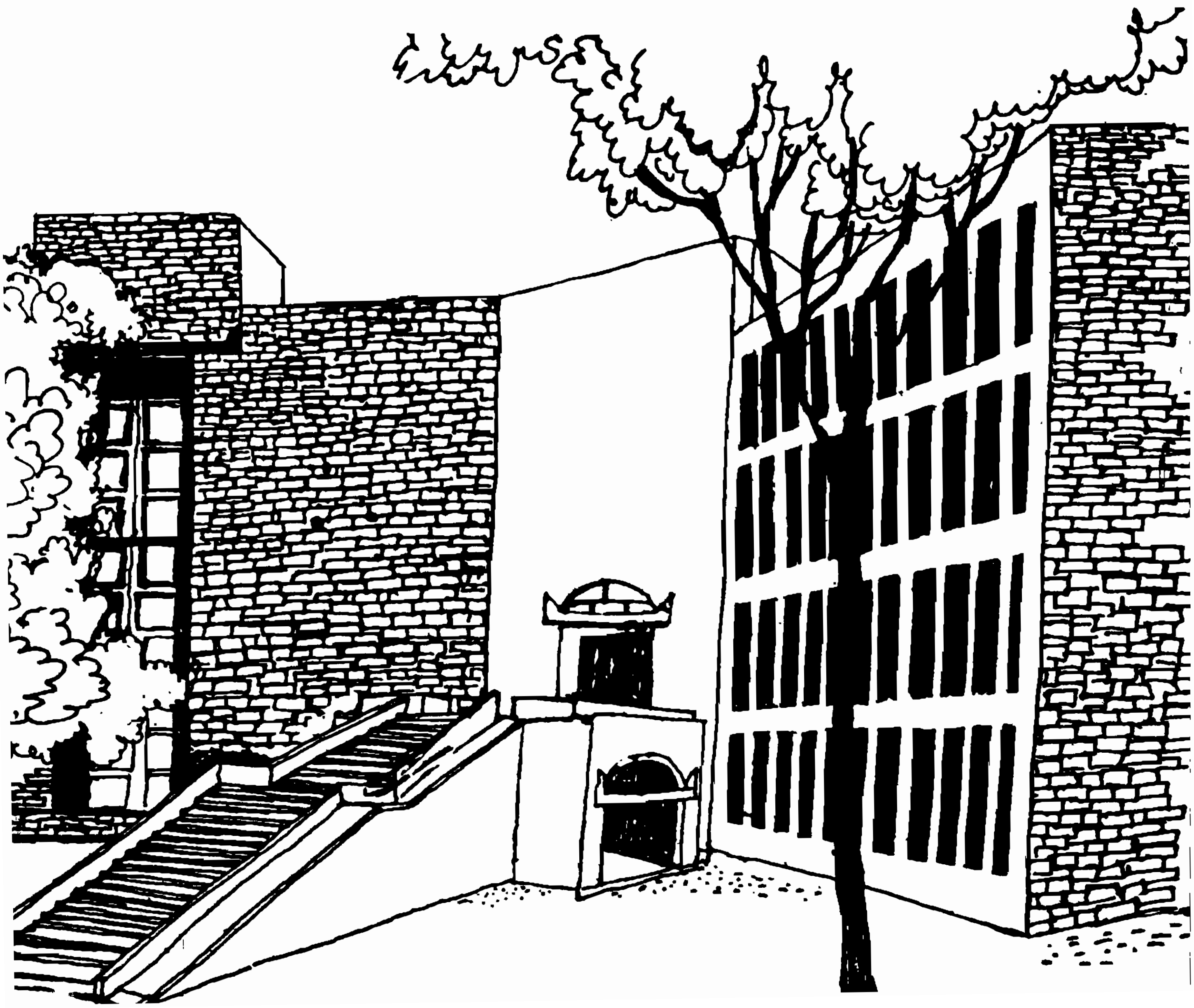
विद्याविनियोगाद्विकासः

IIM

AHMEDABAD

Working Paper



AN APPLICATION OF OPTIMIZATION BASED DECISION SUPPORT SYSTEM IN A POLYMER MANUFACTURING COMPANY IN INDIA

By

Goutam Dutta
Robert Fourer

W.P.No.99-09-03 /1542
September 1999

The main objective of the working paper series of the IIMA is to help faculty members to test out their research findings at the pre-publication stage.

