A SYSTEM DYNAMICS BASED MODEL FOR EVALUATING THE PERFORMANCE OF AN ENGINEERING FIRM

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Abstract: This paper examines four policy options for evaluating the overall performance of a Public sector engineering firm in India. The major areas viz. finance, production, human resources and research & development are taken up for the study. The System Dynamics methodology was chosen as the tool for conducting the analysis because it provides means for understanding the dynamic inter-relationships between key functional parameters thereby allowing to explore the impact of different policies.

Public sector firms in India holds a key position for accelerating the pace of industrial development and socio-economic growth. Poor performance of some of them has caused great concern as they were conceived to provide support to the economic structure. As such, the performance of each industry needs to be monitored at the highest level to increase productivity and profitability.

System Dynamics| 1, 4| models are constructed, based on a theory of causes of dynamic behavior. It identifies options which can be tested and then used to predict the outcome of such alternatives. For the firm under study an integrated model has been presented after developing the finance, human resources, production and the research & development sub-models individually. Fig.1 gives the overall influence diagram of the integrated model. A brief discussion of each of the sub-models is as follows.

Finance Resource Sub-model: For evaluating the financial performance the major function have been studied| 2| and the resultant influence diagram of the developed Finance Sub-model is given in Fig.2. Subloop F1 starts from proposed profit level and shows that it is in turn dependent on the input resource, the sales volume and the orderbook position. The level of pre-tax profit(PBT) determines the quantum of income-tax(ITAX) and dividend payments. Subloop F2 achieves the organisation's proposed profit level through financial planning for budgeted resource allocations. Subloop F3 aims at increasing the organization's supply of funds through loans(LADV) in the context of monetary resources needed by it. The other cycle of this subloop consists of the loan repayments(REPAY). Intended role of this cycle is to meet the organisation's requirements of monetary resources needed through its supply of funds after taking into consideration its commitments towards loan repayments. Subloop F4 helps to maintain a sound financial position of organization by keeping its unpaid debt and other payment liabilities restricted in relation to its assets. Subloop F5 maintains the consistency of firm strategy with assets and assessments of the internal resource capabilities based on an estimation of the assets position and trained personnel available.

