PRODUCTION SYSTEM SYNTHESIS AND APPLICATION OF OPERATIONS RESEARCH TECHNIQUES TOWARD OPERATIONS MANAGEMENT DECISION MAKING

By

Md. Abdul Hannan
B.Sc. Engg. (Mech.)

A Thesis

Submitted to the Department of Industrial and Production Engineering, Bangladesh University of Engineering and Technology, Dhaka, in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE IN ENGINEERING (IP).

Major Subject : Industrial & Production Engineering

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

December 1990

PRODUCTION SYSTEM SYNTHESIS AND APPLICATION OF OPERATIONS RESEARCH TECHNIQUES TOWARD OPERATIONS MANAGEMENT DECISION MAKING

By

Md. Abdul Hannan
B.Sc. Engg. (Mech.)

Approved as to the style and content by:

M. M. Rahman

1. Dr. Md. Mizanur Rahman — Chairman (Supervisor)
   Professor & Head
   Department of I.P.E., BUET
   Dhaka

2. Md. Golam Mohiuddin — Member
   Assistant Professor
   Department of I.P.E.,
   BUET, Dhaka

3. Dr. Ashraf Ali Shikdar — Member
   Assistant Professor
   Department of I.P.E.
   BUET, Dhaka

4. Professor Dr. Md. Sekendar Ali — Member (External)
   Director
   Bangladesh Institute of Technology
   Dhaka

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

DEDICATED TO

MY

BELOVED PARENTS

CERTIFICATE OF RESEARCH

This is to certify that the work presented in this thesis is the result of the investigations carried out by the candidate under the supervision of **Dr. Md. Mizanur Rahman**, Professor & Head, Department of Industrial & production Engineering, Bangladesh University of Engineering & Technology, Dhaka, Bangladesh.

Counter signed by Supervisor	Signature of the Candidate
M. M. Rahman	Hannan
Dr. Md. Mizanur Rahman	**Md. Abdul Hannan**

DECLARATION

Hereby declared that neither this thesis nor any part thereof has been submitted or is being concurrently submitted in candidature for any degree or deploma at any other university.

Signature of the
Candidate

Md. Abdul Hannan

CONTENTS

CONTENTS (Contd.)

CONTENTS (Contd.)

LIST OF FIGURES

LIST OF FIGURES (Contd.)

LIST OF TABLES

LIST OF TABLES (Contd.)

LIST OF TABLES (Contd.)

LIST OF TABLES (Contd.)

ACKNOWLEDGEMENT

The author likes to express his thanks to the authority of Bangladesh Institute of Technology (B.I.T.), Dhaka, especially to the Director, Professor Dr. Md. Sekendar Ali for awarding a UNDP scholarship for persuing the M.Sc. Engineering program.

The author wishes to express his profound gratitude and gratefulness to the thesis supervisor, Dr. Md. Mizanur Rahman, Professor and Head, Department of Industrial and production Engineering, Bangladesh University of Engineering & Technology, Dhaka for unfailing patience guidence and valuable & constructive suggestions and encouragement in every step in execution and compilation during the preperation of this thesis, without which it would be impossible to carryout this work.

The author is also grateful to Dr. A.F.M. Anwarul Haque, Professor, Department of Industrial and Production Engineering, Bangladesh University of Engineering and Technology, Dhaka for his valuable advice and suggestions time to time.

His indebtedness is due to Mr. Golam Mohiuddin, Assistant Professor, Department of Industrial and Production Engineering, Bangladesh University of Engineering and Technology, Dhaka for his encouragement regarding the work.

His indebtedness and gratitudes are also due to Dr. Nurul Amin and Dr. Ahsan Ali Khan, Associate professors, Department of Industrial and Production Engineering for their inspiration and encouragement regarding the work.

Sincere gratitudes and thanks are due to authority of Bangladesh Freedom Fighter Welfare Trust for extending sympathetic assistance in connection to getting access and supplying various data from the Head Office.

Sincere thanks and appreciations are due to the General Manager of the Mimi Chocolate Factory, one of the units of Bangladesh Freedom Fighter's Welfare Trust, for his kind cooperation for various kinds of data collection from the factory.

The author wishes to thank the officers and staff of Mimi Chocolate Factory, specially to Mr. Belal Ahmed, Production Officer, Mr. Mostafa Wamik, Sales Promotion Officer and Mr. Moshiur Rahman, Chief Executive of Accounts.

Thanks and appreciations are due to Mr. Siddiqur Rahman for his patient and untired work to produce the thesis.

Finally, his never ending gratitude to his brothers who inspired constantly with the best of their prayers and wishes.

ABSTRACT

Profitable performance of an industrial unit depends on a rationale production system. The level of performance depends solely on the production policy along with any other relevant factors. Establishment of a clearcut relation between the level of performance and cost of production as a whole would require such considerations as,

i. Use of mathematical tools and Scientific methodology of Operations Research (OR) and statistics.

ii. Scientific approach of record keeping, sorting and retrieval of basic data etc.

The present research work is intended primarily to explore the use of OR techniques and demonstrate their application to an industrial unit through its different stages of production decisions.

The work starts with an analysis of the production system of the Mimi Chocolate Factory, with the aim to find out idle time of both man and machine, the bottlenecks in the production system.

Secondly, the work is concerned with the estimation of demand of the products through the use of the historical

sales data of past 24 months of consecutive periods. The Winters' method of exponential smoothing was applied for the purpose.

Thirdly, the work is concerned with the determination of the optimal product-mix of the Mimi products. An LP model was developed on the basis of plant capacity,availability of man-hrs. and machine-hrs., ingredients and forecasted demand.

Finally, an optimum procurement policy for some of the major raw materials and ingredients of Mimi chocolate factory was formulated on the basis of various cost elements related to inventory. The Dynamic Programming technique was applied to arrive at a solution to each of the ingredients of the problem.

Chapter – I

I N T R O D U C T I O N

Chapter — I

INTRODUCTION

The country's industrial sector, amongst other sectors, is suffering in most situations both in strategic planning and execution due to lack of endeavours and efforts directed in line with Operations Research (OR) thinking. The industrial sector along with other vitally important sectors of the economy is reluctant to use mathematics in its decision making. The present study is thus devoted to find an application of OR in a small to medium size production unit so that it may take rational decisions using quantitative techniques.

1.1 THE RATIONALE OF THE PRESENT WORK

The process of industrialization, its development and growth influence mostly the agricultural development which in turn ensures the economic growth of the country.

It has been reported by the Bureau of Statistics[25] that the overall production in some sectors of the economy to have gone down which has affected the financial efficacy of mills & factories in jute & cotton textile as well as engineering and food & sugar sectors. At current prices contribution of industries sector to the GDP (mining, manufacturing, country's electricity, gas and water) was 16.69% in 1981, while in 1988-89 it was 15.26%. Corresponding contribution of the manufacturing sector to the GDP at current prices drop from 10.40% in 1980-81 to 7.82% in 1988-89. The manufacturing sector growth rate during 1988-89 was 2.56% per annum while the GDP itself grew at the rate of 3.20% which reveals the poor performance of the sector. The purpose of the present work is not to explore and search for the possible reasons and factors behind the above cause and not even to suggest strategies and solutions and possible way to alleviate the situation. Moreover, the objective of the present work is not to investigate at the macro level but to look into matters at the operational unit level. It is however believed that if the operational units of industries operate efficiently, their sum would make the whole of the economy efficient.

From a survey, it has been identified that unplanned system of production is one of the inhibitive factors in the field of production. A proper and prior development of systems would ensure proper utilization of man-power and machines and this would boost the enterprises to become profitable.

Developing countries are incapable of raising the industrial growth with their own technology and limited resources. Thus, they have to spend a huge amount of valuable foreign currency for import of technology, equipment and machinery. With scarce resources, what the country needs most, at this stage for proper industrial development is a rigorous industrial planning. An important analytical tool to the industrial planners, project directors and production managers as has been proven in many situations is the OR, which refers to the standard Industrial Engineering Techniques.

1.2 OPERATIONS RESEARCH TECHNIQUES IN INDUSTRIAL PROBLEM SOLVING

Operations Research (OR) approach could be applied in decision making problems in strategic situations met within industry, agricultural and various field of economy. The oldest profession which has been involved in a sophisticated OR work is that of an actuary who has been applying life contigency, probability and various mathematics and other methods to enable the life offices to decide what the premium rates of various policies should be, how best profits could be distributed in case of with profit policies, etc. The problem in industry start from procurement of raw materials upto the despatch of the finished products. In both developing and developed economies, there is a great scope of developing an OR approach towards planning. The basic problem in most of the developing countries in Asia & Africa is to weedout poverty and hunger as quickly as possible; there is a great scope for economists, statisticians, administrations, politicians, technicians work together to workout this problem with an OR approach.

The OR approach needs to be equally developed in various agricultural problems, (nevertheless, there have been successful applications of OR in industries in developed countries). The scientific approach aims at giving a quantitative analysis of the problems posed, in order to develop a mathematical model on the basis of which data are collected and numerical investigations are made.

The basic OR approach is

i. *to formulate the problem as precisely as possible*

ii. *to device methods of attacking problems*

iii. *to undertake investigations on the basis of (ii) and draw conclusions.*

In stage (ii) a model is to be devised and decision to be made what data should be collected and how they should be analyzed. The stage (iii) is very often followed by a study of implementation of the recommendations.

Having specified OR way of attacking problem various techniques are applied for the purpose of solving the problem and should not distort the problem to apply a particular technique.

Operations Research Techniques are continually being evolved indeed the OR worker must often avoid the pitfalls of existing techniques in maintaining his enquiring experimental attitude of mind.

Many of these techniques are derived from mathematical statistics which is still one of the most powerful tools in the OR approach. This is necessary so because one common property of industrial systems is their variability and mathematical statistics is the method of handling the problem of variability. The other techniques are linear programming, queueing theory, simulation methods, stock and production control models, decision theory and game theory, operations gaming, information theory and evolutionary operations, time series analysis, dynamic programming etc. These techniques do not ofcourse represent the limit of an OR team's capabilities, nor are they the sum total of existing OR techniques. Other methods which could have been mentioned are - search theory, symbolic logic, Boolean algebra etc. Some techniques applied in OR are borrowed from other disciplines - actuarial theory and value theory for example. There are others being developed continually. Some are applicable in but a few rare cases, others acquire the powerful sweep of queueing theory or simulation.

In the present work an application of time series model, LP model and dynamic programming model are sought.

Investment, which is an important factor contributing to industrial growth, is often over-rated by economic planners although the choice of technology and the conditions surrounding the transfer of technology and innovation are equally important factors. There is indeed tremendous scope for industrial growth through better industrial house keeping. The planning of activities that constitute an industrial project, the planning of the use of plant and labor to ensure lowest cost completion of production targets, create conditions of low capital-output ratios. With the proper use of analytical planning and control techniques, it is usually possible to squeeze a greater increase in industrial productivity.

Sound industrial planning calls for the selection of a sequence of decisions that would be most conducive to rapid and sustained industrial growth and productivity on the basis of optimal utilization of materials, facilities and manpower. Such decision making is aided enormously when industrial engineering techniques are employed. Each country or region has unique local factors such as availability of material, human involvement, technological development, environment etc. While applying industrial engineering techniques in any organization these local factors must be given due consideration.

1.3 SCOPE OF IE TECHNIQUES IN BANGLADESH

IE techniques refer to the theoretical analysis carried out from the real life data. Some of the IE techniques with their areas of applications are mentioned in Appendix-I, from which, importance of IE techniques could easily be understood.

The IE Techniques have got a very wide scope of their applications. But their applications are dependent upon the availability of substantial factual data. In developing countries, considerable effort is needed for collecting the pertinent data, which calls for specialized professional knowledge and skill. Nevertheless, there have been successful applications of management sciences in developing countries.

The use of IE Techniques in different types of organizations in the country is not impossible although it is often limited due to the nonavailability of factual data and other reasons. The following are some of the studies and work carried out using O.R approach:-

	Title	Description of work
1.	A model for Business Failure Analysis	A general mathematical model based on conventional financial ratios has been derived for analysing business performance and its trend. The model is in the form of a single linear function consisting of seventeen accounting ratios found to be significant by a 2-way Discriminant analysis.
2.	Technological constraints in Urea Production in Bangladesh	An analysis of downtime was made to identify the causes of failure of machines and equipments in a fertilizer factory. Thus helping management to operate the factory at designed economic levels.
3.	OR Technique applied in Replacement of Street Lights of Dhaka City	Statistical techniques were used and replacement models were suggested in formulating strategies in the replacement of street light bulbs in the Dhaka City.
4.	Development of operational Reliability Assessment model and its application to a Urea Fertilizer Factory.	The model has been applied to assess the reliability of a fertilizer plant which helps in identification of critical equipment with low reliability. The causes of low reliability and various possibilities of improving reliability of critical

		equipment have been studied. Steady state availability and operational readiness have also been calculated for individual equipments as well for the total plant.
5.	Evaluation of worker's Job Performance and its relation with the labour Productivity in manufacturing units	A performance model has been proposed showing different factors which impede or impel the productivity of a worker. The relative importance of these factors has also been shown in the proposed model.
6.	Development of a model for Repairable Spare parts provisioning	A generalized model for repairable spare parts provisioning has been developed considering a group of M identical units in operation, served by an on-site store containing N spares. As the units failed, they were sent away for repair and then returned to the store after repair. In the long run, each of the M units experience an unavailability U due to occassional stock-outs. Using state transition diagram, mathematical relationships have been derivied between quantities M, N, U, unit failure rate in operation, unit failure rate in storage and repair rate.
7.	A study on preventive maintenance modelling applied to jute mills machinery	In this work, a through study of preventive maintenance has been made. Failure modes of each equipment has been investigated to identify critical components

which are liable for the complete breakdown of the equipment of a typically medium sized jute mill. Data has been analysed to determine appropriate failure distribution. Maintenance plan for each equipment has been developed on the basis of cost minimization and downtime minimization.

The case studies forwarded above are few pioneer works carried out in BUET. The works have revealed that benefits could be achieved for production units if OR techniques could intelligently be used.

In the present work also effort has been directed to find a useful application of the OR techniques in a production unit. The various problems of a production unit are described in the following section.

1.4 STATEMENT OF PROBLEMS:

A small to medium size chocolate and chocolate products manufacturing plant named Mimi Chocolate Factory has been considered in the present work. The factory has few basic general management problems as could be seen in other prodcution systems of the country. The present work is directed to identify the various problems while making a system study. The problem areas are firstly categorized below:

MARKET SHARE & PRODUCT DEMAND:

The product lines of the unit are as follows:

i) Chocolate, (ii) Chewing gum and (iii) Sweets. The competitors of these products are, (i) Import source and (ii) Local production.

The market for chocolate and gum products are highly competitive. But the management is not in a position to assess mimi's market share. This imposes two obvious difficulties such as (i) the unit can not make strategic plan for its growth in the market share and make programmes accordingly, and (ii) the unit cannot ascertain the supply-demand situation and setting optimum price levels of its products. In the existing setup of the system operation, planned forecasting of future demands are not made scientifically not even the market trend is known. The bases used for production are (i) thumb rule coupled with experiences of sales department, and (ii) wholesale customer order at the plant gate. Even if there is no order, the production is continued.

BALANCING & MODERNIZATION:

The operations management techniques are seldomly applied in the unit and no such appropriate personnels are available for the purpose. Thus the production system, more specifically, the production lines could not be properly balanced using scientific methods and the system not being modernized. The production system is not available for some proportion of available time due to erratic failures of some key machinery; production is affected due to bottlenecks in the line. Lack of application of planned maintenance policy is also found.

The production engineering department is very weak as no qualified production/mechanical engineer is employed by the company. The capacity and utilization of the facilities and the factory as a whole are neither improved nor effort being given to improve the situation. This resulted in some of the machines were operating at a very low level of performance and implanting bottle-neck in the production line.

RAW MATERIAL PROCUREMENT POLICY:

The raw materials are being procured not on the basis of a clear cut and scientific-based policy. The consumption rates of the raw materials as used in the production line are not known. Nornally, the imported raw materials are procured two times a year and the local purchased raw materials are procured five or six times a year. Few raw materials are procured locally as and when required basis. There is no basis or explanation of the above frequency of purchases made during a year. The management is neither concerned nor aware of the penalty cost they are paying for not using scientific procurement and inventory policies.

DEMAND SUPPLY SITUATION:

The demand, for mimi products amongst other important and relevant factors, depends on the quality, price, sales promotion associated with the products. Currently no effort being given on the above. The wholesalers buy the mimi-products at the factory gate; the buying pattern as observed is highly irregular. The company gives no effort to assess its market and no market analysis is ever been taken by the company. Thus demand supply situation is not known to the company.

The company has no distribution system of its own nor it appoints distributors/agents for marketing its products. The channel of distribution is absent and as such no coverage is given in the media in the form of advertisement. Study on sales-response and advertisement outlay (taka spent basis) relationship may be made.

PRODUCTIVITY & OVER-EMPLOYMENT:

Some of the facilities and resources are excessively used, an example being that two low-temperature environment rooms are being used while a single room with a central air conditioner would serve the purpose. The crude measure of productivity as the ratio of output quantity and employees employed shows that there exist high over-employment of semi-skilled and non-technical employees. This resulted in low level of productivity and high production cost.

1.4.1 SCOPE OF THE PRESENT WORK:

The various problem areas in the system has been identified earlier. The management would be able to prioritise the above problem areas. A possible rational approach may be such as follows:

i. *an effort to sales promotion*

ii. *set a target of production (planned)*

iii. *a planned operations management activities*

iv. *designing an optimum purchase schedule for raw materials.*

etc.

In the present work the problem is defined as follows:

i. *Determination of capacities of the facilities and there by balancing the production flow line.*

ii. *Forecasting of demand of mini-products and assessment of market shear.*

iii. *Determination of optimum product-mix of the mimi-products.*

iv. *Determination of an optimum procurement policy of raw materials.*

DEMAND FORECASTING:

The target may be estimated by using any of the tools of OR such as Regression method, moving average method, exponential method, winter's method etc. In present work Winters' method was used to show the seasonal variation of demand.

OPTIMUM PRODUCT-MIX:

The company is a multiproduct manufacturing plant. The classical linear programming model is found to be appropriate to determine the optimum levels of production of each of the products to gain maximum profit. The restriction equations could be developed based on raw materials restriction, man-hour restriction, machine-hour restriction, plant capacity restriction and maximum market demand restriction.

OPTIMUM PROCUREMENT POLICY OF RAW MATERIALS:

The consumption rate data of each of the major raw materials were collected for twenty four months periods. A dynamic programming technique was used to prepare a procurement schedule for optimum level of inventory cost.

1.5 OBJECTIVE OF THE RESEARCH WORK

The present work attempts to explore the possibility of applying IE techniques in different stages of production decisions in a small to medium size manufacturing plant (Mimi Chocolate Factory).

The following are the important objectives of the present work:

i. *To analyze the production systems of the factory, with the aim to find out the idle time of both man and machine, the bottle neck (if any) in the production process so that the proper utilization of man and machine occur and ultimately the productivity can be increased.*

ii. *To forecast the demand of Mimi products in the market.*

iii. *To determine an optimum product-mix for the mini-products on the basis of the forecasted demand.*

iv. *To formulate an optimum purchase scheduling policy for the major raw materials and ingredients of the Mimi products.*

Chapter – II

LITERATURE SURVEY

Chapter — II

LITERATURE SRUVEY

A Thorough review of the existing literature should be the first activity of a research project like the present work. The present work is directed towards exploring the scope of application scientific methodologies of industrial engineering more specifically O.R. techniques in a production system. In the country there is practically insignificant application of scientific management approach. It has been proven that success of an enterprise depends entirely on the systematic application of scientific methodologies of management science. Thus the literature survey is divided into following constituent areas: namely

i. *Work measurement,*

ii. *Forecasting demand,*

iii. *O.R. Techniques.*

An integrated and successful planning of a production system depends on a production goal setting. A system planner always wants to know what forecasting tools are available and what assumptions influence their applications, production schedules, purchasing of inventory, capital expenditures, rental of facilities such as warehouses, budgets for labour etc. are the few areas where different types of forecasting methods are used.

Elaborate discussions are made by Montogomery[6], Tersine[3], Riggs[4], Bedworth, & Bailey[1] and Greened[5]. Time-series prediction is a mathematical model that assumes that data is correlated with time. Time series analysis as it applies to forecasting future events based on historical data trend evaluations.

The technique of exponential smoothing is a special kind of weighted moving average which is especially suitable for data-processing applications[17]. The exponential smoothing technique has been extended to include the trend component in time series analysis by Montogomery[6]. Forecasting based on exponential smoothing becomes inappropriate because they do not take advantage of the dependency in the observations in the most efficient way. D' Amico[21] showed how to improve Forecasting accuracy by varying the value of the exponential smoothing constant according to demand pattern.

Time series data may contain upto five interacting components - levels, trends, seasonal variations, cyclical variations and random variations[3]. Some or all components may present in a set of data. Winter's method of forecasting is a very efficient tool to reflect all the variations except the random variations. Box Jenkin method of forecasting is very useful to reflect the seasonal variation, cyclical variation and random variation[6]. The Winters' method of forecasting is a special type of exponential smoothing method of forecasting. This method efficiently treats the seasonal effect, trend and cyclical variations Winter's[18] and Montogomery[6].

i. Work Measurement:

Work measurement is a tool used for evaluating and planning labour utilization and machine utilization in production systems. Studies have revealed that proportion of time consumed by machines is significantly less compared to that of human intervention. Thus to increase productivity, human component of the total work component should be properly utilized. Yet the production capacities of machinaries and equipments would be such that there exists no bottleneck in production line. The bottleneck in production line can be found out also through time study, Barnes[19], Mundel[20], Tersine[3] and Riggs[4].

ii. O.R. Techniques:

An exhaustive list of text books of the past and contemporary could be given along with technical papers on the subject. In the present work such texts consulted were of Greene[5], Taha[15], Hillier & Lieberman[16] and Cooke[7], Anderson[8] and also done by Tarapada[23], Sarker[24]. Balm[14] attempted to describe the various applications to which LP has been put in Scottich agriculture, and secondly to give some observations about the value and difficulties of using LP in agriculture. Sharp[12] used Linear Programming in optimization a job shop when operators work on two or more product line, at a time, where the reduced costs of common labour has been taken into account. Mingnez, Romero and Domingo[13] analysed the optimum fertilizer combination and through the development of a goal programming model. Under this approach, the fertilizer requirements, instead of being fixed values as in traditional linear programming, was considered targets which may or may not be achieved. Rahman[2] made an effort to formulate an LP model for optimization of profits of jute textile mills. He showed how the different constraints could be developed in a jute textile industry.

Dynamic Programming (DP) is a computational technuique used for optimization. Few important types of problems solved by dynamic programming are production/purchase inventory problem, capital budgeting problems and network problems, Cooke[7], Taha[15], and Hiller and Lieberman[16] presented detailed discussion on DP with special prototype problem of inventory control.

Ritchie[9] suggested an approach for analytical optimal solution for inventory policy considered for the situation of a deterministic linear trend in demand followed by a period of constant demand. Phelps[20] gave an approach for the classical deterministic inventory model considered for the case of constant time between each replenishment and linear trend in demand. The performance of an approximate method for determining inventory replenishment quantities for the case of a variable demand was examined by Kicks and Donaldson[11], using an exact analysis, where increasing and decreasing the linear trend in demand was considered.

Chapter — III

STUDY OF THE PRODUCTS AND THEIR PRODUCTION PROCESSES

Chapter — III

STUDY OF THE PRODUCTS AND THEIR PRODUCTION PROCESSES

The various manufactured products of the Mimi-Chocolate Factory, the raw materials used and the manufacturing processes involved are discussed in this chapter.

3.1 PRODUCTS OF THE FACTORY

The Mimi Chocolate Factory, when first installed, started with production of about thirty items. Production of some of these products have been stopped due to lack of some facilities and some machines becoming not available. Currently the major products are grouped into three classes as given in Table 3.1. The flow diagrams of the two main production lines are shown in Fig. 3.1 and Fig. 3.2.

Table 3.1 : List of Mimi-products

	Sl.	Name of Products
CHOCOLATE PRODUCTS	1.	Orange Chocolate
	2.	Large Chocolate
	3.	Nut Chocolate
	4.	Pineapple Chocolate
	5.	Almondnut Small Chocolate
	6.	Milk Medium Chocolate
	7.	Block Chocolate
	8.	Picnic Delight
	9.	Wafer Cream Biscuit
	10.	Tea-Time Biscuit
	11.	Lucky-Dip

Table 3.1 : List of Mimi-products (Contd.)

	Sl.	Name of Products
GUM PRODUCTS	12.	Chewing Gum
	13.	Bubble Gum
	14.	Ball Gum
SWEETS	15.	Icing Sugar (Loose)
	16.	Icing Sugar (Packed)
	17.	Table salt (Iodine enriched & crushed).

The consummers of the above listed products are

i. Star-marked hotels and big bakeries for icing sugar & salt and icing sugar & raw chocolate respectively,

ii. all other products by the general public.

The mostly used raw materials used are listed as given in Table 3.2.

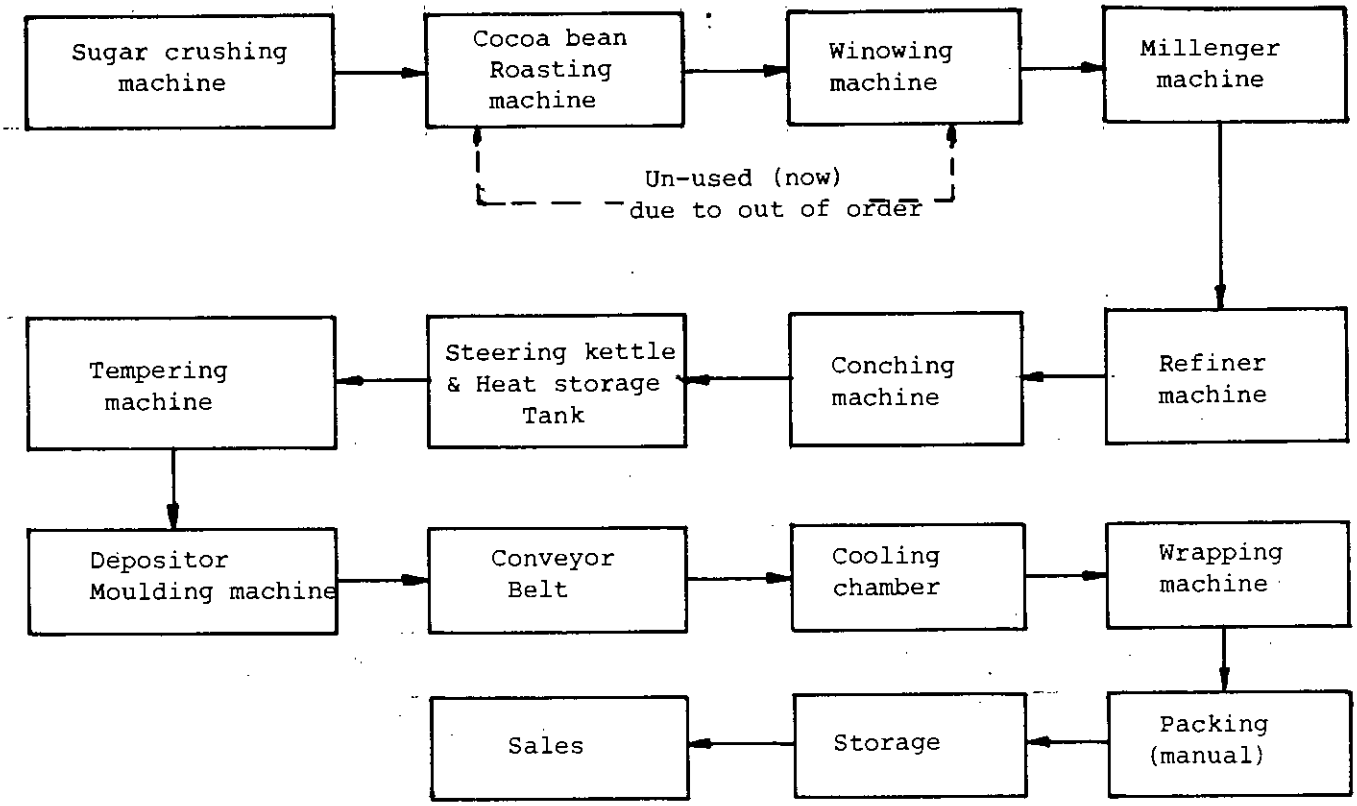


Fig 3.1: Flow diagram of chocolate section

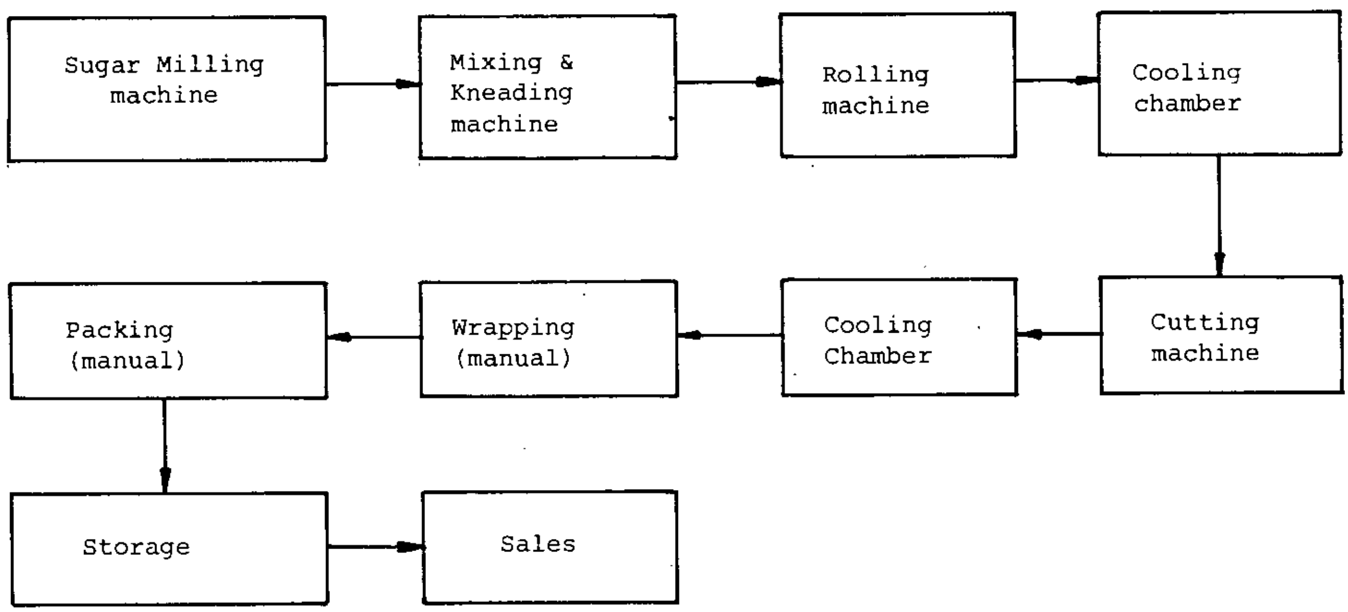


Fig. 3.2: Flow process diagram of chewing Gum section

Table 3.2 :
List of raw materials and their costs per Kg.

Sl.	Item description of raw materials	Cost in Tk. per Kg	Remarks
1.	Sugar	25.25	
2.	Milk Powder	87.24	
3.	Cocoa-Powder	124.00	The cost
4.	000-HI	147.55	figures are
5.	Lecithene	124.65	as in 1988
6.	Hyfoma	1197.74	year base
7.	Liquid Glucose	25.52	
8.	A.B. Biscuit	37.50	
9.	Haque Biscuit	37.50	
10.	Condensed Milk	43.84	
11.	Ground nut	41.96	
12.	P.K. Oil (V.oil)	39.92	
13.	Soap stone Powder	7.70	
14.	Chewing gum base	109.00	
15.	Bubble gum base	109.00	
16.	Gumbase softener	109.00	
17.	Chocolate flavour	821.80	
18.	Orange flavour	636.56	
19.	Banana flavour	643.35	
20.	Pine apple flavour	3475.00	
21.	Pippermeant flavour	505.95	
22.	Cardamon flavour	503.30	
23.	Cazu-nut flavour	493.00	
24.	Almond-nut flavour	633.85	
25.	Anti-oxident	2000.00	
26.	Magnesium Powder	95.03	
27.	Calcium Carbonet	10.40	
28.	Food colour Pippermeant green	1817.00	
29.	Food colour chocolate brown	314.82	
30.	Food colour appolow green	575.00	
31.	Food colour orange red	470.45	
32.	Food colour yellow	303.67	
33.	Vaniline Powder	1150.00	
34.	Bourn vita	112.50	

3.2 PRODUCTION PROCESSES

The production process of the various products consists of few common steps and then different processes for different products. The common step is the crushing of Sugar. The crushed sugar is used in all sections. Crushed sugar is a universal raw material used in producing any type of chocolate or gum or sweet products.

PRODUCTION OF CHOCOLATE:

Step-1:

The production starts with the mixing of main raw materials such as crushed sugar, cocoa-powder, milk-powder and vegetable oil. All these are well mixed in malenger machine for about ten minutes each batch.

Step-2:

Then mixture is refined in a refining machine. At the same time during refining, the mixture is roasted by steam heating of rollers.

Step-3:

The refined mixture is taken into the conching machine, where more liquid vegetable oil is added. The mixture is agitated and heated continuously for about eighteen hours to prevent settle down.

Step-4:

The mixture is then transferred manually into steering kettle, which is continuously steered and heated by electric heater. Mixture from steering kettle is then taken into tempering kettle. Anti-oxidant and flavour are mixed in the kettle. Upto this step, processing of raw materials for the production of chocolate-products is same.

Production of Chocolate Products:

Step-5: Casting

The mixture from tempering kettle is taken into the depositor molding machine through piping. There are large number of dies of different shapes for large, small and medium size chocolate. The dies are placed on the conveyor belt one after another, when just during passing the dies beneath the molding machine, a fixed controlled mass of liquid chocolate drops on the mold.

Step-6:

The conveyor belt, during conveying the molds into cooled room, performs the function of vibrator, for uniform settling the liquid chocolate on the molds. The molds are then carried manually into the cooling chamber. After about twelve minutes, the molds are taken out, ejected manually and placed on a flat plate in array for the purpose of wrapping in anfomatic wrapping machine.

Step-7:

About 40 pieces are wrapped per minute in the automatic wrapping machine. The wrapped pieces are then packed and labelled manually. And then shifted to store.

Production of Chocolate Coated Products:

Step-1:

For the production of chocolate coated items like picnic delight, wafer cream biscuits, Tea-time biscuit etc., the liquid chocolate is taken on tray into the cooled room.

Step-2:

The raw biscuits are then dipped into liquid chocolate one by one manually. Then placed into the cooling chamber of the freeze. After ten to twelve minutes, they are taken out and then trimmed manually and wrapped and packed manually and then shifted for storage.

Production of gum items:

Step-1:

The main raw materials such as crushed sugar, gum base, softener, liquid glucose, food colour and flavour are mixed together into the Mixer (mixing machine). After well-mixing in the mixing machine, the mixture is then taken out on a tray.

Step-2:

The whole mass is divided into several pieces manually and then each of the pieces are then passed through rolling machines to make the pieces into sheets. During rolling soap-stone powder is used for dehumidification.

Step-3:

The sheets are stacked on trays. All the trays are arranged on shelves in a cooled room for about twelve hours for slight hardening and dehumidification.

Step-4:

The sheets are then passed through cutters. The cut-pieces are then again stored in cooled room for two hours.

Step-5:

The cut-sheets are then broken into pieces manually. Each of the pieces are wrapped with Aluminium foil manually.

The flow process diagrams showing the sequence of steps of Production Processes for Chocolate, Gums and Icing sugar are shown in Fig. 3.3 through Fig.3.7.

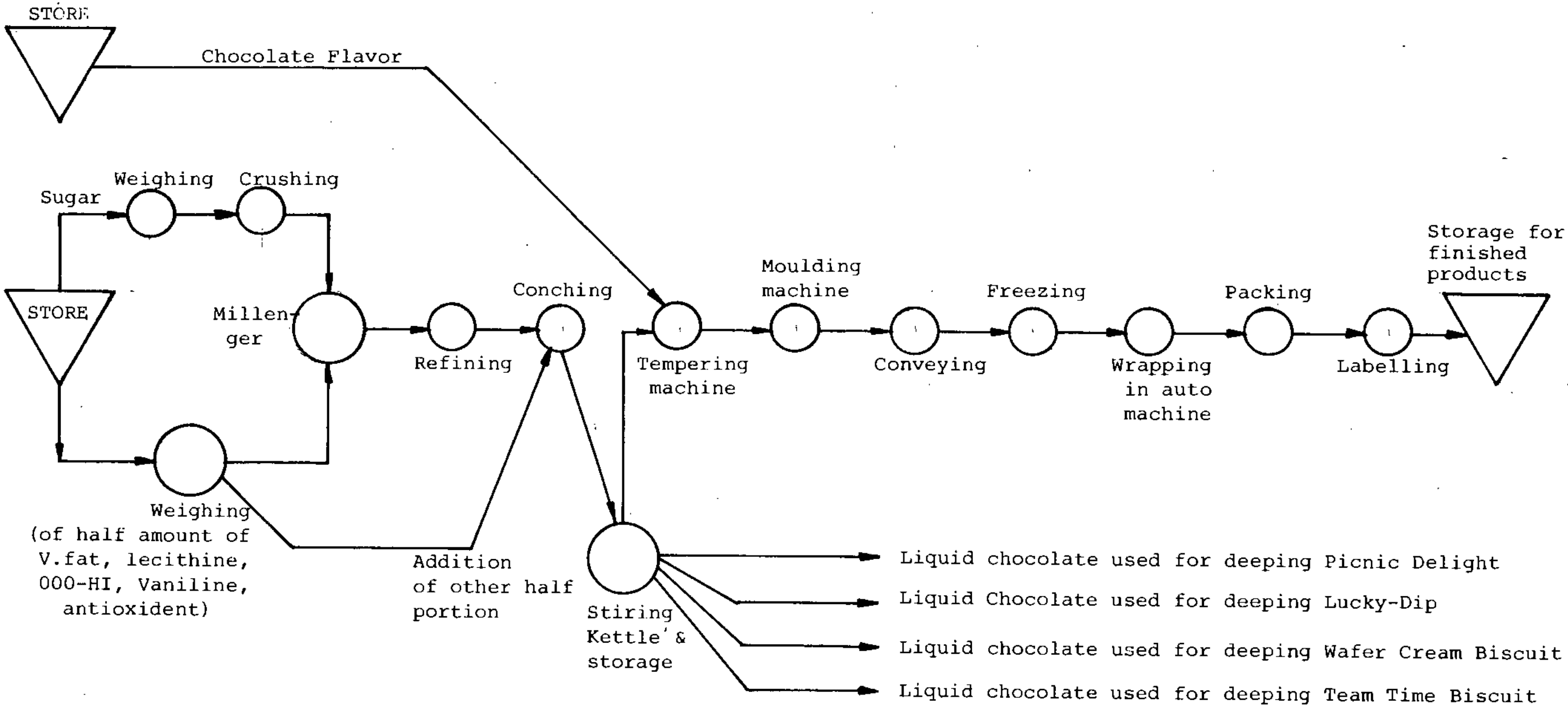


Fig.3.3 : Flow process chart for the production process of chocolate.