INDIAN INSTITUTE OF MANAGEMENT
AHMEDABAD - 380 015
INDIA

An Application of Optimization Based Decision Support System in a Polymer Manufacturing Company in India

Goutam Dutta
Indian Institute of Management
Ahmedabad 380015
India

Robert Fourer
Department of Industrial Engineering and Management Science
Northwestern University, Evanston-IL 60208,USA

 We gratefully acknowledge the financial support given by the Indian Institute of Management, Ahmedabad.

Abstract

In this paper we describe the application of the multi-period optimization based DSS in a polymer manufacturing company in India. This is probably the first attempt to use a mathematical programming model for operating and strategic decision making in a polymer manufacturing company in India. The study demonstrates a (contribution to) profit improvement potential of 2.67 per cent and unit contribution improvement of 0.237 per cent.

1. Introduction

This work is an extension of multi-period optmization based decision support system (DSS) developed at Northwestern University (Fourer, 1997) in 1987-90. As AISI (American Iron and Steel Institute) supported the work in the late 80s and early 90s, this work was a generic DSS and could be customized in any steel plant in the world. Later, in 1991-96, a multi-period version was developed (Dutta, 1996) which demonstrated that profit per ton of steel could be increased by substantial amount.

We anticipated that the model could be applied to another process industry in a different country. In this paper we demonstrate the application of DSS in a polymer manufacturing company in India. In section 2, we discuss the features of this DSS. Section 3 describes an outline of the polymer manufacturing process. Section 4 demonstrates how we used DSS to model the production process. Section 5 outlines the results of the model. Section 6 discusses the extensions work.

2. Features of the DSS

We recall the salient features of the optimization based DSS (Dutta, 1996) that was developed in 1991-96:

1. The work is a generic DSS, which can be customized by any process industry in the world. The focus of the earlier work was integrated steel plants and the focus of this paper is a polymer manufacturing company. However, the DSS developed is transportable to other process industries.

2. The DSS is user-friendly. Managers with little or no background in mathematical programming can comfortably use this DSS.

3. It incorporates multi-period planning which shows the effect of changes of parameters in one time period on optimal decisions in other time periods.

4. It is applicable to both strategic and operational planning.

5. It has the flexibility to choose a product route through facilities as part of optimization.

6. It has the flexibility to add and delete materials, facilities and storage areas

7. It encompasses all areas of the company from raw materials procurement function to marketing function.

3. Manufacturing Process of a Polymer Company

The polymer manufacturing company is located in western India. The products manufactured by the company are medium density polyethylene (MDPE), silicon grafted polyethylene, low-density polyethylene and engineering plastics. The flow charts of the different products are shown in figures 1, 2, 3, 4 and 5. Figures 1 and 2 show the manufacturing process of 30% chalk-filled polypropylene and 60% chalk-filled polypropylene respectively. From Figures 1 and 2 we find that the production processes of both products are identical. The raw materials are filler chalk, filler talc, polypropylene and additives. The raw materials are mixed in various proportions in hoppers and sent to an extrusion machine. After extrusion it goes through a stand cutter and then to a packing unit before being sent to the market.

