National Institute of Technology, Calicut

ME3111D Optimization Methods in Engineering

Linear Programming for Optimal Use of Bakery Raw Materials

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CONTENTS

INTRODUCTION

- Bakery's, like any business establishment is profit oriented.
- There are many ways to increase profits.
  - Proper utilization of resources is one of the main ways.
  - Reducing production and labour cost.
- Here we aim to devise the best method of production taking raw materials into consideration.

LITERATURE REVIEW

SI - no	Title of the paper	Authors , year of publication	Major finding
1	An introduction to linear programming problem	Steven J. Miller,2007	Reason for the great versatility of linear programming is due to the ease at which constraints can be incorporated into the linear programming model.
2	Optimizing profit with the linear programming model: A focus on Golden plastic industry limited, Enugu, Nigeria	Benedict I. Ezema, Ozochukwu Amakon ,2012	The problem of industries all over the world is a result of shortage of production inputs which result in low capacity utilization and consequently low outputs.
3	Application of linear programming to semi-commercial arable and fishery enterprises in Abia State, Nigeria	Igwe, K.C, C.E Onyenweaku, J.C. Nwaru ,2011	linear programming is a relevant technique in achieving efficiency in production planning, particularly in achieving increased agricultural productivity

OBJECTIVE

To find a optimum solution for maximizing the profit of a bakery in producing three types of bread loaves from the collected raw materials data using linear programming in LINGO software.

THEORY

- linear programming (LP) is a special techniques employed for the purpose of optimization
- Optimum utilization of resources in limited environment
- Obtain maximum profit out of available resources
- Linear programming determines the way to achieve best outcome.
- The technique of linear programming is used in a wide range of applications.
- decision making based on the use of limited resource is a major factor

THEORY

The general linear programming model with n decision variables and m constraints can be stated in the following form:

Optimize (max or min)$z = c_1x_1 + c_2x_2 \dots\dots + c_nx_n$

St.

$$a_{11}x_1 + a_{12}x_2 \dots\dots\dots + a_{1n}x_n(\leq, =, \geq)b_1$$
$$a_{21}x_1 + a_{22}x_2 \dots\dots\dots + a_{2n}x_n(\leq, =, \geq)b_2$$

.

.

.

$$a_{m1}x_1 + a_{m2}x_2 \dots\dots\dots + a_{mn}x_n(\leq, =, \geq)b_m$$

THEORY

- The Bakery LPP is to be solved using the LINGO software.
- LINGO was one of the first modeling language software and was released In 1994,
- LINGO software uses SIMPLEX algorithm to solve Linear Programming Problems.
- LINGO helps solve complex and long LPPs with ease.

METHODOLOGY

Following is the data collected from the bakery

Raw material	Product			Total available raw material
	Big loaf	Giant loaf	Small loaf	
Flour (kg)	0.20	0.24	0.14	200.0
Sugar (g)	0.14	0.20	0.16	160.0
Yeast (kg)	0.02	0.02	0.02	20.0
Salt (g)	0.0011	0.00105	0.00017	8.5
Wheat gluten (g)	0.000167	0.002	0.00012	15.0
Soybean oil (L)	0.015	0.021	0.0098	10.0
Profit (N)	30	40	20	

METHODOLOGY

Model formulation

- Let the quantity of big loaf to be produce = x_1
- Let the quantity of giant loaf to be produce = x_2
- Let the quantity of small loaf to be produce = x_3

From the collected data, profit contribution per unit of each bread produced by the bakery is:

- Each unit of Big Loaf = Rs 30
- Each unit of Giant Loaf = Rs 40
- Each unit of Small Loaf = Rs 20

METHODOLOGY

∴ **Formulating the equation using the given data**

$z = 30x_1 + 40x_2 + 20x_3$

In order to maximize profit, maximize the function:

MAX $z = 30x_1 + 40x_2 + 20x_3$

Subject to the Constraints:

- $0.2x_1 + 0.24x_2 + 0.14x_3 \leq 200$
- $0.14x_1 + 0.2x_2 + 0.16x_3 \leq 160$
- $0.02x_1 + 0.02x_2 + 0.02x_3 \leq 20$
- $0.0011x_1 + 0.002x_2 + 0.00017x_3 \leq 8.5$
- $0.000167x_1 + 0.002x_2 + 0.00012x_3 \leq 15$
- $0.015x_1 + 0.021x_2 + 0.0098x_3 \leq 10$
- $x_1, x_2, x_3 \geq 0$

