Maximisation of Profit Contribution in Private and Joint Sector Paper mills in A.P.

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ABSTRACT

The Paper industry is vital for social, cultural, economic and educational development of a country. As such, it needs to survive and compete with global giants in the world. Therefore, it has to produce standard products at minimum cost. Against this background and for maximisation of contribution, two paper mills i.e. private and joint sectors are brought into the sample. The optimal product mix for private sector paper mill is writing and printing paper and coated board while writing and printing, colour printing / process paper and newsprint for joint sector paper mill. The duality analysis shows that one hour of working in pulp mill and paper making departments increase profit contribution by Rs. 95,149 in the private sector paper mill whereas Rs. 82,621 in paper making department of joint sector paper mill.

The sensitivity analysis reveals that within the range, a change either positive or negative in profit contribution per unit of optimal product mix would not cause for change in the optimal solution. The sensitivity analysis shows that the optimal product mix for writing and printing paper is in the range of $43,400 \leq C_{p1} \leq 50,100$ *and 26,946 34,848 for coated board. Similarly in the joint sector paper mill, writing and printing paper in the range of 41,167 1,13,583; colour printing / process paper 38,917 41,750 and news print 15,418 35,064. Finally, the private sector paper mill should produce 2,378 tonnes of writing and printing paper and 37,449 tonnes coated board to earn maximum profit. Like wise, 4,592 tonnes of writing and printing paper, 2,796 tonnes of colour printing/process paper and 4,714 tonnes of newsprint for joint sector paper mill.*

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Introduction

Paper industry is one of the key industries of India. This industry is vital for social, cultural, educational and economic departments of a country. The process of manufacture is carried out in a sequence of operations. Different varieties of paper are manufactured. It was accorded "core" sector status since paper is categorical as an essential commodity. There are many studies concerning paper industries at the macro level. A few studies are organised at the micro/firm level covering size and scale growth, structure, functional areas etc. The studies on optimal product mix in paper making is almost absent. There is no specific study on the maximisation of profit contribution either at the all India level or firm level as far as the knowledge and understanding of the researchers is concerned. Therefore, a modest attempt is made in that direction at the plant level.

The performance of an enterprise in a competitive market would depend on the quality of decision making. The quality of decisions depends upon the quality of data and information provided to decision makers. Operation research is one of the tools used for maximising profitability with wise decisions. In manufacturing organisations, input resources and production capacities are limited. These limited input resources and facilities should be utilised in a most economical way to produce the desired output at a lesser cost. Therefore, one of the many important decisions that have to be made periodically in a manufacturing concern is that of selecting manufacturing plan to make the best use of existing facilities and which will also help to maximise profits for the enterprise.

The product mix in the paper industry is plagued by a plethora of problems such as shortage of raw materials, high production cost, modernisation, utilisation of machines etc. In fact, several paper mills were closed in the country due to heavy losses during the last few decades. One of the causes for closure is low productivity. This is on account of non-adoption of optimal product mix, apart from several other causative factors. The mills can earn better profits by adopting optimal product mix. An earnest attempt is made in this paper to determine the best product mix for a month's production in the select mills. In other words, an attempt is made to decide which products are to be manufactured out of a list of potential products.

The main objective of the study is to analyse maximisation of profit contribution. The specific objectives are: to determine capacity utilisation in private and joint sector of papers mill in A.P; to determine optimal product mix for maximising profit contribution; to arrive at an optimal solution for mininising machine hour cost; and to investigate whether there can be any change in product mix if the amount of available resources are changed. Of the paper mills in A.P, one paper mill from each

of private and joint sectors is purposely drawn into the sample. The sample is limited to two mills due to time, resources and other constraints.

To achieve the objectives, a work sampling analysis is carried out in order to find out effective machine capacities available in each department. A linear programming technique is employed. An optimum product mix is accomplished by constructing a linear objective function and linear constraints representing the decision variables along with the profit contribution and processing time respectively and also the amount of scarce resources available. After solving the original problem, its dual was formulated so as to find out machine hour cost. It is felt necessary to carry out post optimality analysis. The primary data is collected from the sample paper mills by administering a questionnaire specially designed for the purpose by personal interview method.

