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Formulation of Linear Programming for Cost Optimization in Soap Stone Powder Industry

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Abstract

The study analyzed the existing state of manufacturing process of soap stone powder in an industry, named "Kothari Plaster Industry", situated in 'Madari Industrial Area', Udaipur (Raj). The study focused on various operations performed during process of manufacturing various grades of soap stone powder in the industry. The results of the study were a success with the formulation of linear programming model for cost optimization in the industry. The results of the study show a considerable amount of saving in labour cost of handling of material i.e. up to 86.25 % of total labour cost of material handling between crusher unit to pulverizer unit. It also proposes a new method of transporting material through automated conveyor belt system.

Key Words: soap stone powder, linear programming model, labour cost, transportation

1. Introduction

The management of an enterprise is responsible for looking that the enterprise resources are utilized in the best possible way to achieve the highest productivity. For this purpose the management frequently calls on specialists to assist it in improving productivity. One of the most powerful tool they use is that of work study. Work study is the systematic examination of the methods of carrying on activities so as to improve the effective use of resources and to set up standards of performance for the activities being carried out.

2. Concept of Lean Manufacturing

In its most basic form, lean manufacturing is the systematic elimination of waste from all aspects of an organization's operations. Here, waste is viewed as any use or loss of resources that does not lead directly to creating the product or service a customer wants. The basic principle ideas behind the lean manufacturing system which have been practiced for many years in Japan, are waste elimination, cost reduction and employee empowerment. The reduction in cost is achieved through continuous improvement in processes leading more profits.

3. Linear Programming

All organizations, big or small, have at their disposal, various resources , i.e. men, machines, money and materials. Supply of resources being limited, the management must find the best allocation of its resources in order to maximize the profit or minimize the loss or utilize the production capacity to the maximum extent.

However, this involves a number of problems, which can be overcome by quantitative methods, particularly the 'Linear Programming'.

Linear programming is a technique for determining an optimum schedule of interdependent activities in view of the available resources. It indicates the right combination of various decision variables which can be best employed to achieve the objective, taking full account of the practical limitations within which the problem must be solved.

4. **Formulation of Linear Programming**

In this study our aim was to minimize human effort and time required in various material handling operations in the said industry. For this purpose, a detailed study was carried out using work study and time study, on material transportation operation between crusher unit and pulverizer unit in this industry. Method study techniques, including charts and diagrams were also used.

5. **Observations**

The observations for time taken for each micro – motion (therblig) were recorded upto accuracy of mili-seconds. The observations were recorded on daily basis for one month. Every day the time recording was done for one complete cycle of filling the hopper of pulverizer , during three different time slots: i.e. in morning, afternoon and evening timings. The summary (average) of the data recorded as above during one complete month for the three time – slots is shown in the three outline process charts.

On the basis of average time recorded for each micro – motion in above charts, formulation of linear programming was carried out. All the micro – motions other than transportation were categorized in ' operation' activities and actual transportation motions were kept in ' transportation' activity.

The objective function equation was formulated , keeping the average time of 'operation' and 'transportation' activities as variables and maximum allowable time were made constraints. Then graphical solutions were obtained for time taken for each round.

6. **Data Analysis**

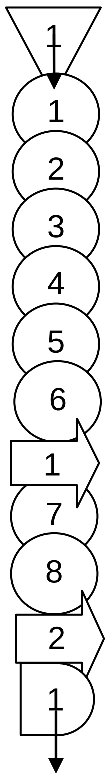
The three outline process charts along with their relevant linear programming equations and graphical solutions are shown on the next pages , from chart 1 to chart 3 and figures of graphs from figure 1 to figure 3.

On the basis of complete data analysis, the cost analysis for material handling using present method in the industry is shown in table 1. The cost of material transportation between the same points in the industry , using proposed conveyer belt system is analyzed in table 2. The comparison of the cost analysis with the two methods is shown in table 3.

Chart 1

Outline Process Chart-1:

Transportation of material from crusher to pulverizer, Time: 8.30 a.m. to 10.30 a.m.



