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DEVELOPMENT OF AN OPTIMIZATION MODEL TO IMPROVE PERFORMANCE IN A PALLETIZING SYSTEM

Brahmananth K J*
*(Manufacturing Systems Management, Department of Production Engineering, Government Engineering College, Thrissur
Email: itismebrahman@gmail.com)

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Abstract:

Production is one of the key functions in the manufacturing company. Any decision related to it can be crucial to the management to increase or decrease the production capacity. It can affect directly the productivity and efficiency of the production as well as the profitability of the company.

As a result of the development of computer technology there are many optimization tools are available. Linear Programming Technique has gained a considerable impact on agricultural, livestock and animal husbandry research in recent years. It is now one of the most powerful tools which all managers must apply before achieving effective decision. To take a decision, company management has to consider it on solid base of analysis of all the affecting factors. The problem of decision making based on the use of limited resource is a major factor that brought the application of linear programming model.

The methodology consists of on line control of the manufacturing process of animal feed. The data of batch processing is used to construct a linear programming problem. The objective of this program is to maximize the productivity and reduce energy consumption with acceptable resources. The linear programming model is taken to analyze the ability of increasing productivity and energy efficiency of the problem and it can be positively effective in the results.

Keywords —**optimization, energy, production, feed, simplex method**

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I. INTRODUCTION

The Manufacturing Company frequently face some difficulty to measure the actual production efficiency and productivity and this is due to many circumstances like resource availability and the uncertainties may happen during the production process. Linear Programming Technique has gained a considerable impact on agricultural, livestock and animal husbandry research in recent years. So it can be implemented in the production of pelleted animal feed manufacturing sector to improve the performance of feed production and reduce energy consumption.

The study assists the pelleting process and to establish processing conditions that achieve maximum productivity with minimum use of energy. To identify the process variables needs to check the key performance indexes (KPIs). By using KPIs the process variables are divided into Control variables and environmental variables. The control variables can be used for on-line control of the pelleting process. The environmental variables denote the processing conditions of the batch. Which is consider as fixed and cannot be changed during pelleting process because decisions are made before the batch is started. The experimental part of the study has been carried out at pellet manufacturing company. The formation of pellets from raw materials is the major step in the production of pelleted animal feed, because the production process capacity is usually determined by the productivity of the pelleting process. Additionally pelleting process uses a relatively high amount of energy and the quality of the pellets is mainly established during the pelleting process. Research will be based on the data taken from actual production line and will be formulated in linear programing to get the targeted results. Then, the productivity & energy used will be analyzed based on the result we come up with.

II. LITERATURE SURVEY

There were articles discussed the productivity and another talked about application of linear programming. I will try to match and apply the methodology of linear programming model to improve productivity & energy efficiency.

Carl Fredrik, (2015) In this research they studied the Key Performance Indicators and its importance for monitoring the performance in the industry. Their analyzing is to identify poor performance and the improvement potential. kpis can be defined for individual equipment, sub processes, and whole plants. Different types of performances like energy, raw material, control and operation can be measured by kpis. Comparing kpis with kpis from similar equipment and plants is one method of identifying poor performing areas and estimating improvement potential. Actions for performance improvements can then be developed, prioritized and implemented based on the kpis and the comparing results. A process which is described in this paper is to identify the process signals that are strongest correlated with the kpi and then change these process signals in the direction that improves the kpi. This method has been applied to data from a combined heat and power plant and a suggestion are given on how to improve the boiler efficiency.Michael Brundage[14] studied about the procedure inselecting key performance indicators for sustainable manufacturing has been studied in this article. Individual manufacturers how to select kpis for measuring, monitoring and improving environmental aspects of manufacturing processes are described in this paper. The procedure presented by standardization within ASTM International. The steps used are identifying candidate kpis from existing sources, defining new candidate kpis, selecting appropriate kpis based on kpi criteria, and composing the selected kpis. The paper explains how the developed procedure complements existing indicator sets and sustainability-measurement approaches at the manufacturing process level.

El Haddad [16] the researchers studied a local pelleting machine to determine the effect of die speed, die holes, diameter , moisture content of feed mixture, adhesive material and different sources of power. Identified the equations for finding energy consumption, productivity are selected from this paper. The parameters they studied such as productivity, pelleting efficiency, pellets durability, specific consumption energy and production cost. Akpan[12] here linear program technique used and solved profit maximization problem. Here the concept of Simplex algorithm in linear programing to allocate raw materials to competing variables in a bakery. The decision variables in this research work are the three different sizes of bread produced by Goretta bakery limited. The researcher used data of six raw materials used in the production and the amount of raw material required of each variable .then they identified Goretta bakery limited what should produce to satisfy their customers and attain maximum profit because they contribute mostly to the profit earned by the company.

