A SYSTEM DYNAMICS MODEL FOR CORPORATE PLANNING FOR AN ENGINEERING COMPANY

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ABSTRACT

This paper describes the design and application of a System Dynamics Model in simulating the future of an Engineering Company. The stress has been given in this paper to explain the application of System Dynamics principles in designing long range policies of the company. The Model is being used by the company in testing various strategies to be adopted by the management related to new projects for expansions and modernisation by simulating the impact of these strategic decisi ons on the objective variable. The Model assists the management in designing their long range policies to achieve the corporate objectives.

INTRODUCTION

A public sector company in India was established in the year 1964 with the main objective of creating self reliance in the field of process control instrumentation in the country. The company diversified its activities to take up the design, manufacture and installation of Instrumentation System on turnkey basis. The company had a monopoly in its market during 1964-74, however, with the change in Government policies in seventies, a number of competitors entered the market. The management of the company, therefore, was interested in designing a planning system which could assist them in taking Strategic decisions related to long term investments for achievement of its objectives. Keeping in view the needs of the management, a planning system was designed using the principles of System Dynamics. This planning system guides the management in understanding its environmental and strategic policy variables and assist the management in understanding the causes of the dynamic behaviour of its objective variables to shift it to the desired end.

THE PLANNING SYSTEM - ITS BOUNDRIES

The company is engaged in manufacturing of process control instruments. The instruments are manufactured in its two units located about 1000 miles apart. The manufactured instruments from these units are supplied to the market as loose instruments as well as Turn Key Systems.

The numerous variety of instruments being manufactured by the company are grouped into seven product categories as given below:

* Temprature Transmitters
* Primary Instruments
* Secondary Instruments
* Analytical Instruments
* Flow Instruments
* Control Values
* Pannels and Annunciators

In the planning system of the company, the behaviour of these seven product categories have been modelled from the two units of the company. The planning system of the company requires exogenous inputs about the planned investments by public and private sector in different market segments, the supply of Raw materials and the inflation behaviour. The system also requires exogenous inputs about the management decisions related to strategic policy variables about the choice of technology, organisation, purchasing policy and recruitment policy etc.

The Planning System simulates the behaviour of the following important objectives variables:

* Demand of Seven categories of product groups as well as of Turnkey Systems
* Production of Seven categories of instruments and two categories of Instrumentation System with semifinished goods at each stage of production.
* Inventories of Raw material, components, finished instruments and finished goods system at site
* Profit, Sales and Expenses
* Undepreciated Gross Block
* Return on Assetts

The Planning System of the company consists of four System Dynamics Models as given below:

* Demand Model
* Company Model for Unit 1
* Company Model for Unit 2
* Corporate Financial Model

Each of the above model has been separately programmed, using Dynamo language. These Models have been tested and validated separately except the Corporate financial Model. The Corporate Financial Model, though has a separate identity, yet has to be seen in conjunction with the company models of Unit 1 and 2. The outputs of Demand Model of the company is fed as one of the inputs

to the company Models for Unit 1 and Unit 2. The Corporate Financial Model gets the Input from the two company models for Unit 1 and Unit 2. The flow between the Models is given in Fig. (i). The Models were tested and validated using a PDP-11/23 System and are being implemented on PDP-11/44 System. The design of the Model was carried out by a team consisting of planners, technologists, economists, marketing specialists, financial experts and electronic data processing specialists. The principles used and the feed backs in each model is given below.