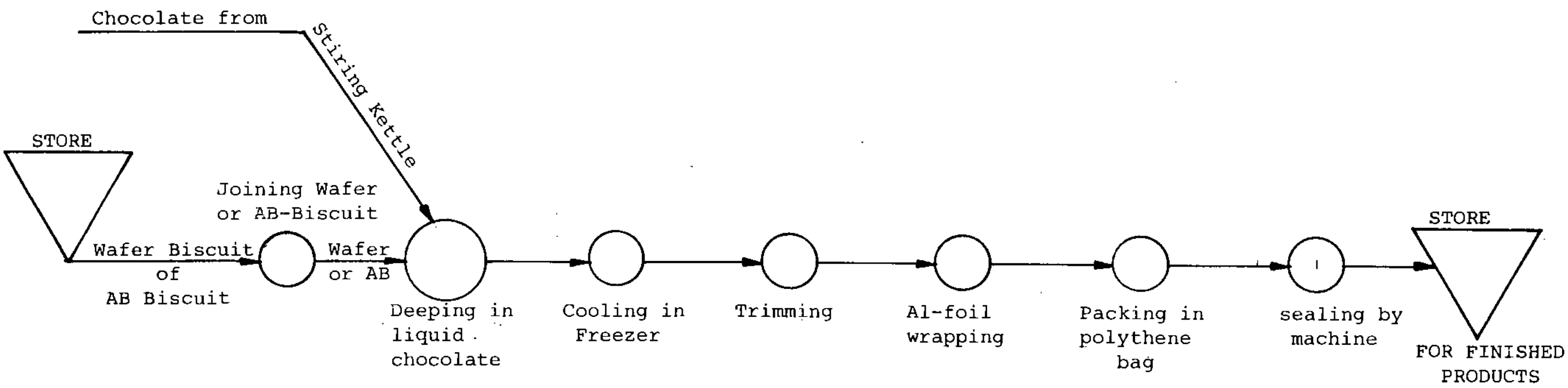


Fig.3.4 : Flow process chart for the production process of wafer cream Biscuit and Tea time Biscuit.

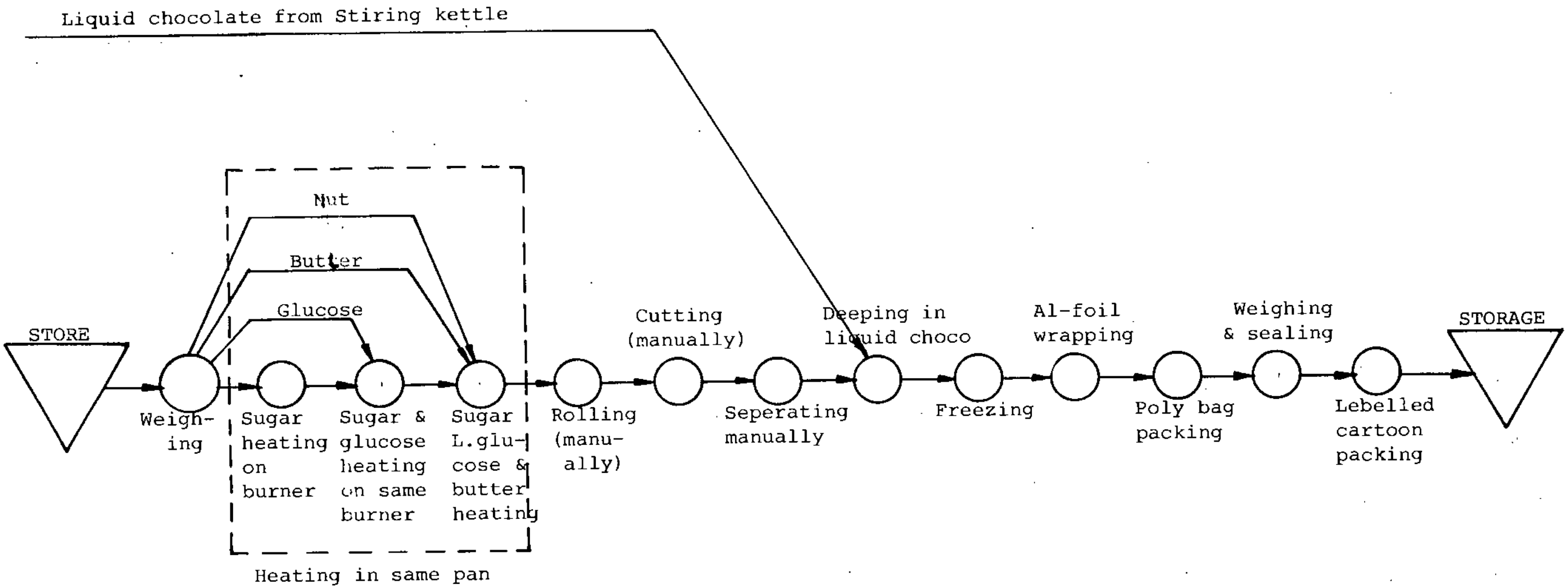


Fig.3.5: Flow process chart for the production of chocolate coated lucky-Dip

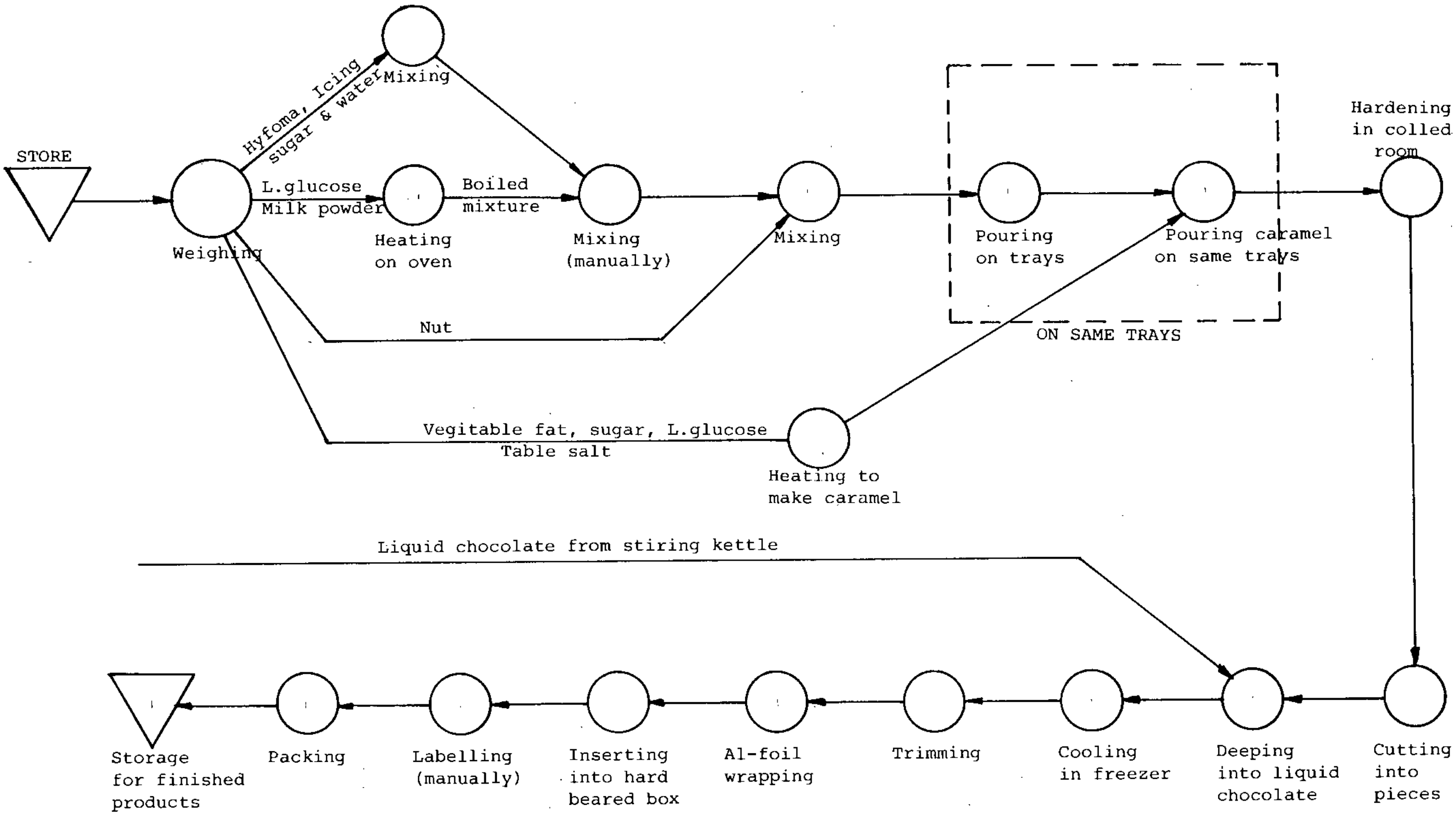


Fig.3.6: Flow process chart for the production process of picnic-delight

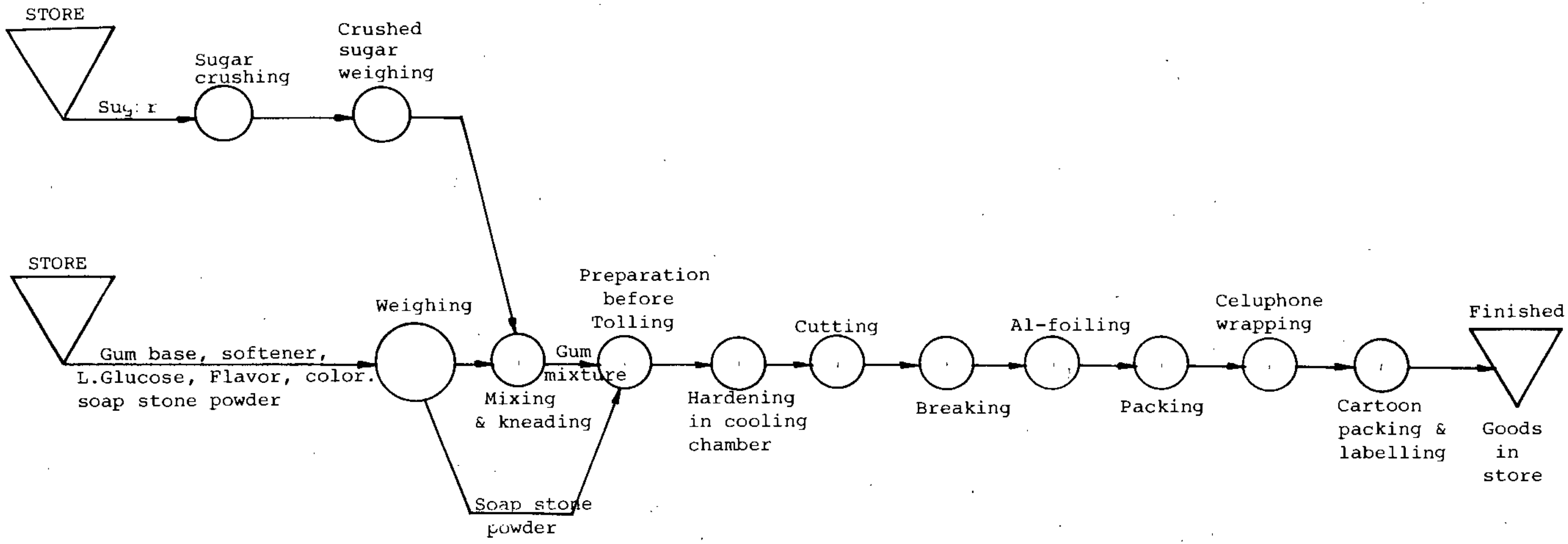


Fig.3.7: Flow process chart for the production process of Gum (of any type)

The purpose of this chapter was to identify the major raw materials required for production of the various mimi products and also to provide a first-hand knowledge of the production processes. The idea was that in formulation of the L.P. model for optimum product-mix, the various restrictions in terms of machinery and man-hour, raw materials, storing capacity and others could be identified; also to identify relevant data which should be collected in this respect. The next chapter is devoted to data collection and data upgrading.

Chapter — IV

DATA COLLECTION & UPGRADING THE DATA IN REQUIRED FORM

Chapter — IV

DATA COLLECTION & UPGRADING THE DATA IN REQUIRED FORM

In the previous chapter, a detailed discussion was made on the different types of products of the Mimi Chocolate Factory, the raw materials used and the related production processes. This chapter presents the various data that were collected from the production system. These data would subsequently form the basis for,

i. *analysing the production system and thereby balancing the production lines after identifying the bottlenecks in the production lines.*

ii. *forecasting the future demand of Mimi products.*

iii. *determining the profitable product-mix.*

iv. *preparing an optimum purchase schedule.*

The data were processed in an IBM 4331 Computer in the University Computer Centre using FORTRAN IV Language.

4.1 DATA COLLECTION AND ASSOCIATED PROBLEMS

The collection of data in relevant and usable form is seldom possible. This is the most difficult and some time frustrating part in carrying out research work in similar situations like the present case.

Procedure for data collection should be such that the desired accuracy could be achieved with loss of information kept at the lowest. At the same time there must be a clear understanding of the objectives and the requirements.

The raw data come primarily from the following sources:

i. *Loose sheets of operational, maintenance, procurement or supply forms as used by the system operatives.*

ii. *Special data forms originated by the research fellow for a specific requirement for specific period.*

iii. *Direct data generation by time study and instrumentation measurement, etc.*

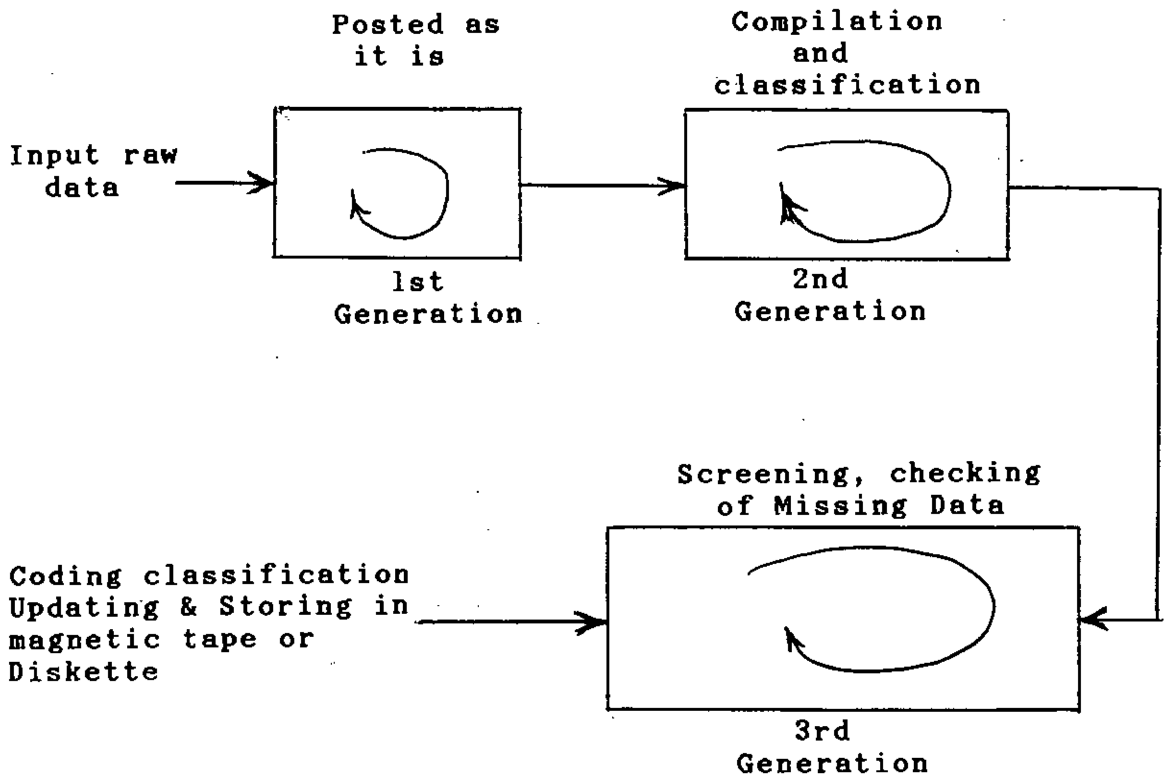
The basic means of collecting data are the study of procedures and processes, manual evaluation of forms and interviewing of departmental representatives. The departmental employees can also provide useful information in most cases. These objectives and requirements of each systems are clearly and concisely stated in a procedures manual.

The data sources as mentioned above was categorized into two broad classifications namely, generation of primary data and collection of data in secondary form.

In the present study, some of the data have been collected from the register books of departmental representatives and some from the time study of the different processes of different items.

The data recorded by the different departments are of the first generation type where only the first hand records are put in the prescribed forms specified for the statement of different things.

The process of data collection could be depicted in figure below:



Thus it was observed that data could be available in any of these generation levels as mentioned above such as (i) First generation, (ii) Second generation and (iii) Third generation.

In the first generation the raw data are posted in specified forms as obtained from the production system. The forms are however continuously updated. These data could be arranged sequentially, when the data are compiled according to requirements, also they are scrutinized, classified etc. to some degree and transferred to a permanent record file or register. These could be designated as second generation data. Recent developments in computer technology have made possible to store massive quantity of data economically, cheaply and conveniently. In this generation the data are screened and missing data are checked. Here input data were coded which makes it possible for easy searching are retrieval.

4.1.1 Problem of Data Collection in Developing Countries

The problems encountered in data collection in a developing country could be mentioned as follows:

i. *The source of data is available in its raw form, unprocessed and uncompiled. In most cases these are available in first generation form with few exceptions of second generations. Proper data storage system is absent and filing of data is processed very unwisely and unscientifically.*

ii. *It is difficult to retrieve data from these records at the right time.*

iii. *The records are kept unscientifically and not properly maintained. Thus missing data is not uncommon.*

iv. *Documentation centre and data processing centre are seldomly found. Data organization and Data Management* *are the two vitally important activities in data handling. In most cases these were absent. Thus collection of data became extremely difficult.*

v. *Relevant data could not be available at right time and needs to be extracted from a large volume of disorganised documents, registers and ledgers etc.*

The fact occassionally confronted by the researcher that the desired data are not available and that reliable data cannot be obtained because relevant records have not been kept.

4.2.1 DATA COLLECTION FOR THE PRESENT STUDY

The various data collected in the present work are as follows:

i. *Cost and price data of raw material and finished products respectively.*

ii. *Sales volume and facility capacities and utilization.*

iii. *Batch composition data.*

iv. *Labour-hours.*

v. *Machine-hours.*

COST DATA:

The following cost-data were obtained from the relevant department of the Mimi Chocolate Factory.

Unit Cost: Unit cost of each of the raw materials, are given in Table-3.2, Chapter-3.

Variable Cost:

Total variable cost per kg. and per packet of each of the products. The variable cost includes raw materials, power, fuel, distribution costs, spares and maintenance costs. A sample calculation for finding the variable cost of one of the items, e.g., "Orange chocolate" is shown below:

Name of Ingredients (1)	Qnty. per batch (2)	Rate per Kg., Tk. (3)	Amount in Tk. (2) x (3)
1. Icing Sugar	21.163	25.25	534.36
2. Milk Powder	11.250	87.06	979.42
3. Vegitable oil (P.K. Oil)	12.875	39.92	513.97
4. Cocoa Powder	3.875	148.00	573.50
5. 000 HI	0.500	225.00	112.50
6. Lecithene	0.313	124.41	38,94
7. Chocolate flavour	0.025	940.80	23.50
Total	50.00 Kg.		Tk.2,776.20

Daily production in 9 batches = 50 x 9

= 450 kg. of liquid chocolate.

Cost of liquid chocolate per kg. = 2,776.20/50

= Tk. 55.75

Raw materials base for 252 boxes = 230 kgs.

1.	Liquid chocolate	230.00 kgs	@ Tk.55.75 per kg.	=	Tk.14526.60
2.	Essence	0.300 kgs	@ Tk.800 per kg.	=	Tk. 240.00
3.	Anti-oxidant	0.05 kgs	@ Tk.2000 per kg.	=	Tk. 100.00
	Total cost of raw materials			=	Tk.14866.60

A. Cost of raw materials per box = 14866.60/252
= 58.99 $\simeq$ 59.00

Packing materials base for 252 boxes x 24 pieces = 6048 pieces

1.	Aluminium foil 135 mm size 10.25 kg. @Tk.160.00 per kg.	=	Tk.1640.00
2.	Wrapper 6100 pcs @Tk.190.00 per thousand for 255 pcs.	=	Tk.1159.00
3.	Plain carton 255 pcs @Tk.645.00 per thousand	=	Tk. 165.00
4.	Outer label 255 pcs.@Tk.150.00 per thousand	=	Tk. 38.00
5.	Paper cutting/wrapping/Gum/Maida charge	=	Tk. 12.00
	Total cost of packing Materials	=	Tk.3,014.00

B. Cost of Packing materials per box = Tk.3014.00/252

= Tk.11.98

C. Raw + Packing materials cost = Tk.59.00 + Tk.11.98

= Tk.70.98

1. Direct labour (wages) per box = Tk. 5.00

2. Factory overhead x 0.50
i.e. 22.61 x 0.50 per box = Tk.10.30

= Tk.15.30

Factory overhead Tk.22.61 is a semi-variable cost
A component (50%) direct and 50% indirect.
This cost of Tk.22.61 was obtained from factory record.

∴ Total variable cost per box = Tk.70.98 + Tk.15.30

= Tk.86.28

∴ Total variable cost per kg. = Tk.(86.28/0.9127) = Tk.94.54

Since wt. per box = 230/252 = 0.9127 kg.

: Ordering cost and Holding cost of raw materials as shown in Table-4.2

: Selling price of each of the products of Mimi as shown in Table-4.1

: Net profit of each of the products as shown in Table-4.1

: Total available variable cost for the financial year 1988-89 was Tk.88,52,728.00.

In calculating the ordering cost following procedure was used

In general, two orders are placed, at an interval of 6 months, for the imported goods in a year and two orders in each month, for the local goods throughout the year. Thus, the ordering costs were calculated as follows:

Ordering Cost of Local Goods:

Salary of store personnels	=	11000x 12 (months)	= Tk.	1,32,000.00
Salary of Purchase personnels	=	7500 x 12 "	= Tk.	90,000.00
Salary or record keeping	=	2200 x 12 "	= Tk.	26,400.00
Partial salary of typist	=	1000 x 12 "	= Tk.	12,000.00
Printing, stationary & others	=		= Tk.	12,000.00
T.A. & D.A. & carrying charges	=	7000 x 12	= Tk.	84,000.00
		Total	= Tk.	3,56,400.00

$$\therefore \text{ Ordering cost of local goods per order} = \frac{\text{Tk.}356400}{12}$$

$$= \text{Tk. } 29,700.00$$

Ordering Cost of Imported Goods:

Advertising cost in a year,	=	Tk. 2,22,000.00
Salary of personnels in the Head office	=	Tk. 6,00,000.00
Telephone and others	=	Tk. 11,000.00
	Total	Tk. 8,33,000.00

The Trust has fourteen units. The above cost is equally divided between them. Thus, ordering cost per unit becomes on average,

$$\text{Ordering cost per unit} = \text{Tk.}\frac{8,33,000}{14}$$

$$= \text{Tk.}59,500.00$$

Thus ordering cost per order for Imported goods $= \text{Tk.}\dfrac{59,500}{2}$

$= \text{Tk. } 29,750.00$

Holding Cost:

Store rent 12,000 x 12	=	Tk.	1,44,000.00
Electricity charge	=	Tk.	15,000.00
Depreciation of A/c	=	Tk.	4,500.00
Insurance	=	Tk.	22,000.00
Interest on capital	=	Tk.	3,00,000.00
Damarage	=	Tk.	25,000.00
Total	=	Tk.	5,10,500.00

Quantity of goods in a year (1988-89) = 1,50,000 kg.

$\therefore$ Holding cost per unit per year $= \text{Tk.}\dfrac{5,10,500.00}{1,50,000.00}$

$= \text{Tk. } 3.40\text{/kg./year}$

The ordering costs and holding costs are shown in Table 4.2.

Table-4.1 : Approximate variable cost per kg. & per packet, selling price per packet and approximate net profit per packet for each of the products of Mimi (For 1988-89).

Sl. No.	Name of Products	Total variable cost Tk./packet	Total variable cost Tk./kg.	Price Tk./ packet	Net profit Tk./ packet
1	Orange chocolate	85.936	94.54	109.38	14.41
2	Large chocolate	85.936	94.54	109.39	14.41
3	Nut chocolate	85.936	94.54	109.38	14.41
4	Pineapple chocolate	85.936	94.54	109.38	14.41
5	Almond nut small choco	105.82	93.54	135.42	10.66
6	Milk medium choco	101.785	89.60	119.79	7.81
7	Block chocolate	90.14	90.14	154.00	8.21
8	Picnic Delight	67.63	74.40	93.75	13.12
9	Wafer cream biscuit	33.51	111.70	43.75	16.12
10	Tea time Biscuit	18.40	81.07	22.92	2.32
11	Lucky-Dip	17.08	75.25	20.83	2.47
12	Chewing gum	34.395	86.42	47.92	7.94
13	Bubble gum	34.395	86.42	47.92	7.94
14	Ball gum	75.91	83.51	83.33	22.83
15	Icing Sugar (loose)	11.98	26.39	17.71	2.78
16	Icing sugar (packet)	10.97	27.43	18.75	3.40
17	Table salt	5.66	14.15	6.25	13.79

Table-4.2 : Ordering cost and Holding cost for both local and foreign purchased raw materials

Items	Imported raw materials	Local raw materials
Ordering cost per order (Tk./order)	29,750.00	29,700.00
Holding cost (Tk./kg/year)	3.40	3.40

4.2.2 SALES VOLUME AND PLANT CAPACITY DATA:

Plant Capacity Data:

i. The overall sales volume and also the sales volume of each of the products from July 1987 upto June 1989 are shown in Table-4.4 and Table-4.5.

ii. Actual production of the plant considering an average of 80% utilization as shown in Table 4.3.

Table-4.3 : Actual production of the Plant (1988-89)

	Name of Main Products	Actual production/year Kg.
1.	Chocolate Products	94,241.80
2.	Gum Products	37,202.32
3.	Sweets	8,217.88
	Total	1,39,662.00 Kg.

Sales Volume Data:

The actual sales data of period 1987-1989 were collected from the sales department. The data were available in readily usable form as shown in Table 4.4 and Table 4.5.

Table-4.4 : Actual Sales Volume of various products of Mimi (monthwise) during the season 1987-1988.

	Products		Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
1.	Orange Chocolate	(Box)	1849	2605	2208	2534	2106	2456	2955	2939	2321	1962	2850	2171
2.	Large chocolate	"	142	384	302	160	94	117	231	195	37	46	133	70
3.	Nut chocolate	"	1168	1026	1506	1270	1754	1662	1760	1988	1761	1372	1800	1561
4.	Pineapple chocolate	"	222	309	250	456	196	274	397	333	131	118	251	126
5.	Almond nut small choco	"	00	00	00	00	00	00	00	00	176	145	237	156
6.	Milk medium choco	"	399	425	438	334	234	264	405	463	416	143	280	243
7.	Block chocolate	(Kg.)	760	450	1015	20	260	450	00	673	60	480	20	430
8.	Picnic Delight	(Box)	281	475	297	284	244	317	312	452	290	270	379	492
9.	Wafer cream biscuit	"	169	222	546	1800	873	1471	2677	2076	1014	588	718	980
10.	Tea Time biscuit	"	413	532	430	199	431	456	272	362	285	474	274	467
11.	Lucky Dip	"	136	81	88	250	65	78	116	181	137	145	107	126
12.	Chewing gum	"	3066	3874	5469	4554	1749	4911	4280	6896	5920	4018	4680	4129
13.	Bubble gum	"	3231	3672	2879	2181	2033	1574	2929	4283	4578	2427	3502	3143
14.	Ball gum	"	00	48	32	25	00	62	117	40	36	00	00	00
15.	Icing sugar (Local)	Kg.	960	00	50	400	250	420	640	250	300	325	140	300
16.	Icing sugar (Packet)	(Box)	292	00	969	570	57	1051	460	630	967	315	873	714
17.	Table salt	"	00	00	00	00	00	549	378	407	406	444	206	512
	Overall	Kg.	7565	8379	9321	8609	6541	9089	10186	12573	10597	7870	9745	9108

Table-4.5 : Actual Sales Volume of various products of Mimi (monthwise) during the season 1988-1989.

	Products		Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
1.	Orange Chocolate	(Box)	2317	3392	2361	5158	3353	3591	4746	4039	4653	3147	3866	5334
2.	Large chocolate	"	51	111	156	00	89	84	33	105	00	46	189	68
3.	Nut chocolate	"	1497	2357	1965	3244	2082	2496	3230	2353	2809	2011	1885	3115
4.	Pineapple chocolate	"	160	224	280	160	226	170	411	146	237	156	142	242
5.	Almond nut small choco	"	72	66	00	255	296	98	130	260	57	00	00	00
6.	Milk medium choco	"	232	348	203	595	119	679	211	635	662	139	190	426
7.	Block chocolate	(Kg.)	35	100	75	260	270	320	270	270	170	345	105	240
8.	Picnic Delight	(Box)	551	619	492	689	770	965	1065	898	1044	562	420	778
9.	Wafer cream biscuit	"	818	853	284	1367	1838	1931	2288	1453	2062	1105	1318	867
10.	Tea Time biscuit	"	392	417	350	379	300	402	236	213	221	330	224	00
11.	Lucky Dip	"	142	224	78	00	271	166	125	70	00	00	00	00
12.	Chewing gum	"	4406	6708	2982	5710	4285	3810	4376	5447	6933	4150	5798	4751
13.	Bubble gum	"	2658	4510	1994	4181	1413	2736	2492	3260	2408	2025	1858	3671
14.	Ball gum	"	00	00	00	00	126	34	25	31	00	00	00	00
15.	Icing sugar (Local)	Kg.	250	10	00	00	100	360	200	200	200	200	00	00
16.	Icing sugar (Packet)	(Box)	422	551	00	250	2377	1303	738	696	685	581	04	00
17.	Table salt	"	304	743	400	00	00	152	786	373	621	287	1741	399
	Overall Kg.		8730	11954	7492	14023	11002	11969	13164	12534	13786	9216	10306	13147

4.2.3 REQUIREMENTS OF RAW MATERIALS PER UNIT

The ten major basic ingredients out of the thirty three are consumed by various products. The annual consumption of these ingredients in the year 1988-89 is shown in Table-4.6. The direct requirement of these ingredients (gm/packet) are shown productwise in Table-4.7. Also given the standard weight of each product in Table-4.8.

Table-4.6 : Consumption of the main ingredients during the year 1988-89.

Name of the Main ingredients	Consumption per year Kg.	Rate, Tk. per Kg.	Amount Tk.	Percentage-wise
Crushed Sugar	65,572	25.25	16,55,693	26.32
Vegetable oil	22,581	39.92	9,01,434	14.32
Milk Powder	19,755	87.15	17,21,648	27.36
Liquid glucose	8,283	25.50	2,11,217	3.35
Cocoa Powder	6,645	124.00	8,23,980	13.09
Gum base	5,437	109.00	5,92,633	9.42
Soapstone powder	1,208	7.70	9,302	0.14
000 HI	897	140.05	1,26,163	2.00
Lecithine	479	124.41	59,593	0.94
Condensed milk	451	43.84	19,772	0.31
Chocolate flavour	88	821.80	72,318	1.15
Essence	75	636.56	47,742	0.75
Food colour	12	1817.00	21,804	0.34
Hyfoma	23	1197.74	27,548	0.44
Total			62,90,847	100%

Table-4.7 : Raw materials required per unit of each of the products (gm. per packet)

		Mass per packet (gm)									
Sl. No.	Name of the Products	Crushed sugar	Milk powder	Veg. oil	Cocoa powder	000 HI	Lecithine	Chocolate flavour	Liquid glucose	Gum base	Soap stone
1.	Orange chocolate	384.73	204.52	234.00	70.44	9.09	5.68	0.45	0.00	0.00	0.00
2.	Large chocolate	384.73	204.52	234.00	70.44	9.09	5.68	0.45	0.00	0.00	0.00
3.	Nut chocolate	384.73	204.52	234.00	70.44	9.09	5.68	0.45	0.00	0.00	0.00
4.	Pineapple chocolate	384.73	204.52	234.00	70.44	9.09	5.68	0.45	0.00	0.00	0.00
5.	Almondnut small choco	480.80	255.60	292.52	88.04	11.36	7.10	0.57	0.00	0.00	0.00
6.	Milk media chocolate	480.80	255.60	292.52	88.04	11.36	7.10	0.57	0.00	0.00	0.00
7.	Block chocolate	423.25	225.00	257.50	77.50	10.00	6.25	0.50	0.00	0.00	0.00
8.	Picnic Delight	235.65	63.36	75.64	16.00	2.00	1.29	0.10	226.55	0.00	0.00
9.	Wafer cream Biscuit	55.97	29.75	34.05	10.24	1.32	0.82	0.066	0.00	0.00	0.00
10.	Tea time biscuit	64.75	34.42	39.39	11.85	1.53	0.956	0.084	0.00	0.00	0.00
11.	Lucky Dip	199.32	40.71	49.79	14.02	1.80	1.13	0.090	24.01	0.00	0.00
12.	Chewing gum	189.77	00.00	00.00	00.00	00.00	0.00	0.00	75.90	53.60	6.31
13.	Bubble gum	189.97	00.00	00.00	00.00	00.00	0.00	0.00	75.90	53.60	6.31
14.	Ball gum	595.88	00.00	00.00	00.00	00.00	0.00	0.00	145.50	103.07	8.08
15.	Icing sugar (Loose)	454.00	00.00	00.00	00.00	00.00	0.00	0.00	0.00	0.00	0.00
16.	Icing sugar (pkt)	400.00	00.00	00.00	00.00	00.00	0.00	0.00	0.00	0.00	0.00
17.	Table salt	000.00	00.00	00.00	00.00	00.00	0.00	0.00	0.00	0.00	0.00

Table-4.8 : Piece and Packetwise standard weight of mimi products.

Sl. No.	Name of the Products	Pcs. per packet	Mass (gm) per pc.	Mass(Kg.) per pkt.
1.	Orange chocolate	24	37.57	0.909
2.	Large chocolate	24	37.57	0.909
3.	Nut chocolate	24	37.57	0.909
4.	Pineapple chocolate	24	37.57	0.909
5.	Almondnut small choco	96	11.56	1.136
6.	Milk media chocolate	48	23.33	1.136
7.	Block chocolate	1	1000.00	1.000
8.	Picnic Delight	24	37.57	0.909
9.	Wafer cream Biscuit	12	25.00	0.300
10.	Tea time biscuit	15	15.10	9.227
11.	Lucky Dip	22	10.13	0.227
12.	Chewing gum	20	19.79	0.398
13.	Bubble gum	20	19.79	0.398
14.	Ball gum	144	6.23	0.909
15.	Icing sugar (Loose)	1 pck	454.00	0.454
16.	Icing sugar (pkt)	"	400.00	0.400
17.	Table salt	"	400.00	0.400

4.2.4 LABOUR HOURS REQUIREMENTS PER UNIT

The Labour hour data were collected from the three product departments.

i. Labour-hours available Table 4.9. These were calculated from the number of labours available in each department of the factory, the number of working hours each day and total number of working days in a year.

ii. Direct labour-hours required, Table-4.10. These are the appriximate direct labour hours required for each packet of products. These were obtained from a stopwatch time study for each of the process of each of the products. Details of the time study are given in Chapter-5.

Table-4.9 : Total Labour-hours available during the year 1988-89 in each of the departments

Name of the Departments	Total available Labour-hr/yr.	
	Man-hr.	Man-min.
Chocolate department	36,148	21,68,880
Gum department	46,094	27,65,640
Sweets department	5,505	3,30,300

Table-4.10 : Direct labour-hours and direct machine hours required per unit

Sl. No.	Name of the Product	Direct Labour-hours required per packet (in man-min.)	Direct machine-hours required per packet (in machine-min/packet)
1.	Orange chocolate	6.50	29.73
2.	Large chocolate	6.50	29.73
3.	Nut chocolate	6.50	29.73
4.	Pineapple chocolate	6.50	29.73
5.	Almondnut small choco	22.72	48.22
6.	Milk media chocolate	16.04	42.27
7.	Block chocolate	6.52	187.40
8.	Picnic Delight	36.36	21.03
9.	Wafer cream Biscuit	10.46	2.09
10.	Tea time biscuit	8.85	1.80
11.	Lucky Dip	10.00	5.09
12.	Chewing gum	22.29	2.16
13.	Bubble gum	22.29	2.16
14.	Ball gum	191.80	64.40
15.	Icing sugar (Loose)	3.21	3.21
16.	Icing sugar (pkt)	3.42	3.42
17.	Table salt	9.60	1.56

4.2.5 MACHINE-HOURS REQUIREMENTS PER UNIT

The Machine-hours data were collected from the three departments.

i. Machine-hours available (Table-4.11. These were calculated from the number of machines available in each department separately, the number of working hours each day and total number of working days in a year (the year 1988-89). All the machines are considered to have an average of 80%utilization.

ii. Direct Machine-hours required (Table-4.10).These are the approximate direct machine hours required for each packet of products. These are obtained from a stopwatch time study for each of the process of each of the products. They indicate the standard time.

Table-4.11 : Total available machine-hours for each of the departments.

Number of departments	Total available machine-hrs/yr	
	Machine-hr.	Machine-min.
Chocolate department	12,41,856	7,45,11,360
Gum department	6,77,376	4,06,42,560
Sweets department	2,25,792	1,35,47,520

A percentage composition of ingredients of each of the products of mimi are given in Table-4.12 which were used to develope linear material constraint.

Table-4.12 : Ingredients composition in percentage in chocolate, gum and in sweets products

		Percent of		
Sl. No.	Name of the Ingredients	Chocolate products	Gum products	Sweet products
1.	Sugar	0.424	0.560	1.00
2.	Milk powder	0.225	-	-
3.	Cocoa powder	0.078	-	-
4.	Vegetable oil	0.258	-	-
5.	000 HI	0.010	-	-
6.	Lecithene	0.0063	-	-
7.	Chocolate flavour	0.0005	-	-
8.	Liquid glucose	0.420	0.224	-
9.	Gum base	-	0.180	-
10.	Ground nut	0.102	-	-
11.	Soap stone powder	-	0.020	-
12.	Essence	0.0065	0.0047	-
13.	Food colour	-	0.00023	-
14.	Hyfoma	0.0034	-	-
15.	Salt	-	-	1.00

Table-4.13 : Showing the scrap, process loss and overall output of gum products.

END PRODUCT : GUM

UNIT OF WEIGHT : KG

		INPUT			OUTPUT				
Date	Batch No.	Fresh Ingre-dients weight	Initial scrap weight	Total weight	Fresh Gum weight	Final scrap weight	Total weight	% of Scrap	% Average
15 Oct. 1989	1	23.564	4.535	28.091	21.95	4.27	26.22	16.29	
"	2	23.508	4.535	28.043	22.50	4.75	27.25	17.43	
"	3	22.940	4.535	27.475	21.38	4.40	25.78	17.07	
"	4	23.453	4.535	27.988	22.10	4.67	26.77	17.44	
"	5	23.972	4.535	28.507	23.05	5.45	28.50	19.12	17.65
"	6	22.773	4.535	27.308	22.00	4.70	26.70	17.60	
"	7	23.734	4.535	28.269	22.95	5.50	28.45	19.33	
"	8	23.792	4.535	28.327	22.20	4.05	26.25	15.42	
"	9	23.934	4.535	28.469	24.75	5.85	30.60	19.12	
"	10	23.699	4.535	28.234	22.23	4.82	27.05	17.81	
			Total	= 280.72	225.11		273.57		

$\therefore$ Total input = 280.72 kg.

Total output = 273.57 kg.

Process Loss = 7.15 kg.

$$\therefore \text{\% process loss} = \frac{7.15 \times 100}{280.72}$$

$$= 2.54$$

And % overall output of fresh gum (end product)

$$= \frac{225.11 \times 100}{280.72} = 80.20$$

Chapter — V

PRODUCTION SYSTEM STUDY AND DETERMINATION OF CAPACITIES & UTILIZATIONS OF THE VARIOUS FACILITIES OF THE PRODUCTION SYSTEM USING TIME STUDY METHOD

Chapter — V

PRODUCTION SYSTEM STUDY AND DETERMINATION OF CAPACITIES & UTILIZATIONS OF THE VARIOUS FACILITIES OF THE PRODUCTION SYSTEM USING TIME STUDY METHOD

Mention has earlier been made about the various problems and shortcomings in Operations management of the factory under current study. The fundamental primary problem which generates various other secondary problems is lack of planning to evolve organized, systematic and scientific production and sales programmes. There exists no relationship between these functions that as if they function isolately. In order to set production programmes, amongst other important factors, the capacity of the plant and its utilization need consideration. Thus in this chapter a consolidated study of the production system has been made to identify few problem areas, the Mimi factory has been encountering and also to assess the capacity of the system.