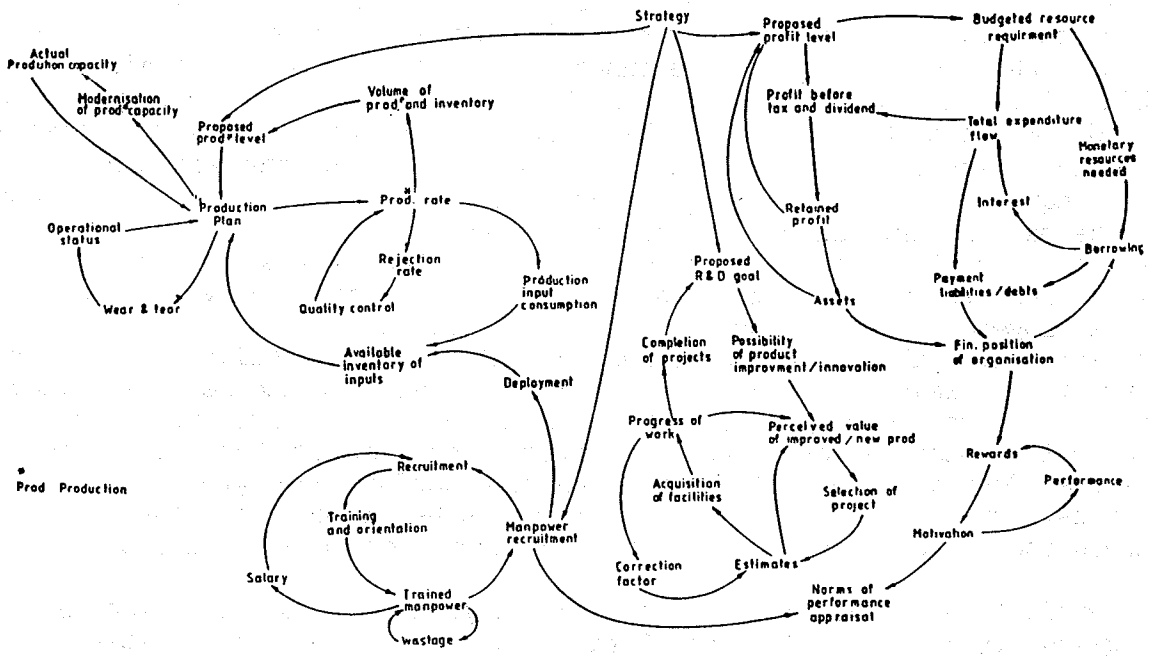

Fig 1 Over all influence diagram

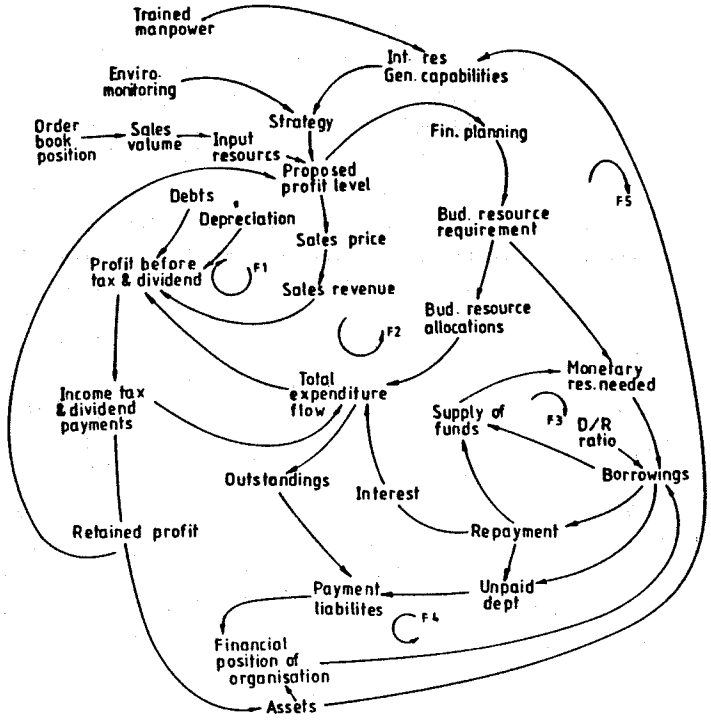

Fig. 2 Influence diagram for the finance submodel

Human Resource Sub-model: Here the primary sections are acquisition, development, motivation, maintenance and evaluation| 3|. Fig.3 gives the influence diagram of the main variables included in each of these sections. Subloop HR1 keeps track of the number of trained manpower available after taking into account the personnel who have left the firm during a given period. Subloop HR2 maintains the number of trained manpower available in accordance with manpower requirement. In case, the manpower existing is higher than required, the value of recruitment may be null or even negative. Subloop HR3 keeps the grievance level and its impact on work and performance to a very low level. This goal is sought to be accomplished through promotion policy and its implementation as a part of reward offered by organisation to its employees. Subloop HR4 limits the level of recruitment and trained manpower available to budgeted resource allocations available. Subloop HR5 keeps the grievances at a minimum through an appropriate set of managerial measures to meet employees demands. This is concerned with relatively long term policy measure for reducing grievances on a steady base. In case, when measures adopted are directly linked to work performance, prompt and immediate measures for improving the performance can be aimed at. The distinction between these two cycles is in respect of their orientation and cycle time.

