Human Resource planning in a Shore-based Integrated Steel Plant: A System Dynamics Model

Dr. KR Divakar Roy
Principal
Thandra Paparaya Institute of Science and Technology
BOBBILI-535558, AP, India
divakarroy@rediff.com

Dr. Saroj Koul
Assistant Professor
Fred C. Manning School of Business Administration
Acadia University, B4P2R6, NS, Canada
saroj.koul@acadiau.ca

Abstract

This paper elaborates a model of Human Resource supply and demand as it affects the productivity of a shore-based integrated steel plant using the System Dynamics method. The HR scenario at the plant is examined over a period of ten years, during which it successfully operated with one-third of the personnel in comparable steel plants in India. Also examined is the optimal level of human resources necessary to ensure enhanced efficiency and productivity levels, containing personnel, and redeploying surplus personnel through retraining and relocation. The key parameters taken up are non-executive/executive ratio, personnel productivity, and total workers. More precisely, it identifies policies related to (i) downsizing personnel (ii) to decreasing non-executive/executive ratio, and (iii) improving labour productivity and effectiveness.

Keywords: Manpower Policy, Downsizing, Labour Productivity, System Dynamics, shore-based Steel Plants, India.

1. Background

At present the steel plant under study is being operated with one third of the manpower existing in other comparable steel plants in India. In fact, the steel plants are now benchmarking on manpower productivity of steel, i.e., steel produced per man-day employed. Thus the manpower policy, obviously, is to derive a mode of downsizing. Here, SD model is used to test how long it may take to achieve the targeted downsizing if the current situation is continued, i.e., allow the employees to retire at the mature age without any recruitment to those cadres.

2. Objectives

The manpower plan envisaged for the company aims at maintaining optimal level of manpower to ensure enhanced efficiency and productivity levels, with a view to containing manpower, redeploying existing surplus manpower through retraining and relocation. In view of the above, the main focus of study is to (i) downsize the manpower, (ii) increase executive- non- executive ratio, and (iii) improve labour productivity

2.1 Model description

The plant under study has achieved a labour productivity of 253 tonnes per man-year, which is higher than any comparable steel plant in India. And the management aims at achieving a labour productivity of 300 tonnes per man-year [1]. To achieve this target, the management aims at downsizing its manpower by containing the regular manpower and eliminating the contractual manpower. Also, the management aims at reducing the ratio of executives to non-executives in works to 1:4 from the existing 1:8 for having effective control thus shifting the manpower composition progressively from non-executive cadre to executive cadre. Also, management has created a non-unionized junior officers cadre starting with 300 junior officers in 1996.

The dynamics of manpower mobility is captured in the causal loop diagram (Fig.1) and the flow diagram (Fig.2). The manpower composition can broadly be divided into (i) executives (ii) non-executives and (iii) ministerial staff. The direct recruitment is made in three stages for non-executives (Technical), namely, Assistant Technician, Technician and Chargemen. Also, Assistant technicians are being promoted as Technicians and they are in turn being promoted as Chargemen. Also, Charge men are being promoted to Junior Officer Cadre. Executive cadres are again being classified as (i) Front level executives (ii) Middle-level executives and (iii) top and senior executives.

In the executive cadre, the main entry point is trainee executives. After successful completion of the training they are placed in the cadre of front level executives and promoted to the cadres of middle level executives and senior and top level executives.

Recruitment to the cadres of Assistant technician, technician, Chargemen and executives is defined as a third order delay variables and are explained below:

1 a) The recruitment for lowest cadre in non-executive Technical category is Assistant Technician cadre. After successful completion of training they are placed in that category. Therefore, Assistant Technicians under training (ATECUT) is defined as level variable as:

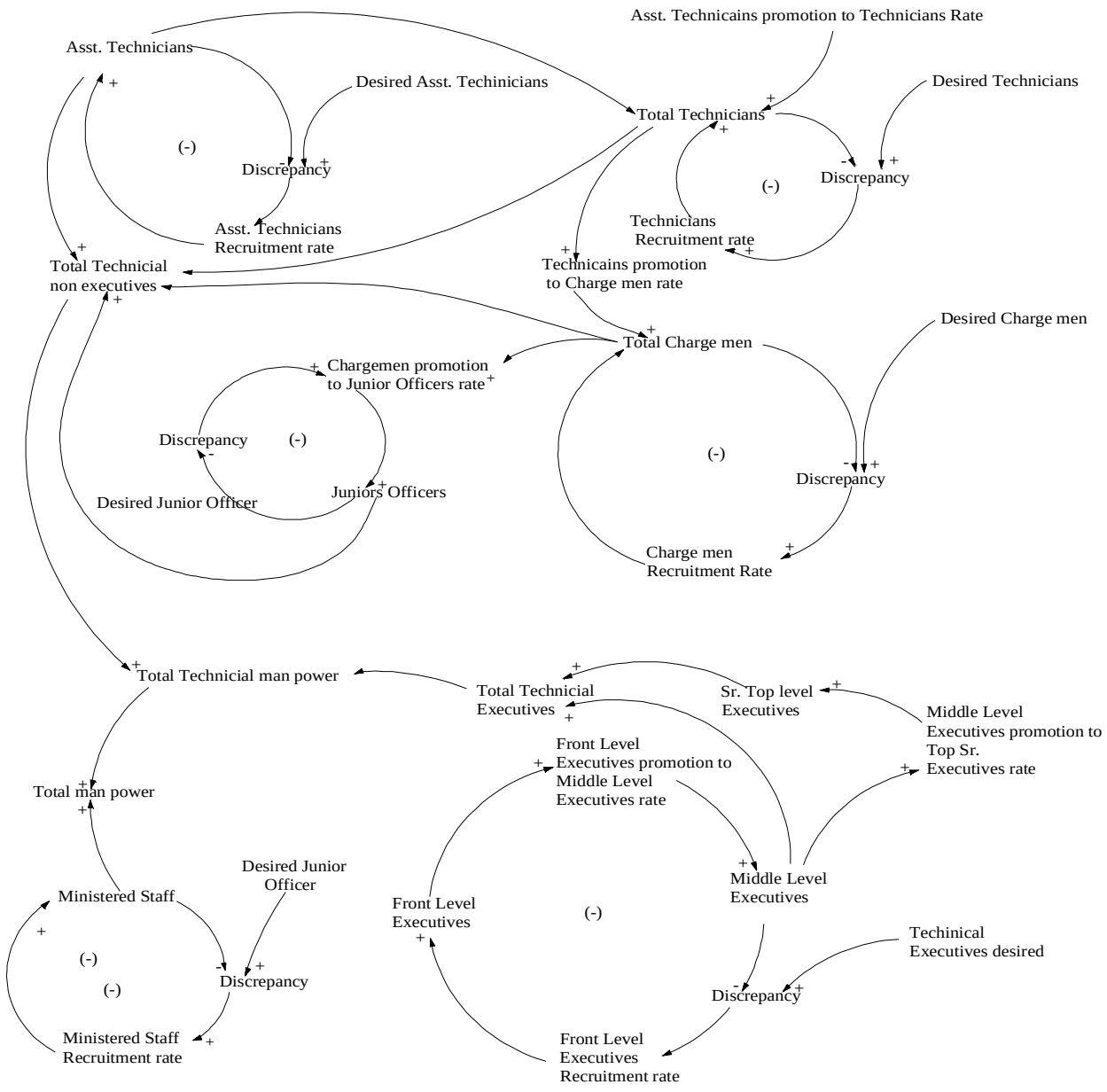

Fig.1 Causal Loop Diagram of Manpower System

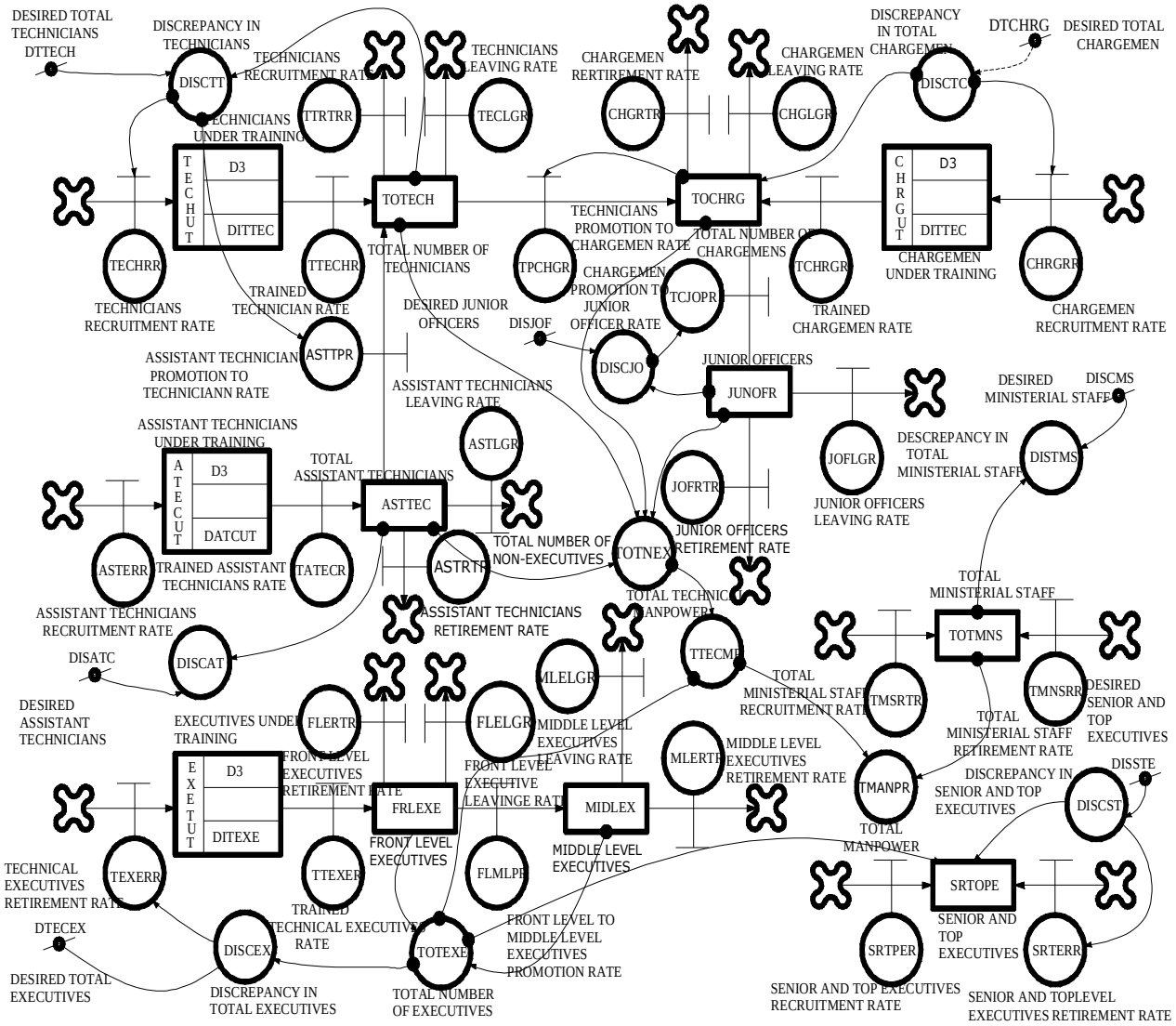

Figure 2 Flow Diagram of Manpower Sub-system

CALL DELAY (ATCRR1, ASTERR, AT1, AT2, TATECR, DATCUT)

where ATCRR1 = Assistant Technicians Recruitment Rate, initial.
AT1, AT2 = Delay constants.
DATCUT = Time Delay for Assistant Technicians under Training, a constant.