Private sector paper mill

The private sector paper mill produces different varieties of paper. Each type of paper is produced in large size. This mill has four departments such as pulp mill, stock preparation, paper making and finishing house (see Table 1). If all the departments put together, there are 62 machines. The number of production units stood at 374. The total units are 428. The wood has to go through all the four departments to become finished paper. All the varieties of paper as a whole consume more processing time in the finishing house (1.077 hours) followed by paper making (1.001 hours), stock preparation (0.518 hours) and pulp mill (0.48 hours) (see Table 2). Of the papers manufactured, Machine Glaze (MG) poster requires the highest time (0.71 hours) followed by photo copy (0.625 hours), writing and printing (0.505 hours), kraft (0.45 hours), uncoated board (0.418 hours) and coated board (0.368 hours).

The mill works on shift basis. There are three shifts in a day. Each shift consists of eight hours. The total number of available hours is the highest in finishing house (6,796.8) followed by paper making (4141.8), stock preparation (3,964.8) and pulp mill (3,186) (see Table 3). Among the different varieties of paper produced by the mill, profit contribution per tonne of paper is the highest in each of photocopy and MG poster (Rs.50,000) followed by writing and printing (Rs.45,000), coating board (Rs. 30,000), uncoated board (Rs.25,000) and kraft (Rs.20,000). It may be concluded that photo copy and MG poster contribute more profit as compared to remaining categories of paper.

Joint sector paper mill

The joint sector paper mill produces five varieties of paper such as writing and printing, colour/ printing process, MG poster, newsprint and kraft. Each product is processed in four departments as was discussed in the private sector paper mill. There are four departments in the joint sector paper mill (see Table 5). They are pulp mill (chipper, digester, washing and bleaching), stock

preparation (chest and refining), paper making (wire part, press part, drying, machine coating, calendaring, rope reeling) and finishing house (rewinding, sheeting and roll packing). The process of manufacture is similar to that of private sector paper mill. There are 9 machines in pulp mill, 12 in stock preparation, 48 in paper making and 16 in finishing house. When all the departments are put together, total units work out to 688. It may be concluded that the number of machines, production units and total units are relatively less in pulp mill. Out of the papers produced, writing and printing requires 2.71 hours when all the departments are put together(see Table 6). Like this, MG poster needs 2.23 hours, news print 1.270 hours, colour/printing process 1.860 hours and kraft 1.150 hours. Of all the departments, for production of one tonne of paper requires the highest processing time in finishing department (3.62 hours) followed by stock preparation (2.24 hours), paper making (2.21 hours) and pulp mill (1.15 hours).

Like private sector paper mill, there is a shift system with eight hours duration (see Table 7). Among the departments, total time available is the highest in finishing house (8,595 hours) followed by stock preparation (6,936 hours), paper- making (5,332 hours) and pulp (4,896 hours). It shows the significance of finishing house. The profit contribution per tonne of paper is the highest in writing and printing (Rs. 41,750) while the lowest is kraft (Rs. 15,000) (see Table 8). It is. Rs.39,000 in colour/printing processing paper and Rs. 37,900 in MG poster and Rs.35,000 in newsprint. It may be summed up that there is a significant variation in profit contribution per tonne among different categories of paper. The primary cause may be selling price and marginal cost.

It can be observed that, of the products manufactured, both the private and joint sector paper mills produce writing and printing, MG poster and Kraft papers only. It may be noted that profit contribution per tonne of writing and printing paper is the highest at Rs. 45,000 in the private sector while the lowest at Rs. 41,750 in the joint sector(see Table 9). A similar trend emerges with regard to MG Poster and Kraft papers. As expected, profit contribution per tonne of paper is the highest in private sector relative to joint sector. This is due to the initiative and personal involvement of private enterprise as compared to joint sector.