Manufacturing Process of a 30% Chalk Filled PP

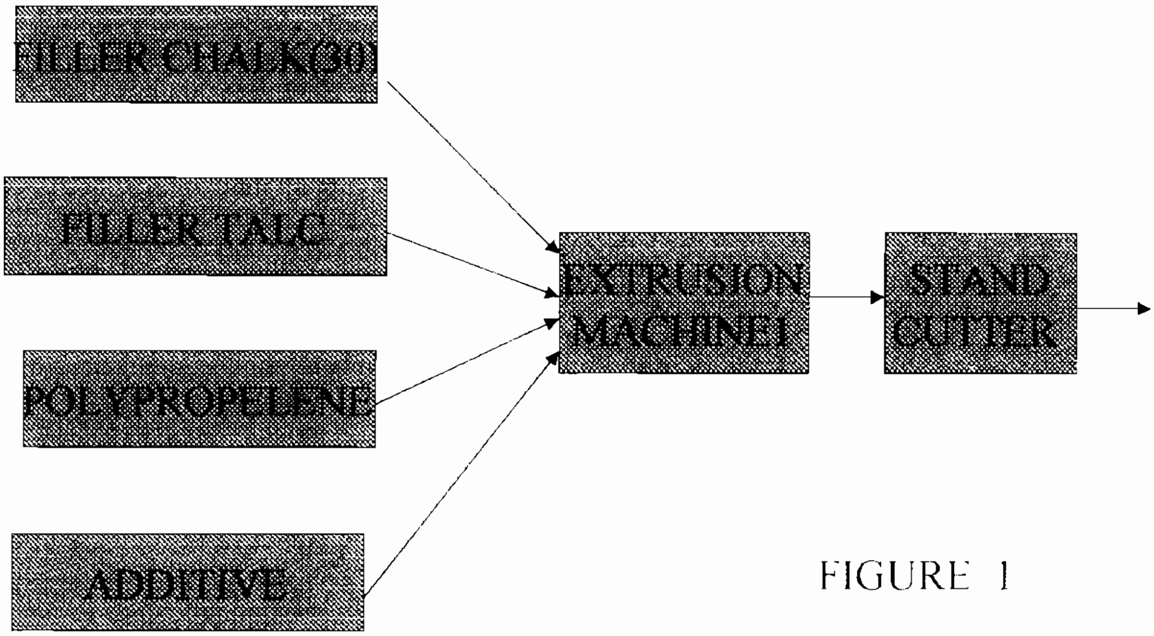


FIGURE 1

Manufacturing Process of a 60% Chalk Filled PP

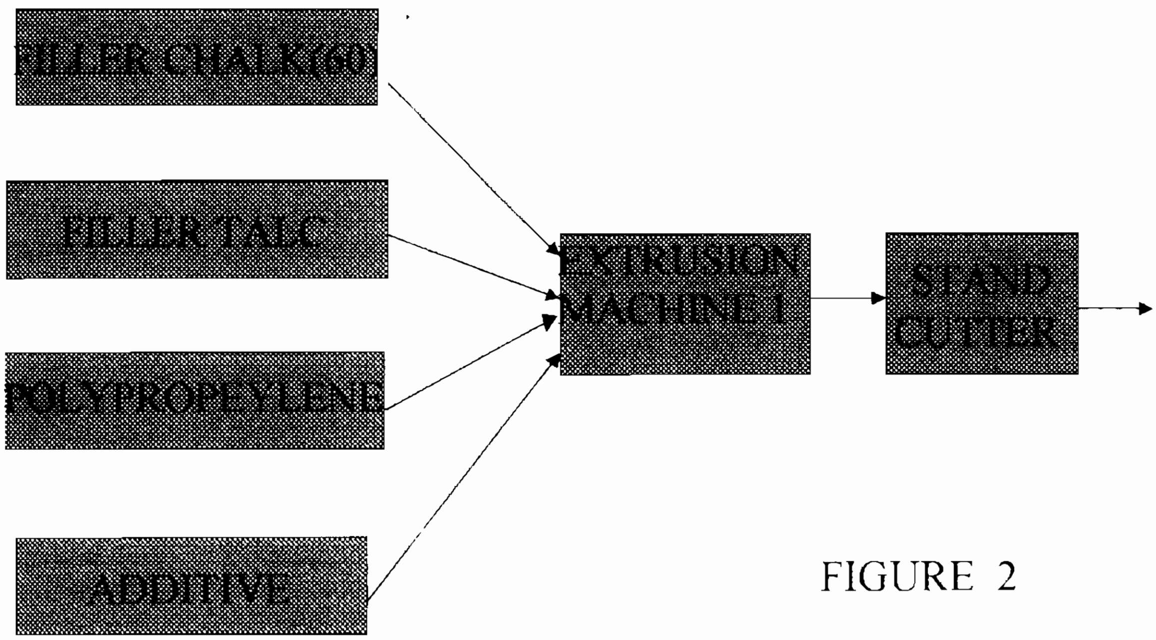


FIGURE 2

In Figure 3, we show the production process of LDPE (black). The raw materials (LDPE type 1, BMB, and HDPE) are mixed in various proportions in hoppers and sent to the same extrusion machine. After extrusion it goes through a stand cutter and then to a packing unit before being sent to the market.

