A SIMULATION MODEL FOR CORPORATE PLANNING IN A STEEL PLANT

R.M. NARCHAL
Director (Corporate Planning)
National Productivity Council
Lodi Road, New Delhi-110003 (INDIA)

ABSTRACT

A Simulation Model for Corporate Planning has been dèsigned for a Steel Plant based on System Dynamics principles. This Model has been designed for Material flow that takes place through a group of 12 production shops arranged in six stages of production. The Model requires a time variant input of Demand of 17 categories of finished steel products and 3 categories of Raw materials. The Model generates behaviour of various objectives based on the assumptions of the environment. The Model can be used for simulating the impact of various strategic policy decisions on the corporate objectives. The Model also guides the management in designing their long term investment policies related to expansion, modernisation and debottlenecking.

INTRODUCTION

The management of a steel plant in India has been very keen to develop a quantitative model of Corporate Planning to achieve the corporate objectives. With the help of such a model, the management is interested in simulating the result of their various strategic decisions related to modernisation and expansion investments, identification of bottleneck shop, and evaluation of different project proposals before they are actually implemented. The management realised the need of such a model based on the fact that in the past a large number of investment decisions made by the company have not shown the results as anticipated by the management. In the past the criteria for investment decisions has been changing based on the environmental conditions, the bias given by the top management and the other conditions prevailing at that time. Based on the discussions with the management it was decided to develop a Simulation Model based on the principles of System Dynamics. The basic objective of this Model was that it should assist the management of the company in designing their long term investment and modernisation policies to achieve corporate objectives of the company.

This paper explains the principles of System Dynamics used in designing such a model. The paper also explains the major applications of the Simulation Model in the area of corporate planning. During the design of the Simulation Model it was realised that the DYNAMO Compiler available with the steel plant has limited capacity. Therefore, it was decided to limit the scope of the Simulation Model only to the production shops of the company with an aggregated Financial Model.

SYSTEM BOUNDRIES MODELLED

This model has been designed for a material flow that taken place through three main zones in the Steel Plant i.e. Iron making, Steel making and Rolling. These three zones consist of group of twelve production shops namely Coke Ovens, Sinter Plant, Blast Furnaces, Steel Melting Shops, Wheel Tyre and Axle Plant, Blooming Mills, Sheet Bar and Billet Mills, Plate Mill, Merchant Mills, Medium and Light Structural Mill, Strip Mills and Sheet Mills. There are only three categories of major Raw Materials i.e. Coal, Ore and Scrap whose flow have been modelled in the six stages of production as shown in Fig. (i). The material flow has been considered unidirectional starting from Coal, Ore etc and resulting in finished Steel. The numerous categories of finished steel products have been grouped into seventeen categories namely Black Plain Sheets, Galvanised Plain Sheets, Galvanised corrugated Sheets, Merchant Mill Products, Skelp, Medium and Light structures, Blooms, Sheet Bar, Billets, Plates, Strip Bar, Wheel Tyres, Ingot, Small Blooms, Small Slabs, Rail Products and Forge Plant Products. The Model does not differentiate the finished product of Steel based on sizes and grades. They are only represented by tonnages.

While designing the Model, a production shop consisting of main equipment as well as auxilliaries is considered as a unified machine. The details of the individual sections, machines and equipment are not considered while modelling a production shop. In case, a number of production shops of different capacities are existing, in the Model these shops have been represented by same number as hypothetical machines of average capacity. Similarly there is no distinction made in the Model about the variety of sizes and grades of material being fed to a shop.

A generic feed back structure of a production shop consists of eight feed back loops. The same feed back structure exists in all the twelve production shops. The integrated production flow, therefore, gets influenced by 96 feed backs. These feed backs have been put in a Dynamo programme consisting of about 1200 statements. The management have to interact with the Dynamo programme with environmental scenarios inputs and its own strategic policy inputs to see the behaviour of the various production outputs. The Model provides an insight in the dynamics of production and assist the management in changing the behaviour towards the desired end by allowing them to simulate the impact of their strategic decisions.

MODEL OF THE STEEL PLANT

The integrated Model of the Steel Plant can be divided into two parts as stated below:

i) Financial Model

ii) Production Model.