Thus, Technicians under training (TECHUT), Chargemen under training (CHRGUT) and Executives under training (EXETUT) are defined as level equations as explained above.

2 a) Total Assistant Technicians (ASTTEC) is defined as a level variable and is given by the following equation.

ASTTEC = ASTTEC + DT* (TATECR – ASTTPR – ASTRTR – ASTLGR)

where ASTTPR = Assistant Technicians Promotion to technicians Rate.
ASTRTR = Assistant Technicians Retirement Rate.
ASTLGR = Assistant Technicians Leaving rate.

b) Assistant Technicians Promotion to Technicians Rate (ASTTPR) is defined as rate equation and is given by the following equation.

ASTTPR = ASTTEC/AYPTEC

where ASTTEC = Assistant Technicians.
AYPTEC= Assistant technicians promoted to Technicians/Year, a constant.

c) Assistant Technicians Retirement Rate (ASTRTR) is defined as a rate equation and is given by the following equation.

ASTRTR = ASTTEC/ATRTAG

where ATRTAG = Assistant Technicians Retirement Age, a constant.

ATECUT=ATECUT+DT*(ASTERR–TATECR)

where ASTERR=Assistant Technicians Recruitment Rate
TATECR=Trained Assistant Technicians Rate

e) Assistant Technicians Recruitment Rate (ASTERR) is defined as rate variable and is given by the product of discrepancy in Total Technicians (DISCAT) and Assistant Technicians Recruitment per year (ASTERY), a constant.

ASTERR = DISCAT* ASTERY

f) Discrepancy in Total Technicians (DISCAT) is the difference between Desired Assistant Technicians (DISATC), a constant and Assistant Technicians (ASTTEC). It is defined as an auxiliary equation.

DISCAT = DISATC –ASTTEC

g) Trained Assistant Technicians Rate (TATECR) is defined as a rate variable and can be obtained from the following call delay function

h) Assistant Technicians leaving rate (ASTLGR) is defined as a rate equation and is given by the following equation.

ASTLGR = ASTTEC * ATCLGF

where ASTLGF = Assistant Technicians Leaving rate Fraction, a constant.

Similarly, Total technicians (TOTECH), Total Chargemen (TOCHRG), Front line executives (FRLEXE), Middle level executives (MIDLEX) and Senior and top level executives (SRTOPE) are modeled as level variables as explained above.

3 a) junior officers (JUNOFR) are modeled as level variable as given below.

JUNOFR = JUNOFR + DT*(TCJOPR – JOFRTR – JOFLGR)

where JUNOFR = Junior officers

TCJOPR = Chargemen promoted as junior officers rate.

JOFRTR = Junior officers retirement rate.

JOFLGR = Junior officers leaving rate.

b) Chargemen promoted to Junior officer rate (TCJOPR) is defined as a rate variable and is given by the following equation.

TCJOPR=DISCJO*TCHPRF

c) Discrepancy in Junior officer (DISCJO) is defined as an auxiliary equation and is given by DISCJO=DISJOF-JUNOFR

where DISJOF= Desired Junior officers.

JUNOFR= Junior officers.

d) Junior officers retirement rate (JOFRTR) is defined as a rate variable and is given by

JOFRTR = JUNOFR/JORTAG

where JORTAG = Junior officers retirement age, a constant.

e) Junior officers leaving rate (JOFLGR) is defined as a rate variable.

JOFLGR = JUNOFR*JOFLGF

where JOFLGF = Junior officers leaving rate factor, a constant.

Total ministerial staff (TOTMNS) is modeled as a level variable.

TOTMNS = TOTMNS +DT*(TMNSRR – TMSRTR)

where TMNSRR = Total ministerial staff recruitment rate.

TMSRTR = Total ministerial staff retirement rate.

4 a) Total Ministerial staff (TOTMNS) is defined as a level equation and is given below.

TOTMNS=TOTMNS+DT*(TMNSRR-TMSRTR)

where TMNSRR=Ministerial staff recruitment rate

TMSRTR=Ministerial staff retirement rate

b) Ministerial staff recruitment rate (TMNSRR) is defined as a rate equation and is given by the following equation

. TMNSRR = DISTMS*MINSRF

where DISTMS = Discrepancy in total ministerial staff.

MINSRF= Ministerial staff recruitment rate factor, a constant.

c) Discrepancy in total ministerial staff (DISTMS) is defined as an auxiliary variable given as DISTMS = DISCMS – TOTMNS

where DISCMS = Desired total ministerial staff, a constant.
TOTMNS = Total ministerial staff

d) Ministerial staff retirement rate (TMSRTR) is defined as a rate variable and is given by

TMSRTR = TOTMNS/TMSRAG

where TMSRAG = Ministerial retirement age, a constant

5) Total number of non-executives (TOTNEX) is defined as an auxiliary variable and is given by the following equation.