5.1 STUDY OF THE PRODUCTION SYSTEM : Problems identification Capacity and Utilization:

These two above terms namely the capacity of a production system and its utilization are very important primary factors which influence other primary and secondary factors. Following are few examples:

i. *Efficient and profitable operation of plant & machinery and resources.*

ii. *Balancing of production line, modernizing, rehabilitation and replacement of machineries.*

iii. Prepare a rationale and achievable production target.

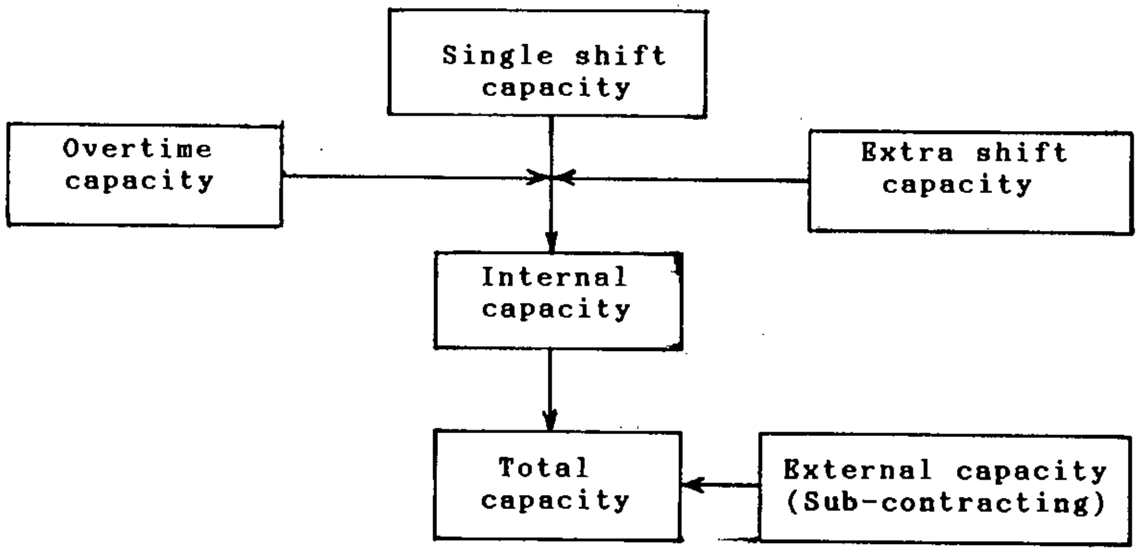
iv. Estimate and plan man-power requirement.

v. Identify weakness and strength.

vi. Give premiums, bonuses on production achievement. etc.

Unfortunately, the mimi is not quite aware of its capacity and utilization. The plant machineries are in the retiring ages and have become obsolete. Thus an effort is given to assess the capacity of the plant and its utilization. These are given in the following section.

Capacity can be expressed either on a single shift basis or multi-shift basis. This could be increased in two ways, either by adding an extra shift or by operating overtimes. Subcontracting is another way to increase capacity. Capacity could be subdivided into internal capacity and external capacity. Internal capacity is the maximum output capability within the organization and the external capacity is the output capability available from sub-contractors. Thus the total capacity is the sum of these internal and external capacities (diagramatically shown below).



Total capacity calculation in Mimi

OVER UTILIZATION OF MANUAL WORK:

A large man-power is being used for manual work and it could be said that in a food producing industry the man-power to output ratio would be the highest compared to any standards internationally. This requires a study to determine to what degree of "automation" would be required to achieve profit as well as to meet the acceptable ratio of manpower employed to output in a food producing factory.

PLANNING PRODUCTION PROGRAMMES:

Some introductory points on setting production targets have been highlighted in chapter-1. The factory, as has been found, does not use any analytical approach in setting production targets rather they resort to thumb rule and assumptions what are thc environmental influence on the demand, what share of the market the mini is holding; answers to these questions are not available to the factory. Also, the market trend of the demand is not known to the factory. In this regard of planning production, some introductory note has been given in Chapter-1.

The factory operates in multiple of eight hours such as 8 hrs.,16 hrs. and 24 hours per day. Thus from logic point of view a facility operating 8 hours a day needs to be nearly three times as large as 24 hours operation in order to produce the same daily output. Moreover, facilities operate for 5 days, 6 days or 7 days a week. The fewer the hours worked, the more the plant capacity would be needed for a given output.

Capacity is a major constraint in preparing a master schedule for a given output. It is influenced by

i. the number of scheduled working days per week as stated above and

ii. the number of shifts, the overtime policy, manpower levels and the state of availability of equipments.

In the present study it was found that a master schedule of production programme is never prepared for the purpose. The factory nromally operates on a single shift, but sometimes and very occassionally a double shift production is made in the chocolate section and overtime and sub-contracting policies are used in the Gum section. These are the symptoms of poor management of the factory. It is convinced that there never existed a clearly set production programme. Thus forward planning of production being absent, resources planning in terms of their capacities utilization was never formulated. This resulted in highly ineffective management of operations lack of scientific maintenance, balancing of production lines not accomplished and modernization programme of plant and machinery not taken. Moreover, due to a production master schedule not prepared, a full day's production solely becomes dependent on the worker's attitude, performance etc. While ascertaining the capacities of the various facilities, effort has also been given to assess man-power requirement in each of the departments such as chocolate and gum departments. A comparison has been made between these required manpower and available manpower in employment. This is shown in later part of this chapter.

PROCUREMENT OF RAW MATERIALS:

The raw materials could be categorized into two types depending on purchase system. One, is the locally purchased raw materials, such as sugar, ground nut, liquid glucose, vegetable oil, etc. and other, is foreign purchased raw materials, such as cocoa-powder, milk powder, 000-HI, gum base, flavour, food colours etc. These materials are purchased through international tendering system and all the local raw materials except sugar are purchased through local tender or spot quotation. The imported raw materials are purchased one or two times a year without any assessment of its proper requirement. The local raw materials are purchased at least six times a year. Sugar is purchased from mill gates of the sugar mills six to eight times a year depending upon requirement. Due to this unplanned and unscientific method of procurement, the factory possibly suffers from non-optimization and incurring loss. It has been revealed, without carrying an ABC analysis even, that huge amount of various flavours, food colours, lecethene are lying unused for more than five years in the store. Those raw materials have erossed the expiry dates long ago and are not fit for use. This is one example out of many similar examples could be given. In the present work effort has been given to prepare a schedule of procurement of some of the raw materials for the year 1989-90. The objective would be minimize the cost of inventory.

5.2 DETERMINATION OF CAPACITIES AND UTILIZATION USING TIME STUDY METHOD

An assessment of existing production capacity of the different products per shift, the utilization of the different facilities and utilization of manpower have been made in this section. Effort has been given to identify the different parameters in capacity measurement and utilization measurement of the facilities. In assessing the required manpower a time study was carried out.

5.2.1 Application of Work Measurement (time study) Method

Although technology, automation and computers are changing work habits and relationship, but still labor remains a predominant factor in the work environment. Work measurement is a tool for evaluating and planning labor utilization in production system. Work measurement finds its use in various purposes such as follows:

i. *Worker's performance*
ii. *Planning work force needs*
iii. *Make or buy decisions*
iv. *Equipment replacement decision,*
Etc.

It is the methodical analysis of tasks for the purpose of establishing standard times for their performance using specified methods under prescribed conditions.

Work measurement, known also as time study, determines the amount of time required to perform a unit of product. It establishes the amount of time required by a qualified worker, using a standard method and working at a standard work piece, to perform a specified operation. When properly used, work measurement can increase overall efficiency, which can make possible higher wages for labour lower prices for consumers, and higher profits for equity interest.

The output from work measurement is production time standards. A time standard usually includes the working time of an employee with allowances for personal delays, unavoidable delays, and fatigue. If management is to utilize labor inputs efficiently, it must formulate standard methods of work performance.

In the present work, a comprehensive stop-watch time study was performed. Three different kinds of time such as

i. *actual time*
ii. *normal time &*
iii. *standard time*

were measured

Actual time is the meantime it takes for the operation to perform each element in the operation.

Normal time is the time required to perform the operation by an operator who is working at 100% efficiency (i.e. 100% performance rating) with no delays (avoidable or unavoidable).

Standard time is the time required to perform the operation by an operator who is working at 100% efficiency with unavoidable dealys but no avoidable delays. The unavoidable delays are called allowances. The allowance factor included time lost because of fatigue, faulty materials, breaks for personal needs, machine breakdowns, maintaining the work area, supervisory directions, and so forth.

After computation of all the elemental times, average elemental times were determined. Once the elemental performance ratings were established, they were multiplied by the average elemental times. The total (summation) of the average elemental times adjusted for efficiency by the performance rating is the normal times for the operation. The inclusion of the allowance time with the normal times results in the standard time for the operation. The normal time and standard time were determined by using the following formula:

$$\text{Normal time} = \sum\left[(\text{average element time}) \times \frac{\text{Performance rating}}{100}\right]$$

Standard time = normal time + allowance time.

An observation sheet that was used in time study analysis is shown below:

Name of the item: Date : _____________

Observer :

Process element	Name of the process	Observations (Sec/process element) 1	2	3	4	5	6	7	8	9	10	(A) Mean time (sec)	(B) Rating	(A) x (B) Normal time (sec)

Standard time = Normal time + % allowance of normal time

= NT(1 + %A)

5.2.2 Capacity of Chocolate Section

In chocolate production it encounters some specific problems. While the capacity of this section is determined, the inherent problems were identified in the process.

Production capacity of chocolate (Moulded chocolate) Section:

Basic Data*

Total working time per shift excluding rest period of 1 hr, (hrs.) = 7

Average production time required per batch of large chocolate, (mins) = 46.7

Average number of batches produced per shift = 9

Freezer capacity in number of trays per cycle = 47

Number of moulds per tray = 4

* *Obtained from time study*

Number of large chocolates per mould = 6

Average weight of large chocolate per piece (gms) = 36.72

Average percentage of chocolate breakage during demoulding = 15.62

Average percentage of chocolate breakage during wrapping = 4.11

Calculations:

i. Weight of chocolate moulded per cycle:

Weight of chocolate moulded per cycle of casting & moulding

= (No. of trays used per cycle) x (No. of moulds/tray) x (No. of chocolates/mould) x (Wt. of chocolate/piece)

$$= \frac{47 \times 4 \times 6 \times 37.72}{1000} \text{ Kg.}$$

= 42.42 Kg.

ii. Weight of chocolate moulded per shift:

Weight of chocolate moulded per shift

= (Weight of chocolate moulded per cycle) x (No. of cycles per shift)

= 9 x 42.42 Kg.

= 381.41 Kg.

The production capacities are shown in Table-5.1 and Table-5.2, while including breakage and excluding breakages respectively. It has been observed from the study that the breakage during demoulding is higher during summertime than in winter time because of inefficiency of the humidity control device.

Table 5.1 : Chocolate Production capacity/shift
(when broken pieces are not packed manually)

Moulding* capacity Kg.	% Breakage			Net capacity	
	Breakage during demoulding		Breakage during wrapping		
	Manually wrapped	Manually not wrapped		Kg.	Equip. Box
381.41	11.41	4.21	4.11	306.157	337.63

* Moulding capacity can be interpreted as the capacity at the stage when the moulded chocolate just come out of the freezer

Table-5.2 : Chocolate production capacity/shift
(when broken pieces are packed manually)

Moulding* capacity Kg. (A)	Breakage during demoulding Kg. (B)		Quantity to automatic wrapping Kg. (E) = (A) - (B)	Breakage during auto wrapping Kg. (F)	Net capacity	
	Manually wrapable Kg. (C)	Manually not wrapable Kg. (D)			Kg. (N) = (A)-(D)-(F)	Equiv. Box
381.41	43.52	16.06	321.83	13.23	352.12	388.31

* Moulding capacity can be interpreted as the capacity at the stage when the moulded chocolate just come out of the freezer

REASON OF PRODUCTION BOTTLENECK IN PRODUCTION OF CHOCOLATE

The freezer is operating with a very poor efficiency. this is because of dramatic reduction of cooling capacity during its life. The equipment has long before (nearly 10 years from now) crossed its useful and economic life. Thus an obsolete and outdated equipment without proper automatic control devices is being used with low freezing capacity. Improper freezing caused the large breakage.

Automatic temperature control and humidity control devices are not available with the freezer. Thus the freezer can not maintain the required constant temperature level of -10^{o} but $+6^{o}C$ is actual. This causes the freezing operation becoming highly in efficient and taking lengthier freezing time for moulded chocolate. It has been found that this operation is the major bottleneck in the production line.

ACTUAL ACHIEVEABLE OUTPUT OF CHOCOLATE

The actual production of chocolate products of the factory have been found to be less than calculated production capacities as shown in Table-5.1 and Table-5.2. The resaons are as follows:

i. The tempering machine and the moulding machine are heated at the begining of the first shift as shown in bar chart in Figure 5.1. The heating time required is 60 minutes. During this period the empty moulds are

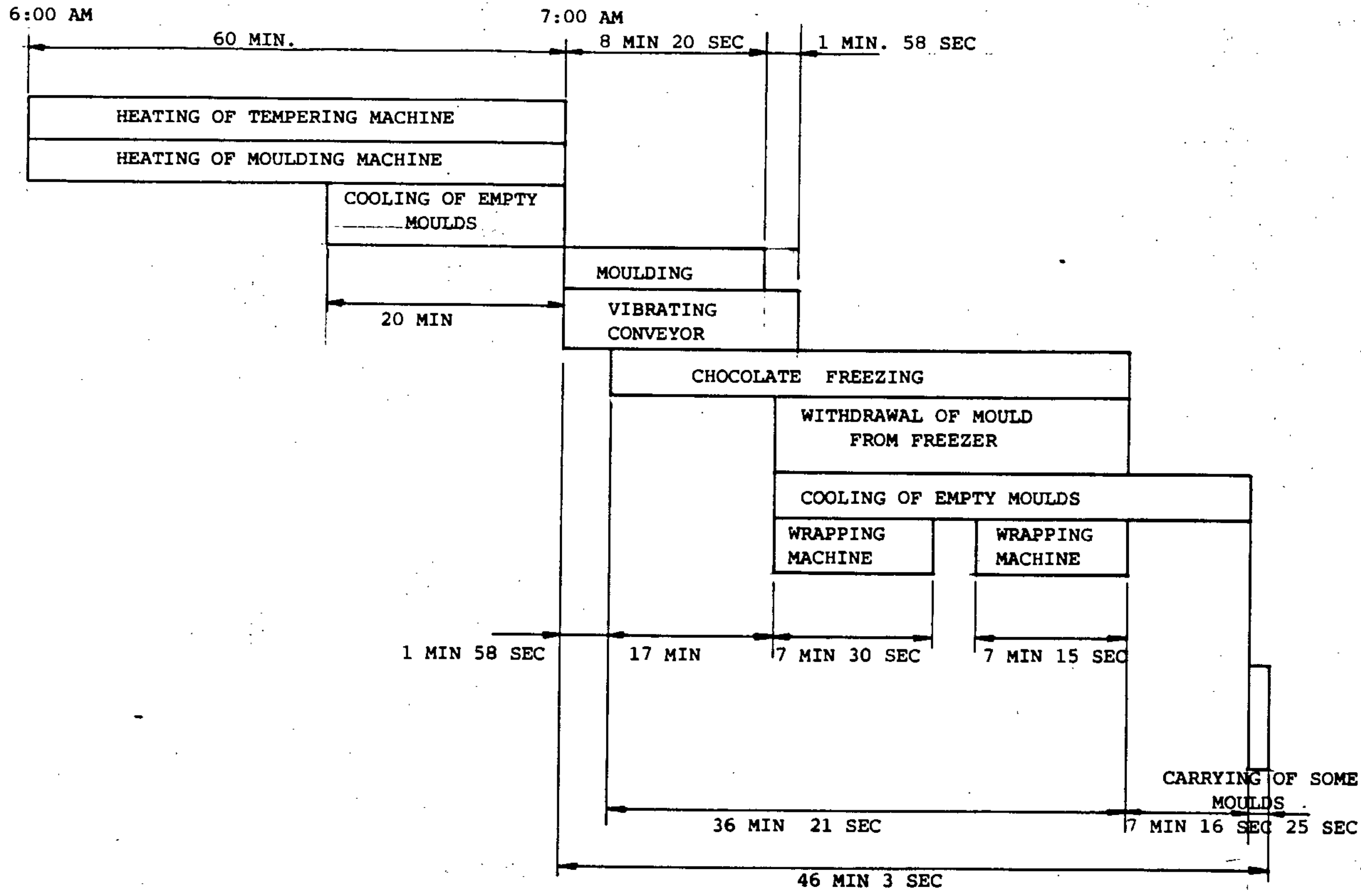


Fig. 5.1 :- Bar chart showing the preperation and making of the first batch of moulded chocolate

simultaneously cooled. The other downstream operations could not be started before the completion of these two operations. As such, the time available for production in the first shift is only six hours. Thus the number of batches (for large chocolates) could be produced in the first shift is (6 x 3600/2802 = 7.72) seven instead of nine as determined earlier. However, if all the operations could be performed effectively and the workers show positive attitude by putting extra efforts, eight batches could be manufactured per shift. Thus for a minimum of 7 batches to a maximum of 8 batches the reduction from the capacity would be by {(9-8)/9 x 100} = 11.11% and a maximum of {(9-7)/9 x 100} = 22.22% respectively.

ii. The freezer capacity for cooling of moulded chocolate is 47 trays with 188 moulds for recommendation per cycle. Currently the factory has only 175 moulds out of which 7 moulds are out of order. Thus only 168 moulds are available for one moulding freezing cycle. This resulted to a reduction of {(188-168)/188 x 100} i.e. 10.64% in production capacity.

From the reductions in production capacities as explained above a combined effect of a minimum of (11.11 + 10.64) i.e. 21.75% and a maximum of (22.22 + 10.64) i.e. 32.86% less from calculated capacities would be available.

MANPOWER UTILIZATION:

Utilization of man and machine is not viewed in isolation since these two are complementary to one another. An example could explain this interrelationship. During one hour of heating of the conching machine and cooling of the moulds in the freezer, rest of the workers in the downstread production line along with the machine are in idle state. This results in the loss of labour-hours which stand at (1 x 13) = 13 labour-hours. The effect of this idle and non-productive hours production of two batches of chocolate is lost. Under this bottlenecking condition the restriction could be released and productivity increased if one or two workers with the responsibility of heating the conching machine and tempering machine one hour before the normal working shift starts. This arrangement would increase the chocolate production to maximum of {(10-8)=2/7 x 100} = 28.52% and a minimum of (2/8 x 100) = 25%.

5.2.3 Calculation of Production Capacity per Shift and Percentage Utilization of Different Facilities:

Production Capacity Calculation:

Production capacity per shift for each of the facilities in each department were calculated. Sample calculations for one or two of such facilities are presented below:

i. Capacity of the chocolate Department

A batch of 42.453 Kg. of raw chocolate mixture is prepared with the following composition of raw material ingredients:

Raw materials	Amount/Batch, (Kg)	Percentage
Sugar	21.079	49.65
Milk Powder	10.868	25.60
Cocoa Powder	3.806	8.97
Vegetable oil	6.700	15.78
So, Total raw mixture =	42.453 Kg/batch	100.00

It has been found that on average, eight batches are produced per shift.

Thus raw mixture, produced would be

= 42.458 kg/batch x 8 batch/shift = 339.624 kg/shift

Other raw material ingredients added per shift gross measurement basis:

Ingredients		Amoung in Kg.
000 HI	=	4.552
Vegetable fat	=	53.601
Lecethine	=	1.592
Vaniline	=	1.360
Antioxident	=	0.040
Raw mixture	=	339.624
Ttoal	=	400.769 Kg.

This liquid chocolate of approximately 400 kg. produced per shift is transferred to the tempering machine where 0.663 kg. of flavour is added.

ii. Sugar Crushing Machine:

From time study data, it was found that on average it runs for 7 hours per shift takes 719 secs. for crushing 30 kg of sugar. Thus the capacity of the crushing machine during the effective working hours per shift would be,

Amount of crushed sugar produced/shift

$$= \frac{30 \times 7 \times 3600}{719} \text{ kg.}$$

$$= 1051.46 \text{ Kg.}$$

In 400 kg. of liquid chocolate 21.079 x 8 = 168.632 kg. of crushed sugar is required. Thus for 1051.46 kg. of crushed sugar per shift the number of boxes of fresh chocolate produced would be as follows:

Amount of liquid chocolate produced per shift

$$= \frac{400 \times 1051.46}{168.632} = 2494.094 \text{ kg.}$$

Add flavouring agent (0.663 kg. per 400 kg. of liquid chocolate) = 4.134 kg.

Weight of flavoured fresh chocolate per 1051.46 kg. of crushed sugar per shift = 2498.228 kg.

Average weight of fresh chocolate/piece = 37.57 gm. and 24 pieces of fresh chocolate = 1 Box.

Thus, number of boxes of fresh chocolate produced per shift

$$= \frac{2498.228 \times 1000}{37.57 \times 24}$$

$$= 2770$$

Therefore, the capacity of the sugar crushing machine

= 2770 boxes of fresh chocolate/shift.

iii. Millenger Machine:

From time study it was found that in average the machine can mix 1 batch (42.453 kg) of raw mixture in 455 sec.

Total number of batches that can be produced during the effective working hours per shift

$$= \frac{1 \times 7 \times 3600}{455}$$

$$= 55.38$$

$$= 55$$

Thus, the capacity per shift $= 55 \times 42.453$ kg.

$= 2334.915$ kg.

It has been found that (42.453 x 8) i.e. 339.624 kg. of raw mixture produces 400.663 kg. of flavour added fresh chocolate.

Thus, 2334.915 kg. of raw mixture produces flavour added fresh chocolate

$$= \frac{400.663 \times 2334.915}{339.624}$$

$$= 2754.56 \text{ kg.}$$

And,

$$2754.56 \text{ kg. of fresh chocolate} = \frac{2754.56 \times 1000}{37.57 \times 24}$$

$$= 3054 \text{ Boxes.}$$

Thus,

Capacity of the Millenger machine = 3054 boxes of fresh chocolate/shift.

Similarly, the capacities of other facilities were calculated and these are given in Table-5.3.

Percentage Utilization Calculations:

In section 5.2.3 maximum capacity for the production of chocolate was calculated and found to be 381.41 kg of flavour-added chocolate per shift.

i. Utilization of Sugar Crushing machine:

Capacity of sugar crushing machine

= 1051.46 kg. of crush sugar/shift

400.663 kg. of flavour added chocolate contains

= 168.632 kg of crushed sugar

So,

381.41 kg of flavour added chocolate requires

$$= \frac{168.632 \times 381.41}{400.663}$$

= 160.528 kg of crushed sugar.

$$\text{So, } \% \text{ utilization} = \frac{160.528 \times 100}{1051.46}$$

$$= 15.27$$

ii. Utilization of the Millenger Machine:

Maximum capacity was calculated to be

= 2334.915 kg of raw mixture/shift

400.663 kg of flavour added chocolate contains

= 339.624 kg of mixture.

So, 381.41 kg. of flavour added chocolate contains

$$= \frac{339.624 \times 381.41}{400.663}$$

$$= 323.303 \text{ kg of mixture.}$$

Thus,

$$\% \text{ utilization} = \frac{323.303 \times 100}{2334.915}$$

$$= 13.85$$

Similarly, the percentage utilizations of all other facilities were calculated and they are shown in Table-5.3.

Table-5.3 : Production Capacity per shift and Percentage Utilization of Various Facilities

End Product	Facilities in sequential operation	Product	Number of Facility		Capacity		Utilization of the Facility	Max. capacity
			Number installed	Operative	Kg/shift	Equivalent number of boxes/shift	%	(Box)
Chocolate	Sugar crushing machine	Crushing sugar	1	1	1051.46	2770	15.27	
	Millenger machine	Raw mixture	1	1	2334.91	3054	13.85	
	Refining machine	Raw mixture	1	1	2377.37	3110	13.60	
	Conching machine	Chocolate	1	1	400.00	444	95.20	
	Stirring kettle machine	Chocolate	1	1	400.00	444	95.20	
	Tempering machine	Chocolate	1	1	2103.92	2249	18.13	407
	Moulding machine	Chocolate	1	1	2103.92	2249	18.13	
	Vibrating conveyor	Chocolate	1	1	2103.92	2249	18.13	
	Freezer	Chocolate	1	1	381.41	407	100.00	
	Wrapping machine	Finished choco	1	1	946.76	1050	38.89	
	Manual workers		3				90.00	

Table-5.3 : Production Capacity per shift and Percentage Utilization of Various Facilities (Contd.)

End Product	Facilities in sequential operation	Product	Number of Facility: Number installed	Number of Facility: Operative	Capacity: Kg/shift	Capacity: Equivalent number of boxes/shift	Utilization of the Facility %	Max. capacity (Box)
Picnic Delight	Oven	Core	2	1	265.01	638	100.00	638
	Cream preparation m/c	Cream	1	1	19.20	638	100.00	
	Conching machine	Chocolate	1	1	400.00	1299	49.16	
	Freezer	Picnic Delight	1	1	6216.34	7343	8.70	
	Manual workers		31				90.00	
Tea Time	Conching machine	Chocolate	1	1	400.00	3009	100.00	
	Freezer	Tea Time	1	1	3079.58	16002	18.81	3009
	Manual Workers		34				90.00	
Wafer Cream	Conching machine	Chocolate	1	1	400.00	2965	100.00	
	Freezer	Wafer Cream	1	1	3883.14	16645	17.82	2965
	Manual workers		41				90.00	

Table-5.3 : Production Capacity per shift and Percentage Utilization of Various Facilities (Contd.)

End Product	Facilities in sequential operation	Product	Number of Facility		Capacity		Utilization of the Facility	Max. capacity
			Number installed	Operative	Kg/shift	Equivalent number of boxes/shift	%	(Box)
Lucky Dip	Oven	Mixture	2	1	545.84	4198	89.11	
	Conching machine	Chocolate	1	1	400.00	3790	100.00	3740
	Freezer	Lucky Dip	1	1	4282.87	18076	20.69	
	Manual workers		40				90.00	
Cum (Any kind)	Sugar crushing machine	Crushed Sugar	1	1	1051.45	6675	24.52	
	Kneading machine	Gum	1	1	513.48	1636	100.00	
	Rolling machine	Fresh gum	2	1	532.00	1672	97.84	1636
	Cutting machine	Fresh gum	2	1	650.87	2046	79.97	
	Manual Workers		62			90.00		

Table-5.4 : Utilization of Various Facilities
(at the maximum production rate)

Facility involved	Number of Facility		% Utilization of each facility when each product is produced at its maximum capacity						
	Number installed	Operative	Choco	Pic. Del.	Tea Time	Wafer Cream	Lucky Dip	Gum	Total
Sugar crushing machine	1	1	15.27					24.52	39.79
Millenger machine	1	1	13.85						13.85
Refining machine	1	1	13.60						13.60
Conching machine	1	1	95.20	49.16	100.00	100.00	100.00		
Stirring kettle m/c	1	1	95.20	49.16	100.00	100.00	100.00		
Tempering machine	1	1	18.13						18.13
Moulding machine	1	1	18.13						18.13
Vibrating conveyor	1	1	18.13						18.13
Freezer	1	1	100.00	8.70	18.81	17.82	20.69		
Wrapping machine	1	1	38.89						38.89
Oven	2	1		100.00			89.11		
Cream preperation m/c	1	1		100.00					100.00
Keading machine	1	1						100.00	100.00
Rolling machine	2	1						97.84	97.84
Cutting machine	2	1						79.97	79.97
Manual workers	241		3	31	34	41	40	62	

Table-5.5 : Average Utilization of Individual Facilities During Study Period of 6 months (July'89-Dec'89)

			Average Production						
			Choco	Pic. Del.	Tea Time	Wafer Cream	Lucky dip	Gum	Total
			271 Boxex	143 Boxes	124 Boxes	122 Boxes	127 Boxes	329 Boxes	
			% of max. Production Capacity						
Facility			66.58	22.39	4.12	4.11	3.39	20.40	
Facility Involved	Number installed	Operative	% Utilization of each of the facility when each product is produced at its av. capacity						
Sugar Crushing machine	1	1	10.17					4.93	15.10
Millenger machine	1	1	9.22						9.22
Refining machine	1	1	9.05						9.05
Conching machine	1	1	63.38	11.01	4.12	4.11	3.39		
Stirring kettle	1	1	63.38	11.01	4.12	4.11	3.39		
Tempering machine	1	1	12.07						12.07
Moulding machine	1	1	12.07						12.07
Vibrating conveyor	1	1	12.07						12.07
Freezer	1	1	66.58	1.95	0.77	0.73	0.70		
Wrapping machine	1	1	25.89						25.89
Oven	2	1		22.39			3.02		25.41
Cream pre. machine	1	1		22.39					22.39
Kneading machine	1	1						19.67	19.67
Rolling machine	2	1						16.07	16.07
Cutting machine	2	1						16.07	16.07
Manual Worker*		48	5	14	4	4	4	17	90.00
Manual Worker**		28	2	7	2	2	2	13	90.00

* *No. of persons engaged by mimi at present.*

** *No. of workers required for 90% utilization (for average production during the 6 months of study period from July'89 to Dec.'89).*

5.3 CAPACITY UTILIZATION AND MAXIMUM PRODUCTION CAPACITY

5.3.1 Maximum Capacity

The maximum production capacities are shown in Table-5.3. It can be seen from this table that under the present conditions of the machines/equipment, the maximum capacities per shift are given in Table-5.6:

Table 5.6 : Maximum capacity per shift of the main products and their constraints.

Products	Maximum Capacity		Capacity constraint Facility
	Weight, Kg.	Boxes	
Chocolate moulded	381.41	407	Freezer
Picnic delight	265.01	638	Ovens
Tea Time	400.00	3009	Conching m/c
Wafer Cream	400.00	2965	Conching m/c
Lucky dip	400.00	3740	Conching m/c
Gum (any kind)	513.48	1636	Almost all related machines

From Table-5.4, it may be observed that some of the facilities of the chocolate section are in underutilization They are shown in Table-5.7 percentagewise:

Table-5.7 : Un-utilized percentage of capacity of the facilities in chocolate section.

Facilities of chocolate section	% Un-utilized
Sugar crushing machine	60.21
Millenger machine	86.15
Refining machine	86.40
Tempering machine	81.87
Moulding machine	81.13
Vibrating conveyor	81.13
Wrapping machine	61.11

The improvement of the utilization of these machines would depend on the increase of production volume. It is also observed from Table-5.5 under prevailing demand situation of the mimi products in the market, the utilization of the freezer and the conching machine are at their upper limits of production capacity. Thus, for any increase in the volume of production would require increase in the capacities of these machines/equipment. For example, if there is an increase in demand of products requring increased production the capacities of both the bottlenecking machines such as the freezer and the conching machine have to be increased. This would in effect improve the utilization of the underutilized machines and equipments mentioned above in Table-5.7. This means that marketing efforts have to be increased to be able to sell more products. This would justify in procuring both the freezing and the conching facilities with higher capacities.

5.3.2 Manpower Utilization:

The manpower utilization figures can be seen from Table-5.4 in the row of "Manual Workers". These figures, however, indicate that maximum number of workers are required for their 90% utilization on average when the production of the corresponding items will be done at its maximum capacity. Table-5.5 reveals that for the current average production (for a period of 6 months) the number of workers (in some cases) had been quite high compared to what was actually needed. Utilization of machine-man is also very poor. It is to be seen if these people are assigned for other tasks when they do not have to operate the machines.

5.4 DISCUSSION ON CAPACITY AND UTILIZATION OF FACILITIES

5.4.1 Chocolate Section:

From the present study on capacity and utilization of the facilities of the factory Table-5.3, Table-5.4 and Table-5.5, it is revealed that the factory as a whole is heavily underutilized. Utilization level percentagewise ranges from 13.60 for refining machine to 100 for cream preparation machine. This fluctuating utilization levels in the sequential operation line as well as for the overall production system evolve three issues. These are, *i. production imbalance,*

ii. restricting increase in production, and

iii. increase in indirect cost items of depreciation cost etc. due to high underutilization.

Thus, imbalancing the sequential production line the capacities of the bottlenecking facilities must be increased. This is also required for increasing the production level. In this respect the freezer and conching machines are the two restricting facilities whose capacities must be increased to balance the production line and/or increasing overall production.

From Table-5.3 following information are extracted. These are relative production capacities of some facilities with respect to the most critical facility of conching machine and stirring kettle (Production Capacity = 381 kg/shift):

Let, Y = 381 kg/shift.

Name of facility	Production capacity, X (Kg/shift)	Ratio, X/Y
Sugar crushing machine	1051	2.75
Conching machine	400	1.05
Stirring kettle	400	1.05
Freezer	381	1.00
Moulding machine	2104	5.52
Wrapping machine	947	2.25

From the above information it is evident that the production of chocolate products could be increased by a minimum of about 2.25 times the current production level. This would require increasing the capacities of the conching, stirring and freezing facilities. Thus, additional conching machines should be installed. Also, it would required installation of a large capacity freezer with at least three times the present capacity with automatic temperature and humidity control devices.

For continuous operation, the following suggestive measures are proposed:

: Installation of a continuous freezing tunnel through which the moulding trays will pass.

: Tunnel should be designed so that the chocolate materials become sufficiently cooled.

: The trays when come out of the tunnel could be demoulded manually.

: The trays containing empty moulds could be loaded on a return conveyor.

: These empty moulds could be reused for casting chocolate material without further cooling.

Additional Facilities:

i. Two additional storage cum stirring kettle would be required to increase capacities. The existing kettle has a storage capacity of 400 kg of liquid chocolate, comparable to the existing capacities of the freezer and conching machines.

ii. For production of the "Picnic Delight", separate arrangement such as the roller and cutter arrangement could be installed so that the core could be given regular shape with increased production rate. Currently, the core is made manually using a very crude and highly time consuming method. Moreover the cores take highly irregular shapes.

iii. Presently, the molten mixture of chocolate is transferred from the conching machine to the storage kettle manually using a bucket. This operation takes about 3 and a half hours. A gear pump may be installed for the above operation. This would save time of manual operation and perform efficiently.

5.4.2 Gum Section:

It can be seen from Table-5.3 that the capacities of the existing gum making facilities are highly under-utilized. Thus marketing effort along with brand redesigning and proper merchandising should be given to create demand of gum products. The existing capacity of the gum section would permit increasing production level by two times the present level.

At present, the breaking and wrapping operations are performed entirely manually. In food processing production system human-handling should be kept as low as possible. Thus, automatic machine should replace human operation.

In the gum section, one automatic wrapping machine of desired capacity must be installed. This would make the wrapping operation very efficient with minimum human handling.

Scrap Reduction in the Gum Section:

The scrap during cutting operation is about 17%; as shown in Table-4.13 this scrap requires considerable rework. Scrap results from the poor quality rolling operation before the final cutting operation. The output after rolling operation is found to be mostly of poor quality. The stocks coming out of the roller are of irregular shape and thereby rejections occur at the cutting stage. This scrap could be reduced as follows:

Modernization of the existing rolling operation along with the cutting operation. Thus automatic cutting cum wrapping machine could be installed for the purpose.

Chapter – VI

FORECASTING DEMANDS USING WINTERS' METHOD

Chapter — VI

FORECASTING DEMANDS USING WINTERS' METHOD

The chapter is primarily concerned with the estimation of the future demand of the Mimi-products. The data used were the actual sales volumes of the past two years presented in Table-4.4 and Table-4.5 in Chapter-4.

6.1 WINTERS' METHOD FOR FORECASTING

Winters' method of forecasting could be used to forecast a seasonal time series represented by the model

$$x_t = (b_1 + b_2 t)c_t + \varepsilon_t$$

where

b_1 = permanent component

b_2 = linear trend component

C_t = a multiplicative seasonal factor

ε_t = error component.

The scheme of the forecasting process could be viewed as of the following three phases:

i. Initialization phase for estimating parameters.

ii. Determination of optimum values of smoothing constants.

iii. Updating of the estimate of the parameters and estimation of forecast values for future periods.

A computer program in FORTRAN-IV language was used for the Winters' method of forecasting in an IBM 4331 computer at BUET Computer Centre. The computer program accomplishes the above phases and is capable of optimizing the smoothing constants over specified ranges. It is capable of estimating the starting values of the model parameters from the imput data.

6.1.1 Initialization Phase for Parameters:

In the initialization phase the starting values of the above model parameters are estimated. The forecasting model has three components, namely, (i) Trend component, (ii) permanent components, and (iii) Seasonality factor. These are estimated using historical data of various time periods. The method is explained in the following steps:

Steps:-

i. For the two years' the average demands for each of the two time periods such as period-1 (July 1987 to June 1988) and period-2 (July 1988 to June 1989) have been calculated as given below:

$$\bar{x}_1 = 9131.91 \text{ kg}$$

$$\bar{x}_2 = 11443.58 \text{ kg.}$$

Here, $\bar{x}_1$, $\bar{x}_2$ are the respective averages of total sales of mimi products during the two time periods called seasons.

ii. The trend component has been estimated using the following equation:

$$\hat{b}_2(0) = \frac{\bar{x}_m - \bar{x}_1}{(m-1)L} = \frac{\bar{x}_2 - \bar{x}_1}{(2-1) \times 12}$$

where,

$\hat{b}_2(t)$ = Trend component at the end of t^{th} period.

m = number of season = 2

L = Length of a season = 12 months.

Thus,

$$\hat{b}_2(0) = \frac{11443.58 - 9131.91}{1 \times 12}$$

$$= 192.639$$

iii. The initial permanent component $\hat{a}_1(0)$ becomes

$$\hat{a}_1(0) = \bar{x}_1 - \frac{L}{2}\hat{b}_2(0)$$

where, $\hat{a}_1(t)$ = permanent component at t^{th} period.

Thus,

$$\hat{a}_1(0) = 9131.91 - \frac{12}{2}(192.639)$$

Thus, $\hat{a}_1(0)$ = 7976.07.

iv. Initial estimates $\hat{C}_t(0)$ of the seasonal factors may be computed using the following equations:

a. Seasonal factors $\hat{C}_t$ are computed for each period $t = 1,2,3,4, \ldots mL$, as the ratio of the actual observation to the average seasonally adjusted value for that season, further adjusted by the trend; that is,

$$\hat{C}_t = \frac{x_t}{\bar{x}_i - [(L+1)/2 - j]\hat{b}_2(0)} \quad \ldots \quad (6.1)$$

where,

$t = 1,2,3, \ldots mL$

x_t = Actual value for t^{th} period.

$\bar{x}_i$ = average for the i^{th} season

j = Position of period t within the season. (where $t = 1$ to $t = L+1$, then $j=1$, etc.)

b. Equation (6.1) will produce m estimates of the seasonal factor for each period. These should be averaged to produce a single estimate of the seasonal factor for each period within the season. This is accomplished by

$$\bar{C}_t = \frac{1}{m} \sum_{k=0}^{m-1} \hat{C}_{t+kL} \quad \ldots \quad \ldots \quad (6.2)$$

where, $t = 1,2, \ldots \ldots L$.

Finally, the seasonal factors $\hat{C}_t(0)$ should be normalized so that they add to L. This produces the initial estimates of the seasonal factors as

$$\hat{C}_t(0) = \bar{C}_t \frac{L}{\sum_{t=1}^{L} \bar{C}_t} \qquad \ldots \quad \ldots \quad (6.3)$$

where, $t = 1, 2, 3, \ldots \quad \ldots \quad L.$

Sample calculations:

Using equation (6.1), $\hat{C}_t$ could be calculated for $t = 1, 2, \ldots mL$. Thus for first season, $i=1$

$$\hat{C}_1 = \frac{x_1}{\bar{x}_1 - [(12+1)/2 - 1] \times \hat{b}_2(0)}$$

or,

$$\hat{C}_1 = \frac{7565}{9131.91 - [(12+1)/2 - 1] \times 192.639}$$

$$= 0.9371$$

$\hat{C}_2 = 1.0379$ and so on.

For season, $i = 2$

$$\hat{C}_{13} = \frac{x_{13}}{\bar{x}_2 - [(12+1)/2 - 1] \times \hat{b}_2(0)}, \quad t = 13$$

or,

$$\hat{C}_{13} = \frac{8730}{11443.58 - [(12+1)/2 - 1] \times 192.639}$$

$$= 0.8407$$

$\hat{C}_{14} = 1.1512$ and so on.

