

# THE FUTURE OF U.K. PAPER INDUSTRY. A SYSTEM DYNAMICS STUDY

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## ABSTRACT

The purpose of this paper is to investigate the different parts of a paper company which affect its dynamic performance.

The demand, which behaves in a cyclic manner, and the foreign competition have resulted in the decline of the market share of U.K. paper companies over the last ten years.

The problems of plant utilisation level and plant efficiency are of great importance, it is argued that such problems may be regarded as a result of policies followed by management.

A system dynamic model for a hypothetical paper company which uses only waste paper as a raw material, has been constructed and the dynamic behaviour of the company is examined under typical historical managerial policies. The behaviour of the model is shown to give rise to many of the phenomena observed in the real world such as production rates, capacity levels and plant efficiency.

By designing new policies, the model is leading to greatly improved dynamic behaviour.

Finally the practical problem of implementing such a study is examined, and the benefits of it are discussed.

## HISTORICAL PERSPECTIVE

The relative importance of the British Paper Industry in the world market has declined noticeably over the past fifteen years. In 1962 Britain was the fourth largest producer of paper in the world, but had fallen to be tenth largest by 1976.

In brief, the reasons for this decline may be outlined as follows (1):

- (a) Historically the British paper industry has relied heavily on supplies of imported wood pulp (approx. 45% in 1976). This use of imported raw material from those countries with forests and cheap energy resources, which have been able to develop integrated pulp and paper industries, are estimated to have 15–20% natural cost advantage over paper produced from pulp in the U.K. Also a dramatic rise in wood pulp prices has occurred during the early 1970's.
- (b) British membership of the European Free Trade Association (E.F.T.A.) during the 1960's removed tariff barriers and allowed Scandinavian paper and board to penetrate the British market with high volumes of low priced paper.
- (c) In an attempt to maintain its competitiveness against the increasing penetration of paper from Scandinavia the British paper industry has been forced to operate on low profit margins since the 1960's and this has prevented major investment in new plant and machinery, or even investment in machinery suitable for reprocessing greater

proportions of waste paper.

The effect of these factors, has been to make British paper makers concentrate on two areas of production. Either on producing the high quality speciality papers, which have a relatively low sales volume and which are of no interest to the Scandinavian manufacturers, who have tended to produce high volume, lower quality papers. Or on manufacturing waste paper-based varieties of paper and board.

## The Financial Position of the Industry

In 1974 the average profit margin was 9.7%, in 1975 it dropped to 4.5% and in 1976 reached a level of 5%. A survey carried out by I.C.C. Business Ratio (2), calculated the average return on capital employed of sixty leading companies as: 12.9% in 1973–1974, 19% in 1974–1975 and 8.3% in 1975–76. Having such low returns, it is difficult to see how mills can provide or raise the necessary financial resources to perpetuate even the present output levels, let alone expand or engage in major modification.

O.E.C.D. figures show that growth in capacity between 1963 and 1973, at 1.3% p.a. for the U.K., was much lower than in other West European countries (3).

As the U.K. paper industry is highly capital-intensive, it consequently has a very high break-even capacity utilisation (on average about 90–95%) (4). Capacity utilisation proves a major problem in the industry; in fact, in a survey carried out in 1977, 74% of firms point out that they are operating their plant below the optimum level (5), as is demonstrated in Figure 1.

The industry which is affected by the business cycle of 4–5

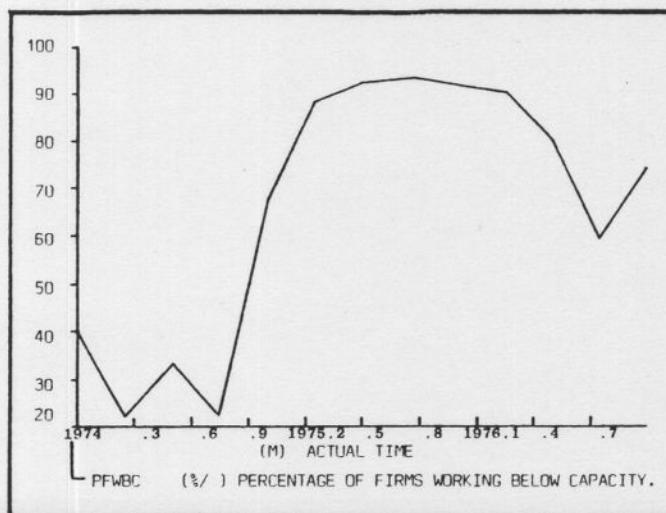


Figure 1. Capacity Utilisation for Paper and Paper Products

years is dependent on making profit in peak years to compensate low profits or losses in bad years.

### Structure of the Industry

The U.K. paper industry, due to financial problems, has been increasingly rationalised over the past 10 years. Reduction in the number of mills and firms has taken place and there exists a growing concentration of production on larger, more efficient production units. For the smaller paper mills it is true to say that their survival has been based on being successfully competitive in a highly competitive market.

The substitution of waste paper for pulp has become a possible route for survival in a large part of the industry. Waste paper is one of the most important raw materials available to U.K. paper and board makers. In 1976, the U.K. consumed 6.8m tonnes of paper and board. The U.K. produced 4.0m tonnes, exported 0.35m tonnes and imported 3.1m tonnes of finished paper and board (6). The main raw materials in the U.K. used in making this paper and board were

	m. tonnes	%
Waste Paper	2.00	49.5
Imported Wood Pulp	1.70	42.1
U.K. produced Wood Pulp	0.34	8.4

The U.K. has been one of the pioneers in exploiting the existence of relatively cheap raw material, and in developing the necessary technology (2/3 of all U.K. mills use waste paper). The waste paper utilisation rate in the U.K. (i.e. the ratio of waste paper consumption to total consumption of fibrous materials in the manufacture of paper and board), is higher than that of other countries (7), although the U.K.'s waste paper recovery rate (the ratio of waste paper collected to P and B apparent consumption) is lower than in many other countries, as demonstrated in the tables 1 and 2.

