

Optimisation Experiments with Forecast Bias

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Abstract

Bias, intended or accidental, can, and certainly does exist in forecasts, and the effects of such bias on corporate performance is studied in this paper. Using system dynamics simulations, experiments were performed to examine the sensitivity of a complex crude-oil supply system to forecast bias, and to find bias factors which minimised a simple cost performance indicator. Forecast biases of the order of  $\pm 10\%$  produced variation in cumulative expenditure on the tanker fleet of only about  $\frac{1}{2}\%$  - a very robust system. Minimum cost was obtained with very unlikely values for biases in some forecasts. Though not definitive, these results suggest that managers should think again when blaming poor system performance on the forecasting function.

Introduction

The forecasting function in a company is probably the most vulnerable to the irregularities in the business environment and is a convenient scapegoat for poor system performance; this is evidenced by the popularly expressed belief of managers that their companies would operate much better if they had 'accurate' forecasts. The author has questioned elsewhere (1975) the notion of system performance depending so completely on forecast accuracy, and discussed some system dynamics studies which showed systems which were sensitive to other aspects of the forecast, apart from statistical accuracy.

The problem nevertheless remains that forecasts will not be perfect - they will be degraded by random error, bias, information delays and that these factors will affect system behaviour and performance. This paper is particularly concerned with the effects of bias, and examines the biasing of five forecasts in a complex model of an oil company's crude-oil supply and tanker-chartering operation. The types of bias considered are typically the consistent over - or under - estimation of a forecast variable, or the exaggeration effect of over-forecasting in a rising market and vice versa.

This paper is not concerned with how the biases arise, but simply assumes their presence and includes factors in the model to account for them. In reality these biases may arise from a number of sources, some accidental and some intended:

- Data errors, inaccurate collection or delayed information
- Inadequacies in the forecasting process
- Subjective adjustments to allow for manager's 'gut-feeling'
- Anticipation of the forecast being used as a target

#### The Tanker Chartering Model

In an attempt to examine the effects of forecast bias on corporate performance, this paper describes experiments carried out on the forecasts in a system dynamics model. Coyle (1974) developed a complex model of the supply system of a major oil company involving the problems of production, crude and refined - oil stocks and the transportation of the crude material from its sources of supply. This transportation constituted a highly complex, and financially burdensome, system involving the company's own fleet of tankers, charters on a time or spot-basis and the variation in supply routes from comparatively near or distant oil suppliers. No purpose would be served by describing the model in any detail here, it is described fully in Coyle (1974).

Fig. 1 shows a simplified diagram of the basic structure of the system, the five forecasts under study are included with their variable names underlined.

There is value though in discussing briefly the five forecasts and their purpose in the control system:

1. FRGAT - forecast of the rate of growth of GNP - this forecast is produced from the table input GNP series and is used for the company's own fleet building policy.
2. MDFC - the company's demand forecast - is based on market share and future oil demand and is used in the medium-term for ordering time - charters for delayed presentation.
3. LTFOT - L-t forecast of owned tonnage - is really a medium term forecast (L-t differentiates it from a similar shorter term forecast in the model) of a controlled variable and is used in conjunction with MDFC in time-chartering control.
4. APOI - a short-term forecast of product-offtake - used for time-chartering for immediate presentation
5. ESCPR - short-term forecast of expected spot charter price - this is used in spot-chartering policy. Any discrepancy in carrying capacity is adjusted through spot-chartering, and ESCPR is used in this control process.

The system is driven by three exogenous inputs, time-series representing reasonable histories of GNP, spot- and time-charter prices. The same series were used for all runs, though there is of course no guarantee that results for these runs would apply for any input series.