No Time	
	Material stored at crusher
(0.33 s)	Found spade, tub etc.
(1.00 s)	Grasped spade
(1.52 s)	Held spade
(18.34 s)	Used spade to fill the tub
(1.00 s)	Grasped the loaded tub
(3.57 s)	Held the loaded tub
(14.5 s)	Transported loaded tub
(1.00 s)	Positioned for unloading
(1.58 s)	Unloaded tub in hopper
(13.62 s)	Transported empty tub
(6.36 s)	Took a rest or waited

Total time taken for 12 activities is 62.82 seconds.

Formulation of linear programming model

Tabulation for linear programming

S.No.	Type of activity	Description of activities	Total No. of activities	Sum of average time taken (s)
1	Operation	1 to 8 & 1	9	34.7
2	Transportation	1 & 2	2	28.12
	Total		11	62.82

Let the sum of average time taken for 9 operation activities be $9x_1$ and the sum of average time taken for 2 transportation activities be $2x_2$.

Objective equation: to minimize $Z = 9x_1 + 2x_2$;

Average value of x1 = 34.7/9 = 3.85; and x_2 = 28.12/2 = 14.06.

Where constraints are:

$x_1 \leq 3.85$ s ; and $x_2 \leq 14.06$ s ; where $x_1 , x_2 \geq 0$.

The graphical solution of above linear programming is shown in figure 1 on the next page.

The solution space satisfying the constraints and meeting the non – negativity conditions is shown shaded area OABC.

The optimum solution of Z is at point B.

Z(B) = 62.82.

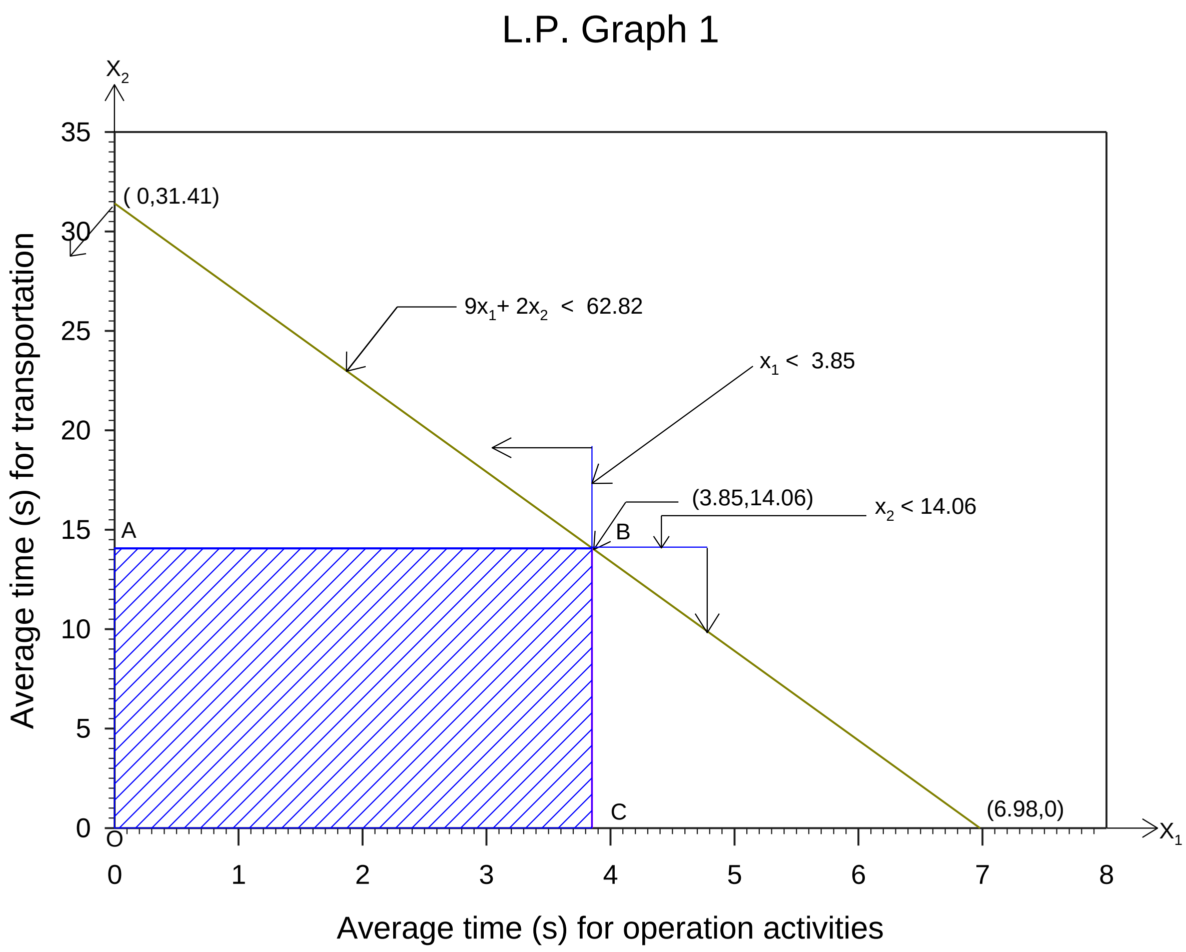
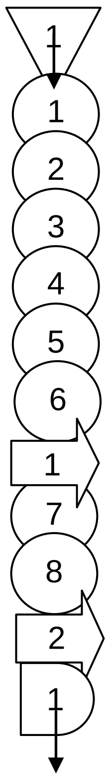