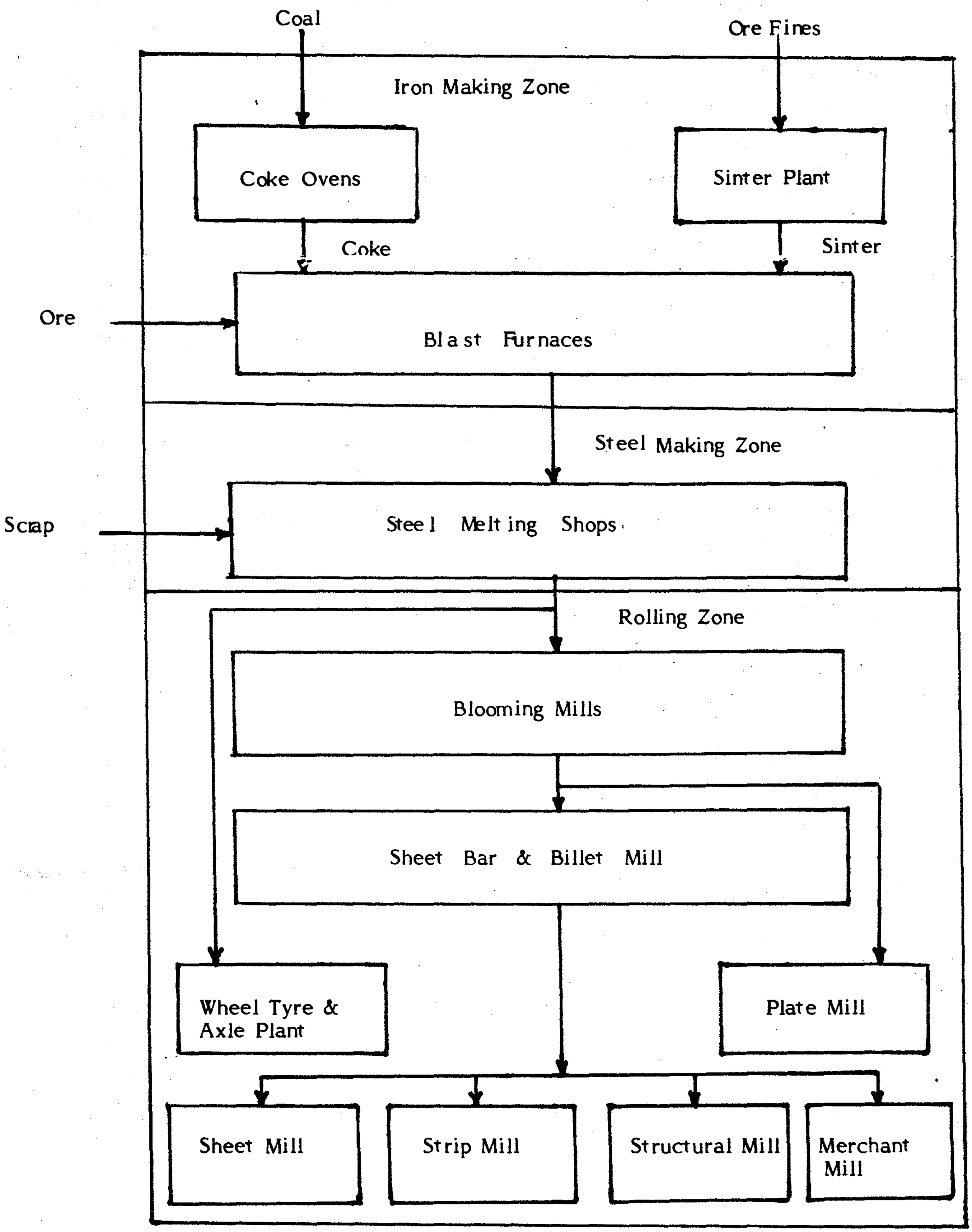
Coal
Ore Fines
Iron Making Zone
Coke Ovens
Sinter Plant
Coke
Sinter
Ore
Blast Furnaces
Steel Making Zone
Scrap
Steel Melting Shops
Rolling Zone
Blooming Mills
Sheet Bar & Billet Mill
Wheel Tyre & Axle Plant
Plate Mill
Sheet Mill
Strip Mill
Structural Mill
Merchant Mill

Fig. (i)

The Financial Model, in a limited manner simulates the financial consequences of the basic resources of production i.e. manpower, materials, machines, etc. and largely depends on the results of the Production Model. This Model simulates the behaviour of Return on Gross Block, Realisation, Works Cost and Undepreciated Gross Block. The feed back process governing the financial flows could not be incorporated in the Financial Model due to the limited capacity of the Dynamo Compiler. The Financial Model has no independent status and has to be run along with Production Model.

The Production Model has been designed to simulate monthly Saleable Steel production comprising of seventeen finished steel products. The material flow takes place through six stages of production constituted of twelve production shops. The Production Model has been designed by judiciously integrating the production models of twelve production shops. A production shop has been the basic planning unit and a generic feed back structure has been applied to model all the production shops. Inspite of the fact that underlying feed back processes of all production models of all the production shops are same, these models are unique to suit the typical material flow to and from these production shops. The generic model of a production shop is discussed below.

Generic Model of a Production Shop:

In this Model, production of a shop shows a dynamic behaviour from month to month based on a number of influencing factors. These factors depict interplay between the three main resources of production i.e. Machines, Manpower and Materials. The machines have been the basis of computation of capacity. To arrive at production, the utilisation of capacity has been taken as a function of Demand for finished products, maintenance requirements of machines, availability of raw materials and manpower. The impact of power shortage has been put as an exogenous input in arriving at the capacity. The influence of significant factors on production has been modelled through feed back processes. There are a set of eight feed back loops existing in each shop. The various feed back loops governing the production behaviour in a Model of a shop are discussed below.

i) Demand Constraint Loop:

The influence of demand on the finished products of a shop can be visulized as a feedback process. The shortages of Demand have been designated as Demand Constraints. Higher is the Demand, lower will be the value of Demand constraint. A low demand indicates higher demand constraint meaning throttling of production. As demand for finished products of a shop goes up, the demand constraint on production reduces indicating a negative relationship of linkage between Demand constraint and production. The feed back loop is shown in Fig. (ii).