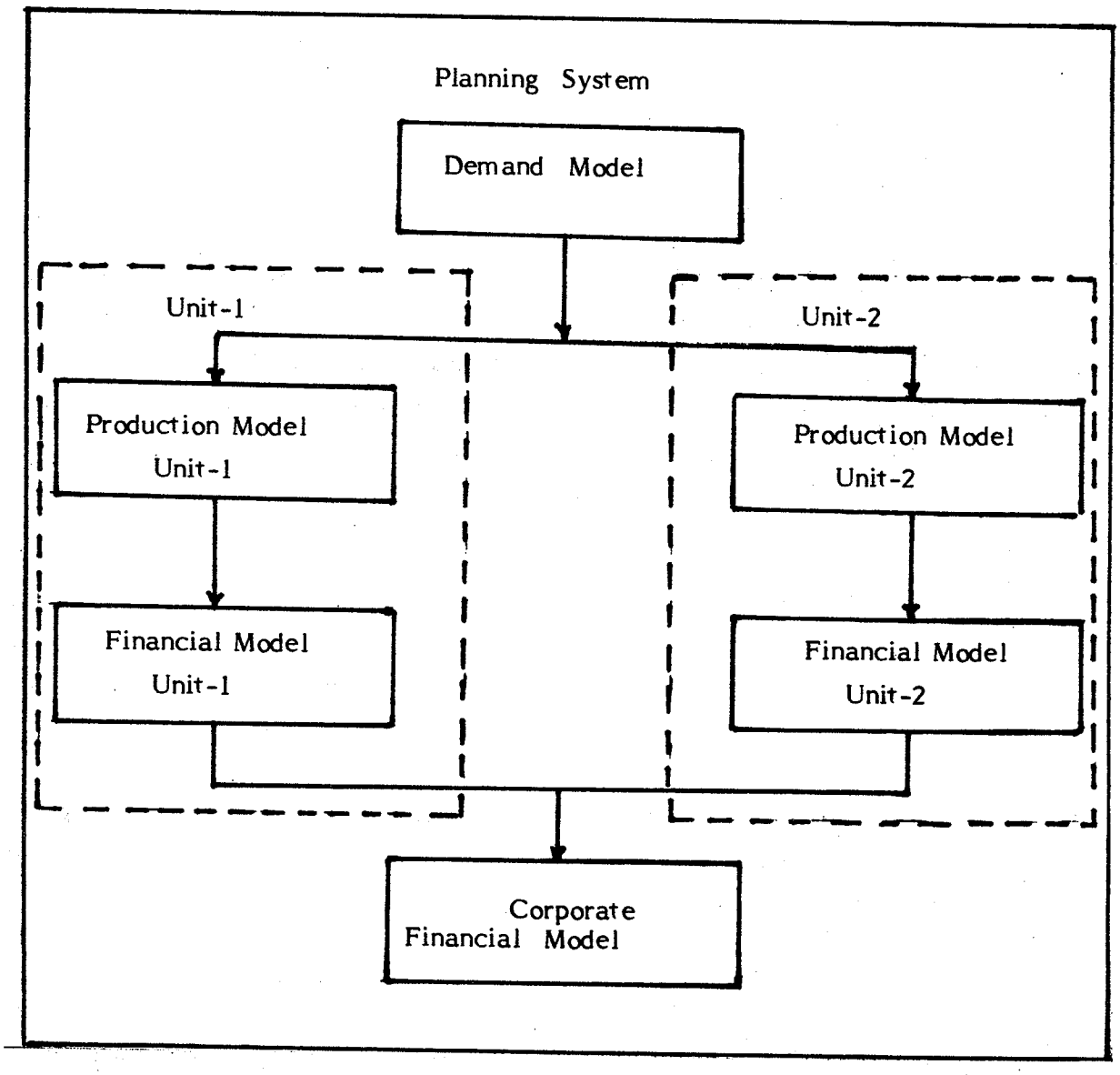

Fig.-1

DEMAND MODEL

The demand of the seven categories of process control instruments and turn key system is closely related to the development in the different sectors of the national economy in which the process control instruments are being used. The total market of the company has been grouped into nine categories of market segments as given below:

* Thermal Power
* Steel Plants
* Refineries and Petrochemicals
* Fertilizers and Chemicals
* Paper
* Cement
* Non Ferrous Metals
* Atomic Power
* Oil Drilling

In each of the nine market segments mentioned above, the demand of the nine categories of instruments as well as of the turnkey job is created. The feed back process governing the creation of demand in a market segment consist of two feed back loops. Therefore, the behaviour of demand of any category of instrument or turnkey job is governed by a total number of 18 feed backs. The generic feed back structure of the Demand Model consists of two feed loops given in Fig. (ii).