Saleh[6] the study of Excel Solver and The optimum solution of linear programming is implemented in the Premium Solver Platform bundled with Microsoft Excel. The tool that allow Excel spreadsheets to be used over linear data with fast computation of optimization solution are also described in it basic theory of optimization as implemented within the Excel's Add-in Solver. The advantage of the Excel Solver in linear programming is adjustment of Solver to solve the linear programming problems. Solver can be used for large problems containing hundreds of variables and constraints and does these relatively quickly. As a teaching tool using small illustrative problems it is very potent, particularly as the user must appreciate the structure of a LP when entering it into the spreadsheet. The researcher arrived that the sensitivity report when compared to Simplex method and due to the spreadsheet nature it does allow the user very quickly to observe the effects of any changes made to constraints or the objective function. Zain [9] the linear programming and sensitivity analysis methods were applied for the optimization of the profit of LCD manufacturing company. The post optimal analysis is used to know the changes in right hand side, specific ranges and coefficients of objective function by the optimal solution. The research takes into the production of flat panel monitor of four sizes and will point more the products that contribute the main function of profit. This research method will be used to get maximum utilization of resources of the problem takes into the production of Flat Panel Monitor of four sizes and will point more the products that contribute the main profit function. Thuleswar Nath[10]the application of linear programming in feed formulation are described in this paper. The linear programming program used to higher productivity in this sector as opposed to the use of relatively inefficient methods such as the trial and error method. The general model can be extended to tackle other types of feed formulation. In this paper a versatile tool called linear programming technique has been discussed in relation to fish feed formulation. Fish farmers of Kamrup District of Assam use traditional method of feeding the fish but modern fish feed are formulated under complex nutrient specifications and there specifications are necessary for the growth of fishes and improving animal productivity.

III. EMPIRICAL FRAMEWORK

A. *Linear programming model*

To achieve research targets we have to follow methods and guidelines of established study Henriette [2]. In this research we discuss mainly linear programming and how to apply it in actual problem figures to improve the performance of the system along with reduce energy consumption without any effect in the quality of product. The methodology consists of on line control of the pelleting process of animal feed. The method is based on the idea that some of the process variables can be considered constant during the pelleting of one batch. The data of batch processing is used to construct equations for the output of the process. These equations are used to construct a linear programming problem. The result of the pelleting process is represented by the output variables. The values of process and output variables of previously produced batches are stored in a data set as a collection of vectors.

The data stored as n vectors. Each vector of the data set is given by
$(x_1, \dots, x_{nx}, y_1, \dots, y_{ny}, z_1, \dots, z_{nz})$.
Where
x_i(i=1, . . . , n_x) is the value of control variables i, y_j (j=1, . . . , n_y) the value of output variable j, and z_k (k=1, . . . , n_z) the of environmental variable k of batch l.

Equations describing the relation between output variables and control variables are constructed from batches produced under similar conditions. The parameter estimation is done by using the linear regression equation.

$$y_j(x) = a_{j1}x_1 + a_{j2}x_2 + \dots + a_{jn}x_n + a_{j0}$$

where a(i=1, . . . , n_x)denotes the parameter of the control variables x_i(i=1, . . . , n_x) in the equation of output variable j. The parameter a_{j0} is a constant by the assumption that the environmental variables, representing the processing conditions of the current batch, are constant.The linear programing equation is used for the optimization is given by

$$\text{Max } y_j(x),$$
$$ly_j \leq y_j(x) \leq uy_j \forall j$$
$$lx_i \leq x_i \leq ux_i \forall i$$

The objective of the LP problem is the equation for the output variable j to optimize. where j denotes the output variable to be optimized and ly_j , uy_j , lx_i and ux_i are, respectively, the lower and upper bounds of output variable j and the lower and upper bound of control variable i.