Country	1968	1969	1970	1971	1972	1973	1974
U.K.	36.0	37.9	38.2	43.2	41.8	44.3	45.8
E.E.C Total	35.2	35.6	35.9	39.3	38.8	40.1	41.4
Sweden	6.7	6.3	6.0	6.1	6.8	6.7	7.3
Total Europe	26.0	25.8	26.0	27.1	27.8	28.2	29.3
Canada	2.9	3.3	5.0	6.0	6.0	6.3	6.4
U.S.A.	20.6	20.1	21.1	21.2	22.1	20.8	20.6

Source: Waste Paper Recycling, OECD 1976  
Table 1. Waste Paper Utilisation Rate

Country	1968	1969	1970	1971	1972	1973	1974
U.K.	27.0	27.0	28.7	28.7	27.0	27.5	27.6
E.E.C Total	27.0	26.9	28.2	28.5	28.2	28.1	30.6
Sweden	23.0	21.6	22.2	24.0	26.5	24.5	28.0
Total Europe	26.8	26.1	27.3	27.4	27.7	27.3	29.5
Canada	12.2	12.5	18.6	21.0	19.6	20.5	18.0
U.S.A.	19.8	19.9	21.3	20.5	22.6	20.4	22.3

Source: Waste Paper Recycling; OECD 1976  
Table 2. Waste Paper Recovery Rate

### Problem Definition

From the previous analysis, it can be seen that the trend of U.K. paper companies utilising greater proportions of waste

paper in paper manufacture, is an attempt to combat the foreign competition. Apart from that one important feature of the paper industry is the high level of break even capacity utilization (i.e. 90–95%); and as it shown before (fig. 1) a great number of U.K. paper companies are working below this level. Finally the poor financial performance of U.K. over the last years, resulted in decreasing the existence number of mills and only the efficient one to be able to survive.

Bearing in mind the above mentioned problems, a System Dynamic (S.D) model has been constructed, which includes the activities of the different sectors of a paper company. This research (8) relates to a hypothetical paper company who present the activities of a "typical" medium size paper company, which for ease of reference, will be referred to as the "THOMAS" company. "THOMAS" is engaged in the production of lower grade paper, using only waste paper as a raw material and its purpose is to survive in the face of highly fluctuating market demand and foreign competition.

It is worth mentioning that the final form of the model, is based upon information drawn from published sources, technical articles, government publications and visits which were under-taken to four paper companies. The main aim of the visits was to confirm the relevance of the model, and to adapt it as necessary in relation to what was happening in the real situation. Thus the values of the different parameters used in the model, and the system structure, have been based on the judgement of people knowledgeable about the "in-situ" system.

Our objectives are:

- to investigate the dynamic behaviour of production, capacity and investment policies in use at present, noting their strengths and weaknesses.
- on the basis of the model developed, to suggest improved strategies designed to meet the company's objectives more effectively.

### Influence Diagram

Fig. 2 is an influence diagram (I.D) which shows the cause and effect relationships between the variables chosen. It includes only those variables which are considered to be significant in influencing the behaviour of the model. The I.D has been proved a useful way of communicating with managers.

The following points should be noted in connection with the diagram:

- It has been assumed that the company uses only waste paper as the raw material for its final product, thereby having a utilisation rate of 1. However, the model has been formulated in such a way that this value can easily be changed for another (9). (This has, in fact, been under-taken in another, separate, piece of research by the author in which a combination of virgin pulp and waste paper is taken as the raw material basis for paper production).
- The company has been considered at a stage of stagnation. Therefore, the policies applied to acquiring new fixed capacity are of a conservative nature.
- The system is driven by a demand pattern, which may



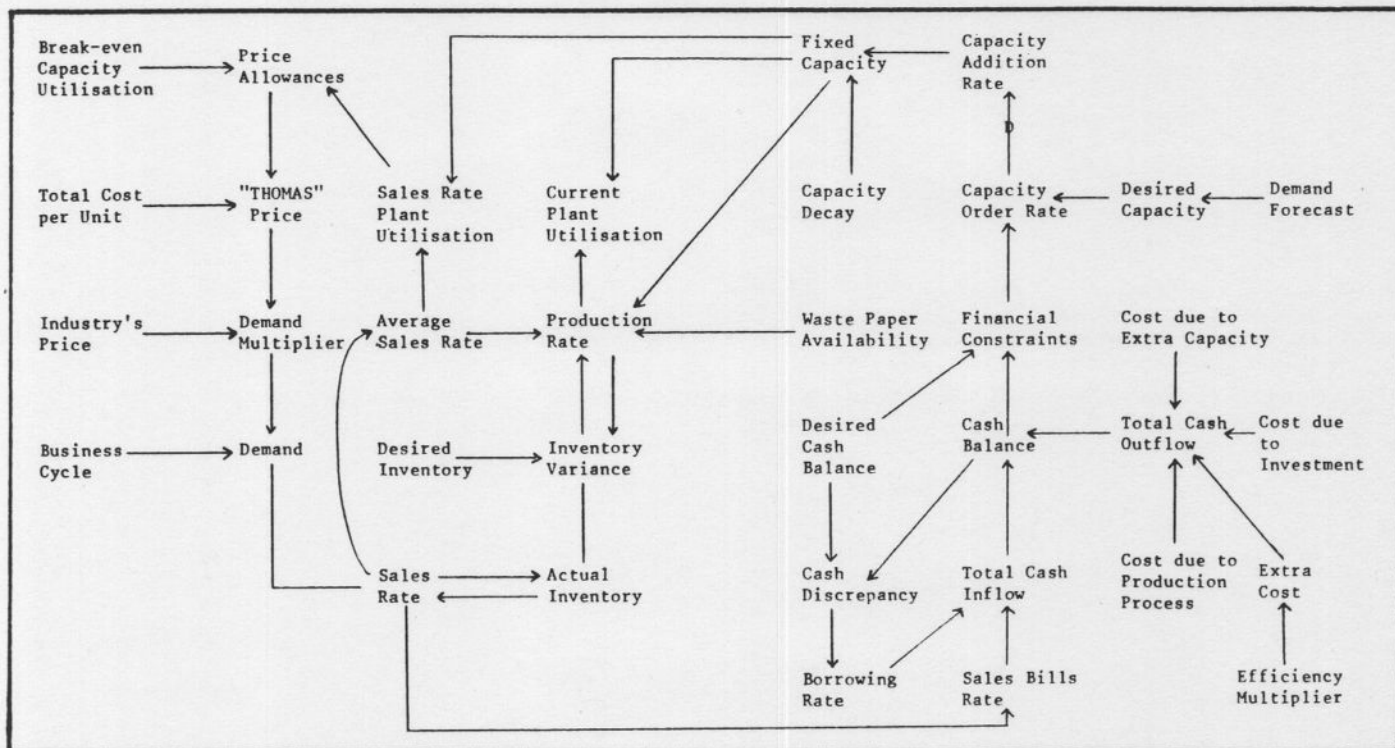


Figure 2 An Influence Diagram

be influenced by exogenous variables such as the business cycle, or by endogenous variables such as price.

