"DYNAMICA" ISSN 0306-7564 Volume 2, Part 1

The Dynamic Implications of Forecasts

Some examples showing the way that such forecasting characteristics as bias, errors, sampling and delays affect the dynamic behaviour and performance of corporate systems.

Graham Winch
System Dynamics Research Group
University of Bradford

Work is currently in progress at Bradford System Dynamics Research Group in an attempt to identify and quantify the dynamic effects that such above mentioned factors have on the corporate system as a whole. This is a different approach to forecasting than the traditional one as it is not so much concerned with the actual accuracy (however statistically measured) of the forecast, but, rather how effective the whole forecasting function is at enabling the enterprise to achieve its set goals - steady growth, high profitability, simple survival, or whatever. It thus accounts for such factors as:-

(i) which variables to forecast - forecasting is expensive and blanket-forecasting is likely to be less cost-efficient than first pin-pointing, and then concentrating on, only those variables which affect performance to a significant degree.

(ii) how forecasts are used - the various company functions may demand different characteristics from their forecasts, even forecasts of the same variable; a simple example is that an inventory controller may well want a forecast that is sensitive to fluctuations in demand to enable him to make rapid adjustments. However, a production controller is likely to want a smoother forecast as production will be constrained by much longer delays and cannot be made to fluctuate rapidly.

(iii) other factors are also involved, such as in-built bias due to the forecasters optimism or pessimism, saturation effects, relationship between time-horizons and sampling periods.

There follows some evidence gained during system dynamics studies, both in the Bradford Group and by other institutions, that more than just the statistical accuracy of forecasts must be considered when assessing the effect of the forecasts on the system. Some of the cases are hypothetical in that they are 'manufactured' systems, though based on real situations, others are real studies carried out in close conjunction with companies.

System Dynamics is a technique for studying, and hopefully improving, the behaviour of an enterprise by examining the inter-relationships between parameters and flows of cash, materials and information, through the corporate structure. Basically the technique consists of the construction of a diagram indicating all the important relevant relationships in the system, and by considering it analogous to the sort of complex flow regulation problems encountered by the control-engineer.

The diagram is translated into mathematical model form which can be used to simulate the behaviour of the real system over time. This emphasis on feedback control loops and dynamic behaviour over time means it has often highlighted the sort of dynamic implications discussed previously.

In a recent study[1] carried out at Bradford by Alex Barnett in conjunction with a major international oil company the researcher aimed to determine optimum policies for the development of off-shore oil-fields. One factor thought to be of major importance in this respect was the rate of increase of crude-oil price, the forecasting of this factor requiring substantial expense and effort on the part of the company. During his simulation experiments to examine all the effects of various policies and errors, Barnett's model produced various outputs of value in assessing the performance of the system, and of these the one judged by the company as most important was the final value of the discounted return. Also produced were two indices of performance based on this output and others with arbitrarily assigned weights. A table of the effect of errors in the estimate of the rate of price increase on these measures of performance is very revealing:-

Table 1 Oilfield Performance with respect to Rate of Price Increase Estimate

Estimate	Final Discounted Return ($\$10^{10}$)	Index 1	Index 2
Perfect estimate	.1832	1.0000	1.0000
-50% under estimate	.1832	0.9776	0.9976
-33% " "	.1832	0.9779	0.9968
+50% over estimate	.1832	1.0327	1.0043
+100% " "	.1827	1.1227	1.0129

Even when quite substantial changes had been made in corporate control policies, these measures of performance remained pretty well the same. It does therefore appear that for the wide range of errors examined, this variable has no influence on system performance, and Barnett did indeed suggest that it could be dropped from consideration, obviating the need for the expensive forecasting machinery currently employed.

Swanson,[3] at the Sloan School of Management M.I.T., has also carried out some simulation experiments to evaluate the quality of management information. Swanson's model concerned the control of labourforce in a factory (through recruitment or over-time working) in order to maintain the required production rate to satisfy sales demand and ensure satisfactory inventory control. He simulated the system for two sets of sales-histories assuming management had perfect information regarding sales rate and inventory levels and compared this with the results for various degrees of degraded information, see table 2.

The use of the control information in this way is akin the use of a short-term forecast in similar circumstances, and the effects of degraded information on the dynamics of the system are likely to be similar to the effects of using degraded forecasts. Indeed as will be seen, performance is improved by the elimination of information delays which can be achieved by the use of a rough short-term forecast of the variable's value.