For the two seasons ($m = 2$), using equation (6.2)

$$\bar{C}_t = \frac{1}{2} \sum_{k=0}^{1} \hat{C}_{t+kL} \qquad \text{for } t = 1, 2, \ldots, L.$$

Thus,

$$\bar{C}_1 = \frac{1}{2} (\hat{C}_1 + \hat{C}_{1+12})$$

$$= \frac{1}{2} (\hat{C}_1 + \hat{C}_{13})$$

or

$$\bar{C}_1 = \frac{1}{2} (0.9371 + 0.8407)$$

$$= 0.8889.$$

Similarly,

$$\bar{C}_2 = \frac{1}{2} (\hat{C}_2 + \hat{C}_{14})$$

$$= \frac{1}{2} (1.0379 + 1.1512)$$

$$= 1.0945 \quad \text{and so on.}$$

Finally using equation (6.3)

$$\hat{C}_1(0) = \bar{C}_1 . \frac{12}{\sum_{t=1}^{12} \bar{C}_t}$$

$$= \bar{C}_1 . \frac{12}{(\bar{C}_1 + \bar{C}_2 + \ldots + \bar{C}_{12})}$$

$$= 0.8889 \times \frac{12}{(0.889 + 1.0945 + 0.93805 + \ldots + 1.0998 + 1.1971)}$$

Thus,

$\hat{C}_1(0) = 0.889$

Similarly, $\hat{C}_2(0) = 1.0720$ and so on.

The computer program as mentioned earlier calculates the above initial seasonal factors and the initial permanent components and trend components. The output is show in Table 6.1. The output summarizes the parameter estimation process.

```
WINTERS'METHOD FOR FORECASTING A SEASONAL TIME   SERIES

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

THE FIRST 24 PERIODS OF DATA WHICH CORRESP    OND TO 2 SEASONS WILL BE USED
              INITIAL PERMANENT COMPONENT= 7976.0731
              INITIAL TREND COMPONENT=  192.6390
              INITIAL SEASONAL FACTOR FOR PERIOD  1 =     0.8399
              INITIAL SEASONAL FACTOR FOR PERIOD  2 =     1.0720
              INITIAL SEASONAL FACTOR FOR PERIOD  3 =     0.8989
              INITIAL SEASONAL FACTOR FOR PERIOD  4 =     1.1372
              INITIAL SEASONAL FACTOR FOR PERIOD  5 =     0.8630
              INITIAL SEASONAL FACTOR FOR PERIOD  6 =     1.0304
              INITIAL SEASONAL FACTOR FOR PERIOD  7 =     1.1223
              INITIAL SEASONAL FACTOR FOR PERIOD  8 =     1.2015
              INITIAL SEASONAL FACTOR FOR PERIOD  9 =     1.1292
              INITIAL SEASONAL FACTOR FOR PERIOD 10 =     0.7315
              INITIAL SEASONAL FACTOR FOR PERIOD 11 =     0.9059
              INITIAL SEASONAL FACTOR FOR PERIOD 12 =     0.9726
```

Table-6.1 : Initial permanent component, trend component of seasonal factors

OUTPUT OF THE INITIALIZATION PHASE

PERIOD	OBSERVATION	PERMANENT COMPONENT	TREND	SEASONAL FACTOR	FITTED MODEL	RESIDUAL
1	7565.0000	8178.9570	192.0462	0.8889	0.0000	0.0000
2	3379.0000	8355.2266	192.4459	1.0720	3974.7070	-595.7070
3	9321.0000	8602.3242	194.0854	0.8989	7683.3008	1637.6992
4	8609.0000	8759.5133	192.9315	1.1372	10003.5430	-1394.5430
5	6591.0000	8911.3945	191.7455	0.9630	7726.0937	-1135.0937
6	9089.0000	9094.3753	191.4916	1.0304	9379.4219	-290.4219
7	10186.0000	9279.3672	191.3026	1.1223	10421.5078	-235.5078
8	12573.0000	9500.7766	192.1967	1.2015	11379.1367	1193.8633
9	10597.0000	9683.9141	191.9190	1.1292	10945.2500	-348.2500
10	7370.0000	9831.5484	192.0934	0.7315	7218.4062	151.5937
11	9745.0000	10074.2422	192.7084	0.9059	9225.7578	519.2422
12	9108.0000	10259.2773	191.3782	0.9726	10005.0391	-897.0391
13	8730.0000	10432.2383	191.3107	0.8889	9290.3125	-560.3125
14	11954.0000	10639.3711	191.7354	1.0720	11388.4766	565.5234
15	7492.0000	10756.2617	189.5335	0.8989	9735.8711	-2243.8711
16	14023.0000	10937.3437	190.7848	1.1372	12447.8945	1575.1055
17	11002.0000	11225.2344	192.1939	0.9630	9646.7305	1355.2695
18	11969.0000	11423.3984	192.3770	1.0304	11763.9531	205.0469
19	13164.0000	11619.1914	192.4794	1.1223	13035.9375	128.0625
20	12534.0000	11770.2852	191.2373	1.2015	14191.1289	-1657.1289
21	13786.0000	11968.9375	191.4603	1.1292	13506.6016	279.3984
22	9216.0000	12149.3398	191.1235	0.7315	9503.8945	-287.8945
23	10306.0000	12311.5469	190.2609	0.9059	11179.1797	-873.1797
24	13147.0000	12532.2695	191.1747	0.9726	12159.1992	987.8008

SUM OF RESIDUALS=-1868.3934 AVERAGE RESIDUAL= -77.8499

VARIANCE=0.1036E+07 STANDARD DEVIATION= 1017.8452

MEAN ABSOLUTE DEVIATION= 302.3147

NUMBERS OF RESIDUALS EXCEEDING TWO STANDARD DEVIATIONS= 1

Table 6.2 : Initialization Phase for the entire 24-period

The quantities in the entire initialization phase for the 24-periods were calculated as shown in Table 6.2. The scheme is described in section 6.1.3.

6.1.2 Determination of Optimum Values of Smoothing Constants

The smoothing constants control the number of past realizations of the time series that influence the forecast. Small values of the smoothing constant give significant weight to many prior observation and result in a slow response of the forecasting system to changes in the parameters of the time series model. Larger values of the smoothing constant give weight to only the more recent historical data and cause the forecasting system to respond rapidly to parameter shifts.

A widely used technique to determine the optimum values of smoothing constants is to carryout a sequence of trials on a set of actual historical data using several different values and then to select the value of α , β and γ that optimize some measure of effectiveness, such as minimum sum of squared errors as used in the present work. The optimum values of α , β and γ using one set of data are shown in Table-6.3. The optimum values for thus set of data are α = 0.03, β = 0.03 and γ = 0.00.

1
0

SMOOTHING CONSTANT OPTIMIZATION ROUTINE

ALPHA	BETA	GAMMA	RESIDUALSUM OF SQUARES.
0.0000	0.0000	0.0000	0.1524952E+09
0.0000	0.0000	0.0100	0.1527205E+09
0.0000	0.0000	0.0200	0.1529468E+09
0.0000	0.0000	0.0300	0.1531737E+09
0.0000	0.0100	0.0000	0.1524952E+09
0.0000	0.0100	0.0100	0.1527206E+09
0.0000	0.0100	0.0200	0.1529468E+09
0.0000	0.0100	0.0300	0.1531737E+09
0.0000	0.0200	0.0000	0.1524952E+09
0.0300	0.0100	0.0300	0.1529546E+09
0.0300	0.0200	0.0000	0.1519933E+09
0.0300	0.0200	0.0100	0.1522470E+09
0.0300	0.0200	0.0200	0.1525016E+09
0.0300	0.0200	0.0300	0.1527574E+09
0.0300	0.0300	0.0000	0.1519946E+09
0.0300	0.0300	0.0100	0.1521496E+09
0.0300	0.0300	0.0200	0.1524058E+09
0.0300	0.0300	0.0300	0.1526628E+09
			...05E+09
0.3500	0.0100	[illegible]	0.1643620E+09
0.3600	0.0200	0.0000	0.1639573E+09
0.3600	0.0200	0.0100	0.1642979E+09
0.3600	0.0200	0.0200	0.1646399E+09
0.3600	0.0200	0.0300	0.1649837E+09
0.3600	0.0300	0.0000	0.1640865E+09
0.3600	0.0300	0.0100	0.1644290E+09
0.3600	0.0300	0.0200	0.1647729E+09
0.3600	0.0300	0.0300	0.1651186E+09

THE OPTIMUM SMOOTHING CONSTANTS ARE

ALPHA= 0.0300 BETA= 0.0300 GAMMA= 0.0000

Table.-6.3 : Smoothing constant optimization routine

The responses of the smoothing constants α, β and γ to the residual sum of squares of the least square criterion are different. Fig. 6.2 shows the responses of γ and β with respect to the residual sum of squares. It is observed from the figure that for the same changes in the values of γ and β, the residual sum of squares changes more in case of γ. It means that for the same increase in the values of γ and β keeping α constant, the value of γ may lead to more error in the estimation. No generalized conclusion can be drawn in this regard.

Fig. 6.3 shows series of sample curves showing the responses of α towards the residual sum of squares. It is observed from the curves that the minimum value of the residual sum of square occurs at $\alpha \doteq 0.03$ corresponding to the curve having $\beta = 0.03$ and $\gamma = 0$. This point refers to the optimum values of the smoothing constants. In the similar way, the optimum values of α, β and γ are found out for each of the products of Mimi and they are shown in Table-6.4.

The series of curves depicting the responses of α towards the residual sum of squares for each of the products of Mimi are not given due to space limitations.

Table-6.4 : Optimum values of smoothing constants α , β and γ for the various products.

Symbolic Name of Products	Name of products	Alpha	Beta	Gamma
Overall	Mimi-overall	0.03	0.03	0.00
Mimi-1	Orange chocolate	0.03	0.03	0.00
Mimi-2	Large chocolate	0.00	0.01	0.00
Mimi-3	Nut chocolate	0.05	0.03	0.00
Mimi-4	Pineapple chocolate	0.00	0.02	0.00
Mimi-5	Almond nut small choco	0.36	0.00	0.00
Mimi-6	Milk medium chocolate	0.00	0.00	0.00
Mimi-7	Block chocolate	0.18	0.00	0.00
Mimi-8	Picnic Delight	0.36	0.00	0.03
Mimi-9	Wafer Cream biscuit	0.00	0.01	0.00
Mimi-10	Tea time biscuit	0.28	0.00	0.00
Mimi-11	Luch Dip	0.10	0.00	0.00
Mimi-12	Chewing gum	0.00	0.00	0.00
Mimi-13	Bubble gum	0.00	0.00	0.00
Mimi-14	Ball rum	0.00	0.00	0.00
Mimi-15	Icing sugar (loose)	0.00	0.01	0.00
Mimi-16	Icing sugar (packet)	0.00	0.03	0.00
Mimi-17	Table salt	0.00	0.00	0.00

From Table 6.4 where the optimum values of the parameters were given, it is observed that the values of γ

in all cases except the product picnic delight are zero. This finding reveals that the seasonal effects have no influence on the prediction. Fig. 6.4 shows, as a sample, how the permanent component of the overall mimi sales varies with time for different values of α, when $\beta = 0.03$ and $\gamma = 0$. These variations for the individual products of Mimi are not given due to space limitations.

In Fig.6.2, as a sample, the residual sum of squares vs. smoothing constant α are depicted for the overall mimi sales, while α varies β and γ are kept fixed. Such variations for the individual mimi products are not shown considering space limitations.

6.1.3 Updating of the Estimate of the parameters and Estimation of Forecast Values for Future Periods

Let, the smoothing constants be $\alpha = 0.03$, $\beta = 0.03$ and $\gamma = 0.00$. The fitted model is given below as in eqn.(6.7)

$$\hat{x}_{T+\tau}(T) = [\hat{a}_1(T) + \hat{b}_2(T)\tau]\hat{c}_{T+\tau}(T+\tau - L) \quad \ldots (6.7)$$

where, τ = time period during which demand to be forecasted.

Using equation (6.7) a forecast for period-1 at July, 1990 at time T=0 is made as,

$$\hat{x}_1(0) = [\hat{a}_1(0) + \hat{b}_2(0)]\hat{C}_1(0)$$

$$= [7976.07 + 192.639] \times 0.8889$$

$$= 7261.16$$

Now, permanent component, trend component and seasonal factor may be computed as follows:

i. **Permanent Component:**

$$\hat{a}_1(T) = \frac{\alpha \cdot x_T}{\hat{C}_T(T-L)} + (1 - \alpha)[\hat{a}_1(T-1) + \hat{b}_2(T-1)] \quad \ldots \quad (6.4)$$

Thus, for T=1

$$\hat{a}_1(1) = \frac{\alpha \cdot x_1}{\hat{C}_1(0)} + (1 - \alpha)[\hat{a}_1(0) + \hat{b}_2(0)]$$

$$= \frac{0.03 \times 7565}{0.889} + (1 - 0.03)[7976.07 + 192.639]$$

$$= 8178.96$$

Thus, $\hat{a}_1(1) = 8178.96$

ii. **Trend Component:**

$$\hat{b}_2(T) = \beta\,[\hat{a}_1(T) - \hat{a}_1(T-1)] + (1 - \beta)\,\hat{b}_2(T-1) \quad \ldots \quad (6.5)$$

for = 0.03 and T = 1.

$$\hat{b}_2(1) = 0.03[\hat{a}_1(1) - \hat{a}_1(0)] + (1 - 0.03) \times \hat{b}_2(0)$$

$$= 0.03\,[8178.96 - 7976.07] + (1-0.03) \times 192.639$$

$$= 192.946$$

Thus,

$$\hat{b}_2(1) = 192.946.$$

iii. <u>Seasonal Factor:</u>

$$\hat{c}_T(T) = \gamma \frac{x_T}{\hat{a}_1(T)} + (1 - \gamma)\ \hat{c}_T(T - L) \qquad \ldots (6.6)$$

for $= 0.00$ and $T = 1$

$$\begin{aligned} \hat{c}_1(1) &= 0.00 + c_1(1 - 12) \\ &= \hat{c}_1(0) \\ &= 0.8889 \end{aligned}$$

Thus, $\hat{c}_1(1) = 0.8889.$

Using the above estimates, forecast for season-2 is obtained by the equation (6.7) for period, $T = 1$

$$\begin{aligned} \hat{x}_2(1) &= [\hat{a}_1(1) + \hat{b}_2(1) \times 1] \times \hat{c}_2(0) \\ &= [8178.96 \doteq 192.946]1.0720 \\ &= 8974.68 \end{aligned}$$

The estimated (fitted model) values of $\hat{x}_{T+\tau}$ (T) for 24-periods were calculated using equation (6.7) along with eqns. (6.4) to (6.6). These estimates are shown in Table-6.2. At the end of period-24, the estimates of the permanent component and trend component were found to be $\hat{a}_1 24)$ = 12532.2695 and $\hat{b}_2 24)$ = 191.1747 respectively. These are the initial values for prediction of x-values.

Using these values of the model parameters, a forecast simulation for July 1989 to June 1990 were performed. Thus, for period-24 (i.e. July 1989) forecasted demand was computed using equation (6.7) as follows:

$$\hat{x}_{25}(24) = [\hat{a}_1(24) + \hat{b}_2(24)]\ \hat{C}_{25}(13)$$
$$= [12532.2695 + 191.1747]\ 0.8889$$
$$= 11309.86$$

The values of model parameters were updated using equation (6.4), (6.5) and (6.6) as follows:

<u>For T = 25</u> and

for $\alpha = 0.03$

$$\hat{a}_1(25) = \frac{\alpha \cdot x_{25}(24)}{C_{25}(13)} + (1 - \alpha)[\hat{a}_1(24) + \hat{b}_2(24)]$$

$$= \frac{0.03 \times 11309.86}{0.8889} + (1 - 0.03)[12532.2695 + 191.1747]$$

$$= 12723.44$$

and for $\beta = 0.03$

$$\hat{b}_2(25) = \beta\ [\hat{a}_1(25) - \hat{a}_1(24)] + (1 - 0.03)\hat{b}_2(24)$$
$$= 0.03\ [12723.44 - 12532.2695] + (1 - 0.03) \times 191.1747$$
$$= 191.1747$$

and for $\gamma = 0.00$

$$\hat{C}_{25}(25) = \frac{\gamma \cdot \hat{x}_{25}(24)}{a_1(25)} + (1 - \gamma)\ \hat{C}_T(T - L) \quad \text{becomes}$$

$$= 0.00 + 1.0(0.8889$$
$$= 0.8889$$

predicted values of x-values for the forecasting periods were determined and presented in Table-6.5.

OUTPUT OF FORCASTING PHASE

1

LENGTH OF THE SEASION IS 12 PERIODS FOR ECAST LEAD TIME IS 1 PERIODS

0

PERIOD	PERMANENT COMPONENT	TREND	SEASONAL FACTOR	FORECAST
25	12723.4414	191.1746	0.8889	11310.2148
26	12914.5094	191.1744	1.0720	13944.5078
27	13105.7773	191.1742	0.8989	11780.4805
28	13296.9453	191.1740	1.1372	15121.6992
29	13488.1133	191.1738	0.8630	11640.2539
30	13679.2812	191.1736	1.0304	14094.4570
31	13870.4531	191.1736	1.1223	15566.2812
32	14061.6211	191.1734	1.2015	16834.3437
33	14252.7891	191.1732	1.1292	16093.8437
34	14443.9570	191.1731	0.7315	11238.6055
35	14635.1250	191.1729	0.9059	13257.9062
36	14826.2930	191.1727	0.9726	14419.9922

STANDARD DEVIATION= 2035.6904

FORECAST FOR THE NEXT 12 MONTHS=0.1653E+06

Table-6.5 : The forecast values for 12-periods of the overall factory

Table-6.6 : Forecasted sales volume of each of the products of Mimi for 12-periods (July, 89 - June, 90)

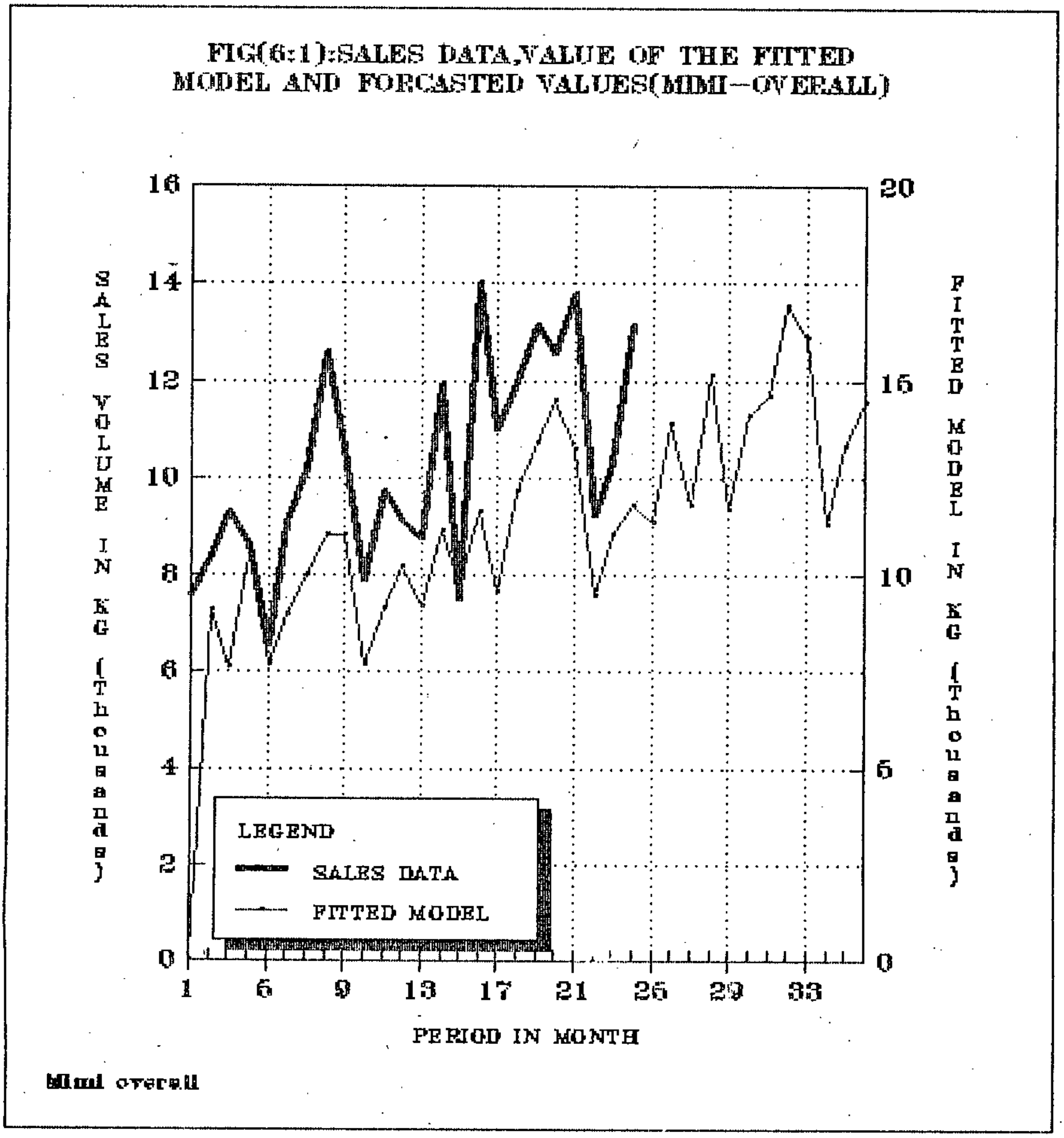
		Products																
Period	Overall	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
July, 1989	11310	4010	18	2530	141	20	368	126	1265	626	189	65	4328	2535	00	00	396	255
August	13844	5040	35	2903	195	19	447	88	1575	685	214	74	6094	3549	07	00	296	610
September	11780	4261	26	3131	197	00	375	150	1041	583	172	36	5007	2085	04	00	560	322
October	15122	6493	04	3684	202	52	466	56	1100	2174	131	45	5945	2780	03	00	463	00
November	11690	4655	02	3357	155	63	206	77	1022	1753	150	75	3434	1471	22	00	1308	00
December	14094	5114	00	3478	158	22	529	93	1259	2244	174	51	5102	1875	12	00	1305	976
January, 1990	15566	5931	00	4019	293	30	358	37	1273	3334	99	45	5022	2319	13	00	764	1153
February	16834	5748	00	3605	166	63	624	67	1320	2382	105	41	7199	3213	06	00	736	851
March	16093	5449	00	3626	135	65	609	14	1160	1962	90	19	7414	2947	02	00	923	1003
April	11289	4025	00	2670	99	60	161	18	763	1080	136	19	4721	1895	00	00	492	782
May	13258	5307	00	2964	135	99	270	00	782	1295	81	13	6022	2255	00	00	503	1508
June	14420	5557	00	3503	133	65	377	00	1150	1212	61	14	5108	2916	00	00	410	899
Total	165300	61590	85	39470	2039	588	4790	726	13710	19330	1602	497	65396	29840	69	00	8156	8359

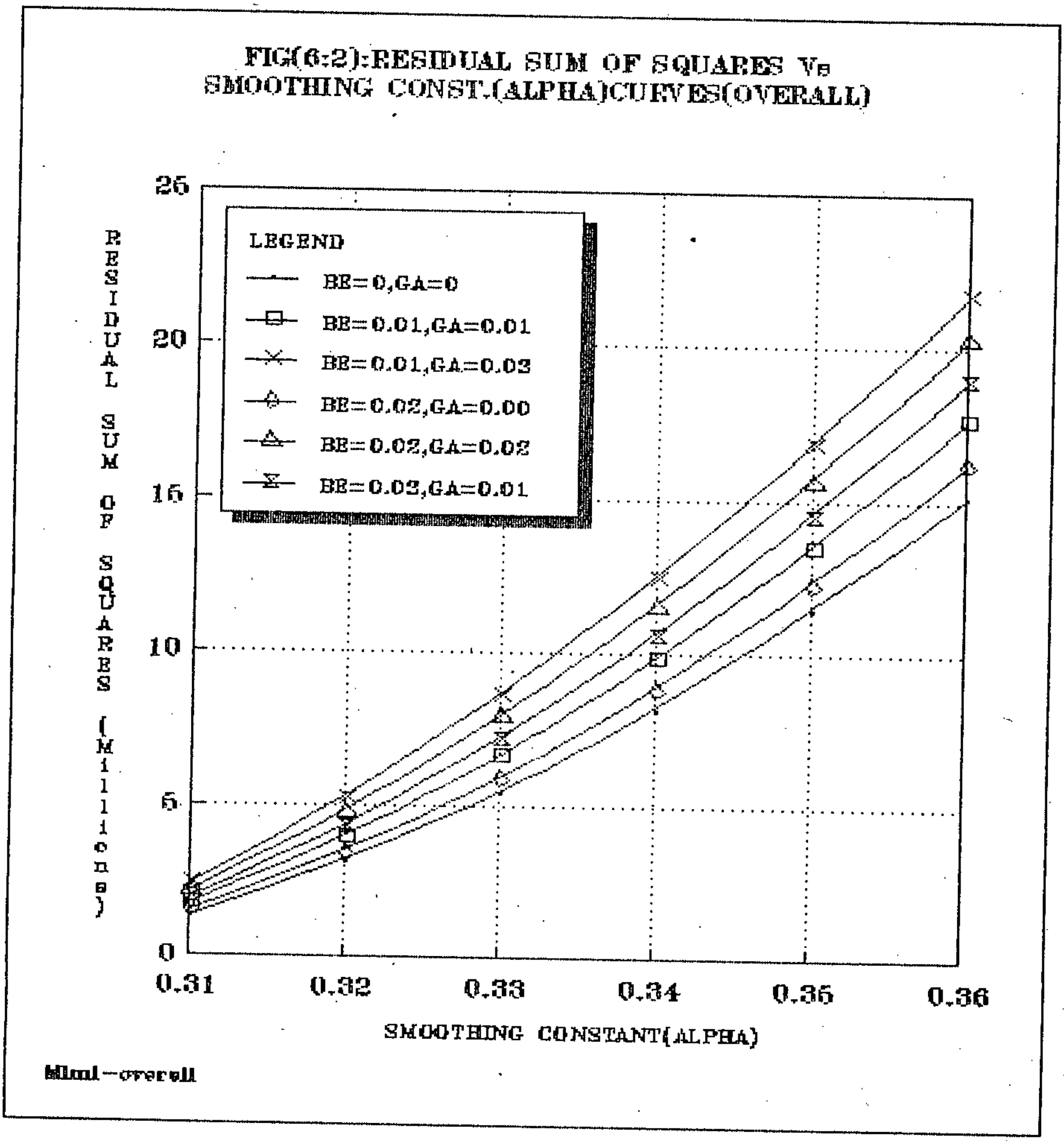
In Table-6.2, the output of the initialization phase is given. A consolidated output using the optimum values of α, β and γ forecasted values called the fitted models were given. These fitted models werecompared with the actual models and thereby the residuals and some basic statistics of average residual, variance, standard deviation etc. were given.

Computer output of the forecasting phase is shown in Table-6.5. The forecasted values for each of the next 12 periods along with its permanent components, trend components and seasonal factors were shown.

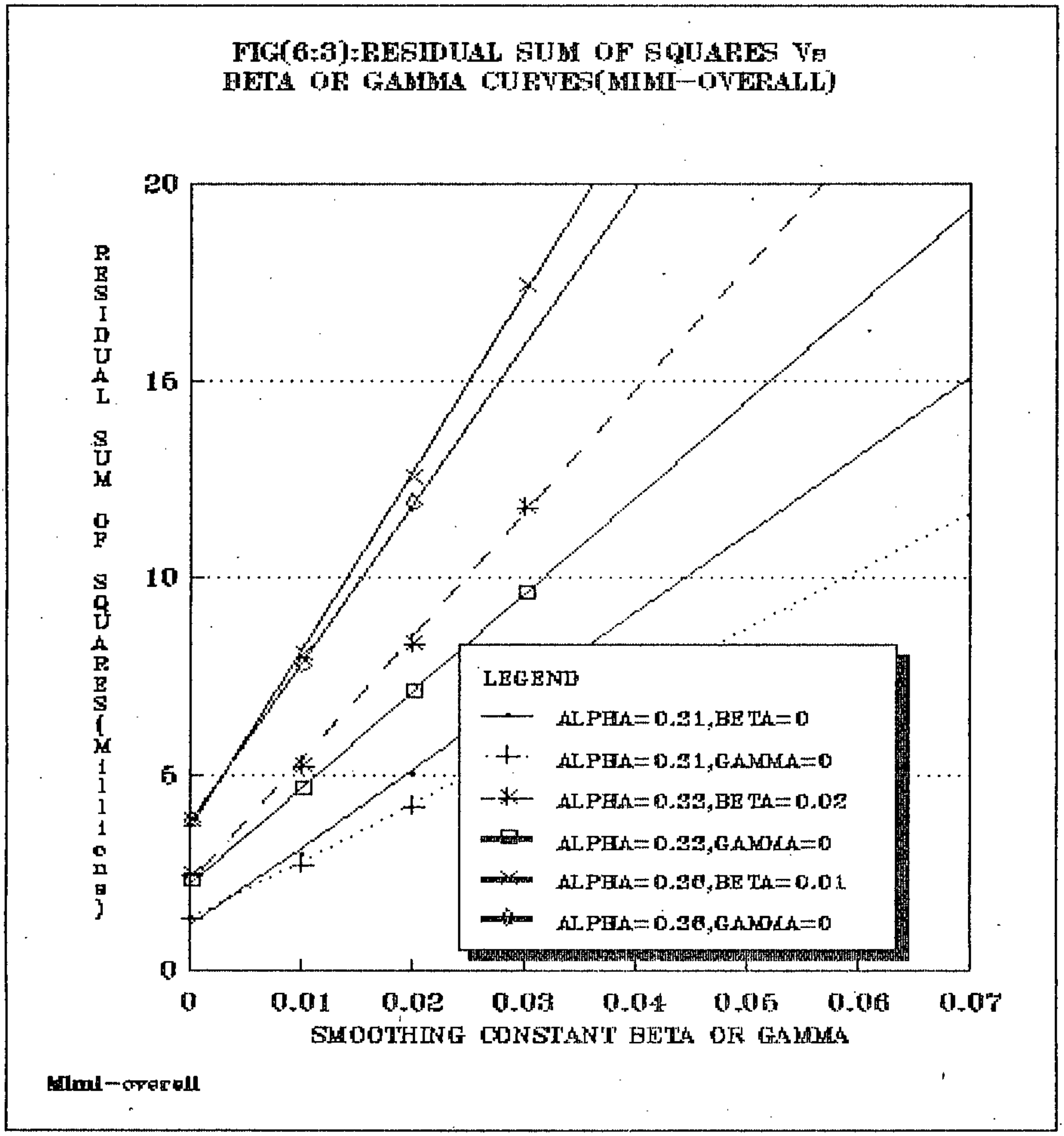
Pictorially the actual sales figures and the values of the fitted model (initialization phase) and the forecasted values for the next 12 periods for the overall sales are shown in Fig.6.1. These values for all the Mimi-products are also reflected pictorially as shown in Fig.6.5 through Fig.6.21.

The scheme of computation of the forecasted values using Winter's Method of forecasting, as used for the total overall sales were repeated for the seventeen different products under study. Considering space limitations detailed outputs for these seventeen products were not given instead the forecast values for the 12 periods. of each of the products were given in Table-6.6.

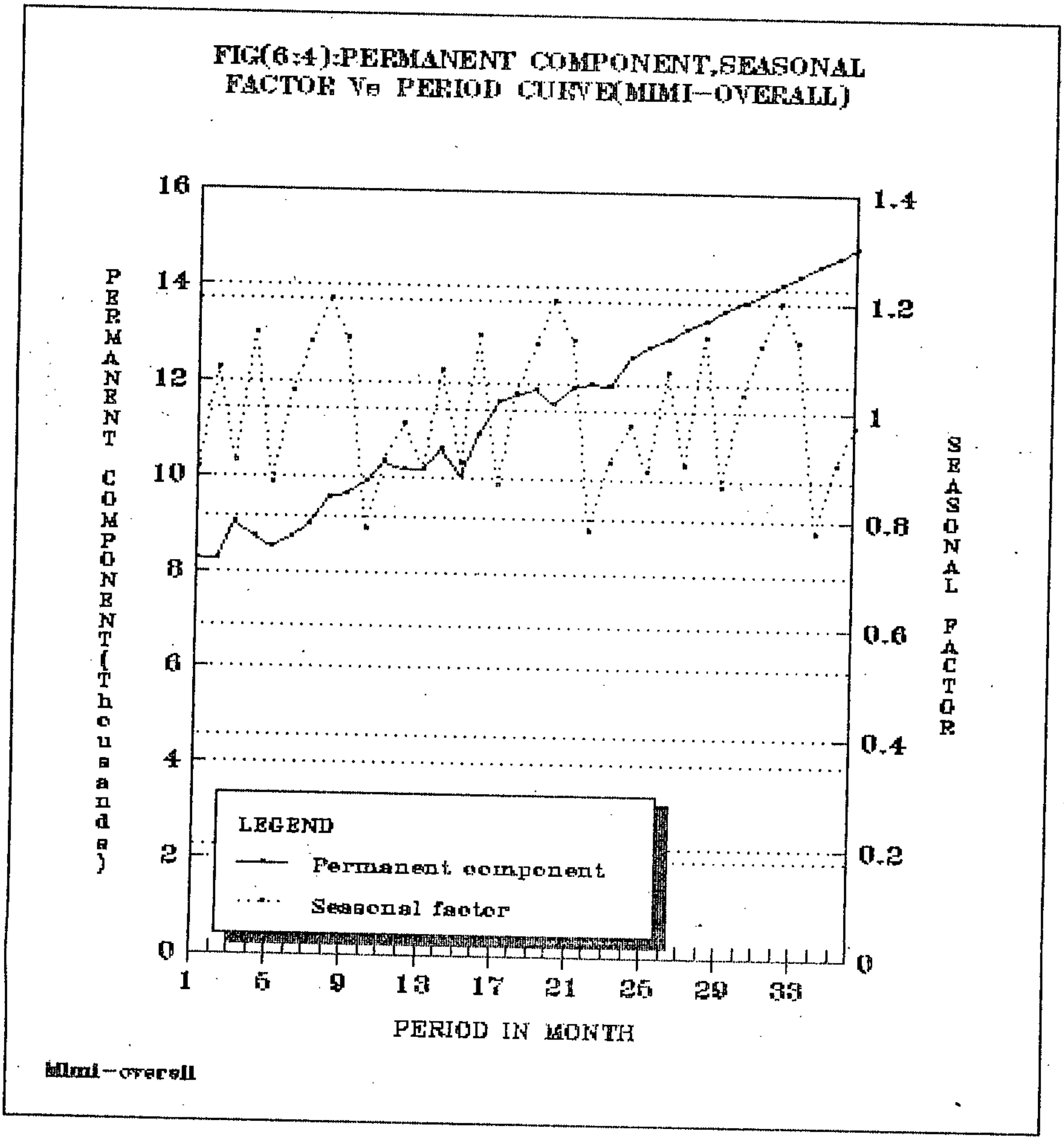

FIG(6:1):SALES DATA,VALUE OF THE FITTED MODEL AND FORCASTED VALUES(MIMI—OVERALL)
SALES VOLUME IN KG (Thousands)
FITTED MODEL IN KG (Thousands)
16
14
12
10
8
6
4
2
0
20
15
10
5
0
LEGEND
SALES DATA
FITTED MODEL
1
6
9
13
17
21
25
29
33
PERIOD IN MONTH
Mimi overall



FIG(6:2):RESIDUAL SUM OF SQUARES Vs
SMOOTHING CONST.(ALPHA)CURVES(OVERALL)
LEGEND
BE=0,GA=0
BE=0.01,GA=0.01
BE=0.01,GA=0.02
BE=0.02,GA=0.00
BE=0.02,GA=0.02
BE=0.02,GA=0.01
RESIDUAL SUM OF SQUARES (Millions)
25
20
15
10
5
0
0.31
0.32
0.33
0.34
0.35
0.36
SMOOTHING CONSTANT(ALPHA)
Mimi-overall

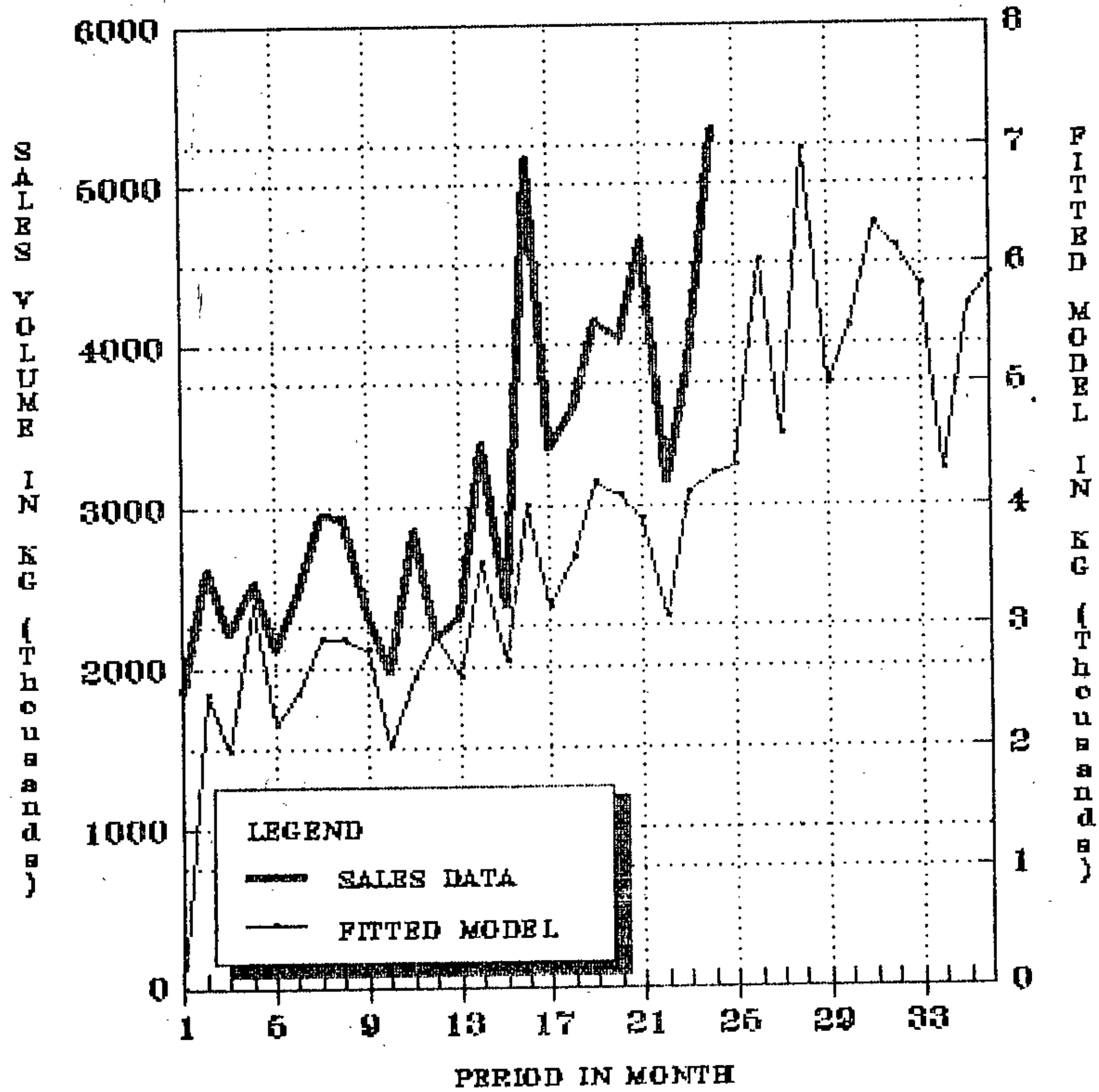


FIG(6:3):RESIDUAL SUM OF SQUARES Vs
BETA OR GAMMA CURVES(MIMI-OVERALL)
RESIDUAL SUM OF SQUARES(Millions)
20
15
10
5
0
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
SMOOTHING CONSTANT BETA OR GAMMA
LEGEND
ALPHA=0.21,BETA=0
ALPHA=0.21,GAMMA=0
ALPHA=0.23,BETA=0.02
ALPHA=0.23,GAMMA=0
ALPHA=0.26,BETA=0.01
ALPHA=0.26,GAMMA=0
Mimi-overall