- d. — The problem of inflation of costs and prices has been neglected in the model. Thus, the figures used are in constant values.

For the relationships stated in the I.D a list of equations has been formulated to represent each relationship quantitatively within the simulation model. DYSMAP (10) has been selected as a convenient computer language. A copy of this model is stored in the archive of S.D.R.G., Management Centre, Bradford University (file name LAMBRIDIS2).

#### Results from the Simulation

Forrester (11) states, "if the model has captured the causes of the actual system difficulties, the model will exhibit the same trouble symptoms as the real system".

Turning to figure 3 (a,b,c,d), we can see that the model exhibits similar behaviour to what we know to be true in the real system.

The production rate fluctuates over a given time span; this can be seen to be a direct consequence of the four-year business cycle which dominates the industry. At the peak of the business cycle, the production rate is increased to cope with a higher level of demand. As the demand falls, production levels must follow suit, to prevent excessive stockpiling of unwanted supplies. This fluctuation in the production rate is an undesirable phenomenon. True to life, the model shows that in times of recession, the underutilisation of the available plant and equipment renders the whole operation uneconomical. No longer is the plant run at optimum efficiency, and the philo-

sophy of the company becomes one of the minimum output for survival rather than maximum output for profit. In our model, the level of plant utilisation falls to a minimum of 0.78.

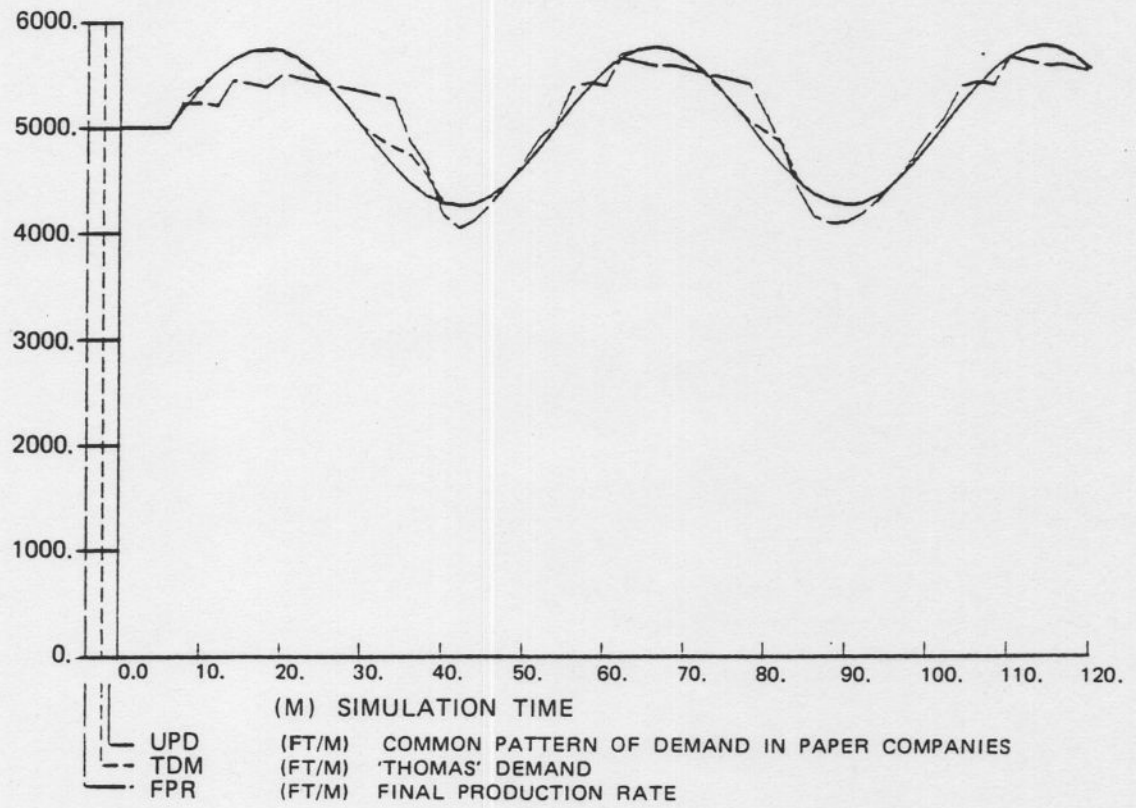
The excess capacity during times of recession manifests itself not only in underutilised plant; factors such as manpower must be considered, particularly in an environment such as exists today where "hiring and firing" of labour is so shrouded with legislation, that the process has become unviably expensive, if at all possible. The dilemma which faces the plant manager now is one of whether to keep on a minimum staff, sufficient to satisfy demand during recession periods, and employ extra casual, hence inexperienced, labour when demand arises, or whether to have enough permanent staff to be able to meet demand during boom periods, when profits are at their highest, but run the risk of an excessive labour force when the business cycle again declines to a trough.

In the absence of any capital investment the efficiency of the production plant in the model is deemed to decrease steadily with time, resulting in a proportionate increase in the extra costs incurred in the production process.

The various factors which play a part in the relatively poor financial performance of most paper companies, such as inefficiency of plant and machinery, the relatively small sales volume during periods of recession over which to spread the over-heads, are accurately mirrored in the model by the low level of profitability throughout the simulation period.

Apart from the above observations, four indices have been calculated, as a measure of performance between the initial (basic) model and the redesigned one (improved).

a)



b)

