DEVELOPMENT OF A DECISION SUPPORT SYSTEM FOR THE PRODUCTION PLANNING IN A PROCESS INDUSTRY

A thesis

By

Md. Mahmudul Gani

Approved to the style and content by:

1. Dr. Md. Mizanur Rahman — Chairman (Supervisor)
   Professor
   Deptt. of IPE, BUET.

2. Dr. A. F. M. Anwarul Haque — Member
   Professor and Head
   Deptt. of IPE, BUET.

3. Dr. Md. Ruhul Amin Sarker — Member
   Assistant Professor
   Deptt. of IPE, BUET.

4. 18/7/93
   Dr. Maglub Al Nur — Member (External)
   Associate Professor
   Deptt. of ME, BUET.

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Department of Industrial & Production Engineering
Bangladesh University of Engineering & Technology

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MD. MAHMUDUL GANI

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Department of Industrial and Production Engineering
Bangladesh University of Engineering and Technology
Dhaka-1000

CERTIFICATE

This is to certify that this work has been done by me and it was not submitted elsewhere for the award of any degree or diploma or for any publication.

Supervisor

Author

To

My Beloved Parents

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Author

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formal system of gather, integrate, compare, analyze, and disperse information internal and external to the enterprise in a timely, effective and efficient manner" [22]

In addition to MIS other areas of information systems such as Decision Support Systems (DSS) and Expert Systems (ES) are now getting increased access in modern organizations. However like other areas of technology, the country is still far behind to extract the benefits from these sophisticated systems. Despite the recognition of its role in decision making the information system has yet to make any notable headway in the country. Although the MIS was introduced in different organization of the country in the early seventies and the eighties, these systems are still in their infancy. This can be concluded from the various surveys and studies. Mohammad and Salam [26] studied the influence of organizational environment including users' attitude on the growth of an effective MIS in three different organization of the country. The study encompassed the evaluation of the MIS effectiveness, its state of integration and its indispensability. The in depth study of the MIS in Bangladesh Agricultural Development Corporation showed that it doesnot have substantial effectiveness in meeting users' information requirements. Its state of integration was found to be inadequate and from the users' point of view it was not quite indispensable. The study pointed out some factors such as user participation, consideration of views of MIS personnel and top management commitments for proper development and growth of MIS in Bangladesh.

Gani et al [24] made a study of the information system of Bangladesh Steel and Engineering Corporation (BSEC). The study showed that although MIS was introduced in BSEC in the early seventies, lack of formal education and training of MIS personnel in information technology hinders its speedy development in the organization. The study also showed that except the two enterprises of BSEC no other enterprises have any independent MIS department. Generally the accounts officer of the respective enterprise is responsible for supplying the data which often leads to improper handling. The MIS concept has also not yet flourished in the organizations. The data bank does not provide any access to any personnel other than the Chairman of the enterprise and the computer personnel of the MIS department.

It is also found that, other than MIS no other areas of information system has made any access to the manufacturing or service organizations of the country. With this background the present work has been directed to explore the applicability of another area of information system namely the Decision Support System (DSS) in a production planning environment.

1.5 PROBLEM OVERVIEW

Bangladesh Insulator and Sanitary Wares Factory (BISF), an enterprise of Bangladesh Chemical Industries Corporation (BCIC), is a sanitary wares, tiles, insulator and refractory bricks manufacturing enterprise in the country. The factory has three production lines to produce three product families. Each product families are composed of several products. Several raw materials are used to produce these items. Most of the raw materials

1.7 ORGANIZATION OF THE THESIS

The thesis is organized as follows:

Chapter Two presents a survey of some relevant literature on DSS, mathematical programming applications in production planning, and information systems application to production and production planning. In the third Chapter study of the case production system is presented. The fourth chapter describes the formulation of the model for production planning. In the fifth Chapter the design and development of the proposed DSS is presented. The sixth Chapter presents the model input data and their organization. Chapter Seven presents the demand forecasting of the product families. In Chapter Eight, solution approach taken to solve the production planning model, the computational complexities experienced and the measures taken to overcome these complexities are discussed. Chapter Nine presents the model output, results and their analyses. Conclusion and recommendations for future research are presented in Chapter Ten.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

Various models along with the application of information system techniques in production and production planning is discussed. As mentioned in the previous chapter production planning is influenced by several factors termed as external and internal, not all of which are controllable by the planner. It is not wise to incorporate all these factors in a single model thereby increasing its complexity. Thus several researchers have addressed the several aspects of production planning. These models can be classified on the basis of their inherent characteristics as follows :

1. Strategic, tactical or operational planning models.
2. Hierarchial production planning models.
3. Single item or multi-item model.
4. Static or dynamic model.
5. Single objective or multi-objective model.

Production planning models could also be classified on the basis of optimization techniques. These are as follows :

1. Linear programming (LP) models including transportation models.
2. Integer programming (IP) models.
3. Mixed integer programming (MIP) models.
4. Goal programming (GP) models.
5. Dynamic programming (DP) models.

Compared to other mathematical models the linear programming, integer programming and mixed integer programming models are more widely used in production planning as they allow the use of standard LP/ILP package for solving these models. Moreover these packages allow the user to perform sensitivity analysis very efficiently.

The following section presents a review of some work on production planning models together with the DSS application to production and production planning.

2.2 REVIEW OF SOME RELEVANT LITERATURE

2.2.1 PRODUCTION PLANNING MODELS

Various mathematical models appears in literature that considers the production planning decisions. The context, formulation and decision variables of these models vary greatly. Some of these models are described below.

Jones and Rope [1] presented an LP model for production planning in a food factory. The model is a multi-period, multi-item one which incorporates the constraints for capacity, minimum labor involvement, demand fulfillment, raw material availability and contract restrictions for raw material supply. The objective function was a cost minimization function which consists of material cost, marginal profit, finished goods stock holding cost and cost of residual raw material. The model doesnot incorporate any constraint either for the physical limitations of total space available or the additional costs for outside warehousing.

Sarker and Haque [2] presents an LP model for determining the product mix in a sanitary wares factory. The single period model is intended to determine the optimum product mix of different items of a single product family. The model incorporates restriction equations for plant capacity, available capital, minimal level of production and labor hours. The objective function was to maximize the profit contribution of each item. The profit contribution function incorporates the selling price and variable cost. The Winter's method was used for forecasting the sales demand of a product family. The use of dynamic programming technique is also demonstrated to determine the purchasing policy for raw materials. As the model is a single period one it does not incorporate the rolling horizon concept.

Adulbhan and Tabucanon [3] described an application of bi-objective linear programming model to determine the optimum allocation of production materials to the major production facilities in a cement factory. Two objectives of the model are the minimization of manufacturing cost and maximization of capacity utilization. By using the compromise constraint technique the bi-objective linear programming problem is transformed into a single objective problem. The amounts of material input to each major production facility are chosen as decision variables in this optimization model. The model is developed as monthly production planning basis and incorporates the constrains for material balance, available capacity and fulfillment of forecasted customer demand. Although bottlenecks exists in the production line no constraint is considered for available space for in process inventory.

Sanderson [4] described a production planning system for a chemical industry which has been designed to satisfy the company wide medium term production planning problem for its major products. The production plan covers a time horizon of 12-18 months ahead broken into monthly and quarterly periods and updated on a routine monthly basis. It is essentially a multi-period product mix LP model. A multiple criteria optimization giving weightages according to their importance were used for solutions which satisfy decision taken externally to the model and which conform with normal operating practices. The approach does not yield a unique "best" solution, instead it allows exploration of the set of good solutions by changing the weights attached to each criterion. The model is also a multi-item, multi-plant one operating under certain restriction equations such as minimum operating level, maximum stock level, minimum and maximum allowable intersite movement. In order to prevent fluctuations in demand, the model utilizes a simple form of production smoothing.

Dunsmuir [5] described a simple allocation algorithm in production planning. It outlined a system that has been implemented in a manufacturing enterprise and concentrated in translating the overall statement of production feasibility into specific production order levels by item. The overall objective of the algorithm is the identification of a common multiplier 'r', of the 'target' stock level for each item whose achievement as closing stock for the period under review would imply a total order level equal to the level prespecified by the production manager. Due to apparent simplicity of the model it would not be possible to use this model for complex production situations involving several items and several production lines.

2.2.2 DECISION SUPPORT SYSTEM

Decision Support System (DSS) is one of the most recent concepts in Management Science. A lot of work is being done at present on this subject. As a result, not much literature is yet published on this subject. However, quite a number of books have been published recently on DSS. A DSS integrates data, models, software interfaces and the user in an effective decision-making system. The computer constitutes an integral part of decision making and planning and thus allows managers to use information rather than simply be recipient of it.

The main feature which differentiates the DSS philosophy from that of traditional data processing systems is the incorporation of decision maker's insight, intuition, judgement and/or past experience into the decision - analysis process. Instead of the system directing the user, the user in a

DSS environment initiates and controls the system. The DSS philosophy thus recognizes that in supporting semi-structured tasks, some of the decisions process can be delegated to the computer but that some aspects of the decision require the judgement of the manager, particularly in making qualitative trade offs and subjective assessments [22].

Turban [19] lists several applications of DSS both as a tool of problem solving and improving productivity and as a tool for executing industrial engineering functions.

Mannur and Dhingra [12] has developed a decision support system (DSS) for long term decision problems of a small scale fabrication and assembly type manufacturing company. The production shop as well as operational environment are analyzed and the production shop problems are modeled as scheduling problems. As the products of the company are made to order type, detailed production planning to solve the product mix problem is not considered in the system. The module of the system is addressed only for scheduling problems.

Chindabaram and Kodali [13] present a prototype model of a DSS for production planning of a manufacturing system and has named it decision aid for production planning (DAPP). DAPP was developed to run on IBM PC/XT and has been written in dBase III. The system consists of several data bases and a model base which incorporates very simple model for production planning. Very high interaction is the characteristic feature of DAPP. The model base supports the user in production planning by using data from data bases.

Plant and Hu [14] developed a prototype decision support system that was capable of acting as an assistant to those studying casting defects. The system allows casting parameters to be set and illustrates diagnostic reasoning of casting faults made. The system demonstrates that artificial intelligence techniques can be used in data and knowledge intensive environments when the system is supplemented by a data base.

Israni and Sanders [11] described a design of a manufacturing decision support system (MDSS) for the control of a flame cutting operation. The MDSS incorporates the overall economics of a continuing rectangular cutting operation, including the costs of trim losses, raw material, cutting and inventory. It also takes into account the use of left-over offcuts or partial plates and the possibility of producing as a flow shop instead of on a job shop cut-to-order basis. The DSS constructs parts nest, generates cutting sequences, directs the use of trim margins and updates and provide outputs of the economics of the whole cutting process.

Kiran and Loewenthal [10] present an integrated decision support system for inventory management (IDSIM). Decision rules for inventory control parameters are combined in a micro-computer based information and decision support system. Decision rules implemented in IDSIM cover a wide variety of models for deterministic and stochastic demand cases. The system consists of four modules. The determination of economic order and production quantities and the evaluation of any arbitrary ordering rule in terms of carrying and ordering costs are accomplished in the first module. The second module deals with aggregate level decision for deterministic demand system, generates total cycle stock curve, and addresses the problems of group replenishment and group discounts for deterministic systems. The third module calculates the optimum safety stock levels and optimum values of control parameters for order/point quantity as well as periodic review/order-up-to level parameters in stochastic systems with normal and laplace distribution. Other sophisticated algorithms, which utilize iterative procedures and yield near optimal solutions, are incorporated in the fourth module for the allocation of total safety stock to minimize either the expected number of stockouts or the total value of shortages.

Mustafa [8] described a prototype of a microcomputer implementation of an integrated multicriterial expert support system (MCESS). The system is an interactive, comprehensive and easy to use tool to support the manager in project selection and resource allocation. The MCESS combines the capabilities of goal programming, the analytic hierarchy process, net present value analysis and a spread sheet.

Blake [9] described a system that addresses three problems in the areas of production forecasting, production scheduling and industrial relations of an aluminum smelter. Three simple FORTRAN programs were developed to aid management in metal purity forecasting, casting, plant scheduling and labor cost modeling. Although the programs were developed to aid decision making the system lack some inherent characteristics of a DSS.

Haddock and Hartson [6] presented a DSS that assists in the specific selection of machine that is required to process specific dimensions of a part. The selection will depend on part characteristics, which are labeled in a part code and correlated with machine specifications. The choice of the optimal machine versus possible alternatives is made by a planner by comparing a criterion measure or measure(s) some of which are the relative location of machines, machining costs, processing time, and availability of machine(s). The developed DSS is composed of three database files, nine program files and one report file. DBase III is used as the model development language.

Sumanth and Carlos Sol [7] described a micro-computer based decision support system of the total productivity model using the Macintosh computer. It is a highly interactive, menu driven program that can provide on-the screen capabilities of individual operational units as well as the firm that comprises them. The system has several convenient features to asses the "Productivity-oriented profitability" of any type of companies or organizations.

Compared to the various DSS discussed above the proposed DSS in the present work is unique in the sense that it is very flexible and highly interactive with the user. This would allow a non-technical user to be able to operate the system and to solve the production planning problem with very little effort. The model base of the proposed system would incorporate a mixed integer type aggregate production planning model, that generates the various decision variables of production planning namely production quantities, inventory policy for both the finished goods and raw materials, labor hour requirement and the raw material ordering policy.

CHAPTER THREE

STUDY OF THE CASE PRODUCTION SYSTEM

3.1 A BRIEF HISTORY OF THE ORGANIZATION

3.1.1 ORGANIZATION

The Bangladesh Insulator and Sanitary wares Factory (BISF) has been selected as case production system. The BISF is an enterprise of Bangladesh Chemical Industries Corporation (BCIC), a state owned corporation. The factory was installed in 1981 with the technical assistance of M/S. Pragoinvest, Checkoslovakia under an agreement between the two governments. The production line of sanitary wares started its production on December, 1981, insulator on May 1983 and tiles on June, 1984. At the initial stage of operation it was making losses. Gradually the management of the factory mobilizes their resources to improve the quality of their products and to attract customers for its products. Increased marketing effort eventually turned it to a profitable organization. Effective management also led to the development of the organizational efficiency of the organization. The existing organization structure of the factory is given in Figure 3.1.

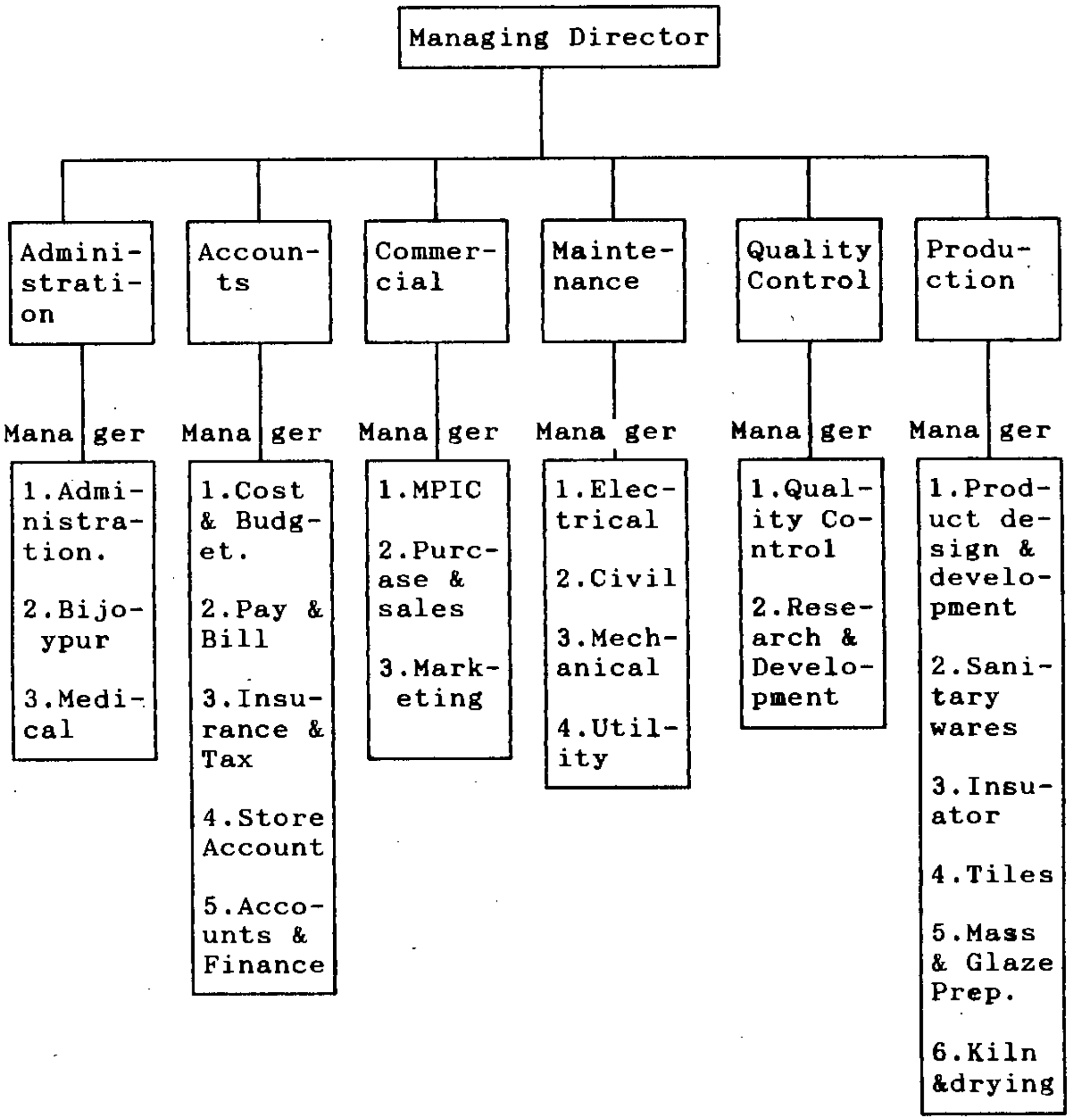

Figure 3.1. Organization chart of BISF.

BISF was the sole sanitary wares, tiles and insulator manufacturing unit in the country. The installed capacity of the plant was as follows:

Sanitary wares	:	4000 MT.
Insulator and bricks	:	1300 MT.
Tiles	:	1,00,000 Sq.m. (1100 MT.)

From its inception the factory is yet to utilize its full production capacity in sanitary wares and insulator production lines. The factory is however utilizing its full production capacity in tiles production line. The capacity utilization by different product lines in the last five years can be observed from the following figure:

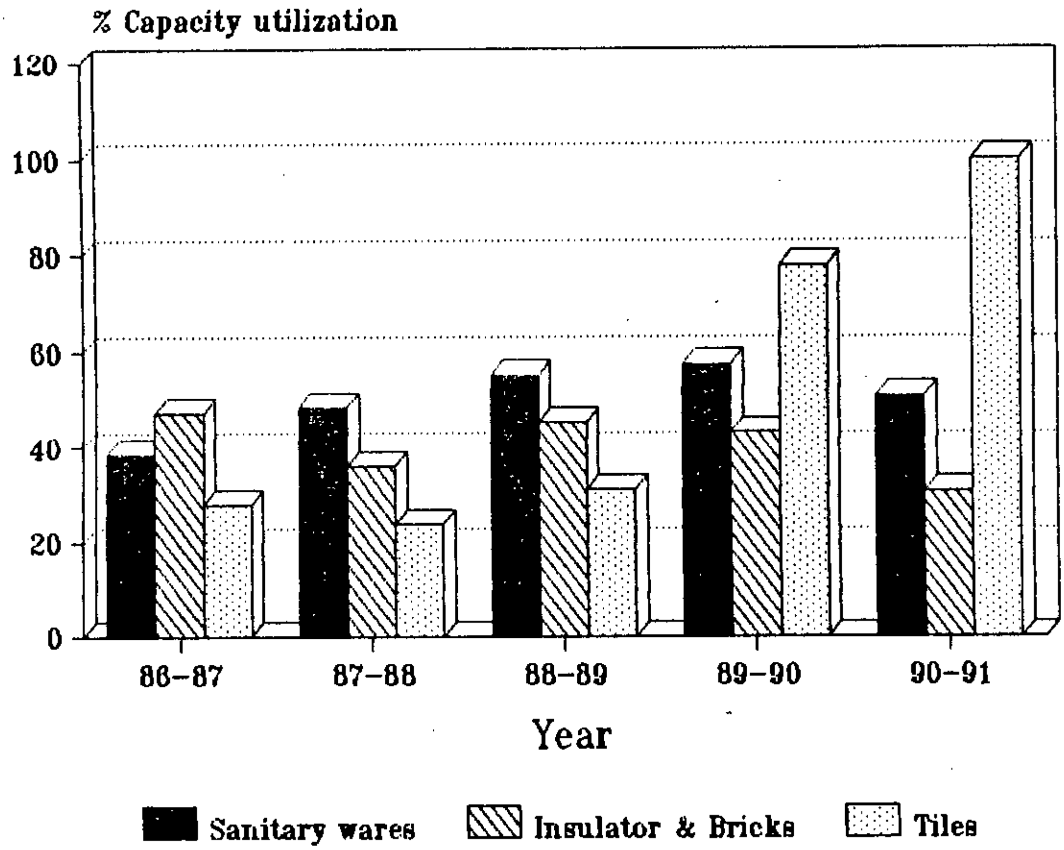

Figure 3.2. Percentage capacity utilization by different product lines.

3.1.2 MARKETING

BISF usually markets its products through three distribution channels. These are as follows:

1. Sales depots.
2. Dealers.
3. Directly to consumers from the factory (only for sanitary wares and tiles)

BISF is now facing a fierce competition from its competitor Dhaka Ceramics. To face the challenge, BISF has taken steps to strengthen its market strategies. These includes increased advertisement efforts in local newspapers, television and publication and distribution of product catalogues. The effectiveness of its marketing department can be observed from the distribution of following sales figures:

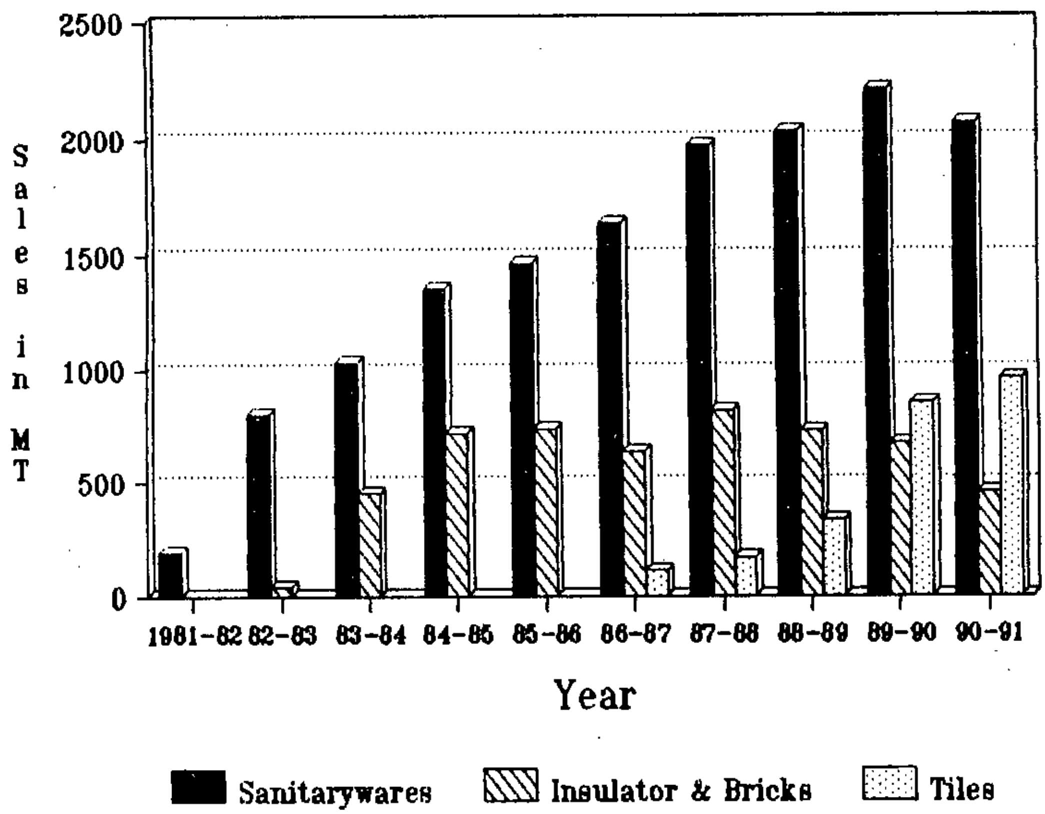

Figure 3.3. Sales in MT. of different product families.