TOTNEX = ASTTEC +TOTECH +TOCHRG +JUNOFR

where ASTTEC = Assistant technicians.
TOTECH = Total number of technicians
TOCHRG = Total Chargemen
JUNOFR = Junior Officers

6) Non-executives to Executives ratio (NEXEXR) is defined as a ratio between Total number of Non-executives and to that of Total number of Executives and is given by the following equation.

NEXEXR = TOTNEX/TOTEXE

where TOTEXE = Total number of executives.
TOTNEX = Total number of non-executives.

3. Computer simulation of the Model

This model consists of a total of 56 equations having 13 level variables, 25 rate variables, 4 third order call delay variables and 14 auxilliary variables. The model is simulated for a period of 20 years from 1994 using DYMOSIM Software package. Simulation is carried out with the assumption that the problem description would remain valid for this period. All together six policies are tested and the results are verified with the available published data.

4. Model Validations

The following three variables have been selected for model validation. They are:

i) Total Technical Manpower
ii). Non- Executive to executives Ratio and
iii) Manpower Productivity

Model generated data for a period of 10 years from 1993-94 to 2002-03 is plotted against the historical data as indicated in the Fig.3 to Fig.5. It can be seen from figures that there is a very good agreement between the model-generated data and that of actual data.

The slump in productivity during the year 1999 was due to the repair of coke ovens and shut down of a blast furnace unit of the steel plant which underwent capital repair resulting in a huge loss of production. The productivity of 258 tonnes per man-year predicted by the model corroborates its validity and confidence.

4.1 Tests of Model structure

i) Structure verification test: The structure of the model was thoroughly validated such that it clearly resembles the structure of the real life system. The model consists of physical flows of manpower. Both the causal loop diagram and flow diagram consist of variables which can be easily identified in the real life system.