Production Sub-model: The influence diagram of the Production Sub-model is given in Fig.4. In Subloop P1 the organization strategy determines the proposed production level. It leads to production plans thereby generating the production rate which in turn determines the volume of production and inventory position. This then indicates the level of fulfillment of the proposed production level and which attains the proposed production goal through production planning and the resultant production rate. A comparison of the proposed production level with the volume of production and inventory determine discrepancy between the actual and planned production. It tries to rectify the discrepancy between actual and planned production by modifying the proposed production level. Subloop P2 aims maintaining a smooth operation of the plant through a maintenance, repair and replacement schedule. As a result, better operational status of machines and equipment may accelerate the full utilization of the organisations production capacity. In Subloop P3 production rate generates some amount of rejections. These depending on its unacceptable level lead to improved production methods and workers training. This determines the extent improvements in quality assurance which in turn affects production rate. Improved production methods and workers training leading to quality assumes improvement is a result of the pressure for quality assurance coming from outside(sales system). Quality control improvement then serves to mitigate this pressure. Subloop P4 shows that the available inventory of production inputs determine production plans, which in turn governs production rate. The latter leads to consumption of production inputs which then goes to affect available inventory of production inputs. Thus a balance is obtained between production schedule with the available production inputs. Another feedback loop(P42) aims to fulfil production input requirement level through acquisition of production inputs. Also to meet the requirements of manpower as part of the production input requirement loop, loop(P43) links production input requirement level deployment of skilled labour and available inventory of production inputs. Subloop P5 aims to meet the production capacity requirements of production plan. These requirements are met through planned changes in the organization's production capacity.