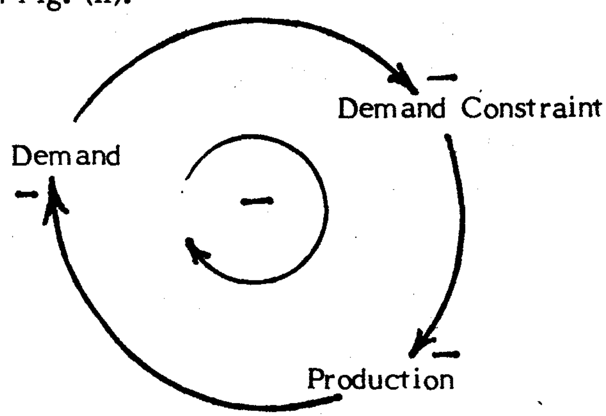

Fig. (ii)

Going round the loop, one finds that as production goes up, Demand gets satisfied and therefore, goes down. The level of Demand decides the Demand constraint. The value of Demand Constraint ranges between zero and one depending on the level of Demand and Capacity for production. All the three linkages round the feed back loop being negative, one finds that the loop is negative in character.

ii) Material Constraint Loop:

The production of a shop is also considered as a function of the Raw material availability. The shortages of material is represented as material constraint and it indicates the extent of throttling of production on account of material shortages. Its value ranges between zero and one. A zero value of material constraint indicates complete production shut down due to non availability of material, whereas the other extreme value of one indicates that the production does not suffer in the month on account of material shortages. The feed back loop is shown in Fig. (iii). When the material availability goes up, the constraint of material on production goes down indicating a negative relationship. As material contraint goes up, the throttling of production increases and the production goes down. This relationship is also negative in character. The extent of feed back of production on material availability indicates a negative relationship as when the production goes up, the material availability goes down. The feed back loop is negative in character as shown in Fig. (iii).

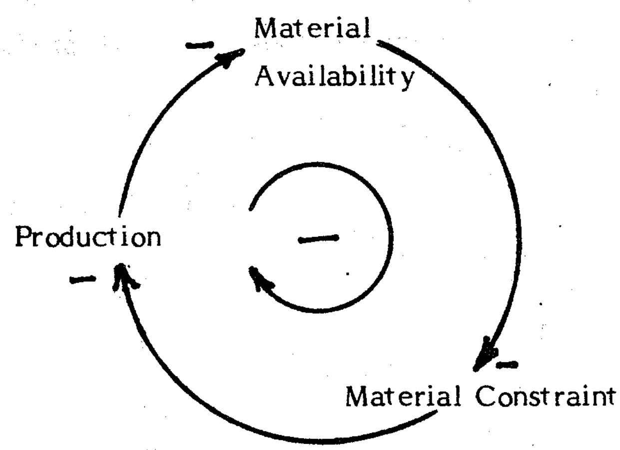

Fig. (iii)

iii) Down Time Loop:

This loop indicates that the maintenance needs of an equipment arrise as a result of the usage. The underlying hypothesis is that if usage goes up, the maintenance requirement will also go up in future and thus, reduces the equipment availability for production. The phenomenon is called Down Time Loop and is shown in Fig. (iv). It shows that equipment usage influences the Down Time and there exists a positive linkage between the two variables. The Down Time, in turn, influences usage i.e. when down time goes up, the production usage goes down due to non availability of equipment. This linkage between Down Time and usage is negative in nature. The feedback loop is negative in character.

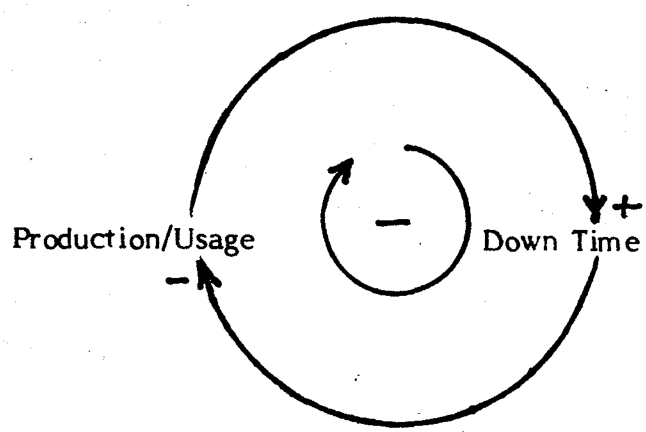

Fig. (iv)

iv) **Capacity Expansion/Divestment Loop:**

Demand for the finished products of a shop not only influences the production but under certain conditions causes expansion/divestment of capacity. In Fig. (v) this phenomenon is explained with the help of a feed back process. As demand goes up, management tends to increase the capacity to meet the Demand. The increase in capacity is the cause of increased production which satisfies the Demand. The feed back is thus negative in character and guides the management in policy design for expansion of capacity. In case due to some reasons the Demand goes down, the feed back process represents the phenomenon of divestment.

