A PRODUCT-MIX PROBLEM IN SANITARY PAPER SECTOR

BY

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ABSTRACT

The study analyzes a multi-product ,single-objective case in sanitary paper tissue sector and solves two linear programming models for it.

Main objectives of the research are to determine a model that will define the short term production policy of the company in order to optimize production , sales and profit and maintain a consistent and safe future for the company.

Linear programming models are used as a tool in the optimization process. Demand data have been estimated by using double exponential smoothing method for linear trend and Winter's method for seasonal trend.

A package program has been used for linear programming and computer programs have been written and run for double exponential smoothing and Winter's method.Results of linear programming have been interpreted by using sensitivity analysis.

ÖZET

Bu çalışmada , temizlik kağıtları sektörü ile ilgili çok-ürünlü , tek-amaçlı bir durum incelenmekte ve ilgili iki model hazırlanmaktadır.

Bu araştırmanın ana amaçları firmanın gelecekteki politikasını belirleyip üretimi , satışları ve karı optimum noktaya getirmek ve böylece firma için istikrarlı ve emin bir gelecek sağlamaktır.

Bu amaçla üretim firmasının hedefini ve kısıtlamalarını gösteren modeller kurulmuş ve lineer programlamanın "Simplex Metodu" uygulanmıştır.Gelecek yılların talep miktarlarını tahmin etmek için geçmis satış miktarlarına değişik ön tahmin metodları uygulanmıştır.

Lineer programlama için paket program , öntahmin metodları için ise Pascal dilinde yazdığım iki program kullanılmıştır. Modellerin sonuçları duyarlılık analizi de uygulanarak incelenmiştir.

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LIST OF SYMBOLS

X[I] .... units to be produced of product I

P[I] .... net profit margin of product I

S[I,J] .... processing time of product I in machine J

MT[J] .... maximum time available for machine J

F[I] .... defective rate of product I in the main machine

A[I] .... lower limit of demand of product I

B[I] .... upper limit of demand of product I

X[I,K] .... amount of product I to be produced in period K

T[I,K] .... amount of product I available for sale in period K

SM[I,K] .... amount of inventory of product I to be transferred from period K to K+1

E[I,K] .... holding cost of one unit of product I in period K

MT[J,K] .... maximum time available for machine J in period K

A[I,K] .... lower limit of demand of product I in period K

B[I,K] .... upper limit of demand of product I in period K

L .... number of periods

M .... number of machines

N .... number of products

AKAP .... capacity of the main machine

CHAPTER I

INTRODUCTION

This is a study of a product-mix problem that defines the production policy of a multi-product company in the sanitary paper sector of Turkey.

For a company to be safe in the long-run and to maintain increasing profit margins in the long term , it is not sufficient to keep market dominance with high sales but the company must also have an optimal production policy with which it can determine seasonal production and inventory amounts , notice all bottlenecks and thus minimize holding and shortage costs and loss of goodwill.

In "Ipek Kağıt" , determination of an optimal policy is required because the production consists of various types of cleaning paper with varying demands throughout a year.Demand patterns of some products show seasonal variations within a year whereas the rest have a continuous linear pattern.

In a multi-product company with varying demand structures, it's important that the production policy should be chosen with care and be the optimum one in order to maximize profit.

In determining the policy , it is known that there are specific profit margins of each product and there are certain constraints like machine capacities, time and demand capacities for the products.To be able to join them optimally , we need a programming tool.Linear programming can be applied for allocation of these limited resources.The simplex method will provide us with the optimal solution that will maximize profit.

In the next chapter of this thesis , sanitary paper sector in Turkey and "Ipek Kağıt" which is a company in the sector are analyzed.

In the third chapter , information is given about products and production technology related to "Ipek Kağıt".

In chapter four , formulation of the product-mix problem is discussed by defining two models.The first model is an aggregate production plan model that gives an overall idea about the annual production policy.The second model is a seasonal model that also considers inventory costs.

The fifth chapter studies the forecasting methods and uses two of these in order to make projections from past demand data and to estimate the necessary demand figures in an optimal way by simulating parameters.

In the sixth chapter the output from the linear programming models are analyzed.

The seventh chapter performs a sensitivity analysis on the results of the two models.

Finally ,the eighth chapter is a conclusion chapter that evaluates all the results in order to provide alternative policies.

CHAPTER II

SANITARY PAPER SECTOR

2.1 Sanitary Tissue Sector in Turkey

First of all ,it is important to point out that sanitary tissue are secondary consumption goods.Since they are not among necessity goods , it is reasonable to find a very high corelation between GNP (Gross National Product) and tissue consumption. Urbanisation and developments in standarts of living are among important factors which increase demand.For someone to purchase cleaning tissues , he must be able to afford his higher priority needs which is a problem of economy.A second condition is that people must be educated enough to feel the need to use sanitary tissue , which is a problem of education and standard of living.

The above stated facts are also problems of Turkey.GNP , standards of living and education level in Turkey have not been able to reach those of developed countries ; however , it is hopeful to see increasing trends.

With a per capita income of $ 1,000 per year, Turkey's consumption of tissue products is only a few hundred grams per person.Most of it is consumed in principal cities Istanbul , Ankara , Izmir.In fact many of population are located in isolated regions and consume practically no paper at all.A long-term program is required to introduce household paper products into their homes.

So we can say that Turkey has and will have increasing demand for sanitary tissue ; however , it will take a long time to reach a consumption level proportional to its population.

Ipek Kagit , the Eczacibasi Group's paper company , built the country's first mill to make creped sanitary tissue at Karamursel in 1970.For long years it has been monopole in the sector ; however , in recent years other companies have also started venturing in this sector.Besides these , some imported brands have also entered the market along with the liberalization of Turkish economy.

2.2 Ipek Kagit in the Market

Ipek Kagit , the sanitary tissue company of the Eczacibasi group is the first company of Turkey in this sector.It has its center in Istanbul but maintains production in its plants in Izmit-Karamursel. The plant was founded in 1969 and started production in 1970 with a single machine making 6,000 tons per year of various grades of household tissue.The machine has since been expanded to make 10,000 tons per year and there are further expansion plans.

The manufacturing programs of Ipek Kagit consist of various types of cleaning paper , such as different qualities of paper napkin , toilet paper , paper handkerchief , woman and baby pad.Apart from these processed tissues , exports of parent rools of tissue form also an important part of company's sales strategy. Of the 10,000 tons of annual capacity , 2,000 tons are separated for export purposes.Expansion of capacity will also bring higher export figures.

The company planned from its inception to build a solid long-term base in Turkey.A management team was set up to learn everything about tissue.Therefore it is important for the company to have long-term or annual plans.

CHAPTER III

PRODUCTION OF IPEK KAGIT

3.1 Products

The tissue paper , which is the building block of the products , is being produced within the plants of Ipek Kagit and transformed into the four types of products.(Appendix A)

The products consist of various types of tissue paper having different weights.These weights are measured in terms of gr/m2 .The quality and absorption of the paper varies inversely with its weights.As the weight in gr/m2 decreases , the softness and absorption ability increases ; thus the quality of the paper increases.The paper production machine (main machine) of Ipek Kagit has the technological capacity to produce tissue paper down to 14 gr/m2 .The following is the data related to the weights and layers of tissue paper used in toilet paper , napkin , handkerchief , baby pad and woman pad. Among these , woman and baby pads are produced in the same production line and which one to produce is up to the decision maker.Therefore , they are handled as one variable in the model.

PRODUCTS AND CHARACTERISTICS

i	Product X[i]	Weight (gr/m2)	No of layers
1	Handkerchief	15	4
2	Napkin:Selpak	15	1
3	Napkin:Sedef	17	2
4	Napkin:Solo	23	4
5	Toilet p.:Selpak	15	2
6	Toilet p.:Solo	17.5	2
7	Toilet p.:Silen	32	1
8	Woman and Baby Pad	17.5	2

3.2 Technology

Main features of technology used are as below :

1.Production Department

-Preparation of pulp

This is the department where the pulp is prepared for use in the manufacturing process of products.This pulp serves as an input to the four types of products.That is , this department is the initial stage of all products.There is no alternative of the process done in this department.Only the dosing of paint and other chemicals can either be done manually or automatically.A combination of these two has been chosen.

It must be emphasized that the capacity of this department determines limit for production of each product.

-Paper production machine

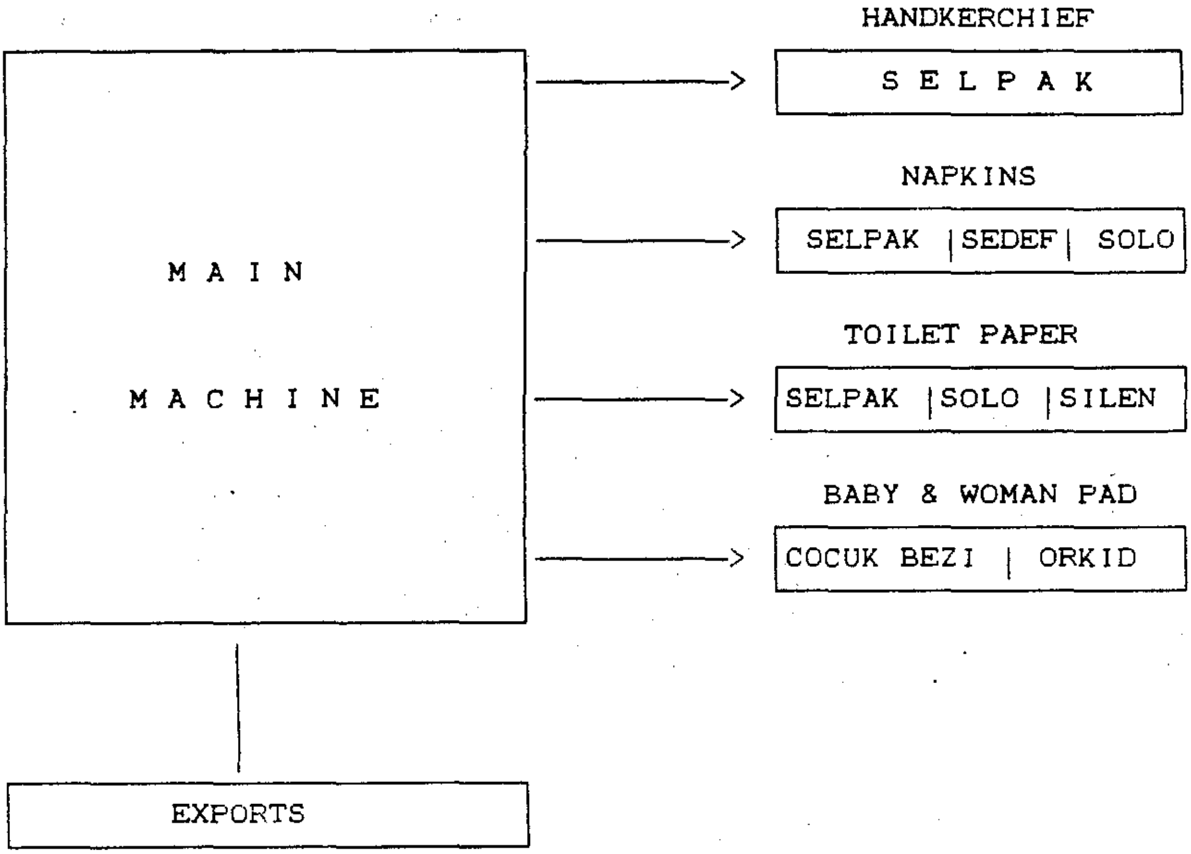
In this department , there are four paper production machines , one for each type of product. These machines operate independently from eachother , and have different capacities.Also , each machine is specialized in a specific product ; therefore each machine can produce only one type of a product.

The most important part of this department is called the wetting operation.This part consists of the formation of the paper layer.

2.Processing and packaging department

The pulps coming from the main machine are processed in the four different machines and then packaged as the finished products.

PRODUCTION


MAIN MACHINE
HANDKERCHIEF
SELPAK
NAPKINS
SELPAK | SEDEF | SOLO
TOILET PAPER
SELPAK | SOLO | SILEN
BABY & WOMAN PAD
COCUK BEZI | ORKID
EXPORTS

CHAPTER IV

FORMULATION

4.1 Definition of Model 1

The product-mix problem is formulated in two different models.The first model uses a more general approach and provides an overall annual production plan for each product considered.The total annual production level of each product is obtained from this model.A year is taken to be a single period , thus the seasonal variations of the demands during the year are not considered.Lower and upper bounds are estimated for the demand of each product during the year using the forecasted demands which are discussed in the following forecasting section.Since the whole year is taken to be a single period and inventory from previous year and inventory to be transferred to the next year is not taken into account the model does not consider inventory holding costs.In addition to the demand constraints , the capacity of the main machine constitutes another constraint.

The main machine provides pulp to all of the production lines related to the different products : toilet paper , paper handkerchief , paper napkin and pad group.Therefore , the sum of the production level of all the products during the year can not exceed this machine's capacity.Moreover , the maximum time limit of each production line related to a product also affects the production levels.Therefore , apart from having a production constraint for the sum of the production lines , there is also a time constraint for each production line.In this model , as in model 2 the objective is the maximization of profit.

4.2 Formulation of Model 1

(1) Objective function

$$\max \quad Z = \Sigma P_I * X_I$$

S.T.

(2) Capacity constraints

(2a) of the main machine

$$\Sigma (1 + F_I) * X_I <= AKAP$$

(2b) of the processing machines

$$\Sigma S_{I,J} * X_I <= MT_J \qquad j = 1,2,\ldots,m$$

(3) Demand forecasts

$$A_I <= X_I <= B_I$$

(4) Non-negativity constraints

$$X_I >= 0 \qquad i = 1,2,\ldots,n$$

4.3 Definition of Model 2

In the second model , a more detailed approach is used as compared with model 1.A year is divided into four periods and a production plan for each period is obtained.Model 2 also considers inventory holding cost.For each product in each period, there is an amount to be produced , an amount available for sale and an amount of inventory at hand.The reason for using such a dynamic production planning model , is that the demands of the products show seasonal variations.As an example , paper napkin is sold more during summer , whereas paper handkerchief is sold more during the winter.

An important point of the model is that , it is conceived as a cyclic model.That is the inventory at hand at the end of period four is transferred to period one of the following year.In this way , optimal beginning and ending inventory amounts are obtained.Like in model 1 , lower and upper bounds are derived for the demand of each product in a period , using the forecasted demand figures.These bounds constitute constraints for the amount available for sale in each period.In addition to this , a material balance equation for each product in each period is constructed.

By this formula the amount of on hand inventory at the beginning of the period , and the amount of production equals the amount available for sale and the amount of inventory transferred to the following period.The main machine capacity is a constraint on the total amount of all types of products produced in a given period.Another constraint is the time constraint for each production line in a period.As a management policy , because of the dynamic structure of demand , minimum 10 per cent of the amount available for sale of a product in a period must be kept in inventory.This can be thought of as a safety stock constraint.
Profit maximization objective is also present in this model.However,the equation involves holding and inventory costs.Shortage cost is also present but it's not included in the objective function since it is rather hard to estimate quantitavely.Since the model is a seasonal one,sales have low and high periods.To meet the changing demand, amount of production might change from one season to another.This creates also the cost of changing production rate.There might be overtime cost or extra machine set up costs.This is also ignored in the model.

4.4 Formulation of Model 2

(1) Objective function

$$\Sigma \ \Sigma \ P_I * T_{I,K} - \Sigma \ \Sigma \ E_{I,K} * SM_{I,K}$$

S.T.

(2) Material balance equation

$$SM_{I,K-1} + X_{I,K} - T_{I,K} - SM_{I,K} = 0$$

$i = 1,2,\ldots\ldots,n$
$k = 1,2,\ldots\ldots\ldots,l$

(3) Capacity constraints

(3a) of the main machine

$$\Sigma \ (1 + F_I) * X_{I,K} <= AKAP_K$$

$k = 1,2,\ldots\ldots\ldots,l$

(3b) of the processing machines

$$\Sigma \ S_{I,J} * X_{I,K} <= MT_{J,K}$$

$j = 1,2,\ldots\ldots\ldots,m$
$k = 1,2,\ldots\ldots\ldots,l$

(4) Demand forecasts

$$A_{I,K} <= T_{I,K} <= B_{I,K}$$

$i = 1,2,\ldots\ldots\ldots,l$
$k = 1,2,\ldots\ldots\ldots,l$

(5) Safety stock constraints

$$SM_{I,K-1} >= 0.10 * T_{I,K}$$

i = 1,2,........,n
k = 1,2,........,l

(6) Non-negativity constraints

$$X_{I,K} >= 0$$

$$T_{I,K} >= 0$$

$$SM_{I,K} >= 0$$

i = 1,2,........,n
k = 1,2,........,n

CHAPTER V

FORECASTING

5.1 Methodology

Forecasting is the process of drawing inferences about the future from historical data. Forecasting involves analyzing past data and projecting it into the future , usually by employing some appropriate mathematical model.

Forecasting is an estimate of a future observation assuming that the underlying time series continues as it has in the recent past.When some factor causes changes in the basic nature of the underlying time series , and the decision maker has knowledge of that change , this information can be incorporated into the forecast.

In general , the uses of a forecast are limited by the lead time over which forecasting is made.Short-range forecasting methods provide forecasts that are at most for a year into the future.Long range forecasts may project up to 10 years into the future.For this study , we shall be dealing with methods for generating short-term forecasts.

Time series may show one or more of three basic characteristics which are constant process, linear and quadratic trends and cyclic or periodic variation.

When observing demand data related to the eight different products of the thesis ,it is seen that data show linear trend and cyclic variation.So different methods for these are analyzed in detail.

For forecasting linear trends linear regression , double moving average , double exponential smoothing are the major methods that can be used.

