The Dynamics of Supply and Demand in Shipping

By

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Abstract

The balance (or imbalance) between supply and demand for cargo-carrying capacity has a very important influence on the behaviour of ship-owners and operators. Conversely, the behaviour of the decision-makers is, itself an influence on the supply/demand ratio. This paper shows that the shipping industry, in particular the dry cargo market, behaves as a dynamic system and a simple model of this system is described.

Introduction

The Shipping Industry, like many other large industries, exhibits behaviour which may be termed 'dynamic'. Within the industry there exist particular factors which may be measured over time, and by examination of the pattern of fluctuation it can be determined whether or not any given fluctuation is due to random variation. If randomness is not the principle cause of the dynamic behaviour then it may be possible to analyse the system producing the behaviour and to construct a working system model.

Figures 2,4 and 6 illustrate some examples of fluctuations which have been observed in the shipping industry. In no case are these fluctuations explained satisfactorily by an hypothesis of random variation.

The level of freight rates can be extremely important in the profitability or cost of an operation which requires the shipment of goods by sea. Developing countries, for example, depend heavily on exports and imports and so the freight rates are of major importance to them. The purpose of the present study which is outlined briefly here, is to understand the mechanisms which produce such behaviour. If the system structure is identified and its behaviour well understood it may be possible to design policies which control the large fluctuations in, say, freight rates. The use of System Dynamics models for the design (and re-design) of management policies and system-structure is reported in the literature (1).

The first step taken by the author, in an attempt to construct a dynamic model of the Shipping Industry, has been to model a sector of the industry concerned with the carriage of dry cargo. This preliminary model is described in the next section of this paper.

A Dynamic Model

The existence of a structure emenable to the modelling approach of System Dynamics has been described by the author in a previous paper. (2). The model outlined in the present paper is highly aggregated, being based on the world market for dry cargo shipping, and consists of a set of simultaneous difference equations using the concepts of 'level' and 'rate' variables. The principles of System Dynamics are well documented elsewhere (3,4) and the interested reader is encouraged to refer to these for further details.

As a whole, the model may be depicted as in Figure 1, which shows the interactions of the various parts of the system with one another. The positive and negative signs in the figure indicate the directions of change in the various cause-effect links. For example, an increase in 'SCRAP RATES' leads to a decrease in 'TONNAGE IN SERVICE' and hence the negative sign.

There are six sectors within the model framework: Shipbuild Orders and Deliveries, Scrapping, Lay-up, Trade Change, Freight Rate, Supply. Brief descriptions of these sectors follow:

Shipbuild Orders and Deliveries

It has been often observed (5,6) that when freight rates are high shipping companies rush to place orders for new ships. Also it has been noted (7) that 'in the longer term the course of freight rates has been affected by bursts of shipbuilding orders placed in response to what may only be short term increases in rates'. This illustrates the circular nature of the system under study and shows how causal loops are seen to exist.

There are many factors which can influence the ship-owners' decision to build a new vessel but for the purpose of the model the most important factor is taken to be profitability. Profitability is dependent upon the level of freight rates and it is perhaps easy to understand the empirical evidence which shows that shipbuild orders are sympathetically linked to (spot-charter) freight rates. (See Figure 2). The statistical correlation between these variables is high, with a correlation coefficient of 0.76 for a lag of 2 months in the freight rate data. This lag reflects the time delay between the decision to order and the actual receipt of the order by the shipyard.

The decision to build a vessel has no effect on the immediate supply of cargo space available. Future supply will be augmented since a delay between the placing of the order and the delivery of the vessel is inevitable. In the simple model described here this delay is taken as a constant although it is accepted that the queue of orders during good shipping years will extend past that normally obtained.