Demand-Investment Loop:

This feed back loop governs the process of planned investments by public and private sector in a market segment. As the Demand of product or service in a market segment rises, the government and private agencies invest in the market segment indicating a positive linkage between Demand and investment. The investments lead to creation of product or service and, therefore, the demand gets satisfied. This linkage is negative and the feed back loop is also negative in Character.

Obsolescence Loop:

This feed back loop exists between four variables i.e. Demand, Investment, Instruments and Obsolescence Rate. As demand for a product or services rises,

the investments in the sector, and the level of instruments in that sector increases. Since the level of instruments goes up, the obsolescence rate of instruments also goes up thereby generating higher demand. All the four linkages in the feed back loop being positive, the feed back loop is positive in character.

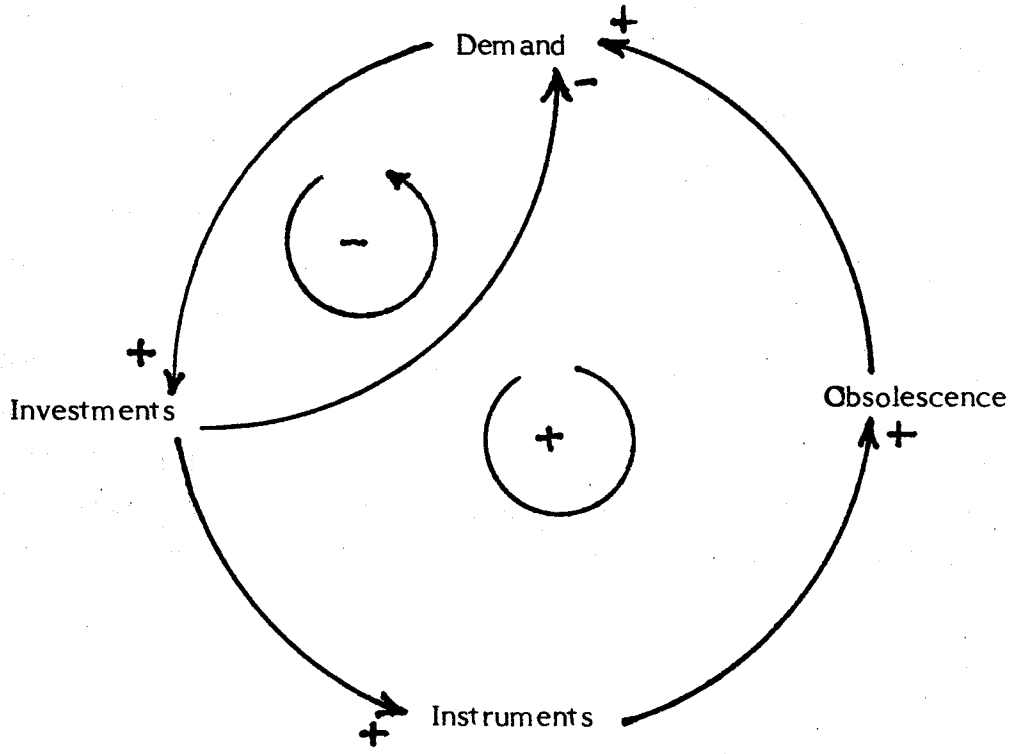

Fig.-(ii)

Feed Back Structure - Demand Model

The above feed back structure is common to the nine market segments mentioned earlier. The Model governs Productwise/Marketwise demand of each of the seven product categories.