Manufacturing Process of a LDPE(Black)

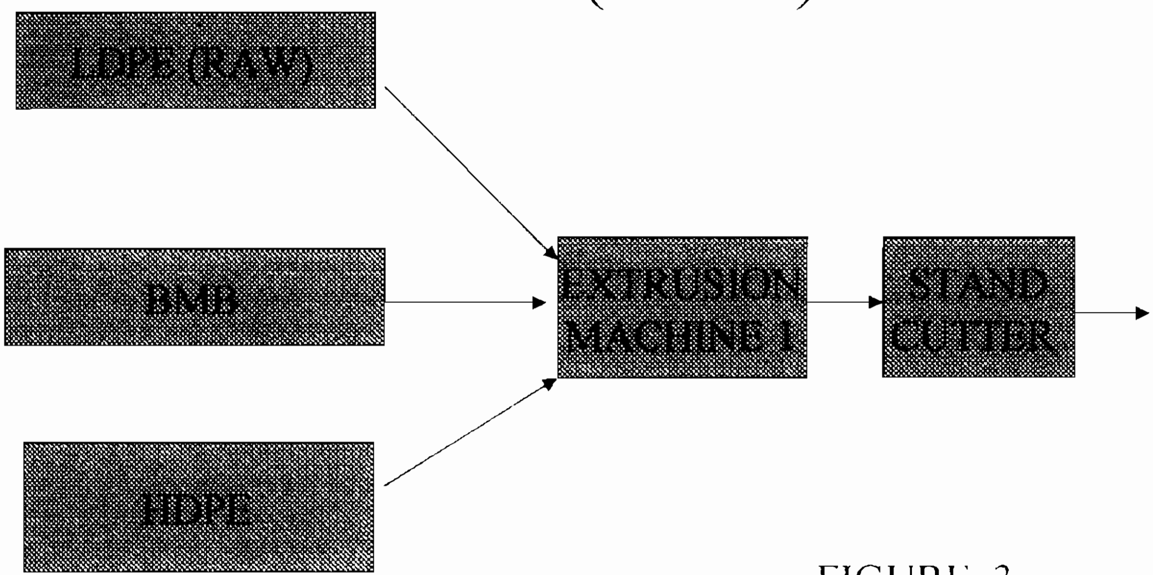


FIGURE 3

Figures 4 and 5 show the manufacturing processes of two types of XLPE. In Figure 4 we find that LDPE, anti-oxidants, vinylsilane, and dicumyl peroxide are mixed in different proportions in hopper and sent to another extrusion machine. Once the product is made, it goes through an under water palletizing machine. Silicon grafting is done on the finished product (XLPE-A) and is packed and sent to market