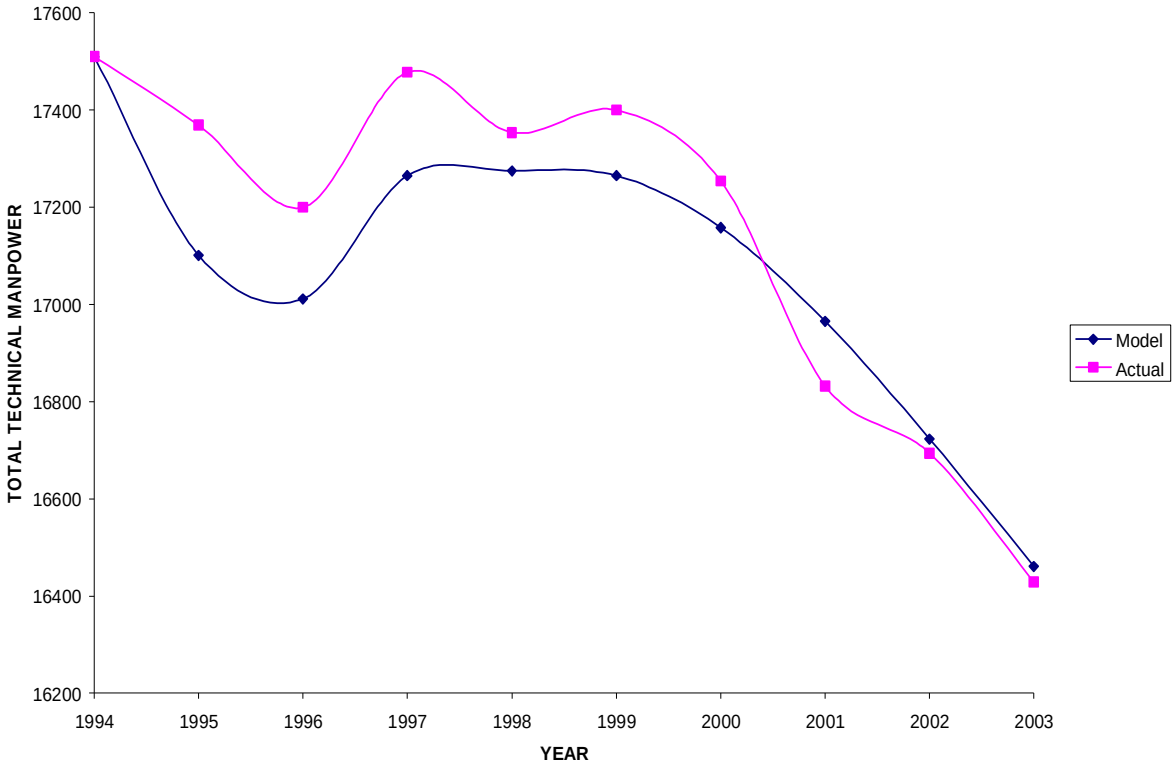

Fig. 3 Total Technical Manpower

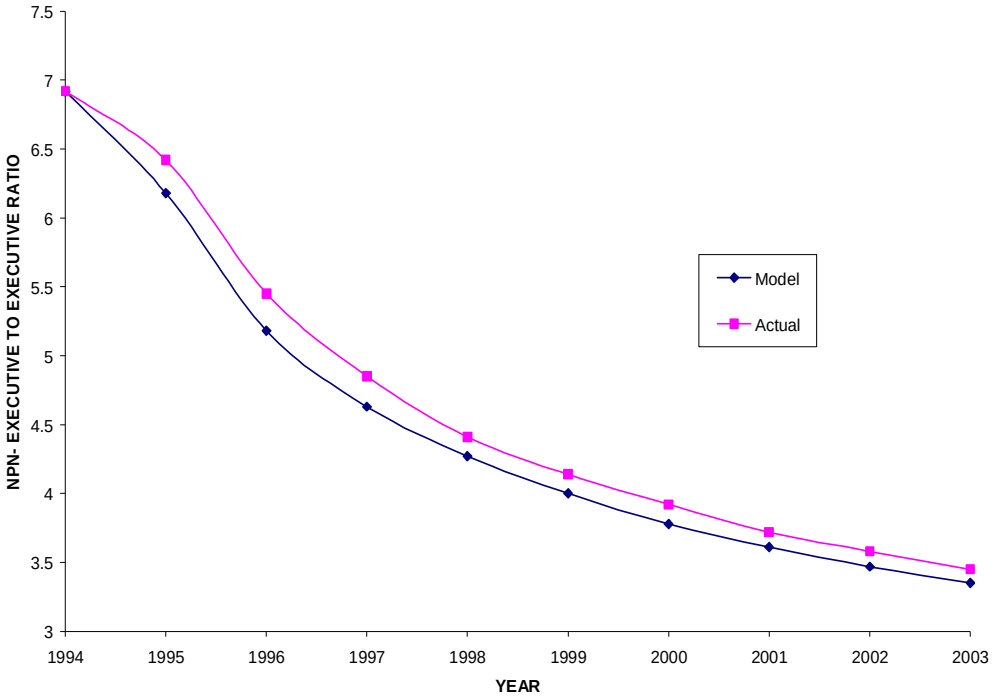

Fig 4 Non- executive to Executive ratio

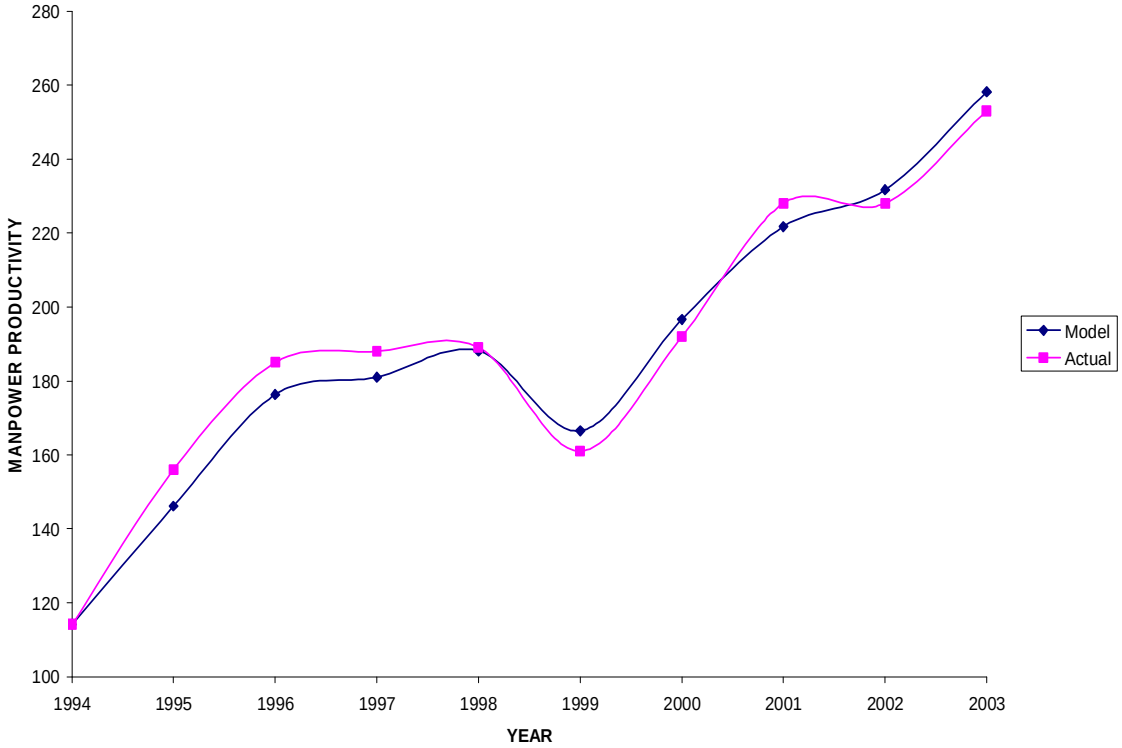

Fig.5 Manpower productivity

ii) **Parameter verification test:** All the parameters considered in the model correspond to the real life system both conceptually and numerically. All these parameters are identified and found to be consistent with the real life system.

iii) **Dimensional consistency test:** The model consists of 56 equations. All these equations are written and thoroughly checked for dimensional consistency between the influencing variables and of resultant variables. Thus the model is found to be dimensionally consistent.

iv) **Boundary adequacy (structure) test:** As indicated by causal loop diagram and flow diagram the factors considered in model have been adequate in addressing the various issues related to real life system. The model boundary set in this study, therefore, is considered adequate for the objectives with which the model developed.

4.2 Tests of Model behaviour

i) Behaviour reproduction test:

The validity of the model is further established by means of the statistical analysis of the data. The results of the analysis are summarized in Table.1. A comparison of the standard deviations also makes it very clear that the there is an excellent agreement of the modeled data and actual data from the industry.