#### Some Simple Experiments with Bias

As explained earlier the tanker-chartering model contains five forecasts of interest, and some simple experiments involving the degradation of each of these forecasts by various bias factors, as described here:

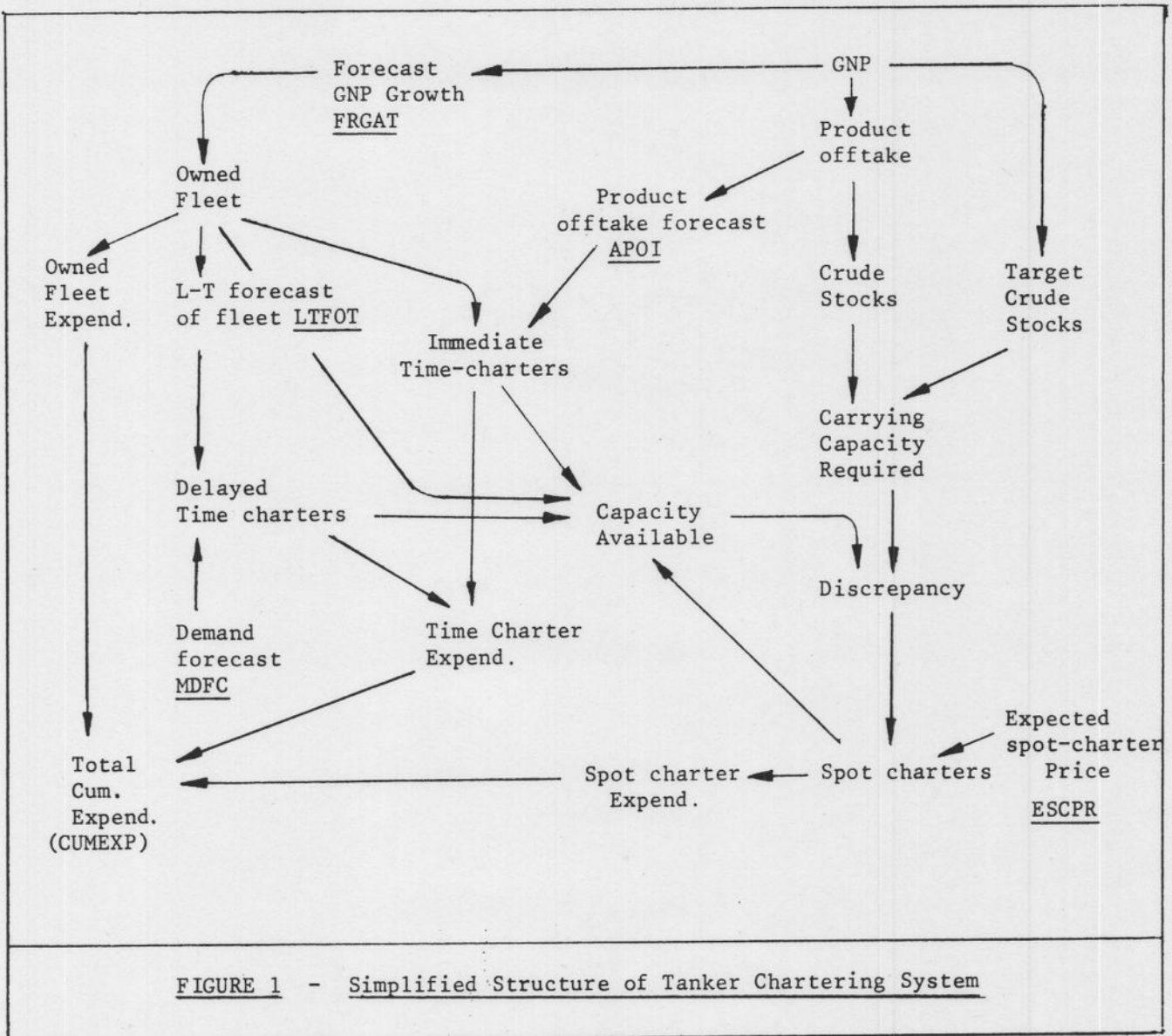
- PERF : bias factor = 1, hence the system assumes a perfect forecast of the variable is available
- PESSI : bias factor = 0.9, a pessimistic forecast assuming the forecast is always under-estimated by 10%
- OPTIM : bias factor = 1.1, an optimistic forecast assuming the forecast is always an over-estimate by 10%
- EXAGER : bias factor varies, it is +10% when the market is rising (i.e. when GNP growth is accelerating) and -10% when falling
- CONTRA : bias factor varies, it is the reverse of the EXAGER case and is -10% in a rising market and v.v.

(It was noted that as these are multiplicative factors applied to the calculated 'perfect' forecast, there may be other biases already introduced by the forecast calculations. - For the demonstration purposes of these experiments these other factors can be disregarded).