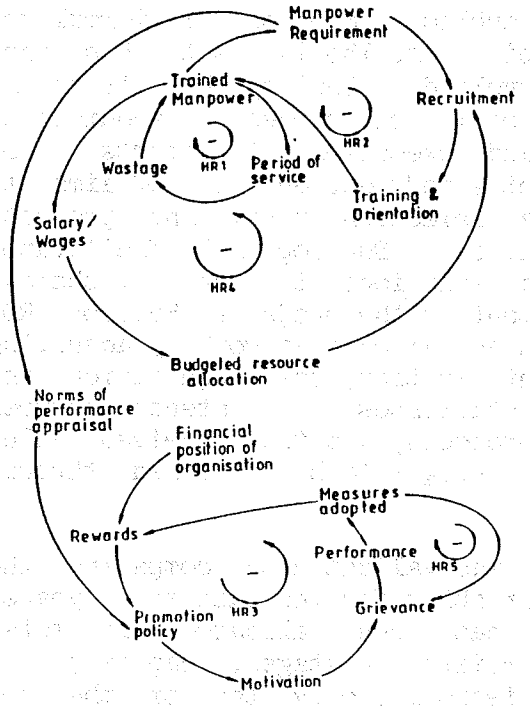

Fig.3 Influence diagram for the human resource submodel

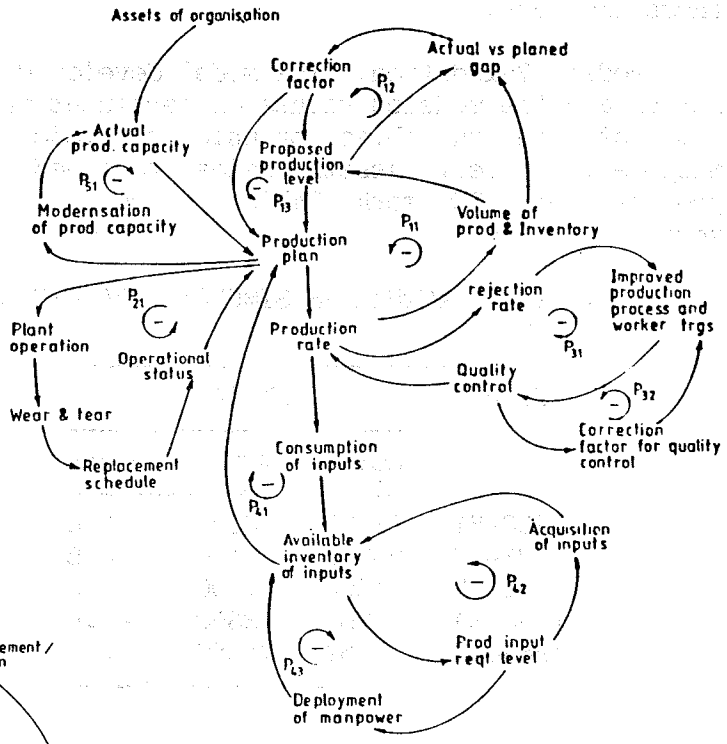

Fig.4 Influence diagram for the production submodel

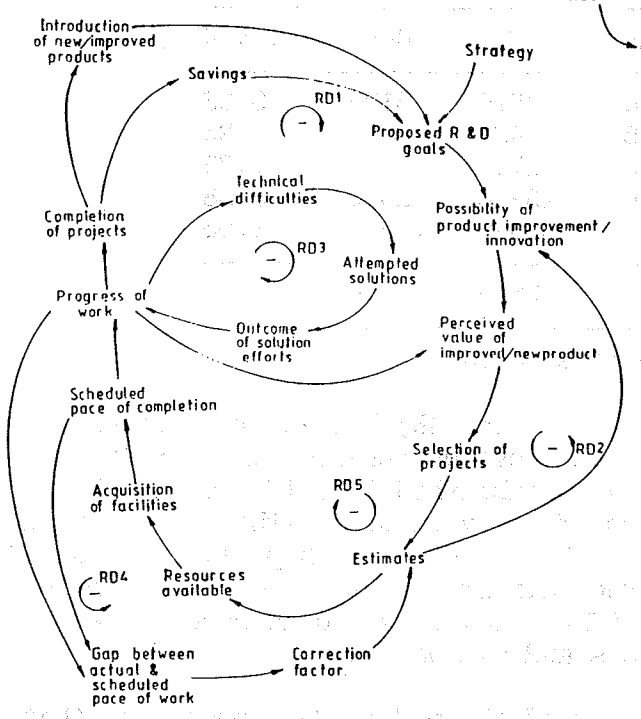

Fig.5 Influence diagram for the R&D submodel

Research & Development Sub-model: The R&D Sub-model influence diagram of Fig.5 on the next page consists of five main subloops. Subloop RD1 formulates the product improvement and innovation possibilities. The inputs to this task are estimates of time, money and effort involved. Subloop RD1 tries to accomplish the R&D goals through a proper selection of projects, acquisition and development of required facilities and execution of efforts for successful completion within time and budget schedules. Subloop RD2 aims to finalise new product possibilities through a selection of relevant projects and an estimation of their cost and duration. Subloop RD3 facilitates continuing progress of work by developing solutions to any technical difficulties encountered during the development of the projects. Subloop RD4 reduces any discrepancy between scheduled and actual pace of work by adjusting the firm's commitment of resources, their utilization, the acquisition and development of R&D facilities. Subloop RD5 establishes consistency between the appraisal of work progress on selected projects, and the perceived value of the improved /new products and technology sought to be realised through these projects.

Model Validation: The model developed was validated by comparing the actual and the modeled values of pertinent variables for the past five years. Some of the variables on which the model has been validated are total manpower, current assets, sales, retained profits, wastages, capacity and progress of R&D work. Table 1 shows comparisons for only two of the key variables.

Table 1: ACTUAL VS SIMULATED VALUES OF CERTAIN MAJOR VARIABLES*
(in Rs. Millions)

YEAR	MTOTAL			SALES		
	ACT	MDL	% VAR	ACT	MDL	% VAR
1980-81	68333	68333	0.0	7870	8132	3.33
1981-82	69788	70140	0.5	9431	9550	1.26
1982-83	71800	71190	-0.8	11790	11950	1.35
1983-84	74793	73350	-1.9	13250	12510	-5.58
1984-85	74464	74580	0.1	14820	14530	-1.95
O'var	2534	2231		2514	2254	

* (Actual as per the 5 yrs published data)

As seen from Table 1 the percentage variation(VAR) between the actual and modeled values is within reasonable limits. Previous research and experience with models of this type and magnitude have established that if the simulated model can reproduce the historical values of key variables within $\pm 10\%$ then structure of the model developed is probably sound| 5 Chap.3|. The data provided in the table lends support to the validity of the model. The model thus realistically represent actual operating conditions and as such it can be used as a flexible tool for policy analysis and evaluation.