Formulation and solution of problem

The first phase of the study requires the problem to be formulated in an appropriate form. The second phase of investigation is concerned with the choice of proper data inputs and the design of appropriate information output. The formulation and solution of primal problem, sensitivity analysis and formulation and solution of dual problem for paper mills are described below.

4.1 Private sector paper mill

4.1.1 Formulation and solution of primal problem

The decision variables in the sample paper mill are:

X_1 = Quantity of writing & printing paper to be processed in one month.

X_2 = Quantity of photo copy paper to be processed in one month.

X_3 = Quantity of uncoated board to be processed in one month.

X_4= Quantity of coated board to be processed in one month.

X_5= Quantity of machine glaze posters to be processed in month.

X_6 = Quantity of kraft paper to be processed in one month.

The objective function is maximisation of profit contribution.

Maximise Z = 45,000 X_1+ 50,000 X_2+ 25,000 X_3 + 30,000 X_4 + 50,000 X_5 + 20,000 X_6.

Subject to

$0.080X_1 + 0.080X_2 + 0.080X_3 + 0.080X_4 + 0.080X_5 + 0.080X_6 \leq 3,186.00$

$0.087X_1 + 0.089X_2 + 0.085X_3 + 0.085X_4 + 0.090X_5 + 0.082X_6 \leq 3,964.80$

$0.167X_1 + 0.200X_2 + 0.125X_3 + 0.100X_4 + 0.267X_5 + 0.142X_6 \leq 4,141.80$

$0.171X_1 + 0.256X_2 + 0.128X_3 + 0.103X_4 + 0.273X_5 + 0.146X_6 \leq 6,796.80$

and

X_1, X_2, X_3, X_4, X_5 and $X_6 \geq 0$

The constraints are in the form of inequalities. Slack variables are introduced to transform inequalities into equalities. The LPP is formulated for the information. The coefficients of equalities constraints and objective function are furnished and the simplex methodology is followed to obtain solution to the LPP. The solution for LPP is worked out by iterative process .Iteration four is optimal (see Table 10).

The optimal solution is

Writing and Printing paper = 2,377.61 tonnes

Coated board = 37,449.39 tonnes

To maximise profit contribution, within the allowed range of volume of each product, product mix recommended are Writing & Printing paper (2,377.61 tonnes) and Coated board (37,449.39 tonnes). Evidently, the optimal solution does not

require the production of uncoated board, photo copy, machine glaze and kraft papers. If these products are produced, profit contribution gets reduced.

4.1.2 Sensitivity analysis

If there is any change in the profit contribution of recommended products, sensitivity analysis is employed to evaluate the range of profit contribution. The profit range for product C_{p1} represented by writing and printing and C_{p4} denoted by product of coated board. The results are given in Table 11.

It may be summed up that in the following ranges of production objective function remains constant.

$43,400 \leq C_{p1}$ 50,100 for product of X_1 i.e., writing & printing paper

$26,946.19 \leq C_{p4} \leq 34,848.49$ for product of X_4 i.e., coated board

4.1.3 Formulation and solution of dual problem

The objective function of LPP is the minimisation of machine hour cost.

Minimise $Z = 3,186.00Y_1 + 3,964.80Y_2 + 4,141.80Y_3 + 6,796.80Y_4$

Subject to

$0.080Y_1 + 0.087Y_2 + 0.167Y_3 + 0.171Y_4 \geq 45,000$

$0.080Y_1 + 0.089Y_2 + 0.200Y_3 + 0.256Y_4 \geq 50,000$

$0.080Y_1 + 0.085Y_2 + 0.125Y_3 + 0.128Y_4 \geq 25,000$

$0.080Y_1 + 0.085Y_2 + 0.100Y_3 + 0.103Y_4 \geq 30,000$

$0.080Y_1 + 0.090Y_2 + 0.267Y_3 + 0.273Y_4 \geq 50,000$

$0.080Y_1 + 0.082Y_2 + 0.142Y_3 + 0.146Y_4 \geq 20,000$

Where

Y_1 = Machine hour cost in pulp mill department

Y_2 = Machine hour cost in stock preparation department

Y_3 = Machine hour cost in paper making department

Y_4 = Machine hour cost in finishing house department

The inequalities are converted into equalities with the help of surplus variables. Afterwards, constraints are changed into equations. The dual problem is solved through dual simplex method. The duality analysis has assigned machine hour cost to departments.