Manufacturing Process of XLPE-A

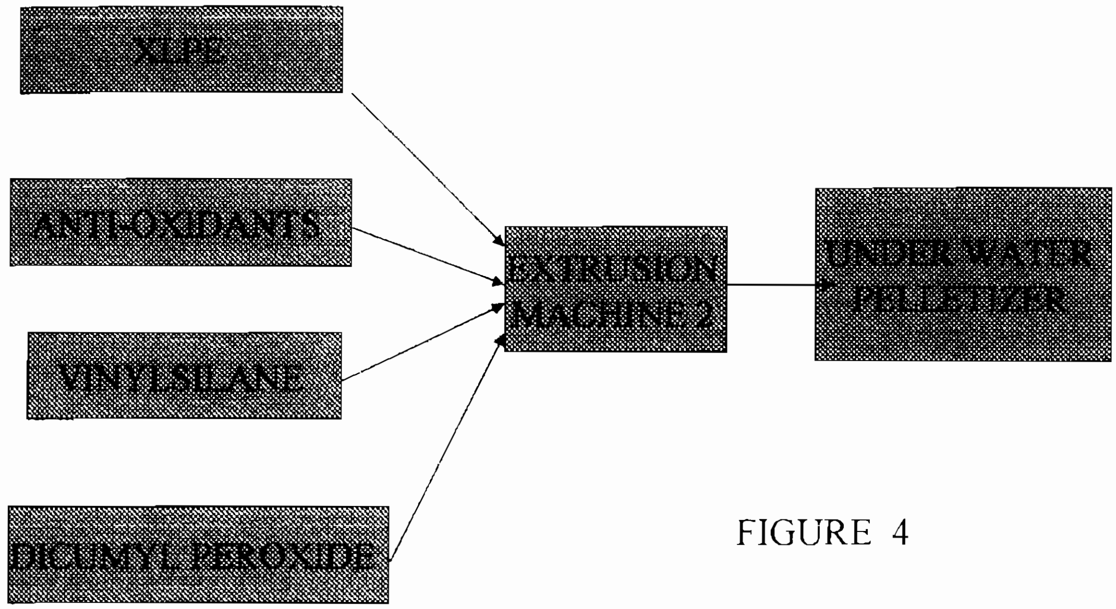


FIGURE 4

In Figure 5, LDPE and DBTDL are mixed in different proportions and hoppers and sent to the same extrusion machine. The product then goes through the underwater palletizing machine and the finished product (XLPE-B) is dispatched after packing.

Manufacturing Process of XLPE-B

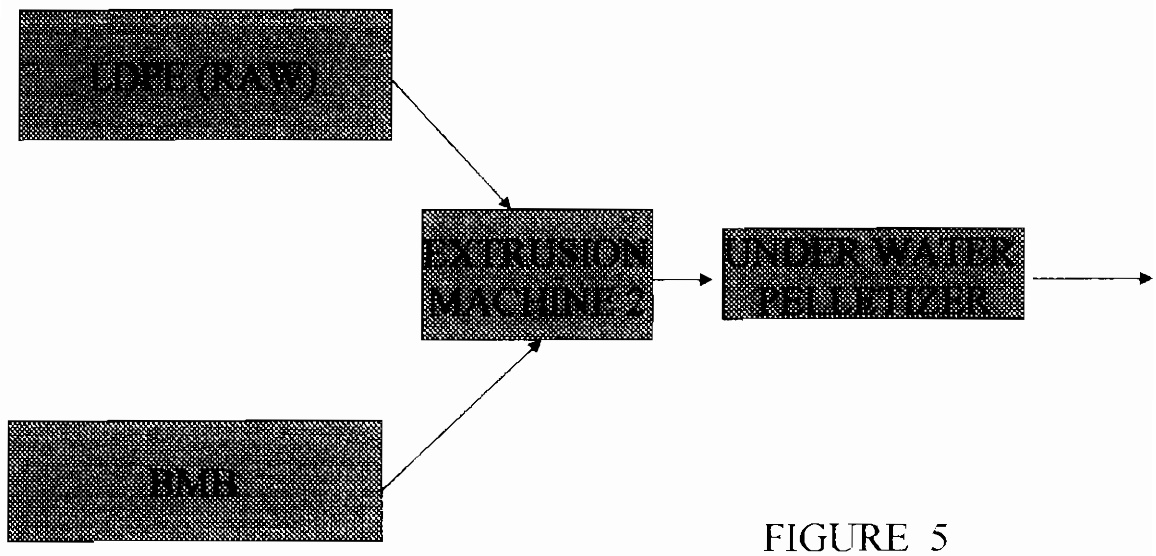


FIGURE 5

We find that a polymer company like an integrated steel plant, has the following characteristics, which are found in any other process industries

1. There are several facilities that are in series, parallel, or combinations of the two
2. In each facility, there is one or more than one activity.
3. There can be purchase, sale, and storage of materials at the raw materials stage, at the finishing end or in the intermediate processing stage.
4. The purchase price of raw materials, selling price of finished goods, and inventory carrying cost varies over time.