Policy Experimentations: The utility of the model developed is that various corporate policies can be analysed and evaluated without actually

tampering with the actual day to day operations of the firm. In this paper the following policy experiments are discussed.

1. Suggesting a policy for setting of profit goals for next planning period: This experiment studies the effect of a few profitability ratios on the variable profit after tax(PAT):

a) Effect of budgeted/actual orders on profit after tax: The organisation depends for its profits on the orders executed in a working cycle. Table 2 gives the value of profit after tax(PAT) as a result of variations in the ratio of budgeted sales to actual sales over a range of 1.25 to 0.7.

Table 2: PROFIT AFTER TAX FOR VARIOUS RATIOS OF BUDGET SALES TO ACTUAL SALES

Ratio of Bud.sales/ PAT (%)	Act.Sales 6th yr	8th yr	10th yr
above 1.25	6.3	9.7	9.9
above 1.00 & upto 1.25	6.9	6.8	6.9
above 0.85 & upto 1.00	4.5	4.8	4.7
above 0.70 & upto 0.85	2.2	2.3	2.1

An inference of this experiment is that the profit after tax(PAT) would always be adequate(4-5%) if measures are adopted to keep the ratio of Budgeted sales to Actual sales around 0.85 to 1.0%.

b) Effect of the Profit margin on sales(PMOS) ratio: Profit margin on sales is the ratio of profit after tax(PAT) to sales(SALES) and is a measure of profitability. Table 3 depicts effect of different values of this ratio and indicates that if the PMOS ratio is held at 4.5% it would yield adequate profit after tax.

Table 3: EFFECT OF DIFFERENT VALUES OF THE PMOS RATIO

Ratio	PAT/SALES 6th yr	8th yr	10th yr
5.0%	4.67	4.73	4.71
4.5%	4.54	4.56	4.55
4.0%	4.21	4.35	4.57

c) Effect of the Return of total assets(ROTA) ratio: Return on total assets is the ratio of profit after tax(PAT) to total assets(TA) and a measure of profitability. Table 4. indicates the effect of different values of

Return of total assets(ROTA) on the ratio of Profit after tax(PAT) and total assets(TA). It indicates that adequate profit may be obtained when this ratio ROTA is fixed around 2.0%.

Table 4: EFFECT OF DIFFERENT VALUES OF ROTA ON PAT/TA

ROTA	PAT/TA (%) 6th yr	8th yr
2.0	4.12	4.93
2.5	5.18	6.20
3.0	6.17	7.38
3.5	7.19	8.61

All the above three experimentations conducted for setting up of the profit goal for the next planning period indicate that adequate profit(4.5%) will be realised if the ratio of Budgeted/Actual Sales is kept within a range of 0.85 to 1.0.

2. Analysing the effect of training gaps and delays on various skill levels: For this experimentation, various skill levels in the organisation have been categorised. Considering the category of un-skilled/semi-skilled workers. It is further divided into twelve trades which have been fixed a priority with respect to the production output and the productivity of a work centre. Fig.6a plots productivity(the VA Ratio)based on regular training cycle for trades|T1(.11) > T2(.08)|. In case, the training period is delayed by a period of two quarters of a year for the same two trades T1 and T2 the plot for productivity(the VA Ratio) varies as indicated in Fig.6b. Also, Table 5 analyses the effect of training delay period on the productivity ratio(VA).