IV. METHODOLOGY

A. *Kpi identification*

There are KPIs (Key Performance Indicators) for a feed mill. A key Performance Indicator is a measurable value that demonstrates how effectively a company is achieving key business objectives). Organizations use kpis at multiple levels to evaluate their success at reaching targets. High-level kpis may focus on the overall performance of the business, while low-level kpis may focus on processes in departments. The processes involved are milling, mixing, cooking, and pelletizing. This study focuses on pelletizing. Three stake holder's production manager, control room operator and maintenance engineer are tasked to select appropriate kpis that would achieve the sustainability goals to make the improvements to the system [14]. Three stake holders production manager, control room operator and production engineer are tasked to select appropriate KPIs as establishing kpi objectives. That would assess the achievement of sustainability goals such as increase productivity and reduce energy consumption. After that In the second step search the literature for candidate kpis that help achieve the above specified goals are Productivity of the pelleting process, Temperature after conditioning, Amperage of the pellet mill, Amount of molasses added during conditioning, Use of energy of the pelleting process, Quality of raw material, Die/Roller changeover. These kpis deemed sufficient for the kips goals.so no new kpis are defined. On the next step selected the following criteria for ranking the kpis, The value functions are then created by subject matter experts for each criterion.

1. Cost effectiveness: The degree of perceived cost benefit of implementing the KPI.
2. Quantifiable: The degree to which a KPI can be stated numerically and precisely.
3. Calculable: The degree of correctness and completeness of the calculation required to compute the value of the KPI.
4. Management support: The willingness of plant management to support the choice of appropriate KPIs.
5. Comparable: The degree to which historic data is maintained andavailable for comparison to current values.
6. Understandable: The degree to which the meaning of the KPI is comprehensible by team members with respect to corporate goals.

Importance Level	Level	Experts Value Assessment
Not important	0	0
Somewhat important	1	30
Fairly important	2	40
Important	3	50
Very important	4	70
Extremely important	5	100

Table 1: Value function example of "Management support"

The stakeholders assign an importance level to the criterion for each KPI. For each importance level assigned, a value is obtained using the value functions. Above Tables shows the importance level on a scale 0-5 for each KPI assigned by one stakeholder. The values (obtained from the value function) vary in range 0-100. All three stakeholders perform the same process and their results averaged in table 2.

	Productivity of the pelleting process	Temperature after conditioning	Amperage of the pellet mill	Amount of molasses added during conditioning	Use of energy of the pelleting process	Quality of raw material	Die/Roller changeover
Cost Effectiveness	86.66	60	73.33	60	73.33	50	53.33
Quantifiable	76.66	30	30	50	30	23.33	23.33
Calculable	83.33	100	100	66.66	83.33	66.66	56.66
Management Support	80	65.66	66.56	80	56.66	63.33	53.33
Comparable	33.33	33.33	33.33	26.66	26.65	26.66	26.66
Understandable	76.66	83.33	83.33	86.66	76.66	70	76.66
Aggregate value	436.66	373.33	386.66	370	3 6.65	300	310

Table 2: Average stakeholder values and final aggregate

From the stakeholder rankings of kpis the control variables and the output variables are selected.Control variables are Amount of molasses added during conditioning, Meal temperature after conditioning, Amperage of the pellet mil. Output variables are Productivity of the pelleting process, Use of energy of the pelleting process, Hardness of the pellets, Durability of the pellet .Environmental variables are Life-time of the die ,Life-time of the rollers ,Raw fiber contents of the raw materials, Raw fat contents of the raw materials ,Factory ambient temperature.

B. *Model formulation*

The basic steps in formulation are: Identify the decision variables, Formulate the objective function, Identify and formulate the constraints, Writing out the non-negativity constraints. The objective is always to maximize or to minimize the linear function of the decision variables. Refer to linear programs formulation the below way a standard form of linear programming. Using "a" to nominate the quantity of material available, and "c" to nominate the variable of each quantity in production process.

X1= The number of required quantity of control variable 1
X2= The number of required quantity of control variable 2
X3= The number of required quantity of control variable 3
Z1= The objective function variable productivity
Z2= The objective function variable Energy

Maximize $c_1x_1 + c_2x_2 + \ldots + c_nx_n$

Subject to $a_{11}x_1 + a_{12}x_2 + \ldots + a_{1n}x_n \le b_1$

$a_{21}x_1 + a_{22}x_2 + \ldots + a_{2n}x_n \le b_2$

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$a_{m1}x_1 + a_{m2}x_2 + \ldots + a_{mn}x_n \le b_m$

$x_1, x_2, x_3, \ldots \ge 0$

C. *Techniques for Model Solution*

The model was solved using The Microsoft excel solver 2010. The reasons to use of Excel for optimization can be considered a viable option are: Excel is readily available in any Windows platform without any additional cost. Excel is easy to use. The data transfer to and from Excel is very flexible. Solver is a Microsoft Excel add-in program that can use for what-if analysis. Use Solver to find an optimal (maximum or minimum) value for a formula in one cell called the objective cell subject to constraints, or limits, on the values of other formula cells on a worksheet.