Figure1

Chart 6.2

Outline process chart-2:

Transportation of material from crusher to pulverizer, Time: 11.30 a.m. to 2.30 p.m.

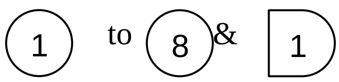
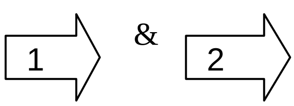


No Time	
	Material stored at crusher
(0.34 s)	Found spade, tub etc.
(1.00 s)	Grasped spade
(1.66 s)	Held spade
(19.00 s)	Used spade to fill the tub
(1.00 s)	Grasped the loaded tub
(3.71 s)	Held the loaded tub
(14.80 s)	Transported loaded tub
(1.00 s)	Positioned for unloading
(1.57 s)	Unloaded tub in hopper
(14.24 s)	Transported empty tub
(6.10 s)	Took a rest or waited

Total time taken for 12 activities is 64.42 seconds.

Formulation of linear programming model

Tabulation for linear programming

S.No.	Type of activity	Description of activities	Total No. of activities	Sum of average time taken (s)
1	Operation		9	35.38
2	Transportation		2	29.04
	Total		11	64.42

Let the sum of average time taken for 9 operation activities be $9x_1$ and the sum of average time taken for 2 transportation activities be $2x_2$.

Objective equation: to minimize $Z = 9x_1 + 2x_2$;

Average value of $x_1 = 35.38/9 = 3.93$; and $x_2 = 29.04/2 = 14.52$.

Where constraints are:

$x_1 \leq 3.93$ s ; and $x_2 \leq 14.52$ s ; where x_1 , $x_2 \geq 0$.

The graphical solution of above linear programming is shown in figure 1 on the next page.

The solution space satisfying the constraints and meeting the non – negativity conditions is shown shaded area OABC.

The optimum solution of Z is at point B.

Z(B) = 64.42.