These are :

Y_1 = Pulp mill department = Rs. 95,149.25

Y_3 = Paper making department = Rs.2,23,880.60

Machine hour cost is the highest in paper making department whereas it is lowest in plup mill department.

4.2 Joint sector paper mill

4.2.1 Formulation and solution of primal problem

The decision variables in the joint sector paper mill include

X_1 = Quantity of writing & printing paper to be produced in one month.

X_2 = Quantity of colour printing / process paper to be produced in one month.

X_3 = Quantity of machine glaze(MG) poster paper to be produced in one month.

X_4 = Quantity of news print paper to be produced in one month.

X_5 = Quantity of kraft paper to be produced in one month.

The objective function is maximisation of profit contribution.

Maximise $Z = 41{,}750X_1 + 39{,}000X_{12} + 37{,}900X_3 + 35{,}000X_4 + 15{,}000X_5$

Subject to

$0.270X_1 + 0.210X_2 + 0.270X_3 + 0.200X_4 + 0.200X_5 \leq 4{,}896.00$

$1.040X_1 + 0.250X_2 + 0.450X_3 + 0.310X_4 + 0.190X_5 \leq 6{,}936.00$

$0.460X_1 + 0.460X_2 + 0.470X_3 + 0.410X_4 + 0.410X_5 \leq 5{,}331.60$

$0.940X_1 + 0.940X_2 + 1.040X_3 + 0.350X_4 + 0.350X_5 \leq 8{,}595.00$

and $X_1, X_2, X_3, X_4, X_5 \geq 0$

The aforesaid constraints are in the form of inequalities. To convert these inequalities into equalities, slack variables are added to each equation. Solution to the problem can be found with the help of simplex method. Among the iterations, fourth one has given the optimal solution(see Table 13).

In order to maximise profit contribution in the joint sector paper mill, the optimum product mix is

X_1 = Writing & printing paper
= 4,591.62 tonnes

X_2 = Colour Printing / Process paper
= 2,796 .48 tonnes

X_3 = Newsprint
= 4,714 .81 tonnes

It indicates that the joint sector paper mill should not produce machine glaze and kraft papers. If these products are produced, profit contribution declines.

4.2.2 Sensitivity analysis

The sensitivity analysis is used to assess the range of profit contribution in the optimum product mix if there is any change in profit contribution. Table 14 reveals the profit range for product C_{j1} represented by variable X_1 i.e. writing and printing

paper; product represented by variable i.e. colour printing/process paper; and product , represented by variable i.e. newsprint. These are as follows.

41,167.08 $\leq C_{j1} \leq$ 1,13,583.13 for product X_1 i.e. writing & printing paper.

38,917.64 $\leq C_{j2} \leq$ 41,750.00 for product X_2 i.e. colour printing / process paper

15,417.72 $\leq C_{j4} \leq$ 35,064.32 for product X_4 i.e. newsprint

Over this range, positive or negative, unit profit would not cause a change in the optimal solution.

Formulation and solution of dual problem

The objective function of primal problem is the maximisation of profit contribution. The objective function of dual problem becomes the minimisation of machine hour cost. The formulation of dual for primal problem is as follows.