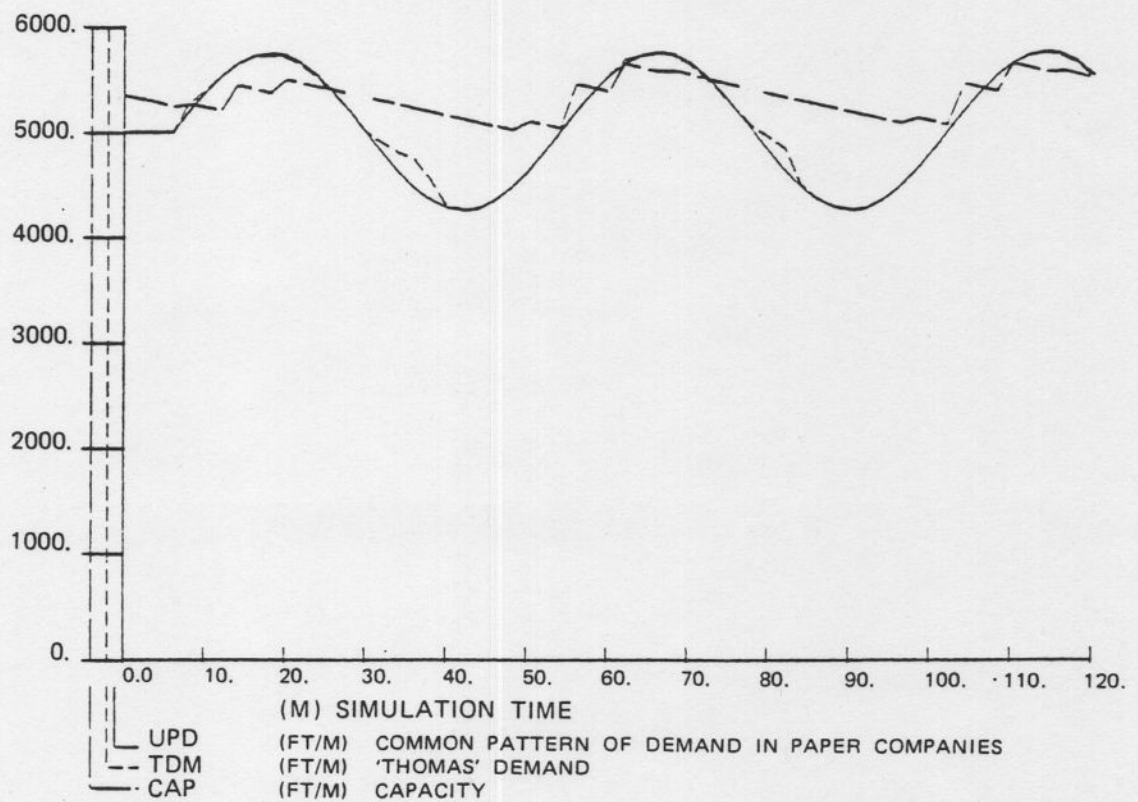
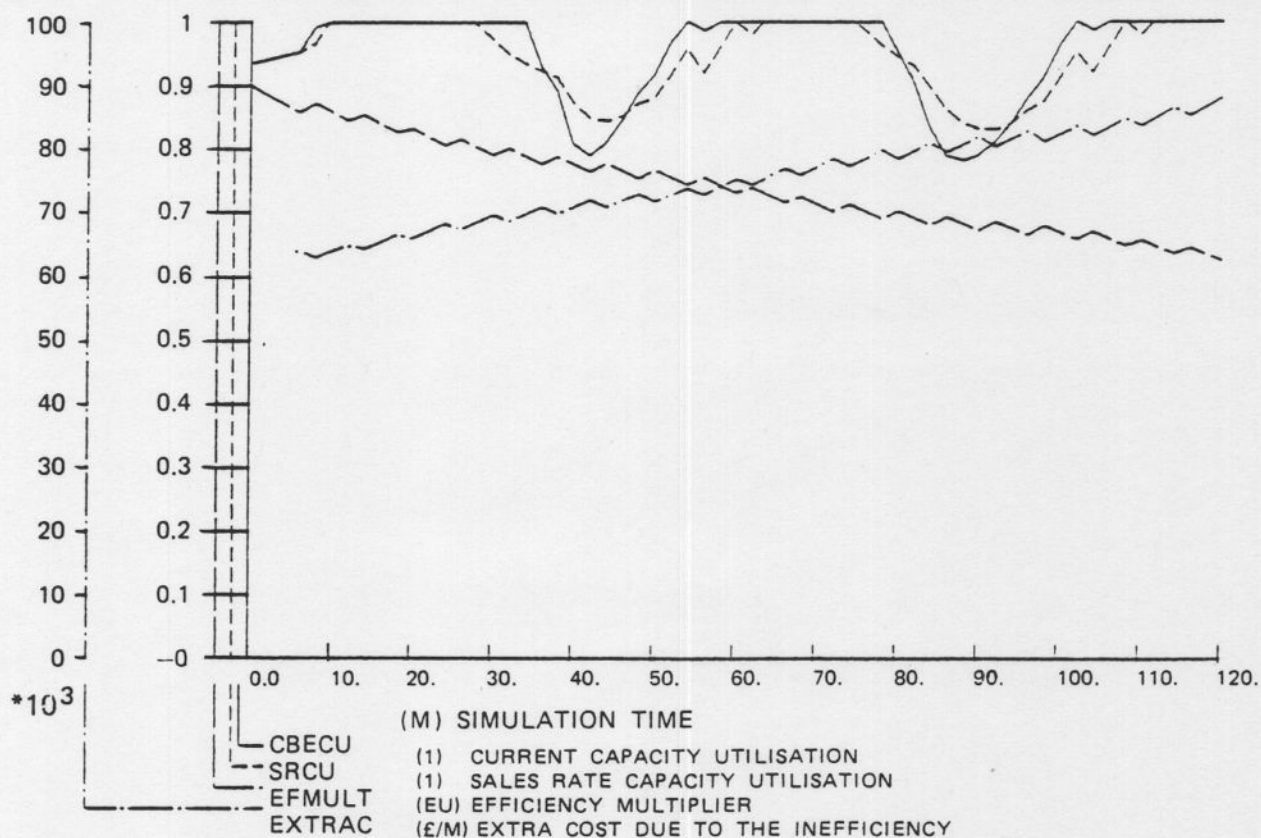


Figure 3 Basic Model. A Corporate Model for a Paper Company

c)



d)

