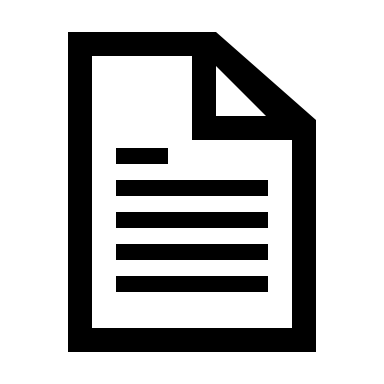
** INTRODUCTION**

The paper mill produces paper rolls of varying widths and costs. The mill sells these paper rolls to newspaper agencies after cutting them to the widths demanded in the order. Table 1 shows the widths and costs of the paper rolls produced.

The numbers are substituted by my Student ID: 20492770.

A = 4, B = 9, C = 2

|  |  |  |
| --- | --- | --- |
| Width (feet) | Icon  Description automatically generated | Icon  Description automatically generated |
| Cost per roll (pounds) | 635 | 1190 |

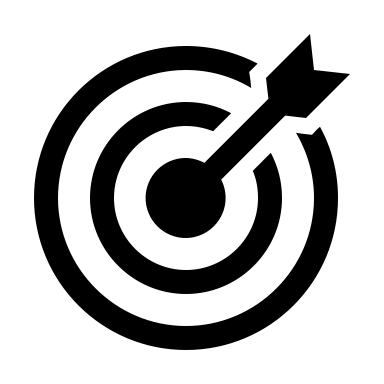
Table : Paper rolls produced by the mill and respective costs

Recently, the mill received an order from one of the newspaper agencies for several rolls to be produced in various widths. Table 2 contains all the necessary information regarding this order, including the specific widths and quantities of the rolls that are to be produced.

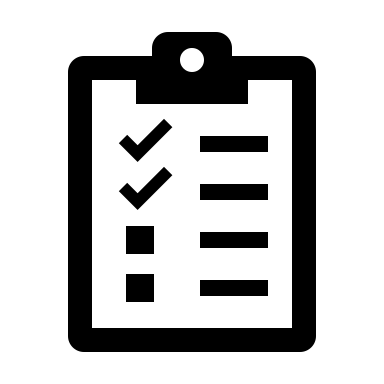
|  |  |  |  |
| --- | --- | --- | --- |
| Width (feet) | Icon  Description automatically generated | Icon  Description automatically generated | Icon  Description automatically generated |
| Number of rolls | 650 | 2430 | 1470 |

Table : Paper rolls ordered

To fulfil this order from the newspaper agency, the mill is looking to analyse and determine the most efficient method for producing and cutting the paper rolls, which helps them reduce the cost price as much as possible.

** FORMULATING LP MODEL**

For the analysis, we will be formulating a linear programming model. We will first define the decision variables, the objective function and the constraints that help us converge at an optimum solution.

 DECISION VARIABLES

In order to formulate our model, we have to first define our decision variables. Since we want to identify different combinations to cut the paper rolls produced,

Let denote the decision variables.

Where is the roll produced by the paper mill. (When = 1, roll used is 14ft and = 2, roll used is 21ft)

And, is the possible way to cut a paper roll.

And since the minimum width of a paper roll ordered is 4ft, we will only be considering combinations that do not waste more than 3ft width of the roll. Using combinations that waste more than 4ft will only increase the expenditure and will not be useful ways to cut.

Table 3 describes all such available ways and also wastage details produced by these combinations. And Figure 1 is a graphical representation of the same.