Figure 1   The Structure of the Model

The equations used to model this sector of the system are as follows:-

$$b_t = b_o \times m_{t-di}$$

$$D_t = b_{t-d2}$$

$$B_t = B_{t-1} + b_{t-1} - D_t$$

$$m_t = \text{Table Function } (f_t)$$

Where b_t is the build ordering rate over the period t to t+1 in deadweight tons (dwt)

b_o is the 'normal' build ordering rate (dwt)

m_t is an order-rate multiplier which is a non-linear function of the freight rate index, f(t), and is computed via a Table Function

D_t is the tonnage delivered at time t. (dwt)

B_t is the total order book (dwt)

f_t is the freight rate index at time t

d_1 is a perception and order delay (months)

d_2 is a delivery delay (months)

The table function used to compute the value m_t is based on the graph of Figure 3. A rough curve has been used as an approximation to the exact elasticity curve and in this model an attempt has been made to differentiate between periods of high and low freight rates. During these periods the function may take a slightly different form.

Scrapping Sector

The tonnage of vessels scrapped over any period will depend upon such factors as the age distribution of the fleet, the prevailing profitability of older vessels, and the level of scrap prices.

In the model the concept of a 'normal' rate of scrapping is used to eliminate the dependency on age distribution, and freight rates are taken as a proxy variable for profitability.

The dependency of scrapping upon the level of freight rates is easily understood; an owner is unlikely to scrap a vessel during periods of high rates when it is possible for even old, uneconomic vessels to be profitable. As long as the owner's expectations remain high he will keep the vessel active, and only when future rates are expected to be low will he resort to the withdrawal of the vessel and its scrapping. This is tantamount to continuously assessing the economic life of the vessel.

It may be expected that the price for scrap will be dependent upon the quantity available Figure 4 illustrates the way in which these factors have changed over time. The statistical correlation coefficient for the interaction of these factors is -0.972 for a lag of 4 months in the 'quantity' variable.
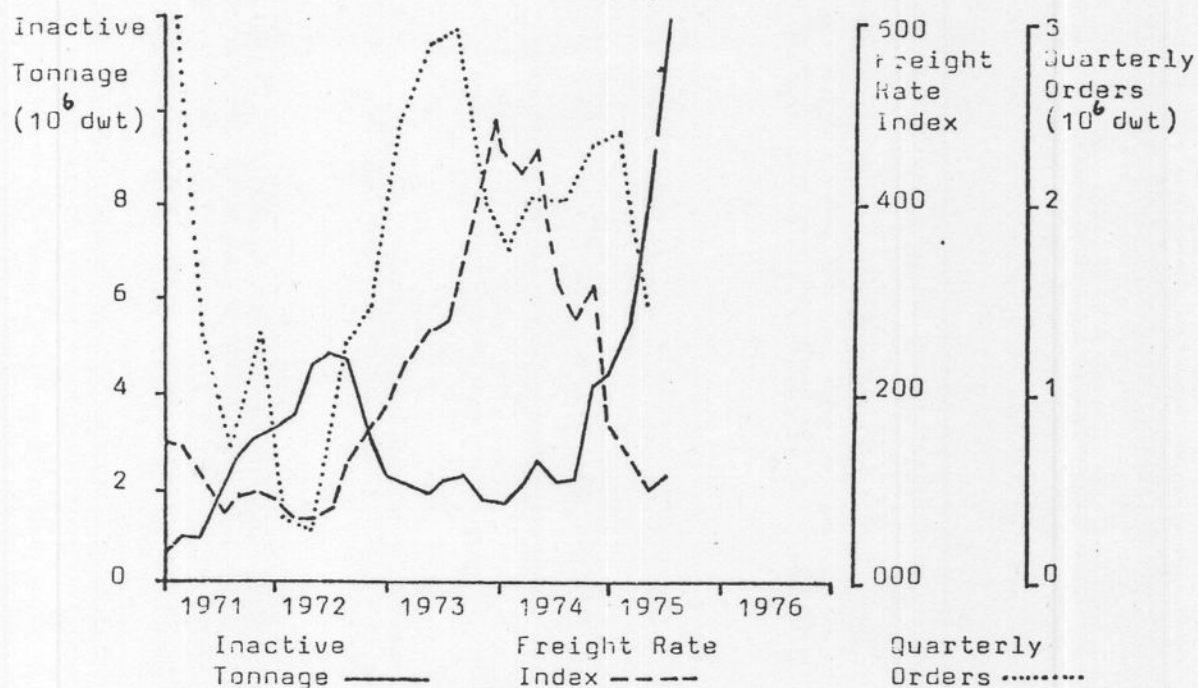
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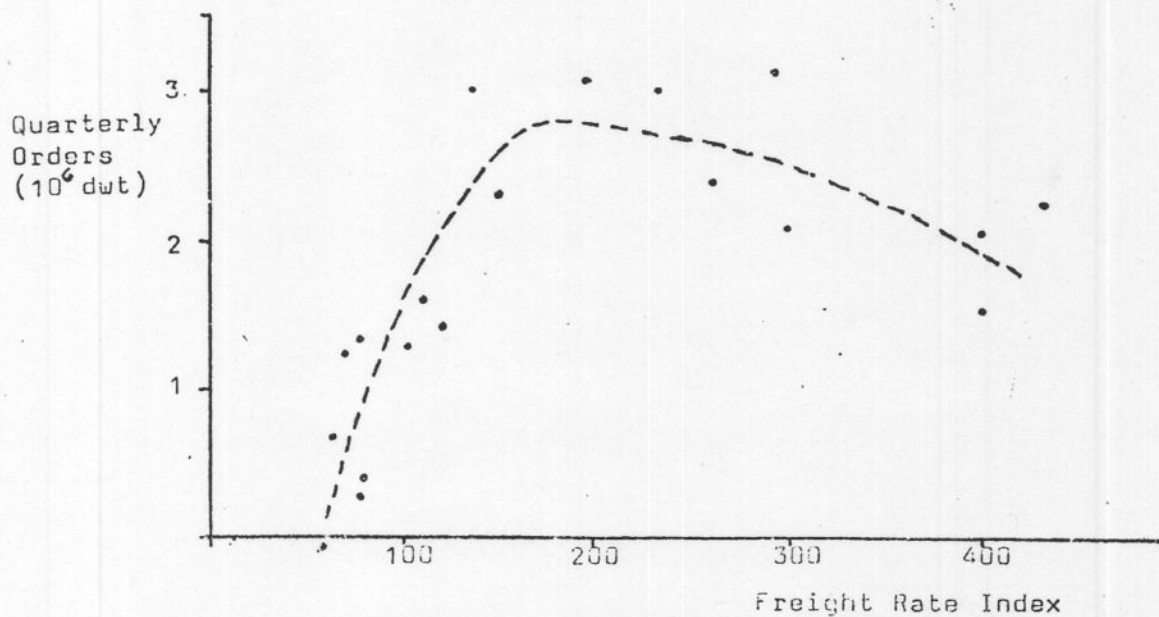Figure 2. Fluctuations in some variables in
the dry cargo market

