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Optimize the Tea Production of Dunkeld Tea Factory Using Goal Programming Approach

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Abstract:- Tea production is one of the main income resources of Sri Lanka. There are 896 tea estates situated in Sri Lanka. Dunkeld tea estate located in Nuwara Eliya district, which has 21 tea estates in total. In this study a step has been taken to develop a mathematical model to optimize the tea production of Dunkeld tea estate. A brief introduction to Goal Programming given in the model. The mathematical model mainly targeted profit, expenditure, production and supply. All the expected values were decided by the factory management. This model can be applied for other industries which have similar environmental situations.

Keywords:- *Optimization, Tea Estates, Goal Programming, Mathematical Model, Sri Lanka, Production.*

I. INTRODUCTION

Sri Lanka, formerly known as Ceylon, is an island 65,610sq.km situated four degrees north of the equator; ascend from level to approximately 2400 meters above the sea level.

Dunkeld is a tea estate situated in Hatton a major commercial city involved in tea production in upcountry of Sri Lanka approximately 1301 meters above the sea level. When we recap the recent history of the Dunkeld estate it was owned by Chandana William in 2008 and the ownership changed in 2009 to Muthusamy who is the owner of Harrington Organic Tea Estate, Dambulla. Under the new management Dunkeld faced heavy losses due to the increase in cost. Muthusamy then sold 51% of the Dunkeld Tea Estate shares to Dilmah one of the market leaders in tea business. At present field expenses are borne by Muthusamy and whereas the factory sector expenses are borne by Dilmah. As per sources there are 8 brokers buying the tea produced at Dunkeld Tea Factory.

II. OVERVIEW OF GOAL PROGRAMMING

Goal programming was introduced in 1961 by Charnes and Cooper. In 1965 Ijiri brought it to a usable point, employing a generalized inverse technique to obtain solutions. In 1968.

Contini considered Goal Programming under conditions of uncertainty, while in the same year Jaaskelainen applied it to aggregate production planning. More recently, Goal Programming can be applied in other areas, including industries, financial, academic, media etc. much of this use is due to a book by Sang Lee entitled “Goal Programming for Decision Analysis” and computer programs developed by Lee and Jaaskelainen.

Linear programming is a mathematical method for maximizing profit or minimizing cost subject to certain constraints or limitations. The concept of goal programming is different from linear programming, here deviation between goals and targets to be achieved with given limitations are minimized. These deviations are known as slack variables.

The general Goal Programming model can be expressed as

$$MinZ = d^- + d^+$$

- *Subject to:*

$$f(x) + d^- + d^+ = g_i$$

$$\sum_{j=1}^{n} a_{ij} \times x_j \leq b_i \ , \ \ i = 1,2, \ldots \ldots, m$$

$$x_j \geq 0, d^- \geq 0, d^+ \geq 0$$

Here g_i is the goal which is expected from the objective functions.

$f(x) = \sum_{j=1}^{n} c_j x_j$ to achieve as closely as possible subject to the given constraints.

III. LITERATURE REVIEW

Application of goal programming was studied by different researchers. Banashri Sinha and Nabendu Sen developed a mathematical model using goal programming to optimize the tea production of tea industry of Barak Valley of Assam. Moreover, Suresh Chand Sharma, Devendra Singh Hade, Sanjay Kumar Bansal and Shilpa Bafna formulated a goal programming model to optimize the environmental risk production in dairy production system. In the other hand some researchers developed model using the concept mixed goal programming. Thierauf et al developed a mixed goal programming model to optimize the production planning. Similar concept followed by M. E. Nja and G. A. Udofia in flour producing companies. Some researchers used this concept in various industries. Vivekandan et al came up with a model to analyze the cropping pattern of a certain region.

➢ *Objectives of the Study*

The management of Dunkeld tea factory mainly targeted a better return; at the same time, they restricted some resources. In this study profit, expenditure, production and supply are decided to be the main objective. Meanwhile production area, inventory space, financial commitment and human and physical resources are restricted by factory management. Considering the above expectations and limitations, a mathematical model which can meet the objectives is desired to be developed in a gainful way for the management of the gardens.

➢ *Source of Data*

Monthly wise data from January 2013 to December 2014 collected from Dunkeld tea factory are used for this study.

