**OPTIMIZATION**

**Group Assignment**

**Group 6**

|  |  |
| --- | --- |
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**Q1.**

**Farm Owner in** **Des Moines, Iowa**

**A. Objective:**

The objective is to maximize the profit per acre from the cultivation of crops on the two farms owned by the farmer in Des Moines, Iowa. The farm owner wants to determine the optimal allocation of land for each crop on each farm to maximize the total profit. The objective is to maximize the total profit generated by the crops planted on the farms by finding the optimal allocation of land to each crop, considering the maximum acreage restrictions and the seasonal demand for each crop.

**B. Optimal Solution:**

Profit is maximized at US$ 639,833

The optimal production allocation of acreage for each crop on both farms is as follows:

|  |  |  |
| --- | --- | --- |
|  | **Farm 1** | **Farm 2** |
| **Corn** | 547 | Do Not Produce |
| **Wheat** | 250 | 300 |
| **Bean** | 203 | 200 |
| **Cotton** | 250 | 350 |

**C. Binding and Non-Binding Constraints:**

Binding Constraints: The following constraints are binding, meaning the allocation was fully utilized.

|  |  |
| --- | --- |
| **Name** | **Constraints** |
| Acres of Land Available for Cultivation in Farm 2 | 850 |
| Maximum Crop Acreage Allowed for Wheat in Farm 2 | 300 |
| Maximum Crop Acreage Allowed for Bean in Farm 2 | 200 |
| Maximum Crop Acreage Allowed for Cotton in Farm 2 | 350 |
| Maximum Storage Available | 2,100 |
| Wheat and Bean Proportion to be Equal to Maximum Acreage Restrictions | 0.73 |
| Demand of Wheat | 550 |
| Demand of Cotton | 600 |

Non-Binding Constraints: The following constraints are non-binding, meaning the allocation was withing the limit but not fully utilized.

|  |  |
| --- | --- |
| **Name** | **Constraints** |
| Acres of Land Available for Cultivation in Farm 1 | 1,250 |
| Maximum Crop Acreage Allowed for Corn in Farm 1 | 547 |
| Maximum Crop Acreage Allowed for Wheat in Farm 1 | 250 |
| Maximum Crop Acreage Allowed for Bean in Farm 1 | 203 |
| Maximum Crop Acreage Allowed for Cotton in Farm 1 | 250 |
| Maximum Crop Acreage Allowed for Corn in Farm 2 | 0 |
| Demand of Corn | 547 |
| Demand of Bean | 403 |

**D. Slack & Surplus:**

Slack or Surplus refers to the difference between the LHS value and the RHS value of a constraint, which helps provide insight into the utilization or availability of resources and indicates the extent to which the constraint is satisfied. The presence of Slack or Surplus corresponds to non-binding constraints.

Slack values represent the amount by which the constraints can be relaxed. These values depict constraints that are not fully utilized, and that resources or conditions are available beyond the minimum used.

|  |  |
| --- | --- |
| **Name** | **Slack/ Unutilized Resource** |
| Acres of Land Available for Cultivation in Farm 1 | 200 |
| Maximum Crop Acreage Allowed for Corn in Farm 1 | 3 |
| Maximum Crop Acreage Allowed for Wheat in Farm 1 | 200 |
| Maximum Crop Acreage Allowed for Bean in Farm 1 | 147 |
| Maximum Crop Acreage Allowed for Cotton in Farm 1 | 150 |
| Maximum Crop Acreage Allowed for Corn in Farm 2 | 250 |

Surplus represents the amount by which the constraint is violated or over-utilized. In this case, demand of corn is 450 acres, however optimally 547 acres should be cultivated.

|  |  |
| --- | --- |
| **Name** | **Surplus/ Overutilized Resource** |
| Demand of Corn | 97 |
| Demand of Bean | 3 |

**E. Sensitivity Analysis:**

Variables in Objective Function:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Variables** | **Optimal Production** | **Reduced Cost** | **Net Profit** | **Allowable Increase** | **Allowable Decrease** | ***Lower Limit*** | ***Upper Limit*** |
| **Corn in Farm 1** | 547 | 0 | 400 | 30 | 0 | *400* | *430* |
| **Wheat in Farm 1** | 250 | 0 | 300 | 0 | 1E+30 | *-∞* | *300* |
| **Bean in Farm 1** | 203 | 0 | 200 | 0 | 1E+30 | *-∞* | *200* |
| **Cotton in Farm 1** | 250 | 0 | 250 | 0 | 1E+30 | *-∞* | *250* |
| **Corn in Farm 2** | 0 | 0 | 430 | 0 | 30 | *400* | *430* |
| **Wheat in Farm 2** | 300 | 0 | 330 | 1E+30 | 0 | *330* | *∞* |
| **Bean in Farm 2** | 200 | 0 | 230 | 1E+30 | 0 | *230* | *∞* |
| **Cotton in Farm 2** | 350 | 0 | 280 | 1E+30 | 0 | *280* | *∞* |

(i) Reduced Cost:

Reduced Cost represents the amount by which the Objective Coefficient of a variable can be increased without changing the optimal solution.

The objective here is to maximize the net profit per acre from cultivation and sale of various crops. The Reduced Cost provides insights into the sensitivity of the model's optimal solution to changes in net profit of the crops produced. If the Reduced Cost of the crops is positive, it implies that increase in the net profit from sale of crops produced by some amount would improve the objective function.