3.1.3 OTHER DATA

Total land area	:	30 Acres.
Factory building	:	4,45,875 sq.ft.
Administrative building	:	19,200 sq.ft
Other	:	32,185 sq.ft

Electricity consumption:

a. P.D.B.	:	2000 kW.
b. Own source (Generator)	:	1600 kW.
Natural gas consumption	:	21,000 MCft.
Water consumption	:	Daily 25,000 gallons

Total Manpower:

Number of labors engaged in production	:	459
Number of employees engaged in production	:	25
Number of officers engaged in production	:	82
Number of employees in other sections	:	120
Number of officers in other section	:	63
Number of labors in master roll	:	48
Number of temporary labors (daily basis)	:	320

3.1.4 PRODUCTS OF BISF

All the products of BISF can be grouped under three families. They are sanitary wares, insulator and refractory bricks and tiles.

Sanitary wares:

According to a survey made by M/S. Bettale Institute, a West German firm in 1964, long before the implementation of the BISF project the annual demand of sanitary wares in the country would stand to 5180 MT in 1979-80 assuming an annual growth rate of 6%. Another survey predicts the demand in 1980 to be equal to 4475 MT which has been mentioned in the original project proposal of the factory. As per recommendation of this report the annual production capacity of BISF was set at 4000 MT. But due to unsatisfactory growth rate of demand the annual demand of sanitary wares at 1988-89 stand at 2400 MT. However the demand for sanitary wares are increasing steadily and it is hoped that if the current trend continues the factory would be able to utilize its 100% production capacity in the near future.

At present the following sanitary ware products are being manufactured by BISF:

No.	Name of the Products	No.	Name of the product
1.	Water closet.	2.	Combi closet.
3.	Wash basin.	4.	Corner basin.
5.	Cabinet basin.	6.	Long pan.
7.	Oriental pan.	8.	Foot rest.
9.	Cistern with cover.	10.	Cover of cistern.
11.	Kitchen sink.	12.	Sink tray.
13.	Stand urinal.	14.	Siphon.
15.	Pedestal.	16.	Gallery.
17.	Soap tray.	18.	Toilet paper holder.
19.	Towel holder.	20.	Tooth brush holder.

Table 3.1: Different sanitary wares products produced by BISF.

These products appear in the following two categories:

1. Normal color: It includes pink, blue, green, yellow, offwhite and shilton brown color.

2. Special color: It includes olive green, ash, biscuit, coffee brown, diamond black, rose pink, alpine blue, camel brown and navy blue.

TILES:

Tiles unit started its trial production on the 16th July, 1986 and commercial production on September, 1986. The annual production capacity of tiles unit is 8,00,000 sq. ft. (1,10,000) sq. m. According to an earlier market survey the annual demand of tiles in Bangladesh was 700,000 sq. ft. But the demand of tiles has increased notably and according to a latest survey the BISF with its' 100% capacity utilization in tiles section can share only 21% of country's total tiles market. This is due to its international standard the BISF tiles are now being exported .

At present the factory produces the following types of tiles at different sizes:

No.	Name of the products	No.	Name of the products
1.	Plain white tiles	2.	Plain color tiles .
3.	Shades over plain color.	4.	Marvel shaded.
5.	Single print over white base.	6.	Single print over color base.
7.	Double print over white base.	8.	Double print over color base.
9.	Droplet over color base.	10.	Acid proof floor tiles.
11.	Special color.	12.	Floor tiles.
13.	Red facing tiles.	14.	Chocolate facing tiles.

Table 3.2: Different tiles products produced by BISF.

INSULATOR:

Generally, Bangladesh Power Development Board (BPDB), Rural Electrification Board (REB), T & T, GEM Plant, Bangladesh Water Development Board (BWDB) are the major consumers of insulator products. During project planning it was assumed that all insulator up to 33 KV. would be bought by these organizations from BISF. But in reality, BPDB purchases the insulator from BISF only for their maintenance work. Both BPDB and REB purchase all insulators products for their development work through international tender. So BISF has to compete with imported insulators in a fierce competition and thus failed to secure the contract. For this reason the factory could not capture the entire insulator market of the country despite the fact that its installed capacity it can easily meet the entire annual demand of Bangladesh. The government has however imposed restriction on the import of 33 KV. insulator form the year 1986-87. But the consuming organizations of insulator are forced to call international tender as per condition of the donor countries in the donor aided development projects.

At present BISF produces the following types of refractory bricks and insulator products:

Refractory Bricks:

No.	Name of the product.	No.	Name of the product.
1.	Acid proof bricks.	2.	Fire bricks.
3.	BISF slab.	4.	Chimney brick.
5.	Main arch brick.	6.	Plug brick.

Table 3.3: Different bricks products produced by BISF.

Insulator:

No.	Name of the product.	No.	Name of the product.
1.	Disc insulator.	2.	Pin insulator.
3.	Shackle insulator.	4.	Guy insulator.
5.	Spool insulator.	6.	Suspension insulator.
7.	Post type insulator.	8.	H.T. insulator.
9.	H.T. bushing insulator.	10.	Transformer insulator.
11.	T & T insulator.	12.	Drop out fuse.
13.	Tread guide.	14.	Ceramic yearn guide.

Table 3.4: Different insulator products produced by BISF.

3.1.5 RAW MATERIALS USED

In manufacturing the above products the following raw materials are currently being used. Some of these raw materials are of local origin and some of them are of foreign origin.

Local Origin:

No.	Raw material name.	No.	Raw material name.
1.	Bijoypur Clay-Grade I	2.	Bijoypur Clay-Grade II
3.	Feldspar local.	4.	Red clay.
5.	Sodium Chloride.	6.	Sodium silicate.

Table 3.5: Raw materials of local origin.

Foreign origin:

No.	Raw material name	No.	Raw material name.
1.	Ball clay -black.	2.	Ball clay-white.
3.	China clay-body.	4.	China clay-glazed.
5.	China clay-highly plastic.	6.	China clay-Caoline carmine.
7.	Feldspar-foreign	8.	Soda ash.
9.	Quartz stone-glazed	10.	Lime stone-glazed
11.	Barium carbonate.	12.	Zinc oxide.
13.	Zirconium silicate.	14.	Dolomite.
15.	Color stain.	16.	Talcum powder.
17.	Cobalt sulphate.	18.	Iron oxide.
19.	Boxite.	20.	Lime stone (body).
21.	Frit for opaque glaze.	22.	Chromium oxide.
23.	Manganese oxide.		

Table 3.6: Raw materials of foreign origin.

Besides these raw materials, broken bodies of sanitary wares and tiles are recycled. Broken insulator and bricks have no use as they cannot by recycled.

In addition to these raw materials, plaster of paris, an imported raw material is used for making molds.

3.2 PRODUCTION PROCESSES

Production processes of BISF can be grouped into three lines. These are sanitary wares, insulator and tiles. The flow diagram of each production along with their description are given below:

3.2.1 SANITARY WARES

The production process of sanitary wares consists of the following stages:

Raw Material Preparation:

Bigger lumps of raw material (feldspar, ball clay, quartz, lime stone, broken sanitary wares) are crushed into medium size particles in the jaw crushers and from where it is taken to cone crusher which crushes them into powders. These powders are kept in silo from where it is transferred to the slip preparation stage.

Slip Preparation:

At this stage crushed raw material are put into the ball mill. In ball mill together with the powdered raw material water is added and slip is prepared. The slip is then taken to blunger where china clay, green broken body (unfired broken body) and sodium silicate is added. The resulting slip is flow through a magnetic iron separator into the reservoir.

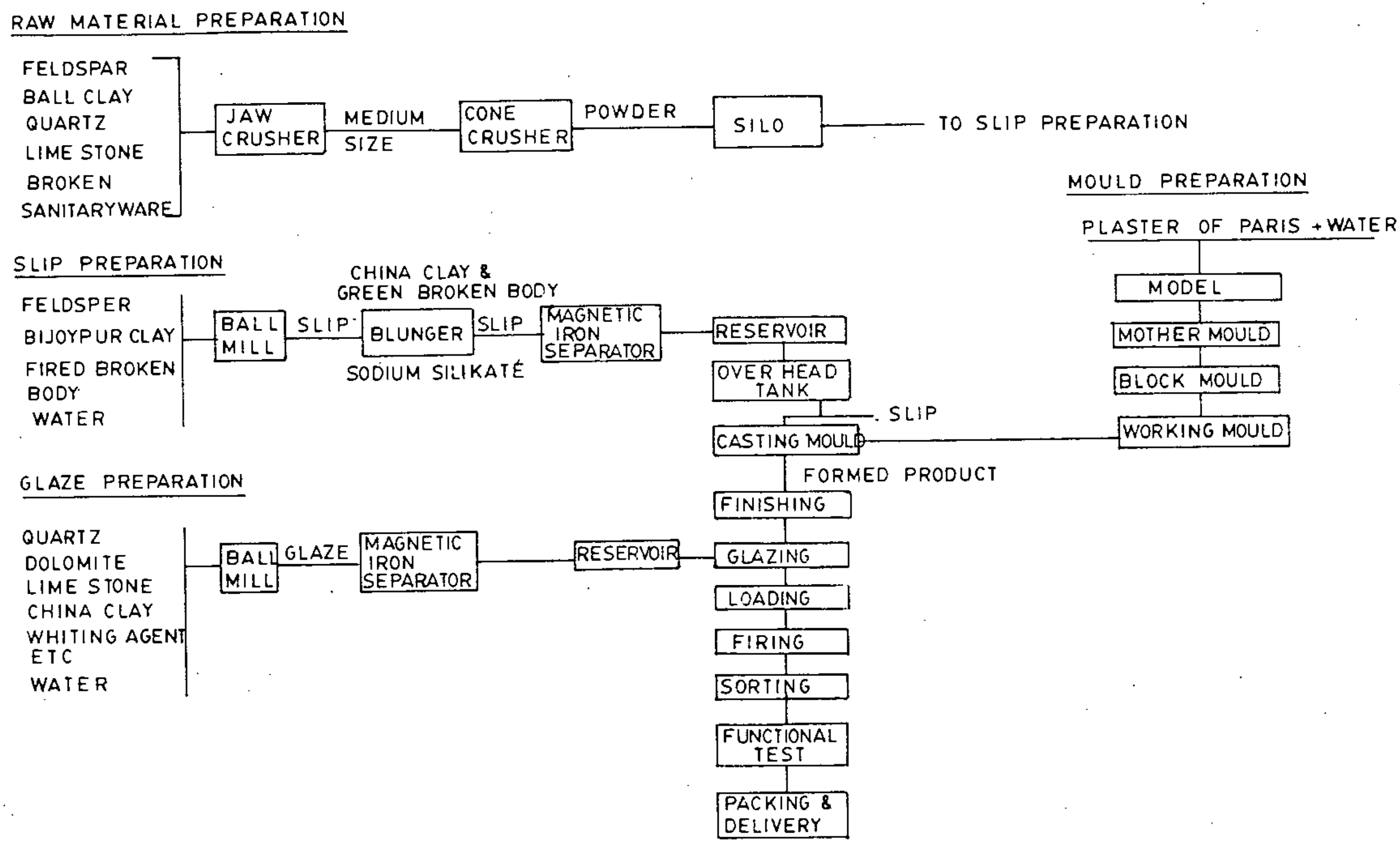

Figure 3.4. Production flow diagram of Sanitary wares production line.

Glaze Preparation:

Appropriate proportion of quartz, dolomite, lime stone, china clay, white washing agents and water are added to the ball mill. The resulting glaze from the ball mill is flown through a magnetic iron separator and is kept in the reservoir.

Mould Preparation:

Plaster of paris and water of appropriate proportion is used to make the model. The model is then transformed into molten mould, then block mould and finally into the working or casting mould.

After the four preparatory stages, the processing of sanitary ware products takes place as follows:

Slip from the overhead tank is taken to the casting molds. The formed product from casting molds is then given finishing touches. The finished items are then glazed by the glaze that was prepared in the earlier stages. After glazing they are fired in kiln. After firing the visibly cracked or broken items are sorted out and functional tests are carried out for the remaining items. The products are then packed and stored for delivery.

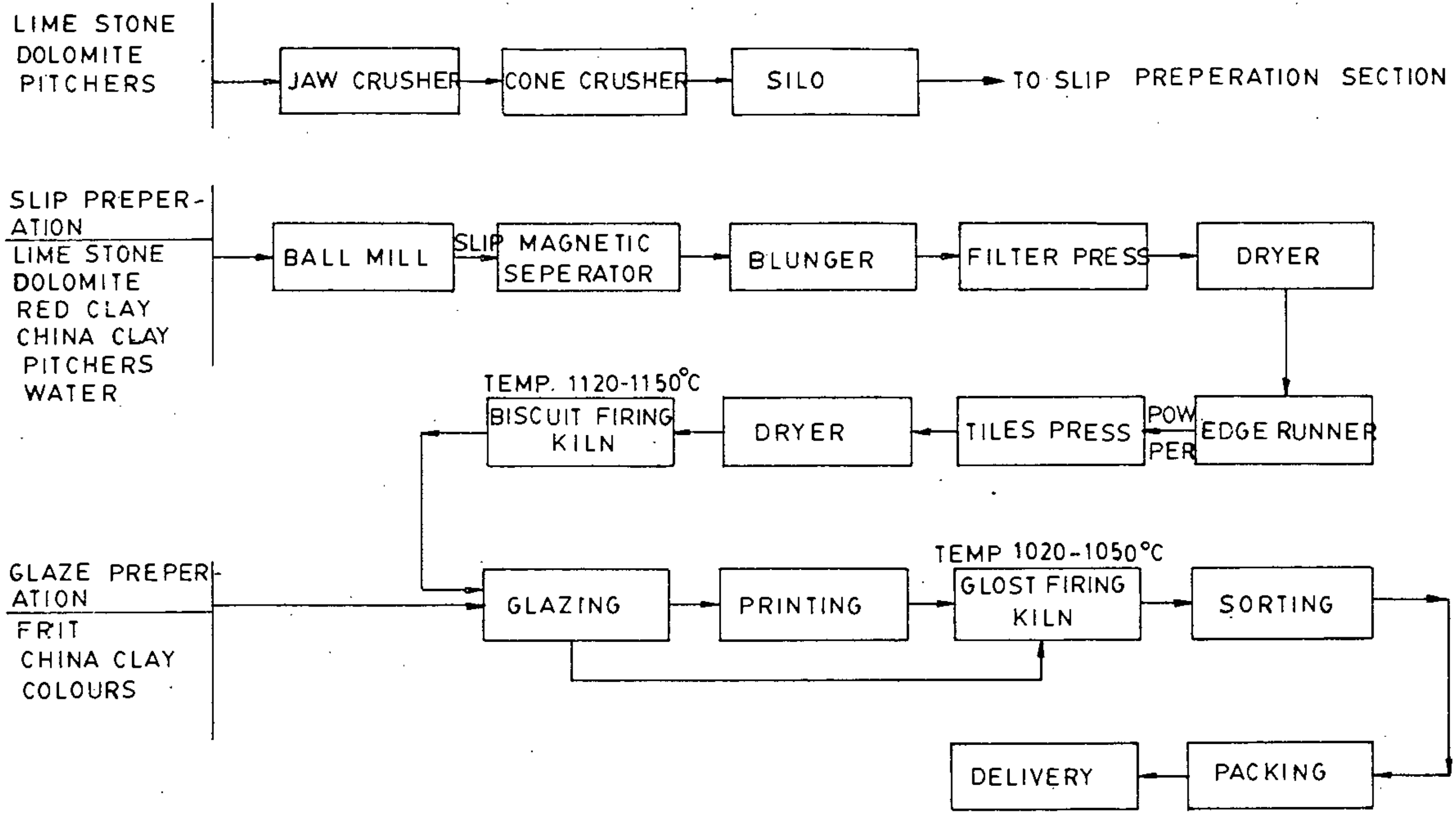

Figure 3.5. Production flow diagram of Tiles production line.

3.2.2 TILES

The slip and glaze preparation stages for tiles are similar to that of sanitary wares. Therefore, their description is omitted. The later stages are described in the following paragraph.

From blunger the slip is taken to the filter press. From there it is taken to a dryer. The dried slip is then taken to the edge runner from where the powdered raw material is taken to another dryer. From the dryer the material is taken to the biscuit firing kiln. After firing at temperature 1120-1150^{0}C the tiles are glazed with the glaze prepared in the earlier stages. After glazing the plain tiles are taken to the glost firing kiln. For designed tiles the printing is done after glazing and then it is taken to the glost firing kiln. In the glost firing kiln the tiles are fired at temperature 1020-1050^{0}C. The finished tiles are then sorted and packed.

3.2.3 INSULATOR AND BRICKS

The slip and the glaze preparation stage for insulator is similar to that of sanitary wares and their descriptions are therefore omitted. The latter stage of production are described in the following paragraph.

Slip form ball mill flows through the magnetic separator and is taken to blunger. In blunger the green broken body of sanitary wares and china

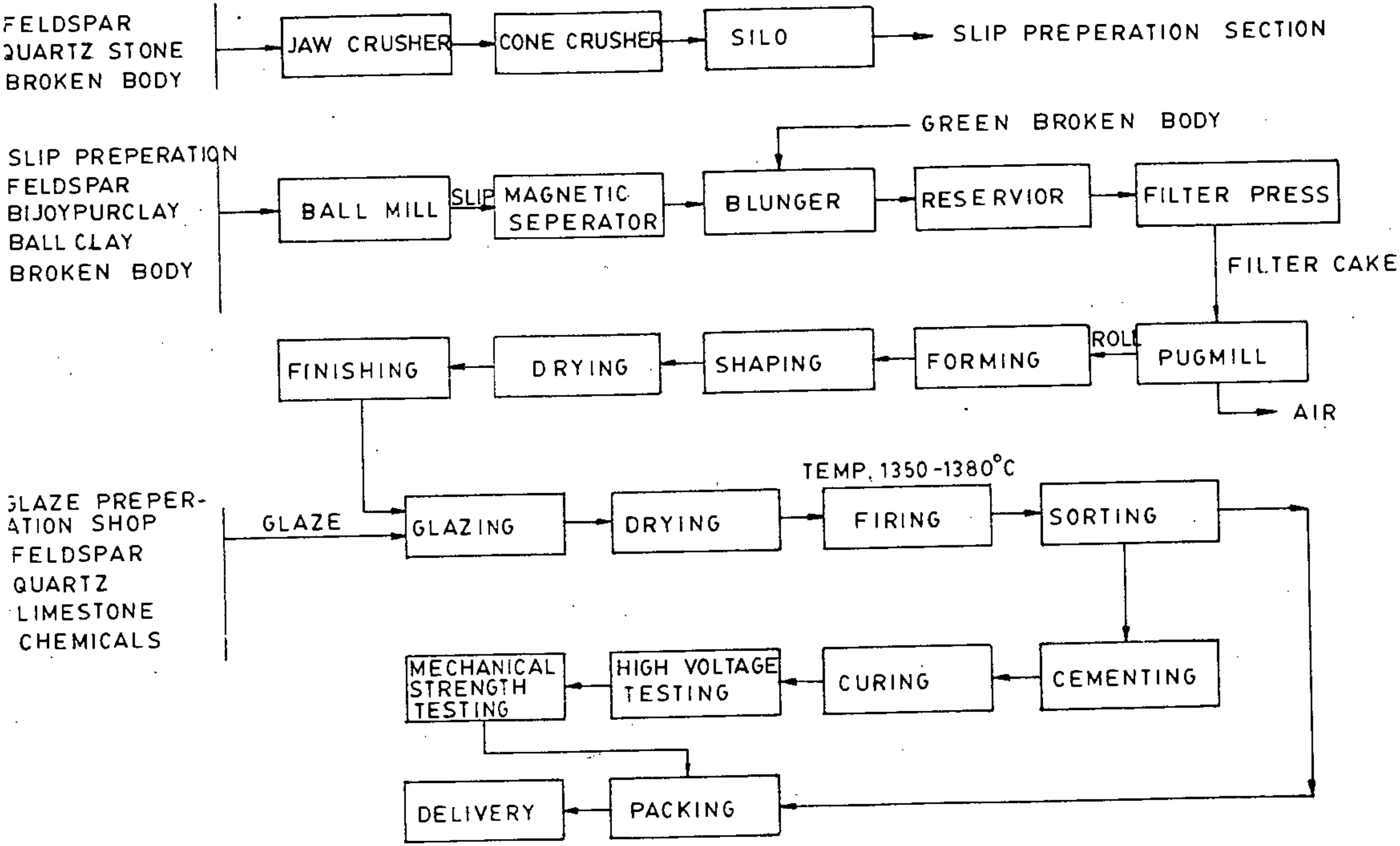

Figure 3.6. Production flow diagram for insulator & bricks.

clay is added. The resulting slip is then taken to a reservoir. The slip from reservoir is taken to a filter press where filter cakes are produced. The filter cake is then taken into the pug mill. From pug mill the resulting slip is formed, shaped, dried and finished. The finished items are then glazed with the glaze prepared in the glaze preparation stage. The glazed items are then dried, fired at a temperature of 1350-1380^{0}C and sorted. After sorting out the defective items the good items are cemented and cured. After that the high voltage and mechanical strength testing is carried out for the insulators.

CHAPTER FOUR

MODEL FORMULATION

4.1 INTRODUCTION

A mathematical model for production planning has been developed in the present chapter. This model would be incorporated in the model base of the proposed Production Planning Decision Support System. The proposed system, as described in the next chapter would be used for tactical or aggregate production planning of the enterprise. Through aggregate planning complex decisions and forecasts made in one area and their consequence effect on other areas could be known because of the interlinked production units. The model would also prove to be a valuable management information tool to disseminate the information throughout the organization. The disaggregation of the aggregated model outputs would be done at the implementation stage of the execution level of the organization.

4.2 THE PROPOSED AGGREGATE PLANNING MODEL

The terminology used to formulate the model is described below.

Decision Variables:

Primarily six types of variables are considered as the decision variables. Appropriate subscripts are used to denote the time and/ or product family and raw material.

Define,

x_{it} = Amount of product family i to be produced in period t (in ton).

i_{it} = Inventory of product family i period t (in ton). (ending inventory of period t)

o_t = Overtime labor hours to be used in period t.

q_{jt} = Amount of raw material j to be replenished in period t (ordering quantity) (in ton)

r_{jt} = average inventory of raw material j in period t (in ton).

$$y_{jt} = \begin{cases} 1, & \text{if any order is placed for the raw material j in period t} \\ 0, & \text{otherwise.} \end{cases}$$

Data:

a. Objective Function Co-efficient:

VC_{it} = Variable cost of production per ton of family i in period t.

C_{it} = Inventory holding cost per unit weight of family i in period t

OLC_t = Overtime labor cost per hour in period t.

S_{jt} = Ordering cost per order of the raw material j in period t.

H_{jt} = Inventory holding cost per unit weight of the raw material j in period t.

b. Constants and Parameters:

D_{it} = Forecasted demand of family i in period t.

K_i = Labor hour required per ton for product family i.