1) Among these methods , the easiest-to-apply method is linear regression.It has no parameters to estimate.Method of least squares is used and two parameters 'a' and 'b' are calculated by using the actual data.The forecast for some future time is

$$X(T+Z) = A + B(T+Z)$$

However , the disadvantages are that it gives equal weight to older and newer data.It also ignores the deviations of data from the linear function and can't make any corrections to minimize errors after each observation.

2) Double moving average method results from applying the least-squares criterion to a data of fixed length.This technique chooses a value of N and only the most recent N periods of data are used for the second forecast.After taking an average of N values , a second average of N first averages must be taken to obtain only the first estimate.Estimates of future periods depend on a recursive formula which uses old actual figures , so it's probable to get erroneous results.

The main disadvantages with this method is that it requires too many data and it gives equal weight to all data points.

3) Double exponential smoothing method is the most widely used class because it's reasonably accurate and computationally efficient.The technique is developed from the weighted least-squares criterion.One of the most important things about the method is that it gives more weight to newer data.To forecast Z periods into the future , the equation is

$$X(T+Z) = (2+ Z * A/(1-A)) * S(T) - (1 + Z * A/(1-A) * S2(T)$$

where

$$S(T) = A * X(T) + (1-A) * S(T-1)$$

$$S2(T) = A * S(T) + (1-A) * S2(T-1)$$

$$A = \text{smoothing constant} \quad 0 <= A <= 1$$

A widely used technique for the choice of A is a sequence of trials on a set of actual historical data using several different values for the smoothing constant , and to select the value that optimizes some measure of effectiveness such as minimum sum of squares error.For example if three years of historical data are available , one might use first two years to optimize the smoothing constant and then simulate a forecast for each month of the remaining year to see how 'optimum' smoothing constant will react to fresh data.

4) Winter's method is the most accepted , efficient and easy-to-use method for data with seasonal variation.The time series model is

$$X(T) = (A + B * T) * C(T) + e(T)$$

where A is the permanent component , B is a linear trend component , C(T) is the seasonal factor for period T and E(T) is the random error component.This model incorporates both a linear trend and a seasonal effect.At the end of any period T , after observing X(T) , estimates of the model parameters A,B,C(T) are revised.Forecast for any future period T+Z is

$$X(T+Z) = [A(T) + Z * B(T)] * C(T+Z)(T+Z-L)$$

where L shows the number of periods in a season. Revision for components are as follows

$$\hat{A}(T) = K * [X(T)/\hat{C}(T)(T-L)] + (1-K) * [\hat{A}(T-1) + \hat{B}(T-1)]$$

$$\hat{B}(T) = L * [\hat{A}(T) - \hat{A}(T-1)] + (1-L) * \hat{B}(T-1)$$

$$\hat{C}(T)(T) = M * [X(T)/\hat{A}(T)] + (1-M) * \hat{C}(T)(T-L)$$

where K , L , M are smoothing constants.

Main problem with the method is the estimation of three different smoothing constants used in calculations of A,B and C.

Simulation may be used for the smoothing constant A of double exponential smoothing method and the three constants of Winter's method .Different runs can be obtained for different smoothing constant values varying from zero to one.By using MSE (minimum squares error) , the run which minimizes the difference between actual and estimated data points will be chosen for each product.

5.2 Choice and Use of Forecasting Methods

In linear programming model that is used for production planning of Ipek Kagit , there are a group of demand constraints.These constraints give the upper and lower bound limits of the demand for eight different products.However , since this is a plan for future , there is no actual data available.So one has to make use of actual sales of past data and by certain methods project them to the future to get the demand estimates.To be able to do this in the best way , forecasting process and the different methods that can be used have been analyzed.

In the linear programming model that is studied , there are four different types of products available data of which show different trends. (Appendix B) Among these , data of paper napkins and handkerchief show a seasonal trend along with a linear trend ; whereas , toilet paper group , woman and baby pads group show only a linear trend.As for handkerchief , demand is more in winter and the least in summer ; mainly because of increasing flu and cold in winter season.On the other hand , demand for napkin is the least in winter and the most in summer , which is a result of increasing touristic activities in summer.

For the toilet paper and pads group which show only linear trend , double exponential smoothing method has been chosen based on the reasons stated in the previous section.

To apply the model to the four different products , i've prepared a computer program in Pascal language.(Appendix C) The program starts with reading in actual values of past data.In second section , method is initiated by calculating values for S[O] and S2[O].These are obtained from estimates of A(O) , B(O) which are estimated from historical data using linear regression.In the next section by using recursive formulas of S[T] , S2[T] demand value is estimated for each period.By using the calculated estimate and real values , error is calculated for each period using MSE measure.

$$MSE = E (X[I]-\hat{X}[I])^{2} / N$$

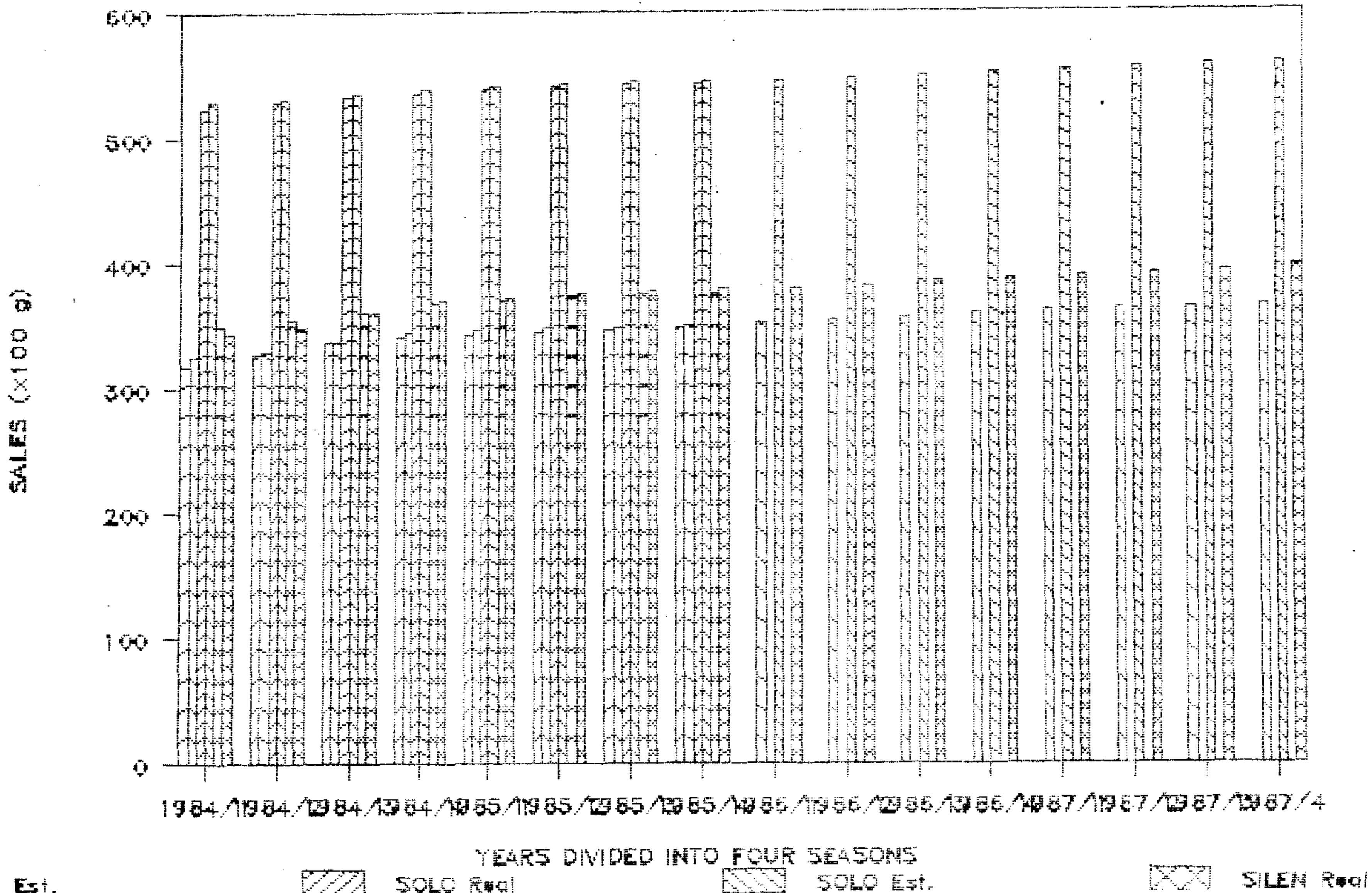
This procedure is repeated for each product.

The program is run for different values of A(alfa) ranging from 0.1 to 1 incremented by 0.1 in each run.The optimum A value has been simulated in a way to minimize the error.

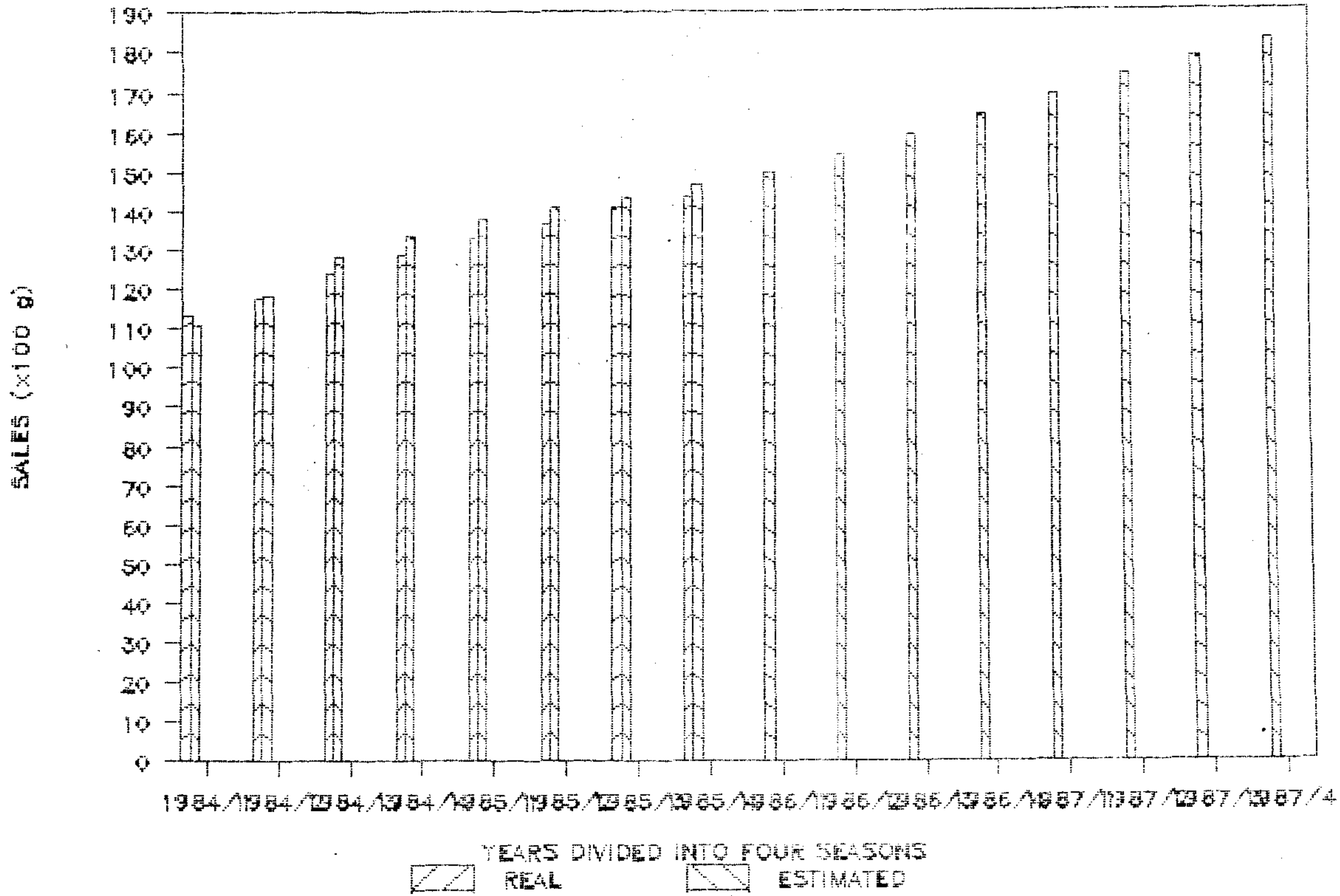
For each product the program has been run again with A(opt) to forecast the future demand.

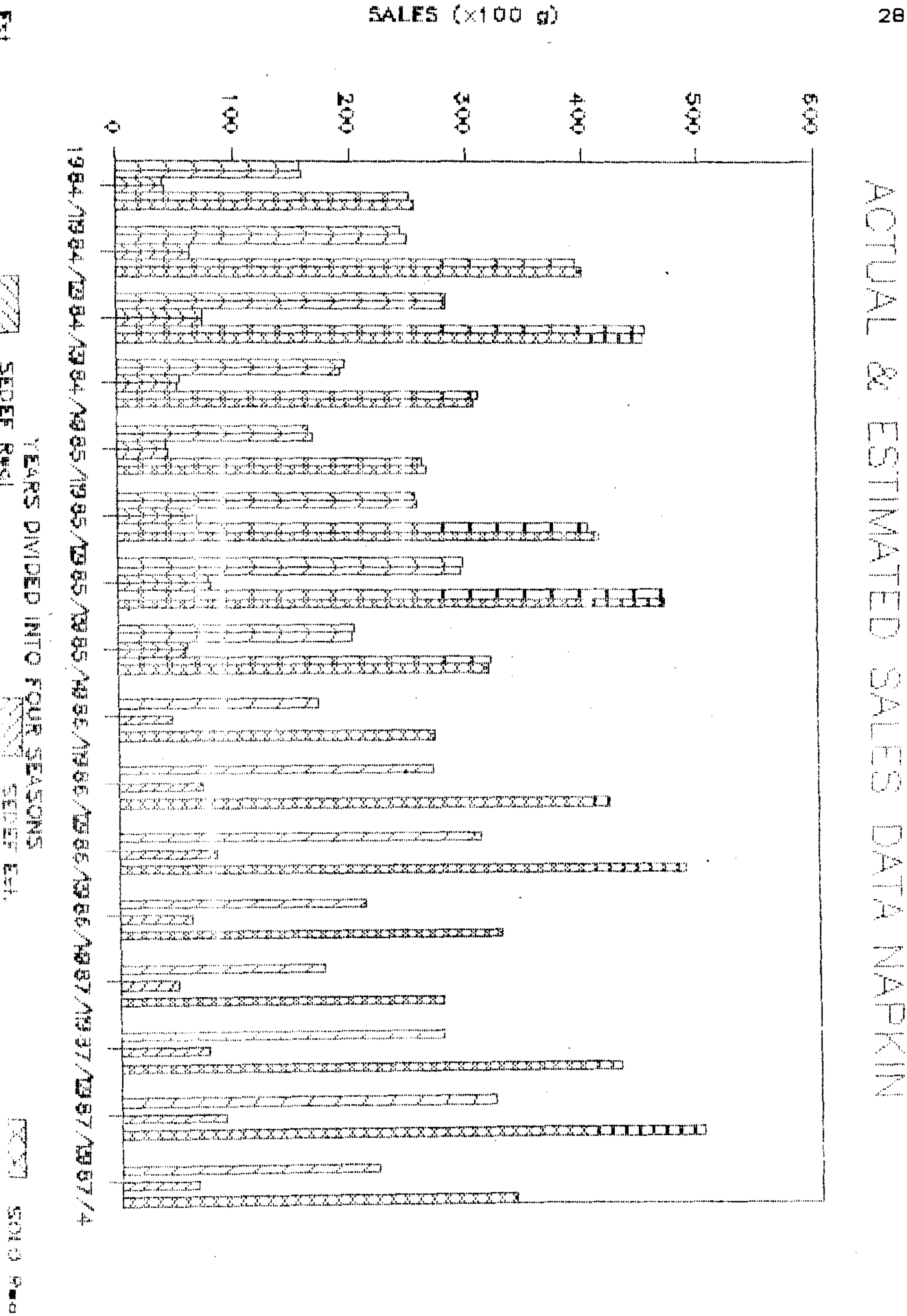
For handkerchief and napkins group which have past data showing both seasonal and linear trend Winter's method has been used to forecast demand.

ACTUAL & ESTIMATED SALES DATA TOILET P.