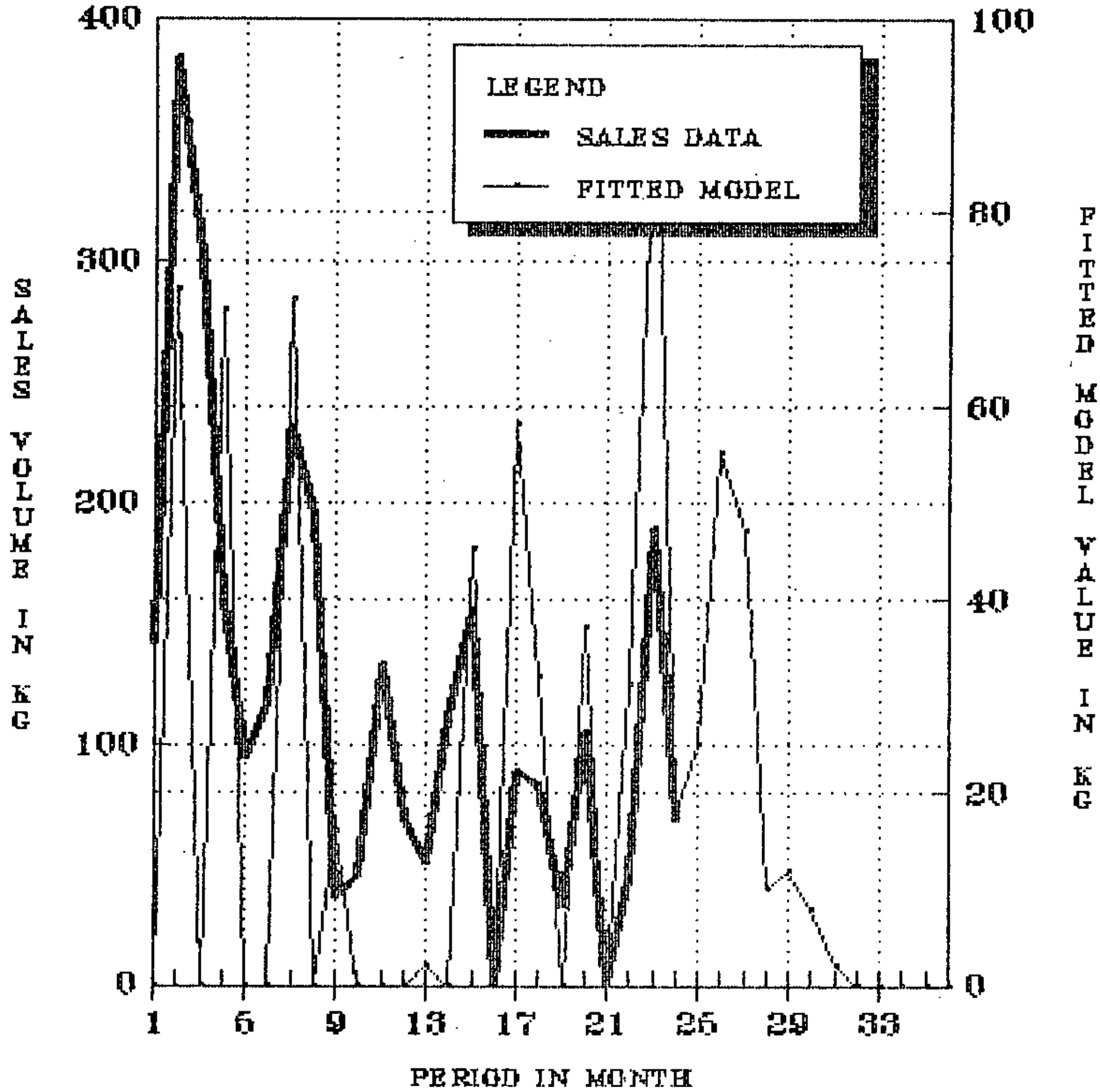
FIG(6:4):PERMANENT COMPONENT,SEASONAL FACTOR Vs PERIOD CURVE(MIMI-OVERALL)
16
14
12
10
8
6
4
2
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
PERMANENT COMPONENT(Thousands)
SEASONAL FACTOR
LEGEND
Permanent component
Seasonal factor
1
5
9
13
17
21
25
29
33
PERIOD IN MONTH
Mimi-overall

FIG(6:5):SALES DATA,VALUE OF THE FITTED MODEL AND FORCASTED VALUES(MIMI-1)



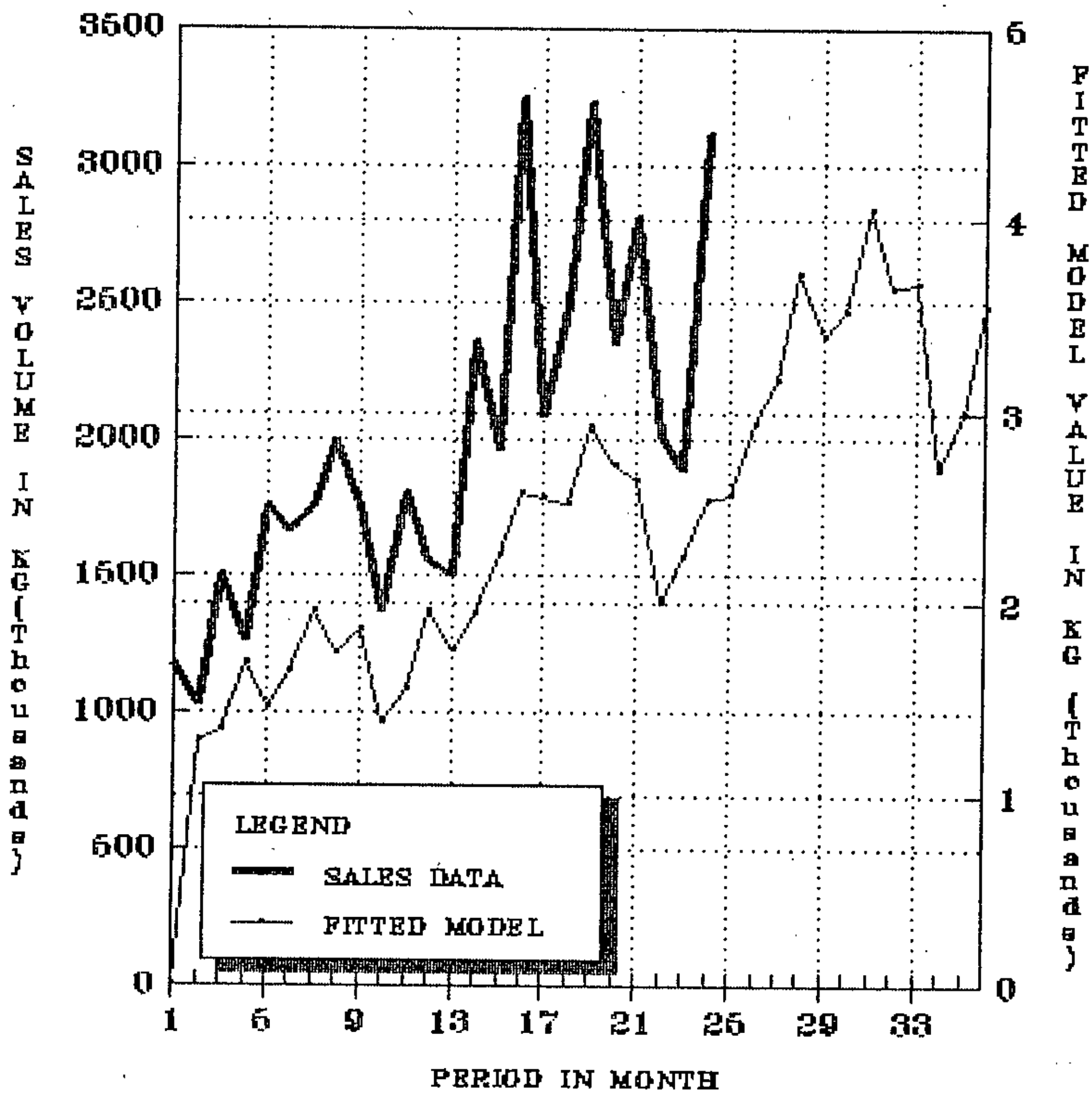
Mimi-1

FIG(6:6):SALES DATA;VALUE OF THE FITTED MODEL AND FORCASTED VALUES(MIMI–2)

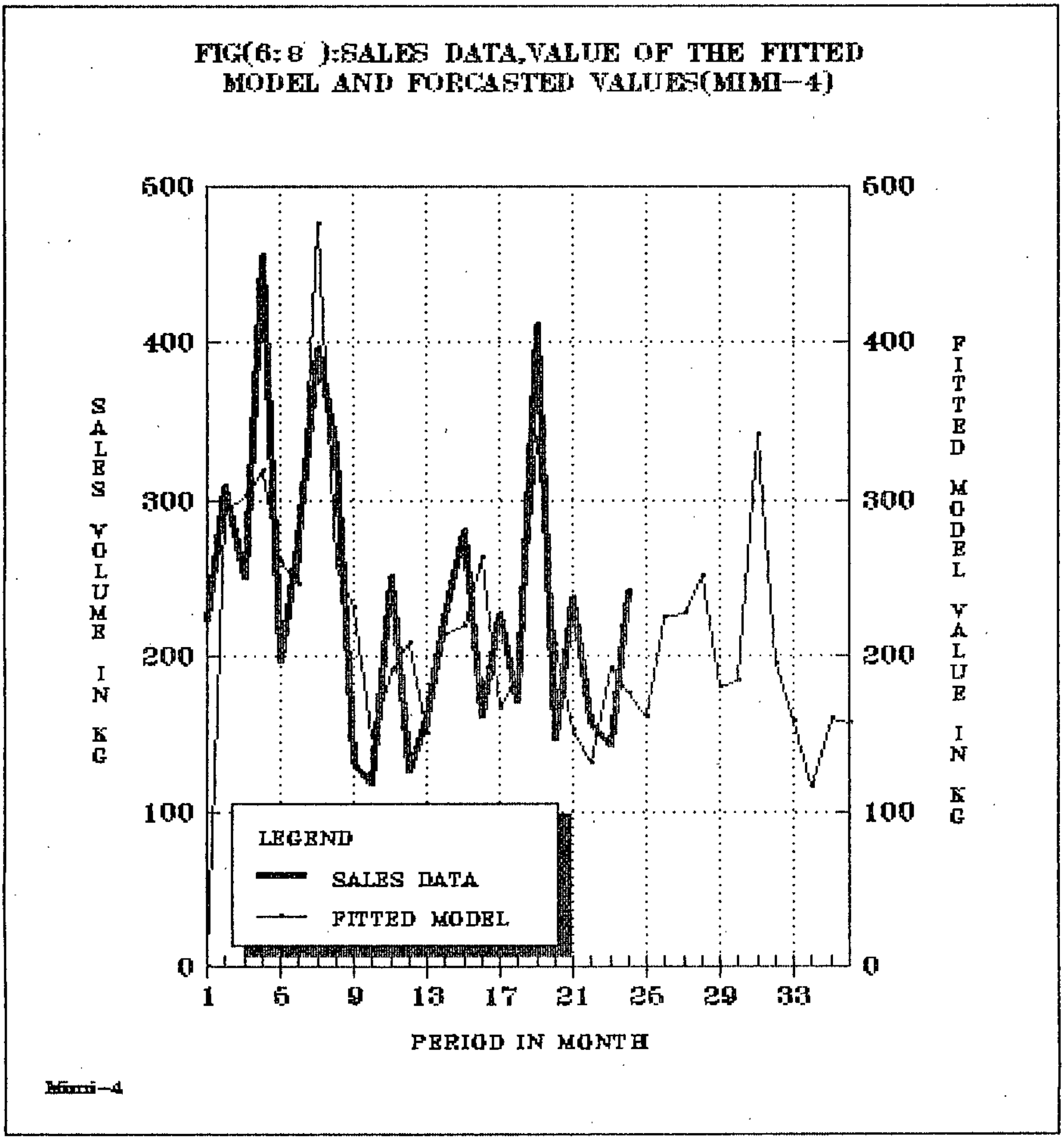


Mimi–2

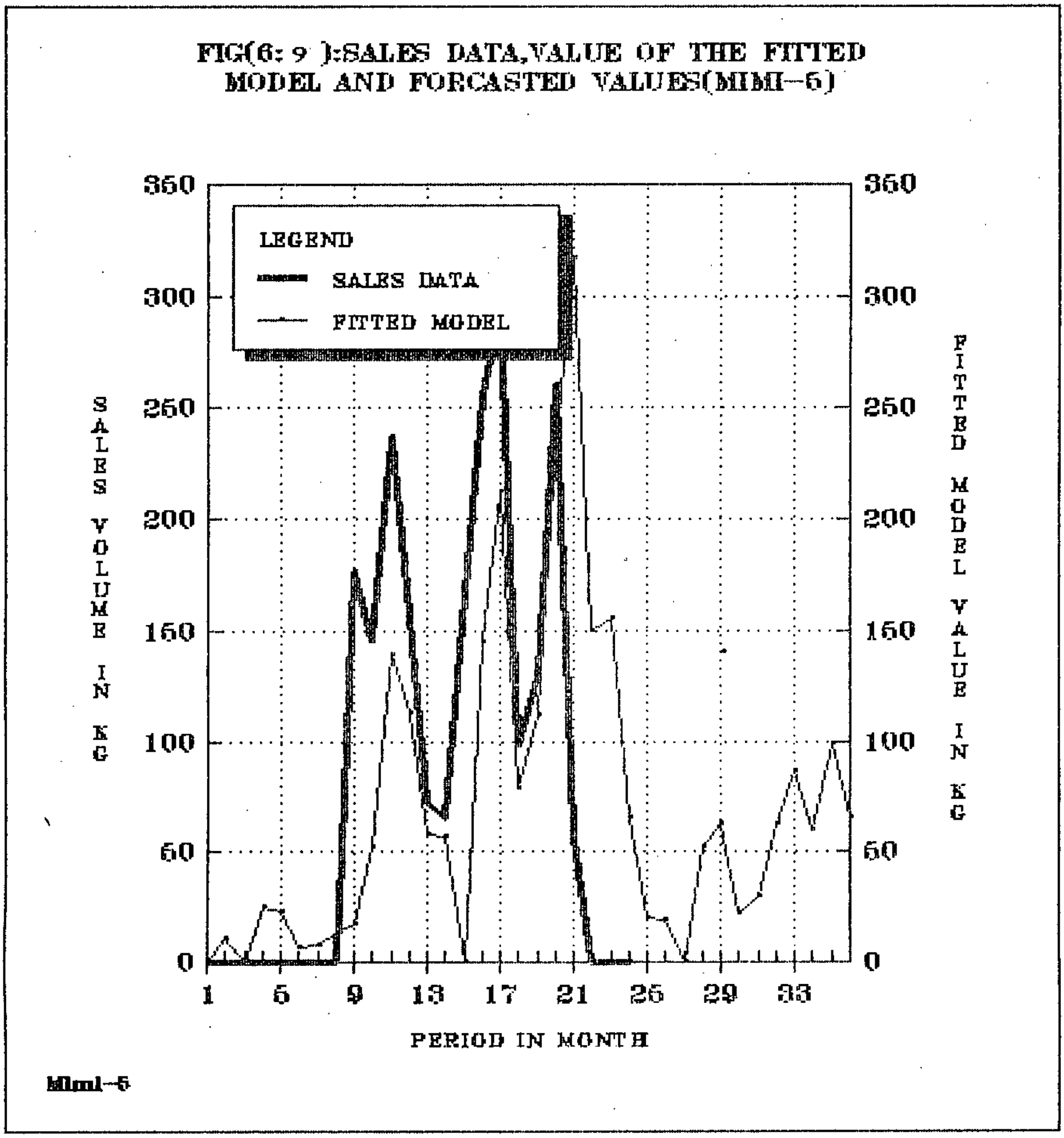
FIG(6: 7):SALES DATA,VALUE OF THE FITTED MODEL AND FORCASTED VALUES(MIMI-3)



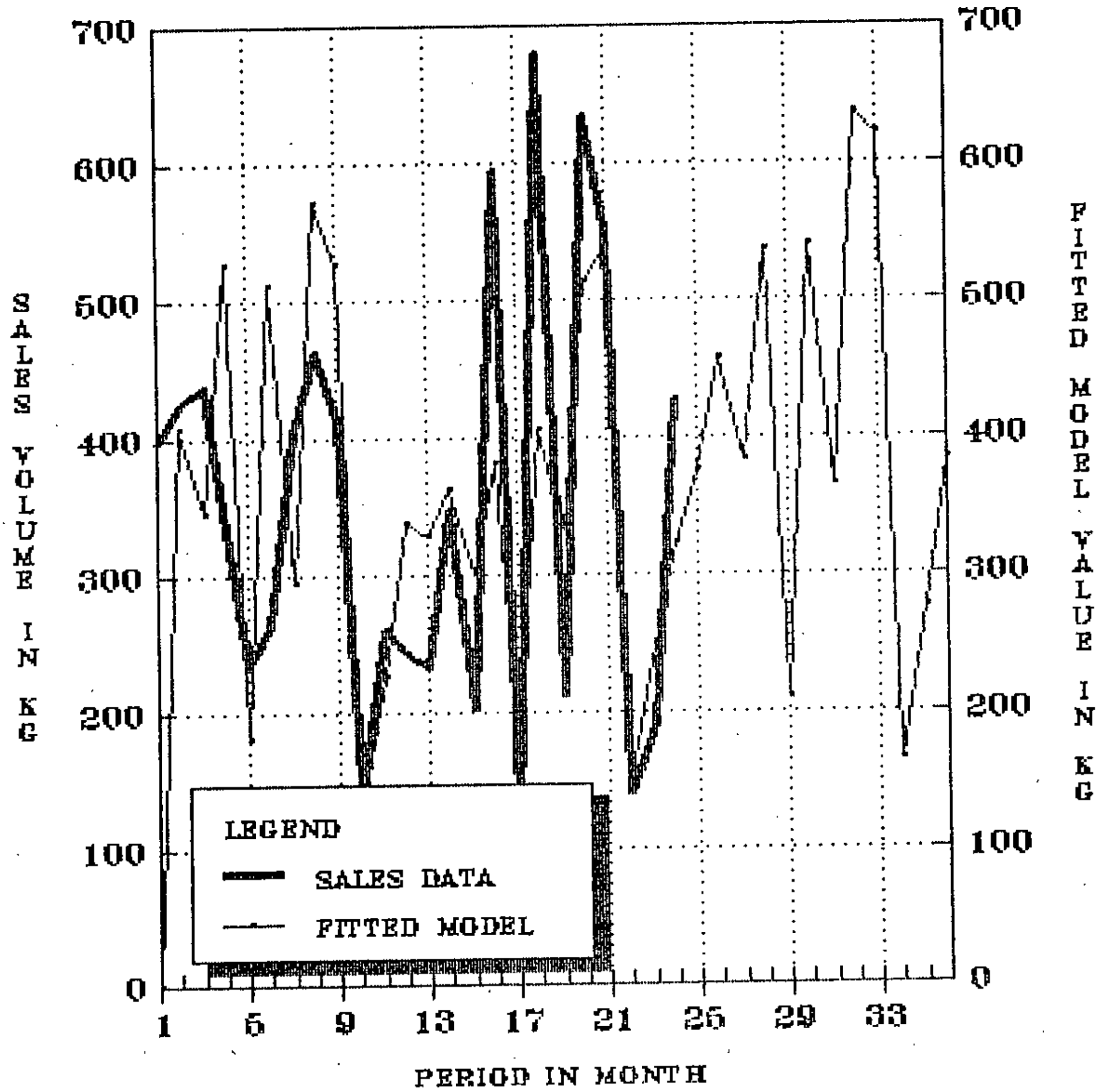
Mimi-3



FIG(6: 8):SALES DATA,VALUE OF THE FITTED MODEL AND FORCASTED VALUES(MIMI-4)
SALES VOLUME IN KG
FITTED MODEL VALUE IN KG
600
400
300
200
100
0
1
5
9
13
17
21
25
29
33
PERIOD IN MONTH
LEGEND
SALES DATA
FITTED MODEL
Mimi-4

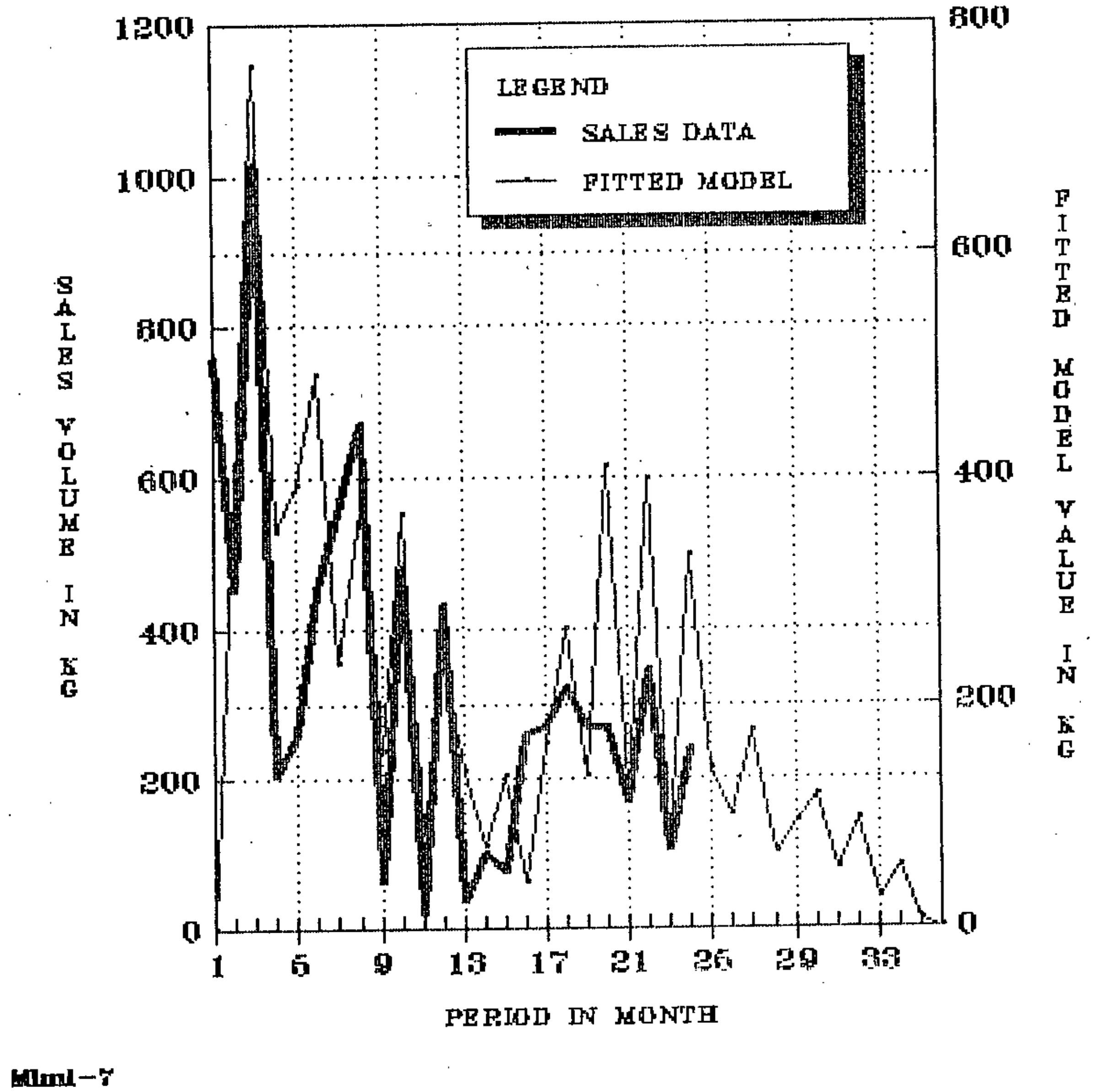

FIG(6: 9):SALES DATA,VALUE OF THE FITTED MODEL AND FORCASTED VALUES(MIMI—6)
LEGEND
SALES DATA
FITTED MODEL
SALES VOLUME IN KG
FITTED MODEL VALUE IN KG
PERIOD IN MONTH
350
300
250
200
150
100
50
0
1
5
9
13
17
21
25
29
33
Mimi—6

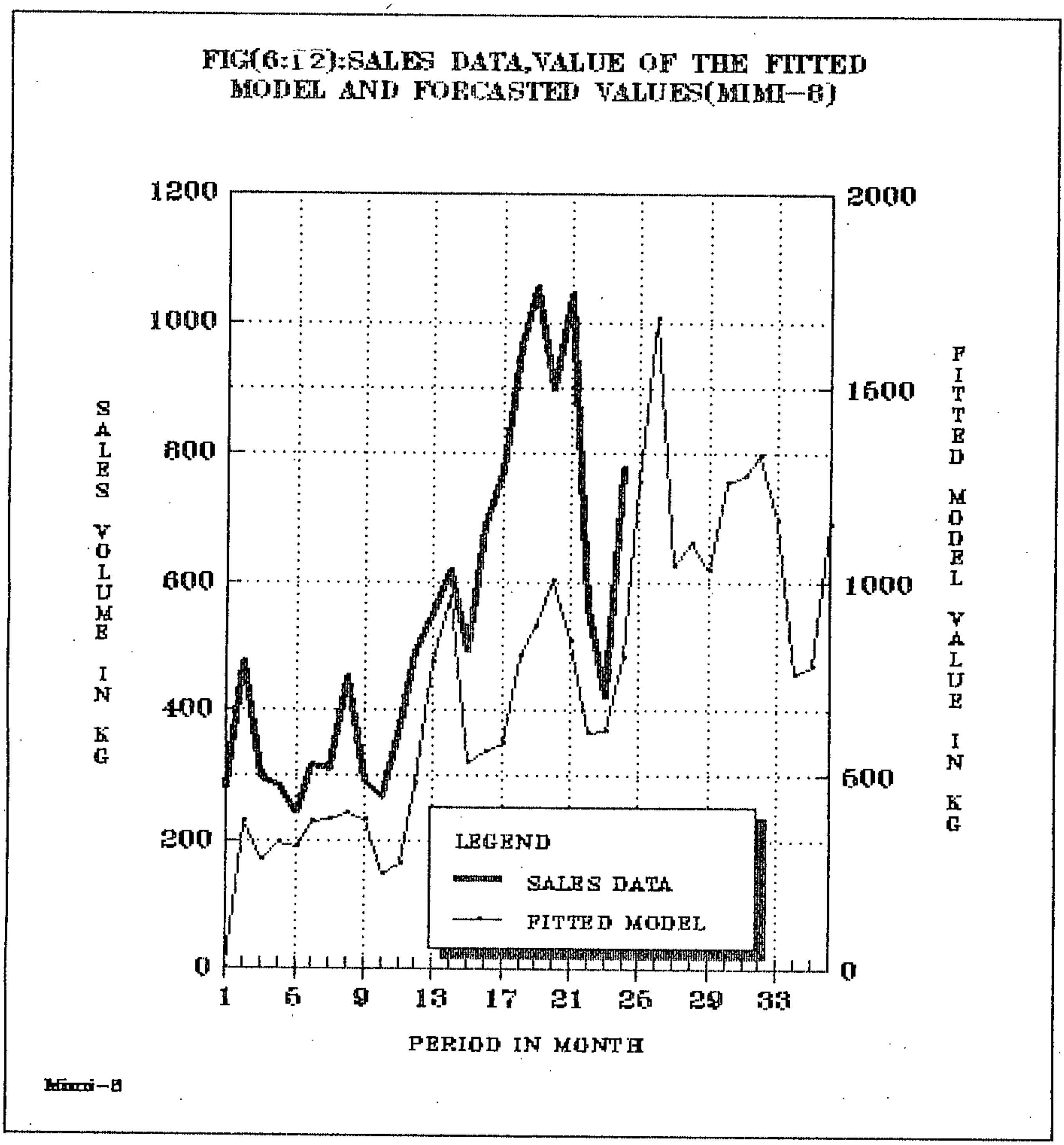
FIG(6:10):SALES DATA,VALUE OF THE FITTED MODEL AND FORCASTED VALUES(MIMI–6)



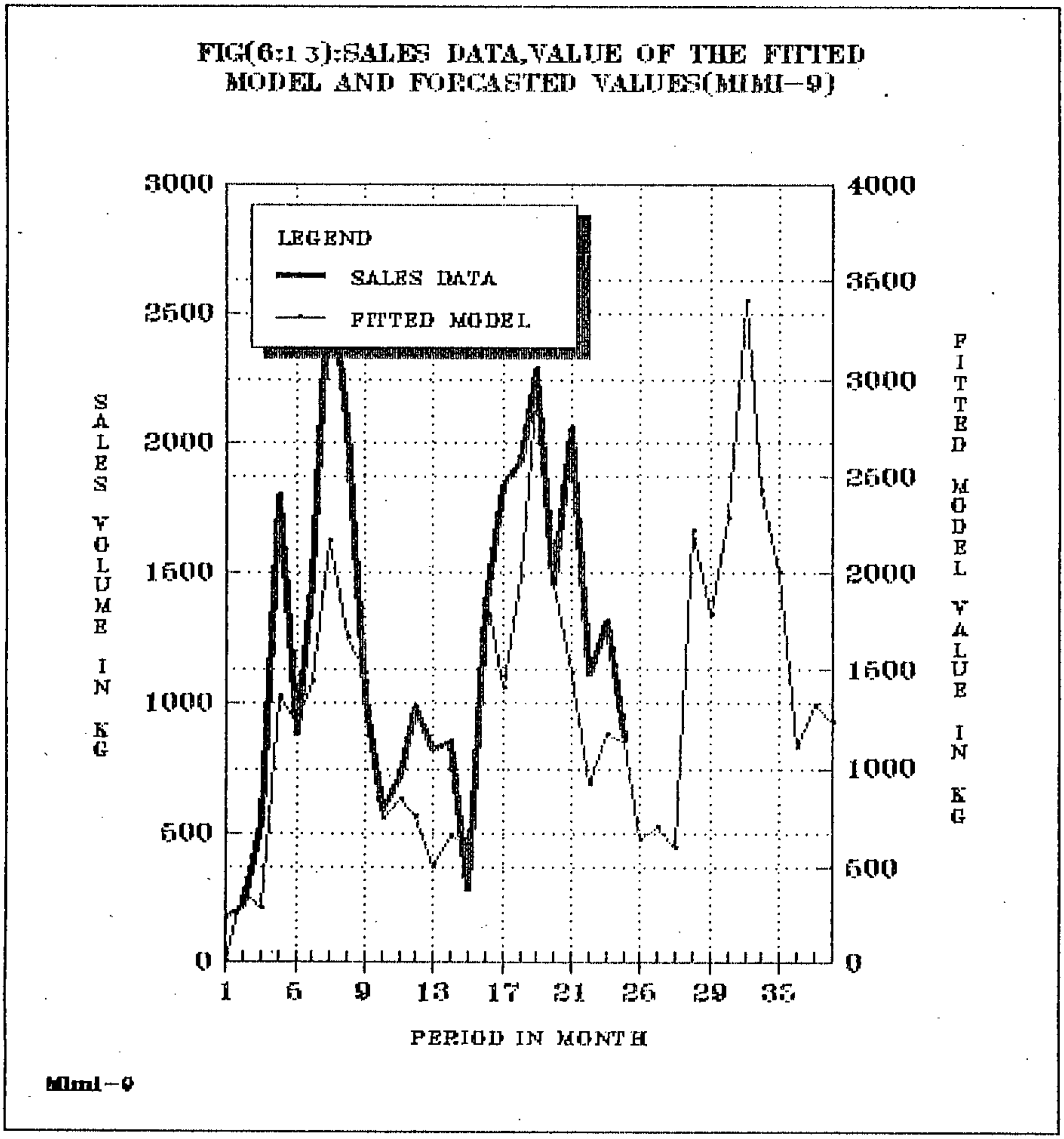
Mimi–6

FIG(6:1 1):SALES DATA,VALUE OF THE FITTED MODEL AND FORCASTED VALUES(MIMI-7)

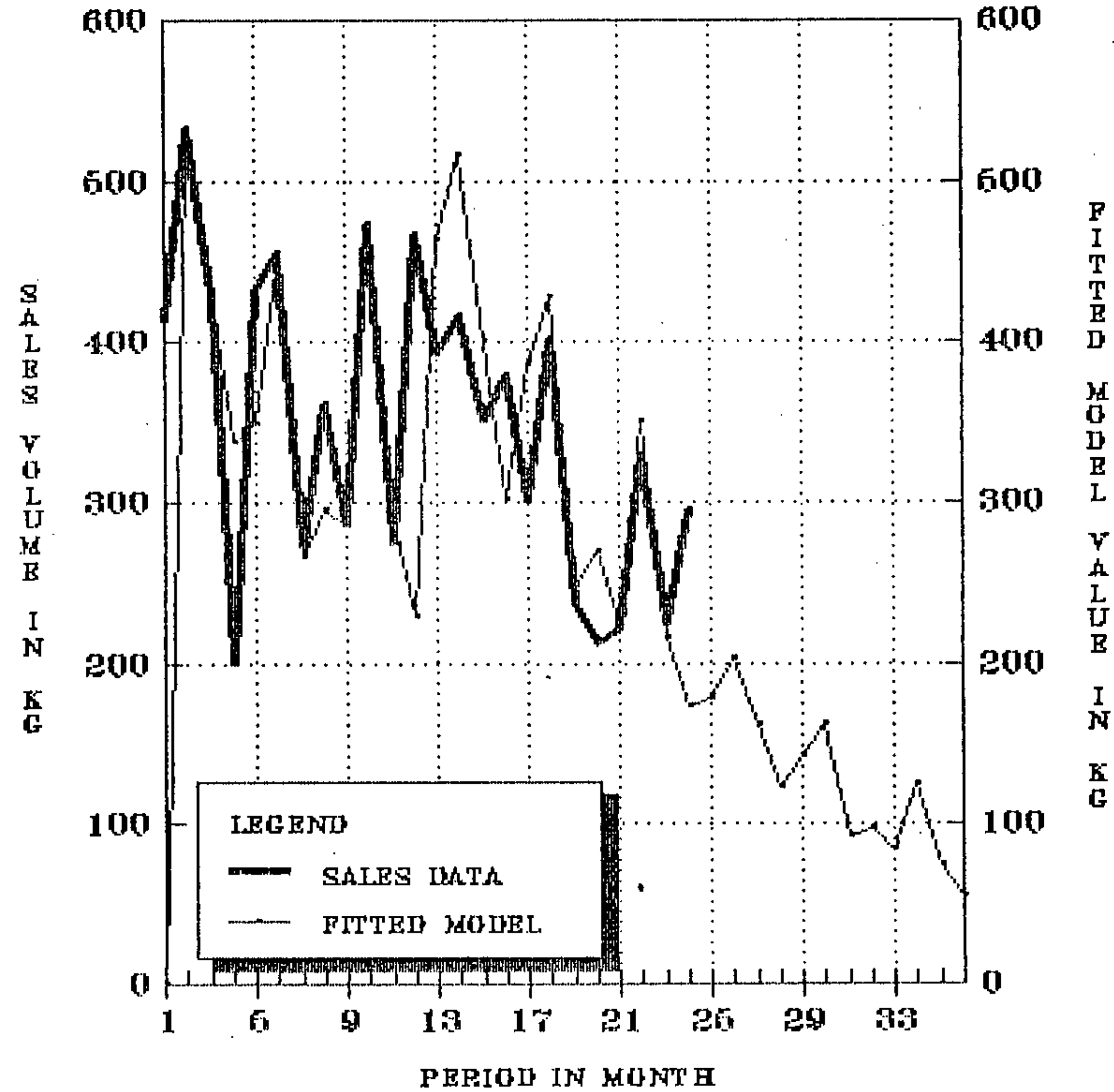




FIG(6:12):SALES DATA,VALUE OF THE FITTED MODEL AND FORCASTED VALUES(MIMI-8)
1200
1000
800
600
400
200
0
2000
1500
1000
500
0
SALES VOLUME IN KG
FITTED MODEL VALUE IN KG
LEGEND
SALES DATA
FITTED MODEL
1
5
9
13
17
21
25
29
33
PERIOD IN MONTH
Mimi-8

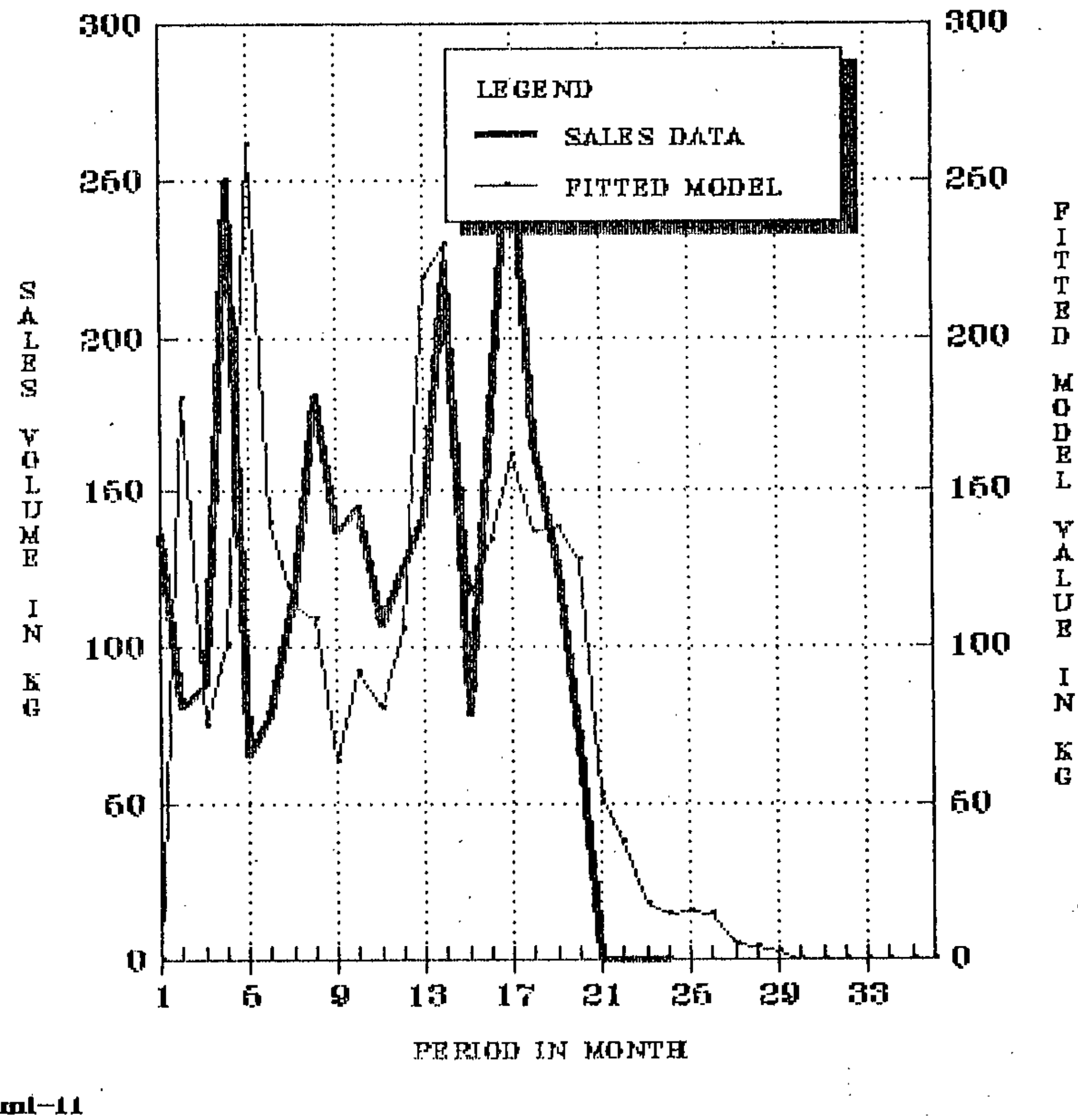

FIG(6:1 3):SALES DATA,VALUE OF THE FITTED MODEL AND FORCASTED VALUES(MIMI-9)
LEGEND
SALES DATA
FITTED MODEL
SALES VOLUME IN KG
FITTED MODEL VALUE IN KG
3000
2500
2000
1500
1000
500
0
4000
3500
3000
2500
2000
1500
1000
500
0
1
5
9
13
17
21
25
29
33
PERIOD IN MONTH
Mimi-9