Figure 3. Variation of dry cargo quarterly orders
with freight rates

Future requirements for scrap steel are not taken into account in this model although it is hoped that this will be incorporated as the model is developed further.

The equations used for this and following sectors are similar in form to those shown earlier.

Lay-up Sector

The argument behind the reason to lay-up a ship is simular to that for scrapping with the difference that 'old' vessels are scrapped whereas any vessel may be laid-up. Expectations of low freight rates leads to a rise in inactive or laid-up tonnage. Thorburn (8) noted that "the extend of the laying-up is mainly influenced by the level of freight rates and has significant repurcussions of the freight level". Here, in fact, exists the basis of another negative feedback loop (figure 1).

Figures 2 and 5 show, respectively, the extent of the variation in laid up tonnage for a period of years, and the relation between inactive tonnage and the freight rates.

Trade Change Sector

It is to be expected that a vessel will seek more profitable employment in other markets if continued operation in its present market is uneconomic. This is, indeed, the case and, for example, it frequently happens that tankers move into the grain trade when oil-transportation rates are low. Also, the 'combined carriers', having the ability to carry ore, oil and/or other bulk cargoes are able to benefit from changing trades. It must be pointed out, however, that not all combined carriers are equally able to take advantage of all trades, due to long-term commitment of inability to navigate certain waterways.