Minimise Z = $4,896.00Y_1 + 6,936.00Y_2 + 5,331.60Y_3 + 8,595.00$

Subject to

$0.270Y_1 + 1.040Y_2 + 0.460Y_3 + 0.940Y_4 \geq 41,750$

$0.210Y_1 + 0.250Y_2 + 0.460Y_3 + 0.940Y_4 \geq 39,000$

$0.270Y_1 + 0.450Y_2 + 0.470Y_3 + 1.040Y_4 \geq 37,900$

$0.200Y_1 + 0.310Y_2 + 0.410Y_3 + 0.350Y_4 \geq 35,000$

$0.200Y_1 + 0.190Y_2 + 0.410Y_3 + 0.350Y_4 \geq 15,000$

Where

Y_1 = Machine hour cost in pulp mill department

Y_2 = Machine hour cost in stock preparation department

Y_3 = Machine hour cost in paper making department

Y_4 = Machine hour cost in finishing house department

The inequalities are converted into equalities with the help of surplus variable. Dual simplex method is used to solve the dual problem. Iteration four is optimal. The optimal solution to the problem is Y_2, Y_3 and Y_4 (see Table 15).

From the duality analysis, machine hour cost is worked out for all the departments. These are assigned to the departments as shown below.

Y_2 = Machine hour cost in stock preparation
= Rs. 3,481.01

Y_3 = Machine hour cost in paper – making department
= Rs. 82,621.31

Y_3 = Machine hour cost in finishing – department
= Rs. 131.36

It can be observed that the machine hour cost is the highest in paper-making department while the least is in finishing – house department. Further, it

can be noticed that the machine hour cost of paper making department in joint sector paper mill is less than that of its counterpart in the private sector paper mill.

5. Comparison between private and joint sector paper mills

A glance at the Table 23 shows that there will not be any change in optimal solution by adding one extra hour in stock preparation and finishing – house departments in the private sector paper mill as its shadow price is zero. It can be observed that the capacity is fully utilised in pulp mill and paper making departments in the private sector paper mill. In the private sector mill, one hour of additional working in pulp mill and paper making-departments results in an increase of contribution of Rs. 95,149.25 and Rs. 2,23,880.60 serially. In respect of joint sector paper mill, pulp mill department has not used machines to their full capacity as its shadow price is zero. Therefore, profit contribution per machine hour does not change if the department works one hour additionally. Contrary to it, one hour of additional working increases profit contribution by Rs. 3,481.01, Rs.82,621.31 and Rs. 131.36 in the stock preparation, paper –making and finishing –house department respectively.

In the private sector paper mill, of the departments, machine utilisation factor is the highest in paper-making (97.5%) whereas it is least in stock preparation department (70%). In the latter, half of the machines i.e. chest and refiners are idle. The former department is critical in this sector. A similar trend exists in the joint sector paper mill. In this mill, machine utilisation in paper-making and stock preparation departments is 95.21 per cent and 76.14 per cent respectively. As already suggested, the management may initiate steps to increase machine utilisation in paper making department by reducing machine breakdowns and end breaks coupled with rise in capacity utilisation in stock preparation department. In other words, without increase in the utilisation factor in the stock preparation, it is not possible to increase the capacity utilisation in paper-making department.

Conclusion

The optimal product mix for maximum contribution in the private sector paper mill is Writing and printing paper = 2,377.61 tonnes; and coated board = 37,449.39 tonnes. The mill may discontinue the production of uncoated board and photo copy, machine glaze and kraft paper. If these are produced, the profit contribution declines. For the joint sector paper mill, the profitiable product mix on the aforesaid lines is writing and printing paper = 4,591.62 tonnes, colour printing/ process paper = 2,796.48 tonnes; and news print paper = 4,714.81 tonnes. On the other hand, machine glaze and kraft paper should be produced. If produced profit contribution decreases.

In the case of private sector paper mill, the machine hour cost is assigned to pulp mill and paper-making departments for Rs. 95,149.25 and Rs.2,23,880.60. It shows that the machine hour cost is maximum in the latter whereas it is minimum in the former. Likewise, the duality analysis in the joint sector paper mill reveals that it is the highest in paper making department at Rs. 82,621.31 while it is the least in finishing department at Rs.131.36. Between the two paper mills, machine hour cost in paper making is higher in private sector paper mill as compared to joint sector paper mill. It means that one hour of working in paper making increases profit contribution by Rs.95,149.25 and Rs. 82,621.31 for private and joint sector paper mills respectively.