FIG(6:14):SALES DATA,VALUE OF THE FITTED MODEL AND FORCASTED VALUES(MIMI−10)

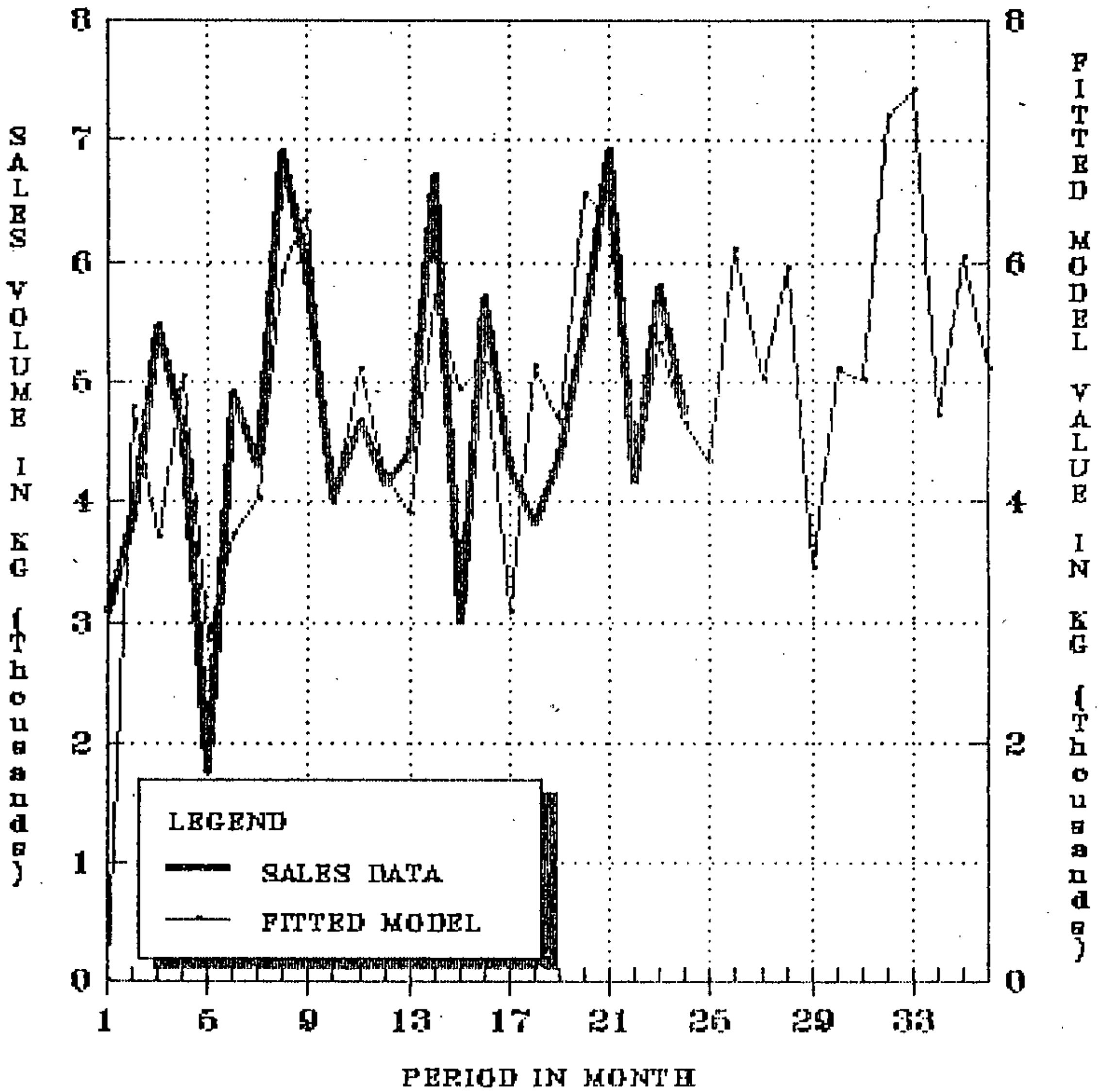


Mimi−10

FIG(6:15):SALES DATA,VALUE OF THE FITTED MODEL AND FORCASTED VALUES(MIMI-11)

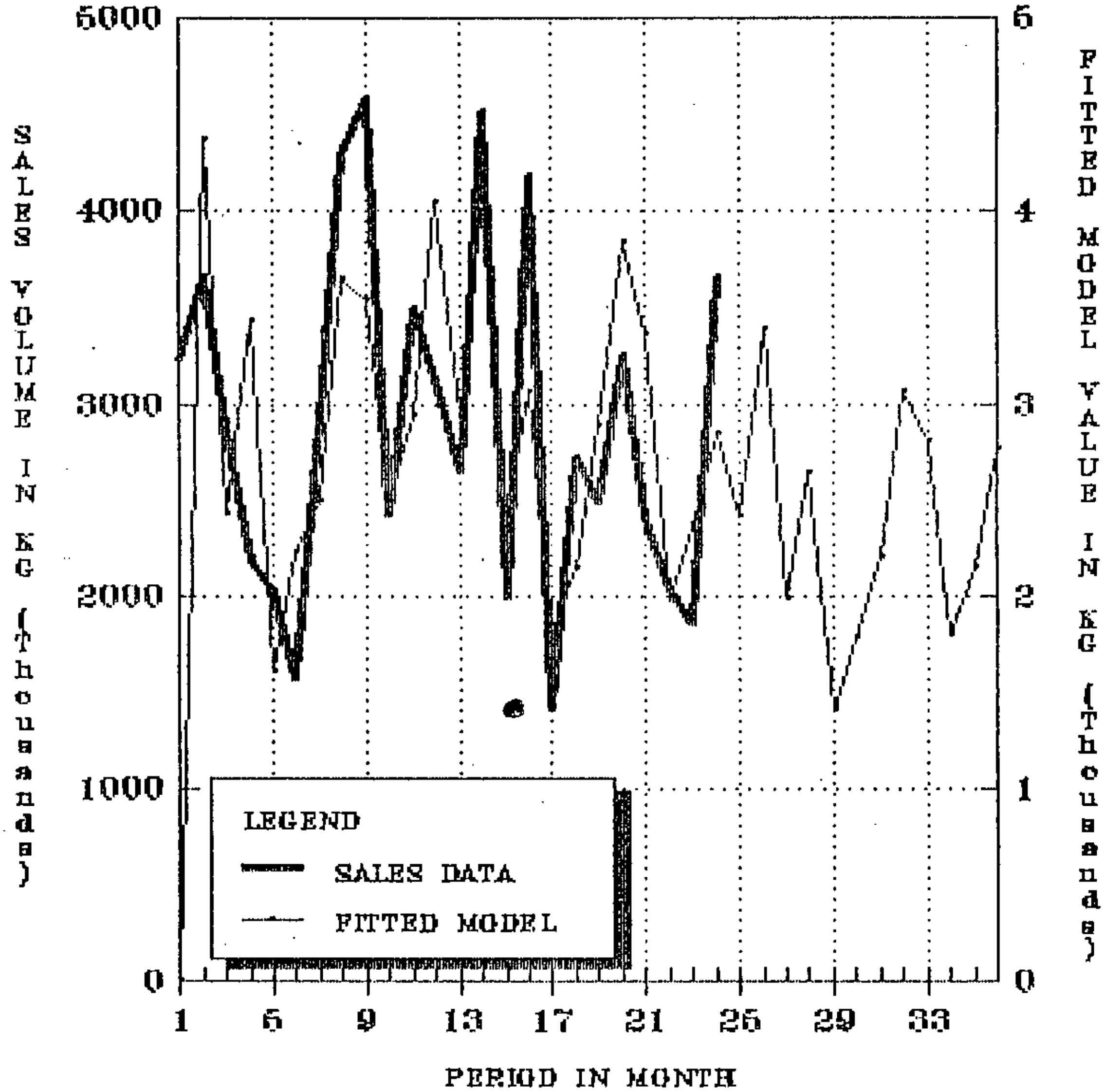


FIG(4:16):SALES DATA,VALUE OF THE FITTED MODEL AND FORCASTED VALUES(MIMI-12)



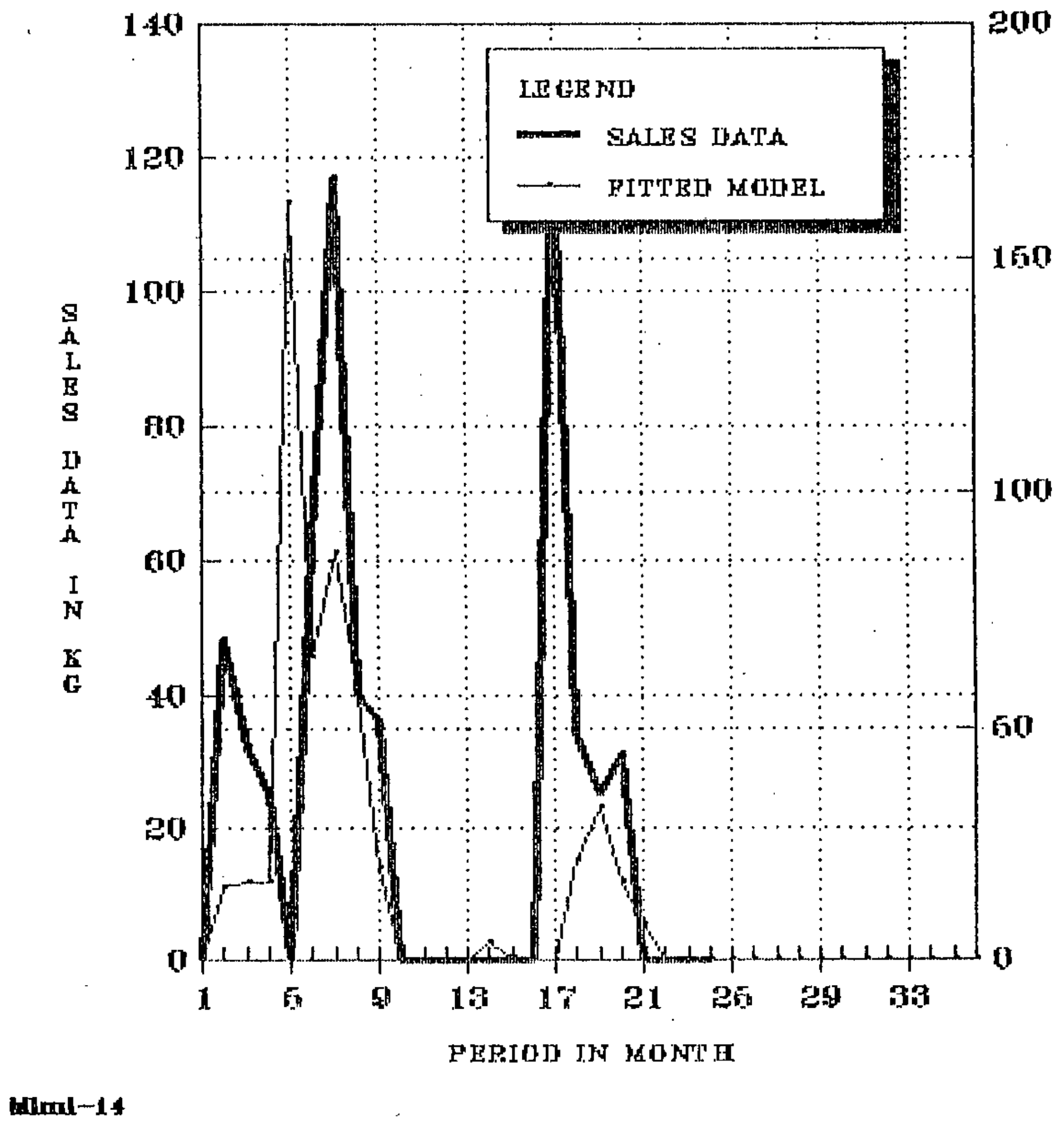
Mimi-12

FIG(6:17):SALES DATA,VALUE OF THE FITTE MODEL AND FORCASTED VALUES(MIMI--13)

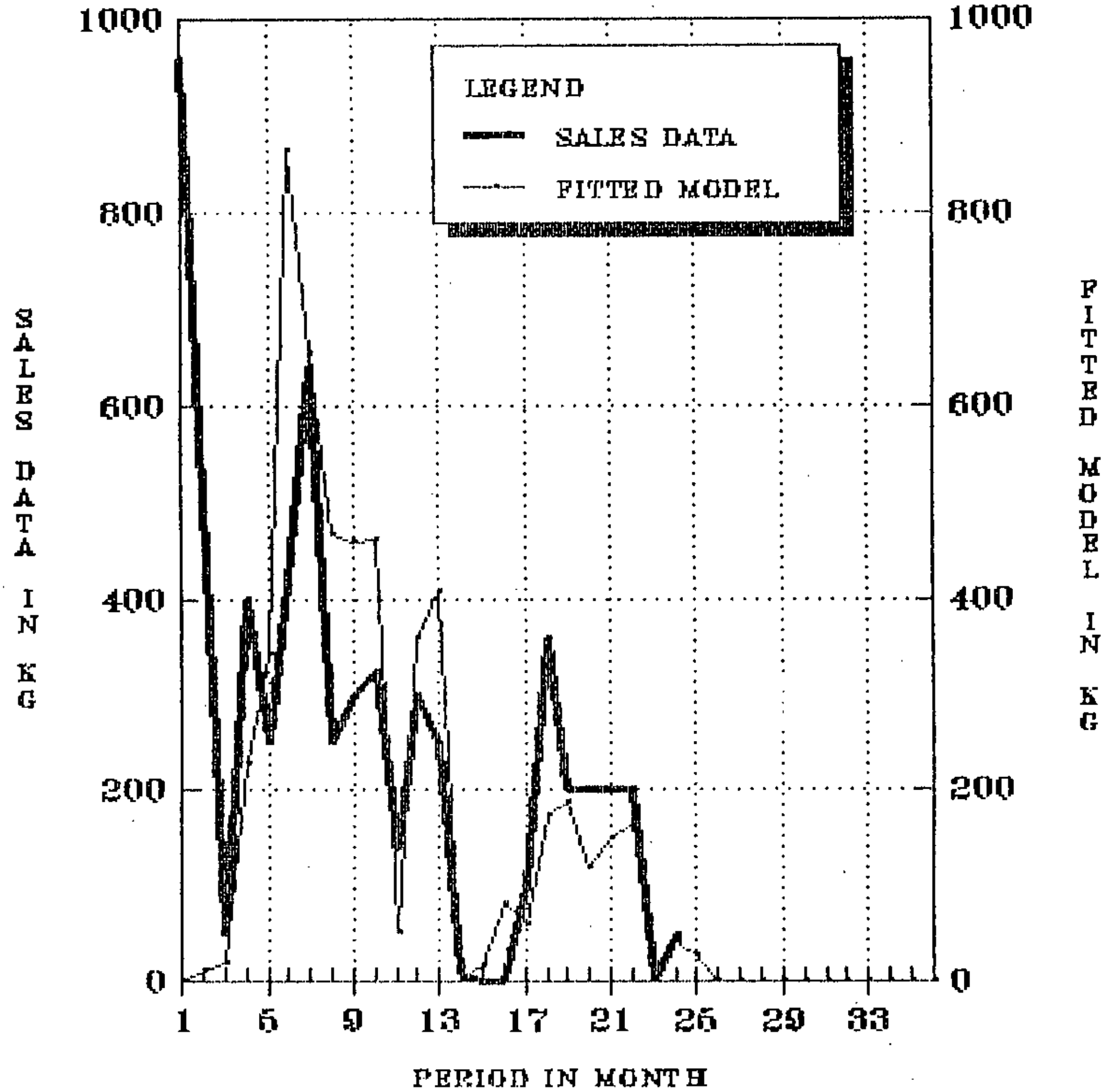


Mimi--13

FIG(6:18):SALES DATA,VALUE OF THE FITTED MODEL AND FORCASTED VALUES(MIMI-14)

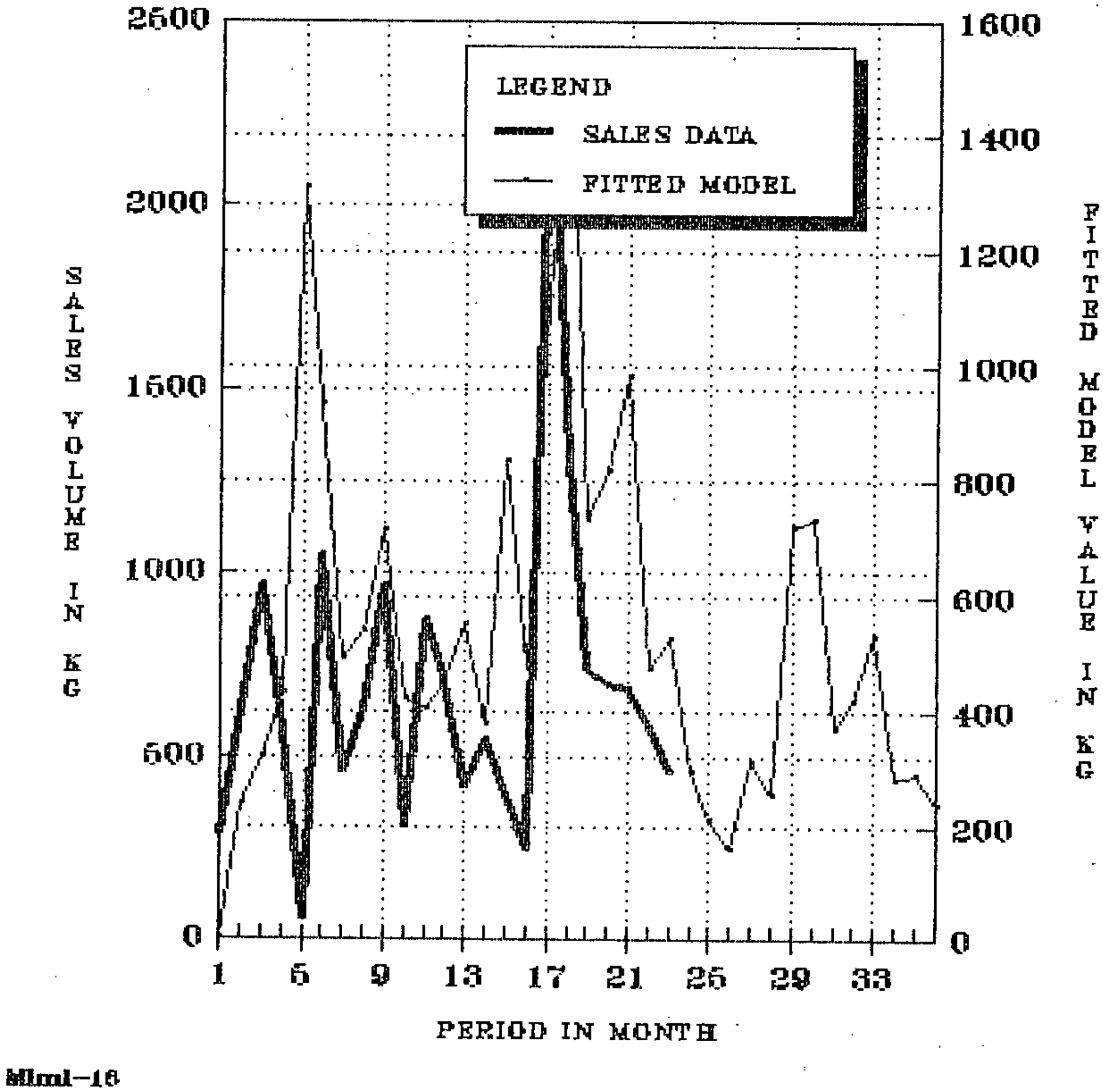


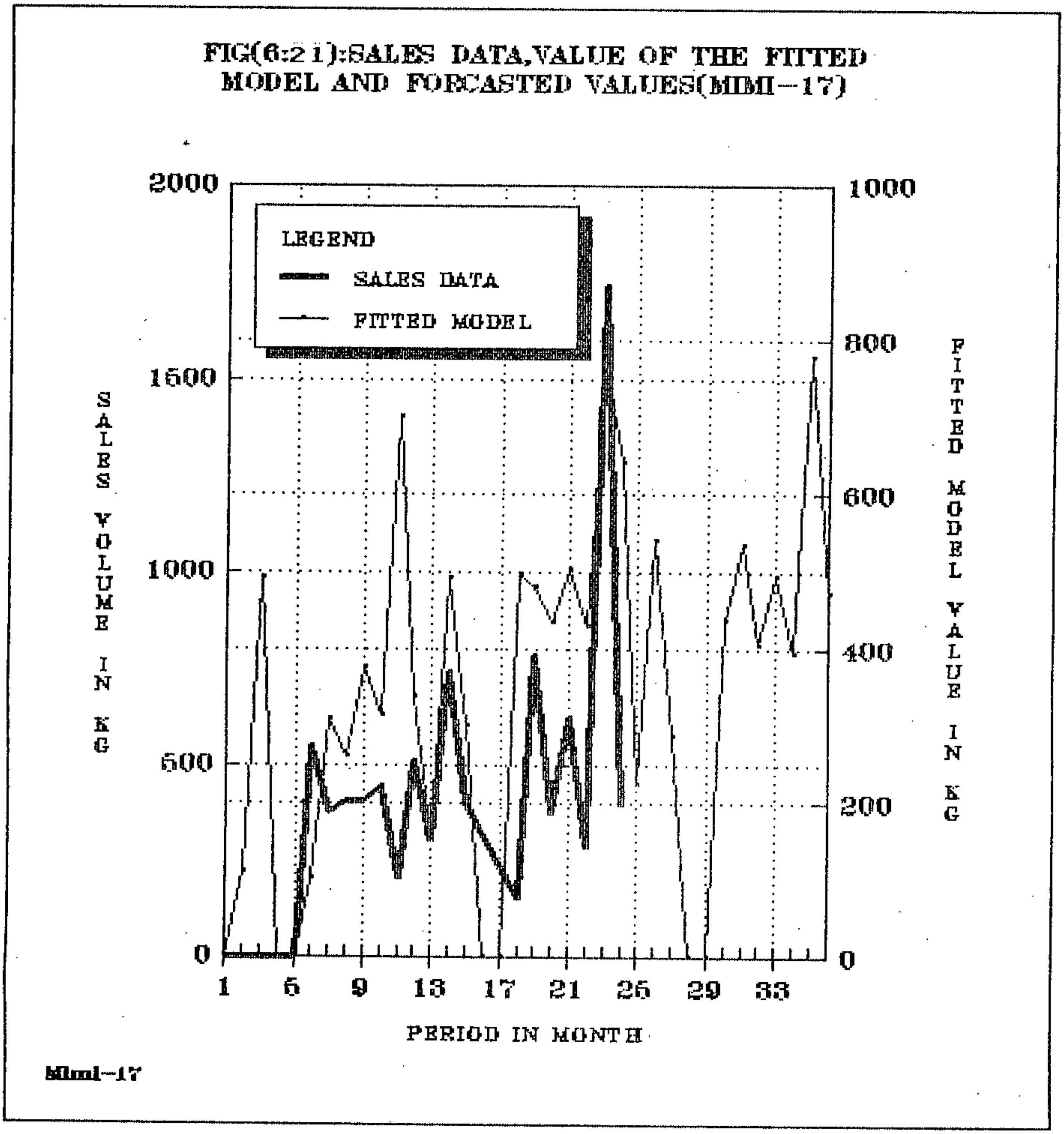
FIG(6:19):SALES DATA,VALUE OF THE FITTED MODEL AND FORCASTED VALUES(MIMI-15)



Mimi-15

FIG(6:20):SALES DATA,VALUE OF THE FITTED MODEL AND FORCASTED VALUES(MIMI--16)





FIG(6:21):SALES DATA,VALUE OF THE FITTED MODEL AND FORCASTED VALUES(MIMI-17)
LEGEND
SALES DATA
FITTED MODEL
2000
1500
1000
500
0
1000
800
600
400
200
0
SALES VOLUME IN KG
FITTED MODEL VALUE IN KG
1
5
9
13
17
21
25
29
33
PERIOD IN MONTH
Mimi-17

Chapter – VII

DETERMINATION OF OPTIMUM PRODUCT-MIX

Chapter — VII

DETERMINATION OF OPTIMUM PRODUCT-MIX

Some of the considerations in industrial planning relate to the determination of profitable product-mix and optimal production scheduling. This chapter illustrates the application of linear programming to the solution of determination of the optimum product-mix of the Mimi Chocolate Factory.

7.1 LINEAR PROGRAMMING - A Profitable Product-Mix

The initial step in determining profitable product-mix is the estimation of the market demand for the different products of the factory. The manufactures from the factory are of seventeen types as listed in Table-4.1. The demand for these products fluctuates throughout the year. To do the estimation, data on production of the different products in the past 24 months i.e. two seasons were collected and market forecasts projected for the coming twelve months. The forecasting procedure employes Winter's Method to analyse historical data, and was facilitated by developing a computer programme (Appendix-II).

7.2 FORMULATION OF THE LINEAR PROGRAMMING (LP) MODEL

7.2.1 Objective Function:

The objectives are (i) to maximize the total sales of Mimi products per year and (ii) to maximize the profit. It would be more appropriate to consider the total profit rather than total sales in the pay off function. But as the total cost of production for individual product could not be obtained profit margin for each of the product can not be ascertained. This may be considered to be one of the limitations of the model. The objective functions are deduced as follows:

(i) Sales maximization function:

Let, Z = Total sales of the Mimi-products per year in Taka.

x_i = Number of units (packets) of product i to be produced.

P_i = Selling price of each unit of product i in Taka.

So, $Z = \sum P_i x_i$

Having the values of P_i's from Table-4.1, the objective function becomes,

$$\begin{aligned} \text{maximize } Z = {} & 109.38x_1 + 109.38x_2 + 109.38x_3 + 109.38x_4 \\ & + 135.42x_5 + 119.79x_6 + 154.00x_7 + 93.75x_8 \\ & + 43.75x_9 + 22.92x_{10} + 20.83x_{11} + 47.92x_{12} \\ & + 47.92x_{13} + 83.33x_{14} + 17.71x_{15} + 18.75x_{16} \\ & + 6.25x_{17} \end{aligned}$$

(ii) Profit maximization function:

$$\text{Maximize} \quad Z = \sum (P_i - C_i)x_i$$

where, P_i = selling price of each unit of product i in Taka.

C_i = variable cost per unit of product i in Taka.

x_i = number of units of product i to be produced.

The objective function then becomes,

$$\begin{aligned}\text{Maximize} \quad Z = {} & 14.41x_1 + 14.41x_2 + 14.41x_3 + 14.41x_4 \\ & + 10.66x_5 + 7.81x_6 + 8.21x_7 + 13.66x_8 \\ & + 16.21x_9 + 2.32x_{10} + 2.47x_{11} + 7.94x_{12} \\ & + 7.94x_{13} + 22.83x_{14} + 2.78x_{15} \\ & + 3.40x_{16} + 13.47x_{17}\end{aligned}$$

The coefficients $(P_i - C_i)$ are obtained from Table-4.1.

7.2.2 Development of Restriction Equations:

There are seven sets of restriction equations, namely,

i. plant capacity

ii. labour hours

iii. machine hours

iv. Ingredients

& v. maximum level of production.

(i) Plant Capacity Restriction:

Let,

W_i = Raw material requirement for each unit of product i, kg./pkt

C = Capacity of the plant, kg./yr.

Thus, the restriction equation with respect to the plant capacity becomes $\sum W_i x_i <= C$

i.e. $W_1x_1 + W_2x_2 + \dots \dots + W_{17}x_{17} <= C$.

With the values of W_i's and C from table-4.8 and table-4.3 respectively, the above restriction equation becomes

$$\begin{aligned}0.909x_1 &+ 0.909x_2 + 0.909x_3 + 0.909x_4 + 1.136x_5 \\ &+ 1.136x_6 + 1.00x_7 + 0.909x_8 + 0.300x_9 \\ &+ 0.227x_{10} + 0.227x_{11} + 0.398x_{12} + 0.398x_{13} \\ &+ 0.909x_{14} + 0.454x_{15} + 0.400x_{16} \\ &+ 0.400x_{17} \qquad <= 1,39,662\end{aligned}$$

(ii) Labour-hours Restrictions:

There are three departments in the factory and there are limited number of workers in each section.

Let,

L_i = Direct labour-hours (in man-minutes) required for each unit of product i.

H_j = Total labour hours (man-minutes/yr.) available for department j (j=1,2,3).

Thus, the restriction equations with respect to available labour-hours become,

<u>Department-1 (Chocolate):</u>

$$L_1x_1 + L_2x_2 + L_3x_3 + \dots + L_{11}x_{11} <= H_1 \quad \dots (a)$$

<u>Department-2 (Gum):</u>

$$L_{12}x_{12} + L_{13}x_{13} + L_{14}x_{14} <= H_2 \quad \dots (b)$$

Department-3 (Sweets):

$$L_{15}x_{15} + L_{16}x_{16} + L_{17}x_{17} \quad <= \quad H_3 \quad \ldots (c)$$

Substituting the values of L_i's and H_j's from table-4.9 and Table-4.10 respectively. The restriction equations become,

Eqn. (a) becomes

$$6.50x_1 + 6.50x_2 + 6.50x_3 + 6.50x_4 + 22.72x_5 + 16.04x_6 + 6.52x_7 + 36.36x_8 + 10.46x_9 + 8.85x_{10} + 10.0x_{11} \quad <= \quad 21,68,880$$

Eqn. (b) becomes

$$22.29x_{12} + 22.29x_{13} + 191.80x_{14} \quad <= \quad 27,65,640$$

and Eqn. (c) becomes

$$3.21x_{15} + 3.42x_{16} + 19.60x_{17} \quad <= \quad 3,30,300$$

(iii) Machine-hours Restrictions:

There are three departments in the Mimi Chocolate Factory. Each department has different types of machines for different types of operations. The machine-hour restriction equation are formed by calculation of the available machine-hour required for each packet of products.

Let,

m_i = Direct machine-hour (in machine-mins) required for each unit of the product i,

M_j = Total machine-hours (machine-mins/yr.) available for department j, Then the restriction equations become,

$$\underline{\text{Department - 1 :}} \quad \sum_{i=1}^{11} m_i x_i \quad <= \quad M_1$$

$$\underline{\text{Department - 2 :}} \quad \sum_{i=12}^{14} m_i x_i \quad <= \quad M_i$$

$$\underline{\text{Department - 3 :}} \quad \sum_{i=15}^{17} m_i x_i \quad <= \quad M_3$$

Putting the values of m_i's and M_j from Table-4.10 and Table-4.11, the restriction equation becomes,

$$\begin{aligned} 29.73x_1 &+ 29.73x_2 + 29.73x_3 + 29.73x_4 + 48.22x_5 \\ &+ 42.27x_6 + 187.40x_7 + 21.03x_8 + 2.09x_9 \\ &+ 1.80x_{10} + 5.09x_{11} \quad <= \quad 74511360 \end{aligned}$$

$$2.16x_{12} + 2.16x_{13} + 64.40x_{14} \quad <= \quad 40642560$$

$$3.21x_{15} + 3.42x_{16} + 1.56x_{17} \quad <= \quad 13547520$$

(iv) Ingredients Restrictions:

Let,

m_i = mass of each of the ingredients required for each unit (packet) of product, i, kg./pkt.

M_i = total mass for each of the ingredients required in one year (kg./yr). the restriction equations for each of the ingredients is given by,

$$\sum m_i x_i \quad <= \quad M_i$$

Taking the values of m_i and M_i from Table-4.7 the restriction equation for the major raw materials become, Crushed sugar:

$$384.73x_1 + 384.73x_2 + 384.73x_3 + 384.73x_4$$
$$+ 480.80x_5 + 480.80x_6 + 423.25x_7 + 235.65x_8$$
$$+ 55.97x_9 + 64.75x_{10} + 199.32x_{11} + 189.77x_{12}$$
$$+ 189.77x_{13} + 595.88x_{14} + 454.0x_{15} +$$
$$+ 400.0x_{16} + 000.0x_{17} \quad <= 65572000$$

Milk powder:

$$204.52x_1 + 204.52x_2 + 204.52x_3 + 204.52x_4$$
$$+ 255.60x_5 + 255.60x_6 + 255x_7 + 63.36x_8$$
$$+ 29.75x_9 + 34.42x_{10} + 40.71x_{11} <= 19755000$$

Vegetable oil:

$$234.0x_1 + 234.0x_2 + 234.0x_3 + 234.0x_4 + 292.52x_5$$
$$+ 292.52x_6 + 257.50x_7 + 75.64x_8 + 34.05x_9$$
$$+ 39.39x_{10} + 49.79x_{11} \quad <= 22581000$$

Cocoa-powder:

$$70.44x_1 + 70.44x_2 + 70.44x_3 + 70.44x_4 + 88.04x_5$$
$$+ 88.04x_6 + 77.50x_7 + 16.00x_8 + 10.24x_9$$
$$+ 11.85x_{10} + 14.02x_{11} \quad <= 6645000$$

000 HI:

$$9.09x_1 + 9.09x_2 + 9.09x_3 + 9.09x_4 + 11.36x_5$$
$$+ 11.36x_6 + 10.0x_7 + 2.0x_8 + 1.32x_9 + 1.53x_{10}$$
$$+ 1.80x_{11} \quad <= 897000$$

Lecithine:

$$5.68x_1 + 5.68x_2 + 5.68x_3 + 5.68x_4 + 7.10x_5$$
$$+ 7.10_6 + 6.25x_7 + 1.29x_8 + 0.82x_9$$
$$+ 0.956x_{10} + 1.13x_{11} \quad <= 379000$$

Liquid Glucose:

$$226.55x_8 + 24.01x_{11} + 75.90x_{12} + 75.90x_{13} + 145.50x_{14} <= 8283000$$

Gum Base:

$$53.60x_{12} + 53.60x_{13} + 103.07x_{14} <= 5437000$$

v. Maximum Level of Production:

The factory must produce each product to meet the market demand. Demand forecast of each product is considered to be the maximum level of production.

Let,

b_i = Demand forecast for product i in kg/yr.

The restriction equations with respect to maximum level of production becomes,

$W_i x_i <= b_i$, for all i products

The values of b_i, are the found from the demand forecast made in previous chapter from Table-6.6.

Therefore the restriction equations for the minimum level of production becomes as follows:

$0.909x_1$	<=	61590
$0.909x_2$	<=	85
$0.909x_3$	<=	39470
$0.909x_4$	<=	2039
$1.136x_5$	<=	558
$1.136x_6$	<=	4790
$1.000x_7$	<=	726
$0.909x_8$	<=	13710
$0.300x_9$	<=	19330
$0.227x_{10}$	<=	1602
$0.227x_{11}$	<=	497
$0.398x_{12}$	<=	65396
$0.398x_{13}$	<=	29840
$0.909x_{14}$	<=	69
$0.454x_{15}$	<=	00
$0.400x_{16}$	<=	8156
$0.400x_{17}$	<=	8359

A co-efficient matrix for all the objective functions and the inequations is formed as shown in Table-7.1.

Table-7.1 : Coefficient Matrix for Sales/Profit Maximization LP Model

	Variables / Restriction	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}	x_{12}	x_{13}	x_{14}	x_{15}	x_{16}	x_{17}	B
	Objective Function	109.38	109.38	109.38	109.38	135.42	119.79	154.00	93.75	43.73	22.92	20.83	47.92	47.92	83.33	17.71	18.75	6.25	Z=Profit maximization
		14.41	14.41	14.41	14.41	10.66	7.81	8.21	13.66	16.12	2.32	2.47	7.94	7.94	22.83	2.78	3.40	13.49	Z=Profit maximization
	Plant capacity	0.909	0.909	0.909	0.909	1.136	1.136	1.00	0.909	0.30	0.227	0.227	0.398	0.398	0.909	0.454	0.400	0.400	1,39,662
LABOUR-HOUR	Chocolate	6.50	6.50	6.50	6.50	22.72	16.04	6.52	36.36	10.46	8.85	10.00	0.00	0.00	0.00	0.00	0.00	0.00	21,68,880
	Gum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	22.29	22.29	191.80	0.00	0.00	0.00	27,65,640
	Sweets	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.21	3.42	19.60	3,30,300
MACHINE-HOUR	Chocolate	29.73	29.73	29.73	29.73	48.22	42.27	187.40	21.03	2.09	1.80	5.09	0.00	0.00	0.00	0.00	0.00	0.00	7,45,11,360
	Gum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.16	2.16	64.40	0.00	0.00	0.00	4,06,42,560
	Sweets	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.21	3.42	1.56	1,35,47,520
INGREDIENTS	Crushed sugar	384.73	384.73	384.73	384.73	480.80	480.80	423.25	235.65	55.97	64.75	119.32	189.77	189.77	595.88	454.00	400.00	0.00	6,55,72,000
	Milk powder	204.52	204.52	204.52	204.52	255.60	255.60	225.00	63.36	29.75	34.42	40.71	0.00	0.00	0.00	0.00	0.00	0.00	1,97,55,000
	Vegetable oil	234.00	234.00	234.00	234.00	292.52	292.52	257.50	75.64	34.05	39.39	49.79	0.00	0.00	0.00	0.00	0.00	0.00	2,25,81,000
	Cocoa powder	70.44	70.44	70.44	70.44	88.04	88.04	77.50	16.00	10.24	11.85	14.02	0.00	0.00	0.00	0.00	0.00	0.00	66,45,000
	000-HI	9.09	9.09	9.09	9.09	11.36	11.36	10.00	2.00	1.32	1.53	1.80	0.00	0.00	0.00	0.00	0.00	0.00	8,97,000
	Lecithine	5.68	5.68	5.68	5.68	7.10	7.10	6.25	1.29	0.82	0.956	1.13	0.00	0.00	0.00	0.00	0.00	0.00	3,79,000
	Liquid glucose	0.00	0.00	0.00	0.00	0.00	0.00	0.00	226.55	0.00	0.00	24.01	75.90	75.90	145.50	0.00	0.00	0.00	82,83,000
	Gum base	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	53.60	53.60	103.07	0,00	0.00	0.00	54,37,000

Table-7.1 : Coefficient Matrix for Sales/Profit Maximization LP Model (Contd.)