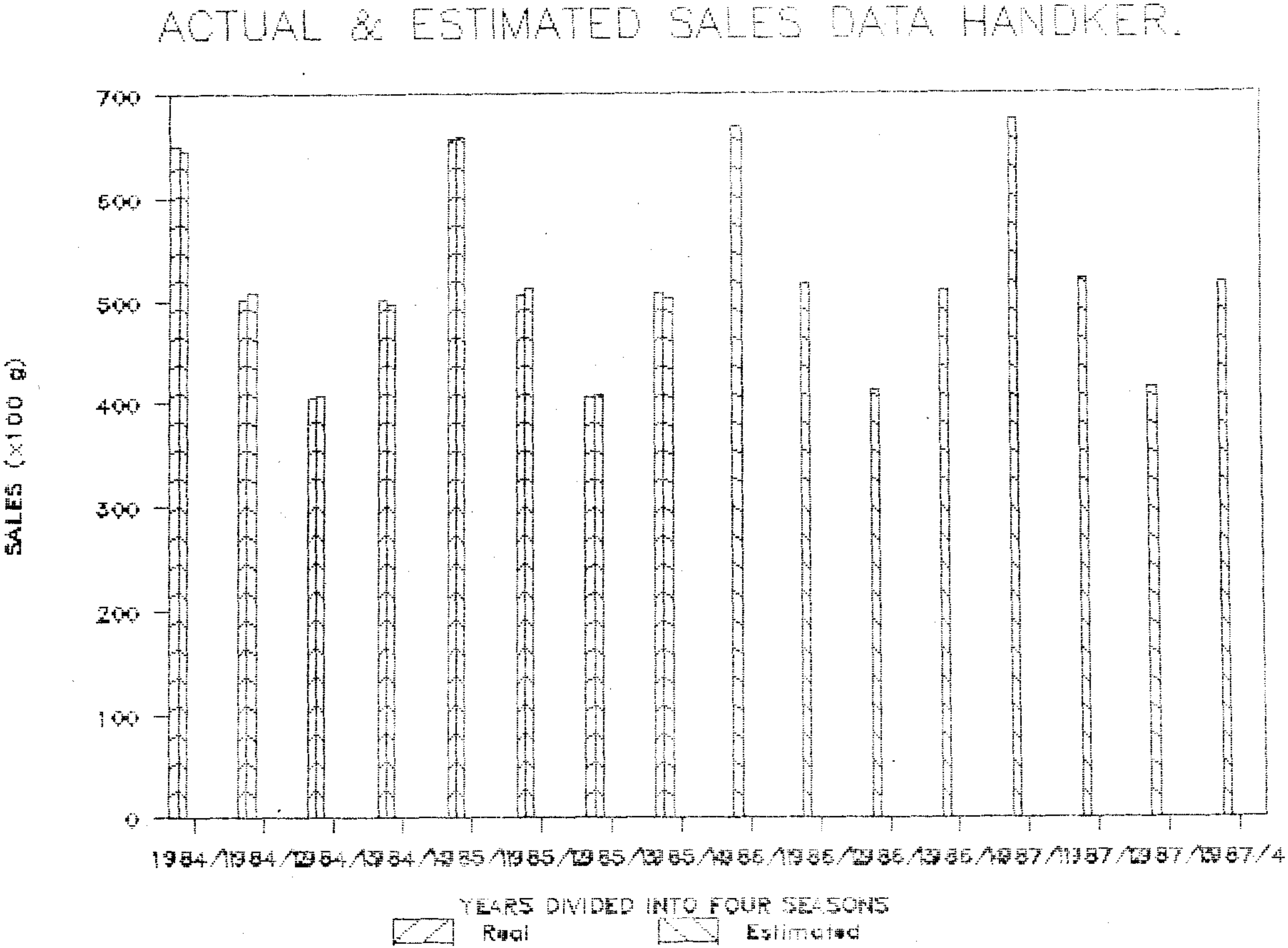


ACTUAL & ESTIMATED SALES DATA PADS





SALES (×100 g)
0
100
200
300
400
500
600
ACTUAL & ESTIMATED SALES DATA NAPKIN
YEARS DIVIDED INTO FOUR SEASONS


ACTUAL & ESTIMATED SALES DATA HANDKER.
SALES (x100 g)
700
600
500
400
300
200
100
0
YEARS DIVIDED INTO FOUR SEASONS
Real
Estimated

To apply the model to four different products , i.e. handkerchief and three brands of napkin , a computer program has been prepared in Pascal language.(Appendix D)

In the program , oldest year's data is used to initialize A(4) , B(4) , C(1),C(2),C(3),C(4).C's give the seasonality parameters.

Later years are used recursively to find optimal K,L,M values.The values of constants start with 0.1 and are incremented by 0.1 up to 1.The values of K,L,M that minimize MSE are chosen as the optimal values.The program is rerun with optimal K,L,M to calculate the forecasted values.

By using the calculated demand estimate and real data available , error for each period is calculated using the MSE measure as in double exponential smoothing method.

For each product , the program is run for different values of K , L , M each ranging from 0.1 to 1 with 0.1 increments.

Choosing the optimum K , L , M values which minimize the error , the program has been run again to get forecasted demand data.

The demand estimates obtained by Exponential Smoothing and Winter's methods are tested to confirm the method used.To be on the safe side the allowable upper and lower limits of estimated demands calculated have to be greater or equal to (3*standard deviation).This procedure has been repeated for each product and chosen forecasting methods have been confirmed.(Appendix E)

CHAPTER VI

OUTPUT ANALYSIS

6.1 Model 1

6.1.1 Giving no Lower Bound Constraints for Demand

In this run (Appendix F), profit for the year obtained is 2,611,441,000.One of the most important results is zero production level of P7 which is one of the toilet paper products.Since the objective is maximization of profit , this result is expected because P7 has the least profit margin.Among other seven products , the first five , P1,P2,P3,P4,P5 are produced at their upper bounds.P2 , P3 , which are two kinds of napkins have the highest profit margins and capacity constraints don't hinder their production at upper bounds.P8 , woman and baby pad , have the third highest profit margin.Although capacity of main machine is sufficient for P8 to be produced at higher bound capacity of pad secondary machine forms a noticable boottleneck.So it is forced to be produced below upper bound.P4 , which is a napkin brand and P1 , which is paper handkerchief are the next two products in terms of profit margins.Since capacities allow , they're also produced at demand upper bounds. P5,P6,P7 , which are different brands in toilet paper group , have considerably lower profit margins.Among these P5 is also produced at upper bound not to leave any idle capacity of main machine and P6 is produced only about one fourth of demand upper bound.

6.1.2 Assigning Lower Bound Values for Demand

When no lower bounds are given for demand constraints as in first run of model 1 , seventh product, P7 , the one with the lowest profit margin , isn't produced at all.Although this seems more profitable at first glance , it's indeed a cause to incur shortage cost and a cause to have a loss of good-will in the market in which it is dominant. Besides , it's the product with third highest demand , which is 1,541,400 out of 10,380,000.

For the above stated reasons , a second run is taken with lower bounds assigned for demand values(Appendix G).These lower bounds have been calculated by a rather heuristic approach , namely , lower bounds have been taken as fifty percent of the expected demands found by forecasting methods.

In this run , profit has decreased from 2,611,441,000 to 2,563,145,000 TL.Comparing the results of first and second runs , it's observed that the production levels of the products P2 ,P3 ,P4 and P8 aren't changed eventhough they're above their lower bounds.This is due to their having the highest profit margins.In order to maximize profit , in both of the runs these products were produced at upper bounds.Because of the lower bound constraints P7 , the one with lowest profit margin , had to be produced at lower bound ; and in order to satisfy the time and capacity constraints , the production levels of P5 and P6 had to be decreased to their lower bounds because of their having lower profit margins than the rest of the products.

6.2 Model 2

6.2.1 Giving no Lower Bound Constraints for Demand

For the first run (Appendix K) , all lower bounds of the amount available for sale are taken to be zero.This implies that the constraints are the capacity of the main machine , time limit of the production lines, material balance and the safety stock constraints.

In the results obtained , profit for the year is 2,504,709,000 TL.As in model 1, P7 isn't produced , sold nor held in inventory since it has the lowest profit margin.Among rest of the products , the most profitable products 2 and 3 are produced at upper bounds and amount available for sale are at upper limit of demand during all the four periods.Third profitable one , P4 ,has to be produced below upper bound for two periods again because of secondary machine constraint and reaches upper bound in other two periods.This machine processes the brands of napkin.Since P4 has the lowest profit margin within the group and sales reach maximum in second and third periods , capacity can't meet all the demand so P4 falls below demand upper bound level in these periods.The next product , which is P 1 , is at upper bound level of demand for three period but machine capacity isn't enough for the first period.This product is handkerchief and since it reaches maximum sales in winter period , production isn't enough.The next profitable P5 belongs to toilet paper group.Although it's less profitable than previously stated products , it's produced and presented for sale at upper bound of its demand.Secondary machine used for toilet paper production doesn't hinder production for this product since other brands of this group are less profitable.P6 is therefore produced and presented for sale much below demand upper bound value and P7 isn't produced at all.

6.2.2 Assigning Lower Bound Values for Demand

Assigning no lower bounds for demand constraints results in zero or very low production and thus sales level of low profit margined products as seen in previous models.Not to lose good will and market dominancy , lower bounds are assigned to least profitable three products in this run of Model 2. (Appendix L) Profit has shown a relatively low decrease from 2,504,709,000 to 2,464,513,000.Lower bounds have forced the least profitable P7 , one of the napkin brands , to be produced and planned to be sold at lower bound values.Producing it above zero level in each period resulted in a decrease level for other products not to exceed main machine capacity and secondary machine capacity which processed toilet paper.As a result , within toilet paper group , the most profitable product that was produced at upper bound in previous run decreased below this amount ; the second toilet paper brand that was above lower bound level decreased to this level in all of the periods.The overall most profitable napkin brands weren't effected.However , for all periods except for the last one , there has been a considerable decrease in handkerchief production level which had a moderate profit margin.

CHAPTER VII

SENSITIVITY ANALYSIS

In an operating firm , there can be changes in sales volume because of factors like new firms entering the market , changing regulations in commercial system like new export and import laws or changes in capacities due to revisions in the plant.Therefore , it is of much value to apply sensitivity analysis to linear programming results.

The analysis gives the changes in profit related to the changes in capacities or in demands.In the thesis , the capacities are related to the time limits for the production lines and the main machine.

The reduced cost of an activity is the amount by which profit will decrease , if one unit of that activity is forced into the solution.On the other hand , the dual price is the shadow price of a given constraint.It is the amount by which profit will increase if the availabilty of the resource associated with this constraint is increased by one unit.

7.1 Model 1

7.1.1 Giving Lower Bound Constraints for Demand

For this run (Appendix F) , taking a look at production values and the reduced costs of eight different products , it is seen that seven of the products have reduced cost value of zero ; whereas P7 , the product with lowest profit margin has a reduced cost of 20.In the output P7 has a production level of zero.This means that if the firm produces this toilet paper brand by selected minimum quantities for the reason of keeping the market share on the desired level , the profit will decrease by

(added production level * reduced cost of product)

The reduced cost of P7 comes out to be 20 because P7 and P6 are the two products with lowest profit margins 255 and 275 respectively.P6 is produced much below its upper bound , P7 isn't produced at all.P8 can not be produced at upper bound because of machine capacity constraint.All the other products are produced at their upper bounds.So one unit production of P7 will force the next low profit margined product to be produced one unit less not to violate main machine capacity constraint.Production of one unit P7 instead of P6 will decrease total profit 20 units since they have profit margins of 255 and 275 respectively.

Observing the slack values and dual prices of the constraints , one can detect a few important points.Right hand side of the constraints shows the availability of that resource.If there is certain surplus associated with that resource then the dual price is zero.In other words , increasing the resource by one unit will not cause profit increase since the total resource is not consumed. However , if the slack is zero ,this designates that the corresponding dual variable is nonzero. Since the total resource is consumed , increasing it by one unit will also increase profit by the amount of the dual price.

In the output observed , there are some constraints that do not use the available resource completely.The first group of these is the secondary machine constraints for the first seven products.These machines can not be fully used either because of the main machine capacity limits or because of demand constraints.Among these , handkerchief and napkin groups have little slack , 339 and 552 respectively , since they have high profit margin and produced at upper bound of demand values.The toilet paper group has a slack of 3065.9 out of 5200 which is quite high.This is because they have low profit margins and therefore produced much below demand.For this reason , the demand constraints of this group also have high

The remaining slack values belong to demand constraints and the products that are produced below their demand upper bounds have slack values equal to the difference between demand and production.

Observing the dual prices , it is noticed that the highest price belongs to the secondary machine constraint of P8,the pads group.Although the upper bound demand value of pads is 628130 , machine constraint limits production to 525252.5 , given by

$$0.0099 * X8 <= 5200$$

In spite of the high profit margin of P8, 102,878 kg can not be produced.So for every unit of increase in the resource , the profit will be increased by 11111.1 which is the dual price.

The second highest dual price is 261.9 and belongs to the main machine capacity constraint. Because of the 8,000,000 kg capacity , all of the product demands can not be satisfied.Therefore the lowest profit margin product P6 is forced to be produced much below its upper bound and P7 isn't produced at all.If capacity increases by one unit P6 can be produced (1/1.05) units more where five percent is the defective rate. 0.9524 units of extra production will increase profit by 261.9 calculated by

(0.9524 units of P6 * profit margin of P6)

There are also nonzero dual prices associated with the group of demand constraints. Dual prices decrease with decreasing profit margin of products.P2 which has the highest profit margin also has the highest dual price within this group.The products with six highest profit margins are produced at their demand upper bounds.So if P2 decreases by one unit , seventh high margined P P6 can be produced.So dual price of P2 ,135 , can be calculated by

(1 less unit P2 produced) * (profit margin of P2)
 - (1 extra unit P6 produced) * (profit margin of P6)

In the same way , dual price of the second highest profit margined product P3 is 125. P4 , P1 , P5 have dual prices of 100 , 55 and 20 respectively.

7.1.2 Assigning Lower Bound Values for Demand

In this run (Appendix G) , taking a look at the production values and the reduced costs of the eight different products , it's seen that there is a certain amount of production for all products and all have reduced cost of zero.So as in comparison with first run of model , adding lower bound constraints forced P7 to be produced also , thus driving its reduced cost to zero.

Observing the slack values and dual prices of the constraints , it can be seen that there are still some constraints with unused resources.These all have zero dual prices because of having idle capacity.The first group of these is the secondary machine constraint for the first seven products. As compared with the first run , the slack amount for handkerchief has increased from 339 to 1116 . For napkin group it has stayed the same with 552 and for toilet paper group it has decreased from 3065.9 to 2744.8.These are expected because forcing a minimum production at demand lower bounds , increases the production of low profit margined toilet paper group.This causes production of moderate profit margined handkerchief to decrease in order not to violate main machine capacity constraint.Production level of napkin group doesn't change since it's the group with highest profit margin and produced at upper bound of demand in both runs of model.

The remaining nonzero slack values belong to the demand constraints.The products produced below their demand upper bounds or above the lower bounds have slacks equal to the difference between demand and production.

Observing the dual prices , the highest price belongs to the secondary machine constraint of pads group as in first run.Although the pads group has high profit margin , demand of 628,130 can not be met since capacity is 525252.5.The dual price which was 11111.1 in previous run has decreased to 5555.5 in this run.If capacity of secondary machine is increased by one unit , total profit will increase by the amount of the dual price , 5555.5 . This increase will be possible since one unit of capacity increase will make production of 101.01 more kg feasible . Not to exceed main machine capacity , production of P1 will decrease by 101.01 kg.P1 is the lowest profit margined product among those that have production above lower bounds. This will give an extra profit of 5555.5 by

(profit margin of P8 * extra amount produced)-(profit margin of P1 * amount of decrease)

Although products 5 ,6 ,7 (P5,P6,P7) have lower profit margins than P1 , its production will have to decrease since others are already at their lower bounds.

The second highest dual price belongs to the main machine capacity constraint.Dual price which was 261.9 in previous run has increased to 314.28 in this run.If capacity increases by one unit , the total profit will increase by 314.28 since this will cause 1/1.05 units nondefective P1 to be produced which is the relatively highest margined product that is produced below upper bound.Profit increases by

(1/1.05 units of P1) * (profit margin of P1)

Another group of dual prices are associated with the demand constraints of products.The ones produced at upper bounds of demand , namely P2 , P3 , P4 have positive dual price ; whereas , P5 , P6 , P7, the ones produced at lower bound , have negative dual price.Because of the greater than or equal to constraint in the model , the corresponding dual variables have to be less than or equal to zero hence dual variable can be negative.The higher the profit margin the more is the dual price.As for P2 , if it's decreased by one unit , P1 will be produced instead to fill the idle capacity of main machine.So dual price of P2 , which is 80 , is calculated by

(one less unit of P2) * (profit margin of P2)

In the same way , dual prices of P3 and P4 are 70 and 45 respectively.

P5 ,P6 ,P7 which have the three lowest profit margins are forced to be produced as much as their lower bound demand values.As for P5 , a dual price of -35 means that if it's produced one unit less , profit increases by 35.This is calculated by

(one less unit of P5 * profit margin of P5) - (one extra unit of P1 * profit margin of P1)

In the same way , P6 and P7 have dual prices of -55 and -75 respectively.

7.1.3 Runs of Model 1 with Revised Constraints

The highest dual price in all runs of Model 1 shows that there is an important capacity restriction in secondary machine of woman-baby pad group , P8.Although P8 is one of the most profitable products , it has to be produced much below upper bound because of this bottleneck.In one of the runs of Model 1 (Appendix I) , processing time is reduced from 0.0099 to 0.00828 hr/kg. This can be possible by improving technology either by new methods or by purchasing a new processing machine. 0.00828 is calculated by distributing whole demand through total annual time.This enables production of 628,130 units with no idle capacity.In the output obtained dual price is zero ; whereas , it was 11111.1 in first run of Model 1.Profit has increased 11,316,470 TL from 2,611,441,000 TL to 2,622,757,000 TL.This is expected because increasing capacity has allowed 102,877 kg more production of P8.Not to exceed main machine capacity , production of the lowest profit margined P6 has decreased this much giving extra profit of 11,316,470 TL by

(profit margin of P8-profit margin of P6) * (102,877 kg)

After eliminating the bottleneck in production of P8 , the highest dual price 261.9 belongs to the main machine capacity.Because of unavailable capacity , P6 is produced very little and P7 can't be produced at all.

When main machine capacity is increased as much as capacity lack , from 8,000,000 to 11,176,595 , profit increases by 801,138,000TL.(Appendix J)This is the result of profit obtained from extra production of p6 and P7.

Another run regarding main machine capacity constraint is taken for the case that both demand lower and upper bounds are assigned and capacity is increased from 8,000,000 to 10,000,000.This has caused 556,691,000 TL or 18 percent increase in total profit. (Appendix H)

These two runs point out the important increase in profit by increasing main machine capacity. It emphasizes how vital it is to enlarge capacity in nearest time possible.

7.2 Model 2

7.2.1 Giving no Lower Bound Constraints for Demand

In this run (Appendix K) , analyzing the reduced cost values , it's seen that for each period there is a cost associated with only product 7 and the rest has zero cost.P7 isn't produced nor held in inventory.If the firm produces this toilet paper by selected minimum quantities to keep market share on desired level , profit will decrease by

(added inven. * reduced cost of inven.)
+ (added prodcn.level * reduced cost of prodcn level)

However , analytically the effect of additional production on the inventory level can't be determined by reduced cost , since there is no constant relationship between production and inventories.Thus to get the profit figure when P7 is produced , a new run with lower limits should be obtained.This is the second run of Model 2 which will be analyzed in next part.