The model was run to simulate the behaviour of this system over a period of ten years and the effects of each of these bias factors with each forecast on corporate performance were examined. The performance measure chosen was the company's cumulative expenditure on its shipping fleet, spot - and time-charters and owned tonnage, CUMEXP. It was, of course, realised that many other factors should enter in the assessment of system performance (typically stability in cash-flows and production rates and maintenance of stock levels) and these, though not discussed fully here, were considered qualitatively during the experiments.

CUMEXP, on the other hand, is a simple tangible measure, expressible in money terms. It was also the performance indicator preferred by the oil company in the original study. Such other factors as were mentioned above did not enter greatly into their assessment of system performance or more particularly of the forecasting function, and a recent survey carried out by the author (Winch 1976) amongst practising forecasters did confirm that such simple monetary measures were by far the most popular in performance assessment. The advantage, therefore, of choosing CUMEXP here, is that it will enable consideration of performance on just the sort of criteria as are adopted in the real situation.





BIAS \ FORECAST	FORECAST				
	FRGAT	MDFC	LTFOT	APOI	ESCPR
PERF	45.43	<u>45.43</u>	45.43	45.43	<u>45.43</u>
PESSI	<u>45.26</u>	<u>45.43</u>	45.37	46.84	45.50
OPTIM	45.64	45.48	45.52	<u>44.44</u>	45.45
EXAGER	45.52	45.47	<u>45.25</u>	46.78	45.49
CONTRA	45.34	<u>45.43</u>	45.63	44.59	45.45

**TABLE 1 - CUMEXP (£100m) For Various Biased Forecasts**

The results for cumulative expenditure at the end of each simulation run (10 years) for each combination of forecast and bias factor are tabulated in Table 1. For each forecast, the lowest value of CUMEXP is underlined indicating the bias factor producing the minimum cost result. (As arbitrary time-series were used for GNP growth rate and World Scale tanker prices and the magnitudes of certain variables were altered for reasons of confidentiality, these results should be considered only as relative).

As can be seen, this system appears extremely robust with respect to these forecast biases - with the exception of APOI (product offtake), none of the applied biases alters CUMEXP by more than about  $\frac{1}{2}\%$ . Further there is no consistency between the bias factors, each one at some time producing the minimum cost result. An obvious conclusion from this is that, with one exception, the company need not concern itself with forecast biases at least up to around  $\pm 10\%$ , and that improvement in performance is unlikely to ensue from the elimination of any such biases from the forecasting function.

It is interesting, however, to discover just how much improvement could be made in system performance by choosing the 'best' bias value for each forecast. This can be achieved by incorporating the model into an optimising routine with the bias factors allowed to vary.

#### Optimisation Experiments

The value of optimisation in policy design has been considered by Sharp (1974), who also discusses the use of hill-climbing techniques in problems of global parameter sensitivities (Sharp, 1976).

In these experiments, the intention was to assign a bias variable to each of the forecasts in the tanker-chartering system and to run the optimising routine with the objective of minimising CUMEXP, and finding those optimum values of the bias variables which produced this minimum cost.

This was achieved by incorporating the FORTRAN translation of the DYNAMO model, as produced by the Bradford DYSMAP compiler (Ratnatunga, 1975), into the NAG-ICL-EO4CAF optimising routine (NAG, 1974). The plots of output for two runs, the first with no bias, the second using the optimum bias values from the optimiser, were produced by DYSMAP's 'DRAW' facility.

It will be recalled that the basic value for CUMEXP with no forecast bias was  $\pounds 45.43 \times 10^8$  this compares with the minimum value using the optimum bias values of  $\pounds 44.31 \times 10^8$  - i.e. a reduction of only about 2%. This again confirms that this system is particularly robust with respect to bias in forecasts.

A look at the optimum bias values which produced the minimum cost result proves interesting:

Growth Rate in GNP	:	FRGAT	:	Optimum bias	0.032*
Company Demand Forecast	:	MDFC	:	" "	1.00
L/T forecast of owned tonnage	:	LTFOT	:	" "	1.59
Actual product off-take	:	APOI	:	" "	1.06
Expected spot-charter price	:	ESCP	:	" "	1.18

\*This factor was constrained to remain positive, though extremely small improvement could be made by allowing it to go negative.