	Variables Restriction	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}	x_{12}	x_{13}	x_{14}	x_{15}	x_{16}	x_{17}	B
Maximum demand of finished products	Orange choco	0.909	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	61,390
	Large choco	0.00	0.909	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	85
	Nut choco	0.00	0.00	0.909	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	39470
	P.apple choco	0.00	0.00	0.00	0.909	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2039
	Almond nut	0.00	0.00	0.00	0.00	1.136	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	553
	Milk medium	0.00	0.00	0.00	0.00	0.00	1.136	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4790
	Block choco	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	726
	Picnic Digt.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.909	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13710
	Wafer cream	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19330
	Tea time	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.227	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1602
	Lucky Dip	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.227	0.00	0.00	0.00	0.00	0.00	0.00	497
	Chewing gum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.398	0.00	0.00	0.00	0.00	0.00	65396
	Bubble gum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.398	0.00	0.00	0.00	0.00	29840
	Ball gum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.909	0.00	0.00	0.00	69
	I.Sugar (ls)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.54	0.00	0.00	00
	I.sugar (okt)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00	8156
	Table salt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	3359

From the above coefficient matrix (Table-7.1), it is observed the following:

i. the values of the coefficients of the variables x_1, x_2, x_3 and x_4 are same both in the objective equation and the restriction equations.

ii. as (i) for variables x_{12} and x_{13}

The above conditions make the variables in each category redundant. This situation is overcome by incorporating a single variable in the model from each category and dropping the rest of the variables as redundant. This transformation is accomplished as follows:

$$x'_1 \sim (x_1,\ x_2,\ x_3,\ x_4)$$

$$x'_9 \sim (x_{12},\ x_{13})$$

The other transformations are done below and the transformed coefficient matrix is followed

$x'_2 \sim x_5$	$x'_5 \sim x_8$	$x'_8 \sim x_{11}$	$x'_{11} \sim x_{15}$
$x'_3 \sim x_6$	$x'_6 \sim x_9$	$x'_9 \sim x_{12}$	$x'_{12} \sim x_{16}$
$x'_4 \sim x_7$	$x'_7 \sim x_{10}$	$x'_{10} \sim x_{14}$	$x'_{13} \sim x_{17}$

Table-7.2 : Coefficient matrix for sales/profit maximization LP model after transformation

		x'_1	x'_2	x'_3	x'_4	x'_5	x'_6	x'_7	x'_8	x'_9	x'_{10}	x'_{11}	x'_{12}	x'_{13}	B'
Objective Function		109.38	135.42	119.79	154.00	93.75	43.73	22.92	20.83	47.92	83.33	17.71	18.75	6.25	Z=sales maximization
		14.41	10.66	7.81	8.21	13.66	16.12	2.32	2.47	7.94	22.83	2.78	3.40	13.49	Z=profit maximization
Plant capacity		0.909	1.136	1.136	1.00	0.909	0.30	0.227	0.227	0.398	0.909	0.454	0.400	0.400	1,39,662
Labour Hour	Chocolate	6.50	22.72	16.04	6.52	36.36	10.46	8.85	10.00	0.00	0.00	0.00	0.00	0.00	21,68,880
	Gum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	22.29	191.80	0.00	0.00	0.00	27,65,640
	Sweets	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.21	3.42	19.60	3,30,300
Machine Hour	Chocolate	29.73	48.22	42.27	187.40	21.03	2.09	1.80	5.09	0.00	0.00	0.00	0.00	0.00	7,45,11,360
	Gum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.16	64.40	0.00	0.00	0.00	4,06,42,560
	Sweets	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.21	3.42	1.56	1,35,47,520
Ingredients	Cr.sugar	384.73	480.80	480.80	423.25	235.65	55.97	64.75	199.32	189.77	595.88	454.00	400.00	0.00	6,55,72,000
	M.powder	204.52	255.60	255.60	225.00	63.36	29.75	34.42	40.71	0.00	0.00	0.00	0.00	0.00	1,97,55,000
	V. oil	234.00	292.52	292.52	257.50	75.64	34.05	39.39	49.79	0.00	0.00	0.00	0.00	0.00	2,25,81,000
	C.powder	70.44	88.04	88.04	77.50	16.00	10.24	11.85	14.02	0.00	0.00	0.00	0.00	0.00	66,45,000
	000-HI	9.09	11.36	11.36	10.00	2.00	1.32	1.53	1.80	0.00	0.00	0.00	0.00	0.00	8,97,000
	Lecithin	5.68	7.10	7.10	6.25	1.29	0.82	0.956	1.13	0.00	0.00	0.00	0.00	0.00	3,79,000
	L.glucose	0.00	0.00	0.00	0.00	226.55	0.00	0.00	24.01	75.90	145.50	0.00	0.00	0.00	82,83,000
	Gum base	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	53.60	103.07	0.00	0.00	0.00	54,37,000

Table-7.2 : Coefficient matrix for sales/profit maximization LP model after transformation (Contd.)

Restriction \ Variables	X'_1	X'_2	X'_3	X'_4	X'_5	X'_6	X'_7	X'_8	X'_9	X'_{10}	X'_{11}	X'_{12}	X'_{13}	B'
Transformed Variables X'_1	0.909	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,03,184
X'_2	0.00	1.136	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	558
X'_3	0.00	0.00	1.136	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4790
X'_4	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	726
X'_5	0.00	0.00	0.00	0.00	0.909	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13710
X'_6	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19330
X'_7	0.00	0.00	0.00	0.00	0.00	0.00	0.227	0.00	0.00	0.00	0.00	0.00	0.00	1602
X'_8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.227	0.00	0.00	0.00	0.00	0.00	497
X'_9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.398	0.00	0.00	0.00	0.00	95236
X'_{10}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.909	0.00	0.00	0.00	69
X'_{11}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.454	0.00	0.00	00
X'_{12}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00	8156
X'_{13}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	8359

7.3 SOLUTION OF THE LP MODEL

A computer program has been used for solving the above formulated linear programming problem. The program was run in an IBM 4331 computer at BUET Computer Centre. The solutions of the LP model are given in Table-7.3. The values of Z_{max} for profit maximization and sales maximization were obtained from the respective final iterations. The total production quantity is obtained for profit maximization by adding the values of the final variables in the solution matrix and the profit quantity for sales maximization is obtained by subtracting the variable costs of the final variables in the solution matrix. These are given in Table-7.4.

Table-7.3 : LP Model values of different variables for profit maximization and sales maximization

Values	Value of variables, x'_i for profit maximization	Values of variable x'_i for sales maximization
x'_1	56837.89	54861.84
x'_2	00.00	00.00
x'_3	00.00	00.00
x'_4	00.00	00.00
x'_5	2577.80	2577.65
x'_6	64433.33	64433.33
x'_7	00.00	00.00
x'_8	00.00	00.00
x'_9	101290.69	101436.44
x'_{10}	75.82	00.00
x'_{11}	00.00	00.00
x'_{12}	20390.00	20390.00
x'_{13}	13294.19	13294.19
	Max. Profit, Z = Tk.29,47,552.00	Max. sales, Z = Tk. 1,46,59,078.00

Table-7.4 : Comparison of the maximum values of profit/sales and corresponding sales/profit values

	Maximum sales value	=	Tk.1,46,59,078.00
1.	Corresponding Profit Value	=	Tk. 29,40,624.31
	Maximum profit value	=	Tk. 29,47,552.00
2.	Corresponding sales value	=	Tk.1,46,01,569.93

Table-7.4 reveals that, the value of Z_{max} in profit maximization is higher than corresponding total profit from sales maximization. Thus management would adapt the profit maximization criteria to earn higher profit; although the sales maximization creteria would inherently provide higher utilization of plant capacity and higher safety stock in the inventory.

Mention has initially been made while formulation of the model that the variables with identical coefficients in both the objective function and restriction equations were transformed to a single variable. But to make the LP output more meaningful detransformation of the vairbles was done. This was done by distributing the value of transofmed variable to the detransformed variables equitably based on their forecast values. For example, for transformed variable $x'_1 \sim (x_1, x_2, x_3\ x_4)$ the value of final solution of 56837 is distributed to x_1, x_2, x_3, x_4 as shown in the 2nd column of Table-7.5. The final solution of the profit maximization model is also given in the Table-7.5 which reveals the following.

Product-wise demand of all the seventeen products obtained by forecast are given again for easy comparison. The last column of the table shown, a percentage wise production - the calculations of the percentages are calculated as,

$$\text{Percentage production} = \frac{\text{LP production quantity}}{\text{Demand forecast}} \times 100$$

An observation of these ratios shows that the optimum production levels of almost all the items are much lower than the forecast value, specially the product 8 of the order of 17%. These optimum level of production are due to tight restrictions at the different stages of the production processes. To identify the causes, the LP requires sensitivity analysis. This is recommended that a future study may be carried on this regard.

Table-7.5 : The LP model value and the adjusted value of the items.

Variables	Name of the products	LP values (Box)	Adjusted LP values (Box)	Forecast value (Box)	% Production
x_1	Orange chocolate		33,926	67,756	50
x_2	Large chocolate	56,837.89	46	94	49
x_3	Nut chocolate		21,742	43,421	50
x_4	Pineapple chocolate		11,742	2,243	50
x_5	Almond nut small choco	00.00	00	492	00
x_6	Milk medium chocolate	00.00	00	4,216	00
x_7	Block chocolate	00.00	00	726	00
x_8	Picnic Delight	2,577.80	2,578	15,083	17
x_9	Wafer cream biscuit	64,433.33	64,433	64,433	100
x_{10}	Tea time biscuit	00.00	00	7,057	00
x_{11}	Lucky Dip	00.00	00	2,189	00
x_{12}	Chewing gum		69,554	164,311	42.30
x_{13}	Bubble gum	1,01,290.69	31,737	74,975	42.30
x_{14}	Ball gum	75.82	76	76	100
x_{15}	Icing sugar (loose)	00.00	00	00	00
x_{16}	Icing sugar (packet)	20,390.00	20,390	20,390	100
x_{17}	Table salt	13,294.19	13,294	20,898	63.60
	Total		2,58,899	4,49,260	57.62

The LP result shows that the following products have zero values. The explanations are given below.

5 - Almond Nuts small

6 - Milk medium

7 - Block

10 - Tea Time

11 - Lucky Dip

14 - Ball gum

15 - Icing sugar

i) Products 5,6,7

These products have high values of the coefficients in the restriction equations and the low values of the coefficients in the objective function. This condition makes the mathematical manipulation to make their values approaching zero values. Experiences suggest that during production most of the chocolates broke away during demoulding operation due to insufficient cooling of the moulds in the freezer. This results in the output to labour hour and output to machine-hour ratios become very low.

ii) Products 10, 11

The labour-hour and machine-hour required for the production of each unit of these items are low and so also the coefficients in the objective function are very low. Moreover the demand of these two items were very low.

iii) Product 14:

The coefficient of the labour hours in the restriction equation was exceedingly large.

iv) <u>Product 15:</u>

The right hand side of the restriction of demand of this item was zero. This obviates the optimal value to take zero.

A comparison of the actual values with the corresponding values of the LP model for profit maximization criteria is given below in Table-7.6. The actual values are the figures obtained from the factory of the year 1988-89.

Table-7.6 : Comparison of actual and LP model values of sales volume and profit volume for the year 1989-90 for the products of Mimi

	Actual Values (1988-1989) (Tk.)	LP model Values (Tk.)
Sales/ production	1,52,53,691.44	1,46,01,569.93
Profit	19,94,027.86	29,47,552.00

A comparison of these sales volume and profit volume obtained by the LP model shows that a higher profit could be achieved by producing and selling a much lower quantity of sales volume. The table shows that a higher profit of

$$\frac{29{,}47{,}552.00 - 1994027.86}{19{,}94{,}027.86} \times 100 = 47.81\%$$

could be achieved if the company produces the amount of the specified items given by the LP model in Table-7.5.

A comparison of each of the products that were actually produced in year 1988-'89 and the amounts of each of the products that are to be produced in the year 1989-'90, determined by LP model is given below in Table-7.7:

Table-7.7 : Comparison of amounts of actual and that for LP model values for each of the products

Sl. No.	Name of the products	Actually produced in 1988-89 (Kg.)	LP Model value for 1989-90	
			Box	Kg.
1	Orange chocolate	42,930	33,926	30,838.74
2	Large chocolate	876	46	41.81
3	Nut chocolate	27,099	21,742	19,763.48
4	Pineapple chocolate	2,068	1,123	1,020.80
5	Almond nut small choco	1,156	0	0.00
6	Milk medium chocolate	4,550	0	0.00
7	Block chocolate	3,250	0	0.00
8	Picnic Delight	8,013	2,578	2,343.40
9	Wafer cream biscuit	3,196	64,433	19,329.90
10	Tea time biscuit	678	0	0.00
11	Lucky Dip	260	0	0.00
12	Chewing gum	23,302	69,554	27,543.38
13	Bubble gum	13,703	31,737	12,567.85
14	Ball gum	196	76	68.40
15	Icing sugar (loose)	1,570	0	0.00
16	Icing sugar (packet)	3,089	20,390	8,156.00
17	Table salt	3,003	13,294	5,317.60

7.4 OVERALL DISCUSSION ON THE LP MODEL

The linear programming model used in this study was designed for short term planning, but is nevertheless flexible enough to accomodate changes in production/demand conditions.

The results from the manipulation of this model were compared with the factory's actual production figures for a given year. However, the optimal production of mimi items proved to be much less (about 50% less) than the forecasted demand, indicating that it would be profitable to leave unutilised a certain amount machine hours due to bottlenecking conditions in the chocolate production line or very high requirement of labour-hours. This complexity could be mitigated through reshuffling the whole production line as already mentioned in Chapter-4.

Chapter – VIII

OPTIMUM PROCUREMENT POLICY FOR RAW MATERIAL INVENTORY

Chapter – VIII

OPTIMUM POLICY FOR RAW MATERIALS INVENTORY

In the previous chapter, an optimum product-mix of the Mimi-products was determined. In the present chapter, an optimum inventory policy for some of the major raw materials are suggested.

The raw materials, which consume large proportions of the operating capital have been identified as shown in Table-4.6. The basis used was that raw materials consumming 1% and above of the total capital used for purchasing company raw materials. A list of such major raw materials are listed below:

i.	*Sugar*	*v.*	*000-HI*
ii.	*Cocoa-powder*	*vi.*	*Liquid glucose*
iii.	*Milk-powder*	*vii.*	*Gum base*
iv.	*Vegetable oil*	*viii.*	*Chocolate flavour*

8.1 ANALYSIS OF THE REQUIREMENT OF MAJOR RAW MATERIALS

8.1.1 Requirement of the raw materials:

Sugar

Total quantity of sugar to be ordered = (chocolate products to be produced) x (Average fraction of sugar used in the chocolate products) + (Gum products to be produced) x

(Average fraction of sugar used in gum products) + Icing sugar (loose) + Icing sugar (packet).

Thus,

$$Ws = (\sum W_i x_i) y_i + (\sum W_j x_j) y_j + \text{Icing sugar (loose + packet)}$$

where,

- Ws = Total quantity of sugar per period
- W_i = Average weight of a unit of chocolate product, i
- x_i = quantity of chocolate products, i, per period (twelve month-period) as obtained from solution of LP model. (Table-7.3).
- y_i = Fraction of sugar content per unit of chocolate products, i.
- W_j = Average weight of a unit of gum product, j
- x_j = quantity of gum products, j per period (twelve month-period) as obtained from solution of LP model (Table-7.3).
- y_j = Fraction of sugar content per unit of gum products, j.

Average consumption rate of sugar per month

$$= \frac{\text{Quantity/yr.}}{12}$$

The composition of ingredients in percentage wise is obtained from Table 4.12.

<u>Sample Calculation:</u>

Amount of sugar consumption per period is thus,

$$Ws = (56838 \times 0.909 \times 0.424) + (2578 \times 0.909 \times 0.424) + (64433 \times 0.300 \times 0.82 \times 0.424) + 101290 \times 0.398 \times 0.56) + (76 \times 0.909 \times 0.56) + (20390 \times 0.400 \times 1)$$

= 60390.70 kg/year

= 60.40 MT/year

$\therefore$ Average rate of consumption per month $= \dfrac{60.40}{12}$

= 5/03 MT

Similarly for other materials including sugar, average consumption per month were calculated and tabulated below (Table-8.1):

Table - 8.1

Average Consumption rate of the main ingredients

Raw materials	Consumption	
	MT/year	Mt/month
Sugar	60.40	5.03
Cocoa powder	5.44	0.45
Milk powder	15.72	1.30
Vegetable oil	18.92	1.57
000 HI	0.74	0.06
Liquid glucose	9.98	0.83
Gum base	7.23	0.60
Chocolate flavour	0.005	0.0004

8.2 SELECTION OF APPROXIMATE INVENTORY MODEL

8.2.1 Continuous Review Model:

Using a classical continuous review model with uniform demand and no shortage, the economic order quantities were calculated and given below in a table-8.2 for a few specific raw materials as examples:

Table-8.2
EOQ of some of the main raw materials

Items	Ordering Cost, k Tk./order	Demand rate, D MT/month	Holding cost, h Tk/kg-yr	Economic order quantity, Q^* MT
Sugar	29,700	5.83	3.40	32.47
Liquid glucose	29,700	0.83	3,40	13.19
Cocoa powder	29,700	0.45	3.40	9.72

Given,

$$Q^* = \sqrt{\frac{2kD}{h}}$$

where,

Q^* = Economic order quantity (EOQ), MT

k = ordering cost, Tk.

D = consumption rate, monthwise

h = holding cost, Tk./period.

Foreign items take on average six months time between placement of an order and the receipt of raw materials. But in case of local purchase of raw materials, particularly in case of sugar (a major component) it takes on average one month between placement of an order and the receipt of the item. However, other local purchased raw materials such as Mg-powder, soap-stone powder, calcium powder, liquid glucose, biscuits of various kinds etc. take two weeks on average. These times are known as lead times.

For the above major raw materials considered, the consumption during the lead time were calculated and given below in Table-8.3:

Table-8.3

Comparison of EOQ and consumption during lead time of some of the main raw materials

Item	Lead time, LT month	Demand rate, D kg./month	Consumption in LT Kg.	Economic order qnty. Q^*,MT
Sugar	1	5030	5030	32.47
Liquid glucose	0.5	830	415	13.19
Cocoa-powder	6.0	450	2700	9.72

The calculated economic order quantities for the various raw materials such as sugar, liquid glucose, cocoa-powder etc. are much higher than the corresponding consumption during their respective lead times. This would increase the holding cost. Thus, inventory model such as the well known Periodic Review Model was tested. For the continuous review model no shortage and uniform demands were assumed. But these assumptions in reality are different. For non-uniform demand the periodic review model would be appropriate.

8.2.2 Periodic Review Model:

In periodic review model, it is assumed that there is no stock on hand initially and the inventory is reviewed at fixed time intervals. A count must be taken of the goods on hand at the designated inventory review data. The size of the replenishment order depends upon the number of units in stock at that time. Therefore, the order quantity varies from period to period, and the decision maker changes the quantity order to reflect changes in the demand rate.

The aim of this model is to enumerate for each of the possible combinations of either purchasing or not purchasing in each period and also the possible quantities that ought to be purchased. With a fixed order period, the periodic system requires safety. Stock for protection against demand fluctuation during both the review period and the lead time. This means that the periodic system will require a large safety stock for a given item than the perpetual system. The Dynamic Programming Technique can very efficiently be used for the periodic system.

8.3 DYNAMIC PROGRAMMING AS APPLIED TO DETERMINE OPTIMUM PROCUREMENT POLICY OF MAJOR RAW MATERIALS

8.3.1 Optimum Procurement Policy for Sugar:

Sugar is a local raw material purchased on average 12 times or more a year. To reduce the purchasing cost (which includes the ordering cost, transportation cost, labour cost etc.) and the holding cost the total demand of the year is divided into 4 periods and it is assumed that the purchases

According to the monthwise consumption, the requirements for the four periods are given in the following table-8.4:

Table-8.4

Segregation of total sugar consumption during a year into four periods

Period, i	1	2	3	4	Total
Requirements, r_i' in Kg.	12,446	16,283	17,623	16,021	62,373
Reduced requrements, r_i (after factorizing)*	2	3	3	3	11

** Factorizing is done by sealing down, r_i', to obtain reduced r_i. Thus, reduced $r_i = \frac{r_i'}{f}$, where f = reduction factor. The value of 'f' was 5874.34 in the present case.*

The dynamic programming approach is explained below:

<u>Iteration-1</u>

The iteration corresponds to periods i=4, that is, a description of the optimal policy at the beginning of period-4. For this case, the model is as follows:

$$C_4^*(x_4) = \text{minimum } [B_4(x_4, Z_4)]$$

$$Z_4 >= 0$$

$$Z_4 >= r_4 - x_4 = 3 - x_4.$$

where,

$C_4^*(x_4)$ = Total cost for the best policy for period-4.

$B_4(x_4, Z_4)$ = Total cost incurred for all possible combinations of x and Z in period-4.

x_4 = Stock on-hand i.e., entering inventory at the begining of period-4.

$x_4 = 0, 1, 2, 3,$ and 4.

Z_4 = Quantity to be ordered at the beginning of period-4.

= 0,1,2,3, and 4.

Now since,

K = ordering cost (=Tk.29700.00)

C = Purchasing cost (=Tk.25.25/kg)

h = Holding cost (=Tk.3.40/kg per year = Tk.0.85/kg per period)

Sample Calculation:

For period 4, when $x_4 = 0$ and $Z_4 = 3$

Ordering cost, k = 29700 = 5.05

Purchasing cost, CZ_4 = 25.25 x 3 = 75.75

Holding cost, $h(x_4 + Z_4 - r_4)$

= 0.85(0 + 3 - 3) = 0.00

∴ Total cost, $C_4^*(x_4)$ = 5.05 + 75.75 = 80.80

when $x_4 = 1$ and $Z_4 = 2$,

Purchasing cost, $C.Z_4$ = 25.25 x 2

= 50.50

Holding cost, B_4 = $h(x_4 + Z_4 - r_4)$ = 0.567(1 + 2 - 3)

= 0.00

Finally, when $x_4 = 3$, $Z_4 = 0$

Purchasing cost = 0.00

Holding cost, $h(x_4 - r_4) = 0.567(3 - 3)$

$= 0.00$

$\therefore$ Total cost, $C_4^*(x_4) = 0.00$

The calculated values are tabulated below:

Table - 8.5

Iteration-1
Period-4

First iteration towards optimum procurement plicy of sugar

(1)	(2)	(3)	(4)	(5)	(6)
x_4	Z_4	$C.Z_4$	$h(x_4+Z_4-r_4)$	$C_4(x_4) = B_4(x_4,Z_4) = (3)+(4)+k^*$	Z_4^*
0	3	75.75	0	80.80	3
1	2	50.50	0	55.55	2
2	1	25.25	0	30.30	1
3	0	0	0	0^*	0^*

k^* = Reduced ordering cost

$$= \frac{\text{Tk.}29{,}700}{(f=5874.34)} = 5.05$$

r_4 = Requirement = 3.

Thus, optimum policy is not to place any order at the beginning of period-4 so that inventory carried from period-3 should be sufficient to cover period-4. Thus, $C_4^*(x_4=3) = 0$.

<u>Iteration-2:</u>

The second iteration requires finding the optimal policy from the beginning of period-3 to the end of period-4. This is given as follows:

$$C_3^*(x_3) = \underset{\substack{Z_3 >= 0 \\ Z_3 >= r_3 - x_3 = 3 - x_3.}}{\text{minimum}} [B_3(x_3,Z_3) + C_4^*(x_3 + Z_3 - r_3)]$$

where,

x_3, Z_3 = 0, 1, 2, ... 6.

$C_3^*(x_3)$ = Total cost for the best policy for the period 3 and 4.

$B_3(x_3,Z_3)$ = cost incurred for all possible combinations of x and Z in period-3.

$C_4^*(x_3 + Z_3 - r_3)$ = Minimum cost incurred for $(x_3 + Z_3 - r_3)$ units in period-4.

The solution to the problem beginning at period-3 is given in a table-8.5 below:

Table-8.6

Second iteration towards optimum procurement policy of sugar

Iteration-2
Period-3

$B_3(x_3,Z_3) + C_4^*(x_3 + Z_3 - r_3)$

x_3 \ Z_3	0	1	2	3	4	5	6	$C_3^*(x_3)$	Z_3^*
0	-	-	-	161.61	162.46	163.30	159.10	159.10	6
1	-	-	136.36	137.20	138.05	133.85	-	133.85	5
2	-	111.11	111.95	112.80	108.60	-	-	108.60	4
3	85.85	86.70	87.55	83.35	-	-	-	83.35	3
4	61.64	60.60	55.55	-	-	-	-	55.55	2
5	37.05	32.85	-	-	-	-	-	32.85	1
6	8.90	-	-	-	-	-	-	8.90	0

For example:

Let $x_3 = 2$ and $Z_3 = 4$. that is,

4 units are purchased; given an initial inventory of 2. (stock-on-hand)

Purchasing cost, $C.Z_3 = 25.25 \times 4 = 101.00$

Holding, $h.(x_3 + Z_3 - r_3) = 0.85(2 + 4 - 3) = 2.55$

Thus, cost incurred in period-3,

$$B_3(x_3,Z_3) = k^* + C.Z_3 + h.(x_3 + Z_3 - r_3)$$
$$= 5.05 + 101.00 + 2.55$$
$$= 108.60$$

and, $C_4^*(2 + 4 - 3) = C_4^*(3) = 0.00$

Hence, Total cost,

$$C_3^*(x_3) = B_3(x_3,Z_3) + C_4^*(3)$$
$$= 108.60 + 0.00$$
$$= 108.60$$

<u>Iteration-3:</u>

The third iteration requres finding the optimal policy from the beginning of period 2 to the end of period-4.

For this case,

$$C_2^*(x_2) = \text{minimum } [B_2(x_2,Z_2) + C_3^*(x_2 + Z_2 - r_2)]$$
$$Z_2 >= 0$$
$$Z_2 >= r_2 - x_2 = 3 - x_2$$

where,

$x_2, Z_2 = 0, 1, 2 \ldots \ldots, 9.$

$C_2^*(x_2)$ = Total cost for the best policy for the period 2 and 3.

$C_3^*(x_2 + Z_2 - r_2)$ = Minimum cost incurred for $(x_2 + Z_2 - r_2)$ units in period-3.

The solution to the problem beginning at period 2 is given in Table-8.7 as follows:

Table-8.7

Third iteration towards optimum procurement policy of sugar

Iteration-3
Period-2

$B_2(x_2, Z_2) + C_3^*(x_2 + Z_2 - 3)$

x_2 \ Z_2	0	1	2	3	4	5	6	7	8	9	$C_2^*(x_2)$	Z_2^*
0	-	-	-	239.90	239.90	239.90	239.90	237.35	239.90	242.20	237.35	7
1	-	-	214.65	215.50	216.35	217.20	215.50	218.90	221.05	-	214.64	2
2	-	189.40	190.25	191.10	191.95	190.25	193.65	195.80	-	-	189.40	1
3	164.15	165.00	165.85	166.70	165.00	168.40	170.55	-	-	-	164.15	0
4	139.75	140.60	141.45	139.75	143.15	145.30	-	-	-	-	139.75	0 or 3
5	115.35	116.20	114.50	117.90	120.05	-	-	-	-	-	114.50	2
6	90.95	89.25	92.65	94.80	-	-	-	-	-	-	89.25	1
7	64.00	67.40	69.55	-	-	-	-	-	-	-	64.00	0
8	42.15	44.30	-	-	-	-	-	-	-	-	42.15	0
9	19.05	-	-	-	-	-	-	-	-	-	19.05	0

Iteration-4:

The final iteration requires finding the optimal policy from the beginning of period-1 to the end of period-4.

For this case,

$$C_1^*(x_1) = \underset{Z \;>=\; 2}{\text{minimum}} \; [B_1(x_1,Z_1) + c_2^*(x_1 + Z_1 - r_1)]$$

The solution to the purchase planning problem is as follows in Table-8.8.:

Iteration-4
Period-1

Table-8.8
Fourth Iteration towards optimum procurement policy of sugar

x_1 \ Z_1	0	1	2	3	4	5	6	7	8	9	10	11	$C_1^*(x_1)$	Z_1^*
0	-	-	292.90	296.30	297.15	298.00	299.70	300.55	301.40	302.25	306.50	309.50	292.50	2

The optimum procurement policy is now given below in Table-8.9:

Table-8.9 : Optimum procurement policy for Sugar

Period i	Iteration	Optimal qnty. ordered each, period Z_1^*	Stock in hand at the beginning of period i x_i	Total cost, $C_i^*(x_i)$
1	4	2	0	292.90
2	3	7	0	237.35
3	2	2	4	55.55
4	1	0	3	0.00

From the table above, the optimum ordering schedule is given in Table-8.10. The orders are placed at the beginning of the period.

Table-8.10 : Optimum ordering schedule for sugar

Period	Order quantity kg.	Adjusted order quantity, Kg.
1	11748	11340
2	41120	39693
3	11748	11340
4	0	0
Total	64616	62373

It may observed that the actual demand was 62,373 kg. of sugar, which compared to model output of 64,616 kg. an adjustment must be accommodated for the built in error due to factorization. The adjusted order quantities are also shown in the above Table-8.10.

The optimum purchase schedule for the various periods are given below:

<u>Period-1:</u>

Place an order at the begining, $Z_1^* = 2$ units $= 11748$ kg.

Stock in-hand at the beginning, $x_1 = 0$

$$C_2^*(x_1 + Z_1 - r_1) = C_2^*(0 + 2 - 2) = C_2^*(0) = 237.35$$

$$C_1^*(x_1 = C_1^*(0) = B_1(x_1, Z_1) + C_2^*(0)$$

$$= B_1(0,2) + C_2^*(0)$$

$$= 55.55 + 237.35$$

$$= 292.90$$

Here, $B_1(0, 2) = k^* + C.Z_1 + h(x_1 + Z_1 - r_1)$

$$= 5.05 + 25.25 \times 2 + 0.85(0 + 2 - 2)$$

$$= 55.55.$$

Period -2 :

Place an order at the beginning, $Z_2^* = 7$ units

$= 41120.38$ kg.

Beginning stock-in-hand $x_2 = 0$

$$C_3^*(x_2 + Z_2 - r_2) = C_3^*(0 + 7 - 3) = C_3^*(4) = 55.55$$

$$C_2^*(x_2) = C_2^*(0) = B_2(x_2, Z_2) + C_3^*(4)$$

$$= B_2(0,2) + 55.55$$

$$= 181.80 + 55.55$$

$$= 237.35$$

Period-3:

Place an order at the beginning, $Z_3^* = 2$ units

$= 11748$

Beginning stock-in-hand, $x_3 = 4$ units

$= 23496$ kg.

$$C^*_4(x_3 + Z_3 - r_3) = C^*_4(4 + 2 - 3) = C^*_4(3) = 0.00$$

$$C^*_3(x_3) = C^*_3(4) = B_3(x_3, Z_3) + C^*_4(3)$$

$$= B_3(4,2) + 0.00$$

$$= 55.55$$

Period-4:

Order quantity at the beginning, $Z_4^* = 0$

Beginning stock-in-hand $x_4 = 3$ units

$= 17623$ kg.

$C_4^* = 0.00$

8.3.2 <u>Optimum Procurement Policy for Other Manor Raw Materials</u>

The optimum procurement policies for other raw materials were determined using dynamic programming model as used earlier. Following were the consolidated analyses including input data and results, Table-8.11:

Table-8.11 : Basic data for dyamic programming model

Raw Material	Procurement cost Tk./kg.	Reduced ordering cost	Holding cost Tk/kg-period	Requirements in period i, r_i kg				Reduction* Factor, f
				r_1	r_2	r_3	r_4	
Liquid Glucose	25.52	48.65	0.85	1799 (3)	1811 (3)	2442 (4)	2187 (4*)	610.50
Cocoa powder	124.00	40.44	1.70	2967 (4)	3678 (5)	-	-	735.60
Milk powder	87.06	13.43	1.70	8862 (4)	10891 (5)	-	-	2215.50
P.K. Oil	39.92	15.09	1.70	9584 (5)	7883 (4)	-	-	1970.75
000 HI	140.65	393.21	1.70	508 (7)	454 (6)	-	-	75.66
Chocolate Flavour	821.80	1023.21	1.70	58.15 (2)	70.20 (3)	-	-	29.075
Gum base	109.00	22.88	1.70	2329 (2)	2602 (2)	-	-	1300

* *Reduction factor is used to factorize the requirements in various periods.*

** *Figures in the parenthesis are the factorized reduced requirements in various periods.*

8.3.2.1 **The optimum procurement policy:**

Liquid Glucose:

The optimum ordering schedule was determined and accordingly the orders were placed at the beginning of the period as given below in Table-8.12.The summary result is given in the following Table-8.13 with the exclusion of intermediate iterations.

Table-.8.12
Order quantity at the beginning of each of the four periods for liquid glucose

Period	Order quantity kg.	Adjusted order qnty.,Kg
1	1831.50	1763
2	1831.50	1763
3	4884.00	4703
4	0.00	0.00
Total	8547.00	8229.00

Table-8.13 : Optimum procurement policy for liquid glucose

Period i	Quantity ordered, Z_i^*	Stock-in-hand at the beginning of period i, x_i	Total cost $C_i^*(x_i)$
1	3	0	506.60
2	3	0	381.40
3	8	0	256.20
4	0	4	0.00

Thus, total cost = 506.60 x 610.50 = Tk.3,09,279.30.

For the other raw materials a consolidated final result is given in the following table-8.14:

Table-8.14
Optimum procurement policy for other main raw materials

Raw Material	Quantity Ordered, Z_i^*		Stock-in-hand at the beginning of period i, x_i		Total Cost $C_i^*(x_i)$	
	Period-1	Period-2	Period-1	Period-2	Period-1	Period-2
Cocoa powder	9	0	0	5	1154.44	0.00
Milk powder	9	0	0	5	805.46	0.00
P.K. Oil	9	0	0	5	381.17	0.00
000 Hi	13	0	0	6	2231.85	0.00
Chocolate flavour	5	0	0	3	5137.31	0.00
Gum base	4	0	0	2	462.28	0.00

From the above solutions for the foreign purchased raw materials, it is observed that the optimal purchase scheduling policy for each of the raw materials (such as cocoa powder, milk powder, vegetable oil, 000 HI, chocolate flavour, gum base) is to place a single order at the beginning of the period-1 for smooth continuation of production throughout the year, which would cause the minimum cost of procurement.

Chapter — IX

CONCLUSION AND RECOMMENDATIONS FOR FUTURE WORK

Chapter — IX

CONCLUSION AND RECOMMENDATIONS FOR FUTURE WORK

9.1 CONCLUSIONS

On the basis of the analysis of the existing system of production and the data available associated with problems identified, the following conclusions are drawn:

1. Managing an industrial unit like Mimi is seriously being faced with difficulty in efficient and profitable performance. The decision making process is subject to irrationality resulting to inefficiency and poor performance.

2. It was found that contemporary not even classical tools and techniques of Industrial Engineering and management were never used in the unit. Thus useful and effective decisions based on rational choices could not be made but only to resort to trial-and-error and rule of thumb.

3. The present research work was directed to explore the possibility of applying Industrial Engineering Techniques in decision making and industrial planning. The production system was analysed and various weaknesses and faults of the system were identified as follows:

i. *weak management system*
ii. *lack of application of operations management techniques*
    a) *operational inefficiency*
    b) *inefficient material procurement policy.*

With the present operational policy the unit is not being able to achieve a level of performance acceptable to any standard.

4. Installation of a common air-conditioning room for both the chocolate and chewing-gum section, could save about 50% of cooling cost and more significantly could improve the quality of products.

5. Installation of a return conveyer for the empty moulds could save about one hour in each shift in the production run,which could be utilized to produce one batch more per day.

6. Installation of a continuous freezing tunnel through which the empty moulds will run on the return conveyor could save about one hour more in each shift of the production run, which could be used to produce one batch more per day.

7. The chocolate product line is presently in an unbalanced condition due to deterioration of capacity of the facilities. The freezer, one of the production facilities

has passed its useful life long before, there by lost its capability by a greater extent.

8. The study has suggested that the production of chocolate product could be increased by a minimum of about 2.25 times the current production level. This would required a freezing facility of three times the present capacity or other three freezer having the same capacity of the existing one. One more conching and one more stirring kettle - each having the same capacity as the existing ones. This effort would remove the bottleneck making the production line in a balanced condition with greater productivity.

9. An excessive over employment of manpower exists in the chocolate section. This increases the labour cost and hence the production cost.

10. Using the existing facilities, capacity of the gum section would permit increasing production level at least by two times the present level.

11. Installation of an automatic wrapping machine of desired capacity would double the productivity at least double which would make the wrapping operation very efficient with minimum human handling and reduction of labour cost by about 80%.

12. The scrap during cutting operation is about 17%, which requires considerable rework. An automatic rolling cum cutting machine could be installed for scrap reduction.

13. An effort was given to asses the future market demand of products of mimi to know the market demand, which is necessary for strategic planning to set-up a goal ahead. Winters' method of forecasting was used to find the market demand. However,it was found that market demand of chocolate products is negligibly affected by the seasonal effect. Forecasting was done for the next 12 months only. These values were used to assess a level of production for maximum profit.

14. An LP model was formulated for the optimum product-mix of the mimi-products. Various restriction equations were developed considering the constraints like minimum level of demand (forecasted values), man-hours availability, machine-hour availability, raw material requirement, plant capacity etc. The objective functions were considered to be profit maximization and sales maximization as presented in chapter-7.

15. The LP model approach shows that the profit margin could be increased significantly, from what could be obtained not applying such an approach. Thus, a profit of Tk.19.94 lacs earned in year 1988-89 could be compared to a profit of Tk.28.48 lacs which could be earned if the LP model was

used. This shows that a higher profit by 47.81% could be achieved if the company produces the amount of the specified items given by the LP model in Table-7.5.

16. The results obtained by using the LP model was compared to the factory's actual production figures of 1988-89. The optimal production of mimi items proved to be much less (about 50% less) than the forecasted demand. This indicated that it would be profitable to leave unutilized a certain amount of machine hours due to bottle necking condition in the chocolate production line or very high requirement of labour-hours. This complexity could be mitigated through BMRE of the whole production line as already mentioned in Chapter-4.

17. Formulation of an optimum purchase scheduling policy for some of the major raw materials was made. A periodic review model instead of a single economic lot-size model was used. As the demands are different from period to period, the EOQ model can not ensure a minimum cost solution. A Dynamic programming technique was used for the above periodic review model. For this purpose, number of periods was reduce to three periods for local raw materials and only one period for imported raw materials for minimum cost of procurement. The purchase schedule is given in Table-8.13 and Table-8.14.

9.2 RECOMMENDATIONS FOR FUTURE WORK:

The following are the areas of future work recommended for more effective planning:

1. A through study of the marketing condition through broad market survey to know the share of mimi-products.

2. A computer based information system could be of benefit to the organization. Future work may be directed in exploring the feasibility of installing an appropriate computer system.

3. While analysing the results of LP model in the present work it was found that the suggested optimum production quantity were around 150% of the forecasted market demand. In other words the factory under study would produce only 50% of what market would consume. This finding would suggest that future works should be carried out to make a sansitivity analysis of the relevant restriction equations and at the same time ascertain the market share of the enterprise. In this regard the bottlenecks in the restricting resources should be identified and balancing should be done.

3. While determining the optimum procurement scheduling policy, the annual production period was divided into four ordering intervals to find at what period what amount is to be ordered at a minimum cost. A future work may be made on this issue to decide the optimum number of ordering periods, for this purpose a computer software may be developed.

APPENDIX – I

APPENDIX — I

Common IE Techniques and Their Applications

Need	Application	IE Techniques	Result
Improvement in productivity	Assessment of necessary workers, labour sarving	- Time study - Work sampling - Human Engineering - Job analysis	Improvement in productivity, reduction in man-hours, improvement in operation rate, reduction in number of personnel required, shortened delivery time, cost reduction, improvement in the capabilities of facilities, standardization of work.
	Operation planning improvement in operation rate	- Time study - Simulation - PERT - Operation analysis	
Improvement of equipment, investment in efficiency	Layout	- Inventory theory - Queueing theory - Material handling analysis - Statistical linear programming	Improvement in productivity, improvement in operation rate, improvement in capacities of facilities, reduction in inventory, effective utilization of spare, improvement in yield, reduction in cost.
	Equipment Planning and explanation of the capacities of facilities	- Flow analysis - Engineering economy - Simulation.	
	Progress control of equipment construction	- PERT	

APPENDIX - I (Contd.)

Common IE Techniques and Their Applications

Need	Application	IE Techniques	Result
Development and improvement of labour	Setting up of standards, contract investigation of subordinate company Motivation	- Time study - Job analysis - Learning curves - Behavior science	Reduction in no. of personnel required, standardization of work, improvement of working conditions, improvement of morale, reduction in cost (improvement in productivity and quality).
Quality & quantity control	Material planning Inventory control Transport planning	- Linear programming - Simulation - Value analysis - Queueing theory - Inventory theory - Statistical method - Time study - Process analysis - Data results - Simulation of LP	Reduction in stock, improvement in yield, improvement in quality, reduction in cost.
Establishment of various control system	Production control, process control, equipment control, clerical work, energy, pollution.	- Simulation - Process analysis - Analysis of flow - work design	Optimum scheduling, standardization of work, easy control, arrangement of control data, simplified business management, reduction in cost

APPENDIX - I (Contd.)

Common IE Techniques and Their Applications

Need	Application	IE Techniques	Result
Development of new products. Expansion of business into new markets	Forecast of demand & supply, developing plans for new products, improvement of circulation system.	- LP - PERT - Theory of games - Creative thinking method - Forecasting method	Shortened delivery time, optimum scheduling.
Others	Work environment improvement, pollution preventives, improvement of companies concerned	- All methods mentioned above	-

APPENDIX — II

<u>A P P E N D I X - II</u>

COMPUTER PROGRAMMES

COMPUTER PROGRAMME FOR WINTERS' METHOD

This computer program uses Winters' method for forecasting a time series of length n consisting of a permanent component, an additive trend components, and a multiplicative seasonal component. The length of the season must be specified by the user. The program is capable of optimizing the smoothing constants over specified ranges and estimating the starting values of the model parameters from the input data.