Analyzing the slacks and dual prices part of the output , it's seen that the highest slack belongs to the demand constraint right hand side values of P7 and P6 respectively which are two brands of toilet paper.The amount presented for sale is much below upper bound of demand.So their processing machine capacities also have slack values since they stay idle.This is because they have the lowest profit margins and thus lowest production levels.The next highest slack values go for handkerchief demand constraint in first period and third napkin brand in thirc period.Although they have high profit margins , they have to be sold below upper bound demand values because of the lack of capacity in processing.

Analyzing the dual prices , it's seen that highest two dual prices which are 65359.5 and 58097.3 TL/unit cap. , belong to secondary processing machine of napkins group for the second and third periods respectively.Napkin group is the most profitable group and both of the dual prices are quite high figures.Since napkin sales are highest in second and third periods , production and inventory lag demand. Another high dual price belongs to handkerchief in first period with 26570 TL/unit capc.Like in napkins case , highest demand in this period can't be met by production capacity. So for napkins and handkerchief , it is quite essential to increase capacities or keep inventory level higher in these critical periods.The next high dual price goes for woman-baby pad.It has a dual price of 11111.1 TL/unit capc. for all four periods. Demand doesn't show a seasonal trend and production capacity of pad processing machine can't meet estimated demand in any of the periods in spite of the high profit margin.

There is also a dual price associated with the capacity constraint of main machine.It can't provide enough pulp to meet demand of all the different products and if secondary machine capacities didn't hinder production at certain periods , need for more pulp would be unavoidable.

Comparing the first runs of Model 1 and Model 2, it's seen that profit which was 2,611,441,000 in Model 1 decreased to 2,504,709,000.This isn't an important change ; however , one of the important causes is the involvement of inventory holding cost in the second model.Another cause is the lack of capacity of processing machines during peak periods of demand in Model 2.In Model 1 , since the year was taken as a whole , fluctuations in demand compensated the total annual production.So in Model 2 , pulp that was produced by main machine had to be converted to products with lower profit margins.

7.2.2 Assigning Lower Bound Values for Demand

Both for reasons stated in previous section and in section 7.1.2 , lowest profit margined products should also have a production level eventhough this might cause a decrease in overall profit.So as in Model 1 , a second run is obtained by giving lower bound values for demand.In this case , each product has to be produced above a minimum level for each period. (Appendix L)

Comparing the results of this run with results of first run of Model 2 , it's seen that profit has decreased from 2,504,709,000 TL to 2,464,513,000 TL.This is expected because assigning lower bounds for demand has caused less profitable products to be produced at a minimum level.Not to exceed main machine capcity , more profitable products had to be produced less.

Analyzing the reduced cost values , it's seen that for each product in each period reduced cost value is zero.Reduced cost of P7 has also decreased to zero since there is a minimum amount of production in each period.

Observing the surplus values of the constraints , it's clear that highest slack values belong to demand constraints of the brands of toilet paper group , namely , P6 , P7 and P5.These results resemble those of previous run of Model 2.However , in this run surpluses of P6 and P7 have decreased relatively since they must be produced above a minimum level.This has caused surplus of P5 to increase relatively for each period not to exceed seasonal machine capacities.

As for the dual prices , constraints with highest prices go in the same rank as of previous run of Model 2.However , there is a relative decrease in all of these prices as compared with previous run.As an example highest dual price , which belonged to secondary processing machine of napkin group for the second period , has decreased from 65,358 to 31,893 TL/unit cap. These relative decreases are due to the lower bounds of demand given.If one unit of resource decreases , another high profit margined product can be produced instead since most of them are produced below upper limit of demand.However , in first run without any lower bounds given , six of the product types had the chance to be produced at demand upper bound.

Comparing the results with second run of Model 1 , which was an annual model also with lower bounds assigned for demand , it's seen that profit which was 2,563,145,000 TL in Model 1 has decreased to 2,464,513,000 TL in Model 2.This is mainly a consequence of inventory holding cost incurred in Model 2.Since year is divided into periods , capacities isn't enough at peak periods of demand.This forms the other cause of decrease.

CHAPTER VIII

CONCLUSION

Before drawing any conclusions from the results of LP models , they will be reviewed and compared.Model 1 provides an overall annual production plan for each product.Model 2 divides the year into four periods and a plan is obtained for each period.This model also considers inventory holding costs.Two different runs are taken for each model.In the first runs of models , lower bounds of demand are restricted ; whereas in the second runs , a minimum lower bound is assigned for demand.

A comparison of the models is given below in terms of the total profit obtained in a year.

TOTAL PROFIT

	First Run (Unrestricted demand)	Second Run (Demand With Lower Bounds)
Model 1	2,611,441,000 TL	2,563,145,000 TL
Model 2	2,504,709,000 TL	2,464,513,000 TL

Total profit values of Model 1 are higher than those of Model 2 for both first and second runs.One of the main causes for the decrease is the involvement of inventory cost in Model 2.Another cause is the lack of capacity of the processing machines during peak periods of demand in Model 2.However in Model 1 seasonal changes in demand did not cause any capacity problems since the year was taken as a single period.

Another conclusion to draw from comparison is that the first runs of both models result in higher total profit values than the second runs.Profit decrease is expected because assigning lower bounds forces even the least profitable products to be produced at a minimum level.This causes more profitable products to be produced less in order not to exceed main machine capacity.

The first conclusion to derive from the results of different runs of the two Linear Programming models is that product seven shouldn't be produced at all in order to maximize profit.This product is a toilet paper brand and has the lowest profit margin.Because of the main machine capacity limits , production of P7 prevents production of more profitable brands.On the other hand , demand for P7 is 1,500,000 kg/year.This is the second highest demand in the market.Since it is the least expensive brand available , there is a certain demand in the market for this product.Therefore the company must make a trade-off between meeting the demand of this market segment and maximizing profits.If the first alternative is chosen the company should take into account that for the additional unit produced total profit will decrease by 20 TL.

The second important conclusion is lack of capacity of the machines during certain periods. Analysis of the annual model designated that the processing machine of woman-baby pad has the highest dual price.This indicates that a unit increase in the capacity of this machine will produce the maximum increase in profits.As a solution , either a more advanced technology should replace the old one to minimize processing time or a new machine with higher capacity must be acquired.However , the acquisition cost must be less than the discounted value of the sum of total loss of profit due to production of this product.

The remaining significant dual prices are seen in the processing machines of the napkin group during the second and third periods of peak.The three brands of napkin have the highest profitability among all the products.Although annual capacity can meet overall demand , when analyzed seasonally production and inventory can not meet demand of peak periods.So as a solution , either capacity must be increased with a new machine or advanced technology must be used to decrease processing time.Another solution might be inventory allocation for the second and third periods. Production will be kept higher than demand in periods of low demand so that more inventory can be transferred to critical periods.This will increase inventory holding cost , which is 40 TL/kg.month whereas an increase of production will bring around 400 TL/kg extra profit.

There is also the problem of insufficient capacity in the case of the main machine.For this reason , all products can not be produced at desired levels.Therefore a capacity increase of the main machine is required and the optimum level of capacity will be around 12,000,000 for domestic demand and 2,000,000 for export purposes. All together this necessiates a capacity of 14,000,000 kg/year.

Another significant result is the fact that the most profitable three products have the lowest annual demand figures.This designates a need for effective advertising in this product group with the objective of increasing sales , hence company profits in the future.

APPENDIX

APPENDIX A

PRODUCTION AND PROFITABILTY DATA

I	PRODUCT	PROCESS TIME	PROFIT MARGIN
1	Handkerchief	0.0023	330
2	Napkin - Selpak	0.0017	410
3	- Sedef	0.0017	400
4	- Solo	0.0017	375
5	T.Paper- Selpak	0.00095	295
6	- Solo	0.00095	275
7	- Silen	0.00095	255
8	Woman-Baby Pad	0.0099	385

Holding Cost = 40 tl/kg.month

APPENDIX B

SALES DATA

NAPKIN
(1000 * KG)

Year	SELPAK	SEDEF	SOLO
1982-1	137	35	218
1982-2	205	57	338
1982-3	246	64	395
1982-4	170	46	277
1983-1	147	38	235
1983-2	235	60	375
1983-3	265	68	425
1983-4	178	47	285
1984-1	158	40	252
1984-2	244	63	395
1984-3	284	73	455
1984-4	194	54	311
1985-1	163	42	261
1985-2	256	66	405
1985-3	297	78	470
1985-4	202	59	320

TOILET PAPER
(1000 * KG)

Year	SELPAK	SOLO	SILEN
1980-1	224	456	230
1980-2	235	465	230
1980-3	233	468	224
1980-4	238	469	228
1981-1	241	470	231
1981-2	245	473	240
1981-3	250	475	238
1981-4	247	477	241
1982-1	257	485	263
1982-2	254	483	260
1982-3	263	497	268
1982-4	270	500	275
1983-1	284	497	295
1983-2	296	510	310
1983-3	309	516	316
1983-4	316	522	323
1984-1	319	525	335
1984-2	329	530	346
1984-3	338	534	358
1984-4	342	537	369
1985-1	344	540	372
1985-2	347	542	375
1985-3	349	544	377
1985-4	351	545	378

HANDKERCHIEF AND WOMAN-BABY PAD
(1000 * KG)

Year	HANDKERCHIEF	WOMAN-BABY PAD
1982-1	575	68
1982-2	435	60
1982-3	360	76
1982-4	450	81
1983-1	610	76
1983-2	485	89
1983-3	395	98
1983-4	480	103
1984-1	651	113
1984-2	503	118
1984-3	405	124
1984-4	501	129
1985-1	658	133
1985-2	507	137
1985-3	408	141
1985-4	508	144

APPENDIX C

Computer Program for Double Exponential Smoothing Method

```
Program  Expad1 (Input,Output);

Const
    N=8;

Var
   I,SUM1,SUM2,SUM3,SUM4 : Integer;
   XF,S,S2               :Array [1..20] of real ;
   X                     :Array [1..20] of integer ;
   DIFF,SUM,MSE,K,A,B    :Real ;

Begin
   X[1]:=68;
   X[2]:=60;
   X[3]:=76;
   X[4]:=81;
   X[5]:=76;
   X[6]:=89;
   X[7]:=98;
   X[8]:=103;
   X[9]:=113;
   X[10]:=118;
   X[11]:=124;
   X[12]:=129;
   X[13]:=133;
   X[14]:=137;
   X[15]:=141;
   X[16]:=144;

   SUM1:=0,
   SUM2:=0;
   SUM3:=0;
   SUM4:=0;

 Readln;
   For  I:=1 to 8 do
      begin
         SUM1:=SUM1+I;
         SUM2:=SUM2+X[I];
         SUM3:=SUM3+I*X[I];
         SUM4:=SUM4+I*I
      end;
   B:=(N*SUM3-SUM1*SUM2)/(N*SUM4-SUM1*SUM1);
   A:=SUM2/N-B*SUM1/N;
   K:=0.1;
      While K<1.1 do
```

```
      S[8]:=A-K/(1-K)*B;
      S2[8]:=A-2*K/(1-K)*B;
      SUM:=0;
    For I:=9 to 16 do
      begin
         S[I]:=(1-K)*X[I]+K*S[I-1];
         S2[I]:=(1-K)*S[I]+K*S2[I-1];
         XF[I]:=(2+(1-K)/K)*S[I-1]-(1+(1-K)/K)*S2[I-1];
         DIFF:=(X[I]-XF[I])*(X[I]-XF[I]);
         SUM:=SUM+DIFF
      end;
         MSE:=SUM/8;
         Writeln(' ','K:',K:4:1,' ','MSE:',MSE:6:2);
         K:=K+0.1
  end
end.
```

```
Program  Expad2 (Input,Output);

Const
     N=8;

Var
    I,SUM1,SUM2,SUM3,SUM4            : Integer;
    XF,S,S2                          :Array [1..20] of real ;
    X                                :Array [1..20] of integer ;
    DIFF,SUM,MSE,MIN,SDEV,K,A,B      :Real ;

Begin
    X[1]:=68;
    X[2]:=60;
    X[3]:=76;
    X[4]:=81;
    X[5]:=76;
    X[6]:=89;
    X[7]:=98;
    X[8]:=103;
    X[9]:=113;
    X[10]:=118;
    X[11]:=124;
    X[12]:=129;
    X[13]:=133;
    X[14]:=137;
    X[15]:=141;
    X[16]:=144;

    SUM1:=0;
    SUM2:=0;
    SUM3:=0;
    SUM4:=0;

 Readln;
    For  I:=1 to 8 do
       begin
          SUM1:=SUM1+I;
          SUM2:=SUM2+X[I];
          SUM3:=SUM3+I*X[I];
          SUM4:=SUM4+I*I
       end;
    B:=(N*SUM3-SUM1*SUM2)/(N*SUM4-SUM1*SUM1);
    A:=SUM2/N-B*SUM1/N;
    K:=0.5;
              S[8]:=A-K/(1-K)*B;
              S2[8]:=A-2*K/(1-K)*B;
              SUM:=0;
```

```
     For I:=9 to 16 do
       begin
          S[I]:=(1-K)*X[I]+K*S[I-1];
          S2[I]:=(1-K)*S[I]+K*S2[I-1];
          XF[I]:=(2+(1-K)/K)*S[I-1]-(1+(1-K)/K)*S2[I-1];
          DIFF:=(X[I]-XF[I])*(X[I]-XF[I]);
          SUM:=SUM+DIFF
          Writeln(X[I]:6,'  ',XF[I]:6:3)
       end;
          MSE:=SUM/8;
          SDEV:=Sqrt(MSE);
     Writeln('K:',K:4:1,'MSE:',MSE:6:2,'SDEV',SDEV:6:3);
End.
```

APPENDIX D

Computer Program for Winter's Method

```
Program Winhan1(Input,Output);

Const
     L=4;

Var
  SUM,DIFF,MSE,CSUM          :Real;
  Y1,Y2,D,E,F                :Real;
  I,T,Y                      :Integer;
  C1,A,B,C,FF                :Array [1..25] of real;
  X                          :Array [1..25] of integer;

Begin
    X[1]:=610;
    X[2]:=485;
    X[3]:=395;
    X[4]:=480;
    X[5]:=651;
    X[6]:=503;
    X[7]:=405;
    X[8]:=501;
    X[9]:=658;
    X[10]:=507;
    X[11]:=408;
    X[12]:=508;

    Y1:=(X[1]+X[2]+X[3]+X[4])/4;
    Y2:=(X[5]+X[6]+X[7]+X[8])/4;

    B[4]:=(Y2-Y1)/L;
    A[4]:=Y2-L/2*B[4];

    For T:=1 to 4 do
        C1[T]:=1/2*(X[T]/(A[4]-(2*L-T)*B[4])
                         +X[T+L]/(A[4]-(L-T)*B[4]));
        CSUM:=C1[1]+C1[2]+C1[3]+C1[4];

    For I:=1 to 4 do
        C[I]:=L*C1[I]/CSUM;

    Readln(D,E,F);

    While D<0.5 do begin
        While E<0.5 do begin
            While F<0.5 do begin

               For T:=5 to 12 do
```

```
                    Y:=T-L;
                    A[T]:=D*X[T]/C[Y]+(1-D)*(A[T-1]+B[T-1]);
                    B[T]:=E*(A[T]-A[T-1])+91-E)*B[T-1];
                    C[T]:=F*(X[T]/A[T])+(1-F)*C[Y];
                    FF[T]:=(A[T-1]+B[T-1])*C[Y]
                  end;
               SUM:=0;
               For I:=5 to 12 do
                  begin
                     DIFF:=(X[I]-FF[I])*(X[I]-FF[I]);
                     SUM:=SUM+DIFF;
                  end;
               MSE:=SUM/8;
  Writeln('D=',D:3:1,'E=',E:3:1,'F=',F:3:1,'MSE',MSE:6:2);
          F:=F+0.1;
          end;
  F:=0.1;
  E:=E+0.1;
 end;
 F:=0.1;
 E:=0.1;
 D:=D+0.1
end
End.
```

```
Program Winhan2(Input,Output);

Const
     L=4;

Var
  SUM,DIFF,MSE,SDEV,CSUM      :Real;
  Y1,Y2,D,E,F                 :Real;
  I,T,Y                       :Integer;
  C1,A,B,C,FF                 :Array [1..25] of real;
  X                           :Array [1..25] of integer;

Begin
    X[1]:=610;
    X[2]:=485;
    X[3]:=395;
    X[4]:=480;
    X[5]:=651;
    X[6]:=503;
    X[7]:=405;
    X[8]:=501;
    X[9]:=658;
    X[10]:=507;
    X[11]:=408;
    X[12]:=508;

    Y1:=(X[1]+X[2]+X[3]+X[4])/4;
    Y2:=(X[5]+X[6]+X[7]+X[8])/4;

    B[4]:=(Y2-Y1)/L;
    A[4]:=Y2-L/2*B[4];

    For T:=1 to 4 do
        C1[T]:=1/2*(X[T]/(A[4]-(2*L-T)*B[4])
                          +X[T+L]/(A[4]-(L-T)*B[4]));
        CSUM:=C1[1]+C1[2]+C1[3]+C1[4];

    For I:=1 to 4 do
        C[I]:=L*C1[I]/CSUM;

    Readln(D,E,F);

               For T:=5 to 12 do
                  begin
                    Y:=T-L;
                    A[T]:=D*X[T]/C[Y]+(1-D)*(A[T-1]+B[T-1]);
                    B[T]:=E*(A[T]-A[T-1])+91-E)*B[T-1];
                    C[T]:=F*(X[T]/A[T])+(1-F)*C[Y];
                    FF[T]:=(A[T-1]+B[T-1])*C[Y];
                    Writeln(X[T]:4,FF[T]:6:2)
                  end;
```

```
                SUM:=0;
                For I:=5 to 12 do
                  begin
                    DIFF:=(X[I]-FF[I])*(X[I]-FF[I]);
                    SUM:=SUM+DIFF;
                  end;
                MSE:=SUM/8;
                SDEV:=Sqrt(MSE);
        Writeln('D=',D:3:1,'E=',E:3:1,'F=',F:3:1,'MSE',MSE:6:2)
   End.
```