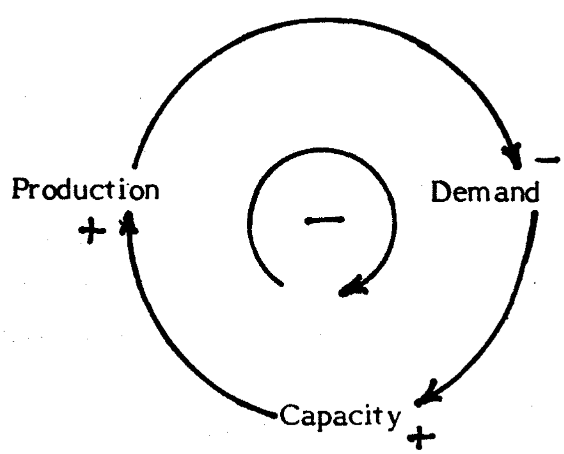

Fig. (v)

v) Manpower Constraint Loop:

This feed back process explains positive feed back phenomenon which exists between four variables i.e. production, demand, capacity and manpower constraint. As the Demand rises the management tends to increase the capacity indicating a positive linkage. With the increase of capacity the manpower constraint increases. A higher manpower constraint indicates shortages of manpower and this reduces production. The feed back loop, thus, is positive in nature. The manpower constraint loop necessarily exists in cònjuction with the capacity expansion loop and therefore, has to be studied and analysed along with capacity expansion/divestment loop. The Loop is shown in Fig. (vi).

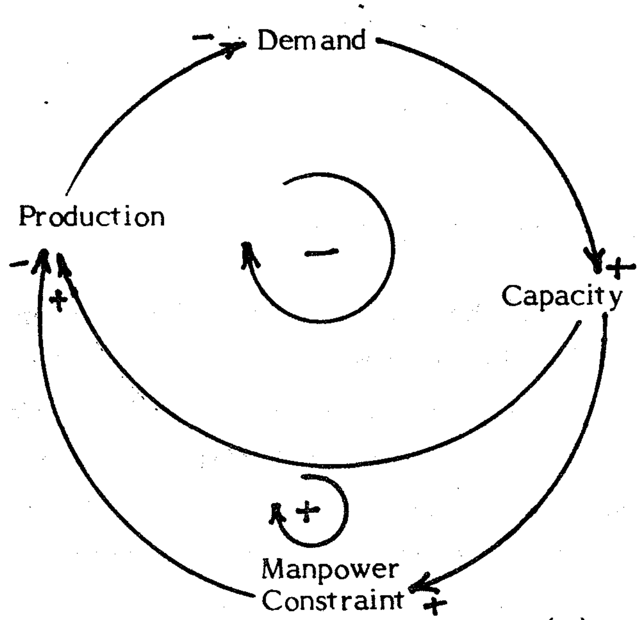

Fig. (vi)

vi) Recruitment/Retrenchment Loop:

Demand for manpower fluctuates in response to the capacity. In case of expansion of capacity, Demand for manpower rises. Till the recruitment is effective, manpower constraint on production operates. Therefore, any deficit on manpower, on one hand influences the manpower constraint as discussed earlier and on the other hand it influences recruitment as shown in Fig. (vii). When recruitment goes up, the level of manpower goes up, thereby reducing the manpower constraint. The loop is negative in character and operates on the management policy of recruitment/retrenchment.

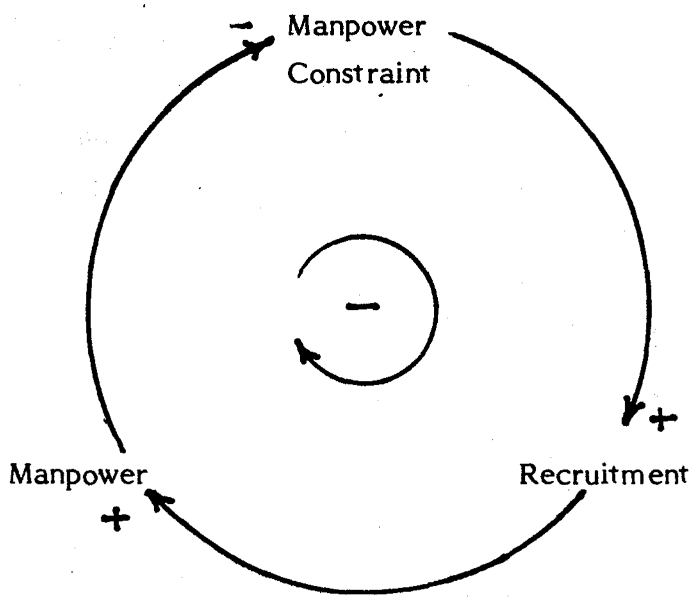

Fig. (vii)

vii) Machine Obsolesence Loop:

Based on the life of the machine, its capacity depletes. The rate of obsolesence effects the capacity, which in turn effects the obsolesence rate as shown in Fig. (viii). A negative feed back process, therefore, explains the phenomenon of machine obsolesence in the model of a production shop.