COMPANY MODELS

There are two units of the company located about 1000 miles apart. In order to give flexibility to the management for developing separate set of strategies for each of the units, it was decided to develop separate company models for each unit. The principles used in development of these models are same in both the units. The company Models have two parts:

- Production Model
- Financial Model

The Financial Model generates a behaviour of the financial results of the unit and has no independent status. It largely depend on resources used i.e. manpower, materials and machines etc. in the Production Model. The Production Model, on the other hand, has been designed to simulate the monthly production of the seven product categories. The material and information flow takes place through twenty two capacity centres arranges in four stages of production. The Production Model takes into account the material flow of the three types of Materials i.e. Raw materials, Bought out components and Completing items in the four stages of production as given in Fig. (iii).

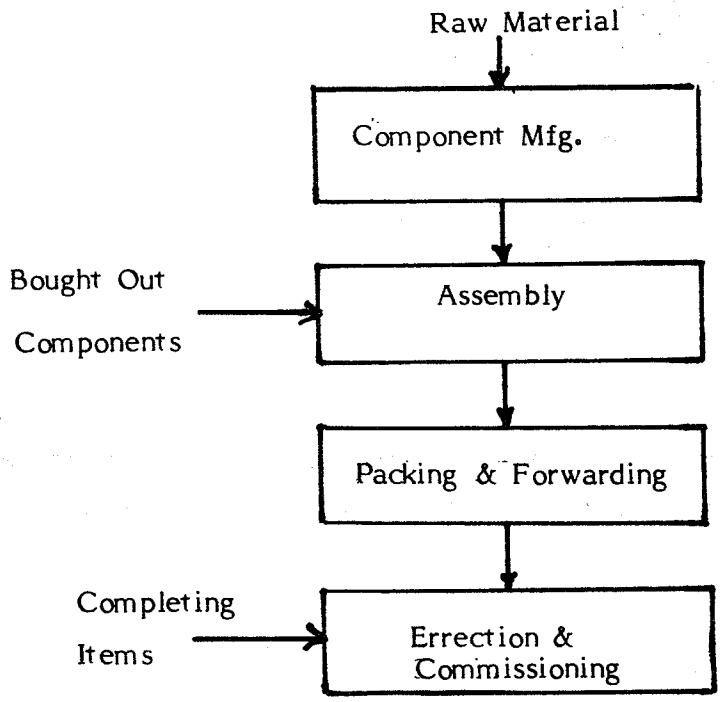

Fig. (iii)
Material Flow Diagram

A capacity Centre has been the basic planning unit and a generic feed back structure has been applied to model the various capacity centre. The generic feed back structure consisting of various feed back loops are discussed below.

i) Capacity Expansion Loop:

The capacity of a production centre is determined in terms of the man-power and machine hours available with the centre. Since the production is basically manually controlled, the machine hours are determined based on the manhours to machine hours ratio. When the Demand of the company products increases, the work load of the production centre interms of manhours and machine hours goes up. The Lead time for the production being constant, the gap between the desired and available capacity increase. The management policy of expansion of capacity, guides the process of recruitment and purchase of new machines to increase the available capacity and reduce the capacity gap. The feed back loop is negative in character. In case of a decrease in Demand of the company products the feed back loop depicts the phenomenon of divestment as illustrated in Fig. (iv).

