A FREIGHT FORECASTING MODEL FOR THE NETHERLANDS

Hans J.Roodenburg and J.Eric Jansen
Netherlands Institute of Transport - Rijswijk - The Netherlands

I - INTRODUCTION

This paper presents a freight forecasting model for the Netherlands. The model has been operational for about two years and extensive use has been made of it over that period. The paper therefore not only discusses the model from a theoretical point of view, but also goes into the experience obtained by building and using an operational model.
Section II gives some general information on transport in the Netherlands. Section III introduces the model, and the data needed to construct the model are dealt with in section IV.
Section V presents the model in more detail, briefly discussing the various sub-models. Section VI gives an appraisal of the model and discusses the way the model could be and has been used.

II - SOME FACTS ON TRANSPORT IN THE NETHERLANDS

Freight transport is relatively more important to Holland than to any other European country, due almost entirely to its position at the end of Europe's most important river. A large proportion of the transport in the Netherlands is destined for or originates from West Germany, making use of one of the Dutch sea ports.
In addition, Holland has an extremely open economy - more than half of the domestic product is exported - so that the international freight flows are relatively heavy. Table one gives the distribution of the total inland transport in tonnes for various categories in the year 1974.

The transport flows between the original six E.C. countries for the year 1972 are presented in diagram 1. From this diagram the relative importance of transport between Holland and W.Germany is immediately apparent.
A second point which places Holland in a special category is the importance of inland shipping. A large network of rivers and canals provides opportunities that do not exist elsewhere in Europe. In investigating inland transport, this paper will therefore consider three modes of transport : road, rail and inland shipping.
Table 1 gives the shares held by the three modes for the various categories of transport. Table 2 compares the modal split of the total transport (in tonnes) for Holland and Great Britain.

The density of population in Holland, and the need to compete with other European ports (Antwerp, Hamburg etc.) have accentuated the importance of an adequate and efficient transport infrastructure.

III - THE MODEL

3.1 - Background , scope

The situation as described in section II, plus the enormous growth in the volume of transport at the time, led the Dutch authorities in the nineteen sixties to initiate a study of the entire transport sector. As part of this very large project the N.V.I. developed a model for the three most important inland transport modes: road, rail and inland shipping. Pipelines were not explicitly included in the model - because of their specific characteristics - and air transport was omitted as it has little significance to the investigation.