APPENDIX E

Product	St.Dev	Demand	Allow.Inc	Allow.Dec.
P1	13,410	2,113,472	147,397	1,381,050
P2	3,162	961,365	324,919	961,365
P3	1,503	262,564	324,919	262,564
P4	11,759	1,509,975	324,919	1,381,050
P5	15,704	1,429,090	817,329	1,381,050
P6	12,850	2,198,380	INFINITY	1,381,050
P7	21,855	1,541,400	INFINITY	1,541,400
P8	22,395	628,130	INFINITY	102,877

APPENDIX F

1 1 First Run

```
    330 X1 + 410 X2 + 400 X3 + 375 X4 + 295 X5 + 275 X6
 + 255 X7 + 385 X8
ECT TO
)     1.05 X1 + 1.05 X2 + 1.05 X3 + 1.05 X4 + 1.05 X5 + 1.05 X6
 + 1.05 X7 + 1.05 X8 <=    8000000
)     0.0023 X1 <=    5200
)     0.0017 X2 + 0.0017 X3 + 0.0017 X4 <=    5200
)     0.00095 X5 + 0.00095 X6 + 0.00095 X7 <=    5200
)     0.0099 X8 <=    5200
)      X1 <=    2113472
)      X2 <=    961365
)      X3 <=    262564
)      X4 <=    1509975
)      X5 <=    1429090
)      X6 <=    2198380
)      X7 <=    1541400
)      X8 <=    628130


LP OPTIMUM FOUND  AT STEP      7


     OBJECTIVE FUNCTION VALUE

        .261144100E+10

ABLE             VALUE              REDUCED COST
1    2113472.000000                  .000000
2     961365.000000                  .000000
3     262564.000000                  .000000
4    1509975.000000                  .000000
5    1429090.000000                  .000000
6     817329.700000                  .000000
7           .000000                20.000010
8     525252.500000                  .000000

OW         SLACK OR SURPLUS        DUAL PRICES
)                 .000000          261.904800
)              339.014200             .000000
)              552.363000             .000000
)             3065.901000             .000000
)                 .000000        11111.110000
)                 .000000           54.999990
)                 .000000          135.000000
)                 .000000          125.000000
)                 .000000           99.999980
)                 .000000           19.999990
)          1381050.000000             .000000
)          1541400.000000             .000000
)           102877.500000             .000000

ITERATIONS=       7
```

RANGES IN WHICH THE BASIS IS UNCHANGED

OBJ COEFFICIENT RANGES

ABLE	CURRENT COEF	ALLOWABLE INCREASE	ALLOWABLE DECREASE
	330.000000	INFINITY	54.999990
	410.000000	INFINITY	135.000000
	400.000000	INFINITY	125.000000
	375.000000	INFINITY	99.999980
	295.000000	INFINITY	19.999990
	275.000000	19.999990	20.000010
	255.000000	20.000010	INFINITY
	385.000000	INFINITY	110.000000

RIGHTHAND SIDE RANGES

ROW	CURRENT RHS	ALLOWABLE INCREASE	ALLOWABLE DECREASE
2	8000000.000000	1450103.000000	858196.100000
3	5200.000000	INFINITY	339.014200
4	5200.000000	INFINITY	552.363000
5	5200.000000	INFINITY	3065.901000
6	5200.000000	1018.487000	5200.000000
7	2113472.000000	147397.500000	1381050.000000
8	961365.000000	324919.400000	961365.000000
9	262564.000000	324919.400000	262564.000000
10	1509975.000000	324919.400000	1381050.000000
11	1429090.000000	817329.700000	1381050.000000
12	2198380.000000	INFINITY	1381050.000000
13	1541400.000000	INFINITY	1541400.000000
14	628130.000000	INFINITY	102877.500000

APPENDIX G

Model 1 Second Run

```
MAX       330 X1 + 410 X2 + 400 X3 + 375 X4 + 295 X5 + 275 X6
     + 255 X7 + 385 X8
SUBJECT TO
   2)      1.05 X1 + 1.05 X2 + 1.05 X3 + 1.05 X4 + 1.05 X5 + 1.05 X6
     + 1.05 X7 + 1.05 X8 <=    8000000
   3)      0.0023 X1 <=    5200
   4)      0.0017 X2 + 0.0017 X3 + 0.0017 X4 <=    5200
   5)      0.00095 X5 + 0.00095 X6 + 0.00095 X7 <=    5200
   6)      0.0099 X8 <=    5200
   7)        X1 >=    1056736
   8)        X1 <=    2113472
   9)        X2 >=    480682
  10)        X2 <=    961365
  11)        X3 >=    131282
  12)        X3 <=    262564
  13)        X4 >=    754987
  14)        X4 <=    1509975
  15)        X5 >=    714545
  16)        X5 <=    1429090
  17)        X6 >=    1099190
  18)        X6 <=    2198380
  19)        X7 >=    770700
  20)        X7 <=    1541400
  21)        X8 >=    314065
  22)        X8 <=    628130
END

   LP OPTIMUM FOUND  AT STEP     14


         OBJECTIVE FUNCTION VALUE

1)          .256314500E+10

VARIABLE          VALUE              REDUCED COST
  X1     1775457.000000               .000000
  X2      961365.000000               .000000
  X3      262564.000000               .000000
  X4     1509975.000000               .000000
  X5      714545.000000               .000000
  X6     1099190.000000               .000000
  X7      770700.000000               .000000
  X8      525252.500000               .000000


  ROW        SLACK OR SURPLUS      DUAL PRICES
  2)              .000000          314.285700
  3)          1116.449000             .000000
  4)           552.363000             .000000
  5)          2744.787000             .000000
  6)              .000000         5555.555000
  7)        718721.000000             .000000
  8)        338015.000000             .000000
  9)        480683.000000             .000000
 10)              .000000           79.999990
```

11)	131282.000000	.000000
12)	.000000	69.999990
13)	754988.000000	.000000
14)	.000000	44.999990
15)	.000000	-35.000010
16)	714545.000000	.000000
17)	.000000	-55.000010
18)	1099190.000000	.000000
19)	.000000	-75.000010
20)	770700.000000	.000000
21)	211187.500000	.000000
22)	102877.500000	.000000

NO. ITERATIONS= 14

RANGES IN WHICH THE BASIS IS UNCHANGED

OBJ COEFFICIENT RANGES

VARIABLE	CURRENT COEF	ALLOWABLE INCREASE	ALLOWABLE DECREASE
X1	330.000000	44.999990	35.000010
X2	410.000000	INFINITY	79.999990
X3	400.000000	INFINITY	69.999990
X4	375.000000	INFINITY	44.999990
X5	295.000000	35.000010	INFINITY
X6	275.000000	55.000010	INFINITY
X7	255.000000	75.000010	INFINITY
X8	385.000000	INFINITY	54.999990

RIGHTHAND SIDE RANGES

ROW	CURRENT RHS	ALLOWABLE INCREASE	ALLOWABLE DECREASE
2	8000000.000000	354915.700000	754657.000000
3	5200.000000	INFINITY	1116.449000
4	5200.000000	INFINITY	552.363000
5	5200.000000	INFINITY	2744.787000
6	5200.000000	1018.487000	2090.756000
7	1056736.000000	718721.000000	INFINITY
8	2113472.000000	INFINITY	338015.000000
9	480682.000000	480683.000000	INFINITY
10	961365.000000	324919.400000	338015.000000
11	131282.000000	131282.000000	INFINITY
12	262564.000000	324919.400000	131282.000000
13	754987.000000	754988.000000	INFINITY
14	1509975.000000	324919.400000	338015.000000
15	714545.000000	714545.000000	338015.000000
16	1429090.000000	INFINITY	714545.000000
17	1099190.000000	718721.000000	338015.000000
18	2198380.000000	INFINITY	1099190.000000
19	770700.000000	718721.000000	338015.000000
20	1541400.000000	INFINITY	770700.000000
21	314065.000000	211187.500000	INFINITY
22	628130.000000	INFINITY	102877.500000

APPENDIX H

Model 1 Third Run

```
MAX      330 X1 + 410 X2 + 400 X3 + 375 X4 + 295 X5 + 275 X6
    + 255 X7 + 385 X8
SUBJECT TO
   2)    1.05 X1 + 1.05 X2 + 1.05 X3 + 1.05 X4 + 1.05 X5 + 1.05 X6
    + 1.05 X7 + 1.05 X8 <=   10000000
   3)    0.0023 X1 <=   5200
   4)    0.0017 X2 + 0.0017 X3 + 0.0017 X4 <=   5200
   5)    0.00095 X5 + 0.00095 X6 + 0.00095 X7 <=   5200
   6)    0.0099 X8 <=   5200
   7)     X1 >=   1056736
   8)     X1 <=   2113472
   9)     X2 >=   480682
  10)     X2 <=   961365
  11)     X3 >=   131282
  12)     X3 <=   262564
  13)     X4 >=   754987
  14)     X4 <=   1509975
  15)     X5 >=   714545
  16)     X5 <=   1429090
  17)     X6 >=   1099190
  18)     X6 <=   2198380
  19)     X7 >=   770700
  20)     X7 <=   1541400
  21)     X8 >=   314065
  22)     X8 <=   628130
END


    LP OPTIMUM FOUND  AT STEP     15


         OBJECTIVE FUNCTION VALUE

 1)          .311983600E+10
VARIABLE          VALUE              REDUCED COST
   X1    2113472.000000               .000000
   X2     961365.000000               .000000
   X3     262564.000000               .000000
   X4    1509975.000000               .000000
   X5    1429090.000000               .000000
   X6    1951392.000000               .000000
   X7     770700.000000               .000000
   X8     525252.500000               .000000


   ROW       SLACK OR SURPLUS       DUAL PRICES
   2)              .000000        261.904800
   3)           339.014200           .000000
   4)           552.363000           .000000
   5)          1256.377000           .000000
   6)              .000000      11111.110000
   7)       1056736.000000           .000000
   8)              .000000         54.999990
   9)        480683.000000           .000000
  10)              .000000        135.000000
  11)        131282.000000           .000000
```

12)	.000000	125.000000
13)	754988.000000	.000000
14)	.000000	99.999980
15)	714545.000000	.000000
16)	.000000	19.999990
17)	852202.000000	.000000
18)	246988.000000	.000000
19)	.000000	-20.000010
20)	770700.000000	.000000
21)	211187.500000	.000000
22)	102877.500000	.000000

NO. ITERATIONS= 15

RANGES IN WHICH THE BASIS IS UNCHANGED

OBJ COEFFICIENT RANGES

VARIABLE	CURRENT COEF	ALLOWABLE INCREASE	ALLOWABLE DECREASE
X1	330.000000	INFINITY	54.999990
X2	410.000000	INFINITY	135.000000
X3	400.000000	INFINITY	125.000000
X4	375.000000	INFINITY	99.999980
X5	295.000000	INFINITY	19.999990
X6	275.000000	19.999990	20.000010
X7	255.000000	20.000010	INFINITY
X8	385.000000	INFINITY	110.000000

RIGHTHAND SIDE RANGES

ROW	CURRENT RHS	ALLOWABLE INCREASE	ALLOWABLE DECREASE
2	10000000.000000	259337.400000	894812.100000
3	5200.000000	INFINITY	339.014200
4	5200.000000	INFINITY	552.363000
5	5200.000000	INFINITY	1256.377000
6	5200.000000	1018.487000	2090.756000
7	1056736.000000	1056736.000000	INFINITY
8	2113472.000000	147397.500000	246988.000000
9	480682.000000	480683.000000	INFINITY
10	761365.000000	324919.400000	246988.000000
11	131282.000000	131282.000000	INFINITY
12	262564.000000	324919.400000	131282.000000
13	754987.000000	754988.000000	INFINITY
14	1509975.000000	324919.400000	246988.000000
15	714545.000000	714545.000000	INFINITY
16	1429090.000000	852202.000000	246988.000000
17	1099190.000000	852202.000000	INFINITY
18	2198380.000000	INFINITY	246988.000000
19	770700.000000	770700.000000	246988.000000
20	1541400.000000	INFINITY	770700.000000
21	314065.000000	211187.500000	INFINITY
22	628130.000000	INFINITY	102877.500000

APPENDIX I

Model 1 with Revised Constraints

```
MAX      330 X1 + 410 X2 + 400 X3 + 375 X4 + 295 X5 + 275 X6
     + 255 X7 + 385 X8
SUBJECT TO
    2)     1.05 X1 + 1.05 X2 + 1.05 X3 + 1.05 X4 + 1.05 X5 + 1.05 X6
     + 1.05 X7 + 1.05 X8 <=   8000000
    3)     0.0023 X1 <=   5200
    4)     0.0017 X2 + 0.0017 X3 + 0.0017 X4 <=   5200
    5)     0.00095 X5 + 0.00095 X6 + 0.00095 X7 <=   5200
    6)     0.00828 X8 <=   5200
    7)      X1 <=   2113472
    8)      X2 <=   961365
    9)      X3 <=   262564
   10)      X4 <=   1509975
   11)      X5 <=   1429090
   12)      X6 <=   2198380
   13)      X7 <=   1541400
   14)      X8 <=   628130
END


     LP OPTIMUM FOUND  AT STEP      7


          OBJECTIVE FUNCTION VALUE

 1)          .262275700E+10

VARIABLE          VALUE             REDUCED COST
   X1    2113472.000000               .000000
   X2     961365.000000               .000000
   X3     262564.000000               .000000
   X4    1509975.000000               .000000
   X5    1429090.000000               .000000
   X6     714452.100000               .000000
   X7           .000000             20.000010
   X8     628130.000000               .000000


   ROW        SLACK OR SURPLUS       DUAL PRICES
   2)               .000000          261.904800
   3)            339.014200             .000000
   4)            552.363000             .000000
   5)           3163.635000             .000000
   6)               .339844             .000000
   7)               .000000           54.999990
   8)               .000000          135.000000
   9)               .000000          125.000000
  10)               .000000           99.999980
  11)               .000000           19.999990
  12)        1483928.000000             .000000
  13)        1541400.000000             .000000
  14)               .000000          110.000000

 NO. ITERATIONS=        7
```

RANGES IN WHICH THE BASIS IS UNCHANGED

OBJ COEFFICIENT RANGES

VARIABLE	CURRENT COEF	ALLOWABLE INCREASE	ALLOWABLE DECREASE
X1	330.000000	INFINITY	54.999990
X2	410.000000	INFINITY	135.000000
X3	400.000000	INFINITY	125.000000
X4	375.000000	INFINITY	99.999980
X5	295.000000	INFINITY	19.999990
X6	275.000000	19.999990	20.000010
X7	255.000000	20.000010	INFINITY
X8	385.000000	INFINITY	110.000000

RIGHTHAND SIDE RANGES

ROW	CURRENT RHS	ALLOWABLE INCREASE	ALLOWABLE DECREASE
2	8000000.000000	1558124.000000	750174.600000
3	5200.000000	INFINITY	339.014200
4	5200.000000	INFINITY	552.365000
5	5200.000000	INFINITY	3163.635000
6	5200.000000	INFINITY	.339844
7	2113472.000000	147397.500000	1483928.000000
8	961365.000000	324919.400000	961365.000000
9	262564.000000	324919.400000	262564.000000
10	1509975.000000	324919.400000	1483928.000000
11	1429090.000000	714452.100000	1429090.000000
12	2198380.000000	INFINITY	1483928.000000
13	1541400.000000	INFINITY	1541400.000000
14	628130.000000	41.053850	628130.000000

APPENDIX J

odel 1 with Revised Constraints

```
AX       330 X1 + 410 X2 + 400 X3 + 375 X4 + 295 X5 + 275 X6
     + 255 X7 + 385 X8
JBJECT TO
  2)     1.05 X1 + 1.05 X2 + 1.05 X3 + 1.05 X4 + 1.05 X5 + 1.05 X6
     + 1.05 X7 + 1.05 X8 <=   11176595
  3)     0.0023 X1 <=    5200
  4)     0.0017 X2 + 0.0017 X3 + 0.0017 X4 <=    5200
  5)     0.00095 X5 + 0.00095 X6 + 0.00095 X7 <=    5200
  6)     0.00828 X8 <=    5200
  7)      X1 <=    2113472
  8)      X2 <=    961365
  9)      X3 <=    262564
 10)      X4 <=    1509975
 11)      X5 <=    1429090
 12)      X6 <=    2198380
 13)      X7 <=    1541400
 14)      X8 <=    628130
ND
```

LP OPTIMUM FOUND AT STEP 8

OBJECTIVE FUNCTION VALUE

) .342389500E+10

ARIABLE	VALUE	REDUCED COST
X1	2113472.000000	.000000
X2	961365.000000	.000000
X3	262564.000000	.000000
X4	1509975.000000	.000000
X5	1429090.000000	.000000
X6	2198380.000000	.000000
X7	1541400.000000	.000000
X8	628130.000000	.000000

ROW	SLACK OR SURPLUS	DUAL PRICES
2)	.500000	.000000
3)	339.014200	.000000
4)	552.363000	.000000
5)	289.573600	.000000
6)	.339844	.000000
7)	.000000	330.000000
8)	.000000	410.000000
9)	.000000	400.000000
10)	.000000	375.000000
11)	.000000	295.000000
12)	.000000	275.000000
13)	.000000	255.000000
14)	.000000	385.000000