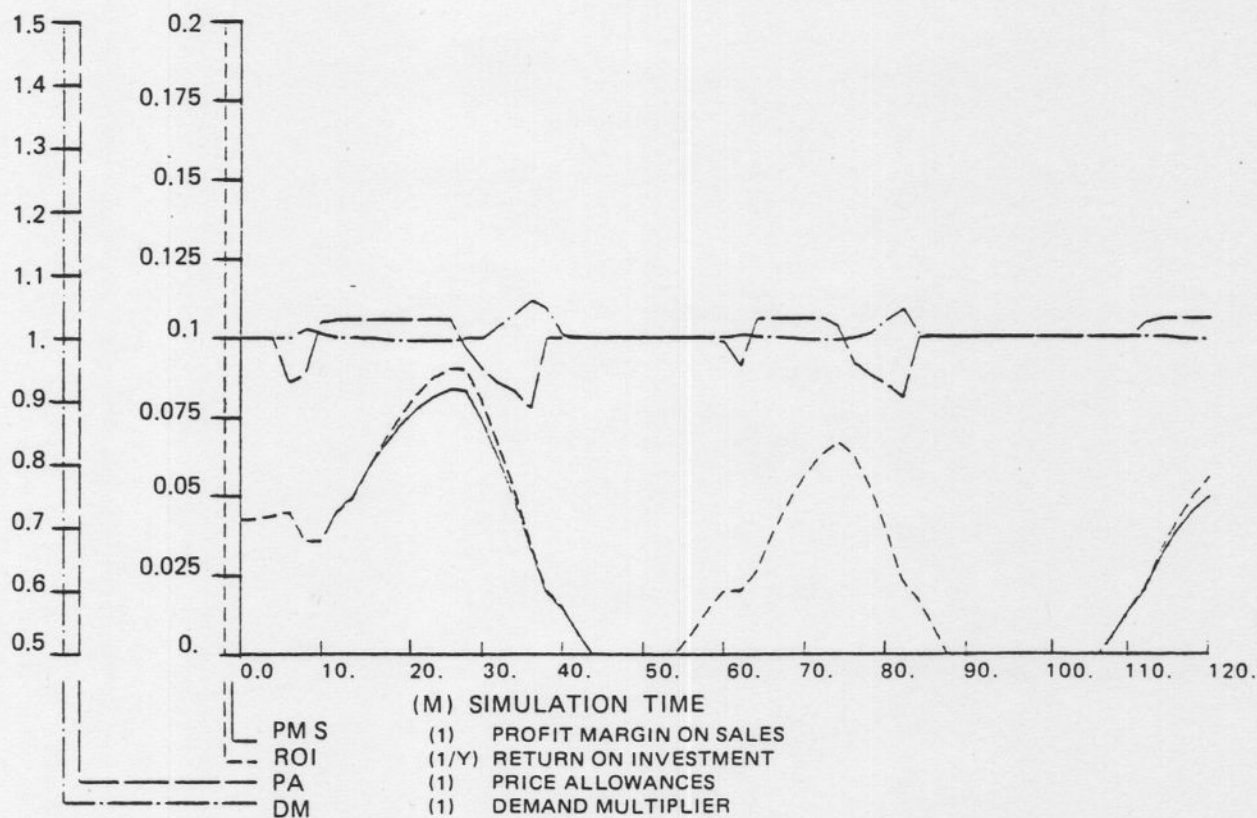


Figure 3 Basic Model. A Corporate Model for a Paper Company



- The cumulative loss or gain in demand, which will occur either because of lack of capacity (in boom periods) or due to the competition. At the end of the simulation, this was found to be equal to -1900 tonnes.
- How long plant utilisation falls below 90%. The period of under-utilisation of the plants was found to be 27 months, out of the total simulation period of 120 months.
- Finally, the inventory which exceeded the desired level was measured at the end of the simulation period, and was found to be equal to 9654 tonnes.

In summary then, it appears that the model behaviour is qualitatively similar to the type of behaviour observed in the real world for a company of this type.

### Validity

The problem of validity is not a simple one, and the subject has been much debated in the past. Any model may be susceptible to the criticism that it is "invalid", even though, as yet, not absolute definition of validity has been formulated.

The necessary steps which have been followed, are discussed in detail in a forthcoming paper by the author. Namely the followed steps are:

- Does the model deal with matters of importance?
- Does the model answer questions to which we need to have answers?
- Can we define and justify each link in the model, and each relationship?
- Does the model contain any gross errors?
- Does the model behave like the real system?

### Policy Redesign

Having constructed the system in a way which gives us some degree of confidence in its approach to reality, we felt free to continue for policy redesign. Our main concern was to identify the loops which affect the plant utilisation, and

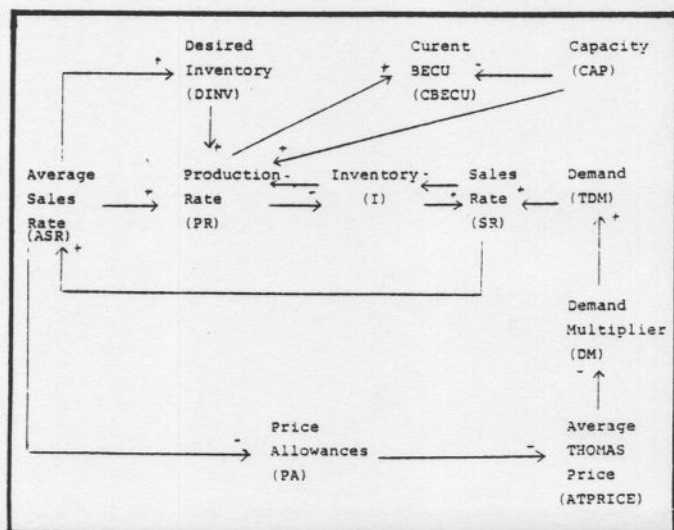


Figure 4. Feedback Loop A

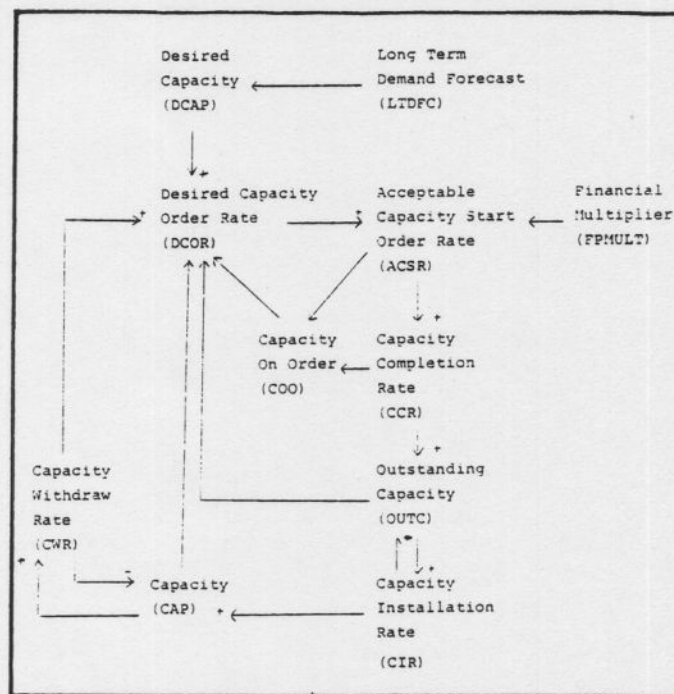


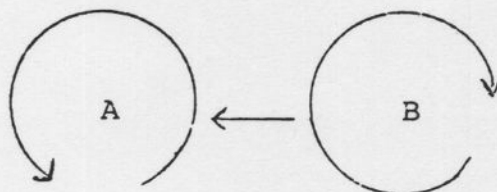
Figure 5. Feedback Loop B

which result from the fluctuations of production rate. It is worth remembering that the main concern of paper companies is to keep their plants utilised at the maximum possible level, since the break-even point lies at the high value of 90%.