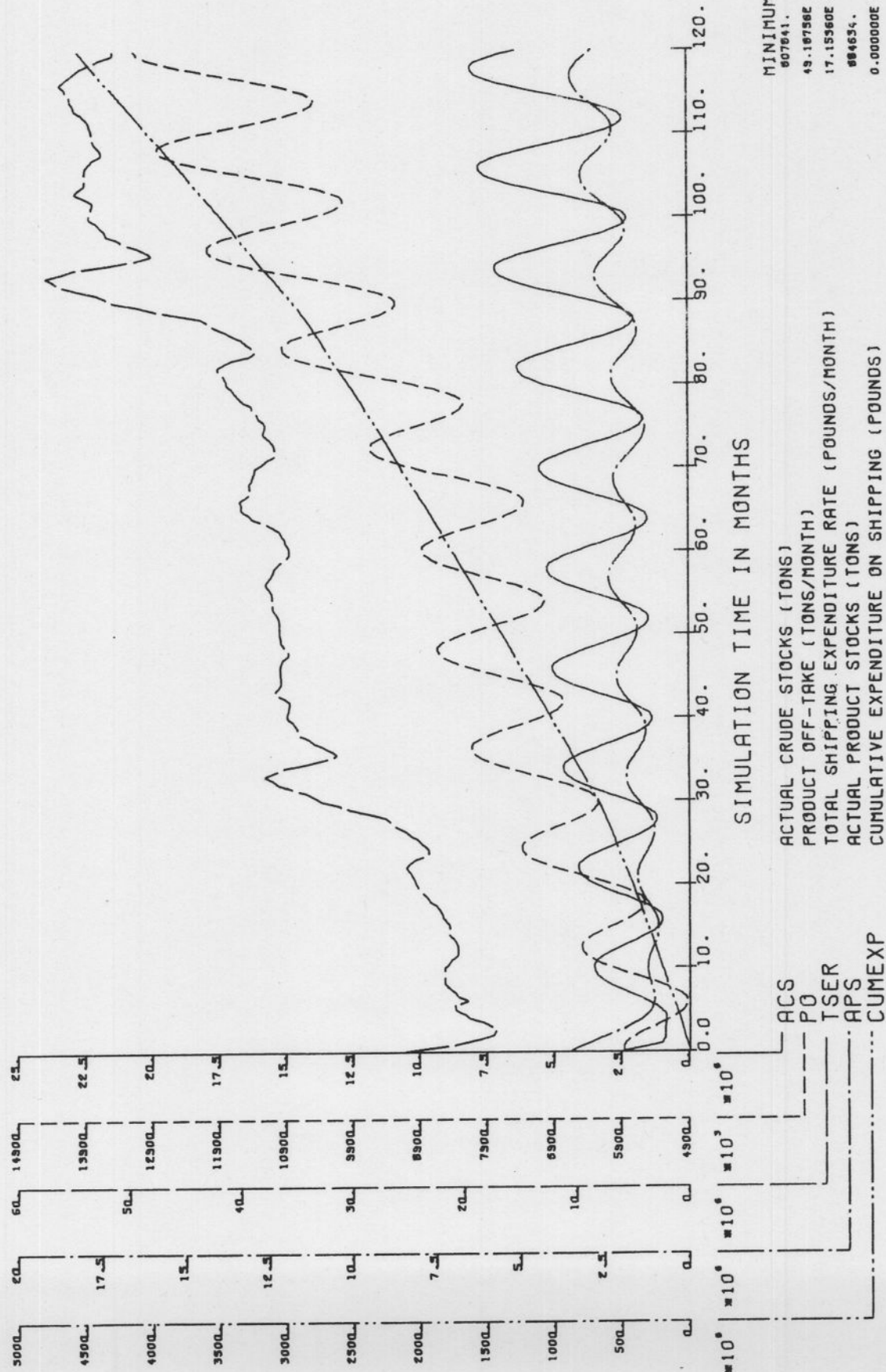
An examination of system structure will give some enlightenment into these values, and each is briefly discussed here. Firstly, the suggested value for FRGAT, the forecast of growth rate in GNP, of near to zero is likely to be due to the fact that the policy of building tankers is more costly to the system than chartering. In a situation, as here, where GNP is always rising, an under-estimate of GNP growth rate will produce a comparatively lower building rate and more emphasis is placed on less costly chartering.