If smoothing constant optimization is desired, then the user must identify the portion of the time series to be analyzed in the optimization scheme. This segment is the first $n_1 (<n)$ observations. The optimum combination of smoothing constants are those values which result in a minimum forecast error sum of squares for the firt n_1 periods. The initial model parameters are estimated from the first n_1 observations, if this option is utilized. If initial model parameters are to be estimated, then n_1 must be a multiple of the length of the season.

The last $n - n_1$ observations are used in a forecast simulation. The forecast lead time must be specified by the user. Output of this phase includes the forecast errors and both smoothed error and cumulative error tracking signals. The smoothing constant used in tracking signal computations is arbitrarily set at 0.10.

Input Data Preparation

Card 1

Columns 1 - 3	Length of time series (integer, right justified).
Columns 4 - 6	Length of time series to be used in model initialization and smoothing constant calculations (integer, right justified).
Culumn 7	0 if the smoothing constants are specified by the user, or 1 if smoothing constant optimization is desired.
Column 8	0 if the initial values of the model parameters are specified by the user, or 1 if the initial values of the model parameters are estimated from the data.
Columns 9 - 11	Length of the season (integer, right justified).
Columns 12 - 14	Forecast lead time (integer, right justified).

Card 2

If smoothing constants are specified by the user:

Columns 1 - 4	Smoothing constant for permanent component (Alpha), F4.2 Format
Columns 5 - 8	Smoothing constant for trend component (Beta)F4.2 Format
Columns 9 - 12	Smoothing constant for seasonal component (Gamma), F4.2 Format.

If smoothing constant optimization is desired (all F4.2 Format):

Columns 1 - 4	Lower limit for Alpha
Columns 5 - 8	Step size for Alpha
Columns 9 - 12	Upper limit for Beta
Columns 13 - 16	Lower limit for Beta
Columns 17 - 20	Step size for Beta

Card 5:

Columns 1 - 4 Initial value of the trend component, F4.2 Format.

Card 6:

Columns 1 - 4 Initial seasonal factor, 1st period, F4.2 Format.

Card 7:

Columns 1 - 4 Initial seasonal factor, 2nd period, F4.2 Format.

...

...

Card L + 5:

Columns 1 - 4 Initial seasonal factor, Lth period, F4.2 Format.

Columns 21 - 24	Upper limit for Beta
Columns 25 - 28	Lower limit for Gamma
Columns 29 - 32	Step size for Gamma
Columns 33 - 36	Upper limit for Gamma

Caution: The program tries all possible combinations of smoothing constants, and unless the ranges and step sizes are carefully chosen a large number of relatively uniformative calculations will be made. For example, if you specify the range of each smoothing constant as 0.00 to 0.99 in steps of 0.01, then $(100)^3$ or 1,000,000 trials will be made. It is better to use a coarse grid at first, and made a second run (if necessary) with a fine grid restricted to a narrow interval.

Card 3 Data Cards

Enter the data, 10 observations per card in F8.2 Format, beginning with the first observation. Use as many cards as necessary.

If initial values of the model parameters (permanent component, trend, and L seasonal factors) are specified by the user, the following additional cards are required:

Card 4:

Columns 1 - 4	Initial value of the permanent value, F4.2 Format.

```
C       FORECASTING OF IEMI-PRODUCTS BY WINTERS' METHOD (JULY'83-JUNE'90)
C
        DIMENSION X(500),A(500),B(500),S(24),V(10),FF(10,24),R(500),F(500)
        DIMENSION FFP(500),SAVE(24),SS(500)
        REAL ONEMAA,ONEMBB,ONEMGG
        OPEN(UNIT=1,STATUS='OLD',FILE='IN')
        OPEN(UNIT=3,STATUS='NEW',FILE='OUT')
        READ(1,1)N,N1,KS,KN,L,LT
    1   FORMAT(2I3,2I1,2I3)
        XLT=LT
        IF(KS.EQ.0) THEN
           READ(1,2) ALPHA, BETA,GAMMA
    2      FORMAT(9F4.2)
        ENDIF
        IF(KS.EQ.1) THEN
           READ(1,3) AL,AD,AU,BL,BD,BU,GL,GD,GU
    3      FORMAT( 9F4.2)
        ENDIF
        READ(1,4)(X(I),I=1,N )
    4   FORMAT(7(F8.2,2X))
        WRITE(3,5)
    5   FORMAT('1',25X,'WINTERS''METHOD FOR FORECASTING A SEASONAL TIME
       *SERIES'/)
        IF(KN.EQ.1) GO TO 12
        WRITE(3,6)
    6   FORMAT('0',10X,' INITIAL VALUES OF THE PERMANENT,TREND AND SEASO
       *NAL COMPONENTS SPECIFIED')
        READ(3,2)A0
        READ(3,2)B0
        DO 7 I=1,L
        READ(1,2)S(I)
    7   SAVE(I)=S(I)
        WRITE(3,8)A0
    8   FORMAT('0',20X,'INITIAL PERMANENT COMPONENT=',F10.4)
        WRITE(3,9)B0
    9   FORMAT('0',20X,'INITIAL TREND COMPONENT=',F10.4)
        DO 10 I=1,L
   10   WRITE(3,11)I,S(I)
   11   FORMAT('0',20X,'INITIAL SEASONAL FACTOR FOR PERIOD',I3,1X,'=',
       *F10.4)
        GO TO 22
   12   WRITE(3,13)
   13   FORMAT('0',3X,'INITIAL VALUES OF THE PERMANENT,TREND AND SEASO
       *NAL COMPONENTS TO BE ESTIMATED FROM THE DATA.')
        KK=N1/L
        WRITE(3,14)N1,KK
   14   FORMAT('0'/,8X,'THE FIRST',I3,1X,'PERIODS OF DATA WHICH CORRESP
       *OND TO',I2,1X,'SEASONS WILL BE USED')
        RL=L
        J1=1
        J2=L
        DO 16 I=1,KK
        V(I)=0.0
        DO 15 J=J1,J2
   15   V(I)=V(I)+X(J)
```

```
      V(I)=V(I)/RL
      J1=J2+1
      J2=J1+L-1
 16   CONTINUE
      RR=N1-L
      B0=(V(KK)-V(I))/RR
      A0=V(1)-RL/2.*B0
      J1=0
      DO 18 I=1,KK
      DO 17 J=1,L
      JT=J+J1*L
      RJ=J
 17   FF(I,J)=X(JT)/(V(I)-(((RL+1.0)/2.0)-RJ)*B0))
      J1=J1+1
 18   CONTINUE
      SUMS=0.0
      RKK=KK
      DO 20 J=1,L
      SUM=0.0
      DO 19 I=1,KK
 19   SUM=SUM+FF(I,J)
      S(J)=SUM/RKK
 20   SUMS=SUMS+S(J)
      WRITE(3,8)A0
      WRITE(3,9)B0
      DO 21 J=1,L
      S(J)=S(J)*(RL/SUMS)
      SAVE(J)=S(J)
 21   WRITE(3,11)J,S(J)
 22   IF(KS.EQ.0)GO TO 32
      WRITE(3,23)
 23   FORMAT(////'1',10X,'SMOOTHING CONSTANT OPTIMIZATION ROUTINE')
      WRITE(3,24)
 24   FORMAT('0',13X,'ALPHA',10X,'BETA',10X,'GAMMA',10X,'RESIDUAL SUM
     *OF SQUARES.'/)
C
C***SEARCH FOR OPTIMUM VALUES*******************************************
C
      KA=(AU-AL)/AD+1.0
      KB=(BU-BL)/BD+1.0
      KG=(GU-GL)/GD+1.0
      AA=AL
      ABEST=0.0
      BBEST=0.0
      GBEST=0.0
      EBEST=1.0E+38
      DO 30 II=1,KA
      ONEMAA=1.0-AA
      BB=BL
      DO 29 IJ=1,KB
      ONEMBB=1.0-BB
      GG=GL
      DO 28 IK=1,KG
      DO 205 IL=1,L
 205  S(IL)=SAVE(IL)
```

```
      ONEMGG=1.0-GG
      A(1)=AA*(X(1)/S(1))+ONEMAA*(AO+BO)
      B(1)=BB*(A(1)-AO)+ONEMBB*BO
      S(1)=GG*(X(1)/A(1))+ONEMGG*S(1)
      XHAT=(A(1)+XLT*B(1))*S(1+LT)
      E=(X(1+LT)-XHAT)**2
      DO 26 I=2,N1
      IL=MOD(I,L)
      IF(IL.EQ.0)IL=L
 25   A(I)=AA*(X(I)/S(IL))+ONEMAA*(A(I-1)+B(I-1))
      B(I)=BB*(A(I)-A(I-1))+ONEMBB*B(I-1)
      S(IL)=GG*(X(I)/A(I))+ONEMGG*S(IL)
      ILLT=IL+LT
      IF(ILLT.GT.L) ILLT=ILLT-L
      XHAT=(A(I)+XLT*B(I))*S(ILLT)
 26   E=E+(X(I+LT)-XHAT)**2
      WRITE(3,27)AA,BB,GG,E
 27   FORMAT(8X,F10.4,5X,F10.4,5X,F10.4,15X,E15.7)
      IF(E.GE.EBEST) GO TO 28
      ALPHA=AA
      BETA=BB
      GAMMA=GG
      EBEST=E
 28   GG=GG+GD
 29   BB=BB+BD
 30   AA=AA+AD
      WRITE(3,31)
 31   FORMAT('0',10X,'THE OPTIMUM SMOOTHING CONSTANTS ARE')
 32   IF(KS.EQ.0) WRITE(3,33)
 33   FORMAT('0',10X,'THE SMOOTHING CONSTANTS ARE SPECIFIED AS')
      WRITE(3,34)ALPHA,BETA,GAMMA
 34   FORMAT('0',10X,'ALPHA=',F10.4,5X,'BETA=',F10.4,5X,'GAMMA=',F10.4)
      IF(N1.EQ.0) N1=L
C
C
C
C******FORECAST WITH OPTIMUM SMOOTHING CONSTANTS************************
C
C
C
      DO 305 IL=1,L
305   S(IL)=SAVE(IL)
      ONEMAA=1.0-ALPHA
      ONEMBB=1.0-BETA
      ONEMGG=1.0-GAMMA
      A(1)=ALPHA*(X(1)/S(1))+ONEMAA*(AO+BO)
      B(1)=BETA*(A(1)-AO)+ONEMBB*BO
      S(1)=GAMMA*(X(1)/A(1))+ONEMGG*S(1)
      F(1)=(A(1)+XLT*B(1))*S(LT+1)
      SS(1)=S(1)
      FFP(1+LT)=F(1)
      R(1+LT)=X(1+LT)-F(1)
      R(1)=0.0
      SUMSQ=R(1)**2
      XMAD=ABS(R(1))
```

```
      DO 36 I=2,N1
      IL=MOD(I,L)
      IF(IL.EQ.0) IL=L
 35   A(I)=ALPHA*(X(I)/S(IL))+ONEMAA*(A(I-1)+B(I-1))
      B(I)=BETA*(A(I)-A(I-1))+ONEMBB*B(I-1)
      S(IL)=GAMMA*(X(I)/A(I))+ONEMGG*S(IL)
      SS(I)=S(IL)
      ILLT=IL+LT
      IF(ILLT.GT.L) ILLT=ILLT-L
      F(I)=(A(I)+XLT*B(I))*S(ILLT)
      FFP(I+LT)=F(I)
      R(I+LT)=X(I+LT)-F(I)
      SUM=SUM+R(I)
      XMAD=XMAD+ABS(R(I))
 36   SUMSQ=SUMSQ+R(I)**2
      DO 306 I=1,LT
306   FFP(I)=0
      J=N1+1
C
C
C
C
C
C**********START THE FORECASTING PHASE**********************************
C
      DO 38 I=J,N
      IL=MOD(I,L)
      IF(IL.LE.0) IL=L
 37   FFP(I)=(A(I-LT)+XLT*B(I-LT))*S(IL)
      A(I)=ALPHA*(FFP(I)/S(IL))+ONEMAA*(A(I-1)+B(I-1))
      B(I)=BETA*(A(I)-A(I-1))+ONEMBB*B(I-1)
      S(IL)=GAMMA*(FFP(I)/A(I))+ONEMGG*S(IL)
 38   SS(I)=S(IL)
      WRITE(3,39)
 39   FORMAT(////'1',25X,'OUTPUT OF THE INITIALIZATION PHASE'//)
      WRITE(3,40)
 40   FORMAT('0',10X,'PERIOD',2X,'OBSERVATION',2X,'PERMANENT COMPONENT',
     *2X,'TREND',2X,'SEASONAL FACTOR',2X,'FITTED MODEL',2X,'RESIDUAL'/)
      DO 41 I=1,N1
          WRITE(3,42)I,X(I),A(I),B(I),SS(I),FFP(I),R(I)
 42       FORMAT(10X,I3,4X,F10.4,10X,F10.4,2X,F10.4,3X,F10.4,3X,F10.4,2X,
     *F10.4 )
 41   CONTINUE
      T=N1
      AVE=SUM/T
      VAR=(SUMSQ-T*AVE**2)/(T-1.0)
      STD=SQRT(VAR)
      XMAD=XMAD/T
      WRITE(3,43)SUM,AVE,VAR,STD
 43   FORMAT('0',5X,'SUM OF RESIDUALS=',F10.4,5X,'AVERAGE RESIDUAL=',
     *F10.4/9X,'VARIANCE=',E10.4,5X,'STANDARD DEVIATION=',F10.4)
      WRITE(3,44) XMAD
 44   FORMAT('0',5X,'MEAN ABSOLUTE DEVIATION=',F10.4)
      KTR=0
      STDM=STD*(-2.0)
```

```
      STD=2.0*STD
      DO 45 I=1,N1
      IF(R(I).GT.STD.OR.R(I).LT.STDM)  KTR=KTR+1
 45   CONTINUE
      WRITE(3,46) KTR
 46   FORMAT('0',6X,'NUMBERS OF RESIDUALS EXCEEDING TWO STANDARD DEVIATI
     *ONS=',I3////)
      WRITE(3,47)
 47   FORMAT('1',20X,'OUTPUT OF FORCASTING PHASE'//)
      WRITE(3,48) L,LT
 48   FORMAT('0',10X,'LENGTH OF THE SEASION IS',I3,1X,'PERIODS',2X,'FOR
     *ECAST LEAD TIME IS',I2,1X,'PERIODS')

      WRITE(3,49)
 49   FORMAT('0','PERIOD',3X,'PERMANENT COMPONENT',3X,'TREND',3X,'SEASO
     *NAL FACTOR',3X,'FORECAST')
      FC=0.0
      DO 51 I=J,M
      FC=FC+FFP(I)
 51   WRITE(3,52) I,A(I),B(I),SS(I),FFP(I)
 52   FORMAT(3X,I3,6X,F10.4,5X,F10.4,7X,F10.4,5X,F10.4)
      WRITE(3,53) STD
 53   FORMAT(10X,'STANDARD DEVIATION=',F10.4)
      FCC=(SUM/2)+FC
      WRITE(3,54) FCC
 54   FORMAT(10X,'FORECAST FOR THE NEXT 12 MONTHS=',F10.4)
C
C
C
C
      STOP
      END
```

```
36 2411 12  1
0.310.010.370.000.010.040.000.010.04
 7565.00    8379.00    9321.00    8609.00    6541.00    9039.00   10186.00
12573.00   10597.00    7370.00    7745.00    9108.00    8730.00   11954.00
 7492.00   14023.00   11002.00   11959.00   13164.00   12534.00   13786.00
 9216.00   10306.00   13147.00      00.00      00.00      00.00      00.00
   00.00      00.00      00.00      00.00      00.00      00.00      00.00
   00.00
```

```
C      *************************************************************
C      * **** ALGORITHM **** LINEAR PROGRAMMING ****||SIMPLEX||****   *
C      *                                                             *
C      *                                                             *
C      * THIS PROGRAM IS DESIGNED TO SOLVE ANY LINEAR PROGRAMMING MODEL*
C      *  MODEL UP TO 25 CONSTRAINTS AND 75 VARIABLES INCLUDING SLACK, *
C      *  SURPLUS, AND ARTIFICIAL VARIABLES. LARGER PROBLEMS CAN BE    *
C      *  SOLVED BY CHANGING THE CORRESPONDING NUMBERS IN THE DIMENSION*
C      *  AND COMMON STATEMENTS IN THE MAINLINE AS WELL AS IN THE SUB- *
C      *  ROUTINES SSARTV AND SIMPLX.                                  *
C      *     THE PROGRAM SUPPLIES THE NECESSARY SLACK,SURPLUS, AND     *
C      *     ARTIFICIAL VARIABLES. IT WILL TREAT MINIMIZATION AS WELL  *
C      *     AS MAXIMIZATION PROBLEMS. EACH COST COFFICIENT MUST BE    *
C      *     LESS THAN 100 IN ABSOLUTE VALUE.                          *
C      *                                                             *
C      *  SUBROUTINE SSARTV SUPPLIES SLACK, SURPLUS, AND ARTIFICIAL    *
C      *  VARIABLES.                                                   *
C      *  SUBROUTINE SIMPLX DOES THE WORK OF THE SIMPLEX ALGORITHM.   *
C      *                                                             *
C      *  IT IS DESIGNED                                               *
C      *     TO READ                                                   *
C      *                                                             *
C      *        CARD 1 COLS  2-80  TITLE DESCRIPTION OF THE PROBLEM    *
C      *                           USING ANY CHARACTERS ON KEYPUNCH    *
C      *                            ** COLUMN 1 MUST BE LEFT BLANK **  *
C      *        CARD 2 COLS  1- 5  M  NUMBER OF CONSTRAINTS (I5)       *
C      *                     6-10  K  NUMBER OF VARIABLES (I5)         *
C      *                    11-15  NLET NUMBER OF <OR= CONSTRAINTS (I5)*
C      *                    16-20  NGET NUMBER OF >OR= CONSTRAINTS(I5) *
C      *                    21-25  NET NUMBER OF = CONSTRAINTS   (I5)  *
C      *                    26-30  NTYPE  0  MINIMIZATION PROBLEM      *
C      *                                  1  MAXIMIZATION PROBLEM(I5)  *
C      *                                                             *
C      *     CARD 3 TO T    M SETS OF CARDS, ONE SET FOR EACH CONSTRAINT*
C      *                                                             *
C      *     CARD I                                                    *
C      *          COLS  1-10  CODE(I)   0 IF <OR= CONSTRAINT           *
C      *                                1 IF >OR= CONSTRAINT           *
C      *                                2 IF = CONSTRAINT    (I10)     *
C      *               11-20  B(I)  CONSTANT IN  CONSTRAINT I  (F10.0) *
C      *     CARD I+1                                                  *
C      *          A(I,J)  J  COEFFICIENTS OF CONSTRAINT :              *
C      *                     PUNCH ROWWISE IN 8F10.0 FORMAT            *
C      *                     IF K>8, CONTINUE ON NEXT CARD.            *
C      *     CARD T+1                                                  *
C      *          C(J)  COST COEFFICIENTS OF OBJECTIVE FUNCTION :      *
C      *                PUNCH ROWWISE IN 8F10.0 FORMAT                 *
C      *                IF K>8, CONTINUE ON NEXT CARD.                 *
C      *     CARD Z                                                    *
C      *          COLS 1-5  NOPT  0  PRINT ONLY OPTIMAL SULUTION       *
C      *                          1  PRINT ALL SOLUTIONS  (I5)         *
C      *                                                             *
C      *       TO SOLVE MORE THAN ONE PROBLEM AT A TIME, REPEATE       *
C      *       SEQUENCE, AND STACK THE DATA ONE BEHIND THE OTHER       *
C      * TO CALCULATE AND PRINT                                        *
```

```
C        *             Z   OPTIMAL VALUE OF THE OBJECTIVE FUNCTION              *
C        *        XB(I)    THE SUBCRIPT OF THE BASIC VARIBLES IN THE            *
C        *                 OPTIMAL BASIC FEASIBLE SOLUTION                      *
C        *    A(I,NP1)     THE VALUE OF THE BASIC VARIABLES                     *
C        ************************************************************************
      COMMON B(34),C(76), CODE(34),KP1,MP1,N,K,M,NGET,NLET,NET,NTYPE,
     +NP1,NC,NC1,INDEXG,INDEXL,INDEXE,IFLAG,BASICS,OPTSOL,SUM,NOPT
      INTEGER CODE, XB, BASICS, OPTSOL
      CHARACTER TITLE*80
      DIMENSION A(34,76),XB(76)
      OPEN (UNIT=1,FILE='IN',STATUS='OLD')
      OPEN (UNIT=3,FILE='OUT',STATUS='NEW')
   50 READ(1,10,END=2000) TITLE
   10 FORMAT(A80)
      WRITE(3,15) TITLE
   15 FORMAT('1',A80,//)
      READ(1,20) M, K, NLET, NGET, NET, NTYPE
   20 FORMAT(6I5)
      DO 25 I = 1, M
      READ(1,30) CODE(I), B(I)
   30 FORMAT(I10,F10.0)
      READ(1,29)(A(I,J),J= 1,K)
   29 FORMAT(9F8.2)
   25 CONTINUE
      READ(1,29) (C(J), J= 1,K)
      WRITE(3,40)
   40 FORMAT(5X, 'THE ORIGINAL COEFFICIENTS OF THE CONSTRAINTS',//15X,
     +'CODE 0 ==> <OR= CONSTRAINT',/15X,'CODE 1 ==>  >OR= CONSTRAINT',
     +/15X,'CODE 2 ==>  = CONSTRAINT',//)
      WRITE (3,55)
   55 FORMAT('I CODE CONSTANT A(I,1) A(I,2) A(I,3) A(I,4) A(I,5),A(I,6),
     +A(I,7) A(I,8)',/)
      DO 45 I= 1, M
      WRITE (3,51) I, CODE(I), B(I)
   51 FORMAT(I3,I4,F12.2)
      WRITE (3,52)(A(I,J), J= 1, K)
   52 FORMAT('+',15X,8F12.2,/(16X,8F12.2))
   45 CONTINUE
      IF(NTYPE.NE.0) GO TO 35
      WRITE(3,36)
   36 FORMAT(//5X,'THE COEFFCIENTS IN THE ORIGINAL OBJECTIVE FUNCTION
     +TO BE MINIMIZED ARE:',/)
      GO TO 37
   35 WRITE(3,38)
   38 FORMAT(//5X,'THE COEFFICIENTS IN THE ORIGINAL OBJECTIVE FUNCTION
     +TO BE MAXIMIZED ARE:',/)
   37 WRITE(3,39)(C(J),J= 1,K)
   39 FORMAT(16X,8F8.2/16X,8F8.2)
      READ(1,20)NOPT
C     ************************************************************************
  150 CALL SSARTV(A,XB)
      IF(IFLAG.EQ.1) GO TO 50
      BASICS = 0
      OPTSOL = 0
      WRITE(3,160)
```

```
 160  FORMAT(//)
      CALL SIMPLX(A,XB)
      IF(NFLAG.EQ.1.OR.NFLAG.EQ.2) GO TO 50
      IF(NTYPE.EQ.1) GO TO 220
      SUM = -SUM
 220  WRITE(3,230) SUM
 230  FORMAT(10X,'OPTIMAL VALUE OF THE ORIGINAL OBJECTIVE FUNCTION IS',
     +F12.2)
      GO TO 50
 2000 STOP
      END
      SUBROUTINE SSARTV(A,XB)
C     ******************************************************************
C     * SSARTV                                                         *
C     *       A SUBROUTINE THAT SUPPLIES THE SLACK,SURPLUS,AND ARTIFICIAL*
C     *       VARIABLES NEEDED TO PERFORM SIMPLEX METHOD.                *
C     ******************************************************************
      COMMON B(34),C(76),CODE(34),KP1,MP1,N,K,M,NGET,NLET,NET,NTYPE,NP1,
     +NC,NC1,INDEXG,INDEXL,INDEXE,NFLAG,BASICS,OPTSOL,SUM,NOPT
      INTEGER CODE,XB,BASICS,OPTSOL
      DIMENSION A(34,76),XB(76),ARTV(52)
C INITIALIZE THE VARIABLES
      IFLAG = 0
      IA = 1
      KP1 =K + 1
      MP1 =M + 1
      N = K + 2*NGET + NLET + NET
      NP1 = N + 1
      NC = K + NGET + 1
      NC1 = NC + NLET
      INDEXG = K + 1
      INDEXL = K + NGET + 1
      INDEXE = K + NGET + NLET + 1
      DO 69 I = 1,MP1
      DO 69 J = KP1,NP1
  69  A(I,J) = 0
 150  DO 5 I = 1, M
   5  A(I,NP1) = B(I)
      DO 4 I = 1, M
      IF(CODE(I).EQ.0) GO TO 6
      IF(CODE(I).EQ.1) GO TO 8
      ARTV(IA) = I
      IA = IA + 1
      XB(I) = INDEXE
      A(I,INDEXE) = 1
      INDEXE = INDEXE + 1
      GO TO 4
   8  XB(I) = INDEXE
      ARTV(IA) = I
      IA = IA + 1
      INDEXE = INDEXE+ 1
      A(I,INDEXG) = -1
      INDEXG = INDEXG + 1
      GO TO 4
   6  XB(I) = INDEXL
```

```
      A(I,INDEXL) = 1
      INDEXL = INDEXL + 1
    4 CONTINUE
C CHECK FOR CORRECT DATA
      IF(INDEXG.NE.NC) GO TO 100
      IF(INDEXL.NE.NC1) GO TO 110
      IF(INDEXE.NE.NP1) GO TO 120
      GO TO 151
  100 WRITE(3,101)
  101 FORMAT(/// 'NUMBER OF >OR= CONSTRAINTS DOES NOT MATCH VALUE READ
     +IN')
      IFLAG = 1
      RETURN
  110 WRITE(3,111)
  111 FORMAT(/// 'NUMBER OF <OR= CONSTRAINTS DOES NOT MATCH VALUE READ
     +IN')
      IFLAG = 1
      RETURN
  120 WRITE(3,121)
  121 FORMAT(// 'NUMBER OF = CONSTRAINTS DOES NOT MATCH VALUE READ IN')
      IFLAG = 1
      RETURN
C  CHECK FOR MAXIMIZATION
  151 CONTINUE
      IF(NTYPE.EQ.0) GO TO 12
      DO 60 J = 1,K
   60 A(MP1,J) = -C(J)
      GO TO 50
   12 DO 55 J =I,K
   55 A(MP1,J) = C(J)
   50 DO 61 J = KP1,NP1
      A(MP1,J) = 0
   61 C(J) = 0
      DO 62 J = 1,K
   62 C(J) = -A(MP1,J)
      DO 63 J = NC1,N
   63 C(J) = -10.E2
      IF(NGET + NET.EQ.0) RETURN
      IA = IA - 1
      KPGTE = K + NGET
      DO 64 J = 1,KPGTE
      SUM = 0
      DO 65 I = 1,IA
   65 SUM = SUM + A(ARTV(I),J)
   64 A(MP1,J) = A(MP1,J) - 10.E2*SUM
      SUM = 0.
      DO 66 I = 1,IA
   66 SUM = SUM + A(ARTV(I),NP1)
      A(MP1,NP1) = A(MP1,NP1) - 10.E2*SUM
      RETURN
      END
      SUBROUTINE SIMPLX(A,XB)
C     ******************************************************************
C     *  SIMPLX                                                        *
C     *          SUBROUTINE TO PERFORM THE WORK OF THE SIMPLEX METHOD  *
```

```
C       ****************************************************************|
        COMMON B(34),C(76),CODE(34),KP1,MP1,N,K,M,NGET,NLET,NET,NTYPE,NP1,|
       +NC,NC1,INDEXG,INDEXL,INDEXE,NFLAG,BASICS,OPTSOL,SUM,NOPT         |
        INTEGER CODE,XB,BASICS,OPTSOL                                    |
        DIMENSION A(34,76),XB(76)                                        |
        NFLAG = 0                                                        |
C       ****************************************************************|
C       *  STEP.1                                                        |
C       *         OBTAIN BASIC FEASIBLE SOLUTION OF EQUIVALENT MODEL.    |
C       ****************************************************************|
 100    BASICS = BASICS + 1                                              |
        IF(NOPT.EQ.0) GO TO 200                                          |
 105    WRITE(3,104) BASICS                                              |
 104    FORMAT(5X,'BASIC SOLUTION',I4,/)                                 |
        DO 110 I = 1,M                                                   |
 110    WRITE(3,106) I,XB(I),A(I,NP1)                                    |
 106    FORMAT(7X,'XB(',I2,')= X(',I2,')=',F12.2)                        |
        SUM = 0.                                                         |
        DO 111 I = 1,M                                                   |
 111    SUM= SUM + C(XB(I))*A(I,NP1)                                     |
        WRITE(3,130) SUM                                                 |
 130    FORMAT(/7X,'CURRENT VALUE OF THE OBJECTIVE FUNCTION IS',E20.8//) |
        IF(OPTSOL.EQ.1) GO TO 920                                        |
C       ****************************************************************|
C       *  STEPS 2,3                                                    *|
C       *         CHOOSE THE NONBASIC VARIABLE WITH THE MOST NEGATIVE   *|
C       *         COEFFICIENTTO ENTER AS A BASIS VARIABLE FOR THE NEXT  *|
C       *         BASIC FEASIBLE SOLUTION. IF NONE ARE NEGTIVE,AN OPTIMAL *|
C       *         SOLUTION HAS BEEN REACHED,SO GO TO STEP 9.            *|
C       ****************************************************************|
 200    NEG = 0                                                          |
        GNEG = 0                                                         |
        DO 21 J = 1,N                                                    |
           IF(A(MP1,J).GE.GNEG) GO TO 21                                 |
           GNEG = A(MP1,J)                                               |
           NEG = J                                                       |
  21    CONTINUE                                                         |
        IF(NEG.EQ.0) GO TO 900                                           |
C       ****************************************************************|
C       *  STEPS 4,11                                                   *|
C       *         CHECK FOR UNBOUND OBJECTION FUNCTION.                 *|
C       ****************************************************************|
 400    SPR = 10.E10                                                     |
        DO 410 I= 1,M                                                    |
        IF(A(I,NEG).LE..00001) GO TO 410                                 |
        IF(A(I,NP1)/A(I,NEG).GE.SPR) GO TO 410                           |
        SPR = A(I,NP1)/A(I,NEG)                                          |
        NSPR = I                                                         |
 410    CONTINUE                                                         |
        IF(SPR.LE.10.E8) GO TO 510                                       |
        WRITE(3,420)                                                     |
 420    FORMAT(/// 'OBJECTIVE FUNCTION IS NOT BOUNDED BY CONSTRAINTS')   |
        NFLAG = 1                                                        |
        RETURN                                                           |
C       ****************************************************************|
```

```
C     *  STEP 5                                                          *
C     *         FIND PIVOTAL ELEMENT AND DIVIDE BY IT.                   *
C     *******************************************************************
 510  PELE = A(NSPR,NEG)
      DO 500 J = 1, NP1
 500  A(NSPR,J) = A(NSPR,J)/PELE
      XB(NSPR) = NEG
C     *******************************************************************
C     *  STEPS 6,7,8                                                     *
C     *         PERFORM ELEMENTARY TRANSFORMATIONS,AND GO BACK TO STEP 1*
C     *         TO PRINT OUT NEW BASIC FEASIBLE SOLUTION.                *
C     *******************************************************************
 600  DO 610 I = 1,MP1
        IF(I.EQ.NSPR) GO TO 610
        HOLD = A(I,NEG)
        DO 620 J = 1,NP1
 620    A(I,J) = A(I,J) - HOLD*A(NSPR,J)
 610  CONTINUE
      GO TO 100
C     *******************************************************************
C     *  STEPS 9,10                                                      *
C     *         IF THERE IS AN ARTIFICIAL VARIABLE AT A POSITIVE LEVEL  *
C     *         A FEASIBLE SOLUTION DOES NOT EXIST; OTHERWISE,AN OPTIMAL*
C     *         SOLUTION OF THE EQUIVALENT LINEAR PROGRAMMING MODEL HAS *
C     *         BEEN OBTAINED.                                           *
C     *******************************************************************
 900  OPTSOL = 1
      IF(NOPT.EQ.1) GO TO 920
      GO TO 105
 920  DO 930 I = 1, M
      IF(XB(I).LT.NC1) GO TO 930
      IF(A(I,NP1).LE.0) GO TO 930
      WRITE(3,940)
 940  FORMAT(/// 'A FEASIBLE SOLUTION DOES NOT EXIST')
      NFLAG = 2
      RETURN
 930  CONTINUE
      WRITE(3,950)
 950  FORMAT(10X,'THE LAST BASIC FEASIBLE SOLUTION IS OPTIMAL')
      RETURN
      END
```

```
CALCULATION OF PRODUCT-MIX OF A MULTI-PRODUCT INDUSTRY LIKE MIMI
  29    17    29     0     0     1
        0   139662.00
   0.91     0.91     0.91     0.91     1.14     1.14     1.00     0.91     0.30
   0.23     0.23     0.40     0.40     0.91     0.46     0.40     0.40
        0  2168880.00
   6.50     6.50     6.50     6.50     9.72     8.04     6.52    36.36     2.16
  12.85    10.00     0.00     0.00     0.00     0.00     0.00     0.00
        0  2765640.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
   0.00     0.00    22.29    22.29   191.80     0.00     0.00     0.00
        0   330300.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
   0.00     0.00     0.00     0.00     0.00     3.21     3.42    19.60
        0 63572000.00
 384.73   384.73   384.73   384.73   480.80   430.80   423.25   235.65    55.97
  64.75   199.32   189.77   189.77   595.38   454.00   400.00     0.00
        0 19755000.00
 204.52   204.52   204.52   204.52   255.60   255.60   225.00    63.36    29.75
  34.42    40.71     0.00     0.00     0.00     0.00     0.00     0.00
        0 22581000.00
 234.00   234.00   234.00   234.00   292.52   292.52   257.50    75.64    34.05
  39.39    49.79     0.00     0.00     0.00     0.00     0.00     0.00
        0  6645000.00
  70.44    70.44    70.44    70.44    88.04    88.04    77.50    16.00    10.24
  11.85    14.02     0.00     0.00     0.00     0.00     0.00     0.00
        0   897000.00
   9.09     9.09     9.09     9.09    11.36    11.36    10.00     2.00     1.32
   1.53     1.80     0.00     0.00     0.00     0.00     0.00     0.00
        0   379000.00
   5.68     5.68     5.68     5.68     7.10     7.10     6.25     1.29     0.82
   0.95     1.13     0.00     0.00     0.00     0.00     0.00     0.00
        0  8283000.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00   226.55    00.00
  00.00    24.01    75.90    75.90   145.50     0.00     0.00     0.00
        0  5437000.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
   0.00     0.00    53.60    53.60   103.07     0.00     0.00     0.00
        0    51590.00
   0.91     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
        0       85.00
   0.00     0.91     0.00     0.00     0.00     0.00     0.00     0.00     0.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
        0    39470.00
   0.00     0.00     0.91     0.00     0.00     0.00     0.00     0.00     0.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
        0     2039.00
   0.00     0.00     0.00     0.91     0.00     0.00     0.00     0.00     0.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
        0      558.00
   0.00     0.00     0.00     0.00     1.13     0.00     0.00     0.00     0.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
        0     4790.00
   0.00     0.00     0.00     0.00     0.00     1.13     0.00     0.00     0.00
```

```
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
         0        726.00
   0.00     0.00     0.00     0.00     0.00     0.00     1.00     0.00     0.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
         0      13710.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.91     0.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
         0      19330.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.30
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
         0       1602.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
   0.23     0.00     0.00     0.00     0.00     0.00     0.00     0.00
         0        497.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
   0.00     0.23     0.00     0.00     0.00     0.00     0.00     0.00
         0      65396.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
   0.00     0.00     0.40     0.00     0.00     0.00     0.00     0.00
         0      29840.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
   0.00     0.00     0.00     0.40     0.00     0.00     0.00     0.00
         0         69.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
   0.00     0.00     0.00     0.00     0.91     0.00     0.00     0.00
         0         00.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
   0.00     0.00     0.00     0.00     0.00     0.45     0.00     0.00
         0       8156.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.40     0.00
         0       8359.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.40
  14.41    14.41    14.41    14.41    10.66     7.91     8.21    13.66    16.12
   2.32     2.47     7.94     7.94    22.83     2.78     3.40    13.49
   1
```

REFERENCES

REFERENCES

1. Bedworth, D.; Bailey J.E, "Integrated Production Control Systems Management, Analysis Design", John Wiley & Sons, Inc., 1982.

2. Rahman, M.M; "Operations Research and Network Analysis in Industrial Planning", Unpublished M.Sc. Engg. Thesis, BUET, Dhaka, March, 1971.

3. Tersin, R.J. "Production/Operation Management: Concept, Structure and Analysis", 2nd Ed. North-Holland. Elseveier Science publishing Company Co. Inc., NY, 1985.

4. Riggs, J.L. "Production Systems : Planning, Analysis and Control", John Wiley & Sons, Inc., NY, 1976.

5. Greene, J.H. "Production and Inventory Control: Systems and Decisions" Richard D. Irwin, Inc., Homewood, Illinois, 1974.

6. Montogomery, D.C., and Johnson, L.A. "Forecasting and Time Series Analysis", McGraw-Hill Book Company Inc., NY, 1976.

7. Cooke, W.P. "Quantitative Methods for Management Decisions", McGraw-Hill Book Company, Inc., NY, 1985.

8. Anderson, D.R., Sweeney, D.J., and Williams, T.A. "An Introduction to Management Science", 3rd ed., West Publishing Company, St. Paul, Minn, 1982.

9. Ritchie, E. "Practical Inventory Replenishment Policies for a Linear.Trend in Demand Followed by a period of Steady Demand", The Journal of the Operational Research Society, Vol. 31, No.7, pp.605-613, 1980.

10. Phelps, R.I; "Optimal Inventory role for a Linear Trend in Demand with a Constant Replenishment Period", The Journal of the Operational Research Society, vol.31, No.5, pp.442, 1980.

11. Kicks, P and Donaldson, W.A; "Irregular Demand : Assessing a Rough and Ready Lot size Formula", The journal of the Operational Research Society, vol.31, No.8, pp.725-732, 1980.

12. Frank Sharp. J; "Linear Programming optimizes use of common labor", Industrial Engineering, vol.3, pp.16-19. February, 1971.

13. Ines Minguez, M. Carlos Romero and Joaquin Domingo "Determining Optimum Fertilizer Combination through Goal Programming with Penalty Functions: An Application to Sugar Beet Production in Spain", Journal of the Operational Research Society, vol.39, No.1, Jan, 1988, pp.61-70.

14. Balm Ian. R, "LP Applications in Scottish Agriculture", Journal of the Operational Research Society, vol.31, No.5, 1980, pp.387-391, 1980.

15. Taha, H.A. "Operations Research", 3rd ed. Macmillan Publishing Co., Inc., NY, and Collier Macmillan Publishers, Canada, 1982.

16. Hillier, F.S. and Lieberman, G.J. "Operations Research", 2nd ed., Holden-Day, Inc., SanFrancisco,1980

17. Robert G. Brown "Statistical Forecasting for Inventory Control, McGraw Hill, Ney York, 1959.

18. Winters, P.R. "Forecasting Sales by Exponentially Weighted Moving Averages", Management Science, vol.6, No.3, pp.324-342, 1960.

19. Barnes, R.M. Motion and Time Study, New York, Wiley, 1980.

20. Mandel, M.E. Motion and Time Study: Principles and Practice, Englewood Cliffs, N.J., Prentice-Hall, 1978.

21. Peter D. Amco "Forecasting System Uses modified smoothing", Industrial Engineering (IE), vol.3, No.1-12, 1971.

22. Schroeder, R.G. "Operations Management : Decision Making in the Operations Function", McGraw-Hill Book Company, Inc, NY 1981

23. Tarapada, B "Operations Research Techniques applied in Replacement of Street Lights of Dhaka City", An unpublished M.Sc. Engg. thesis, BUET Dhaka, February, 1984.

24. Sarker, M.R.A. "Application of IE Techniques in Production Decisions", An unpublished M.Engg. Thesis, BUET, Dhaka, Sept. 1984.

25. "Yearbook of Agricultural Statistics of Bangladesh, 1985-86", February, 1987. Bangladesh Bureau of Statistics Division, Ministry of Planning, Govt. of the People's Republic of Bangladesh, Dhaka, Bangladesh.