METHODOLOGY

Converting to standard form

MAX $z = 30x_1 + 40x_2 + 20x_3 + 0s_1 + 0s_2 + 0s_3 + 0s_4 + 0s_5 + 0s_6$

ST:

$$0.2x_1 + 0.24x_2 + 0.14x_3 + s_1 = 200$$
$$0.14x_1 + 0.2x_2 + 0.16x_3 + s_2 = 160$$
$$0.02x_1 + 0.02x_2 + 0.02x_3 + s_3 = 20$$
$$0.0011x_1 + 0.002x_2 + 0.00017x_3 + s_4 = 8.5$$
$$0.000167x_1 + 0.002x_2 + 0.00012x_3 + s_5 = 15$$
$$0.015x_1 + 0.021x_2 + 0.0098x_3 + s_6 = 10$$
$$x_1, x_2, x_3, s_1, s_2, s_{3,}s_4, s_5, s_6 \geq 0$$

SOLUTION STATEGY

- LINGO codes are created by direct coding method an by compound set method .
- These method are adopted to solve the LPP in the software.
- LINGO codes are as follows:

METHOD 1

```
MODEL:

@gin(x1);
@gin(x2);
@gin(x3);

! Objective Function;

MAX= 30*x1 + 40*x2 + 20*x3 ;

!Constraints;

x1 >= 0 ;
x2 >= 0 ;
x3 >= 0 ;
0.2*x1 + 0.24*x2 + 0.14*x3 <= 200 ;
0.14*x1 + 0.20*x2 + 0.16*x3 <= 160 ;
0.02*x1 + 0.02*x2 + 0.02*x3 <= 20 ;
0.0011*x1 + 0.00105*x2 + 0.00017*x3 <= 8.5 ;
0.000167*x1 + 0.002*x2 + 0.00017*x3 <= 1.5 ;
0.015*x1 + 0.021*x2 + 0.0098*x3 <= 10 ;
```

```
Model:

Title Bakery Problem ;

SETS:

product/1..3/:prod,x;
resource/1..6/:res;
material(resource,product):a;

endsets

[objective]max=@sum(product(j):prod(j)*x(j));
@for(resource(i): [Resource_constraints]
@sum(product(j):a(i,j)*x(j))<=res(i));

@for (product(i): @gin(x(i))) ;

Data:

prod = 30, 40, 20;
res = 200, 160, 20, 8.5, 15, 10 ;

a= 0.2 0.24 0.14
0.14 0.20 0.16
0.02 0.02 0.02
0.0011 0.00105 0.00017
0.000167 0.002 0.00012
0.015 0.021 0.0098 ;

enddata

end
```

METHOD 2

Raw material	Product			Total available raw material
	Big loaf	Giant loaf	Small loaf	
Flour (kg)	0.20	0.24	0.14	200.0
Sugar (g)	0.14	0.20	0.16	160.0
Yeast (kg)	0.02	0.02	0.02	20.0
Salt (g)	0.0011	0.00105	0.00017	8.5
Wheat gluten (g)	0.000167	0.002	0.00012	15.0
Soybean oil (L)	0.015	0.021	0.0098	10.0
Profit (N)	30	40	20	

RESULT

The above linear programming problem was solved using LINGO software, which gives an optimal solution of:

$X_1 = 38.0$
$X_2 = 0.0$
$X_3 = 962.0$

$Z = 20380.0$

SOLUTION OF METHOD 1

```
LINGO/WIN64 19.0.32 (3 Dec 2020 ), LINDO API 13.0.4099.242

Licensee info: Eval Use Only
License expires:  2 SEP 2021

Global optimal solution found.
Objective value:                              20380.00
Objective bound:                              20380.00
Infeasibilities:                              0.000000
Extended solver steps:                               0
Total solver iterations:                             2
Elapsed runtime seconds:                          0.06

Model Class:                                      PILP

Total variables:                      3
Nonlinear variables:                  0
Integer variables:                    3

Total constraints:                   10
Nonlinear constraints:                0

Total nonzeros:                      24
Nonlinear nonzeros:                   0


                              Variable           Value        Reduced Cost
                                    X1        38.00000           -30.00000
                                    X2        0.000000           -40.00000
                                    X3        962.0000           -20.00000

                                   Row    Slack or Surplus      Dual Price
                                     1        20380.00            1.000000
                                     2        38.00000            0.000000
                                     3        0.000000            0.000000
                                     4        962.0000            0.000000
                                     5        57.72000            0.000000
                                     6       0.7600000            0.000000
                                     7        0.000000            0.000000
                                     8        8.294660            0.000000
                                     9        1.330114            0.000000
                                    10       0.2400000E-02        0.000000
```