The sensitivity analysis in the private sector paper mill shows the following range for optimal product mix : 43,400 $\leq C_{j1} \leq$ 50,100 for product of X_1 i.e., writing & printing paper and 26,946.11C_{j1} 34,848.49 for product of X_1 i.e., coated board. Similarly, in the joint sector paper mill, it is 41,167.08 $\leq C_{j1} \leq$ 1,13,583.13 for product X_4 i.e. writing & printing paper ; 38,917.64 $\leq C_{j1} \leq$ 41,750.00 for product X_2 i.e. colour printing / process paper and 15,417.72 $\leq C_{j1} \leq X_1$ 35,064.32 for product X_4 i.e. newsprint. Within these ranges, a change either positive or negative in profit contribution per unit of optimal product mix would not cause a change in the optimal solution. In other words, profit per unit falls below the lower limit or greater than upper limit, the optimal solution would be different.

The private sector paper mill should produce 2,377.61 tonnes of writing and printing paper and 37,449.39 tonnes of coated board to earn maximum profit. The joint sector paper mill should produce 4,591.62 tonnes of writing and printing paper, 2,796.48 tonnes of colour printing/process paper and 4,714.81 tonnes of newsprint only. The rest of papers such as machine glaze and kraft should be discontinued to maximise profit contribution. In terms of duality analysis, private and joint sector mills should reduce unused working hours across the departments, whose shadow prices are zero before a shortage is experienced.

The sensitivity analysis to the objective function of optimal solution suggests that by increasing or reducing the profit contribution of basic variables within the levels, maximum profit contribution cannot be changed. When the aforesaid suggestions are implemented as package and not in isolation, they would result in maximisation of profit contribution. If all this is done, there is no reason why the respondent mills cannot earn fair profits and provide quality paper to consumers at reasonable prices. If these were initiated from their inception, profits would have been much more higher and availability of good quality paper would have been more in the country. Then, it would have served the public better than today.

TABLES

Table 1 : Structure of Private Sector Paper Mill

Department	Number of machines	Number of production units	Total units
Pulp mill	2	1 delivery	2
Chippers	2	1 delivery	2
Digesters	2	1 delivery	2
Washers and bleachers			
Stock Preparation			
Chesters	4	1 delivery	
Refiners	4	2 Streets	20 machines
Paper making			
Wire part	6	1 delivery	6
Press part	6	1 delivery	6
Drying cylinders	6	2 x 35 Cylinders 2 x 60 Cylinders 2 x 85 Cylinders	
Machine coaters	6	1 delivery	6
Calendars	6	1 delivery	6
Paper reel	6	1 delivery	6
Finishing house			
Rewinders	6	1 delivery	6
Sheelers	4	1 delivery	4
Reel bundling	2	1 delivery	2

Source: Sample survey.

Table 2: Time taken to Produce one tonne of paper in Private Sector Paper Mill

Department/ products	Writing & Printing paper	Photo copy paper	Uncoated board	Coated board	MG poster	Kraft paper
Pulp mill	0.080	0.080	0.080	0.080	0.080	0.080
Stock preparation	0.087	0.089	0.085	0.085	0.090	0.082
Paper making	0.167	0.200	0.125	0.100	0.267	0.142
Finishing house	0.171	0.256	0.128	0.103	0.273	0.146

Source : Sample survey.

Table 3. Total Time available in the Private Sector Paper Mill

(hours)

Department	Working timeper each shift	Time available
Pulp mill	8.0	3,186.00
Stock preparation	8.0	3,964.80
Paper making	8.0	4,141.80
Finishing house	8.0	6,796.80

Source : Sample survey.