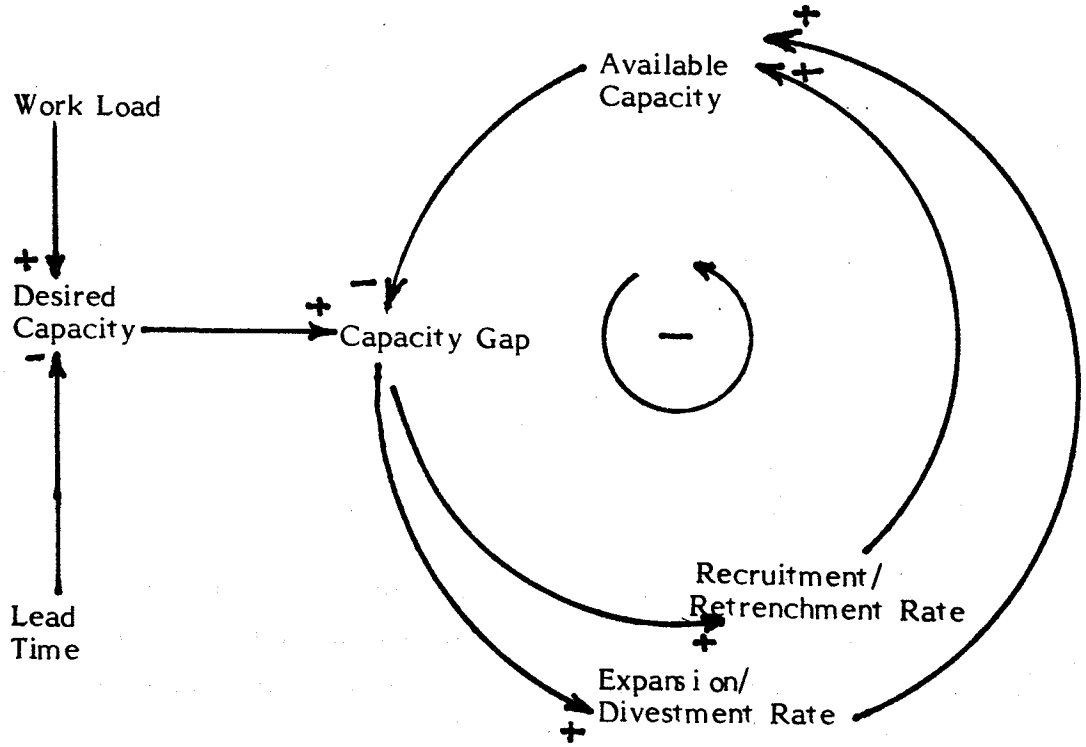

Fig. (iv)

Capacity Expansion Loop

ii) Obsolescence Loop:

The number of machine in a production centre descreases based on the life of a machine. The rate of obsolescence decrease the number of machines which in turn affects the obsolescence rate as shown in Fig. (v). The feed back loop is negative in nature and governs the replacement of machines in a production centre.