RLH_t = Regular labor hour available in period t.

OLH_t = Overtime labor hour available in period t.

F_{it} = Percentage of forecasted demand of family i in period t that is to be kept as inventory.

TSF_t = Total storage capacity (weight) available for finished goods in period t.

TSR_j = Total storage capacity (weight) available for raw material j.

URF_i = Usage ratio of product family i (Weight of total raw materials required to produce one ton of finished goods).

MMC_{it} = Product line capacity for product family i in period t (in ton)

RR_{ji} = Amount of the raw material j used in the production of per ton of product family i.

TS_t = Total storage capacity (weight) available for all the raw material in period t.

N = Total number of product families.

J = Total number of raw materials .

T = Total number of time periods in the entire planning horizon.

FORMULATION:

The objective function for the model is to minimize the total cost obtained by adding the variable cost of production, inventory holding cost for finished goods, overtime labor cost, ordering cost and inventory holding cost of raw materials for the entire planning horizon.

The objective function of the model is:

$$\text{Minimize } Z = \sum_{i=1}^{N} \sum_{t=1}^{T} (VC_{it} * x_{it} + C_{it} * i_{it}) + \sum_{t=1}^{T}(OLC_t * o_t) + \sum_{j=1}^{J} \sum_{t=1}^{T} (y_{jt} * S_{jt} + r_{jt} * H_{jt})$$

The cost of regular labor hour is not included in the model as the payroll of regular labors constitutes a fixed commitment and does not vary in a planning horizon.

The objective function stated above is subject to the following constraints:

1. **Demand Fulfillment Constraints**

The number of tons of product family i needs to be produced in such a quantity that together with the stock in hand of the finished goods it can at least meet the forecasted demand in every period of the planning horizon. Thus the constraint become:

$$x_{it} + i_{i,t-1} - i_{it} \geq D_{it} \qquad i = 1......N, \qquad t = 1......T$$

The constraint represents the typical production inventory balance equation. It does not incorporate any provision for back ordering. The constraint assumes a deterministic demand in every time period for every product family.

While deciding the planning horizon a careful analysis of the previous sales data is to be made. If any demand seasonalities is observed the planning horizon should be so selected that it accommodates a full seasonal cycle.

2. Labor Hour Requirement Constraint:

Labor hour requirement is fulfilled together from regular labor hour and overtime labor hour. Thus the constraint becomes:

$$\sum_{i=1}^{N} (K_i * x_{it}) - o_t \leq RLH_t \qquad t = 1......T$$

Being a state owned enterprise the organization cannot hire and fire workers to meet the variable rate of production because of socio-political environment existing in the country. The constraint therefore does not incorporate any provision for hiring and firing of the work force. The increased demand beyond the capacity of regular workforce is met from the overtime labor hours as provided by the regular workforce.

3. Constraint For Fulfillment of Raw Material Requirement

The ordering quantity of any raw material together with the stock in hand at any time period must be at least equal to the total replenishment of the raw material in producing all the product families. Thus the constraint becomes:

$$\sum_{i=1}^{N} (RR_{ji} * x_{it}) \leq q_{jt} + r_{j,t-1} - r_{jt} \qquad j = 1....J, \qquad t = 1.....T$$

4.Constraint For Total Storage Capacity For Raw Materials

The ordered quantity of any raw material together with the carried over inventory form previous period should not exceed the total storage capacity of raw materials at any period of the planning horizon.

Thus the constraint becomes:

$$\sum_{j=1}^{J} (q_{jt} + r_{j,t-1}) \leq TS_t \qquad t = 1......T$$

5. Constraint For Maximum Ordering Quantity

The ordering quantity at any time period should not exceed the total storage capacity for individual raw material. Thus the constraint becomes:

$$q_{jt} \leq y_{jt} * TSR_j \qquad j = 1.....J, \qquad t = 1.....T$$

The above constraint is set to control the ordering quantity. When any raw material is ordered at any period the corresponding 'y' variables assumes the value of '1' and the constraint forces the ordering quantity to be either less than or equal to the maximum storage area available for that raw material. Whenever no order is placed the decision variable 'y' assumes the value of '0' thereby forces the ordering quantity to be equal to zero.

6. Constraint for maximum storage of finished goods:

As the space for storing the finished goods is limited the total ending inventory at any period should not exceed the maximum storage capacity. Thus the constraint becomes:

$$\sum_{i=1}^{N} i_{it} \leq TSF_t \qquad t = 1......T$$

The above bound is formulated on the assumption that the produced goods are continuously being transferred to market and are not stored in the available storage area for delivering them at the end of planning period.

Another constraint can be added for the maximum storage capacity for the rejected finished products. But it was not incorporated due to the following reasons :

The rejected (broken or cracked) items during production could be classified as green body (unfired) and broken body (fired). The green bodies of sanitary wares and the pitcher tiles (broken tiles) are 100% recycled in the production process. But only a small percentage fired broken body are recycled. The unfired broken insulator are recycled in the production process of the facing tiles. But the insulator items rejected in the sorting and height voltage and strength testing stage cannot be recycled. These unrecyclable and recyclable items are now being stored in the open space of the factory. Some of these has been sold in the past. But because of their little commercial value their sale has now virtually stopped. So if a constraint is added for the maximum storage capacity for the rejected items in the long run the solution of the model may halt the production because of the non availability of space to store these items. To eliminate this effect the constraint is not included.

However it is strongly recommended that the management should take some steps for disposing these rejected items economically or should initiate research to find their increased use as a recyclable raw material.

VARIABLE BOUNDS:

The following bounds need to be set in the formulation.

1. Bound for overtime labor hour:

As the increased demand of labor is met from the regular workforce there is a limitation beyond which these overtime labor hours cannot be utilized. Thus the bound becomes:

$$o_t \leq OLH_t \qquad t = 1....T$$

2. Bound for safety stock:

Constraint 1 assumes the demand of the product to be deterministic and ascertained them by using forecasting method. Thus there remain some uncertainties with these forecasts. One approach to deal with this uncertainty is to incorporate a lower bound for the ending inventories at each period. This ending inventory is the safety stock associated with the family i in period t.

In order to ensure a realistic planning process ,the system is so designed that, the planner or user manager would specify a percentage of forecasted demand that is to be kept as safety stock. Thus the bound becomes:

$$i_{it} \geq F_{it} * D_{it} \qquad i = 1.....N, \qquad t = 1.....T$$

The provision for a safety stock is made with a view to keep a stable market position of the various products. This emphasis on the enterprise's responsibility of the above function as it is the sole producer of the country.

3. Bound for maximum allowable machine capacity:

There is a maximum allowable capacity of the various production machines. This maximum capacity can be ascertained on the basis of whether the production system is balanced or unbalanced. This is the minimum of the maximum capacities of all the machines in the process. Thus the bound becomes:

$$x_{it} \leq \min_{i,t}\{MMC_{it}\} \ / \ URF_i \qquad i = 1.....N, \qquad t = 1.....T$$

The term URF_i refers to the usage ratio for family i. Usage ratio is the aggregate weight of all the raw materials required to produce unit weight of finished goods. The usage ratio is assumed to be the same for the entire planning horizon. In case it varies from period to period in the planning horizon, it is needed to be transformed into a time dependent parameter.

The variables are subject to following non-negativity bounds:

$x_{it} \geq 0$ for all i and t

$q_{jt} \geq 0$ for all j and t

$r_{jt} \geq 0$ for all j and t

$o_t \geq 0$ for all t

$y_{jt} = 1$ if $q_{jt} > 0$

$= 0$ otherwise.

4.3 CHARACTERISTICS OF THE MODEL

The model described in this chapter is a mixed integer programming model because of the incorporation of the integer decision variable for ordering the raw materials. The model is a medium range planning model intended for aggregate planning. The single model would provide the solution of production quantities for various families, finished goods inventory holding policy, labor force management policy together with the raw material purchasing and stock holding policy. Although the model is intended for medium term planning horizon it can be easily extended to longer time periods.

The model ignores the cost associated with the hiring and firing of workforce, backorders, sub-contracting, lost sales etc. It does incorporates a number of technological, organizational, marketing and capacity considerations in setting out the constraints. As the model is formulated as an MIP model it would facilitate the sensitivity analysis on the part of the planner. Besides the planner can also utilize the advantage of wide variety of linear programming packages. During formulation an aggregate approach has been taken instead of detailed approach. The rationales of the approach are as follows:

1. Existing number of product items of different product families would make the problem large.
2. Aggregate demand can be forecasted more accurately than their disaggregated components.
3. The enterprise under consideration kept their data in an aggregate

form. Thus data acquisition and formulation would be practically impossible in disaggregated form.

Because of the inherent uncertainties in the planning process the model is so designed that it would give solution on the basis of the rolling horizon concept which means that at the end of every time period, actual data is used to update the model with a rolling horizon of length . This would ensure consistency in the planning process.

The model has its functional interface. That is the model recognizes the interdependencies between the production and other functional policy areas such as marketing of the enterprise. However, the model neglects the hierarchial interface between the various decision levels . The proposed model is a multi-periodical one. A single period LP model can also been used, but this would require repeated runs for various periods. Thus a multi-period model would be superior because of the importance of stock link between the different time periods of the entire planning horizon.

CHAPTER FIVE

DESIGN AND DEVELOPMENT OF A DECISION SUPPORT SYSTEM

5.1 INTRODUCTION

In this chapter the organization and development and various aspects of the Production Planning Decision Support System would be discussed. The proposed DSS in intended to solve the production planning problem of the case production system. As already mentioned production planning is a diverse are and it would be very difficult to incorporate all aspects of production planning in a single model, the present DSS would deal with the aggregate production planning of the enterprise under study.

5.2 ORGANIZATION OF THE PROPOSED DSS

A prototype decision support system for production planning named production planning decision support systems (PPDSS) has been developed on IBM compatible micro computers. FORTRAN 77 has been used as the system programming language. The system was developed and intended to be able to make an effective company wide medium term production plan. The development of the proposed DSS involves the following steps:

1. Identification of the decision relating to aggregate production plan.

2. Identification of the decision variables.

3. Data base design.

4. Model base design.

5. User interface design.

The proposed system consists of the following major components:

5.2.1 DATA BASES

The data bases are the foundation of the DSS. They contain data which are utilized by the model to run the system. The PPDSS consists of the following data bases:

Name of the data base	Contents of the data base and any Special characteristics
Sales data base	The month wise sales data for all product families. **Special Characteristic:** For the sake of computer memory space the maximum number of months for which the data base will store data is kept to 100 months for each family . If the 101 month's data is entered the system would automatically delete the first months data from the data base and incorporate the new data. However, this number of months is flexible enough and can easily be modified.
Raw material data base	This data base stores the name of all the raw materials that is to be used in the planning process.
Data base for labor hour required per ton,usage ratio of finished produ-cts,maximum machine cap-acity and finished goods stock in hand.	This data base contains the above data items for all the product family for which the planning is desired.

Data base for maximum m/c capacity, variable production cost, inventory holding cost and percentage of cycle service level.	This data base contains the above data items for each product family and for each of the planning periods for the entire planning horizon.
Data base for ordering cost and inventory holding cost .	This data base contains the data of ordering cost and inventory holding cost for each of the raw materials for all the periods in the planning horizon.
Data base for normal distribution:	This data base contains the value of the normal distribution corresponding to different percentage of cycle service level.
Data base for product sub families.	This data base contains the name of all the product sub families corresponding to the name of each of the product family for which the planning is desired.
Data base for break up of usage ratio of raw materials-1.	This data base contains the data for break up of usage ratio of raw materials for all the product sub families.
Data base for break up of usage ratio of raw materials -2	This data base contains the data for break up of usage ratio of raw materials for all the product families that is created on the basis of previous data bases.
Data base for stock in hand and individual storage capacity	This data base stores data of the above data items for each of the raw materials that is to be considered in planning.
Data base for storing the forecasting models outputs	This data base contains the output of the forecasting data base. This is intended to save time during sensitivity analysis by using the same forecast. It can also be of help to the manager who are unfamiliar with the forecasting techniques because the forecasting can be done by a knowledgeable person and the outputs can be saved in these files for future use by the planner or user of the system.

These data bases are created or updated while working with the system.

Improved data base management features can be added if any standard data base management package is used . But in the present work no standard data base management package has been used because the Fortran program cannot be interfaced with the standard data management package. As the system used the various data files in the system's model base programs the data bases are created as Fortran data files.

5.2.2 MODEL BASE

The model base of PPDSS contains the following models:

1. Forecasting Model

This model consists of a program to forecast future sales of the product items. The Winter's method of forecasting has been used with the sales data base. Although the program is prewritten the user has the flexibility to interactively input various model parameters.

2. Mixed Integer Programming Model

A mixed integer programming model for production planning has been used. All the data bases have been used except the sales data bases. It also utilizes the results of the forecasting model in the model development process.The output of this model is an MPS file that is to be solved by a LP/ILP package.

3. LP/ILP Solution Package

This software package utilizes the MPS file generated by the previous model to solve the production planning model.

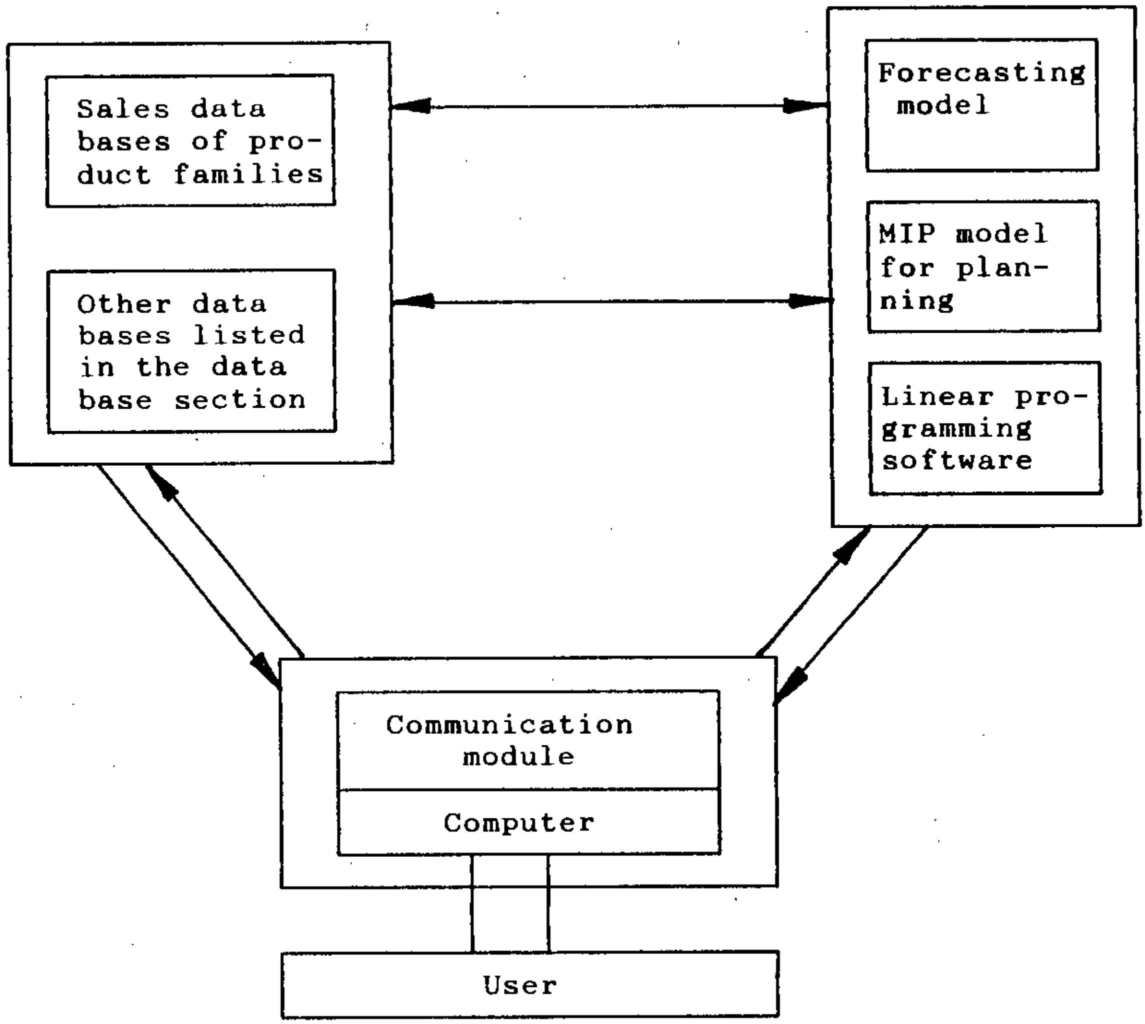

Fig.5.1 Organization of the proposed system

4. Report Generation Model

This portion of the system incorporates a program that would generate report in a non-technical or easy to understand format.

5.2.3 COMPUTER

As mentioned earlier the computer is an integral part of the DSS. While designing the PPDSS special attention has been given to the hardware capability of the computer .

5.2.4 USER

The user is to be the central point of all system development. The PPDSS is developed keeping in mind about the background knowledge of the user. The interactive sessions of the system is kept as simple as possible for facilitating the use of the system by a non-technical person.

5.2.5 COMMUNICATION MODULE

It is that part of the system that acts as bridge between the user and the computer. As the entire PPDSS is written in FORTRAN 77 the module is kept simple enough to allow direct communication with the computer. The overall system flow chart is presented in the figure 5.2. Only by answering simple questions the communication module combines different modules described above and performs the following functions:

1. File Building and Updating

The communication module together with the data base module performs the function of file building and updating. The scheme of the interactive process of a session in presented below :

At the beginning of each session the system asks the user 'Whether this is the first time input or update' and pause for the answer. Entering the appropriate answer would cause the system to shift to the designated portion of the program.

If the user enters 'First time input' the system would ask for the number of data items or time periods or number of product families for which data is to be entered. After entering it the system would ask for the data that is to be entered in the data bases. When the data entering is completed the system would display the data in the screen in tabular form and would ask whether any addition or correction is to be made. Answering affirmative the system asks for the number of rows and columns of the table for which the addition or modification is desired. After entering these values the system would ask for the updated or new data. Then the system would ask for any further corrections. If the user answers affirmative the system would respond in the previous manner otherwise it would again display the modified data and ask for any other modifications and corrections. If the users responds negative then the system would store these data in the appropriate data base otherwise it would repeat the previous stages.

If the user enter the 'Update' choice then the system would display the previously entered data from the data base and the continue the session in the same manner describe in the preceding paragraph.

Creating and updating of the raw materials usage ratio data bases are complex in nature. This is because although the planning is being made for three product families the usage ratio is different among the different sub families of a particular family. For example wall tiles, floor tiles and facing tiles all belonging to the tiles family may have different usage ratios. As

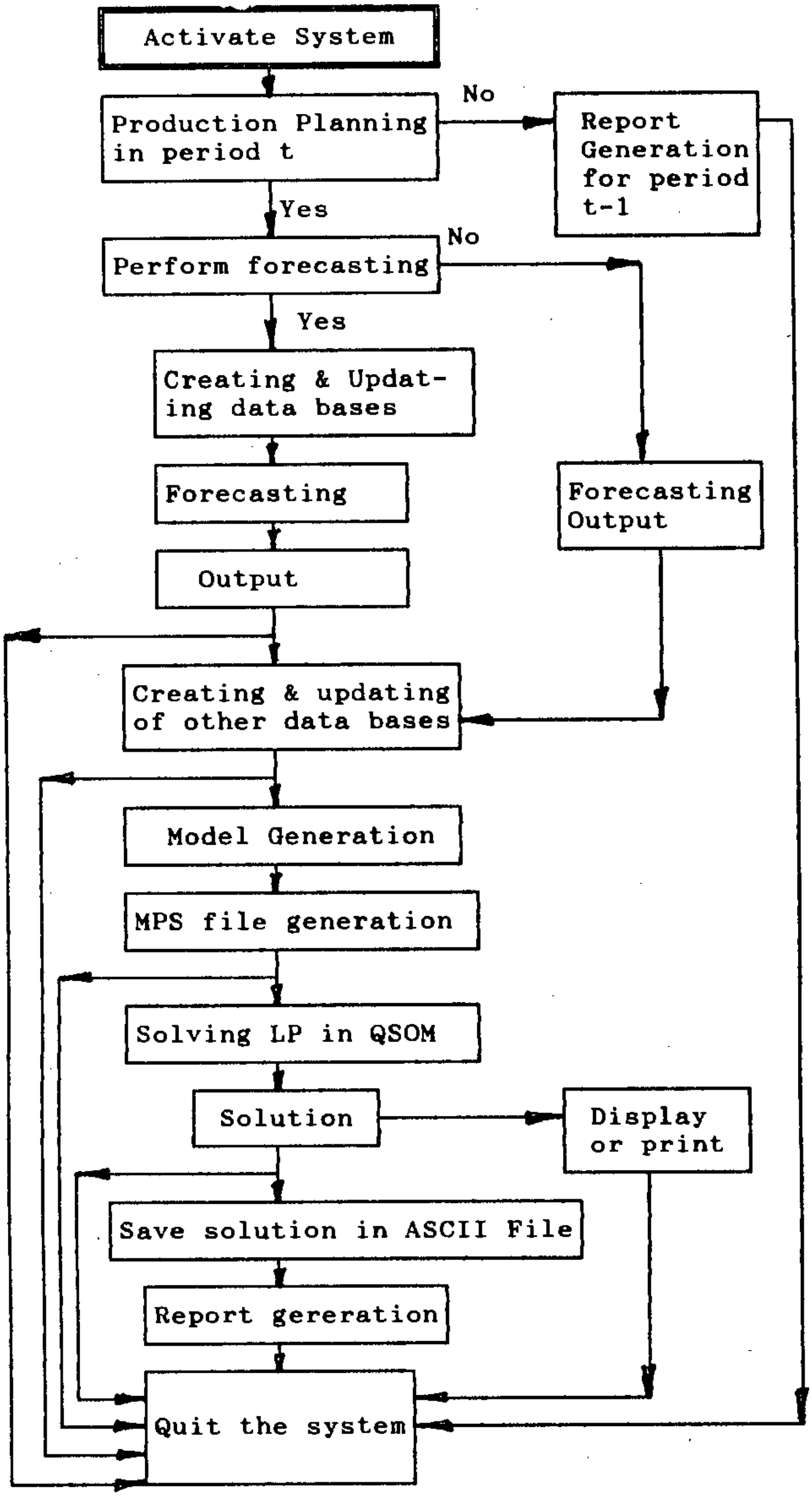

Figure 5.2 System Flow chart

they are aggregated into a single family the usage ratio has to be calculated in aggregate manner. The system, therefore follows the following steps:

At first it asks whether the user wants to change or enter the usage matrix. Answering negative would cause the system to display the previously entered usage ratio of raw materials for all sub families. Answering affirmative, the system would ask whether to enter new sub family name or update the existing names. If the user wants to update the system would display the stored sub family name and their corresponding usage ratio of all the raw materials and would ask if the user want to add any new sub family name and data. The system would act as per the answer of the question. If the user wants to enter or create a new sub family data base the system would create them after entering the name and usage ratio of all the raw materials and would verify them in the same manner described earlier.

Then the system goes for the preparation of usage matrix. Here the system asks the user to enter the number of sub family(ies) in each of the family and ask for their relative percentages in the family (this decision is based entirely on the user of how much percentage of each family he or she want to allocate to a sub family) and accordingly the system would calculate the usage ratio of all the raw materials for all the product families and would display them.

2. Forecasting Output Generation

The communication module together with the sales data bases of the data base module and forecasting model of the model base performs the forecasting activity of the product items.

At the start of this session the system asks for the value of the length of time series, length of time series to be used for model initialization, length of season and forecast lead times. If the sales data is entered for 60 months and the user want to initialize the model with 48 months of data then the system would automatically utilizes the most recent 48 months' data that is from the month 13 to 60 instead of month 1 to 48. Next the system asks whether the user wants to enter the value of smoothing constants alpha, beta and gamma or wants the program to find the best value. If the user wants to enter the value then the system asks for the three values. If the user does not want to then the system asks for the upper and lower ranges and the step size of these constants . The system then calculates the optimum value of these smoothing constants.