V. RESULTS AND DISCUSSION

Data collection and the subsequent results are listed in the table.

A. *Collected data*

PRODUCTION METRIC TON /HR			
PRODUCTION LINE	MILLING	PELLETIZING	CAPACITY/HR
	X1	X2	
L1	.62	.5	6.6
L2	.5	.5	5.8
L3	1.1	.87	7
L4	1	1.1	7.5
PROFIT/MT	6000Rs	7000Rs	

Table 3: production lines data

Due to company confidential, the profit given is assumption but it simulates to reality. The variable X1 & X2 are the process stage in the production line and each stage consume different capacity of materials.

RUN	NO. bags	Capacity(MT)	Temperatue(C)	Average Current(Amp)	Molasses added(MT)	Energy KW/hr
1	3440	172	80	240	0.86	172.308
2	3370	168.5	79	240	0.8425	172.308
3	3350	177.5	80	223	0.8875	160.3421667
4	2990	149.5	81	240	0.7475	172.308
5	1515	75.75	80	240	0.37875	172.308
6	2916	145.5	80	260	0.7275	186.667
7	3500	150	80	250	0.75	179.4875
8	3475	173.75	80	250	0.86875	179.4875
9	3550	177.5	80	250	0.8875	179.4875
10	3440	172.5	80	250	0.8625	179.4875
11	3400	170.5	80	260	0.8525	186.667
12	2525	126.25	82	236	0.63125	169.9148333
13	3490	174.5	80	236	0.8725	169.9148333
14	3555	177.25	80	260	0.88625	186.667
15	3400	170	80	236	0.85	169.9148333
16	3705	185.75	79	260	0.92875	186.667
17	3320	166.75	80	260	0.83375	186.667
18	3130	156.5	81	236	0.7825	169.9148333

Table 4: Energy data of pellet mill

B. ***Linear programming model formulation***

The variable X1 & X2 are the process stage in the production line and each stage consume different capacity of materials. The production lines 1,2,3,4 considered as constraints. The objective is to maximize the productive capacity thus maximize profit.