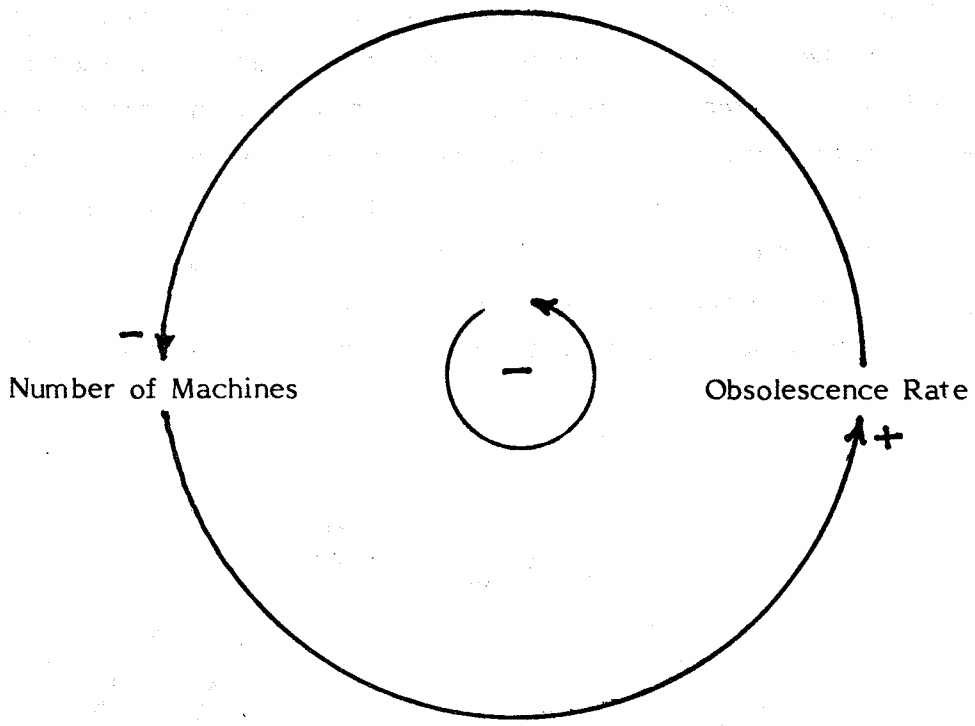

Fig. (v)
Machine Obsolescence Loop

iii) Manpower Turnover Loop:

The manpower in a production shop will go down based on the retirement and turnover of manpower. The turnover and retirement increase with the increase in level of manpower. The loop, therefore, indicates a negative feed back phenomenon as shown in Fig. (vi).

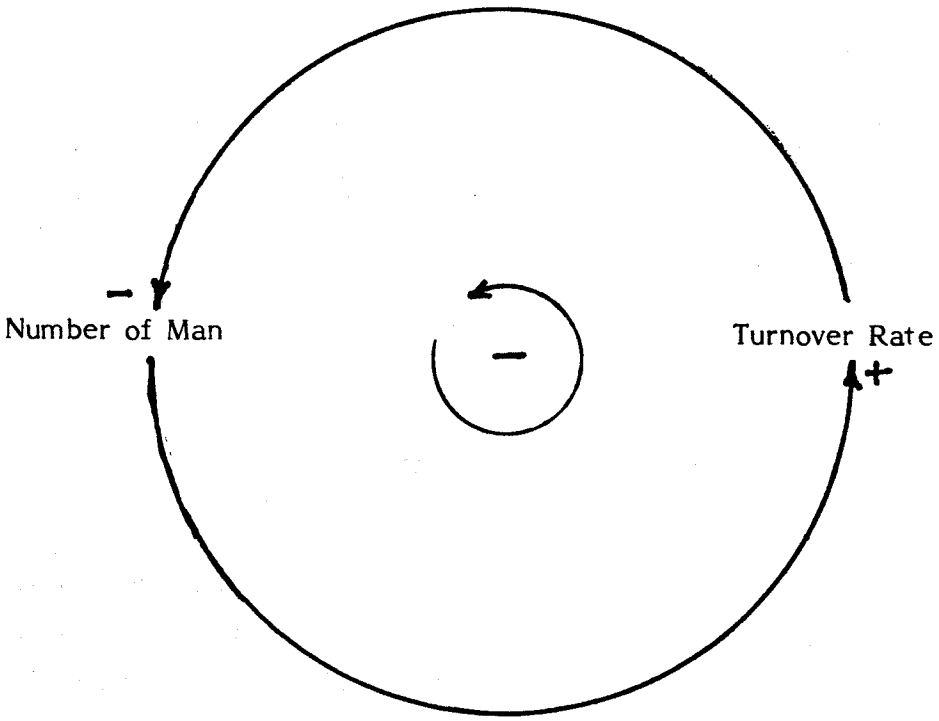

Fig. (vi)
Manpower Turnover Loop

iv) Material Ordering Loop:

This feed back loop explains the phenomenon of inflow of materials based on the demand of seven product categories. As the raw material inventory goes up, the ordering rate of material goes down. The level of pending orders increases with the increase of material ordering rate. The material arrival rate goes up and increases the level of inventory with level of pending order going up. The feed back loop is negative in character and tend to balance the level of inventory based on the Demand for the company products and the level of raw material inventory. The feed back loop is shown in Fig. (vii).