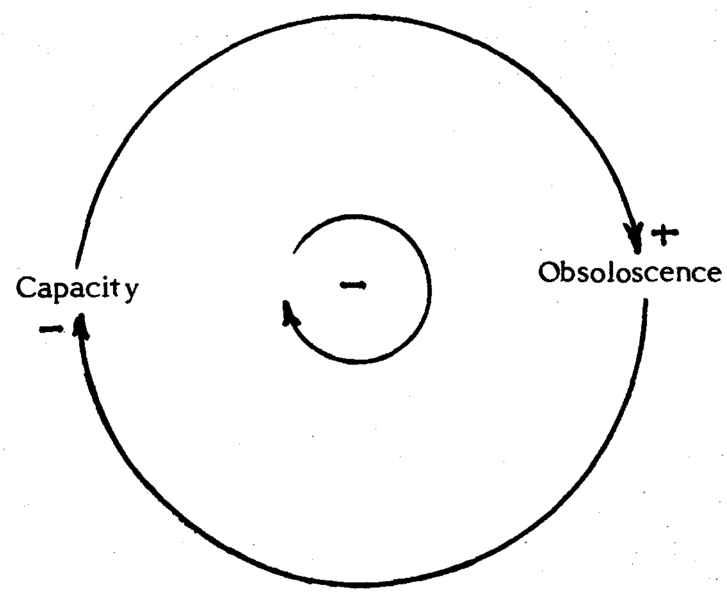

Fig. (viii)

viii) Manpower Turnover Loop:

The manpower in a production shop is likely to go down due to turnover and retirement of manpower. The turnover and retirement increases with the increase of level of manpower. The feed back is, therefore, negative in character as any increase in turnover rate decreases the level of manpower. The feed back process in shown in Fig. (ix).

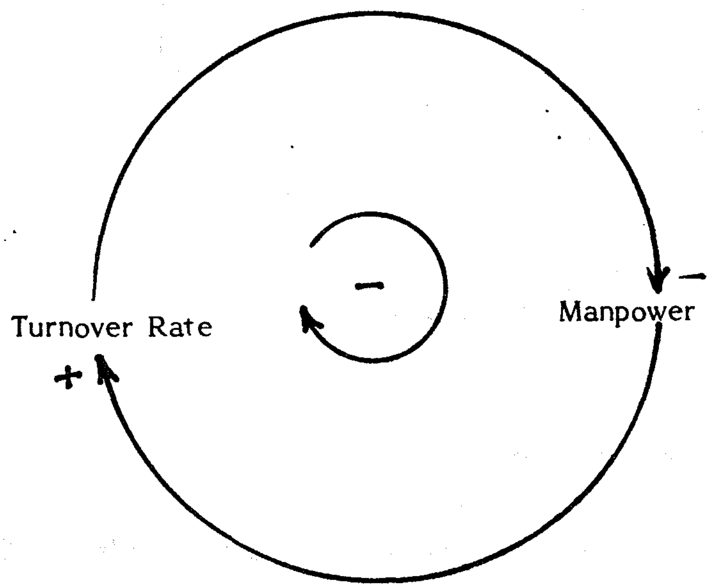

Fig. (ix)

In addition to the feed back loops discussed above there were two more feed back loops identified. One of these feed back loops was related to purchase of the Raw material and the other related to power constraint. These feed back loops could not be incorporated in the Dynamo programme of the Steel Plant model due to the limited capacity of the Dynamo Compiler.

The generic feed back model of a production shop has, therefore, eight feed back loops as discussed above. Production is common variable lying on the feed back loops of Down Time, Material Constraint, Demand Constraint, Capacity expansion and Manpower constraint. Therefore, it provides a common focal point for connecting various loops. The integration of the above loops results in a feed back structure that has been the basis of design of the Production Model of a shop. The integrated feed back structure is shown in Fig. (x).