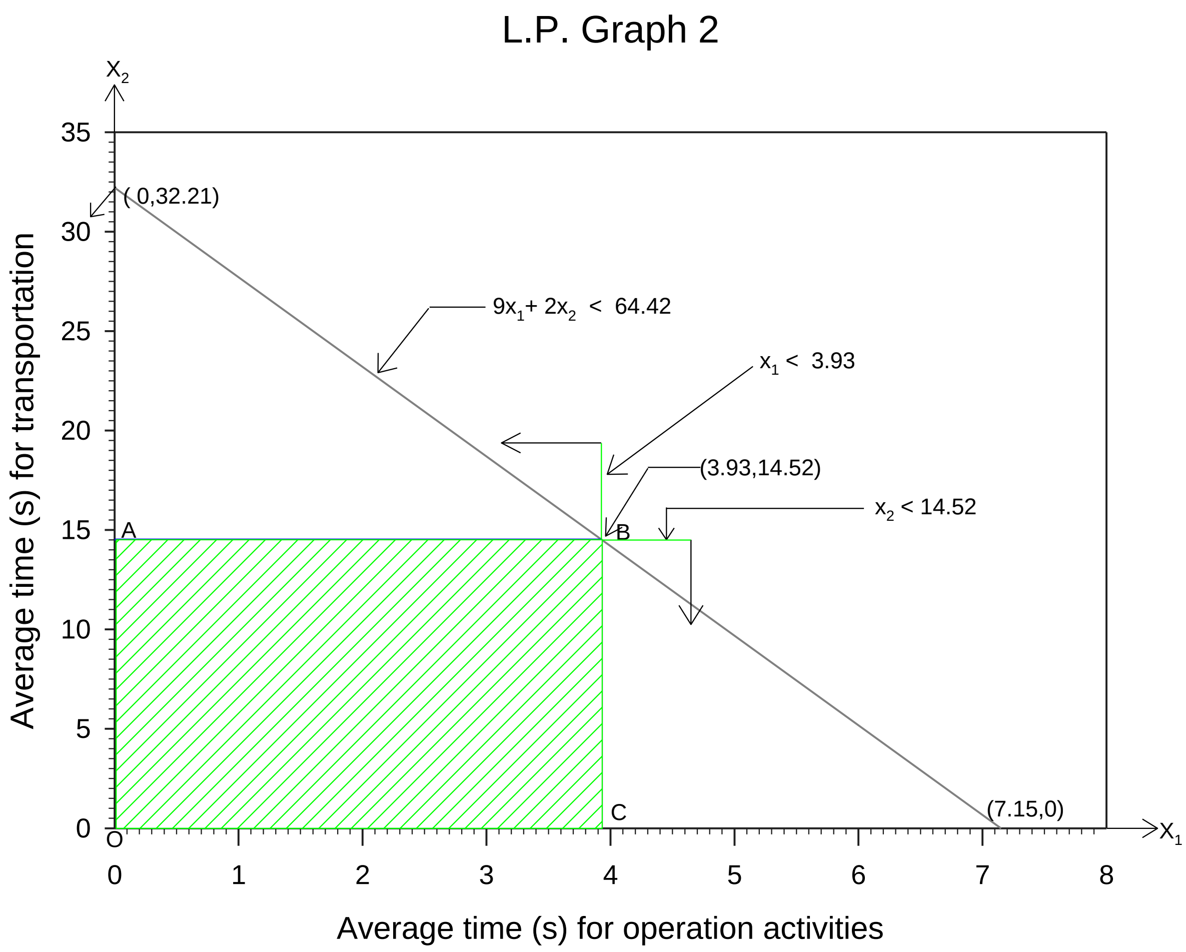
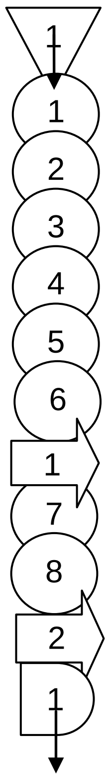


Figure 2

Chart 6.3

Outline process chart-3:

Transportation of material from crusher to pulverizer, Time: 3.45 p.m. to 6.00 p.m.



No Time	
	Material stored at crusher
(0.32 s)	Found spade, tub etc.
(1.00 s)	Grasped spade
(1.65 s)	Held spade
(18.97 s)	Used spade to fill the tub
(1.00 s)	Grasped the loaded tub
(3.78 s)	Held the loaded tub
(14.85 s)	Transported loaded tub
(1.00 s)	Positioned for unloading
(1.62 s)	Unloaded tub in hopper
(14.34 s)	Transported empty tub
(6.90 s)	Took a rest or waited

Total time taken for 12 activities is 65.43 seconds.

Formulation of linear programming model:

Tabulation for linear programming

S.No.	Type of activity	Description of activities	Total No. of activities	Sum of average time taken (s)
1	Operation	1 to 8 & 1	9	36.24
2	Transportation	1 & 2	2	29.19
	Total		11	65.43

Let the sum of average time taken for 9 operation activities be $9x_1$ and the sum of average time taken for 2 transportation activities be $2x_2$.