IV. METHODOLOGY

A. Normality Test

Some statistical procedures are heavily dependent on the assumption of normality, and in case, one can verify that this assumption is questionable. These procedures should be avoided. It is therefore useful to have techniques available that can verify the validity of the normality assumption.

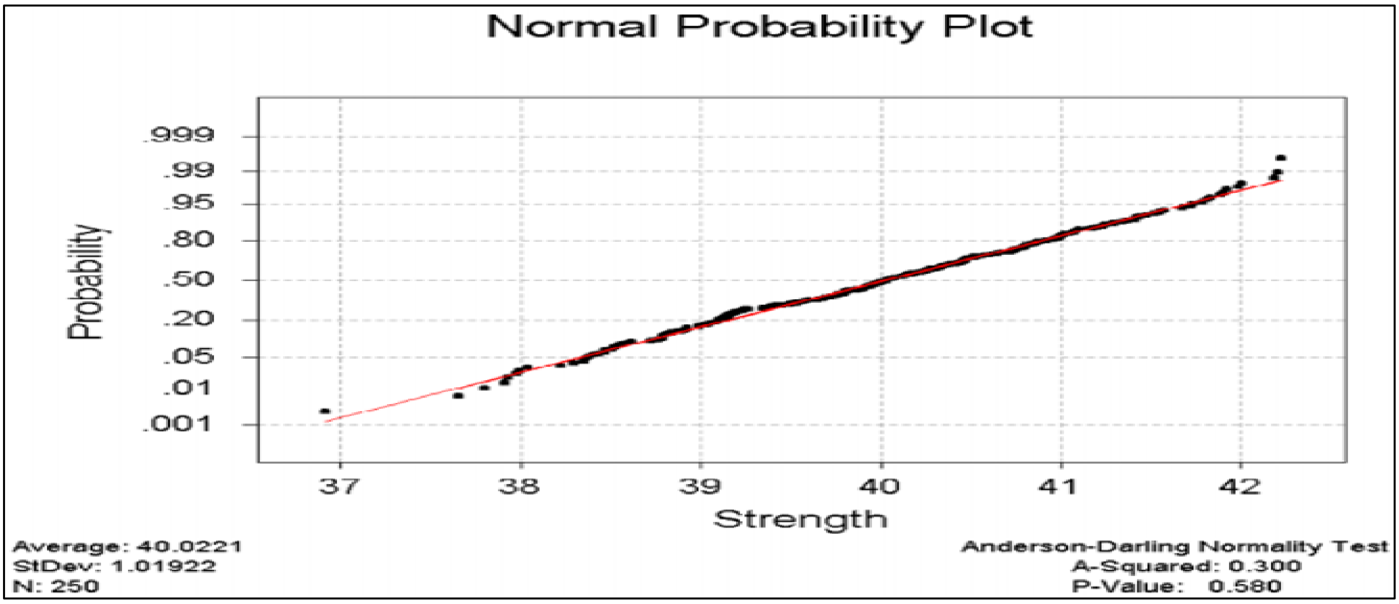

Fig 1: Sample of Normal Probability Plot

Figure 1 shows a sample of a normal distribution graph. If the P-Value associated with Anderson – Darling test is equal or greater than 0.05 means that data is normal with 95% of confidence.

B. Anderson – Darling Statistic

The Anderson – Darling Statistic measure how well the data follow a particular distribution. For a specified data set and distribution, the better the distribution fits the data, the smaller this statistic will be. For example, you can use the Anderson - Darling statistic to determine whether data meets the assumption of normality for a t – test.

C. Confidence Interval

Confidence intervals provide more information than point estimates. Confidence intervals for means are intervals constructed using a procedure that will contain the population mean a specified proportion of the time, typically either 95% or 99% of the time. These intervals are referred to as 95% and 99% confidence intervals respectively.

D. Hypothesis Test (T – Test)

A statistical hypothesis is an assumption or a statement which may or may not be true concerning one or more populations. The purpose of hypothesis testing is to choose between two conflicting hypotheses about the value of a population parameter.