Table 1 - Distribution of total transport for some transport categories in 1974

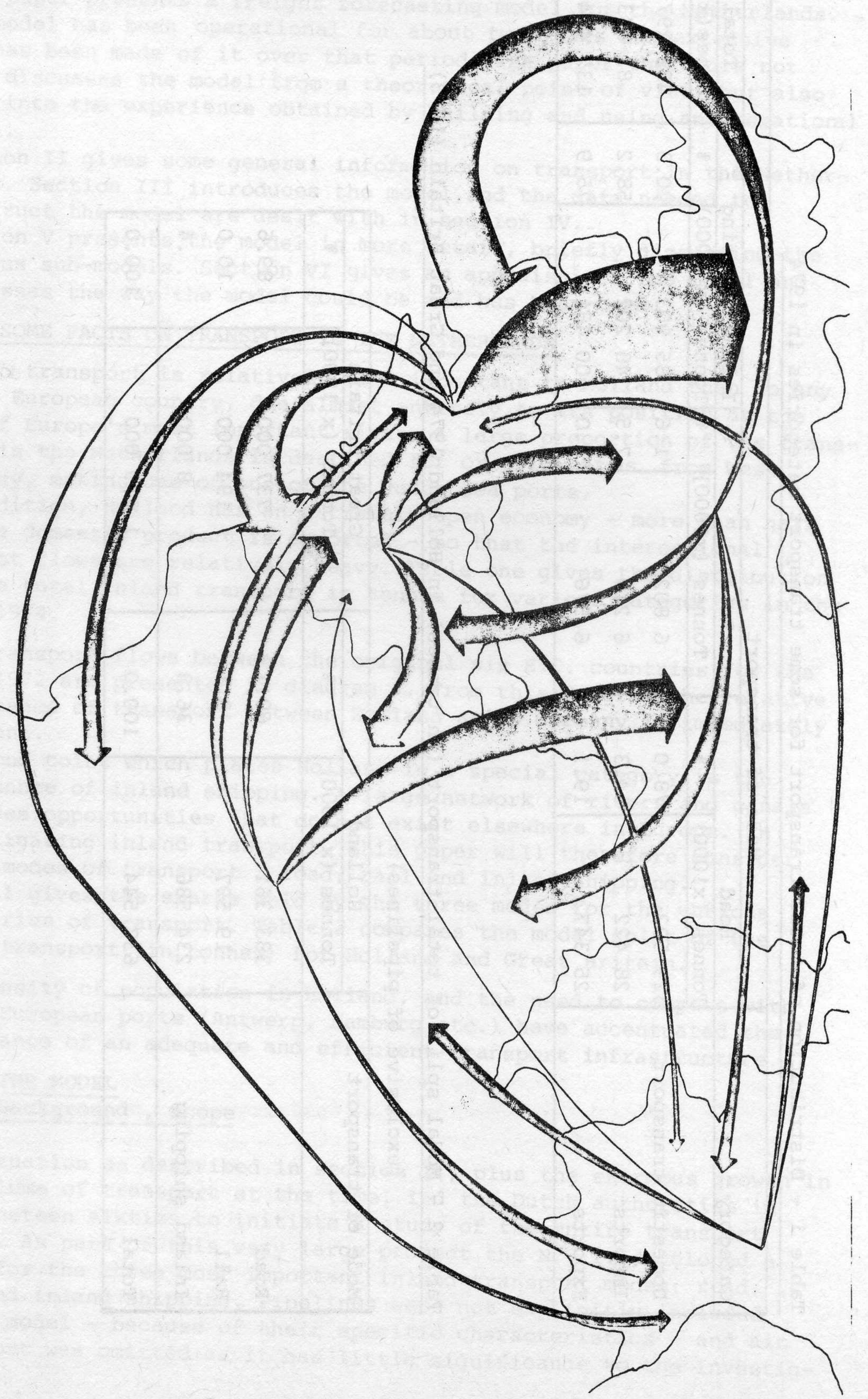
Category	Mode of transport							
	Road		Rail		Inland shipping		Total	
	Tonnes (x1000)	%	Tonnes (x1000)	%	Tonnes (x 1000)	%	Tonnes(x 1000)	%
Domestic transport	329 592	78.0	6 802	1.6	85 903	20.3	422 297	100
Imports	28 422	34.3	6 219	7.5	48 202	58.2	82 843	100
Exports	25 347	19.1	6.576	5.0	100 481	75.9	132 404	100

Table 2 - Modal split of total transport (in tonnes) in Holland (1974) and Great Britain (1973)

(exclusive of pipelines)

Mode of transport	Holland		Great Britain	
	Tonnes (x 1000)	%	Tonnes (x 1000)	%
Road	383 361	60.1	1 737 000	89.6
Rail	19 597	3.1	194 000	10.0
Inland shipping	234 586	36.8	8 000	.4
Total	637 544	100.0	1 939 000	100.0

Diagram 1 - Transport flows between the original six E.C. countries
(exclusive of pipeline)



The object of the exercise was to obtain a model which could be used as a tool in gauging the policy in traffic problems in general and on questions regarding the infrastructure in particular.

3.2 - Theoretical outline of the model

Figure 1 presents the structure of the model. This is the standard structure of most transport models, and further information may be obtained from references.*

Two points affected the size and usefulness of the model:
-the number of zones
-the number of commodity groups

In the present model the number of zones is 76. Although this might appear a large number for a geographically small country, for certain purposes a larger number of zones would be desirable. The number of commodity groups was fixed at fifteen, which hitherto has proved satisfactory.
Until the "traffic production" phase of the model, all calculations are carried out according to commodity group. This has the advantage that future changes in the distribution of total transport over the commodity groups will be fully indicated by the model. As the transport of each commodity may be very differently structured, this is a point of considerable importance.
Differences between commodity groups exist not only for modal split and distribution but also for distribution according to class of ship, type of vehicle or rolling stock.