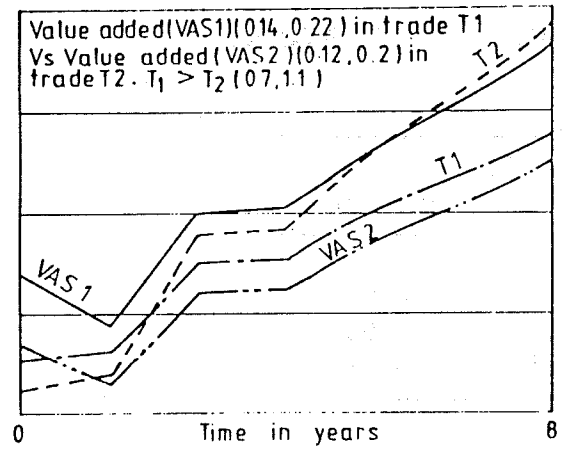

Fig 6a FOR TWO TRADES IN THE CATEGORY OF UN-SKILLED/SEMISKILLED WORKERS THE MANPOWER Vs THE CORRESPONDING VALUE ADDED

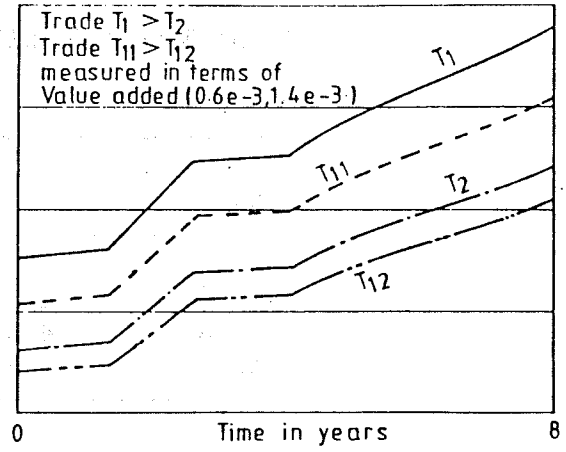

Fig 6b VARIATION DUE TO TRAINING DELAYS FOR TWO TRADES IN THE UNSKILLED/SEMI-SKILLED CATEGORY

TABLE 5: EFFECT OF TRAINING DELAY ON PRODUCTIVITY

TRAINING	VALUE ADDED UNSKILLED/SEMISKILLED		
	4th yr	6th yr	8th yr
a) No delay	69.25	92.30	113.0
b)Delay by 1 qtr.	65.78	87.70	107.3
c)Delay by 2 qtr.	55.40	73.85	90.5
d)Delay by 3 qtr.	48.47	69.60	79.0

An inference here is that to keep the productivity within the actual limits the delay in training for this type of category should never exceed one quarter of a year.

3. Suggesting a desirable policy for funds commitment so as to reduce the working capital employment: Main variables affecting working capital are inventory(RVI), sundry debtors(SDEBT), loan advances(LADV), cash(CASH), liabilities(LIAB) and the provisions(PROV). In the present policy experiments, only the effect of inventory and sundry debtors has been studied. Fig.7 shows(in days) the effect of these variables for a ten-year period. Table 6 relates the effect of working capital by changing the inventory and sundry debtors.

Table 6 : EFFECT OF INVENTORY AND SUNDRY DEBTORS ON WORKING CAPITAL

Inventory	Working Capital		Sundry Debtors	Working Capital	
	8th yr	10th yr		8th yr	10th yr
a) Reduction by 40%	0.7	0.17	a) Realization increased by 30%	1.8	0.42
b) Reduction by 30%	0.8	0.2	b) Realization increased by 20%	1.6	0.39
c) Reduction by 15%	1.0	0.25	c) Realization increased by 10%	1.5	0.35

An optimal mix of working capital, as can be inferred from Table 6 is generated if the inventory is reduced by 15% and measures adopted to realise bad debts by 10%.

Some of the policy experimentation that can be conducted in future are:-

1. Analysing the profits and internal resources generated and hence suggesting a desirable range of rate of return that improves the liquidity.

2. Suggesting a suitable policy for investment only to be made from internal resources.

3. Analysing the interests and dividends and suggesting a suitable policy for supplementary source of income.

4. Suggesting a policy for financial packages.

Conclusions: An integrated model consisting of four areas, namely finance, human resources, production and R&D for effective policy analysis of a firm has been developed. The model also provides a means by which the maturity, effectiveness and feasibility of realisation of corporate goals can be evaluated. The 'ideal' policy so identified can then be implemented with a greater degree of confidence. The potential improvement after successful implementation will eliminate the limitations of present practices.

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