The system then asks whether the user wants to specify the model parameters. Answering affirmative would cause the system to ask for the values of the initial values of permanent, trend and seasonal components, otherwise the system computes these values and writes them in an output file. After that the system performs the forecasting of sales and writes them in an output file together with the sum of residuals, average residuals, variance and standard deviations.

3. MPS File Generation

The communication module together with the MIP programming model of model base and the data bases generate the MPS file for production planning function .

During the session the system would ask the user whether each of the constraints and bounds would be used. By answering affirmative to all these choices the user would incorporate all the constraints and bounds in the MPS file or the user could delete any number of constraints or bounds he/she wishes. By answering 'yes' or 'no' question the system would generate the MPS file incorporating the objective function together with all the constraints and bounds. During the session, whenever possible provision has been made to use user's judgement as an alternative way for using a mathematical formula. As the formulation is a mixed integer problem the user can specify the bound (upper and lower) for the integer variables it is to be solved by a MIP software or in absence of that he/she can specify the value and then test different alternatives to find the optimal solution using a LP software.

4. Generation of the Model Solution

This is done by the software package that is incorporated in the model base. The menu driven options of software package would read the MPS file generated in the earlier stages and would generate solution of the problem.

5. Report Generation

The solution generated by the LP/ILP software package can be displayed and printed out from the menu options of the software. These reports specify the solution by variable names. If a report is desired in a non-technical format the user would save the solution generated by the package in an ASCII file. Then after quitting the solution generation stage the user can call the report generating model from the model base and can generate report from the data stored in the ASCII file.

5.3 FEATURES OF THE PROPOSED SYSTEM

The following are the notable features of the proposed system:

1. The system would improve the effectiveness of the managerial decision making for tasks that cannot be completely routinized. The system is implemented for a semi structured task where some functions can be most effectively be performed by the computer while some others require managerial expertise. Thus the system utilizes both managerial judgement and computational efficiency of modern computers.

2. The system integrates the information system technology together with quantitative techniques of management science.

3. The system is flexible enough. Its flexibility is reflected by its ability to change with time. The system would be able to adapt to changes without major structural change in the model.

4. The user has the control over the model base and data bases.

5. Although intended for medium range planning the system can be easily adapted for short and long term planning.

6. By providing what-if analysis feature the system allow the manager to improve the quality of solution by evaluating different alternatives.

7. The most attractive part of the model is its interactive nature. Interactive system utilizes human judgement in addition to using the capability of a computer during the decision making process. Human being although limited by their ability to process information can recognize patterns, identify problem areas, resolve ambiguity and uncertainties and can adapt themselves to changing conditions. Kondaki [18] reports several studies that support the use of interaction between human and computers in solving ill structured and combinatorial problems.

Another advantage of the interactive system is that it increases the belongingness and participatory attitude of non technical managers in the decision making process and results in the more acceptability of the solutions generated by the process.

CHAPTER SIX

MODEL INPUT AND THEIR ORGANIZATION

6.1 INTRODUCTION

The model base of the system uses the data from data bases. The data bases were created with the primary data collected from the organization. In the present chapter data collection methodolgy, the strength and weakness of the existing data collection system, suggested form of data flow in the organization , the collected data and their refinement stages are presented.

6.2 DATA COLLECTION PROCESS AND PROBLEMS IN DATA COLLECTION

The data are collected from the various departments of the organization under study. Some of these are documented data and some are undocumented. These data are then compiled and after necessary refinement they are converted to desried format. The documented data are collected from the record of various departments. The undoucmented data are collected by personal interview, consultation with the individual and by inspecting the site. The collected data are then refined and formatted in a style that suits the need for input in the data base module of the proposed DSS.

The methodology used in collecting data is shown in the following figure:

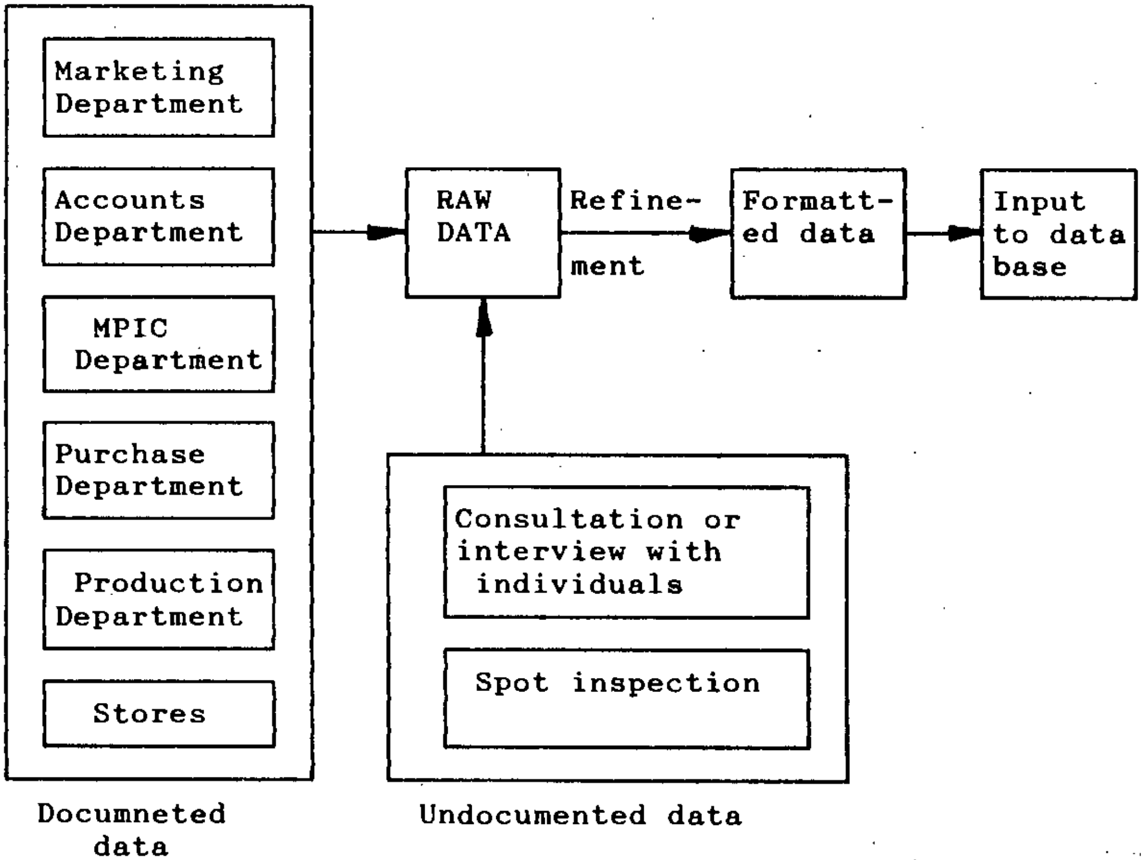

Fig 6.1 Mehthodology of data collection.

Problems associated with the data collection:

The process of data collection is a tedious and difficult task in this country. The primary reason is being an absence of any well established information system for collecting and managing data in an organization.In BISF it is also not an exception. The organization has no MIS department but it has a manual operational information sytem. Characteristically inherent to the operating system, information are maintained decentrally by individual department without any co-ordination between them. There does not exist any centralized data bank.

The data provided by the various departments were available in a format different from what the present work required. Thus it had to be regenerated and converted into a form readily usable in the present work. Moreover, the work required some additional data than those supplied. The undocumented data infulence the accuracy of the model input. During collection of these undocumented data a great deal of difficulty were encountered. These include, unwillingnes of some departments to provide data, inconsistent and conflicting data provided by some departments, and in some cases inability to measure or verify the collected data with accuracy.

6.3 COST DATA

Although the developed system is run by keeping the values of the following cost data same for each period in the planning horizon the system has the provision to vary them if it is requied to do so. The following cost data are used as input to the data bases:

a. Total Variable Cost of Production

The variable cost of production include the cost of raw material, power, fuel, spares and packing. These data items are presented in the following table for each product family .

Sanitary Wares	Inuslator and bricks	Tiles
Tk. 26,566.00	Tk. 41,447.00	Tk. 24,191.00

Table 6.1: Total variable cost per ton of product families

Source: The Accounting department of BISF.

b. Inventory Holding Cost

At present no such cost data is available to the accounting department. The organization doesnot have any inventory control department for finished goods. In this circumstances this cost data have to be ascertained. The basis of calculating these data them the following formula is developed:

Let,

Selling price per unit weight of finished goods	: Tk.A
Bank interest rate	: Tk.B
Total salaries and wages of the officers and employees associated with the storage department	: Tk.C
Total storage capacity for the product family (wt)	: D
Cost of paper, stationaries etc. of the storage department	: E
Total storage area available for the product family	: F
Rent per unit of storage area	: G
Total storage capacity for all finished goods (wt)	: H

Then the inventory holding cost per month per unit weight of finished goods is equal to:

$$(A * B)/(12 * 100) + (F * G)/D + (C + E)/H$$

Taking an example for Sanitarywares:

Selling price per ton	= Tk.63,971.00
Bank interest rate	= Tk.8%

Toatal salaries and wages of officers and employees of storage departement	= Tk.15,000.00
Cost of stationaries	= Tk. 500.00
Total storage capacity for sanitary wares	= 500 MT.
Total storage area available for sanitary wares	= 6,000 Sq.ft.
Rent per sq. ft. of storage area	= Tk.3.00
Total storage capacity for all finished item	= 1200 MT.

Thus the inventory holding cost per ton per month becomes:

= (63,971 * 8)/(100 * 12) + (6000 * 3)/500 + (500 + 15,000)/1200

= Tk.475.39

In a similar manner the inventory holding cost for insulator and tiles were calculated and are tabulated in Table 6.2 below:

Sanitarywares	Insulator & bricks	Tiles
Tk. 475.39	Tk. 382.79	Tk. 265.51

Table 6.2: Inventory holding cost per ton of product families.

c. Overtime Labour Cost

The overtime labour cost per hour is calculated based on the data provided by the accounting department of the year 1991-92. The aggregate cost of overtime labour hor engaged in production:

Total Taka spent for overtime labour hour: Tk.3,32,000.00

Total labour hours used : 3,38,400 hrs.

Thus the overtime labour cost per hour= (332000)/(338400) = Tk.9.81

d. Ordering Cost of Raw Materials

At present neither accounting department nor the purchase department calculate the cost associated with ordering the raw material. For this reason the cost is calculated in the following manner based on the data collected from the accounting and purchase department.

The preperation and processing of an order involves the following cost items:

1. Preparation and distribution of tender documents (60 sets) @ Tk.30.00 per set	: Tk.1800.00
2. Advertisement (minimum three newspapers for 3 consecutive days) @ Tk.1,200 per day	: Tk.7200.00
3. Preperation and distribution of letter of intent (cost of stationary items, labor and distribution)	: Tk. 100.00
4. Preperation and distribution of purchase order (cost of staionary items and distribution) 20 sets @ Tk.25.00 per set	: Tk.500.00
Total cost for an order	: Tk.9,600.00

Table 6.3 gives the ordering cost in taka for various raw materials.

China Clay-body	China Clay-hp	Fledspar (foreign)	Ball caly (white)	Ball Clay (black)
9600.00	9600.00	9600.00	9600.00	9600.00

Table 6.3.: Ordering cost of different raw materials.

e. Raw Material Inventory Holding Cost

Similar to the finished goods inventory holding cost the concept of such cost is new to the organization and at present no such cost is available. For this reason this cost is calculated in the same manner as it was calculated for the finished products using the following formula:

Let,

Purchasing price per unit weight of raw material	: Tk.A
Bank interest rate	: Tk.B
Total salaries and wages of the officers and employees associated with the inventory control and storage department	: Tk.C
Total storage capacity for the raw material (wt)	: D
Cost of paper, stationaries etc. of the storage and inventory contorl department	: E
Total storage area available for the raw material	: F
Rent per unit of storage area	: G
Total storage capacity for all the raw materials (wt)	: H

Then the inventory holding cost per month per unit weight of raw material is equal to:

$$(A * B)/(12 * 100) + (F * G)/D + (C + E)/H$$

Taking an example for China Clay-body:

Price per ton	= Tk.9180.00
Bank interest rate	= Tk.8%
Toatal salaries and wages of officers and employees of storage and inventory control departement	= Tk.1,25,000.00
Cost of stationaries	= Tk. 1500.00
Total storage capacity for the raw material	= 700 MT.
Total storage are available	= 600 Sq.ft.
Rent per sq. ft. of storage area	= Tk.3.00
Total storage capacity for all raw materials	= 4500 MT.

Thus the inventory holding cost per ton per month becomes:

$$= (9{,}180 * 8)/(100 * 12) + (600 * 3)/700 + (1{,}500 + 1{,}25{,}000)/4{,}500$$

$$= Tk.91.88$$

In the similar manner the cost of holding inventory for the various raw materials are calculated (Table 6.4):

China Clay body	China Clay HP	Feldapar foreign	Ball clay (White)	Ball caly (black)
Tk.91.98	Tk.92.21	Tk.58.06	Tk.69.84	Tk.81.59

Table 6.4 : Inventory holding cost of different raw materials.

6.4 SALES VOLUME DATA

The monthwise sales data of product families are collected from the marketing department. The sales data presented below are in aggregate form that is the following data correspond to the sales figures of product families and not individual items (Table 6.5, 6.6 and 6.7).

Month	1987-88	1988-89	1989-90	1990-91	1991-92
July	153.39	120.19	101.72	142.98	118.69
August	125.39	196.26	167.78	187.08	180.32
September	168.52	81.79	139.62	149.37	146.20
October	147.84	173.68	152.09	165.89	151.70
November	123.68	171.63	138.83	142.18	155.10
December	173.60	138.66	178.78	139.70	141.02
January	181.20	144.73	226.15	154.09	177.78
February	153.91	156.73	171.94	151.26	146.99
March	200.72	188.09	201.40	234.66	166.10
April	148.44	188.43	129.96	157.46	136.72
May	158.98	184.93	293.54	242.14	239.25
June	239.06	290.82	315.50	204.45	193.05

Tabel 6.5.: Sales data for sanitarywares.

Month	1987-88	1988-89	1989-90	1990-91	1991-92
July	0.17	22.97	18.41	18.74	96.32
August	44.32	2.02	19.67	43.37	42.16
September	20.87	0.02	26.71	30.23	62.86
Octoberr	52.25	3.22	89.23	40.06	60.22
November	0.01	20.72	22.16	22.43	80.35
December	22.59	21.85	98.83	28.63	83.55
January	66.65	31.23	76.10	36.30	66.73
February	63.42	17.95	46.05	26.01	22.65
March	63.93	66.53	57.44	12.90	92.20
April	37.17	59.88	14.64	57.60	32.12
May	86.01	88.64	43.81	18.46	102.25
June	89.74	94.82	97.29	94.59	56.65

Table 6.6 : Sales data for insulator and bricks

Month	1987-88	1988-89	1989-90	1990-91	1991-92
July	11.43	9.32	50.21	71.65	44.91
August	7.5	16.29	92.25	85.43	53.19
September	8.43	10.45	63.55	86.26	66.63
October	13.26	16.18	64.89	80.18	52.16
Noveber	10.32	16.58	56.34	76.09	70.05
December	16.03	13.31	66.09	76.92	78.89
January	15.70	28.73	61.99	79.54	79.88
February	16.11	29.81	68.59	75.00	71.39
March	9.58	46.25	69.39	86.56	77.07
April	9.21	38.03	63.87	60.32	48.09
May	15.64	34.37	95.11	85.12	95.10
June	33.38	81.74	98.06	97.47	119.47

Table 6.7 : Sales data for tiles.

6.5 MAXIMUM MACHINE CAPACITY

The capacity of the plant has already been mentioned in chapter three. They are:

Sanitarywares	:	4000 MT
Insulator & bricks:		1300 MT
Tiles	:	1,10,000 Sq.ft. (1100 MT)

For sanitarywares the actual production capacity by weight would be lower than what has been given earlier i.e. 4000 MT. During installation of the plant the product was designed by a contracting firm. As the indegenious engineers, chemists and designers gained more and more experience they continued to improve the product design. This resulted to reducing the unit product weight keeping the product gross volume, shape and sizes unchanged.Thus with improved product design the casting and molding shops while producing the same maximum number of products would have a reduced production turnover by weight. Thus production capacities (in terms of number of products) remaining same the production turnover (in terms of weight) would be less than 4000 MT.

In the present work the data for maximum machine capacity rather than the plant capacity are requuired. For a balanced production system these two should be equal. But a study of individual sections of the production sytems of the BISF reveals that the existing system is not balanced. However as the capacity utilization or improvement is beyond the scope of the present work, the detailed description of the plant capacity is omitted. For the present work, the maximum machine capacity of all the machines in every production line is studied and the machines having the lowest cpacity in any produciton line is identified. The study shows that the Mass Body section that is the ball mill capacity at the slip preperation stage is the lowest among all the machines in all the three production lines and there capacity is taken to be the maximum machine capacity of the production lines. Their values are given in Table 6.8 below:

Name of the production line	Maximum ball mill capacity
Sanitarywares	460.00 MT
Insulator and bricks	191.74 MT
Tiles	151.00 MT

Table 6.8: Maximum machine capacity of different production lines.

6.6 USAGE RATIO OF THE FINISHED PRODUCTS

The usage ratio for finished products is the aggregated weights of raw materials required to produce unit weight of a finished product. There is a standard usage ratio for each product family. They are:

Sanitrarywares	:	1.56
Insulator and bricks	:	1.77
Tiles	:	1.65

The usage ratio of insulator and bricks and tiles can vary depending upon the amount of their sub-families which have different usage ratios.

The stages by which this aggregate tons of raw materials is transformed into a single ton of finished goods are shown below:

Sanitarywares:

Standard Usage Ratio : 1.56

1. After loss due to raw material processing in blunger and reservoir (2%) : 1.5288
2. After loss in pump and tank (1%) : 1.5135
3. After loss in dryer (12%) (Moisture loss and broken body) : 1.3050
4. After loss on ignition due to firing (13%) : 1.1350
5. After loss in firing rejection (12%) : 1.0000

It may be noted here that green broken body (unfired) from dryer is 100%

recycled. Whereas 6-14% of fired rejection bodies are added to the batch composition of sanitarywares and a small fraction is added to the batch composition of insulator.

Insulator and bricks:

Standard usage ratio : 1.77

1. After loss due to raw material processing in blunger and reservoir (2%)	:	1.7396
2. After loss in pump and tank	:	1.7173
3. After loss in filter press (2%)	:	1.6830
4. After loss in the pug mill (1%)	:	1.6660
5. After loss in forming and shaping (5%)	:	1.5830
6. After loss in drying (moisture and broken loss) (10%)	:	1.4250
7. After loss in ignition due to firing (13%)	:	1.2393
8. After firing rejection (11%)	:	1.1030
9. After loss due to high voltage and mechanical strength test etc. (10%)	:	1.0000

The rejected products at stage 8 and 9 cannot be recycled. However the product loss from the process from stage 1 to 7 can be recycled .

Tiles:

Standard Usage Ratio : 1.65

1. After loss due to raw material processing in blunger and reservoir (2%)	:	1.6170

2. After loss in pump and tank (1%) : 1.6008

3. After loss in filter press (2%) : 1.5690

4. After loss in the dryer, moisture loss (12%) : 1.3800

5. After loss in the tiles press (1%) : 1.3667

6. After loss in tunnel dryer, moisture loss (5%) : 1.2984

7. After loss in biscuit firing (18%) : 1.0647

8. After loss in glost firing (7%) : 1.0000

It should be noted that the loss in filter press, loss in tiles press and loss in biscuit firing can be 100% recycled.

6.7 BREAK UP OF USAGE RATIO

The breakup of usage ratio of all the raw materials for different product family is given below:

SANITARY WARES:

Raw Material for slip preperatin:

No.	Name of the raw materils	Std. Usage ratio
1.	Bijoypur clay (Grade-I)	0.2300
2.	Ball clay (black)	0.1300
3.	Ball clay (white)	0.0860
4.	China clay (body)	0.3000
5.	China caly (highly plastic)	0.04500
6.	Feldspar (local)	0.50000
7.	Feldspar (foreign)	0.10000
8.	Soda ash	0.0012
9.	Broken body of sanitary wares	0.0652
10.	Sodium silicate	0.009
	Sub total	: 1.4664

Table 6.9 : Raw materials usage ratio for Sanitary wares

Chemicals for glaze preperation:

No.	Name of the chemicals	Std. Usage ratio
1.	China clay (glazed)	0.0062
2.	Feldspar (foreign)	0.0330
3.	Quartz stone (glazed)	0.0250
4.	Lime stone (glazed)	0.0120
5.	Barium Carbonate	0.0030
6.	Zinc Oxide	0.0020
7.	Dolomite	0.0012
8.	Colour stain	0.0009
9.	Talcum powder	0.0012
10.	Sodium Chloride	0.00003
11.	Cobalt sulphate	0.00007
12.	Zirconium silicate	0.0090
	Sub total	: 0.0936
	Total	: 1.5600

Table 6.9 (Contd.): Raw materials usage ratio for Sanitary wares.

INSULATOR:

Raw materials:

No.	Name of the raw materials	Std. Usage ratio
1.	Bijoypur clay Grade - I	0.5600
2.	Ball clay (black)	0.1400
3.	China clay (body)	0.1400
4.	China clay (highly plastic)	0.1800
5.	Feldspar (local)	0.5200
6.	Feldspar (foreign)	0.1400
7.	Broken body of sanitarywares	0.0314
	Sub total	: 1.7114

Table 6.10 : Raw materials usage ratio for insulator.

Chemicals for glaze preperation:

No.	Name of the chemicals	Std. Usage ratio
1.	China Clay (glazed)	0.0040
2.	Zirconium silicate	0.0006
3.	Feldspar (foreign)	0.0080
4.	Lime stone	0.0300
5.	Zinc oxide	0.0003
6.	Iron oxide	0.0018
7.	Mnganese di oxide	0.0027
8.	Cromium oxide	0.0017
9.	Dolomite	0.0095

Sub total : 0.0586
Total : 1.7700

Table 6.10 (Contd.) : Raw materials usage ratio for Insulator.

BRICKS:

Raw materials for slip preperation:

No.	Name of the raw materials	Std. Usage ratio
1.	Refractory groge	0.3300
2.	Bijoypur clay (grade -2)	0.3600
3.	China clay (Caoline carmine)	0.0900
4.	Boxite	0.2800
5.	Ball clay (black)	0.2400

Total : 1.3000

Tabel 6.11 : Raw materilas usage ratio for bricks.

WALL TILES:

Raw materials used for slip preperation:

No.	Name of the raw materials.	Std. Usage ratio.
1.	Ball clay (White)	0.1000
2.	Bijoypur clay (Grade -2)	0.7400
3.	Lime stone (body)	0.2400
4.	Red clay	0.1500
5.	Dolomite	0.0800
6.	Pitcher tiles (broken body)	0.2150
	Sub total :	1.5250

Table 6.12 : Raw materials usage ratio for wall tiles.

Chemicals for glaze preperation:

No.	Name of the chemicals used.	Std. Usage ratio.
1.	China clay (glaze)	0.01100
2.	Quartz stone	0.0020
3.	Colour stain	0.0020
4.	Frit for opaque glaze	0.1100
	Sub total :	0.1250
	Total :	1.6500

Table 6.12 (Contd.): Raw materials usage ratio for wall tiles.