Table 2 - Labour Control. Increase in Total System Costs for Degraded Information compared with Perfect Information

Quality of Information	Sales 1	Sales 2
Perfect Information	BASE	BASE
Typical Degraded Information i.e. 10% Random Errors 20% Overestimate of inventory ½ month delay ½ month sample time	+7.5%	+4.7%
Possible information improvements:		
No inventory error	+7.0%	+4.7%
No sales rate errors	+6.2%	+4.7%
No inventory bias	+5.1%	+3.2%
1/4 month delay	+5.6%	n.a.
No delay	+3.5%	+1.8%
1/4 month sample time	+6.5%	+3.8%
No delay, no inventory bias	+2.0%	n.a.

As would be expected the use of degraded information results in an increase in total costs and this increase can be reduced when various degrading factors have removed or improved. The value of this analysis however is to indicate which information improvements produce the best reductions in costs, and as can be seen it is delays that are most important - removal of random errors produces only a small improvement. The suggestion is then that, in this case anyway, the tolerance to error means that the easiest reduction in costs can probably be obtained by eliminating the information delays. This is normally difficult even allowing for high speed data processing, but early estimates could be used knowing the system is comparitively tolerant to random errors. Swanson does not claim this to be the definitive solution, simply that the experiments indicate the sorts of improvement made under various information policies, cost analysis would indicate the optimum policy to choose.

Geoff Coyle, director of the Bradford System Dynamics Group, has also described[2] an interesting phenomenon concerning forecasting error. It came to light during an extensive study of the order-backlog problems of a large consumer-durable manufacturer which devoted considerable effort to forecasting. During the study a model of the company was constructed to test how sensitive its performance was to forecasting. It was found that quite large errors (even up to 30%) made no difference to system performance except in the first few weeks of product life-cycle. This suggested that the company structure included mechanisms which effectively corrected for forecasting errors, and that effort concentrated on obtaining accurate forecasts was wasted.

In order to further examine some of the implications of forecasting on system performance Coyle experimented with a simplified model based on actual situations. The model concerned the controlling of order-backlog by varying production capacity, the capacity decision being based on a forecast. Also of prime importance is the delivery delay caused by the backlog as this will affect the customers' order rate. The basic structure in the form of an Influence Diagram is shown in Figure 1. Cumulative Orders is used as the measure of performance and it is examined for various forecasting policies, the results shown in Table 3.