Table 4. Profit Contribution per Tonne of Paper in Private Sector Paper Mill

(Rs.)

Type of paper	Writing & printing	Photo copy	Uncoated board	Coatedboard board	MG poster	Kraft
Profit contribution per tonne of paper	45,000	50,000	25,000	30,000	50,000	20,000

Source: Sample survey.

Table 5. Structure of Joint Sector Paper Mill

Department	Number of machines	Number of production units	Total units
Pulp mill			
Chippers	3	1 delivery	3
Digesters	3	1 delivery	3
Washers & bleachers	3	1 delivery	3
Stock preparation			
Chesters	6	2	6
Refiners	6	3 streets	18 machines
Paper making			
Wire part	8	1 delivery	8
Press part	8	1 delivery	8
Dry cylinders	8	1 x 35 3 x 70 4 x 85	

Department	Number of machines	Number of production units	Total units
Machine coaters	8	1 x 0	
		2 x 1	
		3 x 2	
		2 x 3	14
Calendars	8	8 x 2	16
	8	1 delivery	8
Finishing house			
Rewinders	8	1 delivery	8
Sheeters	6	1 delivery	6
Roll packing	2	1 delivery	2

Source: Sample survey

Table 6. Processing Time required to produce one Tonne of paper in Joint Paper Mill

Department/Products	Writing & Printing	Colour printing / process	MG poster	News- print	Kraft
Pulp mill	0.270	0.210	0.270	0.200	0.200
Stock Preparation	1.040	0.250	0.450	0.310	0.190
Paper making	0.460	0.460	0.470	0.410	0.410
Finishing house	0.940	0.940	1.040	0.350	0.350

Source : Sample survey.

Table 7. Total Time Available in each department of Joint Sector Paper Mill

(hours)

Department	Work time per each shift	Time available
Pulp mill	8.0	4,896.00
Stock preparation	8.0	6,936.00
Paper making	8.0	5,331.60
Finishing house	8.0	8,595.00

Source : Sample survey.

Table 8. Profit Contribution per Tonne of paper in Joint Sector Paper Mill

(Rs.)

	Type of Paper				
Department/Products	Writing & Printing	Colour printing / process	MG poster	News- print	Kraft
Profit contribution per one tonne of paper	41,750	39,000	37,900	35,000	15,000

Source: Sample survey.

Table 9. Comparison of Profit Contribution per Tonne of paper between Private and Joint Sector Paper Mills

(Rs.)

Product	Private sector	Joint sector
Writing and Printing	45,000	41,750
Photo copy	50,000	—
Uncoated board	25,000	—
Coated board	30,000	—
MG Poster	50,000	37,900
Kraft	20,000	15,000
Colour printing/Process	—	39,000
News print	—	35,000

Source : Tables 4 and 8.

Table 10. Primal Linear Programming Output Summary for Private Sector Paper Mill

Variable	Value (tones)	Objective coefficient (Rs. per tonne)	Objective value contribution(Rs.)
X_1 : Writing & Printing Paper	2,377.61	45,000.00	10,69,92,537.31
X_2 : Photo copy paper	0	50,000.00	0
X_3 : Uncoated board	0	25,000.00	0
X_4 : Coated board poster	37,449.39	30,000.00	1,12,34,81,641.79
X_5 : MG Poster	0	50,000.00	0
X_6 : Kraft paper	0	20,000.00	0

Constraint	R. H. S. (hours)	Slack / Surplus (Rs.)
1 (<)	3,186.00	0
2 (<)	3,964.80	574.92-
3 (<)	4,141.80	0
4 (<)	6,796.80	2,533.15-

Table 11: Results of Sensitivity Analysis of Optimal Solution for Private Sector Paper Mill (Rs. per tonne)