IV - THE DATA

Building a model such as the one discussed here requires a great deal of data. Researchers in Holland are in a privileged position in having access to a great amount of data already collected.
The necessary information can be divided into three parts:

a) Freight matrices, base year

The model takes the transport matrices for the base year as a starting point. The total transport flows in Holland are divided into domestic transport, export, import and transit without transhipment. The export and import flows also include the transit transport which comprises a considerable proportion of the total.
For the domestic freight matrix the following information was available per mode of transport and per origin/destination pair:

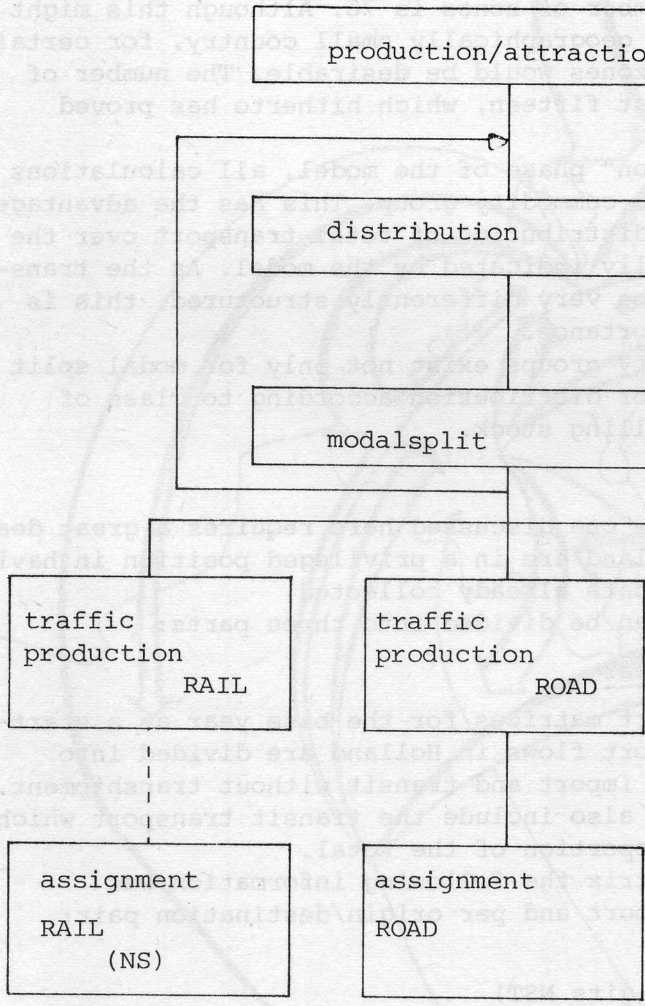
-tonnes carried
-commodity group (3 or 2 digits NST)
-number of journeys
-type of vehicle / ship / rolling stock
-tonne-kilometers

The information on international freight transport was less detailed and did not, for example, give information on the number of journeys for all modes.

---

* Modal choice in freight transport. J. van Es and C.J.Ruijgrok Paper presented at the International Conference of Transportation Research - Brugge 1973.

Figure 1 - Structure of the model



b) Cost and tariff functions

In two parts of the model cost and/or tariff functions are needed: the modal split and the traffic assignment. In the latter case costs are used as a basis for choice between alternative routes, while in the former costs or tariffs are used to decide between the alternative modes.
The transport costs are made up of costs per kilometer and costs per hour.
The cost functions used present the transport costs as a function of distance, size and type of vehicle (ship etc.). There are in principle different functions for different commodity groups.
The functions not only include information on direct costs, such as the costs of tyres, but also reflect the structure of the transport industry (e.g. degree of utilization of the rolling stock (ships); the number of unladen kilometers).
The composition of these functions facilitates the inclusion of changes in the level of cost components: labour, materials, energy and taxes.

c) Networks

Data was required in order to construct the road and inland waterway networks (the rail assignment is not incorporated in the model).
It may be noted that a network of inland waterways is a great deal more complicated than a road network. The former will include locks, with their resistances (as a function of traffic volume), bridges with their restriction on head room and opening hours (railway bridges) and rivers with different speeds for the two directions.
Moreover the accessibility to ships varies among the canals and the rivers.

V - THE MODEL IN MORE DETAIL

a) Production - attraction

The aim of a production-attraction analysis is to formulate forecasts for the total transport from (production) and to (attraction) each zone. Solving this problem directly requires a lot of detailed information (population per zone, output per industry per zone etc.) plus a great deal of time. When developing the present submodel, the amount of time available was limited. It was therefore decided to perform the calculations in two parts:
-estimate the overall total
-establish the distribution over the different zones

The overall total (i.e. the total tonnes carried) was then forecasted directly by linking it to a number of exogeneous variables, using time series analysis. This was done for each of the fifteen commodity groups and for each category of transport.
One of the advantages of this approach is that the forecasts are dependent upon a set of assumptions regarding the exogeneous variables. Some of the exogeneous variables used in the present model are: gross national product - industrial production - production of the building industry - steel production in W.Germany - share of the power bill attributable to oil.