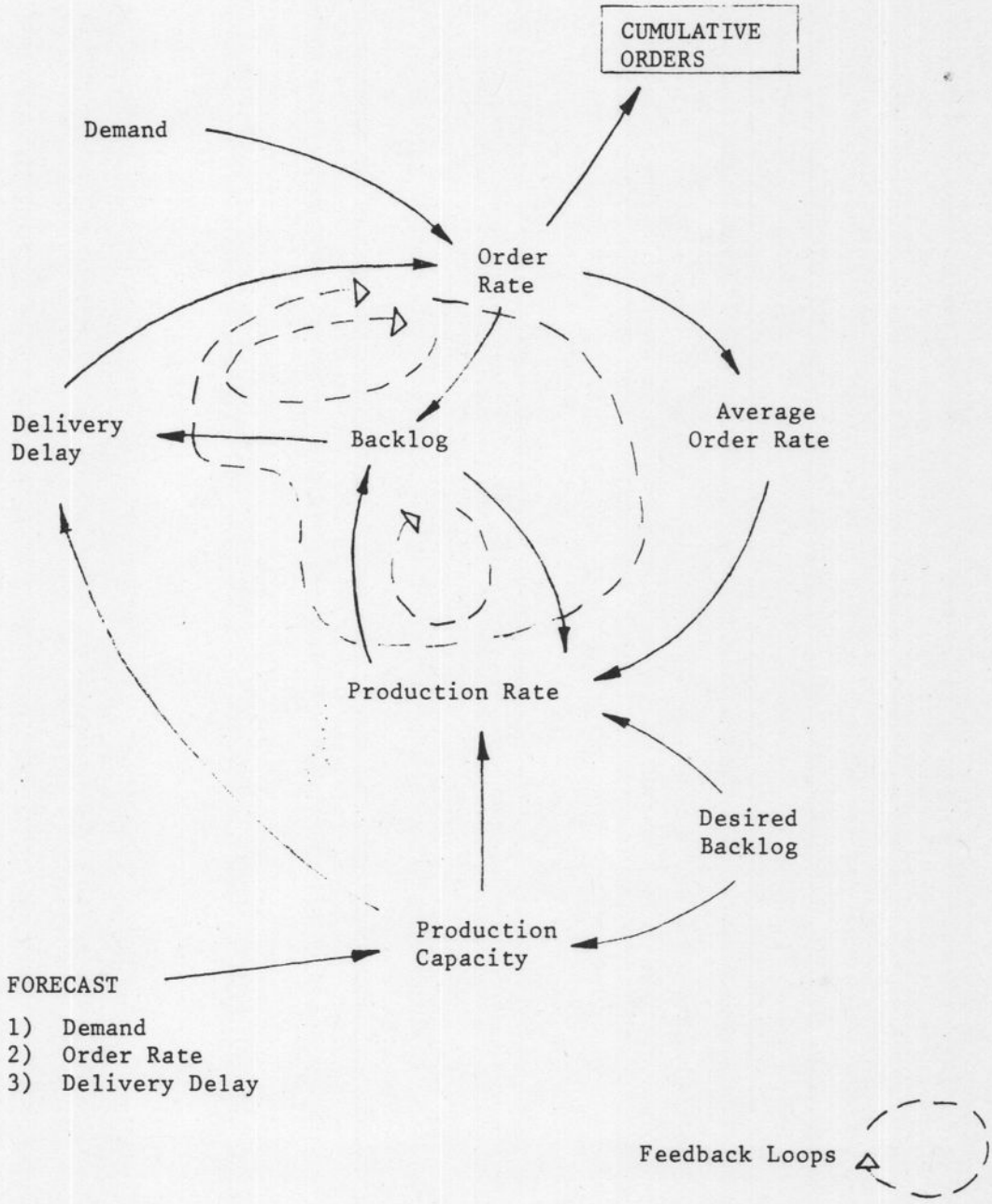

Figure 1 Structure of Forecasting Experiment Model (Influence Diagram)

Table 3 The Effect of Forecasting Policies on Performance

Factor used for Forecast	Cumulative Orders
Perfect Forecast of Demand (Horizon 3 periods)	35394
" " " " (Horizon 1 period)	35646
" " " " (Horizon 6 periods)	34799
20% Optimistic demand forecast	42119
Average Order Rate	46640
Average Order Rate with +20% bias	60419
Forecast effect of Delivery Delay on Demand	60931

The reasons for these seemingly remarkable improvements over the "perfect forecast" result are not too difficult to see if the structure of the system is studied and result mainly from the relationship between delivery delay and demand. Also cumulative orders may not be the best measure, especially if payment is only made on delivery and not with order!

In conclusion it is worth summarising the main points made in this paper. The prime purpose has been to suggest, and support with examples of studies, that successful forecasting consists of much more than simply obtaining an "accurate" forecast. The forecasting function is an integral part of the corporate structure and consequently other characteristics apart from accuracy will affect the performance of the system. The examples have shown in two cases that companies appeared to be expending unnecessary forecasting effort either on an inconsequential variable or in a system which compensated for large errors anyway. Another example showed that the use of an early estimate, accepting the likely error, would probably be more beneficial than concentrating on the reduction of error. Dr. Coyle's final experiments have shown that where a forecast is to be used in some way as a controlling policy the application of a bias factor or the forecasting of a different function may produce better performance than the naive use of a 'perfect' demand forecast.

The 'whole system approach' of a system dynamics study does therefore highlight the deeper implications of forecasting on corporate behaviour and performance, and suggests that there is more to forecasting than selecting the most accurate technique, a fact which most forecasting literature and research ignores.

References

(1) Barnett A.B., 1973 "A System Dynamics Model of an Oilfield's Development". Ph.D. Thesis, Univ. of Bfd.

(2) Coyle R.G., 1975 "A System View of Forecasting" in Practical Aspects of Forecasting, proceedings of 1973 conference of Industrial Application Section of Royal Statistical Society/Forecasting Study Group of O.R. Society. Published by O.R. Society 1975.

(3) Swanson C.V. 1971 "Evaluating the Quality of Management Information", Working Paper 538-71, Sloan School of Management, M.I.T.