Loop A attempts to regulate production rate to demand. Also it tries to influence the demand pattern through the price allowances.

Loop B, tries to regulate the capacity to its desired level, the letter of which is determined by the forecasting demand.

The whole point of the loop analysis method is that a system must possess feedback to achieve tight, effective control. If no control exists, we must introduce it. In our case, loop A and B have a poor connection between them.



The connection actually between B to A appears only as a constraint. There is not any connecting link, although both loops play a crucial role in the problem of plant utilisation. The phenomenon of underutilisation occurs because of the excessive capacity which exists during periods of recession. It appears that there is no control mechanism to prevent this phenomenon. The necessary link from A to B will appear in the policy which determines the desired level of capacity. Apart from the forecasting demand, the desired level will

also be determined by the past sales rate. In other words, the past performance needs to be taken into consideration, to prevent over-optimistic decisions being made. It is to the paper companies benefit to keep their existing production capacity "profitably utilised" and also to undergo some expansion if and only if, there is a strong indication from historical pattern of sales, that the increase in demand will be permanent. Otherwise, the company will have to absorb unnecessarily high operating costs, as well as the cost of unnecessary capacity.

Thus,

$$DCAP.K = DF * LASR.K + (1 - DF) * LTDFC.K$$

$$LASR.K = LASR.J + (DT / FHOR) (SR.JK - LASR.J)$$

where:

DCAP	= (FT/M)	Desired capacity
DF	= (1)	Damping factor
LASR	= (FT/M)	Long average sales rate
LTDFC	= (FT/M)	Demand forecast
SR	= (FT/M)	Sales rate
FHOR	= (M)	Forecasting horizon

From the simulation runs it was calculated that the most appropriate value of DF to use was 30%.

By looking at loop A, it can be seen that the production rate does not take the capacity utilisation into consideration. During times of recession, paper companies, because of the problem of BECU, face the situation where they are forced either to work below their BECU or to continue working by maintaining a high level of Inventory.

Thus, the final form of the model's production rate (FPR) has been constructed by keeping the production rate at a level at least equal to the BECU; in this case, equal to 90%. But the production rate has been restricted in the case of any discrepancy between the actual and desired level of inventory. These restrictions are formulated by the modeling device called the inventory multiplier (INVM), in order to avoid an excess of inventory which would create serious liquidity problems in the company.

Thus,

$$FPR.K = \text{MIN} ((\text{MAX}(\text{IPR.K}, \text{ABECU} * \text{CAP.K}) * \text{INVM.K}) * \text{WPCAV.K}, \text{CAP.K})$$

$$\text{IPR.K} = \text{ASR.K} + (\text{DINV.K} - \text{INV.K}) / \text{TAI}$$

$$\text{INVM.K} = \text{TABHL}(\text{TINVM}, \text{INVM.K}, 0, 1, 4, 0, 2)$$

$$\text{TINVM} = 0.5 / 0.55 / 0.70 / 0.90 / 0.95 / 1 / 1$$

$$\text{INVR.K} = \text{DINV.K} / \text{INV.K}$$

when:

FRP	= (FT/M)	Final production rate
IPR	= (FT/M)	Initial production rate
ABECU	= (1)	Break-even capacity utilisation

CAP	= (FT/M)	Capacity
INVM	= (1)	Inventory Multiplier
WPCAV	= (1)	Waste paper availability constraints
ASR	= (FT/M)	Average sales rate
DINV	= (FT)	Desired inventory
INV	= (FT)	Inventory
TAI	= (M)	Time to adjust inventory
TINVM	= (1)	Table for INVM
INVR	= (1)	Inventory ratio

Turning now to the financial loops of the model, our main concern is to identify the causes of the low profitability. Paper companies are suffering from low profit margins, which in turn have caused the decline in the number of working paper mills over the last 10 years.

Loop C (Fig. 6) is a negative one which contains a variable output EXTRAC. Its purpose is to keep the efficiency at the desired level. The way of formulating the efficiency sector is described in detail in a forthcoming paper by the author.

Given that paper companies are forced to operate with low profit margins due to the foreign competition, it is to their benefit to minimise the value of EXTRAC (extra cost) i.e. the costs which are incurred due to inefficient use of the plant, and which reduce even further the profits of the company.