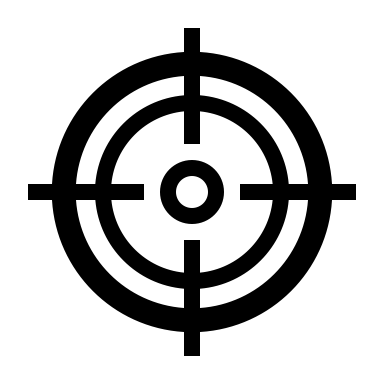
|  |  |  |  |
| --- | --- | --- | --- |
| Decision variable | Cut method | Roll used (feet) | Wastage (feet) |
|  | 12’ | 14 | 2 |
|  | 9’ + 4’ | 14 | 1 |
|  | 4’+ 4’ + 4’ | 14 | 2 |
|  | 12’ + 9’ | 21 | 0 |
|  | 9’ + 9’ | 21 | 3 |
|  | 9’ + 4’ + 4’ + 4’ | 21 | 0 |
|  | 4’ + 4’ + 4’ + 4’ + 4’ | 21 | 1 |
|  | 12’ + 4’ + 4’ | 21 | 1 |

Table : Decision variables

Chart, bar chart

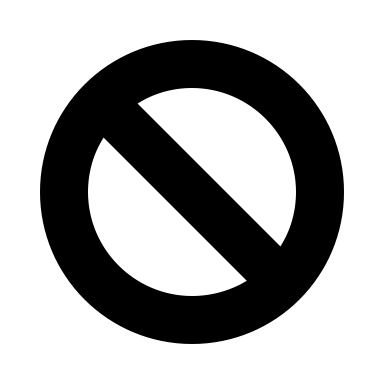
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Figure : Possible ways to cut (decision variables)

 THE OBJECTIVE FUNCTION

Now, the objective is to find the number of rolls to cut in these different combinations which minimize the expenditure. So the objective function, by referring to Table 1 and Table 3, is given by:

→

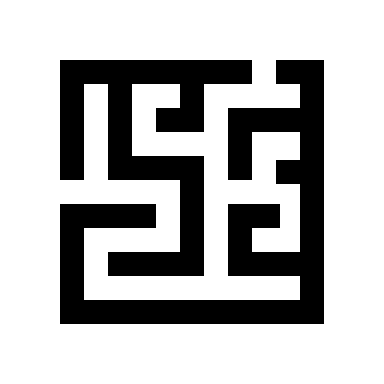
 CONSTRAINTS

Constraints are the demands of the order made by the newspaper agency. So we have to identify how many ordered rolls each combination of cutting the production roll will provide and equate it to the demand. Using Table 2 and Table 3, the constraints can be defined as given in Table 4.

|  |  |
| --- | --- |
| 4ft demand |  |
| 9ft demand |  |
| 12ft demand |  |

Table : Constraints

Also all .

 **SOLVING THE MODEL**

Now that the model, i.e., the objective function and constraints are formulated, we can input these equations to excel and use the solver to analyse the combinations that meet the demand with the minimum cost incurred. Figure 2 indicates a screenshot from excel with all the details input and the minimum cost calculated.

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Figure : Excel screenshot

As denoted by Figure 2, the minimum cost required to meet the demand is **£2,346,500**. The optimal way to cut the rolls to achieve this as given by the figure is indicated in Table 5.

|  |  |  |
| --- | --- | --- |
| Width of roll (feet) | Cut method | Number of rolls |
| 14 | 9’ + 4’ | 650 |
| 21 | 12’ + 9’ | 1470 |
| 21 | 9’ + 9’ | 155 |

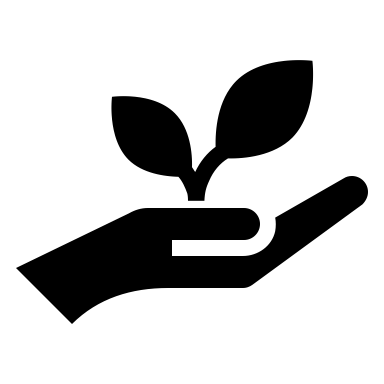
Table : Optimum solution combinations

There is no overproduction using this method, but there is wastage produced as indicated by Table 6. The total wastage is 1115 feet of paper.

|  |  |  |
| --- | --- | --- |
| Way to cut | Wastage (feet) | Number of rolls |
| 9’ + 4’ | 1 | 650 |
| 9’ + 9’ | 3 | 155 |

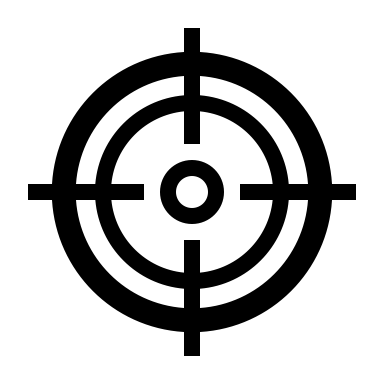
Table : Wastage

For sensitivity analysis and answer report, refer appendix.