LP Model 1

Max. Profit (Z1) = 6000 X1 + 7000X2

Constraint 1 = $0.62X1 + 0.5\,X2 \leq 6.6$

constraint 2 = $0.5\,X1 + 0.5\,X2 \leq 5.8$

constraint 3 = $1.1X1 + 0.87X2 \leq 7$

constraint 4 = $1X1 + 1.1X2 \leq 7.5$

$x_1, x_2 \geq 0$

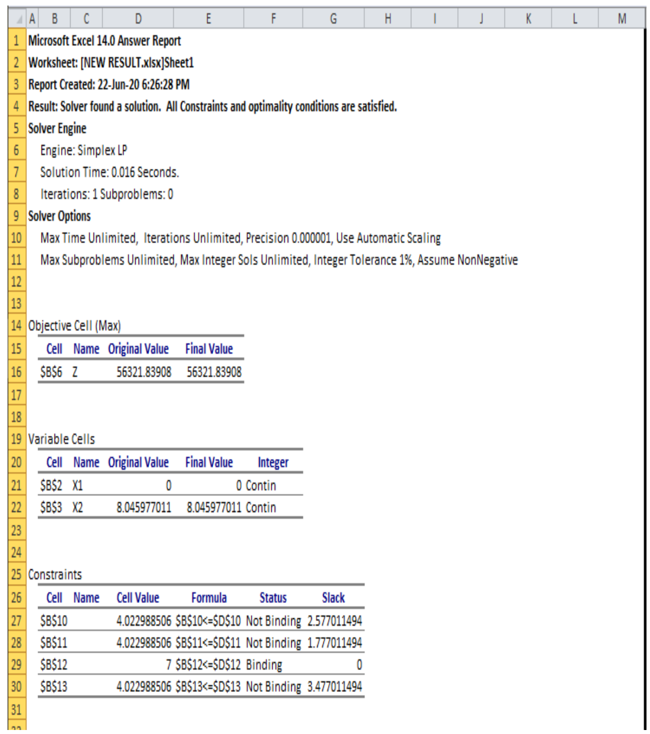
LP Model 2

$$\text{Max } Z2 = 5.228x_1 + 0.021x_2 - 2.99x_3$$

Subject to

$$0.86x_1 + 240x_2 + 80x_3 \leq 172.30$$
$$0.84x_1 + 240x_2 + 79x_3 \leq 172.30$$
$$0.88x_1 + 240\,x_2 + 80x_3 \leq 160.34$$
$$0.74x_1 + 223x_2 + 81x_3 \leq 172.30$$
$$0.37x_1 + 240x_2 + 80x_3 \leq 172.30$$
$$0.72x_1 + 240x_2 + 80x_3 \leq 186.66$$
$$0.75x_1 + 260x_2 + 80x_3 \leq 179.48$$
$$0.86x_1 + 250x_2 + 80x_3 \leq 179.48$$
$$0.88x_1 + 250x_2 + 80x_3 \leq 179.48$$
$$0.86x_1 + 250x_2 + 80x_3 \leq 179.48$$
$$0.85x_1 + 250x_2 + 80x_3 \leq 186.66$$
$$0.63x_1 + 260x_2 + 82x_3 \leq 169.91$$
$$0.87x_1 + 236x_2 + 80x_3 \leq 169.91$$
$$0.88x_1 + 236x_2 + 80x_3 \leq 186.66$$
$$0.85x_1 + 260x_2 + 80x_3 \leq 169.91$$
$$0.92x_1 + 236x_2 + 79x_3 \leq 186.66$$
$$0.83x_1 + 260x_2 + 80x_3 \leq 186.66$$
$$0.78x_1 + 260x_2 + 81x_3 \leq 169.91$$
$$x_1 \geq 0.60$$
$$X_2 \geq 220$$
$$X_3 \geq 75$$
$$X_1 \leq 0.95$$
$$X_2 \leq 270$$
$$x_3 \leq 90$$
$$x_1, x_2, x_3 \geq 0$$

The objective of the LP problem is the equation for the output variable Z2(energy) to optimize. Assuming that each shift considering as single run. And the linear equation is created by considering each run as constraints. Constraints include the control variables they are arranged as restricting the values of the control values. Control variables are molasses added during conditioning(X1), Amperage of the pellet mil(X2), Meal temperature after conditioning(X3).



Microsoft Excel 14.0 Answer Report
Worksheet: [NEW RESULT.xlsx]Sheet1
Report Created: 22-Jun-20 6:26:28 PM
Result: Solver found a solution. All Constraints and optimality conditions are satisfied.
Solver Engine
Engine: Simplex LP
Solution Time: 0.016 Seconds.
Iterations: 1 Subproblems: 0
Solver Options
Max Time Unlimited, Iterations Unlimited, Precision 0.000001, Use Automatic Scaling
Max Subproblems Unlimited, Max Integer Sols Unlimited, Integer Tolerance 1%, Assume NonNegative

Objective Cell (Max)

Cell	Name	Original Value	Final Value
$B$6	Z	56321.83908	56321.83908

Variable Cells

Cell	Name	Original Value	Final Value	Integer
$B$2	X1	0	0	Contin
$B$3	X2	8.045977011	8.045977011	Contin

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$B$10		4.022988506	$B$10<=$D$10	Not Binding	2.577011494
$B$11		4.022988506	$B$11<=$D$11	Not Binding	1.777011494
$B$12		7	$B$12<=$D$12	Binding	0
$B$13		4.022988506	$B$13<=$D$13	Not Binding	3.477011494

Fig 1: Answer report of LP model 1

The answer report is shown all the details of the problem and the binding & non-binding constrains .the objective function & final variables, with the original value and final values shown.A column showing the constraint 3 was binding and other were non-binding at the solution. The slack value is the difference between the lower or upper bound and the final value.

Microsoft Excel 14.0 Sensitivity Report
Worksheet: [NEW RESULT.xlsx]Sheet1
Report Created: 22-Jun-20 6:26:28 PM