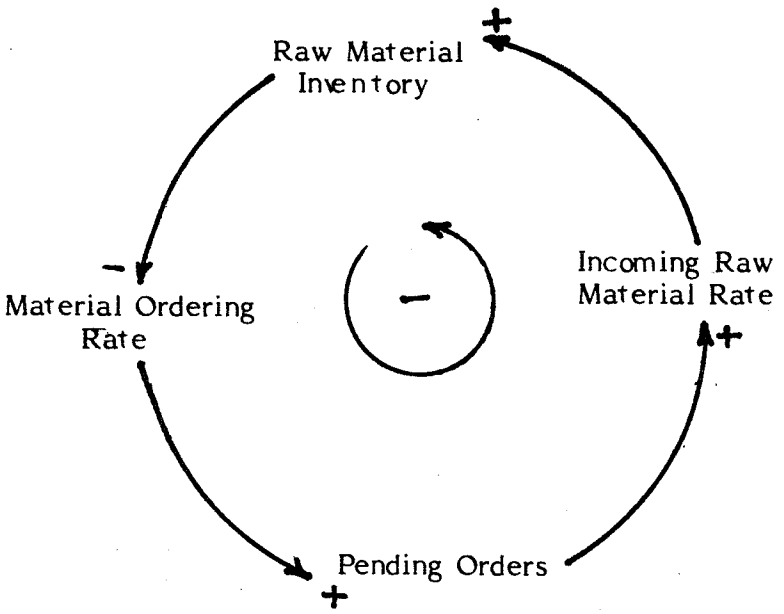

Fig. (vii)

MaterialOrdering Loop

v) Mechanisation Loop:

This feed back loop explains the phenomenon of higher profit through mechanisation in a company. As the investment in the machines of a company goes up, the capital intensity also increases indicating higher mechanisation. Higher is the mechanisation more is the production from the company in the same time. As the production rises, the sales of the company go up increasing its profits and generating more funds for further investment. As all the linkages in the feed back loop are positive, the loop explains the phenomenon of positive feed back and is shown in Fig. (viii).

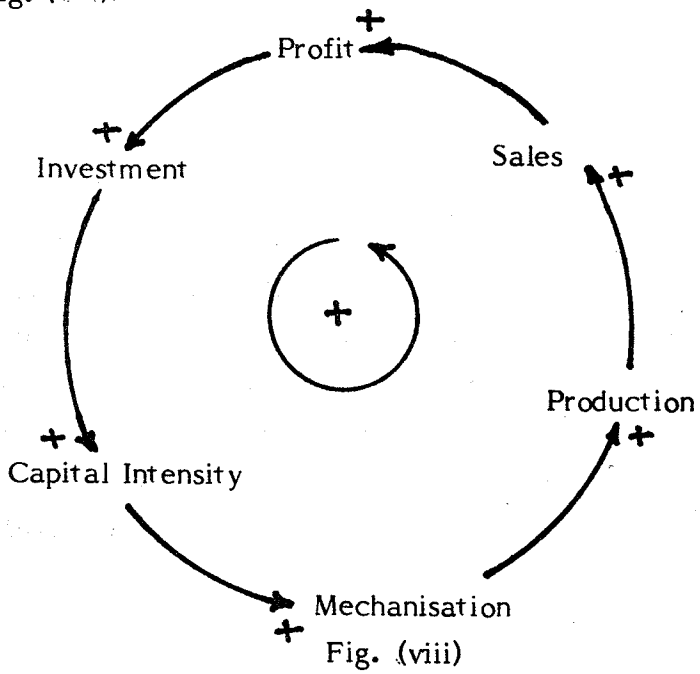

Fig. (viii)

Mechanisation Loop

The feed back loops stated above are governing the production behaviour of the seven category of product groups of the company. The production of the company is converted into the sales figures using the pricing policies of the company. The resources used in having the production are also converted into its financial consequences such as Expenses, Assets etc. The Company Model, through these financial conversions, also generate the behaviour of the various financial objectives of the company.