Objective equation: to minimize $Z = 9x_1 + 2x_2$;

Average value of $x_1 = 36.24/9 = 4.02$; and $x_2 = 29.19/2 = 14.59$.

Where constraints are:

$x_1 \leq 4.02$ s ; and $x_2 \leq 14.59$ s ; where $x_1 , x_2 \geq 0$.

The graphical solution of above linear programming is shown in figure 1 on the next page.

The solution space satisfying the constraints and meeting the non – negativity conditions is shown shaded area OABC.

The optimum solution of Z is at point B.

Z(B) = 65.43.

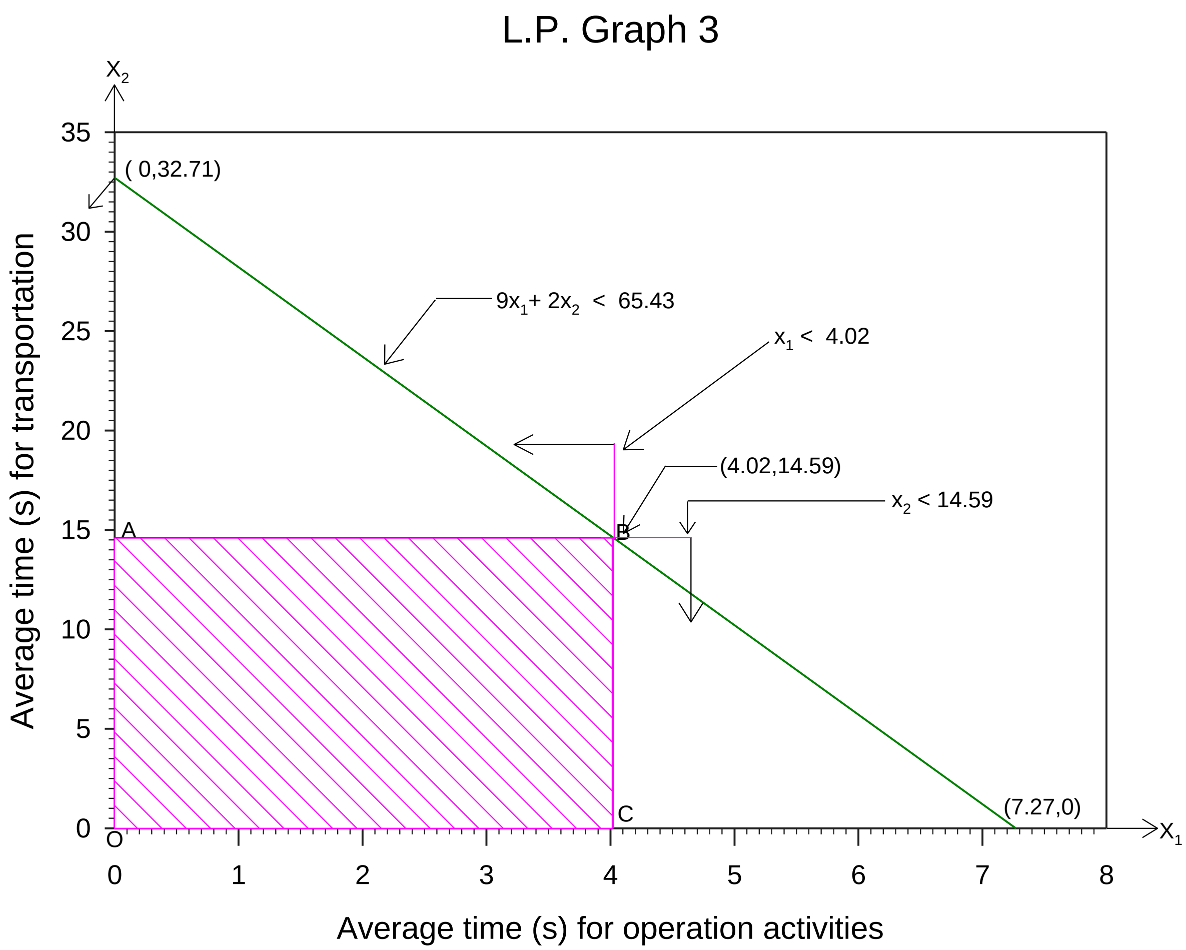


Figure 3

The average value of the three optimum values of Z(B) is 64.22 s.