Table 1: Comparison of Model generated and Actual values for select variables

YEAR	Executive / Non-Executive Ratio		Labour Productivity		Technical Manpower	
	Model	Actual	Model	Actual	Model	Actual
1993-94	6.92	6.92	114.22	114.2	17510	17510
1994-05	6.18	6.42	146.18	156.0	17101	17369
1995-96	5.18	5.45	176.34	185.0	17012	17200
1996-97	4.63	4.85	181.03	188.0	17265	17478
1997-98	4.27	4.41	188.14	189.0	17275	17354
1998-99	4.00	4.14	166.52	161.0	17265	17400
1999-00	3.78	3.92	196.7	192.0	17158	17254
2000-01	3.61	3.72	221.72	228.0	16965	16832
2001-02	3.47	3.58	231.72	228.0	16723	16694
2002-03	3.35	3.45	258.18	253.0	16461	16429

So as to further enhance confidence in the model, t-test and F-test are conducted and the results are tabulated in Table 2. The results are well within the limits and there is a close agreement between the simulated data and that of the actual data. The difference in both values is insignificant. On the basis of the qualitative and quantitative tests, it is thus concluded that the model is replicating the real situation.

Table 2: t- test and F-test for Model and Actual values for selected variables

Variable	Actual		Model		t- Values $[t_9(0.05) = 2.26]$	F-Values $[F_{9,9}(0.05)= 3.18]$
	Mean	Standard Deviation	Mean	Standard Deviation		
Non-executive to Executive Ratio	4.686	1.2135	4.539	1.2083	0.27145	1.0086
Labour Productivity	187.5	38.84	188.0	41.96	0.02688	1.167
Technical Manpower	17196	401.34	17073	302.94	-0.77164	1.07552

ii) Behaviour prediction test: Valid prediction of the real system behaviour can be made only if the model structure, the managerial policies and time variation of exogenous variables can be predicted (Mohapatra 1994). The model is run for the period from 2004 to 2013 and found that the results of the model are identical with that of the values predicted by the management. This is vindicated by the results for period 2004 to 2006.

iii) Behaviour anomaly test: The model did not produce any behaviour anomalous to that of the real system.

iv) Family member test: The model has been developed for an integrated steel plant located in Visakhapatnam. But it is generic in nature and with appropriate modifications in the initial values of the level variables and constants; it can be applied to any other steel plant either in India or elsewhere.

v) Surprise behaviour test: The model did not produce any surprise or counter intuitive behaviour.

vi) Boundary adequacy (behaviour) test: This test was intended to check whether the model boundary can be expanded to include other related aspects like domestic sales, export sales, owning captive mines. At aggregate level, however, inclusion of these factors is not expected to produce significance changes in the model results.

vii) **Behaviour sensitivity test:** The model was tested for changed values of various parameters. Qualitatively the model retains its behaviour for all the variables.

5. Policy options

Human resource planning is the process by which an organization should move from its current manpower position to desired manpower position. In view of the current trends in industry with emphasis on technology, cost reduction, quality and productivity etc., it is imperative to retrain and redeploy the manpower on a continuous basis and the requirements of the manpower can be met from internal human resources of the organization. The following six policies are considered for implementation and forecasting the organizational behaviour in tune with the desired manpower requirements.

Policy-1 (Base Run):

In this policy, it is assumed that the present trend with reference to recruitment to various cadres will continue in future also.

Policy-2:

In this policy, it is presumed that there will not be recruitment for any cadre. In view of the management aim at reducing manpower, this policy aims at examining the implications if the recruitment is banned.

Policy-3:

The management aims at reducing the strength of non- executive cadre. In light of this policy, it is assumed that there will not be any recruitment at non-executive level i.e., to the cadres of assistant technicians, Chargemen, technicians and ministerial staff.

Policy-4:

In this policy, the implication of reducing the total length of service by 5 years, for all cadres is tested. Government of India has been encouraging voluntary retirement by the employees of public sector undertakings. In light of the above policy of the government, it has been proposed to study the implications if total length of service is reduced by 5 years.

Policy-5:

In this policy, it is presumed that the total length of service is reduced by 5 years for non-executives. As the management is intending to reduce the non- executive cadre, it is tested what happens if the total length of service for the said cadre is reduced by 5 years.

Policy-6:

In this policy, it is presumed that the total length of service is reduced by 5 years for executives only. The impact on the organization, if the length of service of executive cadre is reduced by 5years is tested.

6. Results of model simulation

After simulating the model for different policy options listed above, the behaviour of key variables was examined in detail. The base run (Policy-1) results have also been compared with the available data. A comparative study of various policy results has been made. The results of base run for the selected variables are presented in Table.3.

Table 3: Base run results of key variables

Sl. No.	Variables	1994	1997	2000	2003	2006	2009	2013
1	Technical Manpower	18410	18483	17959	17169	16335	15548	14607
2	Non-Executive to Executive Ratio	7.33	5.12	4.05	3.56	3.25	3.02	2.76
3	Manpower Productivity (Tonnes/ Man/year)	109	172	216	256	300	315	335

7. Policy analyses

The results of the policies adopted are shown in Figs.6 to Fig.8. A comparison of performance under different policy options is given in Table 4.

7.1 Total technical manpower

Among the policies tested, Policy-2 is resulting in the lowest number followed by Policies-3, 4, 5, 6 and 1 (Table.4 and Fig.6). So as to bring down the strength of manpower, various options like complete stoppage of recruitment, reduction of total length of service at various levels are considered. At one stage, the government has offered a voluntary retirement scheme for public sector employees. Because of this reason only, the implication of reduction in total length of service is considered. But this policy is not having much impact in reducing the manpower and the viable policy is stopping of recruitment totally for all cadres as it gives a solution as contemplated by the management.