MODEL VALIDATION

The company Models for Unit 1 and Unit 2 have been validated for a period of 1 year on monthly basis. The validation of the company Models could not be done for more than one year due to the lack of availability of actual data. For the purpose of validation the simulated plots of the production of each of the seven category of products were superimposed on the actual behaviour of production of each of the product group. The similarity of dynamics between the actual and simulated behaviour of production as shown in Fig. (ix) indicates that the Company Model is a fairly good representation of the reality. Further, the yearly production figures of simulated production were compared with the actual figures of production. It was observed that the simulated production figure was well with in ± 5% of the actual results.

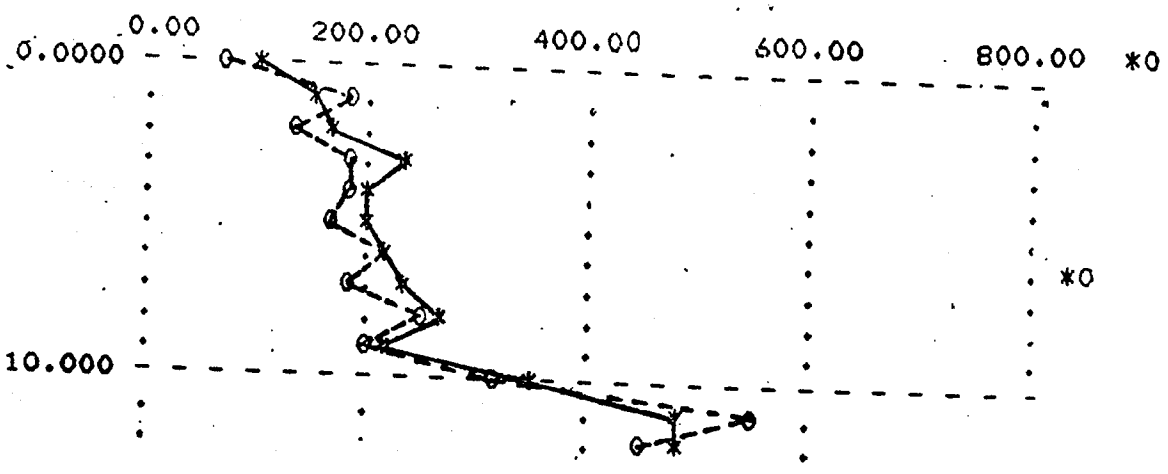

Fig. (ix)
Validation Result - Primary Instruments

Corporate Financial Model:

This Model combines the company Model for Unit 1 and Unit 2 and simulates the value of the financial objectives for the total company. This Model, though is independent in nature, yet it has no independent strategies importance for the company as the strategic of the company can not be tested by this Model. This Model has been designed separately due to the limited capacity of Dynamo Compiler installed with the company as well as to allow the company to independently look into the performance of each of two Business Units.

APPLICATIONS OF THE PLANNING SYSTEM

The planning system of the company is being applied to carry out a set of experiments under specified conditions to study the behaviour of the objectives variables such as Demand of seven product categories, Production, Profit, Return on Gross Block etc. These experiments tend to answer "What if" questions related to various strategies likely to be adopted by the Management. The Planning System assists the management of the company to generate three sets of scenarios of demand based on optimistic, pessimistic and most probable assumptions of the environment. Based on the Demand scenarios, the Model simulates the behaviour of the objective variables based on the strategic policy decision likely to be taken by the management. The Model can also be used in simulating the impact of investment strategies for mechanisation on the objective variable such as profit or Return on Gross Block. The management, through the Models, has an insight on the causes of behaviour of the Objectives. The strategic policy variables underlined by the Model assist the management in identifying the sensitivity of each strategic policy variable on the Corporate Objectives. The management can identify, test and evaluate various modernisation and investment projects by simulating the impact of each project on the Corporate Objectives of the company.

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