Bias in the company demand forecast, MDFC, has only a marginal effect on the total cumulative shipping expenditure, and although the optimum value is 1.00 variations from this have little effect. MDFC is used in delayed presentation time chartering, and its effects are likely to be over-shadowed by the owned tonnage forecast which is also used.

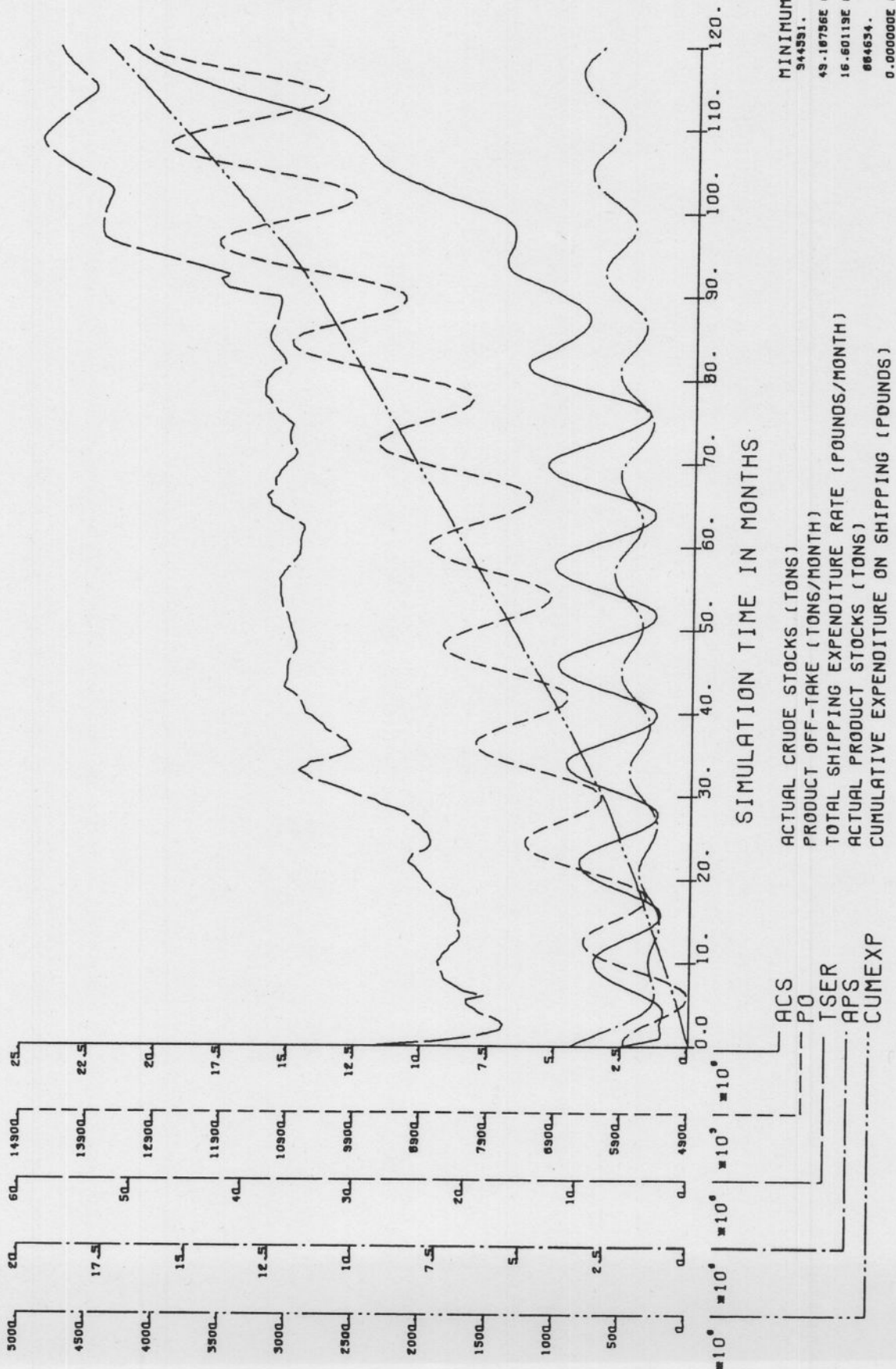
Over-estimation of the forecast of owned tonnage, LTFOT, as suggested by the optimum value of 1.59 will reduce the ordering of time-charters for delayed presentation. The efficacy of this suggests that this sort of time-charter is of limited benefit in terms of reducing total shipping costs.