5. At any time, one or more materials are used as input and output in a facility. Generally more than one material is used to produce one product. The relative proportion of various inputs and outputs (generally called technological coefficients) in an activity remains the same in a project. Technological coefficients vary with time.
6. The capacity of each facility and each storage area is finite.

7. Since the facilities will have different patterns of preventive maintenance schedules, the capacity of machines will vary over time period.

8. Essential features of the production-planning problem can be captured in a deterministic, linear optimization model.

4. Optimization

The details the optimization model have been described by Dutta (1996). The formulation of the model and implementation are beyond the scope of this working paper and interested readers are encouraged to refer to the above publication.

The model consists of five fundamental elements: times, materials, facilities, activities, and storage-areas.

Times: These are the periods of the planning horizon, represented by discrete numbers (1, 2, 3..).

Materials: Any product in the steel company in any stage of production (input, intermediate, and output) is considered to be a material.

Facilities: A facility is a collection of machines that produces some materials from others. For example, an extrusion machine is a facility.

Activities: At any time, each facility houses one or more activities, which use and produce material in certain proportions. In each activity at each time, we have one or more input materials being transformed to various output materials. Productions of low-density polyethylene, and 30% chalk-filled polypropylene are examples of activities.

Storage-Areas: These are warehouses where raw materials, intermediate products and finished products are stored.

The objective function of this model is to maximize revenue from sales, less the cost of purchasing, converting, running activities, vendoring and holding inventories of all periods of time. The constraints are:

1. Material Balance
2. Facility Inputs
3. Facility Outputs
4. Facility Capacity
5. Storage Capacity
6. Storage Total

In addition to these above constraints, every variable like buying or selling material has its own upper and lower bounds.

The steps of optimization are described in Figure 6.

OPTIMIZATION STEPS

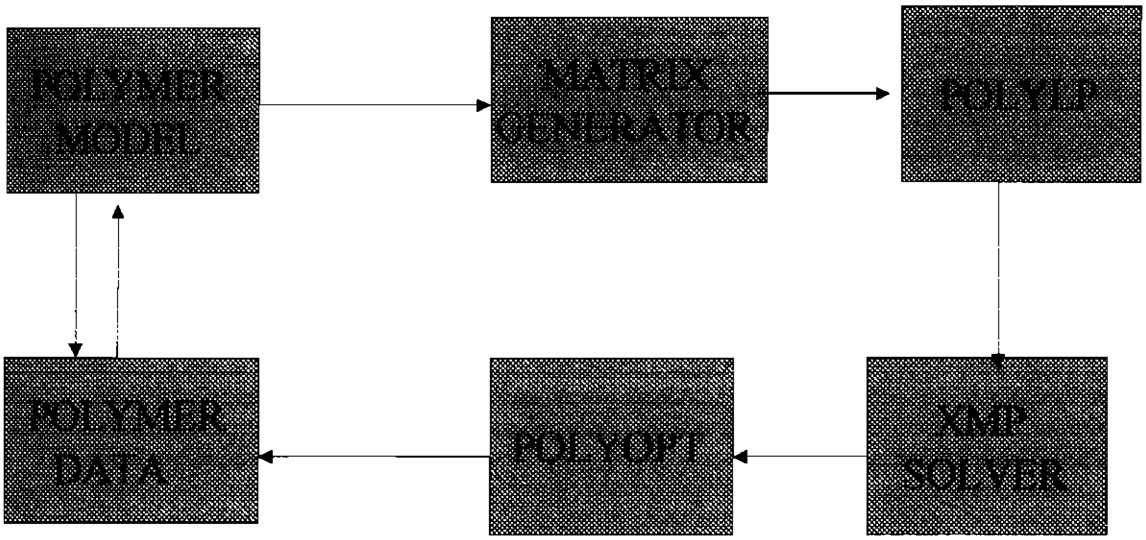


FIGURE 6

This company has been modeled with 18 materials, 2 facilities, 5 activities, and one time period. Since this is a single period model and the company was not interested in multi-period features, storage-areas were not taken care of. This translates in to 39 constraints and 62 variables. The model runs on a Power Macintosh 7100 and it takes about 3 seconds to solve this linear program.