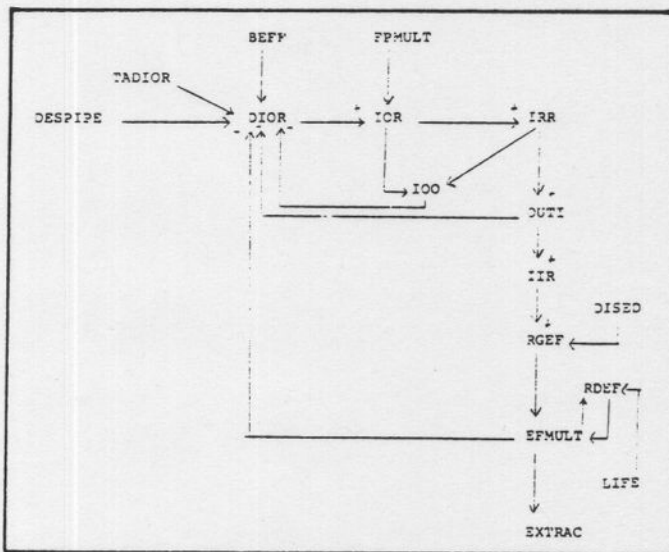
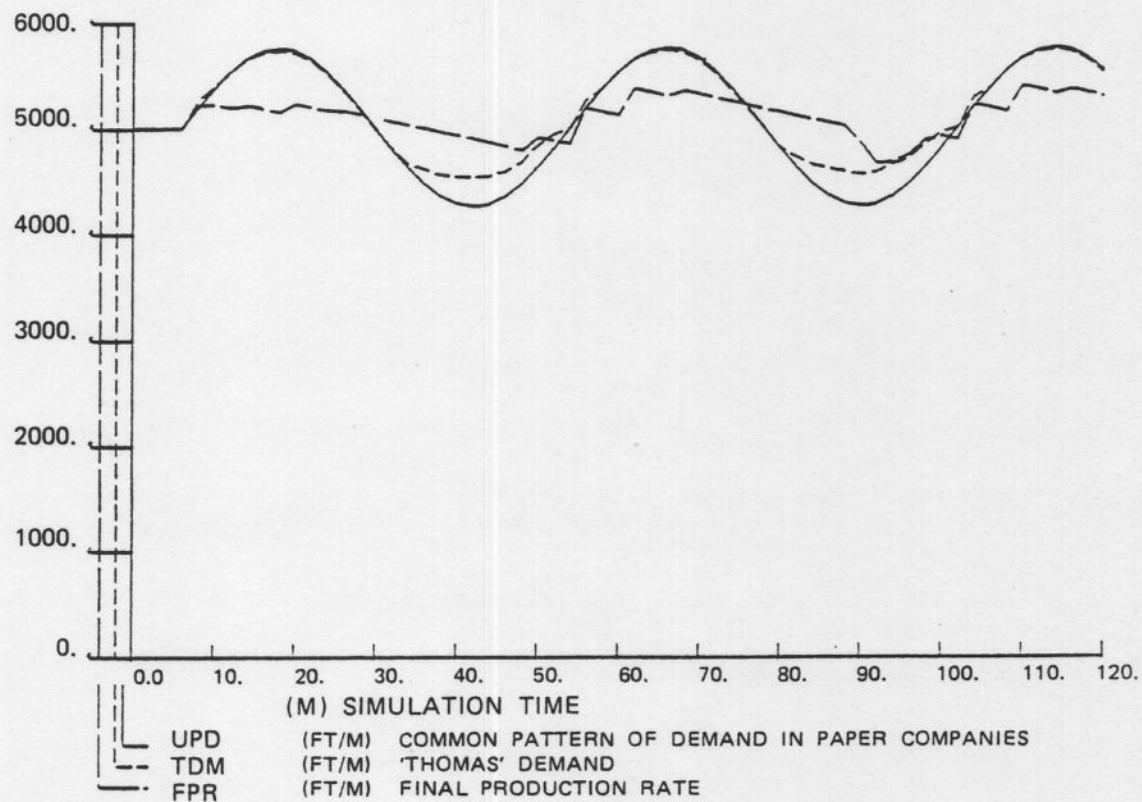


Figure 6 Feedback Loop C

In the basic model, it was assumed that the company follows the traditional policy which leads to low investment and therefore it is unable to keep its plants at maximum efficiency, which explains the poor financial performance seen in Fig. 3 (d).

In the revised model, we have moved away from the traditional policy of low investments, to one in which the hypothetical company invests the maximum needed amount of money in maintaining the plant efficiency to improve its chances of survival.

a)



b)