O. ITERATIONS= 8

RANGES IN WHICH THE BASIS IS UNCHANGED

OBJ COEFFICIENT RANGES

VARIABLE	CURRENT COEF	ALLOWABLE INCREASE	ALLOWABLE DECREASE
X1	330.000000	INFINITY	330.000000
X2	410.000000	INFINITY	410.000000
X3	400.000000	INFINITY	400.000000
X4	375.000000	INFINITY	375.000000
X5	295.000000	INFINITY	295.000000
X6	275.000000	INFINITY	275.000000
X7	255.000000	INFINITY	255.000000
X8	385.000000	INFINITY	385.000000

RIGHTHAND SIDE RANGES

ROW	CURRENT RHS	ALLOWABLE INCREASE	ALLOWABLE DECREASE
2	11176600.000000	INFINITY	.500000
3	5200.000000	INFINITY	339.014200
4	5200.000000	INFINITY	552.363000
5	5200.000000	INFINITY	289.573600
6	5200.000000	INFINITY	.339844
7	2113472.000000	.476191	2113472.000000
8	961365.000000	.476191	961365.000000
9	262564.000000	.476191	262564.000000
10	1509975.000000	.476191	1509975.000000
11	1429090.000000	.476191	1429090.000000
12	2198380.000000	.476191	2198380.000000
13	1541400.000000	.476191	1541400.000000
14	628130.000000	.476191	628130.000000

APPENDIX K

Model 2 First Run

```
MAX..:  330 T11 + 330 T12 + 330 T13 + 330 T14 + 410 T21 + 410 T22
     + 410 T23 + 410 T24 + 400 T31 + 400 T32 + 400 T33 + 400 T34
     + 375 T41 + 375 T42 + 375 T43 + 375 T44 + 295 T51 + 295 T52
     + 295 T53 + 295 T54 + 275 T61 + 275 T62 + 275 T63 + 275 T64
     + 255 T71 + 255 T72 + 255 T73 + 255 T74 + 385 T81 + 385 T82
     + 385 T83 + 385 T84 - 120 SM11 - 120 SM21 - 120 SM31
     - 120 SM41 - 120 SM51 - 120 SM61 - 120 SM71 - 120 SM81
     - 120 SM12 - 120 SM22 - 120 SM32 - 120 SM42 - 120 SM52
     - 120 SM62 - 120 SM72 - 120 SM82 - 120 SM13 - 120 SM23
     - 120 SM33 - 120 SM43 - 120 SM53 - 120 SM63 - 120 SM73
     - 120 SM83 - 120 SM14 - 120 SM24 - 120 SM34 - 120 SM44
     - 120 SM54 - 120 SM64 - 120 SM74 - 120 SM84

SUBJECT TO:
-----------
   2)  - T11 - SM11 + SM14 + X11 =  0
   3)  - T21 - SM21 + SM24 + X21 =  0
   4)  - T31 - SM31 + SM34 + X31 =  0
   5)  - T41 - SM41 + SM44 + X41 =  0
   6)  - T51 - SM51 + SM54 + X51 =  0
   7)  - T61 - SM61 + SM64 + X61 =  0
   8)  - T71 - SM71 + SM74 + X71 =  0
   9)  - T81 - SM81 + SM84 + X81 =  0
  10)  - T12 + SM11 - SM12 + X12 =  0
  11)  - T22 + SM21 - SM22 + X22 =  0
  12)  - T32 + SM31 - SM32 + X32 =  0
  13)  - T42 + SM41 - SM42 + X42 =  0
  14)  - T52 + SM51 - SM52 + X52 =  0
  15)  - T62 + SM61 - SM62 + X62 =  0
  16)  - T72 + SM71 - SM72 + X72 =  0
  17)  - T82 + SM81 - SM82 + X82 =  0
  18)  - T13 + SM12 - SM13 + X13 =  0
  19)  - T23 + SM22 - SM23 + X23 =  0
  20)  - T33 + SM32 - SM33 + X33 =  0
  21)  - T43 + SM42 - SM43 + X43 =  0
  22)  - T53 + SM52 - SM53 + X53 =  0
  23)  - T63 + SM62 - SM63 + X63 =  0
  24)  - T73 + SM72 - SM73 + X73 =  0
  25)  - T83 + SM82 - SM83 + X83 =  0
  26)  - T14 + SM13 - SM14 + X14 =  0
  27)  - T24 + SM23 - SM24 + X24 =  0
  28)  - T34 + SM33 - SM34 + X34 =  0
  29)  - T44 + SM43 - SM44 + X44 =  0
  30)  - T54 + SM53 - SM54 + X54 =  0
  31)  - T64 + SM63 - SM64 + X64 =  0
  32)  - T74 + SM73 - SM74 + X74 =  0
  33)  - T84 + SM83 - SM84 + X84 =  0
  34)    1.05 X11 + 1.05 X21 + 1.05 X31 + 1.05 X41 + 1.05 X51
     + 1.05 X61 + 1.05 X71 + 1.05 X81 <=   2,000,000
  35)    1.05 X12 + 1.05 X22 + 1.05 X32 + 1.05 X42 + 1.05 X52
     + 1.05 X62 + 1.05 X72 + 1.05 X82 <=   2,000,000
  36)    1.05 X13 + 1.05 X23 + 1.05 X33 + 1.05 X43 + 1.05 X53
     + 1.05 X63 + 1.05 X73 + 1.05 X83 <=   2,000,000
  37)    1.05 X14 + 1.05 X24 + 1.05 X34 + 1.05 X44 + 1.05 X54
     + 1.05 X64 + 1.05 X74 + 1.05 X84 <=   2,000,000
```

```
38)    0.0023 X11 <=   1,300
39)    0.0023 X12 <=   1,300
40)    0.0023 X13 <=   1,300
41)    0.0023 X14 <=   1,300
42)    0.0017 X21 + 0.0017 X31 + 0.0017 X41 <=    1,300
43)    0.0017 X22 + 0.0017 X32 + 0.0017 X42 <=    1,300
44)    0.0017 X23 + 0.0017 X33 + 0.0017 X43 <=    1,300
45)    0.0017 X24 + 0.0017 X34 + 0.0017 X44 <=    1,300
46)    0.0099 X84 <=   1,300
47)     T11 <=   669,333
48)     T12 <=   518,411
49)     T13 <=   414,139
50)     T14 <=   511,590
51)     T21 <=   171,915
52)     T22 <=   268,715
53)     T23 <=   310,381
54)     T24 <=   210,354
55)     T31 <=    45,585
56)     T32 <=    71,765
57)     T33 <=    83,531
58)     T34 <=    61,683
59)     T41 <=   271,024
60)     T42 <=   423,106
61)     T43 <=   486,697
62)     T44 <=   329,148
63)     T51 <=   353,605
64)     T52 <=   356,050
65)     T53 <=   358,495
66)     T54 <=   360,940
67)     T61 <=   546,940
68)     T62 <=   548,710
69)     T63 <=   550,480
70)     T64 <=   552,250
71)     T71 <=   381,300
72)     T72 <=   384,000
73)     T73 <=   386,700
74)     T74 <=   389,400
75)     T81 <=   149,830
76)     T82 <=   154,630
77)     T83 <=   159,430
78)     T84 <=   164,240
79)    0.00095 X51 + 0.00095 X61 + 0.00095 X71 <=    1,300
80)    0.00095 X52 + 0.00095 X62 + 0.00095 X72 <=    1,300
81)    0.00095 X53 + 0.00095 X63 + 0.00095 X73 <=    1,300
82)    0.00095 X54 + 0.00095 X64 + 0.00095 X74 <=    1,300
83)    0.0099 X81 <=   1,300
84)    0.0099 X82 <=   1,300
85)    0.0099 X83 <=   1,300
86)  - 0.1 T12 +  SM11 >=   0
87)  - 0.1 T22 +  SM21 >=   0
88)  - 0.1 T32 +  SM31 >=   0
89)  - 0.1 T42 +  SM41 >=   0
90)  - 0.1 T52 +  SM51 >=   0
91)  - 0.1 T62 +  SM61 >=   0
92)  - 0.1 T72 +  SM71 >=   0
93)  - 0.1 T82 +  SM81 >=   0
94)  - 0.1 T13 +  SM12 >=   0
95)  - 0.1 T23 +  SM22 >=   0
96)  - 0.1 T33 +  SM32 >=   0
97)  - 0.1 T43 +  SM42 >=   0
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 98)  - 0.1 T53 +  SM52 >=   0
 99)  - 0.1 T63 +  SM62 >=   0
100)  - 0.1 T73 +  SM72 >=   0
101)  - 0.1 T83 +  SM82 >=   0
102)  - 0.1 T14 +  SM13 >=   0
103)  - 0.1 T24 +  SM23 >=   0
104)  - 0.1 T34 +  SM33 >=   0
105)  - 0.1 T44 +  SM43 >=   0
106)  - 0.1 T54 +  SM53 >=   0
107)  - 0.1 T64 +  SM63 >=   0
108)  - 0.1 T74 +  SM73 >=   0
109)  - 0.1 T84 +  SM83 >=   0
110)  - 0.1 T11 +  SM14 >=   0
111)  - 0.1 T21 +  SM24 >=   0
112)  - 0.1 T31 +  SM34 >=   0
113)  - 0.1 T41 +  SM44 >=   0
114)  - 0.1 T51 +  SM54 >=   0
115)  - 0.1 T61 +  SM64 >=   0
116)  - 0.1 T71 +  SM74 >=   0
117)  - 0.1 T81 +  SM84 >=   0
END
```

LP OPTIMUM FOUND AT STEP : 123

OBJECTIVE FUNCTION VALUE

.250470900E+10

VARIABLE	VALUE	REDUCED COST
T11	570,418.100000	.000000
T12	518,411.000000	.000000
T13	414,139.000000	.000000
T14	511,590.000000	.000000
T21	171,915.000000	.000000
T22	268,715.000000	.000000
T23	310,381.000000	.000000
T24	210,354.000000	.000000
T31	45,585.000000	.000000
T32	71,765.000000	.000000
T33	83,531.000000	.000000
T34	61,683.000000	.000000
T41	271,024.000000	.000000
T42	422,207.100000	.000000
T43	368,962.900000	.000000
T44	329,148.000000	.000000
T51	353,605.000000	.000000
T52	356,050.000000	.000000
T53	358,495.000000	.000000
T54	360,940.000000	.000000
T61	360,902.000000	.000000
T62	136,300.700000	.000000
T63	217,939.900000	.000000
T64	299,734.000000	.000000
T71	.000000	20.000000
T72	.000000	8.000000
T73	.000000	20.000000

T74	.000000	8.000000
T81	131,313.000000	.000000
T82	131,313.100000	.000000
T83	131,313.100000	.000000
T84	131,313.000000	.000000
SM11	51,841.100000	.000000
SM21	26,871.500000	.000000
SM31	7,176.500000	.000000
SM41	42,220.710000	.000000
SM51	35,605.000000	.000000
SM61	13,630.070000	.000000
SM71	.000000	120.000000
SM81	13,131.310000	.000000
SM12	41,413.900000	.000000
SM22	31,038.100000	.000000
SM32	8,353.101000	.000000
SM42	38,896.310000	.000000
SM52	35,849.500000	.000000
SM62	21,794.000000	.000000
SM72	.000000	.000000
SM82	13,131.310000	.000000
SM13	51,159.000000	.000000
SM23	21,035.400000	.000000
SM33	6,168.300000	.000000
SM43	32,914.800000	.000000
SM53	36,094.000000	.000000
SM63	29,973.380000	.000000
SM73	.000000	120.000000
SM83	13,131.250000	.000000
SM14	57,041.810000	.000000
SM24	17,191.500000	.000000
SM34	4,558.500000	.000000
SM44	27,102.400000	.000000
SM54	35,360.500000	.000000
SM64	36,090.000000	.000000
SM74	.000000	.000000
SM84	13,131.000000	.000000
X11	565,217.400000	.000000
X21	181,595.000000	.000000
X31	48,203.000000	.000000
X41	286,142.300000	.000000
X51	353,849.500000	.000000
X61	338,441.700000	.000000
X71	.000000	.000000
X81	131,313.100000	.000000
X12	507,983.800000	.000000
X22	272,881.600000	.000000
X32	72,941.600000	.000000
X42	418,882.700000	.000000
X52	356,294.500000	.000000
X62	144,464.700000	.000000
X72	.000000	.000000
X82	131,313.100000	.000000
X13	423,884.100000	.000000
X23	300,378.300000	.000000
X33	81,346.200000	.000000
X43	382,981.300000	.000000
X53	358,739.500000	.000000
X63	226,119.400000	.000000
X73	.000000	.000000

X83	131,313.100000	.000000
X14	517,472.800000	.000000
X24	206,510.100000	.000000
X34	60,073.200000	.000000
X44	323,335.600000	.000000
X54	360,206.500000	.000000
X64	305,850.700000	.000000
X74	.000000	.000000
X84	131,313.100000	.000000

ROW	SLACK OR SURPLUS	DUAL PRICES
2)	.000000	-324.111100
3)	.000000	-263.000000
4)	.000000	-263.000000
5)	.000000	-263.000000
6)	.000000	-263.000000
7)	.000000	-263.000000
8)	.000000	-263.000000
9)	.000000	-373.000000
10)	.000000	-263.000000
11)	.000000	-374.111100
12)	.000000	-374.111100
13)	.000000	-374.111100
14)	.000000	-263.000000
15)	.000000	-263.000000
16)	.000000	-263.000000
17)	.000000	-373.000000
18)	.000000	-263.000000
19)	.000000	-361.765400
20)	.000000	-361.765400
21)	.000000	-361.765400
22)	.000000	-263.000000
23)	.000000	-263.000000
24)	.000000	-263.000000
25)	.000000	-373.000000
26)	.000000	-263.000000
27)	.000000	-263.000000
28)	.000000	-263.000000
29)	.000000	-263.000000
30)	.000000	-263.000000
31)	.000000	-263.000000
32)	.000000	-263.000000
33)	.000000	-373.000000
34)	.000000	250.476200
35)	.000000	250.476200
36)	.000000	250.476200
37)	.000000	250.476200
38)	.000000	26570.050000
39)	131.637200	.000000
40)	325.066600	.000000
41)	109.812500	.000000
42)	422.901500	.000000
43)	.000000	65359.480000
44)	.000000	58097.320000
45)	297.137900	.000000
46)	.000000	11111.110000
47)	98914.910000	.000000
48)	.000000	48.888890

49)	.000000	55.000000
50)	.000000	55.000000
51)	.000000	135.000000
52)	.000000	35.000000
53)	.000000	34.999990
54)	.000000	125.123500
55)	.000000	125.000000
56)	.000000	25.000000
57)	.000000	24.999990
58)	.000000	115.123500
59)	.000000	100.000000
60)	898.937500	.000000
61)	97734.130000	.000000
62)	.000000	90.123460
63)	.000000	20.000000
64)	.000000	20.000000
65)	.000000	20.000000
66)	.000000	20.000000
67)	186038.000000	.000000
68)	412409.300000	.000000
69)	332540.100000	.000000
70)	252516.000000	.000000
71)	381300.000000	.000000
72)	384000.000000	.000000
73)	386700.000000	.000000
74)	389400.000000	.000000
75)	18517.000000	.000000
76)	23316.880000	.000000
77)	28116.880000	.000000
78)	32927.000000	.000000
79)	642.323400	.000000
80)	824.278800	.000000
81)	744.384100	.000000
82)	667.245700	.000000
83)	.000000	11111.110000
84)	.000000	11111.110000
85)	.000000	11111.110000
86)	.000000	-181.111100
87)	.000000	-8.888885
88)	.000000	-8.888885
89)	.000000	-8.888855
90)	.000000	-120.000000
91)	.000000	-120.000000
92)	.000000	.000000
93)	.000000	-120.000000
94)	.000000	-120.000000
95)	.000000	-132.345700
96)	.000000	-132.345700
97)	.000000	-132.345700
98)	.000000	-120.000000
99)	.000000	-120.000000
100)	.000000	-120.000000
101)	.000000	-120.000000
102)	.000000	-120.000000
103)	.000000	-218.765400
104)	.000000	-218.765400
105)	.000000	-218.765400
106)	.000000	-120.000000
107)	.000000	-120.000000
108)	.000000	.000000

109)	.000000	-120.000000
110)	.000000	-58.888890
111)	.000000	-120.000000
112)	.000000	-120.000000
113)	.000000	-120.000000
114)	.000000	-120.000000
115)	.000000	-120.000000
116)	.000000	-120.000000
117)	.000000	-120.000000

NO. ITERATIONS = 123

RANGES IN WHICH THE BASIS IS UNCHANGED

OBJ COEFFICIENT RANGES

VARIABLE	CURRENT COEF	ALLOWABLE INCREASE	ALLOWABLE DECREASE
T11	330.000000	53.000000	55.000010
T12	330.000000	INFINITY	48.888890
T13	330.000000	INFINITY	55.000000
T14	330.000000	INFINITY	55.000000
T21	410.000000	INFINITY	135.000000
T22	410.000000	INFINITY	35.000000
T23	410.000000	INFINITY	34.999990
T24	410.000000	INFINITY	125.123500
T31	400.000000	INFINITY	125.000000
T32	400.000000	INFINITY	25.000000
T33	400.000000	INFINITY	24.999990
T34	400.000000	INFINITY	115.123500
T41	375.000000	INFINITY	100.000000
T42	375.000000	7.999974	100.000000
T43	375.000000	24.999990	88.888900
T44	375.000000	INFINITY	90.123460
T51	295.000000	INFINITY	20.000000
T52	295.000000	INFINITY	20.000000
T53	295.000000	INFINITY	20.000000
T54	295.000000	INFINITY	20.000000
T61	275.000000	20.000000	7.198876
T62	275.000000	20.000000	7.198903
T63	275.000000	20.000000	20.000000
T64	275.000000	20.000000	7.198903
T71	255.000000	20.000000	INFINITY
T72	255.000000	8.000000	INFINITY
T73	255.000000	20.000000	INFINITY
T74	255.000000	8.000000	INFINITY
T81	385.000000	107.835600	97.181480
T82	385.000000	107.835700	97.185180
T83	385.000000	107.835700	97.185180
T84	385.000000	107.835700	97.185180
SM11	-120.000000	181.111100	488.888900
SM21	-120.000000	8.888885	350.000000
SM31	-120.000000	8.888885	250.000000
SM41	-120.000000	7.999970	1000.000000
SM51	-120.000000	120.000000	200.000000
SM61	-120.000000	107.983500	71.989030