➢ *There are Three Types of T-Tests:*

- T-Test for one sample
- T-Test for dependent samples
- T-Test for independent samples

When a T-Test is used to determine whether the two sample means of two independent samples come from the same population, we use the statistical test called the T-Test for independent means. This is the most common T-Test used in science. The formula for calculating “t” depends upon whether the two samples being compared have equal variances. The null and alternative hypotheses for this type are:

- $H_0: m_1 = m_2$; the means are equal
- $H_1: m_1 \leq or \geq m_2$; the means are different

This is a two-tailed test because the null hypothesis does not specify a direction, only the condition of equality.

- *The Assumptions are:*

- The data are normal
- The two samples come from distributions that may differ in their mean value, but not in the standard deviation.
- Observations are independent of each other.

V. PRELIMINARY RESULTS AND DISCUSSIONS

In this preliminary analysis part, the behavior of the data is described. For this study the data from January 2013 to December 2014 are taken for the analysis. Dunkeld tea factory produces 6 types of tea grades. They are B.O.P.F, B.O.P, Fanings, Dust 1, Dust. Profits, production and expenditure are considered as soft constraints variables.

Table 1: Average Profit

Tea Grade	Mean
B.O.P	33.41
B.O.P.F	47.50
Fanings	30.29
Dust 1	48.33
Dust	-72.54

From table 1, it is clear that the factory is making more profit from B.O.P.F and Dust 1 and the factory is facing loss from producing Dust. Next the above data values are checked for normality.

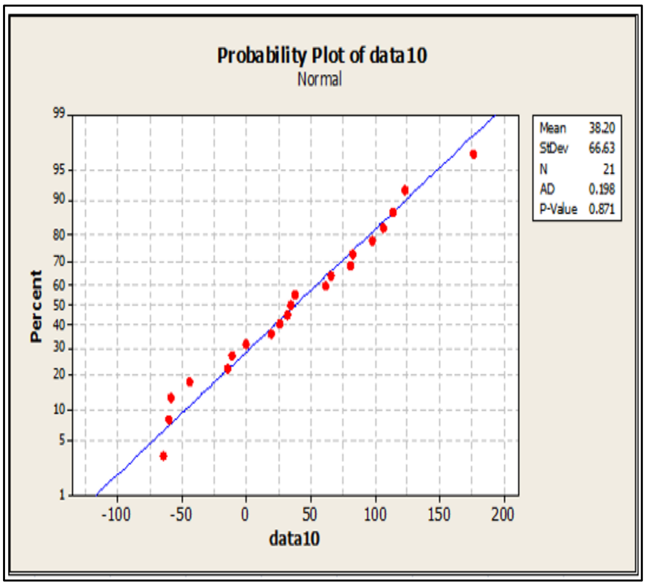

Fig 2: Normality Test for Profit (B.O.P)

Figure 2 gives the normality test of B.O.P. Here the P-Value is greater than 0.05. Therefore, this is a normal distribution. Confidence interval for the profit B.O.P is between 8.2552 and 59.7848. Finally T-Test used to finalize the profit value for B.O.P. So here P-value is between 0.05 – 0.10. Therefore, we can take the average 33.41 as our profit of B.O.P. Same procedure followed for other tea grades and for other soft constraints variables.

Table 2: Average Values for Profit and Expenditure

Tea Grade	Profit (per Kg)	Expenditure (Per Kg)
B.O.P	33.41	394.28
B.O.P.F	47.50	394.28
Fanings	30.29	394.28
Dust 1	48.33	394.28
Dust	-72.54	394.28

VI. DEVELOPING GOAL PROGRAMMING MODEL

- *Step 01: Defining the Decision Variables*

- Quantity of B.O.P grade of tea produced per month = x_1
- Quantity of B.O.P.F grade of tea produced per month = x_2
- Quantity of Fanings grade of tea produced per month = x_3
- Quantity of Dust 1 grade of tea produced per month = x_4
- Quantity of Dust grade of tea produced per month = x_5

- *Step 02: Defining the Soft Constraints (Target to be Achieved is)*

- Profit: $33.41x_1 + 47.50x_2 + 30.29x_3 + 48.33x_4 - 72.54x_5 + P_1 - n_1 = \alpha$
- Production: $x_1 + x_2 + x_3 + x_4 + x_5 + P_2 - n_2 = \beta$
- Expenditure: $394.28(x_1 + x_2 + x_3 + x_4 + x_5) + P_3 - n_3 = \gamma$

- *Suppy:*

$$x_1 + P_4 - n_4 = \delta$$
$$x_2 + P_5 - n_5 = \varepsilon$$
$$x_3 + P_6 - n_6 = \eta$$
$$x_4 + P_7 - n_7 = \lambda$$
$$x_5 + P_8 - n_8 = \mu$$

Here $\alpha, \beta, \gamma, \delta, \varepsilon, \eta, \lambda, \mu$ are the target values. These target values are decided by the decision maker.