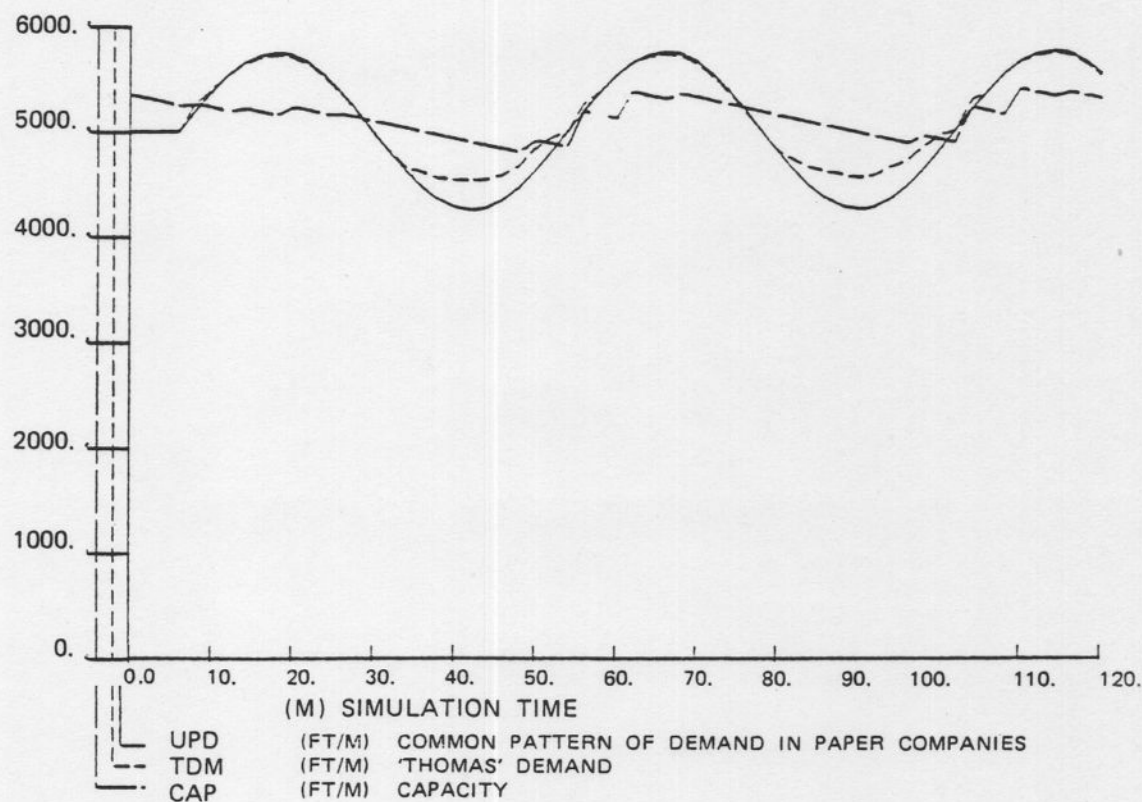


Figure 7. Improved Model. A Corporate Model for a Paper Company



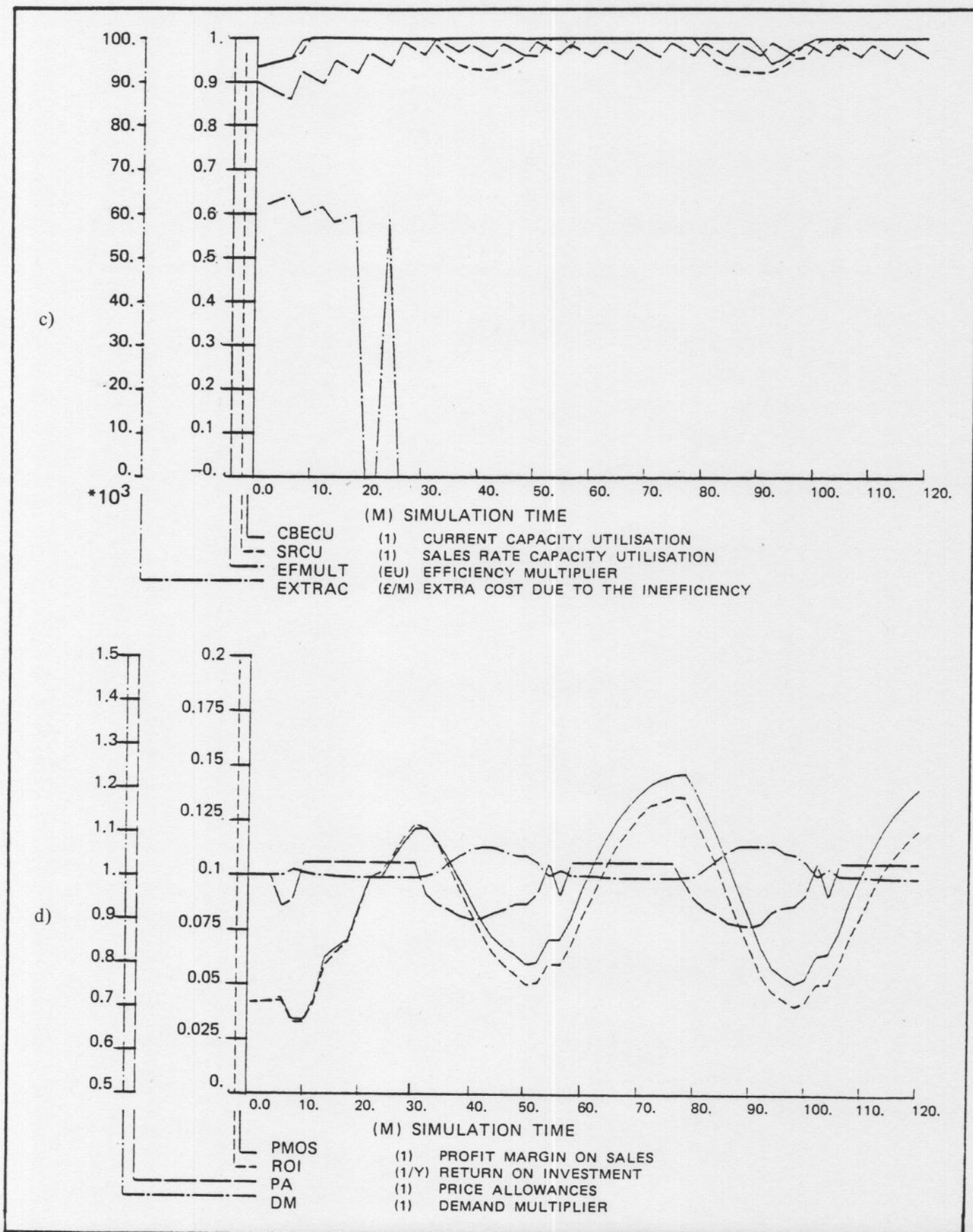


Figure 7. Improved Model. A Corporate Model for a Paper Company

### Performance of the Improved System

The performance of the improved system is shown in Fig. 7., and should be compared with the behaviour of the basic system shown in Fig. 3.

The production rate in the improved system has been smoothed out, by attempting to maintain a fixed level of output throughout, rather than allowing the output capacity to fluctuate to the market levels dictated by the four year business cycle. This has the advantage of eliminating periods of underutilisation of the plant during times of recession, or not being able to service a higher demand when the market is buoyant. In the former case, the fact that overheads have been spread over the maximum economic number of units throughout the period of utilisation means that the company can afford to attract custom by offering rebates off the market prices. When demand increases there should be sufficient stock to ensure that the company can provide for at least some of the increased demand.

Quite apart from smoothing out the peaks and troughs from the company's operating policy, giving a greater stability to the whole operation the improved model has been further enhanced by investing capital in improving, or at least maintaining, the level of efficiency of the plant and machinery at competitive levels. This prevents the company incurring extra costs with time in manufacturing, which would otherwise effectively have to be recovered as increased overheads.

The consequently improved profit margin and return on investment is also demonstrated in the improved model.

Further, regarding the indices previously discussed, we can see that the accumulated gain of demand (ALD) was equal to 8090 tonnes which indicates that there was far greater potential for gain than in the basic model, plus the fact that the inventory was never above the desired level through the simulation.

Thus, a considerably better performance was obtained from the revised model.

### Robustness of the Model

Coyle (12) states that a system is robust "if it can be made to work well regardless of what happens to it from the environment or the complement, by making suitable changes to its policies and to its structure".

The robustness of the model, external and internal, has been tested by applying a range of standard tests. In the case of external, has been used the input functions, upon the variable demand, such as STEP, RAMP, NOISE; and the model response was satisfactory. For internal purpose, a sensitivity test applied against errors in constants and table functions to investigate the system's quantitative and perhaps qualitative behaviour; and the model behaved in a manner similar to that displayed by the improve system.

Therefore, applying Coyle's definition about robustness, we can conclude that the model is robust.

### Implementation and Usefulness of the Model

The successful implementation of a System Dynamic model,

as with any type of model, depends heavily on mutual understanding between management and the modeller. To succeed in this aspect, it is important to gain an involvement of management with the project from the beginning. This is vital for success especially when, as in this case, we are dealing with the long term survival of the company.

The model can be applied as a planning tool which enables corporate management to explore all feasible and attractive production and price policies under different conditions. It makes possible the examination of all the consequences of those alternative policies and determination of their long-term net effects on the firm's profitability and stability, with no detriment to the company itself, which might have been caused by experimentation with the real system. Thus the alternative which best satisfies these objectives could be selected.

Finally the model can be used as a device for management to develop a better understanding of the mechanism of the paper companies.

### Conclusion

This paper was aiming to show how a System Dynamics model can be applied to corporate planning in a paper company. Especially the emphasis was given to how one can model the problem of plant utilisation, and to suggest "policies" which results in a better performance than the existing one.

The considerably better performance, as discussed earlier was derived after the careful examination, of the interaction between the sub-systems of the model, and fully understanding the system behaviour.

From this analysis we concluded that "investment policies" are crucial for the survival of the paper companies if they want to survive from the external competition and cycle fluctuations of its demand.

These investment policies resulted in a better financial performance, greater stability to its operation, and the level of efficiency of the plant and machinery at competitive levels.

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