The second part of the production-attraction analysis, i.e. establishing the distribution over the different zones, was solved by keeping the shares of the respective zones constant.

An exception was made for one commodity group - sand and gravel. For this very important commodity group - 31% of domestic transport - the distribution over the zones was established in a rather complicated way, taking the production potential of each zone into account.

b) Distribution and modal split

The distribution and modal split phase of the model is solved differently for domestic and international transport. The domestic model, which is of greater interest, will be discussed here. The distribution function, calibrated for each of the commodity groups separately, had the following general form:

$$\ln T_1 = \alpha_1 \ln T_6 + \alpha_2 \ln T_7 + \alpha_3 \ln X_4 + \alpha_4 \ln X_{11} + \alpha_5 \ln X_{13} + \alpha_0 \qquad (1)$$

where,

T_1 = transport volume per origin/destination pair (relation)

T_6 = row total

T_7 = column total

X_4 = weighted distance per relation

X_{11} = weighted costs per relation

X_{13} = weighted time per relation

The resistance variables X_4, X_{11} and X_{13} were weighted according to the shares of the respective modes. This makes the distribution dependent on the modal split. The modal split is dependent upon the distribution, as can be seen from the general form of the equations:

$$\ln\frac{a_r}{a_W} = \alpha_1 \ln\frac{R_{12}}{W_{11}} + \alpha_2 \ln\frac{R_{14}}{W_{13}} + \alpha_3 \ln T_1 + \alpha_4$$

$$\ln\frac{a_b}{a_W} = \beta_1 \ln\frac{B_{12}}{W_{11}} + \beta_2 \ln\frac{B_{13}}{W_{13}} + \beta_3 \ln T_1 + \beta_4 \qquad (2)$$

where,

a_r = share rail

a_b = share inland shipping

a_w = share road

R_{12}, B_{12} = tariffs (per tonne) for rail and inland shipping

W_{11} = transport costs (per tonne) road

R_{14} = transport times rail (excluding night hours)

B_{13}, W_{13} = transport times inland shipping and road

T_1 = transport volume

The model represented by the equations (2) is a so called "share model" (the sum of the calculated shares = 1).

The interdependence between distribution and modal split is determined iteratively: first the distribution is calculated using the modal split shares of the base year, then the modal split is carried out and after that the distribution again, using the newly calculated modal split shares. The process continues until equilibrium has been reached.
The following equation - for the commodity group miscellaneous articles - serves as an example of distribution equations:
(t-ratios are shown in parentheses)

$$\ln T_1 = \underset{(57.01)}{.832 \ln T_6} + \underset{(55.56)}{.889 \ln T_7} - \underset{(35.40)}{.881 \ln X_4} - \underset{(32.13)}{1.02 \ln X_{11}} - \underset{(18.47)}{6.33}$$

R = .823

For the modal split the equations for the commodity group ores and metal waste serve as examples:
(t-ratios are shown in parentheses)

$$\ln\frac{a_r}{a_W} = - \underset{(8.91)}{4.150 \ln\frac{R_{12}}{W_{11}}} - \underset{(2.39)}{1.041 \ln\frac{R_{14}}{W_{13}}} + \underset{(2.54)}{.487 \ln T_1} - \underset{(1.12)}{1.965}$$

R = .718

$$\ln\frac{a_b}{a_W} = - \underset{(4.84)}{4.221 \ln\frac{B_{12}}{W_{11}}} + \underset{(1.57)}{.361 \ln T_1} - \underset{(1.92)}{3.73}$$

R = .397

c) Traffic production

The traffic production model translates the freight flows into traffic flows, laden and unladen. Calculating the laden journeys is done by raising the number of journeys in the base year by the relevant growth factor. The possibility exists however to change the distribution according to class of vehicle (ships etc.) by specifying a growth factor for the average loading capacity of the transport equipment. The model then shifts the distribution to the right until the desired growth has been reached. Safeguards have been built in to check against inadmissible outcomes (e.g. lorries bigger than the maximum allowed).
The unladen journeys are calculated in different ways for the different modes of transport. For rail this exercise is undertaken by the Dutch Railways.
The empty lorry movements are estimated per relation as a function of the number of loaded lorry movements in the opposite direction and the distance.
For inland shipping an advanced distribution model, predicting the empty ship movements, is under construction.