SM71	-120.000000	120.000000	INFINITY
SM81	-120.000000	107.983500	971.851900
SM12	-120.000000	120.000000	550.000000
SM22	-120.000000	132.345700	349.999900
SM32	-120.000000	132.345700	249.999900
SM42	-120.000000	119.111100	888.889100
SM52	-120.000000	120.000000	200.000000
SM62	-120.000000	107.983500	200.000000
SM72	-120.000000	120.000000	INFINITY
SM82	-120.000000	107.983500	971.851900
SM13	-120.000000	120.000000	550.000000
SM23	-120.000000	218.765400	1251.235000
SM33	-120.000000	218.765400	1151.235000
SM43	-120.000000	218.765400	901.234600
SM53	-120.000000	120.000000	200.000000
SM63	-120.000000	107.983500	71.989030
SM73	-120.000000	120.000000	INFINITY
SM83	-120.000000	107.983500	971.851900
SM14	-120.000000	53.000000	550.000100
SM24	-120.000000	120.000000	1350.000000
SM34	-120.000000	120.000000	1250.000000
SM44	-120.000000	120.000000	1000.000000
SM54	-120.000000	120.000000	200.000000
SM64	-120.000000	107.983500	71.988750
SM74	-120.000000	120.000000	INFINITY
SM84	-120.000000	107.983500	972.423100
X11	.000000	INFINITY	61.111120
X21	.000000	8.888885	120.000000
X31	.000000	8.888885	120.000000
X41	.000000	7.999970	111.111100
X51	.000000	120.000000	22.222220
X61	.000000	22.222220	7.999970
X71	.000000	22.222220	120.000000
X81	.000000	INFINITY	110.000000
X12	.000000	120.000000	54.320990
X22	.000000	132.345700	8.888885
X32	.000000	132.345700	8.888885
X42	.000000	8.888885	111.111100
X52	.000000	120.000000	22.222220
X62	.000000	22.222220	8.000000
X72	.000000	8.000000	120.000000
X82	.000000	INFINITY	110.000000
X13	.000000	120.000000	61.111110
X23	.000000	218.765400	38.888880
X33	.000000	218.765400	27.777770
X43	.000000	27.777770	98.765450
X53	.000000	120.000000	22.222220
X63	.000000	22.222220	22.222220
X73	.000000	22.222220	120.000000
X83	.000000	INFINITY	110.000000
X14	.000000	53.000000	61.111110
X24	.000000	120.000000	139.026100
X34	.000000	120.000000	127.915000
X44	.000000	120.000000	100.137200
X54	.000000	120.000000	22.222220
X64	.000000	22.222220	8.000000
X74	.000000	8.000000	120.000000
X84	.000000	INFINITY	110.000000

RIGHTHAND SIDE RANGES
****

ROW	CURRENT RHS	ALLOWABLE INCREASE	ALLOWABLE DECREASE
2	.000000	513,376.300000	89,023.410000
3	.000000	248,765.600000	167,408.700000
4	.000000	248,765.600000	48,203.000000
5	.000000	248,765.600000	167,408.700000
6	.000000	324,760.500000	167,408.700000
7	.000000	324,760.500000	167,408.700000
8	.000000	324,760.500000	.000000
9	.000000	118,161.000000	16,662.760000
10	.000000	57,233.570000	371,111.700000
11	.000000	379,986.400000	809.043800
12	.000000	379,986.400000	809.043800
13	.000000	379,986.400000	809.043800
14	.000000	122,652.000000	356,294.500000
15	.000000	122,652.000000	371,111.700000
16	.000000	122,652.000000	.000000
17	.000000	118,163.800000	20,981.990000
18	.000000	141,333.300000	299,240.500000
19	.000000	7,281.394000	87,960.710000
20	.000000	7,281.394000	81,346.200000
21	.000000	7,281.394000	87,960.710000
22	.000000	196,116.000000	299,240.500000
23	.000000	196,116.000000	299,240.500000
24	.000000	196,116.000000	.000000
25	.000000	118,163.800000	25,301.330000
26	.000000	47,744.560000	227,229.800000
27	.000000	174,787.000000	206,510.100000
28	.000000	174,787.000000	60,073.200000
29	.000000	174,787.000000	227,229.800000
30	.000000	269,719.300000	227,229.800000
31	.000000	269,719.300000	227,229.800000
32	.000000	269,719.300000	.000000
33	.000000	118,163.200000	29,629.790000
34	2,000,000.000000	175,779.100000	340,998.500000
35	2,000,000.000000	389,667.300000	128,784.500000
36	2,000,000.000000	314,202.500000	205,921.800000
37	2,000,000.000000	238,591.200000	283,205.200000
38	1,300.000000	204.753900	385.098700
39	1,300.000000	INFINITY	131.637200
40	1,300.000000	INFINITY	325.066600
41	1,300.000000	INFINITY	109.812500
42	1,300.000000	INFINITY	422.901500
43	1,300.000000	1.375374	630.986200
44	1,300.000000	149.533200	12.378370
45	1,300.000000	INFINITY	297.137900
46	1,300.000000	293.334800	1,169.816000
47	669,333.000000	INFINITY	98,914.910000
48	518,411.000000	63,592.860000	412,409.300000
49	414,139.000000	157,037.000000	332,540.100000
50	511,590.000000	53,049.520000	252,516.000000
51	171,915.000000	276,406.200000	171,915.000000
52	268,715.000000	422,207.100000	898.937600
53	310,381.000000	388,962.900000	97,734.130000
54	210,354.000000	72,813.940000	210,354.000000

55	45,585.000000	276,406.200000	45,585.000000
56	71,765.000000	422,207.100000	898.937600
57	83,531.000000	388,962.900000	83,531.000000
58	61,683.000000	72,813.940000	61,683.000000
59	271,024.000000	276,406.200000	186,038.000000
60	423,106.000000	INFINITY	898.937500
61	486,697.000000	INFINITY	97,734.130000
62	329,148.000000	72,813.940000	252,516.000000
63	353,605.000000	360,900.000000	186,038.000000
64	356,050.000000	136,300.700000	356,050.000000
65	358,495.000000	217,939.900000	332,540.100000
66	360,940.000000	299,733.800000	252,516.000000
67	546,940.000000	INFINITY	186,038.000000
68	548,710.000000	INFINITY	412,409.300000
69	550,480.000000	INFINITY	332,540.100000
70	552,250.000000	INFINITY	252,516.000000
71	381,300.000000	INFINITY	381,300.000000
72	384,000.000000	INFINITY	384,000.000000
73	386,700.000000	INFINITY	386,700.000000
74	389,400.000000	INFINITY	389,400.000000
75	149,830.000000	INFINITY	18,517.000000
76	154,630.000000	INFINITY	23,316.880000
77	159,430.000000	INFINITY	28,116.880000
78	164,240.000000	INFINITY	32,927.000000
79	1,300.000000	INFINITY	642.323400
80	1,300.000000	INFINITY	824.278800
81	1,300.000000	INFINITY	744.384100
82	1,300.000000	INFINITY	667.245700
83	1,300.000000	164.961300	1,169.794000
84	1,300.000000	207.721700	1,169.822000
85	1,300.000000	250.483200	1,169.822000
86	.000000	370,603.400000	51,841.100000
87	.000000	809.043800	26,871.500000
88	.000000	809.043800	7,176.500000
89	.000000	809.044100	37,998.640000
90	.000000	292,286.000000	35,605.000000
91	.000000	292,289.600000	12,265.200000
92	.000000	.000000	INFINITY
93	.000000	20,953.260000	11,816.380000
94	.000000	57,233.570000	41,413.900000
95	.000000	87,960.720000	728.139400
96	.000000	81,346.200000	728.139400
97	.000000	87,960.720000	728.139400
98	.000000	110,386.800000	35,849.500000
99	.000000	110,386.800000	19,611.610000
100	.000000	.000000	.000000
101	.000000	25,266.660000	11,816.380000
102	.000000	141,333.300000	47,744.560000
103	.000000	7,281.394000	21,035.400000
104	.000000	7,281.394000	6,168.300000
105	.000000	7,281.394000	32,914.800000
106	.000000	176,504.400000	36,094.000000
107	.000000	176,504.400000	26,971.930000
108	.000000	.000000	INFINITY
109	.000000	29,589.210000	11,816.320000
110	.000000	42,970.110000	51,337.630000
111	.000000	167,179.400000	17,191.500000
112	.000000	48,203.000000	4,558.500000
113	.000000	167,179.400000	27,102.400000

114	.000000	167,179.400000	35,360.500000
115	.000000	167,179.400000	32,476.050000
116	.000000	.000000	.000000
117	.000000	16,639.930000	11,816.100000

Model 2 Second Run

```
MAX...: 330 T11 + 330 T12 + 330 T13 + 330 T14 + 410 T21 + 410 T22
    + 410 T23 + 410 T24 + 400 T31 + 400 T32 + 400 T33 + 400 T34
    + 375 T41 + 375 T42 + 375 T43 + 375 T44 + 295 T51 + 295 T52
    + 295 T53 + 295 T54 + 275 T61 + 275 T62 + 275 T63 + 275 T64
    + 255 T71 + 255 T72 + 255 T73 + 255 T74 + 385 T81 + 385 T82
    + 385 T83 + 385 T84 - 120 SM11 - 120 SM21 - 120 SM31
    - 120 SM41 - 120 SM51 - 120 SM61 - 120 SM71 - 120 SM81
    - 120 SM12 - 120 SM22 - 120 SM32 - 120 SM42 - 120 SM52
    - 120 SM62 - 120 SM72 - 120 SM82 - 120 SM13 - 120 SM23
    - 120 SM33 - 120 SM43 - 120 SM53 - 120 SM63 - 120 SM73
    - 120 SM83 - 120 SM14 - 120 SM24 - 120 SM34 - 120 SM44
    - 120 SM54 - 120 SM64 - 120 SM74 - 120 SM84

 SUBJECT TO :
 ------------
  2)  -  T11 -  SM11 +  SM14 +  X11 =  0
  3)  -  T21 -  SM21 +  SM24 +  X21 =  0
  4)  -  T31 -  SM31 +  SM34 +  X31 =  0
  5)  -  T41 -  SM41 +  SM44 +  X41 =  0
  6)  -  T51 -  SM51 +  SM54 +  X51 =  0
  7)  -  T61 -  SM61 +  SM64 +  X61 =  0
  8)  -  T71 -  SM71 +  SM74 +  X71 =  0
  9)  -  T81 -  SM81 +  SM84 +  X81 =  0
 10)  -  T12 +  SM11 -  SM12 +  X12 =  0
 11)  -  T22 +  SM21 -  SM22 +  X22 =  0
 12)  -  T32 +  SM31 -  SM32 +  X32 =  0
 13)  -  T42 +  SM41 -  SM42 +  X42 =  0
 14)  -  T52 +  SM51 -  SM52 +  X52 =  0
 15)  -  T62 +  SM61 -  SM62 +  X62 =  0
 16)  -  T72 +  SM71 -  SM72 +  X72 =  0
 17)  -  T82 +  SM81 -  SM82 +  X82 =  0
 18)  -  T13 +  SM12 -  SM13 +  X13 =  0
 19)  -  T23 +  SM22 -  SM23 +  X23 =  0
 20)  -  T33 +  SM32 -  SM33 +  X33 =  0
 21)  -  T43 +  SM42 -  SM43 +  X43 =  0
 22)  -  T53 +  SM52 -  SM53 +  X53 =  0
 23)  -  T63 +  SM62 -  SM63 +  X63 =  0
 24)  -  T73 +  SM72 -  SM73 +  X73 =  0
 25)  -  T83 +  SM82 -  SM83 +  X83 =  0
 26)  -  T14 +  SM13 -  SM14 +  X14 =  0
 27)  -  T24 +  SM23 -  SM24 +  X24 =  0
 28)  -  T34 +  SM33 -  SM34 +  X34 =  0
 29)  -  T44 +  SM43 -  SM44 +  X44 =  0
 30)  -  T54 +  SM53 -  SM54 +  X54 =  0
 31)  -  T64 +  SM63 -  SM64 +  X64 =  0
 32)  -  T74 +  SM73 -  SM74 +  X74 =  0
 33)  -  T84 +  SM83 -  SM84 +  X84 =  0
 34)     1.05 X11 + 1.05 X21 + 1.05 X31 + 1.05 X41 + 1.05 X51
    + 1.05 X61 + 1.05 X71 + 1.05 X81 <=   2,000,000
 35)     1.05 X12 + 1.05 X22 + 1.05 X32 + 1.05 X42 + 1.05 X52
    + 1.05 X62 + 1.05 X72 + 1.05 X82 <=   2,000,000
 36)     1.05 X13 + 1.05 X23 + 1.05 X33 + 1.05 X43 + 1.05 X53
    + 1.05 X63 + 1.05 X73 + 1.05 X83 <=   2,000,000
 37)     1.05 X14 + 1.05 X24 + 1.05 X34 + 1.05 X44 + 1.05 X54
    + 1.05 X64 + 1.05 X74 + 1.05 X84 <=   2,000,000
```

```
38)      T11  <=   669,333
39)      T12  <=   518,411
40)      T13  <=   414,139
41)      T14  <=   511,590
42)      T21  <=   171,915
43)      T22  <=   268,715
44)      T23  <=   310,381
45)      T24  <=   210,354
46)      T31  <=    45,585
47)      T32  <=    71,765
48)      T33  <=    83,531
49)      T34  <=    61,683
50)      T41  <=   271,024
51)      T42  <=   423,106
52)      T43  <=   486,697
53)      T44  <=   329,148
54)      T51  <=   353,605
55)      T52  <=   356,050
56)      T53  <=   358,495
57)      T54  <=   360,940
58)      T61  <=   546,940
59)      T62  <=   548,710
60)      T63  <=   550,480
61)      T64  <=   552,250
62)      T81  <=   149,830
63)      T82  <=   154,630
64)      T83  <=   159,430
65)      T84  <=   164,240
66)   - 0.1 T12 +  SM11 >=   0
67)   - 0.1 T22 +  SM21 >=   0
68)   - 0.1 T32 +  SM31 >=   0
69)   - 0.1 T42 +  SM41 >=   0
70)   - 0.1 T52 +  SM51 >=   0
71)   - 0.1 T62 +  SM61 >=   0
72)   - 0.1 T72 +  SM71 >=   0
73)   - 0.1 T82 +  SM81 >=   0
74)   - 0.1 T13 +  SM12 >=   0
75)   - 0.1 T23 +  SM22 >=   0
76)   - 0.1 T33 +  SM32 >=   0
77)   - 0.1 T43 +  SM42 >=   0
78)   - 0.1 T53 +  SM52 >=   0
79)   - 0.1 T63 +  SM62 >=   0
80)   - 0.1 T73 +  SM72 >=   0
81)   - 0.1 T83 +  SM82 >=   0
82)   - 0.1 T14 +  SM13 >=   0
83)   - 0.1 T24 +  SM23 >=   0
84)   - 0.1 T34 +  SM33 >=   0
85)   - 0.1 T44 +  SM43 >=   0
86)   - 0.1 T54 +  SM53 >=   0
87)   - 0.1 T64 +  SM63 >=   0
88)   - 0.1 T74 +  SM73 >=   0
89)   - 0.1 T84 +  SM83 >=   0
90)   - 0.1 T11 +  SM14 >=   0
91)   - 0.1 T21 +  SM24 >=   0
92)   - 0.1 T31 +  SM34 >=   0
93)   - 0.1 T41 +  SM44 >=   0
94)   - 0.1 T51 +  SM54 >=   0
95)   - 0.1 T61 +  SM64 >=   0
96)   - 0.1 T71 +  SM74 >=   0
97)   - 0.1 T81 +  SM84 >=   0
```

```
 98)     0.0099 X81 <=    1,300
 99)     0.0099 X82 <=    1,300
100)     0.0099 X83 <=    1,300
101)     0.0099 X84 <=    1,300
102)     0.0023 X11 <=    1,300
103)     0.0017 X22 + 0.0017 X32 + 0.0017 X42 <=    1,300
104)     0.0017 X23 + 0.0017 X33 + 0.0017 X43 <=    1,300
105)     0.00095 X52 + 0.00095 X62 + 0.00095 X72 <=    1,300
106)     0.00095 X53 + 0.00095 X63 + 0.00095 X73 <=    1,300
107)     0.00095 X54 + 0.00095 X64 + 0.00095 X74 <=    1,300
108)      T61 >=    273,470
109)      T62 >=    274,355
110)      T63 >=    277,400
111)      T64 >=    276,125
112)      T51 >=    176,802
113)      T52 >=    178,025
114)      T53 >=    179,247
115)      T54 >=    180,470
116)      T71 >=    190,650
117)      T72 >=    192,000
118)      T73 >=    193,350
119)      T74 >=    194,700
END
```