Table 4: Comparison of key Variables

Sl. No.	Variables	Year	P_1	P_2	P_3	P_4	P_5	P_6
1	Technical Manpower	2004	16889	16785	16868	16782	16822	16850
		2007	16066	14839	15548	15679	15806	15939
		2010	15300	12936	14173	14732	14894	15138
		2013	14606	11259	12931	13905	14082	14430
2	Non-Executive to Executive Ratio	2004	3.44	3.51	3.44	3.46	3.42	3.48
		2007	3.16	3.71	3.03	3.2	3.1	3.27
		2010	2.95	3.9	2.66	2.97	2.85	3.08
		2013	2.76	4.09	2.33	2.75	2.63	2.89
3	Manpower Productivity	2004	255	257	256	257	256	256
		2007	305	330	315	312	310	307
		2010	320	378	345	332	329	323
		2013	335	435	379	352	348	339

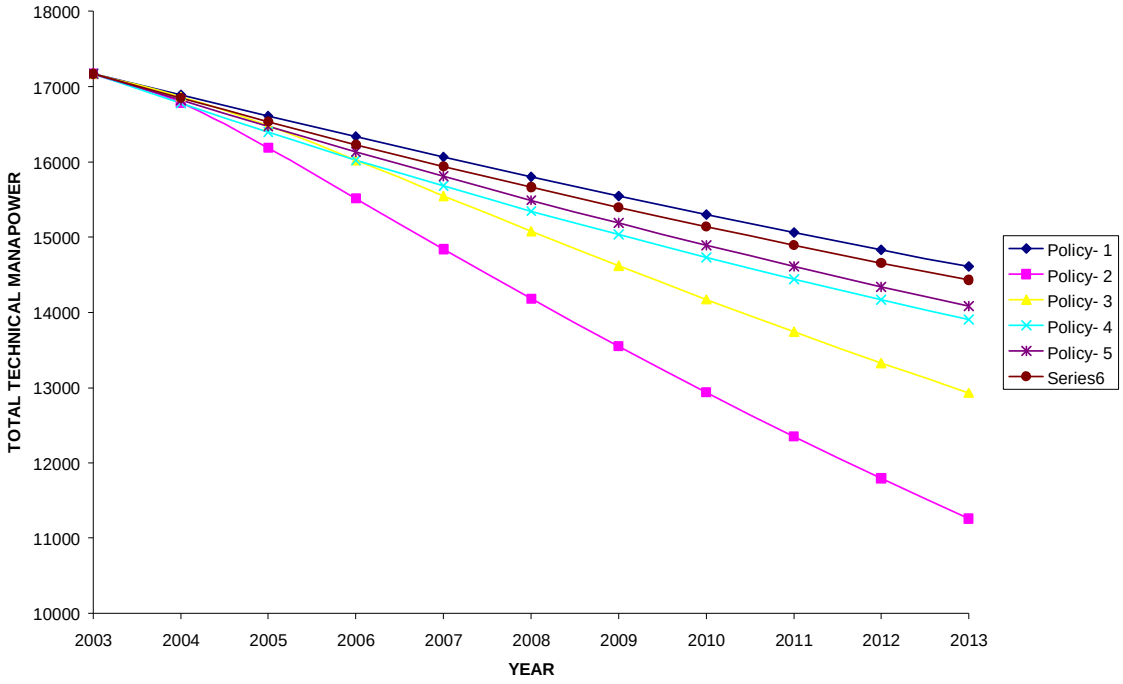

Fig. 6 Total technical manpower with policy changes

7.2 Non-executive to executive ratio

The best ratio is given by Policy-3 followed by Policies-5, 4, 1, 8 and 2 (Table.4 and Fig.7). But, the ratios given by these policies are almost identical. However, it may not be practicable to implement any one of these policies because of practical difficulties. In these policies, it assumed either stoppage of recruitment or reduction in the total length of service, which is not feasible in the prevailing environment. At present, the management wants to maintain a ratio of 1:4, which is reflected by Policy-2, and can be achieved by the year 2013.

7.3 Manpower productivity

The best result is given by the Policy-2, followed by Policies 3, 4, 5, 6 and 1(Table.4 and Fig.8). Thus, Policy-2 is giving the best policy in view of the reduction in manpower. Therefore, the management has to adopt Policy-2 to achieve its goal.