d) Assignment

In the final stage of the model the traffic will be assigned to the different networks. For rail this is carried out by the Dutch Railways and therefore not incorporated in the model. For road and inland shipping the model has two options:

- all-or-nothing (congestion not taken into account)
- capacity restraint (congestion taken into account)

The capacity restraint assignment takes as its starting point the all-or-nothing solution and tries to find a better solution by selecting alternative routes which have become more attractive because of delays on the initially chosen route. The criterion used here is the transport costs, made up of costs per kilometer and per hour.
The capacity restraint assignment is an iterative process, which can be said to have generated a satisfactory solution if the transport costs of alternative routes are approximately equal.
A capacity restraint assignment for road, makes sense only if the passenger traffic is assigned simultaneously. A similar model for the passenger traffic has not yet been developed, so that a capacity restraint assignment has so far not been undertaken by the N.V.I.

For inland shipping the situation is quite different, as there is very little interaction between freight transport and water recreation. It should be noted that a capacity restraint assignment is more complex for inland shipping, than for road, because of the complexity of the network and the heterogeneity of the traffic production.*

The present procedure uses an algorithm which guarantees satisfactory solutions (as defined above) in the case of homogeneous traffic production.**
In a situation involving many classes of traffic a satisfactory solution cannot however be guaranteed.
Past experience at the Institute has therefore led to various adjustments in the mechanism which controls the transition from one iteration to another. The capacity restraint assignment model has now reached a stage where the results are normally as good as might reasonably be expected.

VI - APPRAISAL AND APPLICATIONS

6.1 - Appraisal

A model structured as described here, always has drawbacks because of its very structure. The two main points are:
- the mainly sequential approach
- the high degree of aggregation, especially regarding the spatial differentiation.

These points, common to all transport models of this kind, will not be discussed here.
Probably the strongest point of the model is the large amount of initial information that goes into it. Because of the relatively good quality of statistics on transport matters available in the Netherlands, it was possible to establish the structure in the base year in great detail.
A second point is the fact that the exercise, insofar as is needed, is carried out per commodity group. This means that differences in

---

* Lock capacity and traffic resistance of locks
Ir.C.Kooman, P.A. de Bruijn- Rijkswaterstaat,The Hague 1975

** A new look at some old problems in transportation planning
Michael Florian and Sang Nguyen; paper presented at PTRC summer annual meeting - 1974.

the structure of the transport of different commodity groups are automatically carried right through the model.
On the other hand, it should be noted that the model does not consider the relationship between land use and transport; the distribution of total transport according to zones, for example is in most cases kept constant. This means that the model will be most suited for use in the medium/long term (up to 10 years) as the land use will not in general change appreciably in such a period.

6.2 - Applications

The results from the model are twofold:

1 - forecasts of the volume of transport by mode and commodity group
2 - volume of traffic per link

When calculating these results the model requires input of a great number of exogenous variables. These variables can be broadly divided into three groups:

a) socio-economic variables; they determine the growth in the volume of transport
b) variables that determine the transport costs/tariffs (e.g. wages, price of energy, taxes etc.)
c) specification of the various networks

The model therefore provides the opportunity to calculate the marginal or simultaneous effects of certain assumptions regarding the exogeneous variables mentioned. For instance it would be possible to calculate the effect of a certain transport policy (defined by the variables under b) on the modal split or on the traffic volume of any of the three modes. Because of the uncertainty about the future values of the socio-economic variables, these calculations could be carried out for two sets of alternative developments, such an exercise being facilitated by the flexible structure of the model.

The model has so far been used in particular to assist the medium/long term planning for the inland waterways. From the traffic volumes per link the potential bottle-necks in the networks become immediately apparent.

Recently the model has been used to evaluate alternative schemes for the improvement of a group of canals in the south of Holland. By modifying and extending the existing model it was possible to calculate the total transport costs for each of the five schemes. The benefits of the respective projects were then calculated by taking the difference between the transport costs of each of four schemes and the fifth scheme ("nul alternative"). These benefits were used in a cost-benefit analysis.
Although the model has produced very satisfactory results and has proved to be a useful tool in decision making, development is still in progress to improve the reliability of the model and increase its potential.