FLOOR TILES:

Raw materials used for slip preperation:

No.	Name of the raw materials	Std. Usage ratio
1.	Bijoypur clay (Grad - I)	0.5600
2.	Ball clay (black)	0.1400
3.	China clay (body)	0.1400
4.	China clay (Highly plastic)	0.1800
5.	Feldspar (local)	0.5200
6.	Feldspar (foreign)	0.1400
7.	Broken body	0.0314
	Total :	1.7114

Table 6.13 : Raw materials usage ratio for floor tiles.

FACING TILES:

Raw materials used for slip preperation:

No.	Name of the raw materials	Std. Usage ratio
1.	Broken body of insulator	0.462
2.	Red clay	1.010
3.	Pitcher tiles (wall tiles)	0.0780
4.	Cromium oxide	0.0310
	Total	: 1.581

Table 6.14 : Raw materials usage ratio for facing tiles.

6.8 LABOR HOUR

The labour hours both avaiable and required are calculated using the data data collected from the accounting department.

The total available regular labour hours are calculated on the basis of the following data:

Total number of persons involved in production :

Skilled = 299
Semiskilled = 83
Unskilled = 77

Total = 459
Daily working hours : 8 Hours.
Working day per year : 300 days.

Total regular labour hour available per month:

=(459 * 8 * 300)/12 = 91,800 hrs.

Total Avaialable Overtime Labour Hour

As not all the workforce are allowed for overtime only 300 persons were considered for working on overtime. Thus the total overtime labour hour available per month is as follows:

= (300 * 8 * 300)/12 = 60,000 hrs.

The following table shows the regualr and overtime labour available per month :

Regular labour hours	Overtime labour hours
91,800	60,000

Table 6.15 : Regular and overtime labour hour available.

In running the developed system these data like the cost data mentioned above are assumed to be the same for all the time periods. However the system has the flexibilty to accomodate the different data for different time periods.

Labour Hour Required to Produce per Ton of Finished Goods:

This data is calculated on the basis of data provided by the accounting department.

Total annual regular labour cost: Tk. 2,42,03000

Total annual overtime labour cost: Tk. 33,20,000

Total annual labour cost for produciton :Tk.2,75,23,000

Total regual labour used during the period : 11,28,000

Total overtime labour used : 3,38,400

Total labour hour used in production : 14,66,400 hrs.

Average cost of labour per hr = 2,75,23,000/14,66,400 = Tk.18.77

Average labour cost per ton of sanitarywares : Tk.6498

Average labour cost per ton of insulataor & bricks : Tk.5542

Average labour cost per ton of tiles : Tk.6500

Thus the average labour hour required per ton of production:

Sanitarywares = 6498/18.77 = 346.19

Insulator & bricks= 5542/18.77 = 295.26

Tiles = 6500/18.77 = 346.30

6.9 STORAGE CAPACITY

The individual raw materials storage capacity are as follows:

Name of the raw materials	Storage capacity in MT.
China clay (body)	700
China clay (Highly plastic)	350
Feldspar (foreign)	500
Ball clay (White)	700
Ball clay (black)	350

Table 6.16 : The storage capacity of the selected raw materials.

The total storage capacity of all the raw materials and finished products are as follows:

Raw materials Storage capcity in MT for the selected raw materials.	Finished goods storage capacity in MT.
2600.00	1200.00

Table 6.17: Total storage capcity for raw materials and finished goods.

6.10 STOCK IN HAND

The stock in hand of finished goods (as on 30th June, 1991) are collected from the marketing department and the stock in hand of the raw materials (as on 30th June, 1991) are collected from the material procurement and inventory control departments. The folliwng tables list these values:

Product family name	Stock in hand in MT
Sanitary wares	464.21
Insulator and bricks	128.00
Tiles	328.71

Table 6.18 : Stock in hand of finished goods.

Name of the raw material.	Stock in hand.	Name of the raw material.	Stock in hand.
China Clay-body	71.86	China clay-hp	25.19
Fledspar-foreign	7.94	Ball clay-white	0.00
Ball clay-black	41.30		

Table 6.19 : Stock in hand of raw materials.

CHAPTER SEVEN

FORECASTING OF SALES

7.1 INTRODUCTION

In a production planning environment, 'forecast' means prediction of future sales. Thus its inherent characteristic is to deal with uncertainties. Effective forecasting would thus be able to minimize these uncertainties. It must be borne in mind that the forecasted values only provide some useful estimates for planning purposes. The primary reason contributing to uncertainties is the customer demand. This is influenced by several factors both external and internal to the organization. In such an uncertain situation the selection of an appropriate forecasting system is always the prerequisite to better planning.

In the present chapter a forecasting system would be presented that has been incorporated in the model base of the proposed production planning decision support system and would be used for forecasting sales of BISF products.

7.2 SELECTING THE FORECASTING METHOD

The selection of an appropriate forecasting method is a very crucial decision on the part of a planner or analyst. In choosing a method of forecasting it is essential that the following notable few principles of forecasting [15] are given due considerations. These are as follows:

1. Forecasting involves error.
2. Forecasts should include a measure of forecast error.
3. Family forecasts are more accurate than item forecasts.
4. Short range forecasts are more accurate than long range forecasts.

In the present work of forecasting the demand of BISF products the family of products were used instead of individual items. A forecast period of one year is used instead of a short range. It is also planned to incorporate the measures of forecast error in the forecasting model output.

The choice of an appropriate system would require primarily an initial analysis of the historical sales data. The last five years' sales data of the three product families are depicted pictorially in Figures 7.1, 7.2 and 7.3 and the trend of this sales data are shown in Figures 7.4, 7.5 and 7.6. The curves indicate that seasonal influences exist in the demand of the product families. A linear trend is also observed in the sales figure of the product families. For handling seasonality influences various methods of forecasting can be used. One such method is the moving average method. But there are some shortcomings of this method [15]. They are :

1. An important decision in using the moving average method is the selection of number of past observations 'N'. Forecasts in this method are always based on data from the last N periods with no consideration given to prior data.

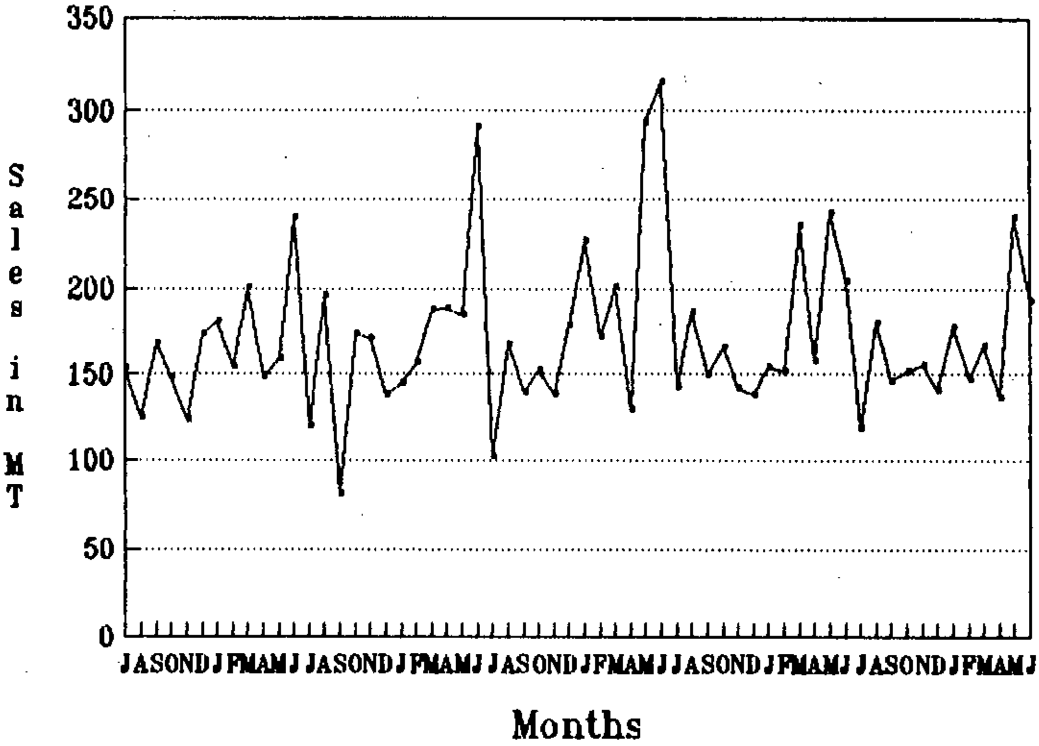

Fig 7.1 Sales data of Sanitary wares

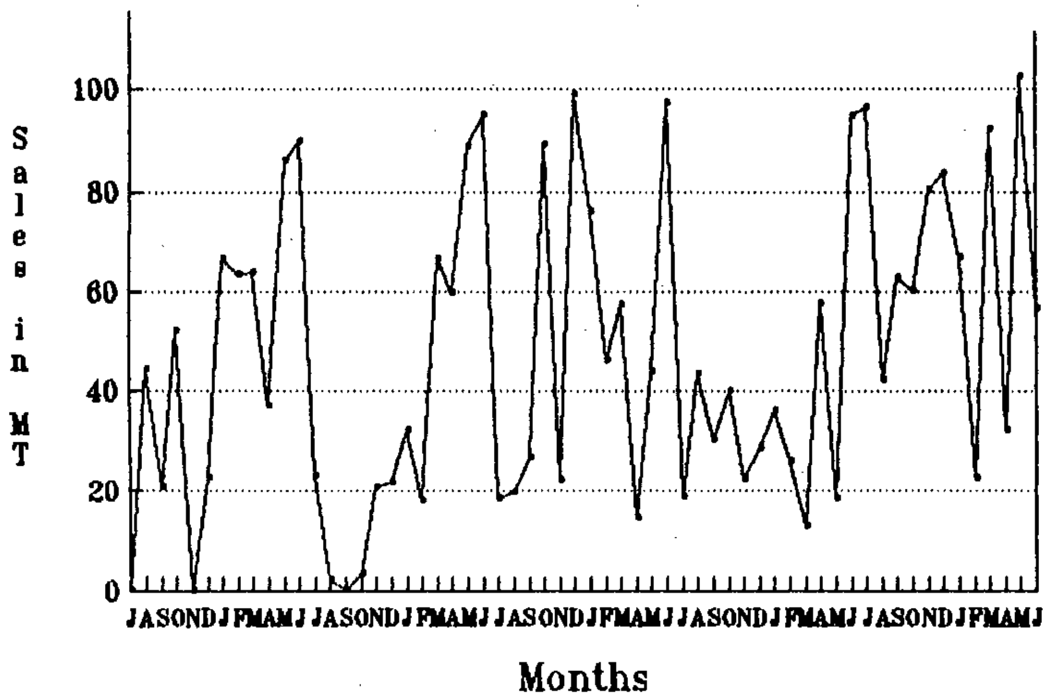

Fig. 7.2. Sales data of insulator & bricks.

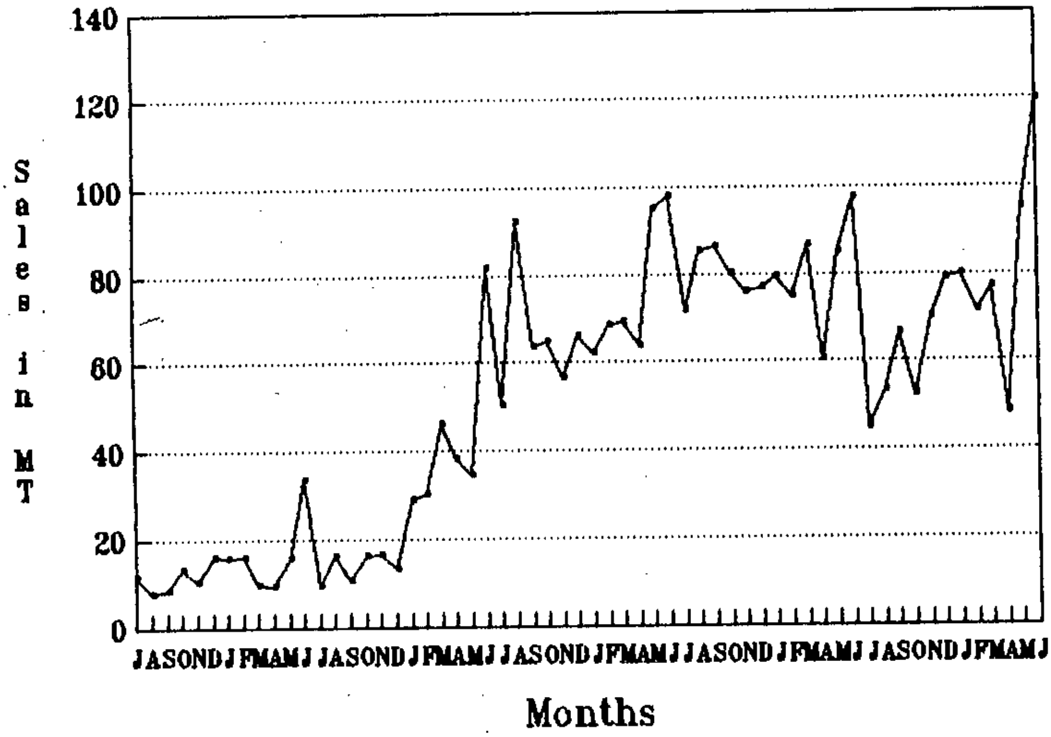

Fig. 7.3. Sales data of tiles.

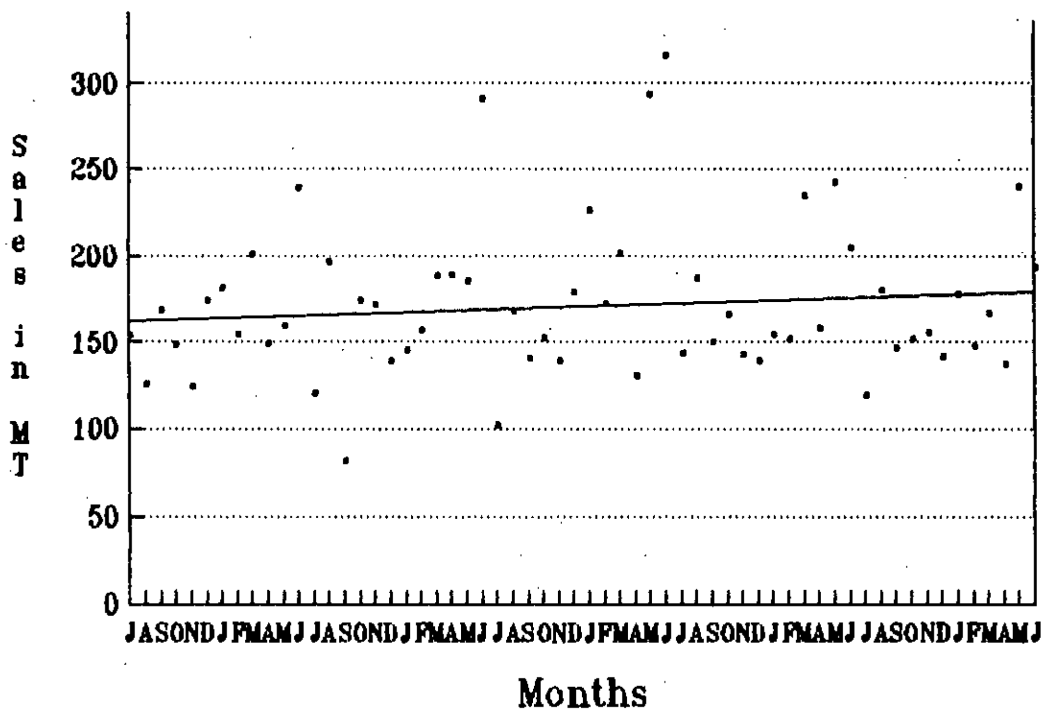

Fig. 7.4. Trends in sales data of Sanitary wares

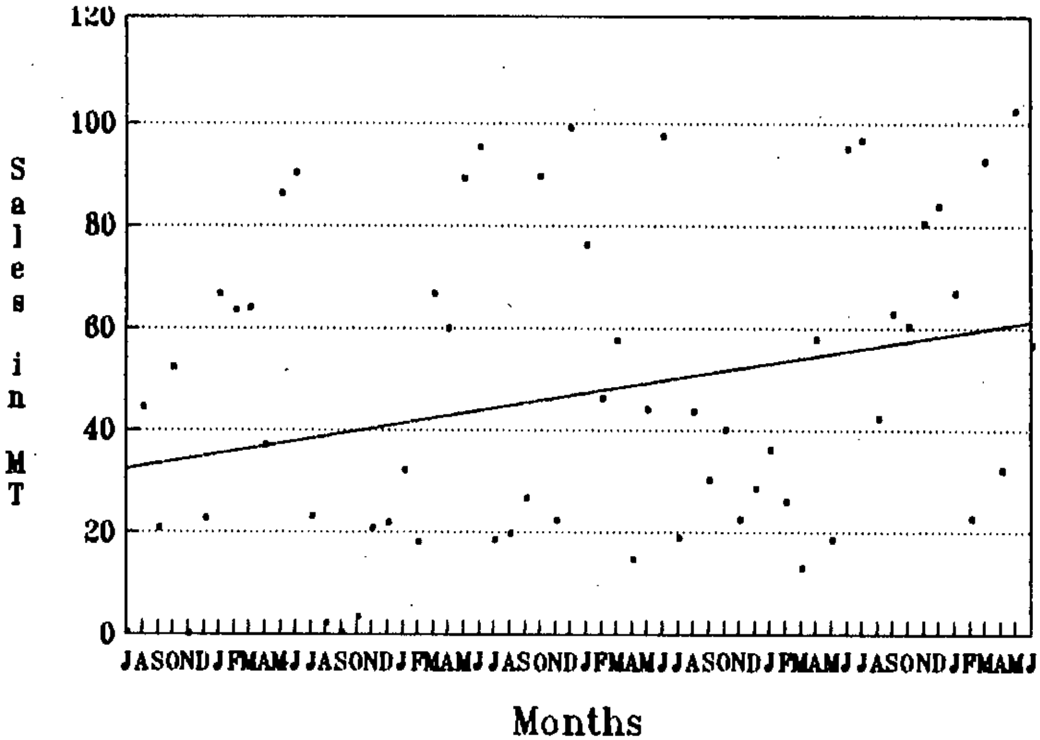

Fig. 7.5. Trends in sales data of insulator & bricks.

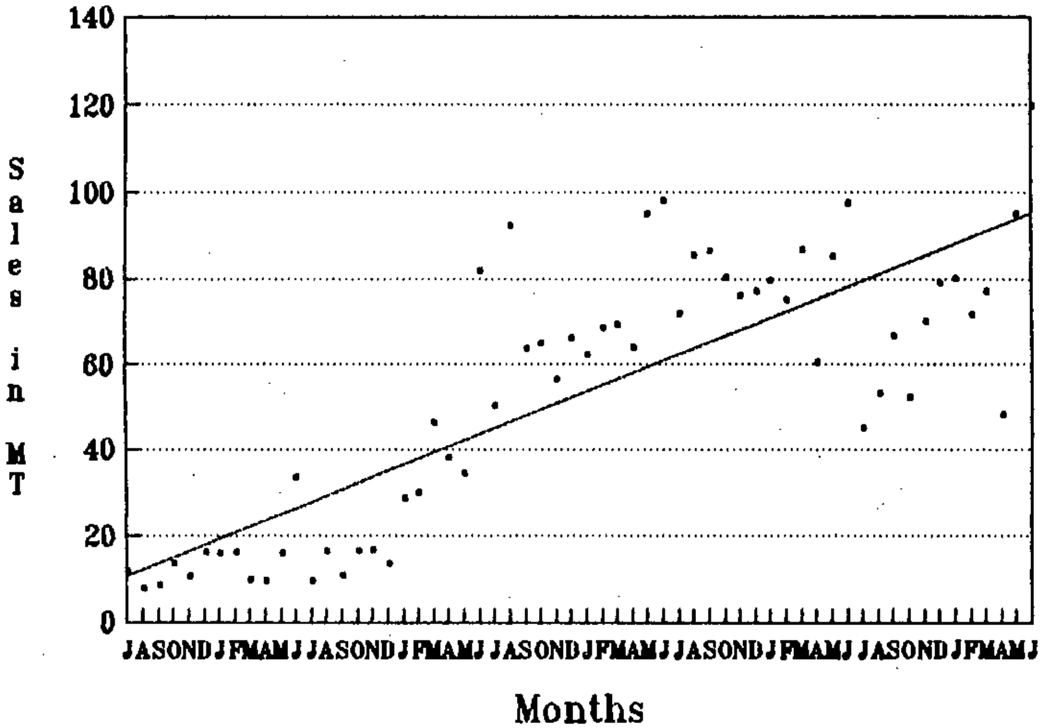

Fig. 7.6. Trends in sales data of tiles.

2. Equal weights are given to observations from each of the last N periods whereas it is more reasonable that in predicting future, recent data should be given more weight than the older ones.

Although the Weighted Average Method overcomes the second problem associated with moving average method, this technique of forecasting is computationally inefficient as it requires storing of large amount of past data.

Compared to moving average, exponential smoothing is more efficient method for forecasting with considerations of seasonal variations. This method overcomes the principal shortcomings of the moving average by taking all past data into account, while recent data are given more weight. It requires less data storage and is computationally more efficient.

Various exponential smoothing techniques are used in forecasting such as single exponential smoothing, double exponential smoothing with linear trend, exponential smoothing incorporating seasonal variations etc.

Exponential smoothing technique with both linear trend and seasonal variation can be of the following two types:

1. Additive seasonal method: This method is used when a constant seasonal influence is observed regardless of the average level of demand.
2. Multiplicative seasonal method: This method is used when seasonal influences depend on the level of the demand. The peaks and valleys are more extreme when the average demand is high.

By analyzing the past sales data of all the product families in the present work, it is decided that a multiplicative seasonal method would be appropriate for the present case. Winter's method is selected for the present work as this method is widely used in practice for a multiplicative seasonal model.

7.3 FORECASTING BY WINTER'S METHOD

A computer program in FORTRAN 77 (Watfor-77, Version 3.0) is used for the Winter's method of forecasting which is incorporated in the model base of the production planning decision support system. The program utilizes the data from the sales data base and the data entered in the interactive mode to generate the output. The results are saved in a file and the reports are written in another file. These are used for subsequent sensitivity analysis. This eliminates the need for repeated forecasting during the sensitivity analysis.

Computer outputs from the Winter's method of forecasting are given in the following sections . Initial values of the permanent component, trend component and seasonal factors are estimated using the data of past 60 months.

Instead of specifying the value of the smoothing constants alpha, beta and gamma they are optimized by carrying out a sequence of trials based on the data for the ranges and step size provided by the user in the interactive mode. It may be mentioned that unless the range and step size are carefully chosen a large amount of iterations needs to be made. It is therefore considered wise to use a coarse grid initially and then made subsequent runs with finer grid in a narrow interval. The provision for entering these data in an interactive mode has facilitated the process of choosing the value of smoothing constants.

In the initialization phase using the optimum values of alpha, beta and gamma a fitted model was developed. This fitted model was compared with the actual values and statistics such as sum of residuals, average residuals, variance and standard deviation etc. are obtained.

The forecast value for each of the periods (months) of the entire planning horizon (one year) along with the permanent component, trend component, seasonal factor, sum of residuals, average residuals, variance, standard deviation and mean standard deviation are shown in the output of the forecasting phase.

7.4 OUTPUT OF THE FORECASTING SYSTEM

WINTERS' METHOD FOR FORECASTING A SEASONAL TIME SERIES FOR SANITARY WARES

INITIAL VALUES OF THE PERMANENT, TREND AND SEASONAL COMPONENTS TO BE ESTIMATED FROM THE DATA.