On the basis of data analyzed so far, material transportation cost analysis with use of present method is shown in table 1 on the next page.

Table 1

Material transportation cost analysis: present method

(From crusher unit to pulverizer unit)

S. No.	Analysis parameter	Quantity
1	Average time taken for one round , as per flow process charts (table no. 1 to 3)	64.22 sec.
2	Material carried in one round	20 Kg.
3	Rounds required for transporting 1 ton	1000/20 = 50 rounds
4	Work - hours required for transporting 1ton (Basic work content)	50*64.22/3600 = 0.892 Work-hours
5	Actual output – 2 persons transport 5 tons in 8 hours, so total work hours required for 5 tons (excluding 1 hour rest for each person)	2*7 = 14 Work-hours
6	Work - hours required for transporting 1 ton (Total work content)	14/5 = 2.8 Work-hours per ton
7	Total ineffective time , for preparation and mixing of material etc.	2.8 – 0.892 = 1.908 Work-hours
8	Labour cost for one work-hour @ ` 200/- per day	200/7 = ` 28.57 per work-hour
9	Labour cost for transportation of 1 ton	2.8*28.57 = ` 79.996 Or ` 80/- per ton
10	Labour cost for transportation per day (for average production of 10 tons per day)	80*10 = ` 800.00 per day
11	Labour cost for transportation per annum	800*365 = ` 292000/-

The cost material transportation between the same units of the industry with use of proposed conveyer belt system is analyzed in table 2 on the next page.

Table 2

Material transportation cost analysis: proposed method

(From crusher unit to pulverizer unit using conveyor belt system with motor capacity 2 H.P. at 960 rpm)

S. No.	Analysis parameter	Quantity
1	Work output (transportation of material) per hour	4 ton per hour
2	Electricity consumption per hour	2 units
3	Electricity expense per hour @ ` 6/- per unit	2*6 = ` 12/- per hour
4	Electricity expense for transporting 1 ton (Basic work content)	12/4 = ` 3/- per ton
5	Labour cost for one operator per hour (for transportation of 4 tons)	200/7 = ` 28.57 per hour
6	Labour cost for transporting 1 ton (Total work content)	28.57/4 = ` 7.14 or ` 7/- per ton
7	Maintenance cost per ton	` 1/- per ton
8	Total cost for transportation of 1 ton	3+7+1= ` 11/- per ton
9	Total cost for transportation per day (for average production of 10 tons per day)	11*10 = ` 110/-
10	Labour cost for transportation per annum	110*365 = ` 40150/-
11	Saving in labour cost for transportation per annum , with proposed method	292000 - 40150 = ` 251850/-
12	Percentage annual saving in labour cost for transportation	251850*100/292000 = 86.25 %

The comparison of the cost analysis of material handling with the two methods is shown in table 3 on the next page.

Table 3

Comparison of cost analysis

S. No.	Analysis parameter	Quantity	
		Present method	Proposed method
1	Total cost for transportation of 1 ton	` 80.00	` 11.00
2	Total cost for transportation per day (for average production of 10 tons per day)	` 800.00	` 110.00
3	Labour cost for transportation per annum	` 292000.00	` 40150.00
4	Saving in labour cost for transportation per annum , with proposed method		` 251850.00
5	Percentage annual saving in labour cost for transportation		86.25 %

7. Results and Discusion

As shown above in table , the total percentage annual saving in the labour cost for material transportation from crusher unit to pulverizer unit only, is calculated as ` 251850/- i.e. 86.25% of the total labour cost. This amount is calculated assuming an average production of 10 ton per day. If the production is more during peak demand period, the amount of saving can increase even more.

If the same method is adapted for transportation of material from storage place to grader machine, and also from grader to crusher unit, the saving in total material transportation cost can further be increased. Due to this saving in material transportation cost, a considerable reduction in total production cost can be achieved. It will increase the net profits of the industry, which is one of the aims of our study.

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