As a measure of the relative profitability of the dry cargo market the ratio

Dry Cargo Freight Rate/Worldscale

was determined on a monthly basis for a number of years. (Worldscale is an index of the tanker freight rates in the transportation of crude oil). Also determined was the percentage of the combined carrier fleet which was operating each month in the dry cargo market. (See figure 6). The statistical correllation coefficient for the linking of thes variables shows a value of 0.839 for a lag of one month in the ratio.

Freight Rate Sector

The formation of the freight rate is determined by the level of competition in the market, where competition is measured as the ratio of supply to demand for cargo space. Demand, in this model, is an exogenous variable and no account is taken of the (relatively weak negative feedback from the level of freight rates.
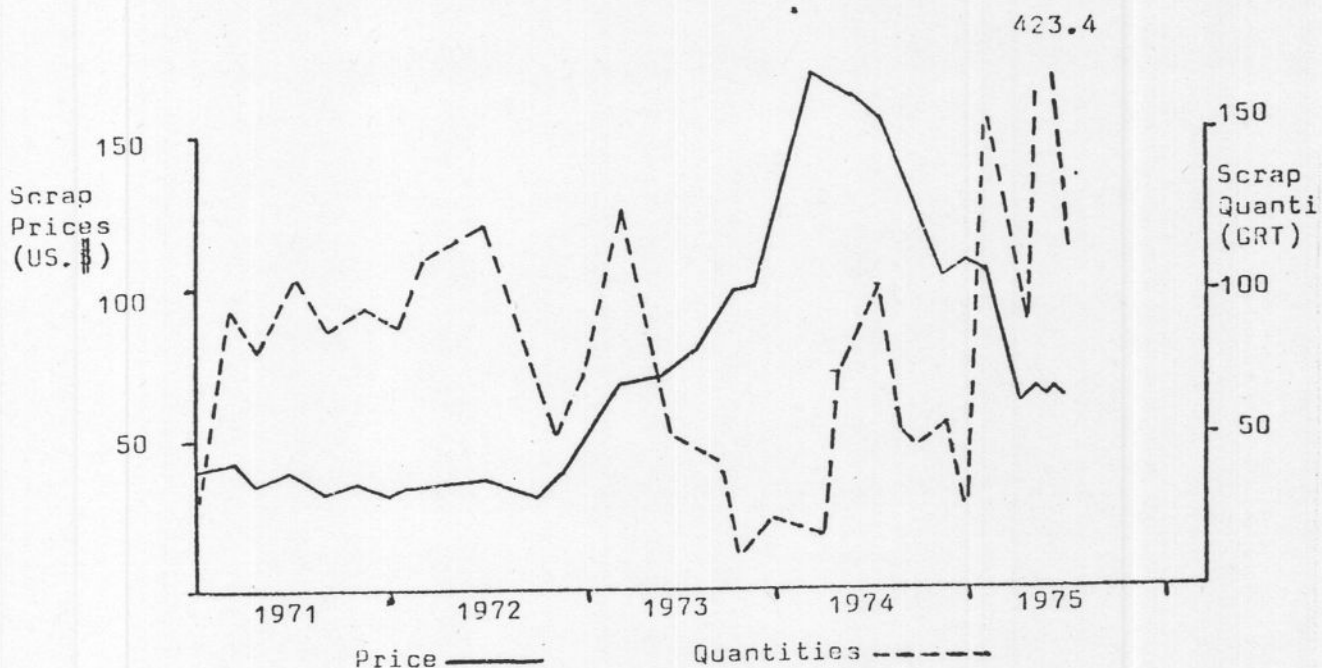
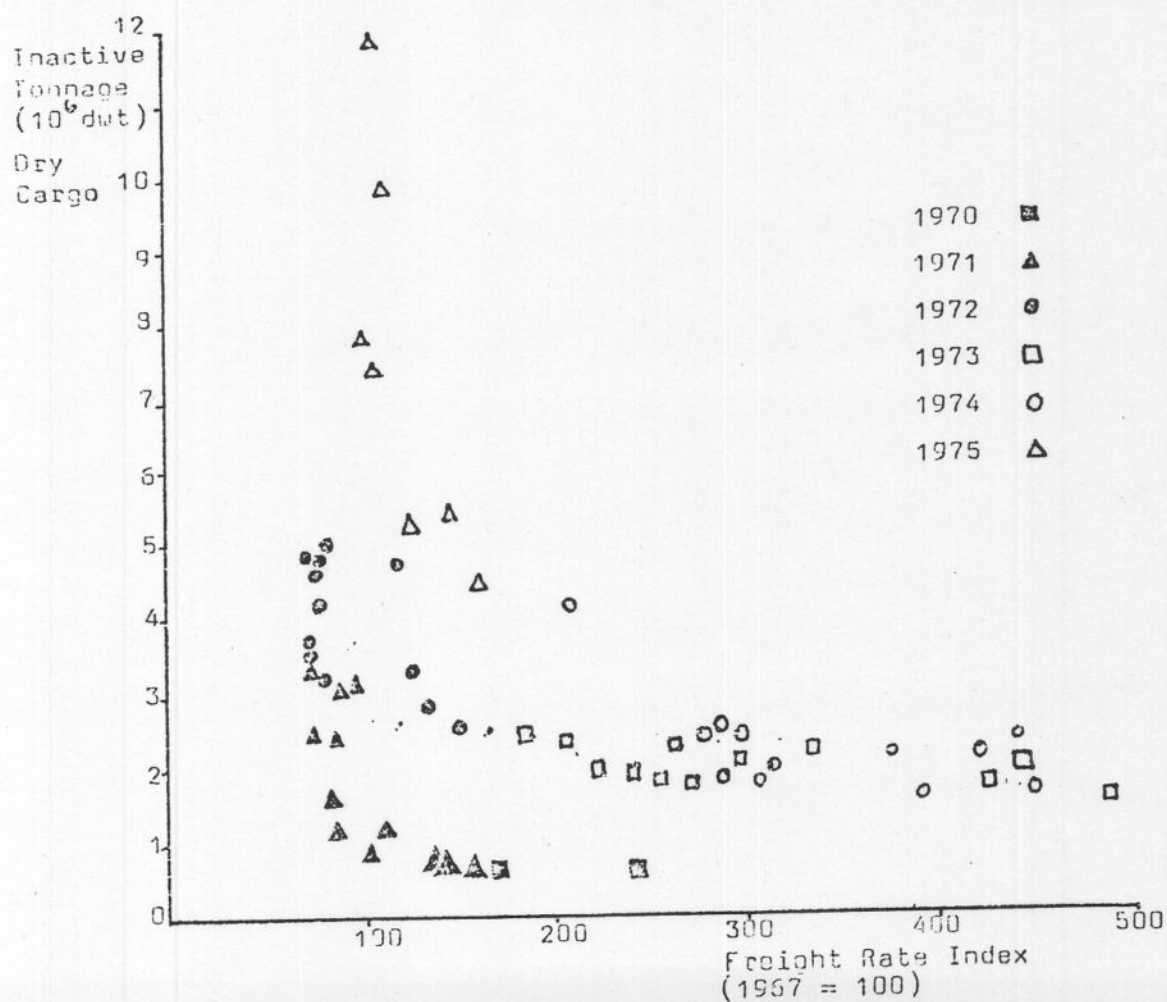Figure 4. Scrap price and quantity(Europe)