Variable Cells

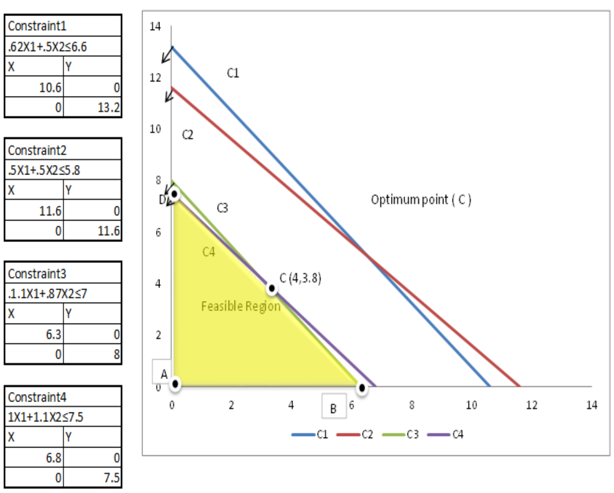
Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
$B$2	X1	0	-34.48275862	6000	34.48275862	1E+30
$B$3	X2	8.045977011	0	7000	1E+30	40

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
$B$10		4.022988506	0	6.6	1E+30	2.577011494
$B$11		4.022988506	0	5.8	1E+30	1.777011494
$B$12		7	8045.977011	7	3.092	7
$B$13		4.022988506	0	7.5	1E+30	3.477011494

FIG 2: SENSITIVITY REPORT OF LP MODEL 1

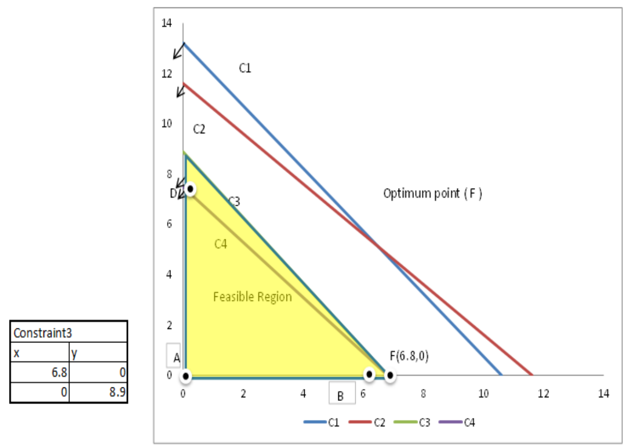
Figure shown the sensitivity report with the result details of each constraints and final value of both constraints and variable cells. The reduced costs shown the objective coefficients can beincreased or decreased before the optimal solution changes.



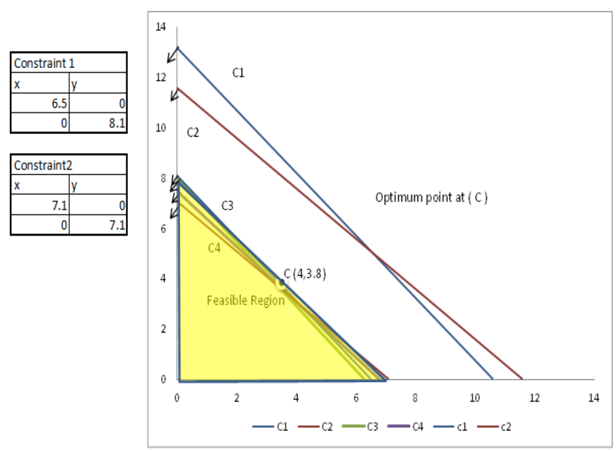
Graph 1: Feasible region ABCD

From the graph 1The points A, B, C, D, are our solution and the area confined on these points called feasible region. Point C is the optimum point of the solution that reflect the maximum profit of all production lines and the line which cross the point C is the Binding constraint which shows the ability to increase the productivity.The optimum point will be the C point and the Binding constraint is 3.

A (0, 0) , ZA = 6000 (0) + 7000 (0) = 0
B (6.3, 0) , ZB = 6000(6.3)+ 7000(0) = 37800
C (4, 3.8) , ZC = 6000 (4) + 7000(3.8)= 50600
D (0, 7.5) , ZD = 6000 (0) + 7000 (7.5)= 51100



Graph 2: The possible increase of feasible region in resource constraint 3



Graph 3: The possible decreased in resource constraints 1, 2& 4

From the graph 2 and 3 it is clear that resource to be increased in order to improve the optimum value and a resource to be decrease without causing a change in current optimum value. Moved the constraint number 3 outward to touch new point F to increase the feasible region which reflected to our profit and increased optimum point to other point which it's the highest ability of profit it can reach in our solution. The point F intersection of line 3 with X1-axis (X2=0) The F value (6.8 , 0) , X1 = 6.8, X2 = 0 We substitute these value in constraint 3 to get the maximum allowable level of resource in constraint 3 .