SOLUTION OF METHOD 2

```
LINGO/WIN64 19.0.32 (3 Dec 2020 ), LINDO API 13.0.4099.242

Licensee info: Eval Use Only
License expires:  2 SEP 2021

Global optimal solution found.
Objective value:                              20380.00
Objective bound:                              20380.00
Infeasibilities:                              0.000000
Extended solver steps:                               0
Total solver iterations:                             2
Elapsed runtime seconds:                          0.06

Model Class:                                      PILP

Total variables:                     3
Nonlinear variables:                 0
Integer variables:                   3

Total constraints:                   7
Nonlinear constraints:               0

Total nonzeros:                     21
Nonlinear nonzeros:                  0



Model Title: Bakery Problem
```

Model Title: Bakery Problem

Variable	Value	Reduced Cost
PROD(1)	30.00000	0.000000
PROD(2)	40.00000	0.000000
PROD(3)	20.00000	0.000000
X(1)	38.00000	-30.00000
X(2)	0.000000	-40.00000
X(3)	962.0000	-20.00000
RES(1)	200.0000	0.000000
RES(2)	160.0000	0.000000
RES(3)	20.00000	0.000000
RES(4)	8.500000	0.000000
RES(5)	15.00000	0.000000
RES(6)	10.00000	0.000000
A(1, 1)	0.2000000	0.000000
A(1, 2)	0.2400000	0.000000
A(1, 3)	0.1400000	0.000000
A(2, 1)	0.1400000	0.000000
A(2, 2)	0.2000000	0.000000
A(2, 3)	0.1600000	0.000000
A(3, 1)	0.2000000E-01	0.000000
A(3, 2)	0.2000000E-01	0.000000
A(3, 3)	0.2000000E-01	0.000000
A(4, 1)	0.1100000E-02	0.000000
A(4, 2)	0.1050000E-02	0.000000
A(4, 3)	0.1700000E-03	0.000000
A(5, 1)	0.1670000E-03	0.000000
A(5, 2)	0.2000000E-02	0.000000
A(5, 3)	0.1200000E-03	0.000000
A(6, 1)	0.1500000E-01	0.000000
A(6, 2)	0.2100000E-01	0.000000
A(6, 3)	0.9800000E-02	0.000000

Row	Slack or Surplus	Dual Price
OBJECTIVE	20380.00	1.000000
RESOURCE_CONSTRAINTS(1)	57.72000	0.000000
RESOURCE_CONSTRAINTS(2)	0.7600000	0.000000
RESOURCE_CONSTRAINTS(3)	0.000000	0.000000
RESOURCE_CONSTRAINTS(4)	8.294660	0.000000
RESOURCE_CONSTRAINTS(5)	14.87821	0.000000
RESOURCE_CONSTRAINTS(6)	0.2400000E-02	0.000000

CONTD.

INTERPRETATION OF RESULT

From the solution, we can infer that:

- About 38 units of Big Loaf
- 0 units of Giant Loaf
- And about 962 units of Small loaf
- Are required to yield a maximum profit of Rs.20380

CONCLUSION

Based on the analysis carried out in this research work and the result shown, the bakery should produce the three sizes of bread (big loaf, giant loaf and small loaf) in order to satisfy customers.

Small loaf and big loaf should be produce in order to attain maximum profit, because they contribute mostly to the profit earned by the company.

REFERENCE

- Akpan., N. P.,Iwok., I.A.,2016.Application of Linear Programming for Optimal Use of Raw Materials in Bakery. Volume 4 Issue 8,PP-51-57
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- Igwe, K.C, C.E Onyenweaku, J.C. Nwaru (2011). Application of linear programming to semi-commercial arable and fishery enterprises in Abia State, Nigeria. International Journal of Economics and Management sciences vol. 1, no. 1.
- LINGO FILES: https://drive.google.com/drive/folders/1SGQdqHyaP2jLHNlZ4zRrEJ3ps-_Jg5vT?usp=sharing

THANK YOU

Any Questions?