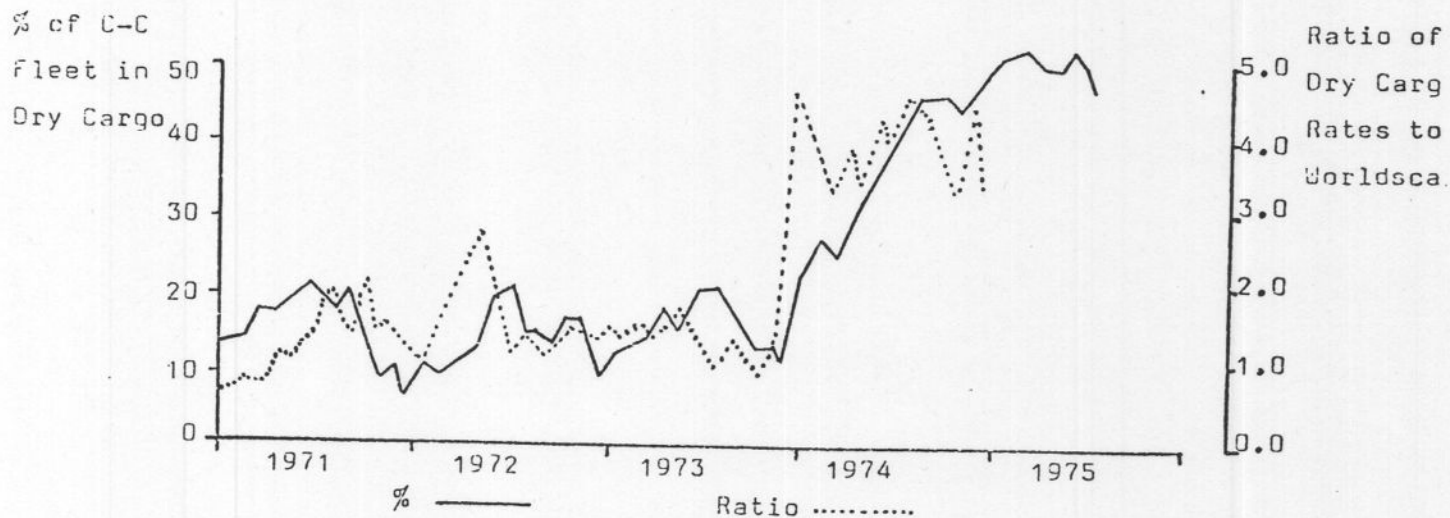Figure 5. Variation of inactive tonnage with freight rate