FEED BACK STRUCTURE OF PHYSICAL FLOWS IN A PRODUCTION SHOP

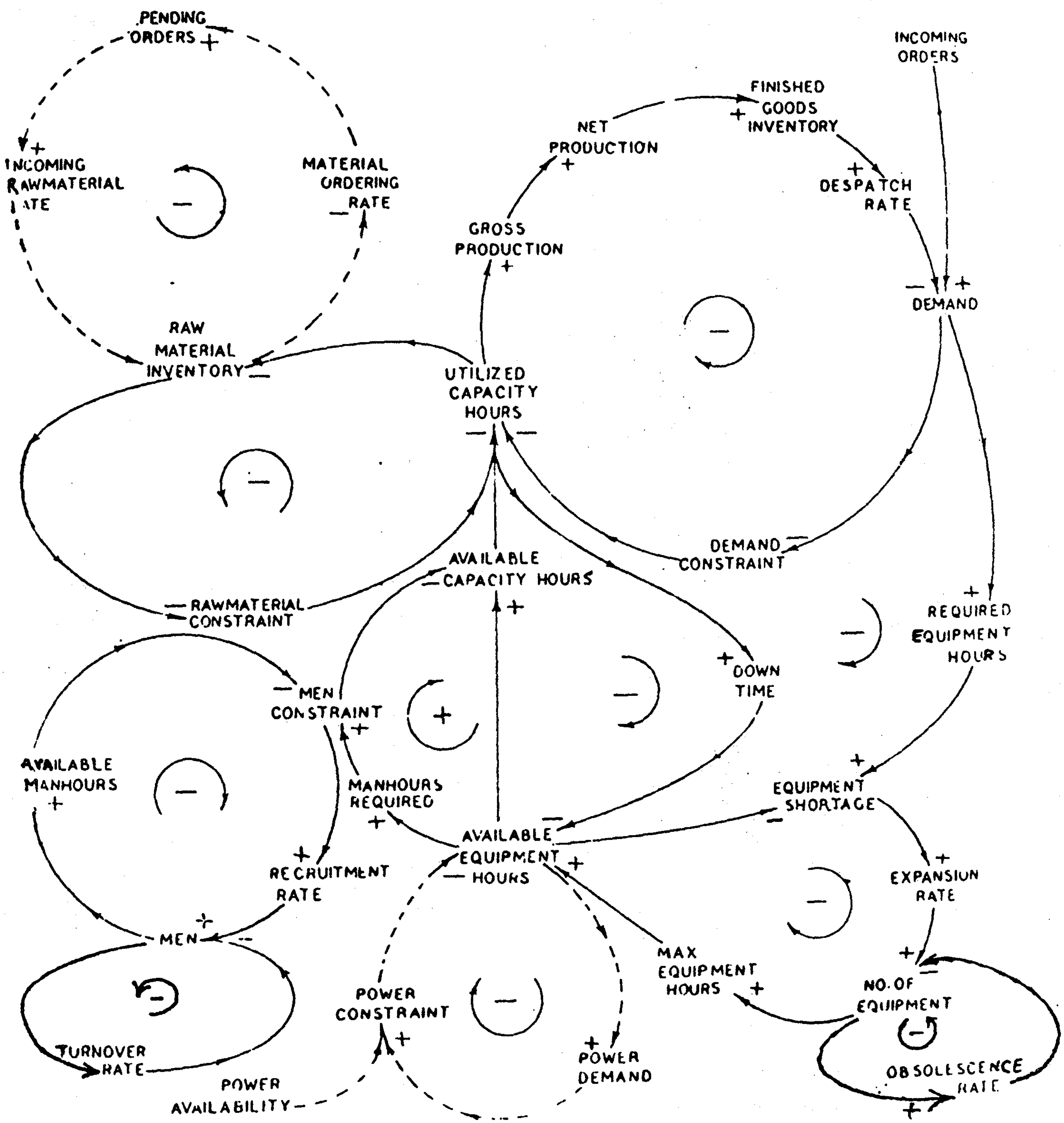

Fig. (x)

Model of each of the twelve production shops is independently designed and valedated before integrating them to arrive at a production Model of Steel Plant. The integrated model requires input of demand of seventeen categories of finished products and supplies of three categories of raw materials as exogenous inputs from the environment. In addition, the production model requires the various strategic parameter related to choice of technology, policy for expansion of capacity, recruitment etc. also as exogenous inputs.

MODEL VALIDATION

Before using the Model for generating future scenarious and undertaking "What if" experiments, the Shop Models as well as the integrated Model have been historically validated for a period of 36 months. The production and inventories as generated by the Model were compared with the actual values taken from the statistical records. Resemblence between the simulated results of the Model and actual values indicate that the Simulation Model of the Steel Plant is a satisfactory representation of reality.

The actual and simulated historical time series of Down Time, production as well as Inventories have been super imposed on each other for the purpose of comparison. In addition to this, the simulated annual values for the production have been compared with the actual yearly totals. The two series i.e. actual and simulated production have also been validated by computing the Root Mean Square Error (RMSPE). The superimposed plots of simulated and actual production for the Saleable Steel is given in Fig. (xi). It can be visualised from Fig. (xi) that the monthly production behaviour simulated by the Model represents the actual behaviour. By comparing the yearly totals of actual and simulated production, it was found that the deviation was below ± 2% of the actual results. The value of Root Mean Square Error between actual and simulated series of Saleable Steel production is 6.66% which was considered acceptable.

MODEL APPLICATIONS

The simulation Model can be used to carry out a variety of experiments under controlled conditions to study the behaviour of various indicators of interest such as Saleable Steel production, works profit, Return on Gross Block etc. These