THE FIRST 60 PERIODS OF DATA WHICH CORRESPOND TO, 5 SEASONS WILL BE USED

INITIAL PERMANENT COMPONENT= 164.7187
INITIAL TREND COMPONENT= -0.0363
INITIAL SEASONAL FACTOR FOR PERIOD 1 = 0.7489
INITIAL SEASONAL FACTOR FOR PERIOD 2 = 1.0026
INITIAL SEASONAL FACTOR FOR PERIOD 3 = 0.8039
INITIAL SEASONAL FACTOR FOR PERIOD 4 = 0.9272
INITIAL SEASONAL FACTOR FOR PERIOD 5 = 0.8580
INITIAL SEASONAL FACTOR FOR PERIOD 6 = 0.9021
INITIAL SEASONAL FACTOR FOR PERIOD 7 = 1.0328
INITIAL SEASONAL FACTOR FOR PERIOD 8 = 0.9142
INITIAL SEASONAL FACTOR FOR PERIOD 9 = 1.1604
INITIAL SEASONAL FACTOR FOR PERIOD 10 = 0.8944
INITIAL SEASONAL FACTOR FOR PERIOD 11 = 1.3048
INITIAL SEASONAL FACTOR FOR PERIOD 12 = 1.4507

THE OPTIMUM SMOOTHING CONSTANTS ARE

ALPHA = 0.1100 BETA = 0.2700 GAMMA = 0.0000

OUTPUT OF THE INITIALIZATION PHASE FOR SANITARY WARES

PERIOD	OBSERVATION	PERMANENT COMPONENT	TREND	SEASONAL FACTOR	FITTED MODEL	RESIDUAL
1	153.3900	169.0972	1.1557	0.7489	0.0000	0.0000
2	125.1900	165.2609	-0.1921	1.0026	170.6871	-45.4971
3	168.0000	169.8987	1.1119	0.8039	132.7018	35.2982
4	147.8400	169.7381	0.7684	0.9272	158.5660	-10.7260
5	123.6800	167.6071	-0.0145	0.8580	146.2955	-22.6155
6	173.6000	170.3250	0.7233	0.9021	151.1908	22.4092
7	181.2000	171.5323	0.8540	1.0328	176.6560	4.5440
8	153.9100	171.9437	0.7345	0.9142	157.5875	-3.6775
9	200.7200	172.7111	0.7433	1.1604	200.3732	0.3468
10	148.4400	172.6311	0.5211	0.8944	155.1340	-6.6940
11	158.9800	167.5079	-1.0029	1.3048	225.9315	-66.9515
12	239.0600	166.3159	-1.0540	1.4507	241.5551	-2.4951
13	120.1900	164.7366	-1.1958	0.7489	123.7666	-3.5766
14	196.2600	167.0850	-0.2389	1.0026	163.9578	32.3022
15	81.7900	159.6843	-2.1725	0.8039	134.1305	-52.3405
16	173.6800	160.7897	-1.2875	0.9272	146.0495	27.6305
17	171.6300	163.9606	-0.0837	0.8580	136.8537	34.7763
18	138.6600	162.7577	-0.3859	0.9021	147.8387	-9.1787
19	144.7300	159.9258	-1.0463	1.0328	167.6950	-22.9650
20	156.7300	160.2620	-0.6730	0.9142	145.2402	11.4898
21	188.0900	159.8644	-0.5987	1.1604	185.1846	2.9054
22	188.4300	164.9216	0.9284	0.8944	142.4439	45.9861
23	184.9300	163.1966	0.2120	1.3048	216.4034	-31.4734
24	290.8200	167.4847	1.3125	1.4507	237.0630	53.7570
25	101.7200	165.1701	0.3332	0.7489	126.4142	-24.6942
26	167.7800	165.7068	0.3882	1.0026	165.9254	1.8546
27	139.6200	166.9287	0.6133	0.8039	133.5267	6.0933
28	152.0900	167.1553	0.5089	0.9272	155.3498	-3.2598
29	138.8300	167.0197	0.3349	0.8580	143.8567	-5.0267
30	178.7800	170.7448	1.2502	0.9021	150.9760	27.8040
31	226.1500	177.1624	2.6454	1.0328	177.6337	48.5163
32	171.9400	180.7184	2.8913	0.9142	164.3719	7.5681
33	201.4000	182.5046	2.5929	1.1604	213.0579	-11.6579
34	129.9600	180.7206	1.4111	0.8944	165.5473	-35.5873
35	293.5400	186.8436	2.6833	1.3048	237.6481	55.8919
36	315.5000	192.6013	3.5134	1.4507	274.9538	40.5462
37	142.9800	195.5430	3.3590	0.7489	146.8726	-3.8926
38	187.0800	197.5492	2.9938	1.0026	199.4092	-12.3292
39	149.3700	198.9216	2.5560	0.8039	161.2201	-11.8501
40	165.8900	198.9951	1.8857	0.9272	186.8159	-20.9259
41	142.1800	197.0120	0.8412	0.8580	172.3568	-30.1768
42	138.7000	193.0014	-0.4688	0.9021	178.4898	-39.7898
43	154.0900	187.7659	-1.7558	1.0328	198.8446	-44.7546
44	151.2600	183.7500	-2.3660	0.9142	170.0417	-18.7818
45	234.6600	183.6766	-1.7470	1.1604	210.4753	24.1848
46	157.4600	181.2834	-1.9215	0.8944	162.7140	-5.2540
47	242.1400	180.0453	-1.7370	1.3048	234.0340	8.1060

48	204.4500	174.1965	-2.8472	1.4507	258.6785	-54.2285
49	118.6900	169.9340	-3.2293	0.7489	128.3255	-9.6355
50	180.3200	168.1519	-2.8386	1.0026	167.1299	13.1901
51	146.2000	167.1335	-2.3471	0.8039	132.8984	13.3016
52	151.7000	164.6564	-2.3822	0.9272	152.7947	-1.0947
53	155.1000	164.3086	-1.8329	0.8580	139.2321	15.8679
54	141.2000	161.8203	-2.0099	0.9021	146.5746	-5.3746
55	177.7800	161.1663	-1.6438	1.0328	165.0496	12.7304
56	146.9900	159.6623	-1.6060	0.9142	145.8280	1.1620
57	166.1000	156.4157	-2.0490	1.1604	183.4061	-17.3061
58	136.7200	154.2016	-2.0936	0.8944	138.0624	-1.3424
59	239.2500	155.5457	-1.1654	1.3048	198.4728	40.7772
60	193.0500	152.0362	-1.7983	1.4507	223.9653	-30.9153

SUM OF RESIDUALS= -69.7747 AVERAGE RESIDUALS= -1.1629

VARIANCE= 754.4188 STANDARD DEVIATION= 27.4667

MEAN ABSOLUTE DEVIATION= 20.9185

NUMBERS OF RESIDUALS EXCEEDING TWO STANDARD DEVIATIONS= 2

OUTPUT OF FORECASTING PHASE FOR SANITARY WARES

LENGTH OF THE SEASON IS 12 PERIODS FORECAST LEAD TIME IS 1 PERIODS

PERIOD	PERMANENT COMPONENT	TREND	SEASONAL FACTOR	FORECAST
61	150.2379	-1.7983	0.7489	112.5149
62	148.4395	-1.7983	1.0026	148.8181
63	146.6412	-1.7983	0.8039	117.8875
64	144.8429	-1.7983	0.9272	134.3026
65	143.0446	-1.7983	0.8580	122.7330
66	141.2462	-1.7983	0.9021	127.4229
67	139.4479	-1.7983	1.0328	144.0196
68	137.6496	-1.7983	0.9142	125.8328
69	135.8513	-1.7983	1.1604	157.6397
70	134.0529	-1.7983	0.8944	119.8941
71	132.2546	-1.7983	1.3048	172.5677
72	130.4563	-1.7983	1.4507	189.2578

FORECAST FOR THE NEXT 12 MONTHS= 1672.8910

WINTERS' METHOD FOR FORECASTING A SEASONAL TIME SERIES FOR INSULATOR AND BRICKS

INITIAL VALUES OF THE PERMANENT, TREND AND SEASON AL COMPONENTS TO BE ESTIMATED FROM THE DATA.
THE FIRST 60 PERIODS OF DATA WHICH CORRESPONDS TO, 5 SEASONS WILL BE USED

INITIAL PERMANENT COMPONENT= 42.9803
INITIAL TREND COMPONENT= 0.4356
INITIAL SEASONAL FACTOR FOR PERIOD 1 = 0.6342
INITIAL SEASONAL FACTOR FOR PERIOD 2 = 0.6905
INITIAL SEASONAL FACTOR FOR PERIOD 3 = 0.5797
INITIAL SEASONAL FACTOR FOR PERIOD 4 = 1.0388
INITIAL SEASONAL FACTOR FOR PERIOD 5 = 0.5845
INITIAL SEASONAL FACTOR FOR PERIOD 6 = 1.0375
INITIAL SEASONAL FACTOR FOR PERIOD 7 = 1.1773
INITIAL SEASONAL FACTOR FOR PERIOD 8 = 0.7705
INITIAL SEASONAL FACTOR FOR PERIOD 9 = 1.2121
INITIAL SEASONAL FACTOR FOR PERIOD 10 = 0.9484
INITIAL SEASONAL FACTOR FOR PERIOD 11 = 1.4093
INITIAL SEASONAL FACTOR FOR PERIOD 12 = 1.9173

THE OPTIMUM SMOOTHING CONSTANTS ARE

ALPHA = 0.0200 BETA = 0.0800 GAMMA = 0.0000

OUTPUT OF THE INITIALIZATION PHASE FOR INSULATOR & BRICKS

PERIOD	OBSERVATION	PERMANENT COMPONENT	TREND	SEASONAL FACTOR	FITTED MODEL	RESIDUAL
1	0.1700	42.5530	0.3666	0.6342	0.0000	0.0000
2	44.3200	43.3449	0.4006	0.6905	29.6359	14.6841
3	20.8700	43.5907	0.3882	0.5797	25.3580	-4.4880
4	52.2500	44.1054	0.3984	1.0388	45.6839	6.5661
5	0.0100	43.6140	0.3272	0.5845	26.0141	-26.0041
6	22.5900	43.4978	0.2917	1.0375	45.5882	-22.9982
7	66.6500	44.0460	0.3122	1.1773	51.5544	15.0956
8	63.4200	45.1173	0.3730	0.7705	34.1760	29.2440
9	63.9300	45.6354	0.3846	1.2121	55.1367	8.7933
10	37.1700	45.8834	0.3736	0.9484	43.6437	-6.4737
11	86.0100	46.5525	0.3973	1.4093	65.1922	20.8178
12	89.7400	46.9469	0.3970	1.9173	90.0188	-0.2788
13	22.9700	47.1215	0.3792	0.6342	30.0237	-7.0537
14	2.0200	46.6092	0.3079	0.6905	32.7991	-30.7791
15	0.0200	45.9795	0.2329	0.5797	27.1965	-27.1765
16	3.2200	45.3502	0.1639	1.0388	48.0040	-44.7840
17	20.7200	45.3127	0.1478	0.5845	26.6047	-5.8847
18	21.8500	44.9726	0.1088	1.0375	47.1646	-25.3146
19	31.2300	44.7103	0.0791	1.1773	53.0753	-21.8453

20	17.9500	44.3595	0.0447	0.7705	34.5082	-16.5582
21	66.5300	44.6140	0.0615	1.2121	53.8203	12.7097
22	59.8800	45.0448	0.0910	0.9484	42.3686	17.5114
23	88.6400	45.4910	0.1194	1.4093	63.6120	25.0280
24	94.8200	45.6873	0.1256	1.9173	87.4507	7.3693
25	18.4100	45.4772	0.0987	0.6342	29.0528	-10.6428
26	19.6700	45.2342	0.0714	0.6905	31.4701	-11.8001
27	26.7100	45.3211	0.0726	0.5797	26.2623	0.4477
28	89.2300	46.2038	0.1375	1.0388	47.1535	42.0765
29	22.1600	46.1726	0.1240	0.5845	27.0882	-4.9282
30	98.8300	47.2759	0.2023	1.0375	48.0320	50.7980
31	76.1000	47.8214	0.2298	1.1773	55.8971	20.2029
32	46.0500	48.2855	0.2485	0.7705	37.0212	9.0288
33	57.4400	48.5111	0.2467	1.2121	58.8258	-1.3858
34	14.6400	48.0914	0.1934	0.9484	46.2401	-31.6001
35	43.8100	47.9408	0.1658	1.4093	68.0499	-24.2399
36	97.2900	48.1593	0.1701	1.9173	92.2368	5.0532
37	18.7400	47.9538	0.1400	0.6342	30.6487	-11.9087
38	43.3700	48.3882	0.1636	0.6905	33.2087	10.1613
39	30.2300	48.6237	0.1693	0.5797	28.1440	2.0860
40	40.0600	48.5885	0.1530	1.0388	50.6847	-10.6246
41	22.4300	48.5340	0.1364	0.5845	28.4912	-6.0612
42	28.6300	48.2489	0.1026	1.0375	50.4947	-21.8647
43	36.3000	48.0012	0.0746	1.1773	56.9254	-20.6254
44	26.0100	47.7895	0.0517	0.7705	37.0402	-11.0302
45	12.9000	47.0972	-0.0078	1.2121	57.9860	-45.0861
46	57.6000	47.3623	0.0140	0.9484	44.6579	12.9421
47	18.4600	46.6908	-0.0408	1.4093	66.7697	-48.3097
48	94.5900	46.7037	-0.0365	1.9173	89.4439	5.1460
49	96.3200	48.7715	0.1318	0.6342	29.5945	66.7255
50	42.1600	49.1464	0.1513	0.6905	33.7676	8.3924
51	62.8600	50.4806	0.2459	0.5797	28.5764	34.2836
52	60.2200	50.8714	0.2575	1.0388	52.6930	7.5270
53	80.3500	52.8555	0.3956	0.5845	29.8868	50.4632
54	83.5500	53.7967	0.4393	1.0375	55.2471	28.3029
55	66.7300	54.2849	0.4432	1.1773	63.8533	2.8767
56	22.6500	54.2214	0.4027	0.7705	42.1654	-19.5154
57	92.2000	55.0530	0.4370	1.2121	66.2073	25.9927
58	32.1200	55.0575	0.4024	0.9484	52.6247	-20.5047
59	102.2500	55.8018	0.4297	1.4093	78.1622	24.0878
60	56.6500	55.6978	0.3870	1.9173	107.8149	-51.1649

SUM OF RESIDUALS= -17.0400 AVERAGE RESIDUALS= -0.2840

VARIANCE= 609.0413 STANDARD DEVIATION= 24.6788

MEAN ABSOLUTE DEVIATION= 19.2557

NUMBERS OF RESIDUALS EXCEEDING TWO STANDARD DEVIATIONS= 4

OUTPUT OF FORECASTING PHASE FOR INSULATOR & BRICKS

LENGTH OF THE SEASON IS 12 PERIODS

FORECAST LEAD TIME IS 1 PERIOD

PERIOD	PERMANENT COMPONENT	TREND	SEASONAL FACTOR	FORECAST
61	56.0848	0.3870	0.6342	35.5668
62	56.4718	0.3870	0.6905	38.9936
63	56.8588	0.3870	0.5797	32.9594
64	57.2459	0.3870	1.0388	59.4652
65	57.6329	0.3870	0.5845	33.6886
66	58.0199	0.3870	1.0375	60.1947
67	58.4069	0.3870	1.1773	68.7638
68	58.7940	0.3870	0.7705	45.2980
69	59.1810	0.3870	1.2121	71.7305
70	59.5680	0.3870	0.9484	56.4921
71	59.9550	0.3870	1.4093	84.4974
72	60.3421	0.3870	1.9173	115.6963

FORECAST FOR THE NEXT 12 MONTHS= 703.3466

WINTERS' METHOD FOR FORECASTING A SEASONAL TIME SERIES FOR TILES

INITIAL VALUES OF THE PERMANENT, TREND AND SEASONAL COMPONENTS TO BE ESTIMATED FROM THE DATA.
THE FIRST 60 PERIODS OF DATA WHICH CORRESPOND TO, 5 SEASONS WILL BE USED

INITIAL PERMANENT COMPONENT= 6.69240

INITIAL TREND COMPONENT= 1.1984

INITIAL SEASONAL FACTOR FOR PERIOD 1 = 0.8979
INITIAL SEASONAL FACTOR FOR PERIOD 2 = 1.0001
INITIAL SEASONAL FACTOR FOR PERIOD 3 = 0.8856
INITIAL SEASONAL FACTOR FOR PERIOD 4 = 0.9322
INITIAL SEASONAL FACTOR FOR PERIOD 5 = 0.8630
INITIAL SEASONAL FACTOR FOR PERIOD 6 = 0.9513
INITIAL SEASONAL FACTOR FOR PERIOD 7 = 1.0178
INITIAL SEASONAL FACTOR FOR PERIOD 8 = 0.9798
INITIAL SEASONAL FACTOR FOR PERIOD 9 = 1.0219
INITIAL SEASONAL FACTOR FOR PERIOD 10 = 0.7837
INITIAL SEASONAL FACTOR FOR PERIOD 11 = 1.0728
INITIAL SEASONAL FACTOR FOR PERIOD 12 = 1.5938

THE OPTIMUM SMOOTHING CONSTANTS ARE

ALPHA = 0.4900 BETA = 0.0000 GAMMA = 0.0000

OUTPUT OF THE INITIALIZATION PHASE FOR TILES

PERIOD	OBSERVATION	PERMANENT COMPONENT	TREND	SEASONAL FACTOR	FITTED MODEL	RESIDUAL
1	11.4300	10.2617	1.1984	0.8979	0.0000	0.0000
2	7.5000	9.5191	1.1984	1.0001	11.4617	-3.9617
3	8.4300	10.1299	1.1984	0.8856	9.4919	-1.0619
4	13.2600	12.7475	1.1984	0.9322	10.5601	2.6999
5	10.3200	12.9719	1.1984	0.8630	12.0354	-1.7154
6	16.0300	15.4837	1.1984	0.9513	13.4800	2.5500
7	15.7000	16.0664	1.1984	1.0178	16.9787	-1.2787
8	16.1100	16.8613	1.1984	0.9798	16.9169	-0.8069
9	9.5800	13.8042	1.1984	1.0219	18.4545	-8.8745
10	9.2100	13.4099	1.1984	0.7837	11.7572	-2.5472
11	15.6400	14.5935	1.1984	1.0728	15.6722	-0.0322
12	33.3800	18.3164	1.1984	1.5938	25.1687	8.2113
13	9.3200	15.0385	1.1984	0.8979	17.5228	-8.2028
14	16.2900	16.2617	1.1984	1.0001	16.2391	0.0509
15	10.4500	14.6863	1.1984	0.8856	15.4635	-5.0135
16	16.1800	16.6061	1.1984	0.9322	14.8075	1.3725
17	16.5800	18.4941	1.1984	0.8630	15.3654	1.2146
18	13.3100	16.8990	1.1984	0.9513	18.7332	-5.4232
19	28.7300	23.0613	1.1984	1.0178	18.4192	10.3108
20	29.8100	27.2797	1.1984	0.9798	23.7708	6.0392
21	46.2500	36.7014	1.1984	1.0219	29.1008	17.1492
22	38.0300	43.1073	1.1984	0.7837	29.7013	8.3287
23	34.3700	38.2938	1.1984	1.0728	47.5327	-13.1627
24	81.7400	45.2716	1.1984	1.5938	62.9416	18.7984
25	50.2100	51.0994	1.1984	0.8979	41.7266	8.4834
26	92.2500	71.8679	1.1984	1.0001	52.3053	39.9447
27	63.5500	72.4239	1.1984	0.8856	64.7110	-1.1610
28	64.8900	71.6564	1.1984	0.9322	68.6298	-3.7398
29	56.3400	69.1447	1.1984	0.8630	62.8745	-6.5345
30	66.0900	69.9172	1.1984	0.9513	66.9166	-0.8266
31	61.9900	66.1133	1.1984	1.0178	72.3804	-10.3904
32	68.5900	68.6292	1.1984	0.9798	65.9552	2.6348
33	69.3900	68.8856	1.1984	1.0219	71.3544	-1.9644
34	63.8700	75.6778	1.1984	0.7837	54.9234	8.9466
35	95.1100	82.6468	1.1984	1.0728	82.4755	12.6345
36	98.0600	72.9092	1.1984	1.5938	133.6303	-35.5703
37	71.6500	76.8944	1.1984	0.8979	66.5430	5.1070
38	85.4300	81.6820	1.1984	1.0001	78.1040	7.3260
39	86.2600	89.9938	1.1984	0.8856	73.4028	12.8572
40	80.1800	88.6542	1.1984	0.9322	85.0082	-4.8282
41	76.0900	89.0272	1.1984	0.8630	77.5437	-1.4537
42	76.9200	85.6357	1.1984	0.9513	85.8307	-8.9107
43	79.5400	82.5789	1.1984	1.0178	88.3784	-8.8384
44	75.0000	80.2322	1.1984	0.9798	82.0891	-7.0891
45	86.5600	83.0364	1.1984	1.0219	83.2111	3.3489
46	60.3200	80.6751	1.1984	0.7837	66.0132	-5.6932
47	85.1200	80.6326	1.1984	1.0728	87.8368	-2.7168

48	97.4700	71.7006	1.1984	1.5938	130.4202	-32.9502
49	44.9100	61.6859	1.1984	0.8979	65.4578	-20.5478
50	53.1900	58.1303	1.1984	1.0001	62.8933	-9.7033
51	66.6300	67.1218	1.1984	0.8856	52.5444	14.0856
52	52.1600	62.2609	1.1984	0.9322	63.6872	-11.5272
53	70.0500	72.1372	1.1984	0.8630	54.7660	15.2840
54	78.8900	78.0366	1.1984	0.9513	69.7634	9.1266
55	79.8800	78.8671	1.1984	1.0178	80.6441	-0.7641
56	71.3900	76.5339	1.1984	0.9798	78.4520	-7.0620
57	77.0700	76.5997	1.1984	1.0219	79.4319	-2.3619
58	48.0900	69.7455	1.1984	0.7837	60.9688	-12.8788
59	95.1000	79.6167	1.1984	1.0728	76.1111	18.9889
60	119.4800	77.9493	1.1984	1.5938	128.8010	-9.3210

SUM OF RESIDUALS= -15.5324 AVERAGE RESIDUALS= -0.2589

VARIANCE= 137.9897 STANDARD DEVIATION= 11.7469

MEAN ABSOLUTE DEVIATION= 8.2401

NUMBERS OF RESIDUALS EXCEEDING TWO STANDARD DEVIATIONS= 3

OUTPUT OF FORECASTING PHASE FOR TILES

LENGTH OF THE SEASON IS 12 PERIODS

FORECAST LEAD TIME IS 1 PERIOD

PERIOD	PERMANENT COMPONENT	TREND	SEASONAL FACTOR	FORECAST
61	79.1477	1.1984	0.8979	71.0687
62	80.3460	1.1984	1.0001	80.3576
63	81.5444	1.1984	0.8856	72.2196
64	82.7427	1.1984	0.9322	77.1318
65	83.9411	1.1984	0.8630	72.4420
66	85.1395	1.1984	0.9513	80.9923
67	86.3378	1.1984	1.0178	87.8733
68	87.5362	1.1984	0.9798	85.7722
69	88.7345	1.1984	1.0219	90.6748
70	89.9329	1.1984	0.7837	70.4787
71	91.1312	1.1984	1.0728	97.7689
72	92.3296	1.1984	1.5938	147.1526

FORECAST FOR THE NEXT 12 MONTHS= 1033.9320

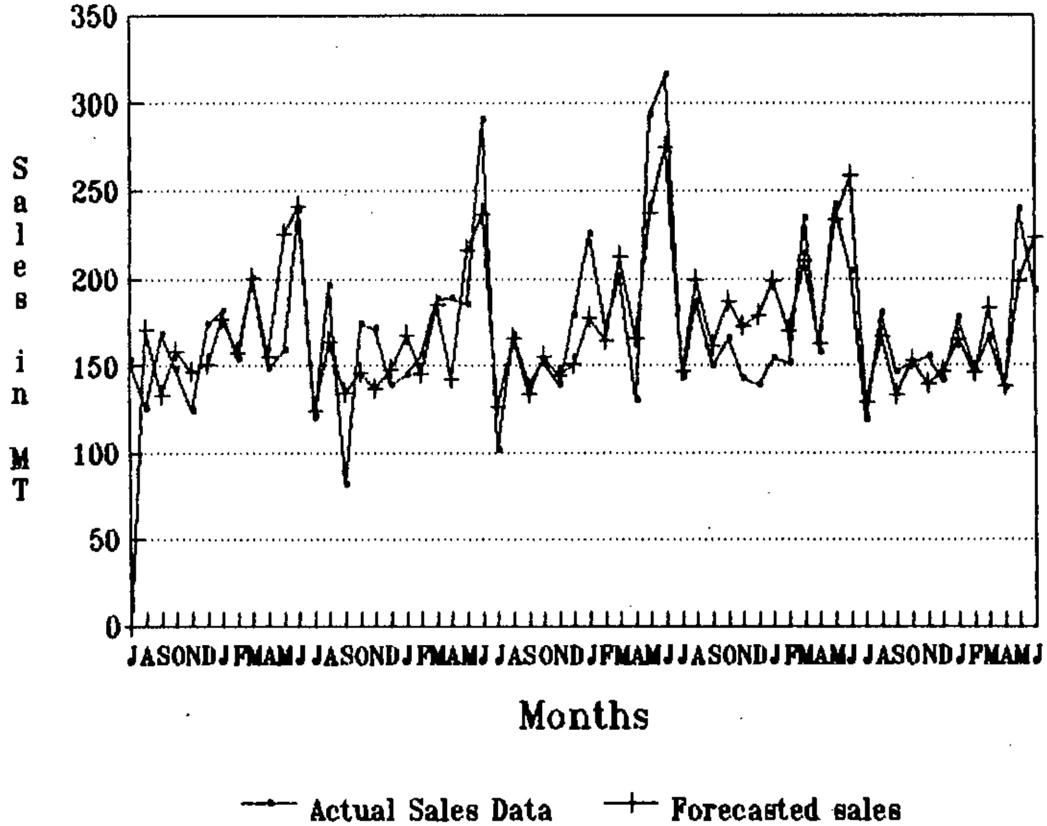

Fig. 7.7. Actual data vs. forecasted value for sanitary wares.