Variable	Current objective coefficient	Minimum objective coefficient	Maximum objective coefficient	Reduced cost
X_1 : Writing & Printing paper	45,000	43,400.00	50,100.00	0
X_2 : Photo copy paper	50,000	- Infinity	52,388.06	2,388.06
X_3 : Uncoated board	25,000	- Infinity	35,597.02	10,597.01
X_4 : Coated board	30,000	26,946.11	34,848.48	0
X_5 : MG poster paper	50,000	- Infinity	67,388.06	17,388.06
X_6 : Kraft paper	20,000	- Infinity	39,402.99	19,402.99

Table 12: Dual Linear Programming Output Summary for Private Sector Paper Mill

Variable	Value (Rs. per hour)	Objective coefficient (hours)	Objective value contribution(Rs.)
Y_1 : Machine hour cost in pulp mill department	95,149.25	3,186.00	30,31,45,510.50
Y_2 : Machine hour cost in stock preparation department	0	3,964.80	0
Y_3 : Machine hour cost in paper making department	2,23,880.60	4,141.80	92,72,68,669.10
Y_4 : Machine hour cost in finishing department	0	6,796.80	0

Constraint	RHS (Rs. per tonne)	Slack - / surplus + (Rs.)
1 (>)	45,000.00	0
2 (>)	50,000.00	2,388.06 +
3 (>)	25,000.00	10,597.02+
4 (>)	30,000.00	0
5 (>)	50,000.00	17,388.06+
6 (>)	20,000.00	19,402.99+

Table 13 : Primal Linear Programing Output Summary for Joint Sector Paper Mill

Variable	Value (tones)	Objective coefficient (Rs. per tonne)	Objective value contribution(Rs.)
X_1 : Writing & printing paper	4,591.62	41,750	19,17,00,135
X_2 : Colour Printing / process paper	2,796.48	39,000	10,90,62,720
X_3 : Machine glaze paper	0	37,900	0
X_4 : News print paper	4,714.81	35,000	16,50,18,350
X_5 : Kraft paper	0	15,000	0

Constraint	RHS (hours)	Slack / surplus (Rs.)
1 (<)	4,896.00	2,126.04
2 (<)	6,936.00	0
3 (<)	5,331.60	0
4 (<)	8,595.00	0

Table 14. Results of Sensitivity Analysis of Optimal Solution for Joint Sector Paper Mill

(Rs. per tonne)

Variable	Current objective coefficient	Minimum objective coefficient	Maximum objective coefficient	Reduced cost
X_1 : Writing & printing paper	41,750	41,167.08	1,13,583.13	0
X_2 : Colour printing / process paper	39,000	38,917.64	41,750.00	0
X_3 : Machine glaze paper	37,900	-Infinity	40,535.60	2,635.60
X_4 : Newsprint paper	35,000	15,417.72	35,064.32	0
X_5 : Kraft paper	15,000	-Infinity	34,582.28	19,582.28

Table 15. Dual Linear Programming output summary for Joint Sector Paper Mill

Variable	Value (Rs. per hour)	Objective coefficient (hours)	Objective value contribution(Rs.)
Y_1: Machine hour cost in pulp mill department	0	4,896.00	0
Y_2: Machine hour cost in stock preparation department	3,481.01	6,936.00	2,41,44,303.80
Y_3: Machine hour cost in paper making department	82,621.31	5,331.60	44,05,03,765.82
Y_4: Machine hour cost in finishing house department	131.36	8,595.00	11,33,306.96

Constraint	RHS (Rs. per tonne)	Slack - / surplus + (Rs.)
1 (>)	41,750.00	0
2 (>)	39,000.00	0
3 (>)	37,900.00	2,635.60 +
4 (>)	35,000.00	0
5 (>)	15,000.00	19,582.28 +

Table 16. Comparative picture of Private and Joint Sector Paper Mill (in Rs.)

Department	Machine hour cost	
	Private sectorpaper mill	Joint sectorpaper mill
Pulp mill	95,149.25	0
Stock preparation	0	3,481.01
Paper making	2,23,880.60	82,621.31
Finishing house	0	131.36

Source: Table 12 and 15.

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