% of C-C
Fleet in 50
Dry Cargo 40

30

20

10

0

Ratio of
Dry Carg
Rates to
Worldsca

5.0

4.0

3.0

2.0

1.0

0.0

1971   1972   1973   1974   1975

% ———   Ratio ···········

Figure 6. Changes in the percentage of the combined-
carrier fleet operating in dry cargo

Inactive tonnage
(10^6 dwt)

14

12

10

8

6

4

2

Deliveries
(000 dwt)

600

500

400

300

200

100

Freight
index

175

150

125

100

75

50

D

F

I

0   10   20   30   40   50   60   70   80   90
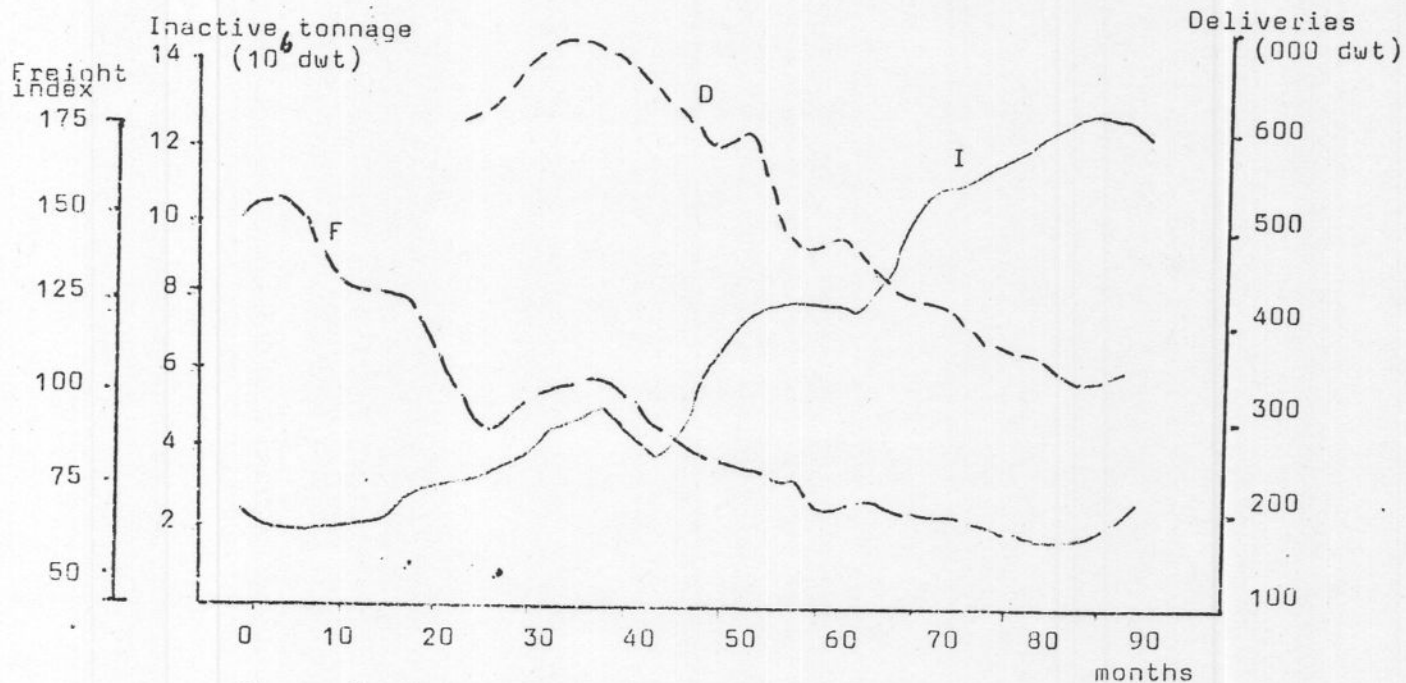months