While modeling this company, we list some of the similarities and differences with our experience in the American steel company.

1. Yields of various products in the American steel company varied between 81% and 100%. In this company the yield figure varied from 98% and 99.5%.
2. The ratio of maximum and minimum selling price was 5.7 in the American steel company while, in this case, it was 2.54.
3. The similar ratio of other raw materials was 64.2857. In case of American steel company, it was 126.87

4. The reliability of was poor in the American steel company. In this case, this was not the case.
5. While working with the American Steel Company, we went through the process of data filtering. As a result, the mathematical model shows inconsistencies. In the polymer company, inter-action was not for a very long time and did not generate any such interesting event.
6. Multiple processing of the same facility as well as re-treatment were considered in the American steel company. However, this was not the case in the polymer company.
7. In the American steel company yield of each facility was available. However, in this polymer company yield of a series of facilities was available. For example, any product coming out of the extrusion process went through underwater palletizing. We know the yield of extrusion and underwater palletizing taken together but not of each facility separately. Hence, we decided to consider extrusion and palletizing machine as one single facility.
8. We retained the same activity definition like the American steel company. (one ton of finished product is considered one unit of activity).

5. Results

We received the marketing bounds of the different products of the company and incorporated those values in the model.

To check that the model represents reality, we have identified contact points. These points are the functions of the variables in the model and measurable quantities in reality at the same time. We consider the following figures and their respective units:

1. Total production of marketable polymer
2. Total revenue in rupees
3. Total cost of purchases
4. Total cost of activities

5. Net profit
6. Product mix

We consider the actual production capacity of the company for 1998-99 and compare this with the optimal results given by the model. We consider two different cases:

Case 1: With company's upper and lower bounds of the market
Case 2: With company's upper bounds removed

The impact of optimization is listed in Tables 1 and 2. When all the bounds are removed, net revenue of the company decreases by 12.8 per cent, cost of raw material decreases by 22.01 per cent and cost of activity also decreases by 7.48 per cent. However, net profit of the company increases by 13.6 per cent. During this time, total production of polymer also decreases from 9179.17 to 8670.92 tons. This analysis shows that, with increasing use of optimization-based DSS and unlimited demand for all products, it is possible to produce fewer polymers and make more profit.

We now compare the impact of optimization on per unit basis. This is shown in Table 2. We find that (average) revenue per ton decreases 7.79 per cent. Cost of raw materials per ton decreases by 17.45 per cent and activity cost per ton decreases by 2.06 per cent. However net profit per ton of polymer produced increases by 20.26 per cent. This analysis demonstrates the following:

1. It is possible to produce less tonnage of polymer and make more profit by suitably changing product-mix.
2. Revenue maximization is not synonymous with profit maximization. It is possible to make a judicious selection of the product-mix and make more profit even at the cost of decreasing revenue as we have found in case 2 of Table 2.

The above table shows the result when market bounds are completely removed. This may be an ideal situation where all products are assumed to have infinite marketability.

Table 1
Impact of Optimization

Contact Points		Case 1	Case 2	% Change
Revenue from Sales	Rupees	462,702,771.92	403022836.4	-12.8981
Cost of Raw Material	Rupees	330,138,795.06	257467070.2	-22.0125
Activity Cost	Rupees	25,366,738.63	23467070.2	-7.48882
Net Profit	Rupees	107,197,238.22	121782221.6	13.60575
Dual Price Macine-1	Rs/Hour	5,782.77	6837.69	
Dual Price Macine-2	Rs/Hour	6,069.81	9,312.09	
Product 1	Tons	2400	0	
Product 2	Tons	2400	5441.7	
Product 3	Tons	1150.17	0	
Product 4	Tons	1429	0	
Product 5	Tons	1800	3229.22	
Total		9179.17	8670.92	