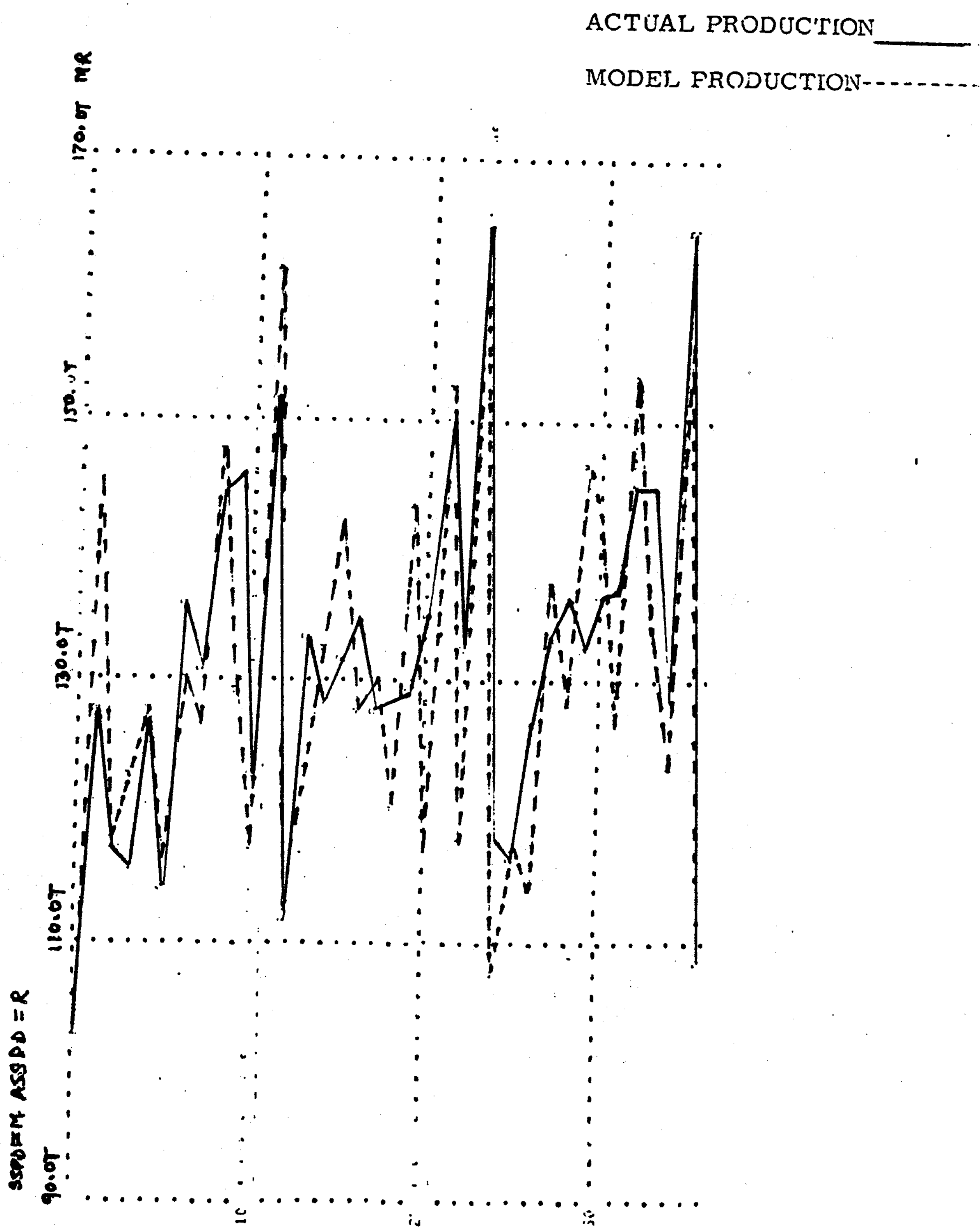

Fig. (xi)

VALIDATION PLOTS OF SALEABLE STEEL PRODUCTION experiments tend to answer the question related to various strategies likely to be adopted by the Management under a set of assumptions from the environment. These experiments are grouped under four sets as given below.

i) Bottleneck Identification:

Investment decisions in a Steel plant has to be guided by understanding of Bottleneck Shop in addition to various other considerations of the management. In Case, it is feasible to identify the bottleneck shop for the future, based on a set of assumptions about environmental influences and decisions about Strategic variables, the investments have necessarily to be made on priority bases in the Bottleneck shop. The investments made in any unit other than the Bottleneck unit are going to be futile till the Bottleneck unit is first debottlenecked. A wrong bottleneck identification can result in very serious consequences leading to investments without any significant production increase of the Steel Plant. This Model has the capability to compute Intensity of Bottleneck every month for every shop. Over the whole simulation period it can identify in a dynamic manner the order in which management decisions have to be taken for debottlenecking. In case, for any length of time in future, behaviour of Demand, essential supplies and power availability are specified, the simulation Model is in a position to arrange all the production shops in the order of debottlenecking priority. The Model, thus, guides the management in taking correct decisions related to investments for debottlenecking purpose.

The dynamically changing conditions assumed during the simulation run as well as the inter-dependencies taken into account amongst dynamic capacities, demands, materials power availability of the twelve production shops in arriving at priority of debottlenecking is one of the major features of this model. The intensity bottleneck graph as produced by the Model is given in Fig. (xii).

ii) Generation of Future Scenarios:

The Model can be used to produce three sets of scenarios under the optimistic, pessimistic and most probable assumptions of the environment related to Demand of seventeen categories of finished steel products, supply of 3 essential raw materials, availability of power and the likely inflation during the simulation

