città più importanti.
JAPAN – JAPON
OECD Publications and Information Center,
Landic Akasaka Bldg., 2-3-4 Akasaka,
Minato-ku, TOKYO 107 Tel. 586.2016
KOREA – CORÉE
Pan Korea Book Corporation,
P.O. Box n° 101 Kwangwhamun, SÉOUL. Tel. 72.7369

LEBANON – LIBAN
Documenta Scientifica/Redico,
Edison Building, Bliss Street, P.O. Box 5641, BEIRUT.
Tel. 354429 – 344425
MALAYSIA – MALAISIE
and/et **SINGAPORE - SINGAPOUR**
University of Malaya Co-operative Bookshop Ltd.
P.O. Box 1127, Jalan Pantai Baru
KUALA LUMPUR. Tel. 51425, 54058, 54361
THE NETHERLANDS – PAYS-BAS
Staatsuitgeverij
Verzendboekhandel Chr. Plantijnstraat 1
Postbus 20014
2500 EA S-GRAVENHAGE. Tel. nr. 070.789911
Voor bestellingen: Tel. 070.789208
NEW ZEALAND – NOUVELLE-ZÉLANDE
Publications Section,
Government Printing Office Bookshops:
AUCKLAND: Retail Bookshop: 25 Rutland Street,
Mail Orders: 85 Beach Road, Private Bag C.P.O.
HAMILTON: Retail Ward Street,
Mail Orders, P.O. Box 857
WELLINGTON: Retail: Mulgrave Street (Head Office),
Cubacade World Trade Centre
Mail Orders: Private Bag
CHRISTCHURCH: Retail: 159 Hereford Street,
Mail Orders: Private Bag
DUNEDIN: Retail: Princes Street
Mail Order: P.O. Box 1104
NORWAY – NORVÈGE
J.G. TANUM A/S Karl Johansgate 43
P.O. Box 1177 Sentrum OSLO 1. Tel. (02) 80.12.60
PAKISTAN
Mirza Book Agency, 65 Shahrah Quaid-E-Azam, LAHORE 3.
Tel. 66839
PHILIPPINES
National Book Store, Inc.
Library Services Division, P.O. Box 1934, MANILA.
Tel. Nos. 49.43.06 to 09, 40.53.45, 49.45.12
PORTUGAL
Livraria Portugal, Rua do Carmo 70-74,
1117 LISBOA CODEX. Tel. 360582/3
SPAIN – ESPAGNE
Mundi-Prensa Libros, S.A.
Castelló 37, Apartado 1223, MADRID-1. Tel. 275.46.55
Libreria Bosch, Ronda Universidad 11, BARCELONA 7.
Tel. 317.53.08, 317.53.58
SWEDEN – SUÈDE
AB CE Fritzes Kungl Hovbokhandel,
Box 16 356, S 103 27 STH, Regeringsgatan 12,
DS STOCKHOLM. Tel. 08/23.89.00
SWITZERLAND – SUISSE
OECD Publications and Information Center
4 Simrockstrasse 5300 BONN. Tel. (0228) 21.60.45
Local Agents/Agents locaux
Librairie Payot, 6 rue Grenus, 1211 GENÈVE 11. Tel. 022.31.89.50
TAIWAN – FORMOSE
Good Faith Worldwide Int'l Co., Ltd.
9th floor, No. 118, Sec. 2
Chung Hsiao E. Road
TAIPEI. Tel. 391.7396/391.7397
THAILAND – THAILANDE
Suksit Siam Co., Ltd., 1715 Rama IV Rd,
Samyan, BANGKOK 5. Tel. 2511630
TURKEY – TURQUIE
Kültur Yayinlari Is-Türk Ltd. Sti.
Atatürk Bulvari No : 77/B
KIZILAY/ANKARA. Tel. 17 02 66
Dolmabahce Cad. No : 29
BESIKTAS/ISTANBUL. Tel. 60 71 88
UNITED KINGDOM – ROYAUME-UNI
H.M. Stationery Office, P.O.B. 569,
LONDON SE1 9NH. Tel. 01.928.6977, Ext. 410 or
49 High Holborn, LONDON WC1V 6 HB (personal callers)
Branches at: EDINBURGH, BIRMINGHAM, BRISTOL,
MANCHESTER, BELFAST.
UNITED STATES OF AMERICA – ÉTATS-UNIS
OECD Publications and Information Center, Suite 1207,
1750 Pennsylvania Ave., N.W. WASHINGTON, D.C.20006 – 4582
Tel. (202) 724.1857
VENEZUELA
Libreria del Este, Avda. F. Miranda 52, Edificio Galipan,
CARACAS 106. Tel. 32.23.01/33.26.04/33.24.73
YUGOSLAVIA – YOUGOSLAVIE
Jugoslovenska Knjiga, Terazije 27, P.O.B. 36, BEOGRAD.
Tel. 621.992

Les commandes provenant de pays où l'OCDE n'a pas encore désigné de dépositaire peuvent être adressées à :
OCDE, Bureau des Publications, 2, rue André-Pascal, 75775 PARIS CEDEX 16.

Orders and inquiries from countries where sales agents have not yet been appointed may be sent to:
OECD, Publications Office, 2 rue André-Pascal, 75775 PARIS CEDEX 16.

65579-9-1982

OECD PUBLICATIONS, 2, rue André-Pascal, 75775 PARIS CEDEX 16 - No. 42335 1982
PRINTED IN FRANCE
(75 82 05 1) ISBN 92-821-1078-8

(75 82 05 1) ISBN 92-821-1078-8 F 45/900