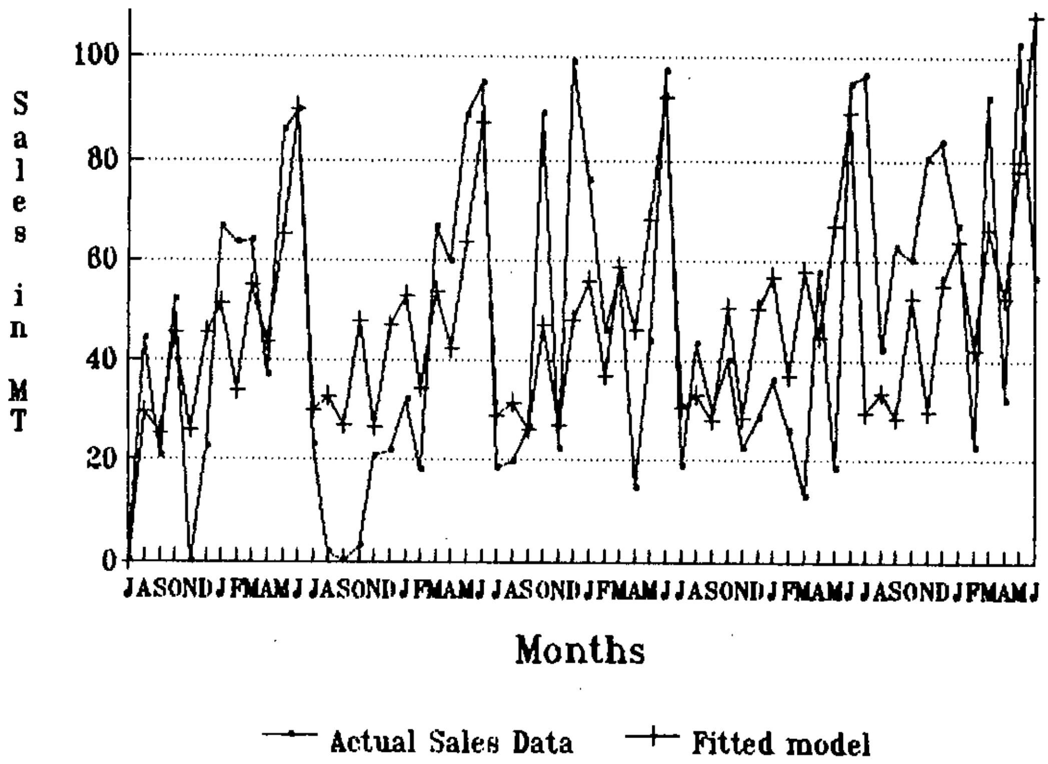

Fig. 7.8. Actual data vs. forecasted value for insulator & bricks.

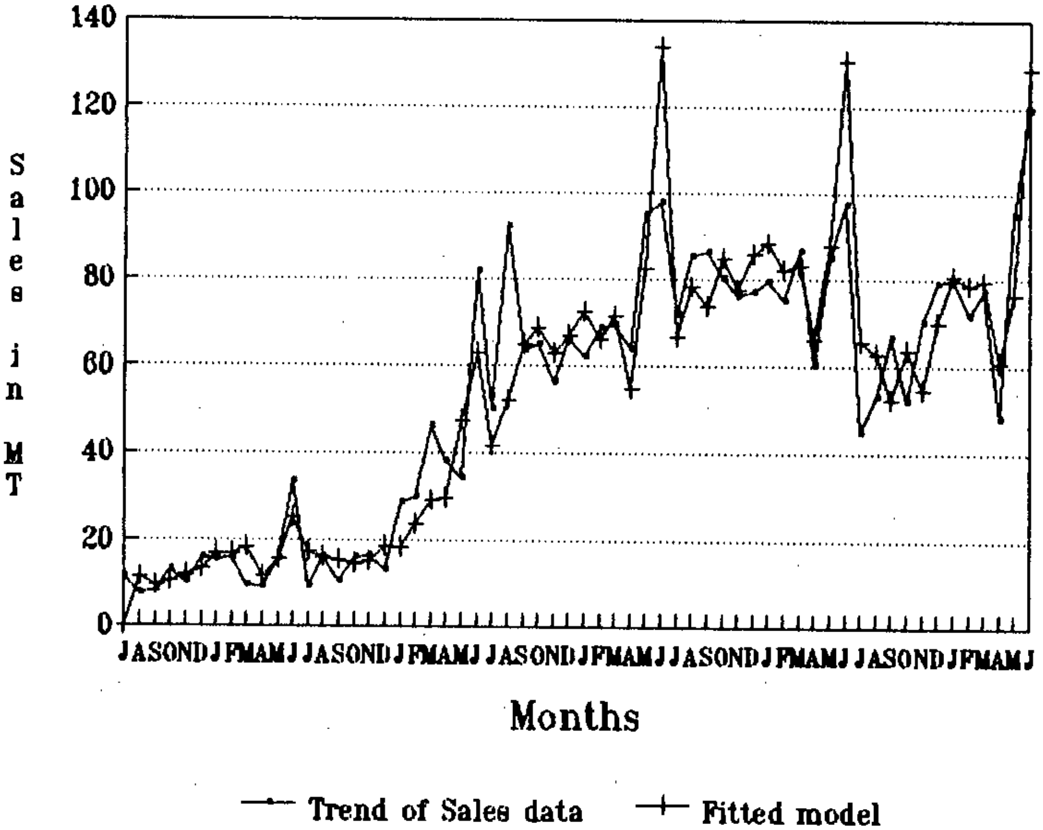

Fig. 7.9. Actual data vs. forecasted value for tiles.

Figures 7.7, 7.8 and 7.9 shows the actual sales data along with the values of the fitted model and forecasted values for the periods of the planning horizon.

7.5 ANALYSIS OF THE FORECASTING RESULTS

A good forecasting system reduces uncertainty but does not eliminate it. Forecasting errors are inevitable and it is very unusual when forecast and actual demand are exactly the same. Forecast error sometimes results from an inability to accurately assess the underlying components of demand and sometimes from random causes outside a firm's control. In order to enable the user to make intelligent decisions the proposed forecasting system provide various measure of forecast error.

The first measure is the sum of residuals which is also called bias. If a forecast is always lower or higher than the actual demand its value gets larger and larger indicating some systematic deficiency in the forecasting approach. For the case under consideration, this value for tiles and insulator is very small but for sanitary wares it is relatively higher. However all the values indicates good system performance.

The second measure is the mean absolute deviation (MAD) and standard deviation which measure the dispersion of forecast error. If standard deviation or MAD is small the forecast is typically close to actual demand. Comparing the forecasts of three families the forecast of tiles indicate a better performance followed by insulator and sanitary wares. None of the values however indicates any alarming situations. The number of residuals exceeding two standard deviation is 2 for sanitary wares, 3 for tiles and 4 for insulator. As the standard deviation of tiles is very small these three residuals does not indicate any inaccuracy. But for insulator despite its relatively high standard deviation 4 residuals exceeded the two standard deviation indicating the relatively poor performance compared to tiles and sanitary wares. This can also be concluded from the figure of the actual sales and the fitted model for insulator and bricks. This is due to the fact that the sales of insulator and bricks is an erratic one because of its limited number of customers and does not fit appropriately to any definite pattern.

Another measure of forecasting systems ability to monitor forecasting performance is called "tracking signal" which is defined as follows:

Tracking signal = Sum of residuals /MAD

If the value of the tracking signal falls outside the limits then the system calls for an attention of the planner.

The limits on the size of the tracking signal are commonly set anywhere from ±4 to ±6. Tight limits recognize most real changes but will also call attention for many readings where only random fluctuations have occurred. Loose limits are more likely to miss real changes or take longer to recognize them but will seldom give false alarm and calls for attention due to random fluctuations [15]. Plossl [17] sets the acceptable maxima for the tracking signal between 4 and 8 and recommended that a tracking signal of 5 might be used for high value items to trigger an early review of forecast. For low value items a fairly high value of 7 and 8 can be used.

For the present case as all the items sales value is higher (per ton selling price) so we can set the limit at ± 4. Then computing the value of tracking signal for sanitary wares, insulator and tiles we get the 3.33, 0.88 and 1.88 respectively, which are well within the acceptable range thereby indicating the system effectiveness.

7.6 MINIMIZATION OF THE EFFECT OF FORECASTING ERROR

As already mentioned, the pattern of consumer demand is not easily predictable rather there exists a degree of uncertainty. Thus there would always remain some errors in forecast. To minimize the effect of forecast error on production planning and inventory control decisions it is customary to hold safety stocks. The safety stock is calculated using the following formula .

$$B = Z * MAD$$

Where, Z = Number of standard deviation from the mean needed to implement the cycle service level.

MAD = Mean Absolute Deviation of the forecasted system.

Some researchers however prefer to use standard deviation instead of MAD. The cycle service level is defined as the desired probability of not running out of stock in any one inventory cycle.

The higher the value of Z and MAD the higher will be the value of B. If Z is 0 there is no safety stocks. The better the job of forecasting demand the smaller will be the value of MAD and thereby B which means that lower safety stock are one reward of accurate forecasts. Taking an example if MAD is given to be 15 the required safety stock for a 90% cycle service level is = 1.28 * 15 = 19.2 (Z = 1.28 is the value of corresponding to the area of 0.90 obtained from the standard normal table).

The value of MAD obtained from the forecasting system is thus utilized to specify the safety stock to minimize the demand uncertainties.

CHAPTER EIGHT

MODEL SOLUTION

8.1 INTRODUCTION

In this chapter the solution approach to solve the developed mathematical model formulated in Chapter 4, the computational experience and the measures taken to overcome these difficulties would be discussed. The validity of the model in actual work setting is also shown.

8.2 SOLUTION APPROACH

The mathematical model is a mixed integer type. The model incorporates five types of decision variables four of which are continuous and the remaining one is binary. The parameters of the model are the total number of product families, total number of raw materials and total number of time periods in the entire planning horizon. A total of 29 raw materials are now being used in the production processes of the three product families. At present the planning horizon of one year broken down into monthly periods is used by the enterprise. For the present case of solving the model the planning horizon is also taken to be one year. A horizon of less than one year would not be justified as demand seasonalities exist for all the product families and a full seasonal cycle of one year should be accommodated in the planning process to reduce the error in forecasting. A horizon of more than one year was also not considered as it had been an established practice of planning in the organization. Moreover all the cost figures are adjusted for one fiscal year. However the system has the flexibility to accommodate any number of periods as planning horizon might change. The planning period is taken to be one month. Planning period less than one month is also not practically feasible as the reports on sales are available by monthly basis.

With these parameters the number of variables, constraints and bounds stands at the following numbers:

VARIABLES:

1. Type 1 variable (x_{it})	=	N * T = 3 * 12	= 36
2. Type 2 variable (i_{it})	=	N * T = 3 * 12	= 36
3. Type 3 variable (o_t)	=	T * 1 = 12 * 1	= 12
4. Type 4 variable (q_{jt})	=	J * T = 29 * 12	= 348
5. Type 5 variable (r_{jt})	=	J * T = 29 * 12	= 348
6. Type 6 variable (y_{jt})	=	J * T = 29 * 12	= 348
		Total	= 1128

CONSTRAINTS:

1. Demand fulfillment constraint	=	N * T = 3 * 12 =	36
2. Labor hour requirement constraint	=	T * 1 = 12 * 1 =	12
3. Constraint for fulfillment of raw material requirement	=	J * T = 29 * 12 =	348
4. Constraint for total storage capacity of raw materials	=	T * 1 = 12 * 1 =	12
5. Constraint for maximum ordering			

quantity of raw materials	=	J * T	= 29 * 12	= 348
6. Constraint for maximum storage capacity of finished goods	=	T * 1	= 12 * 1	= 12

Total = 768

BOUNDS:

1. Bound for overtime labor hour	= T * 1	= 12 * 1	= 12
2. Bound for safety stock of finished goods	= N * T	= 3 * 12	= 36
3. Bound for maximum machine capacity	= N * T	= 3 * 12	= 36

Total = 84

To solve this MIP problem a simplex algorithm coded in FORTRAN would be used.

8.3 COMPUTATIONAL DIFFICULTIES

One of the drawbacks of the selected algorithm was that it treats the variable bounds as constraints. Thus in the present case the number of variables and constraints stands at 1128 and 852 respectively. The algorithm requires to specify five arrays. For M equations and N variables including slack surplus, and artificial variables, the required array sizes are B(M+1), C(N+1), CODE (M+1), A(M+1, N+1) and XB(N+1) [25]. For a full scale problem the equation number(M) stand at 852 and variable numbers(N) including slack, surplus and artificial stands at 2064. Thus for solving the problem array sizes of B(853), C(2065), CODE(853), A(853,2065) and XB(2065) would be required. The model was intended to run on an IBM compatible 386 Microcomputer having a 4 MB RAM . The FORTRAN Compiler that was used for writing the algorithm allows a maximum RAM space of 512 KB. With this space a maximum of 175 equations and 398 variables including slack, surplus and artificial can be used. This means that the model can be run considering 3 product families and only 5 raw materials and 7 planning periods. The model was then run at this small scale. A CPU time of 27 minute was required to solve this size of the problem. After successfully running this small scale problem it was decided that the full scale problem is to be run. For this the RISC6000 series super microcomputer at the BUET Computer Center was used. At this facility a full scale problem considering three product families, one year planning horizon and 18 raw materials covering almost the entire requirement of raw material composition of the product families was run. But the program 'crushed' by blacking out the screen after running for 15 minutes. Then it was decided that the model would be run on a smaller scale. To represent the actual planning process it was not justified to reduce the number of product families and the planning horizon. Besides the raw material number is the highest contributing parameter in increasing the problem size. So it was decided to reduce the number of raw materials to be planned.

In order to run the model in small scale the possibility of using a software package instead of the simplex algorithm was considered. There were three software packages available in the department. They were QSOM, MINOS and LINDO. All these packages were for demonstration purpose. As the QSOM is more user friendly than the other two and the author has previous experience on working with this package, it was selected for running the model. To justify the use of such package a very small problem was taken and solved by both the simplex algorithm and the QSOM. The CPU time taken by QSOM was appeared to be less than the simplex algorithm. This could also be verified by noting that the simplex algorithm takes 27 min of CPU time for a model considering 3 product families, 5 raw materials and 7 month planning horizon whereas the time taken by QSOM for a model of 3 product families, 5 raw materials and 12 month planning horizon is 23 minutes. Another advantage of this package is that it treats the variable bounds separately and do not treat them as constraints.

In order to solve the problem using QSOM an MPS file needs to be generated. For this reason the DSS program was modified to generate the MPS file in an interactive mode. As already mentioned the available QSOM package is for demonstration purpose, it can handle only small number of variables and constraints. The available QSOM package can handle at most 300 variable and 200 constraints. So the problem size needed to be scaled down to suit the capacity of the package. It was, thereby, necessary to reduce the number of raw materials to be planned. Incase of 6 raw materials selected for planning while taking the three product families and one year planning horizon the number of variables and constraints stands at 300 and 216 respectively.

Thus although total number of variables are within the range of the package the constraint number exceeds the capacity. Therefore it was decided to select five raw material for planning. The selection procedure of these five raw materials are given below:

The following nine raw materials constitute a range of 61.85 to 100 percentage of total raw materials composition for all the families.

They are as follows:

No.	Name of raw material	No.	Name of raw material
1.	Bijoypur clay (Grade-I)	2.	Bijoypur clay (Grade-II)
3.	Feldspar (Local)	4.	Red clay.
5.	China clay (hp).	6.	China clay (body)
7.	Ball clay (White)	8.	Ball clay (black)
9.	Feldspar (foreign)		

These nine raw materials constitute the following percentage (excluding the broken body) of total raw materials for the different product sub-families:

Name of sub family	%	Name of sub family	%
Sanitary wares	95.26	Wall tiles	68.99
Floor tiles	100.00	Facing tiles	97.00
Insulator	97.09	Bricks	61.85

Thus consideration of these nine raw materials would be adequate for the planning process. Out of these nine raw materials the first four raw materials (1-4) has very little justification to be included in the planning as they are not regarded as the critical items. This is because the bijoypur clay of both grade are collected form the own mine of BISF and no ordering cost is involved in their procurement. The local feldspar is obtained in a similar manner from the Chatak Cement Factory a corporate enterprise of BCIC. The red clay is also readily available and does not require any processing of tenders. Therefore, the remaining five items could be considered as tenderable and critical items. These are procured through open tendering system involving ordering costs. Thus the planning of these materials are justifiable. The following table gives the name of the selected raw materials:

No.	Name of raw material	No.	Name of raw material
1.	China clay (body)	2.	Ball clay (white)
3.	China Clay (hp)	4.	Feldspar (foreign)
5.	Ball clay (black)		

Table 8.1 : The selected raw materials for planning.

The dropped out raw materials constitute a very small percentage of the entire production family and ignoring them in the raw material inventory policy for the present work would have little effect on the solution.

After selecting the raw materials the problem was solved as an LP problem as the available package has no facility for solving the model as a mixed integer. It was thought that the solution would be generated as such that they decision variable (y) would assume a value of either close to '0' indicating a policy of not ordering or close to '1' indicating a policy of placing an order. But in the solution it was found that although ordering quantities are specified for different periods all the decision variables for ordering quantities for all periods either assume a value of zero or very close to zero. To overcome this problem an alternative approach was taken. It was decided to make a fixed period order i.e. to force some of the decision variables to assume a value of unity and then compare the value of the objective function. This feature would allow the user to specify the number of months in which the order is to be placed. The system then specifies the binary variables corresponding to the months specified to assume a value of unity and the remaining binary variables are set to zero. The model is then run for different ordering periods and their objective function values are compared. The ordering periods that give the lowest objective function value (minimized objective function) is selected to be the optimum ordering policy. An assumption in this regard was made that when an order is placed all the raw materials are ordered at a time. From practical viewpoint this has the advantage of reduced ordering cost because of the processing of all the order at the same time. However the system can be easily modified to accommodate the variation of ordering time if required. The result of various alternative ordering periods is presented in the following table:

Ordering periods in months.	One Month	Two Months	Three Months	Four Months
The value of objective function in Taka	108469300	108280800	108260300	108299000

Table 8.2: Comparison of different alternatives of ordering policy.

From the table it is evident that if the order is placed equivalent to three months replenishment, the cost involvement would be the lowest. Thus it is selected to be the optimum ordering policy. The subsequent solutions of the results would be based on this policy. The ordering of raw materials equal to the five months replenishment is not to be considered . The storage of the raw materials for such a long period would deteriorate their quality .

8.4 MODEL VALIDATION

The production targets set by the model and the actual production quantities for the different time periods of the planning horizon were compared. The results obtained from the model with the updated sales data are presented. The sales data used for forecasting in the model were from July,1988 to June 1992. This section considers the planning after that period.

The overall production target set for the fiscal year 1992-93 by BISF was as follows:

Product family name	Total forecast by the system (MT)	Production target set by BISF (MT)
Sanitary wares	1672.89	2300
Insulator	703.34	700
Tiles	1033.93	1090

Table 8.3 : Total production target set by the model and total production target set by BISF.

The table above shows that the production target set by BISF for sanitary wares was unrealistic. This is because an inventory of 464.21 MT of goods was existing in the stores; moreover projected sales was not also very high. However the production targets of the other two items were very close to the forecasted value for the next year.

The production target set by the model and actual production by BISF for the month of July, 1992 was as follows:

Product family name	Production target set by the model	Actual production by BISF	Actual Sales
Sanitary wares	178.80	143.22	181.61
Insulator & bricks	0.0	91.90	107.96
Tiles	90.96	29.82	50.60

Table 8.4. Comparison of the model's solution with the actual value for period 1.

The target set by the model for the production of sanitary wares and tiles are consistent with the actual sales. The production target set by the model for insulator is zero. The sales demand of insulator is to be met from the stock in hand which is equal to 128 MT. This would reduce the inventory level of insulator.

With this updated sales data the forecasting was performed and new production plan was generated by only updating the stock in hand of raw materials and finished goods keeping all other input data same for the newly included planning period i.e. July, 1992. The targeted production level set by the model and actual production for the Month of August, 1992 is as follows:

Product family name	Production target set by the model	Actual production by BISF	Actual Sales
Sanitary wares	167.51	170.00	198.01
Insulator & bricks	21.92	19.09	22.39
Tiles	91.51	79.23	85.49

Table 8.5 : Comparison of the model's solution with the actual value for period 2.

With this updated sales data the forecasting is performed and new production plan was generated by only updating the stock in hand of raw materials and finished goods keeping all other input data same for the newly included planning period i.e. August, 1992. The targeted production level set by the model and actual production for the Month of September, 1992 is as follows:

Product family name	Production target set by the model	Actual production by BISF	Actual Sales
Sanitary wares	165.93	178.62	162.30
Insulator & bricks	20.44	31.33	30.34
Tiles	91.51	104.18	104.98

Table 8.6 : Comparison of the model's solution with the actual value for period 3.

With this updated sales data the forecasting is performed and new production plan was generated by only updating the stock in hand of raw materials and finished goods keeping all other input data same for the newly included planning period i.e. September, 1992. The targeted production level set by the model and actual production for the Month of October, 1992 is as follows:

Product family name	Production target set by the model	Actual production by BISF	Actual Sales
Sanitary wares	169.32	188.98	164.60
Insulator & bricks	58.21	25.69	25.66
Tiles	91.51	115.31	83.07

Table 8.7: Comparison of the model's solution with the actual value for period 4.