Figure 7. Output of the model for constant demand

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Supply Sector

This sector calculates the net change in the 'tonnage in service', and it will be seen how any change here will have ramifications throughout the system via the freight rates.

Behaviour of the Model

Using data based on the dry cargo trade for 1970/71 the model was programmed in Fortran IV, with graphical output via a Calcomp Plotter. Figure 7 illustrates the behaviour of the model for a situation of constant demand, and it will be seen how there is a correspondence between the 'simulated' inactive tonnage and the 'real' inactive tonnage. The difficulties of validation for any simulation model are great and no attempt will be made here to discuss this aspect of the problem in hand. Let it suffice to say that, in this case, given that the model is a fairly crude, unsophisticated representation of reality, its behaviour is acceptable.

Space does not permit an exposition of experimentation performed with this model, although the reader will appreciate the types of experiment possible- sensitivity to parameter values, effects of creating and/or suppressing feedback loops, changes in exogenous inputs such as demand.

Future Work

The model, as it stands, is a clear unambiguous statement of the interrelationships in the system and to complicate its construction needlessly would be unwise.

However, certain sectors of the model require extending to bring them into line with the complexities of the shipping industry. Also, it is hoped to build a similar model of the tanker trade so that the tanker freight rates are computed within the overall model, instead of, as present, being inputs.

References

1.   For example: (i) R.G. Coyle, J.A. Sharp, The use of a S.D. Model for the Redesign of a Production Planning System. University of Bradford.

(ii) Clough et al, A Simulation Model for Subsidy Policy Determination in the Canadian Uranium Mining Industry, CORS Journal, Nov. 1965.

2.   A.J. Taylor, Systems Dynamics in Shipping, Paper presented at the Annual Conference of the Operational Research Society, Brighton, 1974.(Oct.)

3.   J.W. Forrester, Principles of Systems, M.I.T. Press

4.   R.G. Coyle, Management System Dynamics - an Introductory Text. University of Bradford. 1974.

5. Thomas Thorburn, Supply and Demand of Water Transport, The Business Research Institute at the Stockholm School of Economics, Stockholm, 1960 p.p. 92

6. Z.S. Zannetos, The Theory of Oil Tankship Rates, M.I.T. Press 1966 pp 76-78

7. Report of the Committee of Inquiry into Shipping, H.M.S.O. 1970 para 524.

8. Thomas Thorburn Supply and Demand of Water Transport, Stockholm 1960 pp. 89.