➢ *Step 03: Defining the Hard Constraints*

- *Inventory Space:*

$$\left(\frac{0.01}{50}\right)x_1 + \left(\frac{0.01}{58}\right)x_2 + \left(\frac{0.01}{45}\right)x_3 + \left(\frac{0.01}{65}\right)x_4 + \left(\frac{0.01}{65}\right)x_5 \leq 424.85$$

➢ *Step 04: Deviational Variables of the Soft Constraints*

- Underachievement of soft constraints $= P_i$
- Overachievement of soft constraints $= n_i$

➢ *Step 05: Defining the Objective Function*

$$MinZ = W_1\left(\frac{P_1}{\alpha}\right) + W_2\left(\frac{P_2}{\beta}\right) + W_3\left(\frac{n_3}{\gamma}\right) + W_4\left(\frac{P_4}{\delta}\right) + W_5\left(\frac{P_5}{\varepsilon}\right) + W_6\left(\frac{P_6}{\eta}\right) + W_7\left(\frac{P_7}{\lambda}\right) + W_8\left(\frac{P_8}{\mu}\right)$$

$W_i =$ Penalties of each soft constraints; $i = 1,2,\ldots,8$

➢ *Entire Model:*

$$MinZ = 0.08\left(\frac{P_1}{\alpha}\right) + 0.2\left(\frac{P_2}{\beta}\right) + 0.06\left(\frac{n_3}{\gamma}\right) + 0.1\left(\frac{P_4}{\delta}\right) + 0.05\left(\frac{P_5}{\varepsilon}\right) + 0.17\left(\frac{P_6}{\eta}\right) + 0.17\left(\frac{P_7}{\lambda}\right) + 0.17\left(\frac{P_8}{\mu}\right)$$

- *Subject to:*

✓ $33.41x_1 + 47.50x_2 + 30.29x_3 + 48.33x_4 - 72.54x_5 + P_1 - n_1 = \alpha$
✓ $x_1 + x_2 + x_3 + x_4 + x_5 + P_2 - n_2 = \beta$
✓ $394.28(x_1 + x_2 + x_3 + x_4 + x_5) + P_3 - n_3 = \gamma$
✓ $x_1 + P_4 - n_4 = \delta$
✓ $x_2 + P_5 - n_5 = \varepsilon$
✓ $x_3 + P_6 - n_6 = \eta$
✓ $x_4 + P_7 - n_7 = \lambda$
✓ $x_5 + P_8 - n_8 = \mu$
✓ $\left(\frac{0.01}{50}\right)x_1 + \left(\frac{0.01}{58}\right)x_2 + \left(\frac{0.01}{45}\right)x_3 + \left(\frac{0.01}{65}\right)x_4 + \left(\frac{0.01}{65}\right)x_5 \leq 424.85$
✓ $x_1, x_2, x_3, x_4, x_5 \geq 0$

The developed model can be validated with data available from respective tea industry. The manual calculation for the solution to the model may not be very easy. So, the use of Microsoft excel, LINGO, etc. will be of immense help. In my study I have chosen Microsoft excel to solve the model.

Therefore, table 1 represents the range of the target values

Table 3: The Range of the Target Values

	Target Value
B.O.P	5,207
B.O.P.F	9,515
Fanings	3,275
Dust 1	4,133
Dust 2	3,133
Total Production	27,962
Total Expenditure	10,852,672.23
Total Profit	714,412.47

VII. CONCLUSION

The model has been developed by considering past 5-year data set of supply, profit, production, expenditure, inventory space of the tea factory. In this study all the target values were assigned by the tea factory management. This mathematical module can be more accurate if we extend the data collection period. Moreover, the module can be improved by considering other constraints.

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