Comparing the solution given by the model and the actual production and sales it could be concluded that the model fairly compares with actual and the application of rolling horizon concept was justified.

The usefulness of such a system could be observed by comparing the total cost associated with production for the solution given by the model to that of actual production . As no other cost data is available for the comparison of the total cost associated with this level of production the total variable cost of production was considered. This cost component is also the highest contributing cost factor in the total objective function. Therefore considering only the variable cost of production the following figure for the four months of the planning horizon is obtained.

Family name	Total variable cost of production in Tk.	
	For targets set by the model	Actual production
Sanitary wares	18106322.96	18086664.12
Insulator & bricks	4168324.79	6963510.47
Tiles	8841568.59	7947711.14
Total cost	31116216.34	32997885.73

Table 8.8: Comparison of the total variable cost of production associated with the model's solution and to the actual production.

From the above comparison it is observed that while fulfilling the required customer demand a saving of Tk.1881669.39 in the variable cost of production in four months could be achieved if the model is applied and replanning current practice. However the effectiveness of the model solution can be further improved if all the input data for any new period are updated and included in the horizon. This would also need a guaranteed accuracy of the input data. The overall effectiveness of the model would be further improved and established after applying it for some future time periods.

CHAPTER NINE

RESULTS, ANALYSIS AND DISCUSSION

9.1 INTRODUCTION

In this chapter the results from the PPDSS are presented. The analysis of the results and the various sensitivity analyses are also presented.

9.2 OUTPUT AND RESULTS

9.2.1 OPTIMUM PRODUCT MIX

The optimum product mix for different product family at different time periods are given in the following table. Input data to the model were as presented in chapter six. As the organization under consideration is a state owned enterprise it has to incur the entire regular labor hour cost irrespective of production. Thus the management wants that at least entire regular workforce is utilized in production. For this reason the following solutions are obtained on this basis i.e. the labor hour requirement constraint (Constraint no. 2 in Chapter four) is assumed to be 'equal to' type instead of 'less than or equal to type'.

The production quantity for insulator and bricks for the first three months or periods is zero. The demand during this period would be fulfilled from the stock in hand of this product family.

Period	Sanitary wares	Insulator and bricks	Tiles
1	178.80	0.0	90.96
2	178.80	0.0	90.96
3	178.80	0.0	90.96
4	178.60	44.75	90.96
5	178.66	31.02	90.96
6	178.52	62.75	90.96
7	178.49	69.56	90.96
8	178.61	42.95	90.96
9	178.47	74.34	90.96
10	178.56	54.87	90.96
11	178.41	87.30	90.96
12	178.28	118.82	90.96

Table 9.1: Optimum product mix.

THE MINIMUM OBJECTIVE FUNCTION VALUE = Tk.108260300.00

ELAPSED CPU SECOND = 1424.49

The model could also be formulated as the maximization of profit contribution function. But then the model would have the tendency to give solution to utilize the maximum machine capacity. The excess goods thus produced would then increase the inventory level of the organization which is now burdened with this problem. Besides as the value of the actual sales of the finished goods cannot be estimated accurately, their incorporation in the model would not be a realistic one.

9.2.2 OPTIMUM INVENTORY POLICY FOR FINISHED GOODS.

The required inventory levels for different product families at different time periods are given in the table 9.2.

Period	Sanitary wares	Insulator and bricks	Tiles
1	11.25	92.4	7.11
2	14.88	53.5	8.04
3	11.79	20.6	7.22
4	13.43	5.95	19.60
5	12.27	3.37	38.17
6	12.74	6.01	48.23
7	14.02	6.87	51.39
8	12.58	4.53	56.65
9	15.76	7.17	57.02
10	23.93	5.65	77.59
11	29.85	8.45	70.85
12	18.93	11.57	14.71

Table 9.2: Optimum inventory policy for finished goods.

9.2.3 OPTIMUM RAW MATERIAL ORDERING QUANTITY

The values of ordering quantity of different raw materials at different time periods are given in the following table:

Period	China clay-body	China clay-HP	Feldspar-Foreign	Ball clay White	Ball clay Black
1	91.85	0.0	64.56	64.74	31.16
2	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0
4	173.16	36.63	82.08	64.69	98.7
5	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0
7	176.48	40.97	85.43	64.68	107.86
8	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0
10	181.57	47.63	90.58	64.65	121.9
11	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0

Table 9.3: Optimum ordering quantity for raw materials.

It is to be noted here that the ordering quantity of china clay-HP at period 1 is equal to zero. This explains that the stock in hand of this raw material is sufficient to meet the demand for the following three periods.

9.2.4 OPTIMUM OVERTIME POLICY

As per the solution no overtime labor hours are needed during any period of the planning horizon.

9.2.5 OPTIMUM RAW MATERIAL INVENTORY HOLDING POLICY

The quantity of the raw material that is to kept as inventory at different time periods are given in the following table:

Period	China Clay-body	China Clay-HP	Feldspar -Foreign	Ball Clay White	Ball Clay Black
1	109.1	16.12	48.31	43.16	48.31
2	54.55	8.06	24.15	21.58	24.15
3	0.0	0.0	0.0	0.0	0.0
4	115.54	24.55	54.82	43.13	66.07
5	58.86	13.70	28.51	21.56	36.04
6	0.0	0.0	0.0	0.0	0.0
7	117.15	26.66	56.45	43.12	70.52
8	59.65	14.74	29.31	21.55	38.24
9	0.0	0.0	0.0	0.0	0.0
10	123.25	34.64	62.62	43.09	87.35
11	0.0	18.73	32.40	21.54	46.66
12	0.0	0.0	0.0	0.0	0.0

Table 9.4 : Optimum raw material inventory policy.

9.3 SENSITIVITY ANALYSIS

The following sub sections present the model outputs and their analyses which are obtained by performing various sensitivity analyses. In analyzing the results of these sensitivity analyses comparison has been made with the results obtained in the previous section.

9.3.1 REDUCTION IN REGULAR AND OVERTIME LABOR HOUR

The following results are obtained from the model with the same overtime and regular labor hours reduced by 20% from the actual value.

The optimum product mix for the present analysis is given in Table A1 in

Appendix. The required inventory level of different product families for the present sensitivity analysis are shown in the Table A2 in appendix. The other values of the variables do not indicate any notable variation and thereby their outputs are omitted.

ANALYSIS:

THE MINIMUM OBJECTIVE FUNCTION VALUE IS = Tk.91934230.00

ELAPSED CPU SECOND = 1420.54

From the minimized objective function it is observed that total variable cost of production is reduced by an amount of 15%. In addition to these the organization can save the fixed cost associated with these regular labors that are now being over employed. The solution also shows that even with this 20% cut in regular labor and overtime labor hours no overtime labor hour is required to achieve the targeted production level. By further decreasing the labor hours the management can arrive at a point where the current demand level can be met with a much smaller workforce than that is presently being employed.

The total production quantity of sanitary wares is also almost 22% less than the value obtained in the previous section. This would result in less accumulation of inventory items which is one of the problems the organization is now facing.

In the inventory policy of finished goods a marked rise in inventory level for tiles was observed. The reason would be that the model would utilize all the available regular workforce at each time period . As the model would not utilize any excess overtime labor, the excess inventory is intended to meet the demand from this inventory at the end of the planning horizon when the production quantity of tiles is decreased due the excess production quantity of sanitary wares. However at the last period of the horizon the inventory level of tiles comes to a smaller value.

9.3.2 CONVERSION OF BALL MILL CAPACITY OF INSULATOR SECTION

This analysis is done with the view of increasing sales. There is an increased demand of tiles in the market and BISF now shares only 21% of the country's tiles market with the 100% utilization of the capacity of tiles section. The insulator section is operating at below its installed capacity; thus conversion of some of ball mill capacity in the insulator section to tiles section could be a profitable step.

Thus the present results are obtained by considering a 10% conversion of insulator section ball mill capacity to tiles section. The optimum product mix for the present analysis is shown in Table A3 of Appendix.

ANALYSIS:

MINIMIZED OBJECTIVE FUNCTION VALUE = Tk.108065600.00

ELAPSED CPU SECOND = 1442.99

Although the cost reduction is relatively small, but increased profit can be earned by selling the excess tiles produced. Management can also attempt the alternative to convert some facility of the sanitary wares section as this section is under utilized. The production quantities of sanitary wares are found to be less. This is because some regular labors are now being shared by the increased production quantities of the tiles section.

The value of the other variables do not show any marked variation from that obtained in section 9.2 and thereby their listings are omitted.

9.3.3 REDUCTION IN USAGE RATIO

The total usage ratio of finished goods can be reduced by taking steps to reducing the loss of recyclable and non-recyclable items in the production stage. This would increase the ball mill capacity at the mass body section. The following analysis are performed by decreasing the total usage ratio by 5% for all the product families. The optimum product mix for this analysis is shown in Table A3 in Appendix.

ANALYSIS:

THE MINIMIZED OBJECTIVE FUNCTION = Tk.108159200.00

ELAPSED CPU SECOND = 1378.85

Although the objective function value is reduced to a relatively small amount, the results indicate that this measure would ensure an increased utilization of tiles section the benefits of which are mentioned earlier. Other values of the solution do not show any marked variation.

9.3.4 CHANGING THE TYPE OF LABOR HOUR CONSTRAINT

The optimum product mix is obtained on the basis that the management wants to utilize at least all the regular labor hours. This concept of utilizing at least all the regular labor hour has caused a serious operational inefficiency of the enterprise. Because of this constraint there is a tendency of the model to give solution of the production quantity much higher than that is actually forecasted. This causes inventory accumulation to a alarming level. This can be observed from the stock in hand of different product families at the end of the fiscal year 1991-92 which has been given in chapter six. Besides, to utilize all regular labor hour management in some instances sets production targets much higher than the expected demand. This can be observed from noting the production target of sanitary wares for the fiscal year 1992-93. This was set to 2400 MT. whereas the sales forecast shows the demand to be 1673 MT.

To alleviate the situation the management can take a policy of not utilizing all the regular labor hour in actual production on the basis of which the labor hour requirement constraint was formulated in Chapter four. The model is then solved using this constraint as it was formulated in Chapter four. The optimum product mix for this analysis is given in Table A5 in appendix. The inventory level of different product items at different time period are given in Table A6 in Appendix. Similar to section 9.2 no overtime labor hour is required to achieve the targeted level of production. The raw material ordering quantity at different time periods of the planning horizon is given Table A7 in Appendix.

ANALYSIS:

MINIMIZED OBJECTIVE FUNCTION = Tk.75267000.00

ELAPSED CPU SECOND = 1106.799

From the results above it could be observed that a cost saving of over 30% can be achieved by adapting a strategy of not utilizing all the regular labor work force. The optimum production quantities are also less in this case compared to that obtained from using all the regular labor hours. As seen from the table of production quantities the production quantities in the first three months are zero. This is due to the substantial stock of the finished goods that were being carried over from the last fiscal year. The demand during the period is met from these stocks thereby reducing their levels to an acceptable position as evident from the inventory holding policy of the finished goods. In the current situation also no overtime labor hours are required, even all the regular labor force were not utilized in the solution. The ordering quantity of the raw materials in the first period of the planning horizon is appeared to be zero. This is because, there is no production in the first three periods thus there was no raw material consumption during the period.

By adapting this strategy of not using all the regular workforce the organization can achieve substantial gain in cost of production and profit. But this would need a comparative financial analysis in the cost involved in paying the regular workforce bills when not utilizing all of them in the production.

In the proposed situation where a factory is not producing for three periods or months, may appear to be abnormal. It has been mentioned that this strategy would be profitable. Management may evolve ways of having non-production activities. The management can also calculate the actual labor hour requirement to meet the current level of demand.

9.3.5 REDUCTION OF RAW MATERIAL INVENTORY HOLDING COST

The raw material inventory holding cost can be decreased by cutting the large overhead cost of the Material Procurement and Inventory Control (MPIC) department of the organization. This has been shown in chapter six. The present analysis shows that reduction of 5% of the total cost of holding inventory or raw materials could be achieved by reducing 10% of overhead of MPIC department. From the results obtained it is found that the objective function value is slightly reduced. Besides the saving of cost this reduction in cost would have a definite role in ordering policy. With gradual reduction in the cost of holding inventory and an increase in the cost of ordering raw materials a point would be reached where the optimum ordering policy would be changed to 4 months from 3 months of optimum ordering policy.

9.3.6 CHANGING THE TYPE OF DEMAND FULFILLMENT CONSTRAINT

The demand fulfillment constraint (Constraint 1) could be changed from the 'greater than equal to type' to 'equal to' would ensure that no excess production is required over the forecasted demand and required inventory level. This would prevent in formation of excess inventory. But the model solution gives infeasible solution. This is due to the nature of the labor hour fulfillment constraint. These two constraints were conflicting. The constraint 1 wants to produce quantity that is equal to the forecasted demand whereas the inventory demand, constraint 2 wants the production level equal to what could be attained by utilizing at least all the regular labor workforce. But as the regular labor workforce available is much higher than that required by present level of demand the production level specified by constraint 2 is much higher than that required by constraint 1 thereby forcing the solution to infeasibility.

9.3.7. CHANGING THE CONSTRAINT TYPE OF DEMAND FULFILLMENT AND LABOR HOUR REQUIREMENT

In order to overcome the infeasibility attained in the previous sub section the labor hour requirement constraint was changed to less than equal to constraint. With this modification the model was run. The solution obtained was exactly same as that obtained in the section 9.3.5. This means that changing only the labor hour requirement constraint type can reduce the overall cost of production.

CHAPTER TEN

CONCLUSION AND RECOMMENDATIONS FOR FUTURE WORK

10.1 CONCLUSION

In the present work it was revealed that operations management's present state of application at enterprise level is poor and weak. The enterprise lacks in applying the modern quantitative and analytical techniques of management science, industrial engineering and information systems. It was more evident and reaffirmed when found that not even a single computer was found in the enterprise. Thereby the information system in the enterprise remained at its early stage. Ironically the reality is that the decision makers of the enterprise are well convinced that they are operating the organization with effective operations management techniques and strategies. Thus a considerable amount of work would be needed to generate enthusiasm among the decision makers and motivate them in applying operations management techniques effectively and appropriately. The importance of an appropriate information system for an organization was recognized. In this regard the benefits from such a system and losses from not having such a system were identified. With the aim of improving the effectiveness of the production planning decision making and thereby the operational efficiency of the enterprise a model base decision support system namely Production Planning Decision Support System (PPDSS) were developed and its application in an industrial setting was done. The model base of the proposed DSS incorporated a forecasting model and a mixed integer programming model for aggregate production planning of the enterprise. A Winter's model for forecasting was used to forecast the sales. Based on this forecast and other input data the decision variables of the production planning model were generated which includes production quantities of the various product families, the inventory policy of the finished goods and raw materials, the overtime labor policy and the raw material ordering policy at different time periods of the entire planning horizon. The model was run using the data collected from the enterprise. The analysis of the results obtained by running the model and from the sensitivity analysis for various scenarios shows that :

1. The proposed system is more effective over the present system of production planning.
2. A considerable cost saving can be done by using the proposed system which would generate plan on rolling horizon basis.
3. A reduction in regular workforce would lead to substantial saving in operational cost of the enterprise.
4. By not utilizing all the regular workforce in production management can save substantial amount of production cost .
5. Conversion of some of the insulator section capacity to tiles section could also generate profits to the organization and would ensure greater utilization of capacity of all the product lines.

From the model's solution and its analysis it may be concluded that there is a potential scope of increasing the operational efficiency of an enterprise by effective implementation of such a system.

The developed system is flexible enough to accommodate any change in planning variables such as planning periods, product families and raw materials. This flexibility together with the feature of easy manipulation of various data would allow the managers to analyze various scenarios by performing the sensitivity analysis, some guidelines of which are given in chapter nine. The user of the system does not require any high degree of knowledge in industrial engineering of operations research techniques to run the system. This user friendliness of the system is expected to find increased acceptance amongst the top and middle management of the organization due to the less technical complexities associated to run the model. Careful analysis of the results obtained from different sensitivity analysis would be of immense help to the manager in decision making regarding the selection of different alternatives of cost saving or profit generation.

The system developed for the production planning system in BISF may not be regarded to be the final. This would require a considerable amount of refinement and improvement while put in operation in the organization. The usefulness of the system can be further improved by the active participation of the system designer/analyst and the users of the system. It is hoped that the enterprise would make an effective use of such a system and derive considerable benefits from modern management science techniques and computer technology . This would eventually strengthen the operational efficiency or the organization. A saving in operational cost would be followed by a optimum pricing of the product range probably reducing the prices and increasing the customer satisfaction .

9.2 RECOMMENDATIONS FOR FUTURE WORK

The extensions of present work can be done in different dimensions. Some of they are presented below:

1. An important future work would be the integration of the proposed DSS with a modern MIS in the enterprise. In order to ensure an effective use of the developed DSS it is recommended that an effective MIS department be created in the organization. Redwan [26] carried out a work on MIS design and suggested its implementation in the case production system i.e. BISF. In this regard computer based MIS was suggested. An economic feasibility conform the above suggestion. In the present work also a similar suggestion is made that the MIS department should build a computer based centralized data bank. However due to lack of resources and weak infra-structure it may not be worthwhile to install a computer networking system in an organization like BISF, it is suggested that MIS department should initiate work in this line. To be specific it should start developing the data base with provision of specific formats for each departments of the organization from which data is to be collected in the line of using the proposed system. These departments would there generate and preserve their respective data in that format.The MIS department would be in a position to develop the data base. The data base could then

be shared by the users.

The implementation of the proposed data collection system can be achieved with a affordable financial investment and with some dedicated effort and organizational changes. The implementation of this system would enhance the effectiveness in the long run through providing accurate and up-to-date data to the system. The proposed system could be viewed as shown in figure 10.1 below:

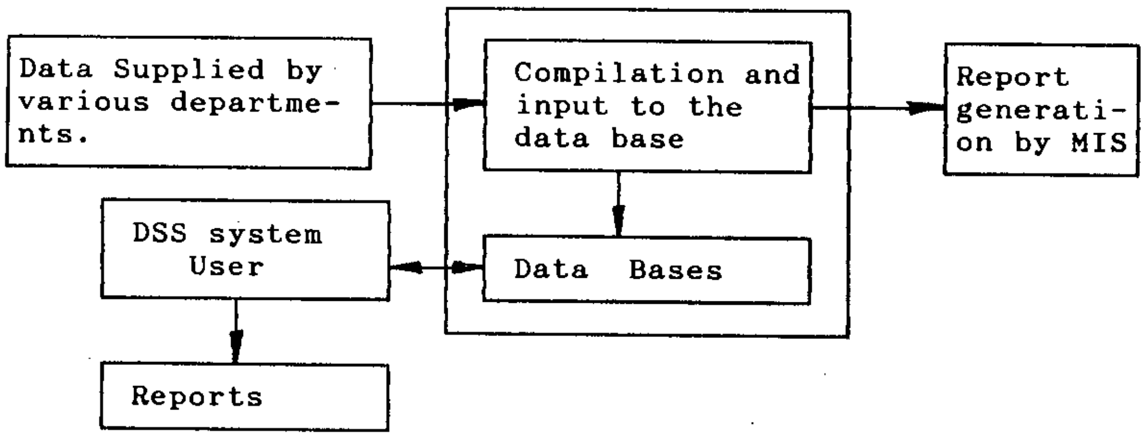

Figure 10.1 : Flow of data in the proposed system .

2. Future work may be directed in transformation of the proposed DSS into an expert systems. In this regard work of Finlay [21] shows that both the component and design methodologies applicable to these systems are very similar despite the differences in the terminology employed.

3. A work can be carried out to apply data management packages for the creation and updating the data base and generation of reports.

4. The system could be extended by incorporating various model for production planning such as inventory control, scheduling etc. thereby increasing the scope of its applications.

5. Another important work can be done by extending the model to incorporate hierarchial production planning model into the system.

6. The mathematical model may be further extended by incorporating other technological, financial and organizational constraints.

7. The future research work can explore the possibility of using the DSS technology to other organizations of the country including job shops, service industries etc.

8. The forecasting model base can be further extended by incorporating more models thereby allowing the user to select the best model and to perform analysis by using various models.

9. The system effectiveness can be further increased by providing a menu driven system and generating various graphic displays during operating stages as well as during the report generating stage of the system.

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APPENDIX

Period	Sanitary wares	Insulator and bricks	Tiles
1	125.77	0.0	90.97
2	125.77	0.0	90.97
3	125.77	0.0	90.97
4	125.57	44.74	90.97
5	125.63	31.02	90.97
6	125.49	62.75	90.97
7	143.26	69.56	72.21
8	125.58	42.95	90.97
9	159.18	74.34	55.42
10	125.52	54.87	90.97
11	168.27	87.3	45.79
12	190.87	118.92	21.85

Table A1: Optimum product mix for sensitivity analysis-1.

Period	Sanitary wares	Insulator and bricks	Tiles
1	37.91	92.40	144.89
2	14.88	53.50	155.55
3	22.85	20.60	174.32
4	14.11	5.95	188.18
5	17.05	3.37	206.75
6	15.14	6.01	216.81
7	14.40	6.87	201.22
8	14.18	4.53	206.48
9	15.76	7.17	171.31
10	21.49	5.65	191.87
11	17.26	8.45	139.97
12	18.93	11.57	14.71

Table A2: Optimum finished goods inventory level for sensitivity analysis -1.

Period	Sanitary wares	Insulator and bricks	Tiles
1	167.84	0.0	102.51
2	167.84	0.0	102.51
3	167.84	0.0	102.51
4	167.64	44.75	102.51
5	167.70	31.02	102.51
6	167.56	62.75	102.51
7	167.53	69.56	102.51
8	167.65	42.95	102.51
9	167.51	74.34	102.51
10	167.59	54.87	102.51
11	167.42	93.70	102.51
12	167.34	112.42	102.51

Table A3: Optimum product mix for sensitivity analysis -2.

Period	Sanitary wares	Insulator and bricks	Tiles
1	173.62	0.0	96.42
2	173.62	0.0	96.42
3	173.62	0.0	96.42
4	173.43	44.75	96.42
5	173.49	31.02	96.42
6	173.35	62.75	96.42
7	173.32	69.56	96.42
8	173.44	42.95	96.42
9	173.30	74.34	96.42
10	173.39	54.87	96.42
11	173.25	87.30	96.42
12	173.12	118.82	96.42

Table A4: Optimum product mix for sensitivity analysis 3.

Period	Sanitary wares	Insulator and bricks	Tiles
1	0.0	0.0	0.0
2	0.0	0.0	0.0
3	0.0	0.0	0.0
4	62.63	44.75	0.0
5	121.54	31.02	78.71
6	127.87	62.75	91.51
7	145.66	69.56	91.51
8	123.98	42.95	91.51
9	160.78	74.34	91.51
10	129.01	54.87	91.51
11	177.89	87.30	91.51
12	177.75	118.82	91.51

Table A5 : Optimum product mix for sensitivity analysis 4.

Period	Sanitary wares	Insulator and bricks	Tiles
1	351.7	92.40	257.60
2	202.9	53.50	177.30
3	85.10	20.60	105.10
4	13.43	5.95	28.00
5	12.27	3.37	34.31
6	12.74	6.02	44.92
7	14.40	6.87	48.64
8	12.58	4.53	54.55
9	15.76	7.17	55.37
10	24.98	5.65	76.48
11	30.37	8.45	70.30
12	18.93	11.57	14.71

Table A6 : Optimum inventory policy of finished good for sensitivity analysis 4.

Period	China clay-body	China clay-HP	Feldspar-Foreign	Ball clay White	Ball clay Black
1	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0
4	105.01	26.65	51.96	38.58	68.59
5	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0
7	144.95	36.78	71.78	56.40	94.20
8	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0
10	166.41	45.62	84.02	60.74	115.34
11	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0

Table A7 : Optimum raw materials ordering quantity for sensitivity analysis 4.