Constraint 3 = 1.1(6.8) + .87(0) = 7.48

The Non-Binding constraints which used resources more than the production lines needs to be reduced on the RHS value in the formula as reflected in graph 3 . The reduction up to the optimum point without changing the current solution is to reduce unnecessary resource of non-binding constraints.

Microsoft Excel 14.0 Limits Report
Worksheet: [NEW RESULT.xlsx]Sheet1
Report Created: 22-Jun-20 6:26:28 PM

Objective		
Cell	Name	Value
$B$6	Z	56321.83908

Variable			Lower	Objective	Upper	Objective
Cell	Name	Value	Limit	Result	Limit	Result
$B$2	X1	0	0	56321.83908	8.88178E-16	56321.83908
$B$3	X2	8.045977011	0	0	8.045977011	56321.83908

Fig 3: Limits report of LP model 1

The limits report shows a lower limit & upper limit for each variable. which are the smallest & largest values that a variables can take while satisfying the constraints and holding all of the other variables constant.

Microsoft Excel 14.0 Answer Report
Worksheet: [NEW RESULT.xlsx]Sheet5
Report Created: 30-Jun-20 12:43:40 PM
Result: Solver found a solution. All Constraints and optimality conditions are satisfied.
Solver Engine
Engine: Simplex LP
Solution Time: 0.031 Seconds.
Iterations: 4 Subproblems: 0
Solver Options
Max Time Unlimited, Iterations Unlimited, Precision 0.000001, Use Automatic Scaling
Max Subproblems Unlimited, Max Integer Sols Unlimited, Integer Tolerance 1%, Assume NonNegative

Objective Cell (Max)

Cell	Name	Original Value	Final Value
$B$8	Maximize	9.511077273	9.511077273

Variable Cells

Cell	Name	Original Value	Final Value	Integer
$B$2	X1	1.822045455	1.822045455	Contin
$B$3	X2	0	0	Contin
$B$4	X3	0	0	Contin

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$B$12		156.6959091	$B$12<=$D$12	Not Binding	15.60409091
$B$13		153.0518182	$B$13<=$D$13	Not Binding	19.24818182
$B$14		160.34	$B$14<=$D$14	Binding	0
$B$15		134.8313636	$B$15<=$D$15	Not Binding	37.46863636
$B$16		67.41568182	$B$16<=$D$16	Not Binding	104.8843182
$B$17		131.1872727	$B$17<=$D$17	Not Binding	55.47272727
$B$18		136.6534091	$B$18<=$D$18	Not Binding	42.82659091
$B$19		156.6959091	$B$19<=$D$19	Not Binding	22.78409091
$B$20		160.34	$B$20<=$D$20	Not Binding	19.14
$B$21		156.6959091	$B$21<=$D$21	Not Binding	22.78409091
$B$22		154.8738636	$B$22<=$D$22	Not Binding	31.78613636
$B$23		114.7888636	$B$23<=$D$23	Not Binding	55.12113636
$B$24		158.5179545	$B$24<=$D$24	Not Binding	11.39204545
$B$25		160.34	$B$25<=$D$25	Not Binding	26.32
$B$26		154.8738636	$B$26<=$D$26	Not Binding	15.03613636
$B$27		167.6281818	$B$27<=$D$27	Not Binding	19.03181818
$B$28		151.2297727	$B$28<=$D$28	Not Binding	35.43022727
$B$29		142.1195455	$B$29<=$D$29	Not Binding	27.79045455
$B$30		1.822045455	$B$30>=$D$30	Not Binding	1.822045455
$B$31		0	$B$31>=$D$31	Binding	0
$B$32		0	$B$32>=$D$32	Binding	0

Fig 4:Answer report of LP model 2

A column showing the cell number 14 was binding and other were non-binding at the solution. Cells 30,31,and 32 are non-negativity constraints that are not considered. The slack value is the difference between the lower or upper bound and the final value.