LP OPTIMUM FOUND AT STEP : 149

OBJECTIVE FUNCTION VALUE

.246451300E+10

VARIABLE	VALUE	REDUCED COST
T11	587,310.100000	.000000
T12	366,382.500000	.000000
T13	340,572.000000	.000000
T14	511,590.000000	.000000
T21	171,915.000000	.000000
T22	268,715.000000	.000000
T23	310,381.000000	.000000
T24	210,354.000000	.000000
T31	45,585.000000	.000000
T32	71,765.000000	.000000
T33	83,531.000000	.000000
T34	61,683.000000	.000000
T41	271,024.000000	.000000
T42	421,888.000000	.000000
T43	389,120.000000	.000000
T44	329,148.000000	.000000
T51	233,728.000000	.000000
T52	178,025.000000	.000000
T53	179,247.000000	.000000
T54	189,824.000000	.000000
T61	273,470.000000	.000000
T62	274,355.000000	.000000
T63	277,400.000000	.000000
T64	276,125.000000	.000000
T71	190,650.000000	.000000

T72	192,000.000000	.000000
T73	193,350.000000	.000000
T74	194,700.000000	.000000
T81	131,313.100000	.000000
T82	131,313.100000	.000000
T83	131,313.000000	.000000
T84	131,313.000000	.000000
SM11	36,638.250000	.000000
SM21	26,871.500000	.000000
SM31	7,176.500000	.000000
SM41	42,240.000000	.000000
SM51	17,802.500000	.000000
SM61	27,435.500000	.000000
SM71	19,200.000000	.000000
SM81	13,131.310000	.000000
SM12	34,057.000000	.000000
SM22	31,038.100000	.000000
SM32	8,353.101000	.000000
SM42	38,912.000000	.000000
SM52	17,924.700000	.000000
SM62	27,740.000000	.000000
SM72	19,335.000000	.000000
SM82	13,131.250000	.000000
SM13	51,159.000000	.000000
SM23	21,035.400000	.000000
SM33	6,168.300000	.000000
SM43	32,914.800000	.000000
SM53	18,984.000000	.000000
SM63	27,612.500000	.000000
SM73	19,470.000000	.000000
SM83	13,131.000000	.000000
SM14	58,731.010000	.000000
SM24	17,191.500000	.000000
SM34	4,558.500000	.000000
SM44	27,102.400000	.000000
SM54	23,360.000000	.000000
SM64	27,347.000000	.000000
SM74	19,065.000000	.000000
SM84	13,131.310000	.000000
X11	565,217.400000	.000000
X21	181,595.000000	.000000
X31	48,203.000000	.000000
X41	286,208.000000	.000000
X51	228,096.000000	.000000
X61	273,558.500000	.000000
X71	190,785.000000	.000000
X81	131,313.100000	.000000
X12	363,801.300000	.000000
X22	272,881.600000	.000000
X32	72,941.600000	.000000
X42	418,882.700000	.000000
X52	178,147.200000	.000000
X62	274,659.500000	.000000
X72	192,135.000000	.000000
X82	131,313.100000	.000000
X13	357,676.000000	.000000
X23	300,378.300000	.000000
X33	81,346.200000	.000000
X43	382,981.300000	.000000

X53	180,308.000000	.000000
X63	277,272.500000	.000000
X73	193,485.000000	.000000
X83	131,313.100000	.000000
X14	519,162.000000	.000000
X24	206,510.100000	.000000
X34	60,073.200000	.000000
X44	323,335.600000	.000000
X54	194,213.400000	.000000
X64	275,859.500000	.000000
X74	194,295.000000	.000000
X84	131,313.100000	.000000

ROW	SLACK OR SURPLUS	DUAL PRICES
2)	.000000	-321.401400
3)	.000000	-283.432600
4)	.000000	-283.432600
5)	.000000	-283.432600
6)	.000000	-283.432600
7)	.000000	-283.432600
8)	.000000	-283.432600
9)	.000000	-373.000000
10)	.000000	-317.622100
11)	.000000	-371.840800
12)	.000000	-371.840800
13)	.000000	-371.840800
14)	.000000	-317.622100
15)	.000000	-317.622100
16)	.000000	-317.622100
17)	.000000	-373.000000
18)	.000000	-318.042000
19)	.000000	-362.017700
20)	.000000	-362.017700
21)	.000000	-362.017700
22)	.000000	-318.042000
23)	.000000	-318.042000
24)	.000000	-318.042000
25)	.000000	-373.000000
26)	.000000	-279.106400
27)	.000000	-279.106400
28)	.000000	-279.106400
29)	.000000	-279.106400
30)	.000000	-279.106400
31)	.000000	-279.106400
32)	.000000	-279.106400
33)	.000000	-373.000000
34)	.000000	269.935900
35)	.000000	302.497200
36)	.000000	302.897200
37)	.000000	265.815700
38)	82,022.880000	.000000
39)	15,028.500000	.000000
40)	73,568.000000	.000000
41)	.000000	35.000000
42)	.000000	115.000000
43)	.000000	35.000000
44)	.000000	34.999990

45)	.000000	110.602400
46)	.000000	105.000000
47)	.000000	25.000000
48)	.000000	24.999990
49)	.000000	100.602400
50)	.000000	80.000000
51)	.000000	.000000
52)	98,304.000000	.000000
53)	.000000	75.602430
54)	119,808.000000	.000000
55)	178,025.000000	.000000
56)	179,248.000000	.000000
57)	171,104.000000	.000000
58)	273,470.000000	.000000
59)	274,355.000000	.000000
60)	273,080.000000	.000000
61)	276,125.000000	.000000
62)	18,516.880000	.000000
63)	23,316.880000	.000000
64)	28,117.000000	.000000
65)	32,927.000000	.000000
66)	.000000	-123.779300
67)	.000000	-31.591800
68)	.000000	-31.591800
69)	.000000	-31.591800
70)	.000000	-85.810550
71)	.000000	-85.810550
72)	.000000	-85.810550
73)	.000000	-120.000000
74)	.000000	-119.580100
75)	.000000	-129.823100
76)	.000000	-129.823100
77)	.000000	-129.823100
78)	.000000	-119.580100
79)	.000000	-119.580100
80)	.000000	-119.580100
81)	.000000	-120.000000
82)	.000000	-158.935500
83)	.000000	-202.911300
84)	.000000	-202.911300
85)	.000000	-202.911300
86)	.000000	-158.935500
87)	.000000	-158.935500
88)	.000000	-158.935500
89)	.000000	-120.000000
90)	.000000	-85.986330
91)	.000000	-115.673800
92)	.000000	-115.673800
93)	.000000	-115.673800
94)	.000000	-115.673800
95)	.000000	-115.673800
96)	.000000	-115.673800
97)	.000000	-120.000000
98)	.000000	9047.209000
99)	.000000	5593.730000
100)	.000000	5551.313000
101)	.000000	9484.197000
102)	.000000	16508.140000
103)	.000000	31893.380000
104)	.000000	25868.060000

105)	687.305400	.000000
106)	681.488300	.000000
107)	668.850500	.000000
108)	.000000	-20.000000
109)	.000000	-51.203130
110)	.000000	-55.000000
111)	.000000	-20.000000
112)	56,832.000000	.000000
113)	.000000	-31.203130
114)	.000000	-35.000000
115)	9,344.000000	.000000
116)	.000000	-40.000000
117)	.000000	-71.203130
118)	.000000	-75.000000
119)	.000000	-40.000000

NO. ITERATIONS= 149

RANGES IN WHICH THE BASIS IS UNCHANGED

OBJ COEFFICIENT RANGES

VARIABLE	CURRENT COEF	ALLOWABLE INCREASE	ALLOWABLE DECREASE
T11	330.000000	77.269940	34.171860
T12	330.000000	48.796880	31.203130
T13	330.000000	39.578130	35.000000
T14	330.000000	INFINITY	35.000000
T21	410.000000	INFINITY	115.000000
T22	410.000000	INFINITY	35.000000
T23	410.000000	INFINITY	34.999990
T24	410.000000	INFINITY	110.602400
T31	400.000000	INFINITY	105.000000
T32	400.000000	INFINITY	25.000000
T33	400.000000	INFINITY	24.999990
T34	400.000000	INFINITY	100.602400
T41	375.000000	INFINITY	80.000000
T42	375.000000	25.000000	48.777800
T43	375.000000	24.999990	39.578130
T44	375.000000	INFINITY	75.602430
T51	295.000000	34.134490	20.000000
T52	295.000000	31.203130	INFINITY
T53	295.000000	35.000000	INFINITY
T54	295.000000	35.000000	20.000000
T61	275.000000	20.000000	INFINITY
T62	275.000000	51.203130	INFINITY
T63	275.000000	55.000000	INFINITY
T64	275.000000	20.000000	INFINITY
T71	255.000000	40.000000	INFINITY
T72	255.000000	71.203130	INFINITY
T73	255.000000	75.000000	INFINITY
T74	255.000000	40.000000	INFINITY
T81	385.000000	107.835700	80.598350
T82	385.000000	107.835700	49.832540
T83	385.000000	107.835700	49.454660

T84	385.000000	107.835600	84.491330
SM11	-120.000000	111.384400	312.031300
SM21	-120.000000	31.591800	350.000000
SM31	-120.000000	31.591800	250.000000
SM41	-120.000000	28.432620	487.587400
SM51	-120.000000	85.810550	INFINITY
SM61	-120.000000	85.810550	INFINITY
SM71	-120.000000	85.810550	INFINITY
SM81	-120.000000	107.983500	498.325400
SM12	-120.000000	107.605700	350.000000
SM22	-120.000000	129.823100	349.999900
SM32	-120.000000	129.823100	249.999900
SM42	-120.000000	116.840800	395.781300
SM52	-120.000000	119.580100	INFINITY
SM62	-120.000000	119.580100	INFINITY
SM72	-120.000000	119.580100	INFINITY
SM82	-120.000000	107.983500	494.546600
SM13	-120.000000	158.935500	350.000000
SM23	-120.000000	202.911300	1106.024000
SM33	-120.000000	202.911300	1006.024000
SM43	-120.000000	202.911300	756.024300
SM53	-120.000000	143.020200	200.000000
SM63	-120.000000	158.935500	INFINITY
SM73	-120.000000	158.935500	INFINITY
SM83	-120.000000	107.983500	844.913100
SM14	-120.000000	77.375920	341.718600
SM24	-120.000000	115.673800	1150.000000
SM34	-120.000000	115.673800	1050.000000
SM44	-120.000000	115.673800	800.000000
SM54	-120.000000	104.106500	200.000000
SM64	-120.000000	115.673800	INFINITY
SM74	-120.000000	115.673800	INFINITY
SM84	-120.000000	107.983500	805.983500
X11	.000000	INFINITY	37.968730
X21	.000000	31.591800	115.673800
X31	.000000	31.591800	115.673800
X41	.000000	28.432620	88.888890
X51	.000000	37.958170	22.222220
X61	.000000	22.222220	115.673800
X71	.000000	44.444450	115.673800
X81	.000000	INFINITY	89.567370
X12	.000000	54.218750	34.670140
X22	.000000	129.823100	31.591800
X32	.000000	129.823100	27.777780
X42	.000000	27.777780	54.218750
X52	.000000	34.670140	85.810550
X62	.000000	56.892360	85.810550
X72	.000000	79.114590	85.810550
X82	.000000	INFINITY	55.377930
X13	.000000	43.975700	38.888890
X23	.000000	202.911300	38.888880
X33	.000000	202.911300	27.777760
X43	.000000	27.777760	43.975700
X53	.000000	38.888890	119.398200
X63	.000000	61.111110	119.580100
X73	.000000	83.333340	119.580100
X83	.000000	INFINITY	54.958000
X14	.000000	77.375920	38.888890
X24	.000000	115.673800	122.891600
X34	.000000	115.673800	111.780500

X44	.000000	115.673800	84.002710
X54	.000000	38.888890	22.222220
X64	.000000	22.222220	158.935500
X74	.000000	44.444450	158.935500
X84	.000000	INFINITY	93.893550

RIGHTHAND SIDE RANGES
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ROW	CURRENT RHS	ALLOWABLE INCREASE	ALLOWABLE DECREASE
2	.000000	528,498.500000	73,809.330000
3	.000000	51,148.800000	75,674.860000
4	.000000	51,148.800000	48,203.000000
5	.000000	51,148.800000	75,674.860000
6	.000000	51,148.800000	75,674.860000
7	.000000	51,148.800000	75,674.860000
8	.000000	51,148.800000	75,674.860000
9	.000000	118,163.800000	16,662.650000
10	.000000	.000000	136,804.800000
11	.000000	379,699.200000	.000000
12	.000000	379,699.200000	.000000
13	.000000	379,699.200000	.000000
14	.000000	.000000	136,804.800000
15	.000000	.000000	136,804.800000
16	.000000	.000000	136,804.800000
17	.000000	118,163.800000	20,981.990000
18	.000000	306,466.300000	66,201.110000
19	.000000	.000000	88,473.590000
20	.000000	.000000	81,346.200000
21	.000000	.000000	88,473.590000
22	.000000	306,466.300000	66,201.110000
23	.000000	306,466.300000	66,201.110000
24	.000000	306,466.300000	66,201.110000
25	.000000	118,163.200000	25,301.440000
26	.000000	8,408.318000	153,970.100000
27	.000000	8,408.318000	153,970.100000
28	.000000	8,408.318000	60,073.200000
29	.000000	8,408.318000	153,970.100000
30	.000000	8,408.318000	153,970.100000
31	.000000	8,408.318000	153,970.100000
32	.000000	8,408.318000	153,970.100000
33	.000000	118,161.000000	29,629.790000
34	2000000.000000	79,458.610000	53,706.240000
35	2000000.000000	.000000	346,178.700000
36	2000000.000000	69,511.160000	321,789.600000
37	2000000.000000	.000000	8,828.732000
38	669333.000000	INFINITY	82,022.880000
39	518411.000000	INFINITY	152,028.500000
40	414139.000000	INFINITY	73,568.000000
41	511590.000000	9,344.000000	171,104.000000
42	171915.000000	56,832.000000	119,808.000000
43	268715.000000	421,888.000000	.000000
44	310381.000000	389,120.000000	98,304.000000
45	210354.000000	.000000	171,104.000000
46	45585.000000	56,832.000000	45,585.000000
47	71765.000000	421,888.000000	.000000
48	83531.000000	389,120.000000	83,531.000000
49	61683.000000	.000000	61,683.000000

50	271024.000000	56,832.000000	119,808.000000
51	423106.000000	INFINITY	.000000
52	486697.000000	INFINITY	98,304.000000
53	329148.000000	.000000	171,104.000000
54	353605.000000	INFINITY	119,808.000000
55	356050.000000	INFINITY	178,025.000000
56	358495.000000	INFINITY	179,248.000000
57	360940.000000	INFINITY	171,104.000000
58	546940.000000	INFINITY	273,470.000000
59	548710.000000	INFINITY	274,355.000000
60	550480.000000	INFINITY	273,080.000000
61	552250.000000	INFINITY	276,125.000000
62	149830.000000	INFINITY	18,516.880000
63	154630.000000	INFINITY	23,316.880000
64	159430.000000	INFINITY	28,117.000000
65	164240.000000	INFINITY	32,927.000000
66	.000000	136,617.300000	32,969.400000
67	.000000	.000000	26,871.500000
68	.000000	.000000	7,176.500000
69	.000000	.000000	38,016.000000
70	.000000	51,150.050000	17,802.500000
71	.000000	51,150.050000	27,435.500000
72	.000000	51,150.050000	19,200.000000
73	.000000	20,953.240000	11,816.380000
74	.000000	66,110.450000	30,646.630000
75	.000000	88,473.600000	.000000
76	.000000	81,346.200000	.000000
77	.000000	88,473.600000	.000000
78	.000000	66,110.450000	17,924.700000
79	.000000	66,110.450000	27,740.000000
80	.000000	66,110.450000	19,335.000000
81	.000000	25,266.790000	11,816.320000
82	.000000	153,759.300000	.000000
83	.000000	.000000	8,396.800000
84	.000000	.000000	6,168.300000
85	.000000	.000000	8,396.800000
86	.000000	153,759.300000	.000000
87	.000000	153,759.300000	.000000
88	.000000	153,759.300000	.000000
89	.000000	29,589.190000	11,816.100000
90	.000000	7,569.823000	52,849.860000
91	.000000	7,567.486000	17,191.500000
92	.000000	7,567.486000	4,558.500000
93	.000000	7,567.486000	27,102.400000
94	.000000	7,567.486000	21,024.000000
95	.000000	7,567.486000	27,347.000000
96	.000000	7,567.486000	19,065.000000
97	.000000	16,639.830000	11,816.380000
98	1300.000000	164.960200	749.181200
99	1300.000000	207.721700	1,169.822000
100	1300.000000	.000000	655.390900
101	1300.000000	83.242350	1,169.794000
102	1300.000000	117.664600	248.049700
103	1300.000000	.000000	232.603600
104	1300.000000	150.398200	.000000
105	1300.000000	INFINITY	687.305400
106	1300.000000	INFINITY	681.488300
107	1300.000000	INFINITY	668.850500
108	273470.000000	56,832.000000	119,808.000000

109	274355.000000	274,355.000000	152,028.500000
110	277400.000000	273,080.000000	73,568.000000
111	276125.000000	9,344.000000	171,104.000000
112	176802.000000	56,832.000000	INFINITY
113	178025.000000	178,025.000000	152,028.500000
114	179247.000000	179,248.000000	73,568.000000
115	180470.000000	9,344.000000	INFINITY
116	190650.000000	56,832.000000	119,808.000000
117	192000.000000	366,382.500000	152,028.500000
118	193350.000000	340,570.000000	73,568.000000
119	194700.000000	9,344.000000	171,104.000000

REFERENCES NOT CITED

Johnson, Lynwood A. Montgomery, Douglas C. Operations Research in Production Planning, Scheduling, and Inventory Control. New York : John Wiley & Sons, 1974.

Killier, Frederick S. Lieberman, Gerald. Operations Research. California : Holden-Day, Inc., 1974.

Meyer, Paul L. Introductory Probability and Statistical Applications. Massachusetts : Addison-Wesley Publishing Company, 1980.

Yamane, Taro. Statistics,An Introductory Analysis. Singapore : Harper & Row, Publishers, Inc., 1973.