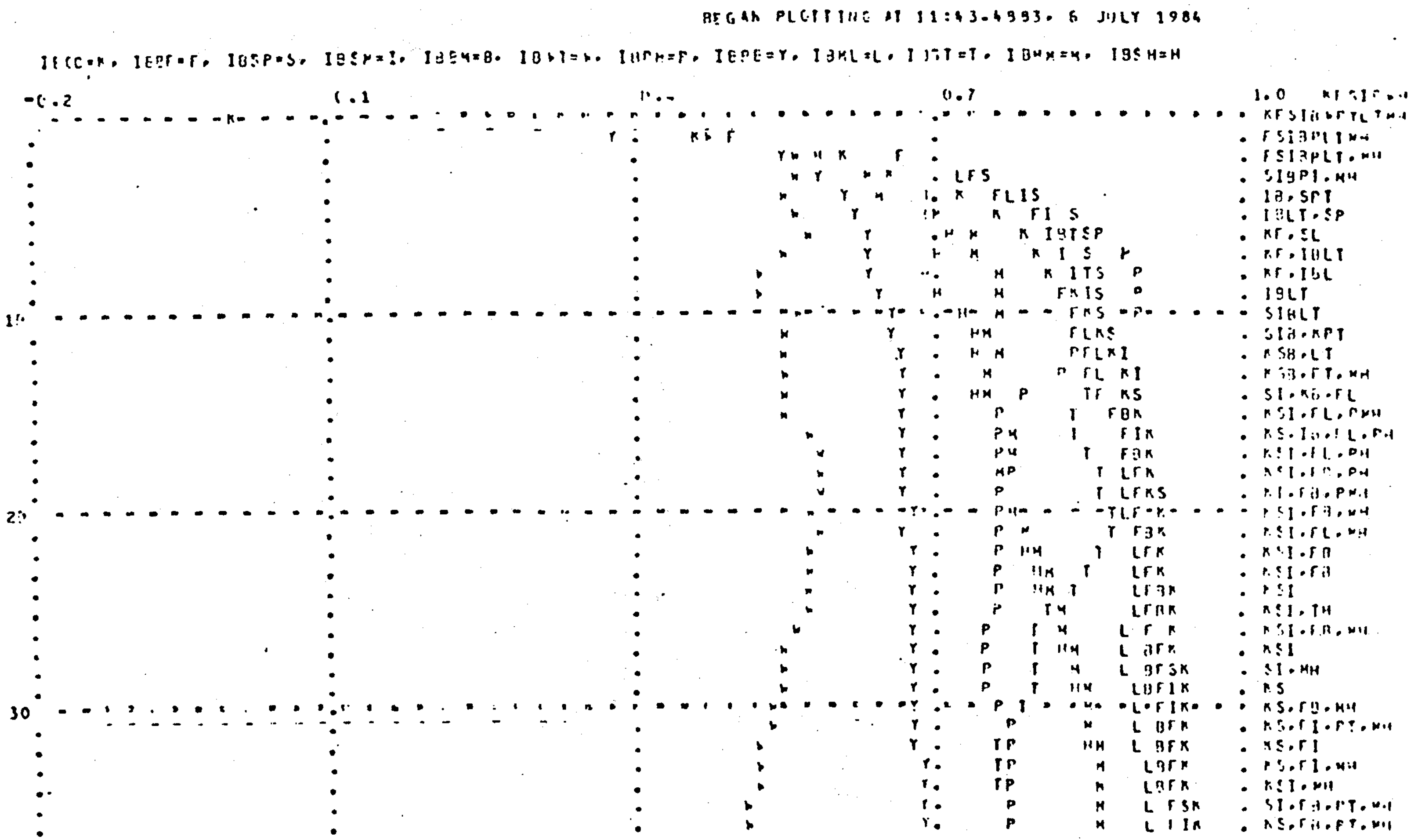

Fig. (xii)
Plot for Intensity Bottleneck

period. In each of these scenarios of the steel plant based on set of assumptions, a priority for debottlenecking of various shops is also listed down by the Model. This priority is applicable for the future period for which the scenarios are prepared. The Model, thus, guides the management to plan for their future strategies based on the optimistic, pessimistic and Most probable scenarios.

iii) Listing of Strategic Variables

The Model lists down the various Strategic policy variables which are within the control of the management. The behaviour of the production is caused based on the dynamics created due to the feed backs existing in the Model as well as due to the strategic policy decisions taken by the management. The Model tends to answer the various "What if" questions related to choice of the strategies by the Management. The Model can be used to simulate the impact of various strategies on the Corporate objectives before the strategies are actually implemented.

iv) Project Evaluation

Whenever a Strategic Policy variable is to be changed by management, it may require a modernisaion project to be undertaken. Often the situation arrises when more than one project can be thought to change value of a strategic policy variable. In such cases the Simulation Model can also be applied to carry out evaluation of projects. This experiment can be done by running the Modelon computer with two sets of values of the parameters. One set of values assums that the project is not implemented and the other set assume the project has been implemented. To illustrate this application of the Model, a project of putting additional sinter plant was taken for evaluation. The results obtained with and without additional sinter plant are given in Fig. (xiii). Based on the results achieved the management can take a decision about the project. In case more than one projects are to be compared, the Model needs to be run for all the projects and comparison made. In each case the simulation Model also lists down the new priority for debottlenecking. The Model can, therefore, be very effectively used for making investment decisions related to various projects in future.

S.No.	Variable	Without Sinter Plant			With Sinter Plant		
		Year			Year		
		1	2	3	1	2	3
1.	Works Profit (Million Rs.)	1808	2006	2292	1833	2088	2380
2.	Realisation (Million Rs.)	4918	5552	6301	4940	5552	6301
3.	Works Cost (Million Rs.)	3110	3546	4010	3108	3464	3921
4.	Return %	45.5	50.52	57.73	46.16	52.60	59.96

Fig. (xiv)
Comparison of Result with and Without Sinter Plant

ACKNOWLEDGEMENTS

The above work was carried out jointly by a team consisting of two NPC consultants and six executives of the Steel Plant. The work done by Mr. Rakesh Kumar, Director, National Productivity Council on this project is deeply acknowledged. The auther is also thankful to the team of Steel Plant for providing all the relevant information in designing the Model.