Microsoft Excel 14.0 Sensitivity Report
Worksheet: [NEW RESULT.xlsx]Sheet5
Report Created: 30-Jun-20 12:43:40 PM

Variable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
$B$2	X1	1.822045455	0	5.22	1E+30	5.212666667
$B$3	X2	0	0	0.02	14.21636364	1E+30
$B$4	X3	0	0	-2.99	7.676136364	1E+30

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
$B$12		156.6959091	0	172.3	1E+30	15.60409091
$B$13		153.0518182	0	172.3	1E+30	19.24818182
$B$14		160.34	0.059318182	160.34	11.52298851	160.34
$B$15		134.8313636	0	172.3	1E+30	37.46863636
$B$16		67.41568182	0	172.3	1E+30	104.8843182
$B$17		131.1872727	0	186.66	1E+30	55.47272727
$B$18		136.6534091	0	179.48	1E+30	42.82659091
$B$19		156.6959091	0	179.48	1E+30	22.78409091
$B$20		160.34	0	179.48	1E+30	19.14
$B$21		156.6959091	0	179.48	1E+30	22.78409091
$B$22		154.8738636	0	186.66	1E+30	31.78613636
$B$23		114.7888636	0	169.91	1E+30	55.12113636
$B$24		158.5179545	0	169.91	1E+30	11.39204545
$B$25		160.34	0	186.66	1E+30	26.32
$B$26		154.8738636	0	169.91	1E+30	15.03613636
$B$27		167.6281818	0	186.66	1E+30	19.03181818
$B$28		151.2297727	0	186.66	1E+30	35.43022727
$B$29		142.1195455	0	169.91	1E+30	27.79045455
$B$30		1.822045455	0	0	1.822045455	1E+30
$B$31		0	-14.21636364	0	0.533540323	0
$B$32		0	-7.676136364	0	2.029620253	0

Fig 5: Sensitivity report of LP model 2

Figure shown the sensitivity report with the result details of each run and final value of both constraints and variable cells. The reduced costs shown the objective coefficients can be increased or decreased before the optimal solution changes. The sensitivity shows only 3rd run is increased the use of energy other than 18 runs.so we can reduce the energy of other 17 runs to the optimum value.

Microsoft Excel 14.0 Limits Report
Worksheet: [NEW RESULT.xlsx]Sheet5
Report Created: 30-Jun-20 12:43:41 PM

Cell	Objective Name	Value
$B$8	Maximize	9.511077273

Cell	Variable Name	Value	Lower Limit	Objective Result	Upper Limit	Objective Result
$B$2	X1	1.822045455	0	0	1.822045455	9.511077273
$B$3	X2	0	0	9.511077273	-1.11022E-16	9.511077273
$B$4	X3	0	0	9.511077273	-2.22045E-16	9.511077273

Fig 6: Limits report of LP model 2

The limits report shows a lower limit & upper limit for each variable. which are the smallest & largest values that a variables can take while satisfying the constraints and holding all of the other variables constant.

C. ***Result***

Table 5: LP model 1 solution

PRODUCTION LINE	RESOURCE	INCREASE	DECREASE
L1	decrease	0	2.5
L2	decrease	0	1.77
L3	increase	3.09	0
L4	decrease	0	3.47
Total		3.09	7.74

Table 6: LP model 2 solution

RUN	ENERGY	INCREASE	DECREASE
1	decrease	0	13.16
2	decrease	0	14.36
3	increase	2.22	0
4	decrease	0	27.97
5	decrease	0	42.56
6	decrease	0	35.92
7	decrease	0	17.97
8	decrease	0	15.85
9	decrease	0	14.65
10	decrease	0	15.85
11	decrease	0	23.63
12	decrease	0	15.60
13	decrease	0	11.96
14	decrease	0	28.11
15	decrease	0	2.40
16	decrease	0	25.71
17	decrease	0	20.35
18	decrease	0	6.60

From thesolution table the production lines 1, 3 & 4 we can reduce the resource by 7.74 MT and we can increase production lines 3 by 3.09 MT and the difference of Abundance production lines and Scarce production lines by 4.65 MT, we can save this resource to achieve the optimum solution of all production lines of the company. From the energy table only 3rd run is increased the use of energy other than 18 runs.so we can reduce the energy of other 17 runs to the optimum value.

VI. CONCLUSIONS

The first objective of maximize productivity of production lines is achieved in one production line which is number three line to the maximum which reflect the increase in lines productivity and reduce the material waste by using the maximum capacity of the production lines. The second objective of minimize production wastes (Material) is achieved in all four production lines as shown in the analysis for production line 1,2,3,4. Production line number one, two& four the raw materials are reduced to the minimum without reducing the productivity and resources of the production lines as shown in graph. Thus the second objective of the research is achieved on all five production lines. The third objective is reduce the energy consumption From the energy table only 3rd run is increased the use of energy other than 18 runs. So we can reduce the energy of other 17 runs to the optimum value. From the result we can conclude that we can improve the productivity and reduce energy consumption & also We can increase the profitability of the company by decrease the resource from some of production lines and increased in other lines.

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