The optimum value for the bias in the product-offtake forecast of 1.06 suggests again that a slight over-estimate is again beneficial in this estimate. This is likely to be due to the resulting over-ordering of time-charters for immediate presentation, for although there is the obvious drawback that the company is committed to these time-charters for the charter duration, this is likely to be more than compensated by the reduction in need for more expensive spot-charters.





1 NO FORECAST BIAS  
TANKFR CHARTERING: FCASTING IN A COMPLEX SYSTEM



2 BIASED FORECASTS - OPTIM. FOR MIN. CUMEXP  
TANKER CHARTERING: FCASTING IN A COMPIEX SYSTEM



Biases in the final forecast under consideration here, the expected spot-charter price ESCPR, again produce only slight variations in CUMEXP - of the order of fractions of 1%. The optimum value of 1.18 probably has no significance except to confirm that accurate, unbiased forecasts are not required for this variable.

In all the discussion so far, the only measure of system performance has been CUMEXP, the total cumulative shipping expenditure, and the minimisation of this variable was the objective function of the optimisation. As suggested earlier though, there are many other aspects of system behaviour that should be considered in an assessment of performance. The experiments described here did not include any quantitative consideration of these aspects, stock stabilities, cash flow rates and so on, though they could be incorporated into the optimisation objective function.

Some qualitative appreciation can be gained, however, from comparing the output plots of a number of model variables for a base run with no forecast bias, and a run incorporating the optimum bias values (see RUN1 - No Forecast Bias, and RUN2 - Optimum Values for Forecast Bias). Comparison shows that the behaviour of the individual variables plotted is broadly similar for both runs. The variable TSER, the instantaneous rate of shipping expenditure, behaves similarly smoothly for both runs, though in the case of the Optimum Values run this value shows a marked jump around month 95. At about this time the level of ACS, the Actual Crude Stocks, begins to rise sharply and could be expected to cause problems in the real situation.

### Conclusions

The results from the simple bias and optimisation experiments lead to some simple but surprising conclusions. In the first place, this system is extremely insensitive to bias in all the forecasts considered, and secondly optimum performance, at least by the simple criteria used here, is obtained with unexpected values of some of the forecast bias factors. There are severe limitations in this examination, the experiments were performed on only one system and with simple performance indicators, and these should be born strongly in mind when extending these conclusions to the general case.

Nevertheless, despite the limitations of the experiments, they do suggest implications of forecast bias that are not at all obvious. Analysis of the control processes explains how these unexpected results arise and indicates the way managers should consider the role of forecasts in the control and decision making processes. Further, the results indicate that this system is particularly robust with respect to

the forecasts involved, on which the company expends much effort, and the forecasting function is not as effective as it might be when judged by the company's own assessment criterion. It might well be that when other factors like stability in stock levels and cash flow are considered, the use of perfect forecasts may become more appropriate.

As a final word, this study has shown that for a simple performance measure, as typically used in industrial situations, this complex system is particularly robust with respect to forecast bias. Analysis of the control process can explain why, and indicates such other aspects that must be considered by the manager when assessing his forecasting function.

#### References

- Coyle (1974) "Management System Dynamics" - an introductory text"  
University of Bradford, Ch. 11.
- NAG (1974) "NAG Mini Manual for the Nag-ICL 1900\*LIBRARY"  
Nottingham Algorithm Group
- Ratnatunga (1975) "DYSMAP Users' Manual"  
University of Bradford
- Sharp (1974) "A Study of some Methodological Problems of System  
Dynamics" Ph.D. Thesis, University of Bradford.
- Sharp (1976) "Sensitivity analysis Methods for System Dynamics Models"  
Paper to be given at the 5th International System Dynamics  
Conference, Geilo, Norway, July, 1976
- Winch (1975) "Dynamic Implications of Forecasts"  
DYNAMICA, 2, 1
- Winch (1976) "The Role of Forecasts in Management"  
Working Paper, University of Bradford.