 **SUSTAINABILITY**

The paper mill is very concerned at finding sustainable ways to meet demands. It is interested to reduce wastage before finding the minimum expenditure required to meet the demand. We can analyse this using goal programming technique by prioritising minimizing waste over minimizing cost.

Let us first minimize wastage and overproduction as the first goal. We should define the new objective function.

 ALTERNATE OBJECTIVE FUNCTION

Now, we will refer to Table 3 to minimise wastage. The total wastage is given by,

→

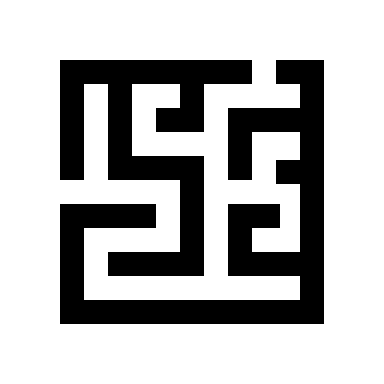
Calculating overproduction is given by the sum of overproduction of each roll given by,

To optimise, we should find the minimum of:

Where is the under-achievement of the goal and is the over achievement.

So the objective is to minimise over-achievement:

SOLVING MINIMUM WASTAGE



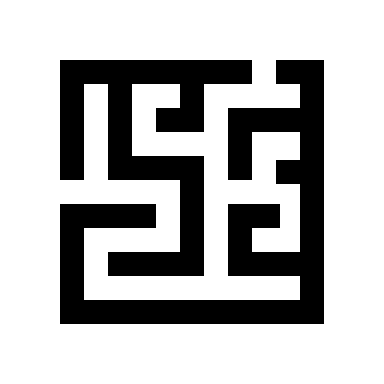
Constraints remain the same as before.

But unfortunately, solving the first goal in excel will give show us that the optimum wastage amount cannot be reduced any more than previously calculated while reducing cost, i.e. a wastage of **1115 feet**. Figure 3 provides an excel screenshot of goal 1 optimisation.

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Figure : Goal programming goal 1

 SOLVING MINIMUM COST

The objective function for minimum cost is the same as before. Now we will introduce under and over-achievement for this as respectively.

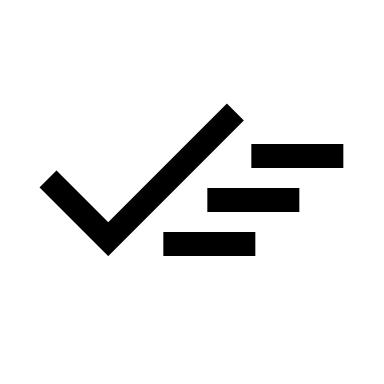
And then again minimise the over-achievement:

Since the minimum wastage is the same as the one produced by the minimum cost optimum solution, minimising the cost after goal 1 will provide the same result as **£ 2,346,500**. This is depicted in Figure 4.

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Figure : Goal programming - goal 2

** CONCLUSION**

Using this linear programming technique, the paper mill can now be sure of taking a decision on their business plan and preparing an estimated cost and profit margins. They can meet the requirement of the demand by the newspaper agency with a minimum cost of **£ 2,346,500** and a wastage of **1115 feet.** The detailed excel file is attached in the appendix section for any further analysis required, including sensitivity reports.

**APPENDIX**

**Solving for minimum cost excel screen shot:**

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**Answer report for minimum cost analysis:**

Table

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**Sensitivity report for minimum cost analysis:**

Table

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**Goal programming excel screenshot:**

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