Table 2
Impact of Optimization

Performance Indicators		Case 1	Case 2	% Change
Revenue/ton	Rupees	50,407.91	46,479.82	-7.7926
Cost/ton	Rupees	35,966.08	29,693.17	-17.4412
Activity Cost/ton	Rupees	2,763.51	2,706.41	-2.06623
Net Profit/ton	Rupees	11,678.31	14,044.90	20.2648

Table 3
Impact of Optimization

Contact Points		Case 1	Case 2	Case3	Case 4	% Change
Revenue from Sales	Rupees	462702771.92	461428541.98	460090601.19	458685774.99	-0.868159253
Cost of Raw Material	Rupees	330138795.06	327963268.63	325679003.05	323280556.44	-2.0773804
Activity Cost	Rupees	25366738.63	25357969.00	25348761.85	25339093.82	-0.108980545
Net Profit	Rupees	107197238.22	108107285.00	109062836.28	110066124.72	2.676269042
Dual Price Macine-1	Rs/Hour	5782.77	5782.27	5782.27		
Dual Price Macine-2	Rs/Hour	6069.81	6069.81	6069.81		
Product 1	Tons	2400	2520	2646	2778.3	
Product 2	Tons	2400	2520	2646	2778.3	
Product 3	Tons	1150.17	980.94	803.5528	616.67	
Product 4	Tons	1429	1339.2282	1244.72	1145.50895	
Product 5	Tons	1800	1890	1984.5	2083.725	
Total		9179.17	9250.1682	9324.7728	9402.50395	

Table 4
Impact of Optimization

Performance Indicators		Case 1	Case 2	Case 3	Case 4	Change %
Revenue/ton	Rupees	50,407.91	49,883.26	49,340.68	48,783.36	-3.222798579
Cost/ton	Rupees	35,966.08	35,454.84	34,926.21	34,382.39	-4.403297575
Activity Cost/ton	Rupees	2,763.51	2,741.35	2,718.43	2,694.93	-2.481652342
Net Profit/ton	Rupees	11,678.31	11,687.06	11,696.03	11,706.04	0.237440315

In reality, this may not be the case. We now analyze four cases where maximum market bounds are increased by 5 per cent in each step and effect of this increase in profitability and unit profitability:

Case 1: With the company's upper and lower bounds

Case2: With the company's upper bounds (market limit 5% increased over case 1)

Case3: With the company's upper bounds (market limit 5% increased over case 2)

Case4: With the company's upper bounds (market limit 5% increased over case 3).

Table 3 and 4 show the results. The Table 3 shows that revenue of the company decreases by 0.86 per cent, cost of material decreased by 2.07 per cent, and cost of all activities decreases by 0.108 per cent. However, the net profit increases by 2.67 per cent.

While comparing the per unit figures in Table 4, we find that revenue per ton decreases by 3.2 per cent, cost per ton decreases by 4.40 per cent, and cost of activity per ton decreases by 2.48 per cent. However net profit per ton increases by 0.237 per cent. This again demonstrates the fact that revenue maximization is not synonymous with profit maximization.

7. Extensions of the DSS

Data for this work are gross generalizations and represent only 18 materials, two facilities, and five activities in one time period. We need to segment the products with respect to market and other characteristics like the demand, market share, revenue, cost, and variation of demand. We also need to consider more than one period to study the effect of inventories and changes in prices.

We find that profitability of the company can be improved significantly by optimization based decision support system. With better data, the DSS can be improved and would prove to be more useful to the company.

Acknowledgement

We acknowledge the help given by Richa Seth, Academic Associate, IIMA in data collection and data entry.

7. References

Dutta, G. (1996), "A Multi-Period Optimization-Based Decision Support System for Strategic and Operational Planning," Ph.D. dissertation, Department of Industrial Engineering and Management Sciences, Northwestern University, USA.

Fourer, R. (1997), "Database Structure for Mathematical Programming Models," Decision Support Systems, Vol. 20, pp. 317-343.