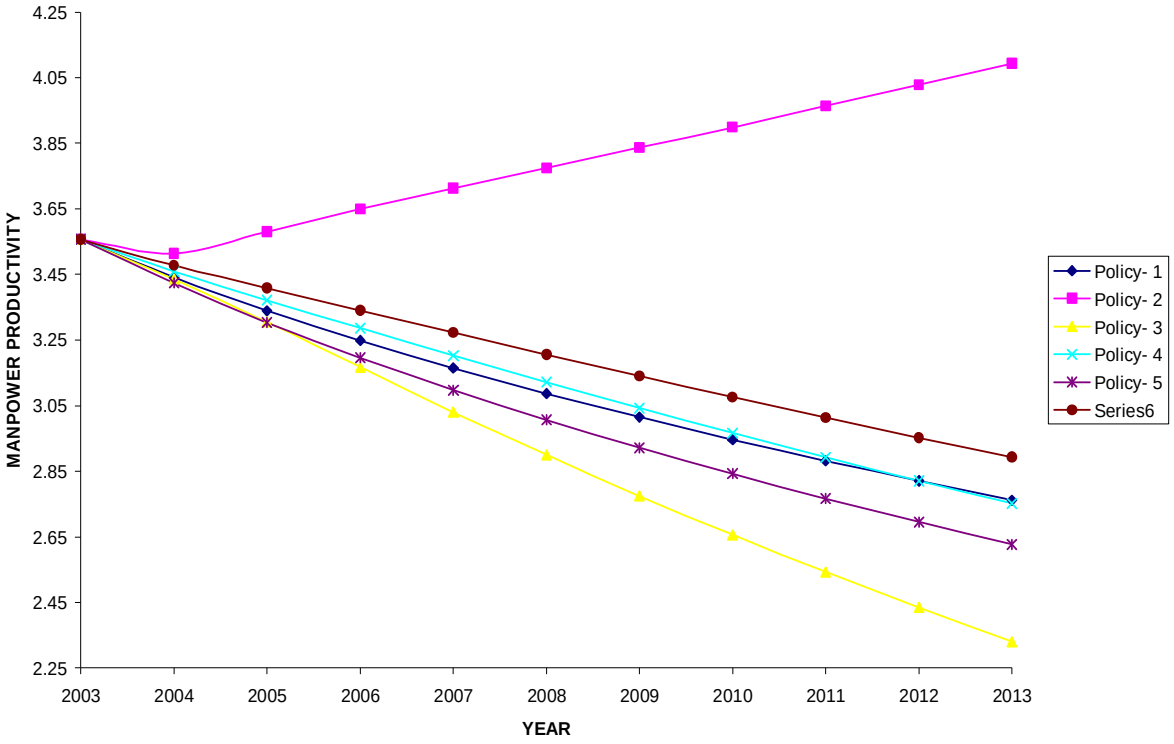

Fig. 7 Non-executive to executive ratio with policy changes

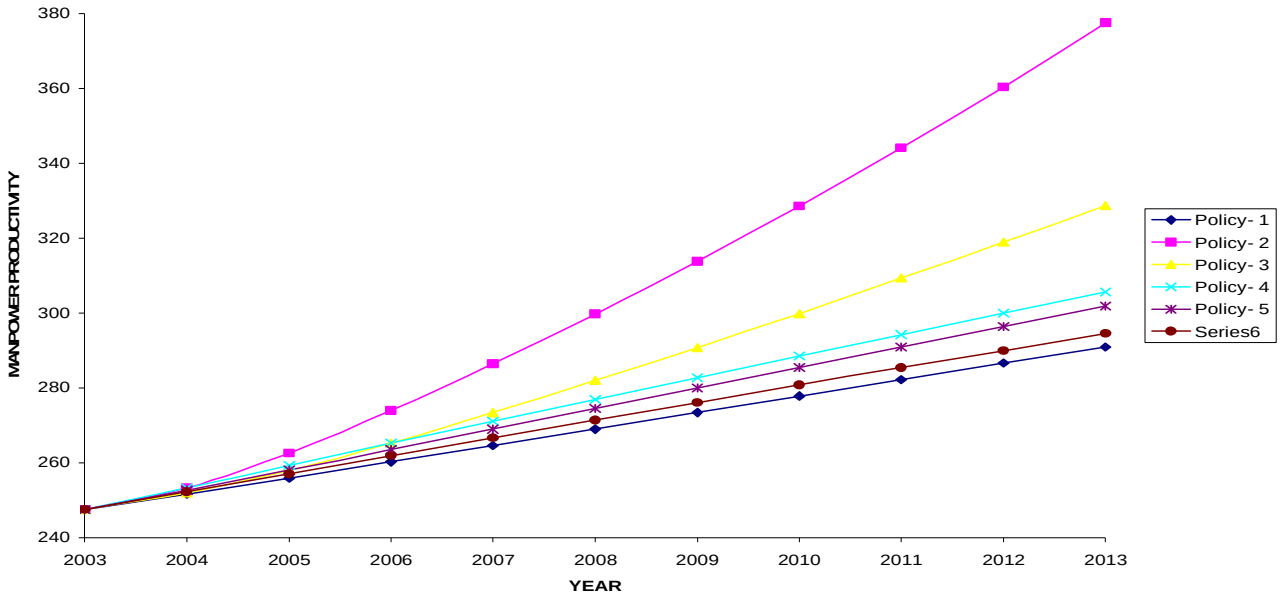

Fig. 8 Manpower productivity with policy changes

8. Summary

Based on the detailed discussion on the results, the following conclusions are drawn.

1. There is a close resemblance between the data simulated by SD modelling and the actual plant data, thus establishing the fact that SD modeling is very effective and useful in the present study.
2. The SD model is further extended to design policies for effective utilization of manpower.
3. Downsizing of manpower both at the executive and non-executive level needs to be carried out so as to improve the productivity and techno-economics of the plant operations.
4. The manpower rendered surplus can be retrained and redeployed in new and existing facilities as the production capacity of the steel plant is being enhanced.

Notes

1. World standard of labour-productivity is 600 tonnes per man-year.

References

Bora, M.C. and Mohapatra, P.K.J., (1982), *Dymosim Package*, Industrial Engineering and Management Dept, IIT Kharagpur, India

Forrester, J.W., (1961), *Industrial Dynamics*, MIT Press, Cambridge, MA

Goodman, M.R., (1975), *Study Notes in System Dynamics*, MIT Press, Cambridge, MA

Khoong, C.M., (1999), Some Optimization Models for Manpower Planning, Information Knowledge Systems Management, 1(2), 159-171

Koul, S. and Vrat P.,(1988), *Evaluating the Performance of an Engineering Firm*, System Dynamics for Management Support, Wiley Eastern Ltd., India, pg 122-137

Mohapatra, P.K.J. Mandal P., & Bora M.C., (1995) *Introduction to System Dynamics Modelling.* Universities Press: India

Richardson, G.P. and Pugh III, A.L. (1983), *Introduction to system Dynamics Modelling with DYNAMO*, MIT Press/Wright-Allen Series in System Dynamics