The Reduced Cost of all the crops is zero, which means that the present net profit is already at an optimal level. An increase in net profit will not change the proposed optimal production level. This is favourable, since at current production, there is a scope to earn more profit.

Also, the production of Corn in Farm 2 is 0. Its corresponding Reduced Cost is also 0, which also emphasizes that the net profit is already optimal and no negotiation is necessary, since increasing it will not change the optimal production plan.

(ii) Allowable Increase:

This refers to the maximum amount by which the net profit of certain crops can be increased while keeping the current optimal solution unchanged.

All other crops in Farm 1 except Corn have an Allowable Increase of 0 which means that there is no scope in increasing net profit without affecting the optimality of the current solution. The same is true for Corn in Farm 2.

Corn in Farm 1 on the other hand, is at an Optimal Production of 547 acres, a Reduced Cost of 0, and it earns a profit of USD$ 400. The allowable increase for this variable is US$ 30. This means that even if the net profit earned from Corn in Farm 1 increases by up to US$ 30, it will not affect the optimality of the solution.

Corn in Farm 1, Wheat, Bean and Cotton in Farm 2 have an Allowable Increase of a very large value. This means that the scope of net profit for these crops is infinity, without having any effect on the optimality of the current solution. These are the crops that the former should target to cultivate, since at current production level, net profit earned can be infinite.

(iii) Allowable Decrease:

This refers to the maximum amount by which the net profit of certain crops can be decreased while keeping the current optimal solution unchanged.

Corn in Farm 1, Wheat, Bean and Cotton in Farm 2 have an Allowable Decrease of 0 which means that there is no scope in decreasing the net profit without affecting the optimality of the current solution. The net profit earned is already at its most minimum value, and any decrease would result in a degradation of the objective function.

Corn in Farm 2 on the other hand, is at an optimal production of 0 acres, a reduced cost of 0, and it could earn a profit of USD$ 430. The allowable decrease for this variable is US$ 30. This means net profit of Corn in Farm 2 can be decreased by up to US$ 30 without affecting the optimality of the solution. However, as per our solution Corn in Farm 2 is not cultivated at all, even though it has maximum profit among all other crops. Decreasing the net profit will make no difference.

Wheat, Bean and Cotton in Farm 1 have an Allowable Decrease of a very large value, meaning the net profit of these crops can be decreased by any amount without affecting the optimality of the current solution. However, this is not a practical in a real-case scenario.

From the Lower Limit - Upper Limit (Range) columns, it can be noted that Corn in both farms have similar ranges for net-profit, and an optimal solution can be maintained when profit for Corn is between US$400 – US$430.

Constraints:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Constraints** | **Final Value** | **Shadow Price** | **Constraint RHS** | **Allowable Increase** | **Allowable Decrease** | ***Lower Limit*** | ***Upper Limit*** |
| Acres of Land Available for Cultivation in Farm 1 | 1,250 | 0 | 1,450 | 1E+30 | 200 | *1250* | *∞* |
| Acres of Land Available for Cultivation in Farm 2 | 850 | 30 | 850 | 250 | 1.14E-13 | *-∞* | *1100* |
| Maximum Crop Acreage Allowed for Corn in Farm 1 | 547 | 0 | 550 | 1E+30 | 3 | *547* | *∞* |
| Maximum Crop Acreage Allowed for Wheat in Farm 1 | 250 | 0 | 450 | 1E+30 | 200 | *250* | *∞* |
| Maximum Crop Acreage Allowed for Bean in Farm 1 | 203 | 0 | 350 | 1E+30 | 147 | *203* | *∞* |
| Maximum Crop Acreage Allowed for Cotton in Farm 1 | 250 | 0 | 400 | 1E+30 | 150 | *250* | *∞* |
| Maximum Crop Acreage Allowed for Corn in Farm 2 | 1.14E-13 | 0 | 250 | 1E+30 | 250 | *-* | *-* |
| Maximum Crop Acreage Allowed for Wheat in Farm 2 | 300 | 0 | 300 | 1.14E-13 | 200 | *100* | *∞* |
| Maximum Crop Acreage Allowed for Bean in Farm 2 | 200 | 0 | 200 | 1.14E-13 | 147 | *53* | *∞* |
| Maximum Crop Acreage Allowed for Cotton in Farm 2 | 350 | 0 | 350 | 1.14E-13 | 150 | *200* | *∞* |
| Maximum Storage Available | 2,100 | 400 | 2,100 | 3 | 97 | *2003* | *2103* |
| Wheat and Bean Proportion to be Equal to Maximum Acreage Restrictions | 0.73 | 1,10,000 | 0 | 0 | 0 | *-* | *-* |
| Demand of Corn | 547 | 0 | 450 | 97 | 1E+30 | *-∞* | *547* |
| Demand of Wheat | 550 | -247 | 550 | 56 | 2 | *548* | *552* |
| Demand of Bean | 403 | 0 | 400 | 3 | 1E+30 | *-∞* | *403* |
| Demand of Cotton | 600 | -150 | 600 | 97 | 3 | *597* | *697* |

(i) Shadow Price:

The shadow price represents the change in the net profit for a unit increase in the Constraint RHS value. For all constraints where the shadow price is 0, this indicates that the profit does not change with an increase or decrease in the constraint value. This means that the proposed allocation is optimal.

The shadow price for Acres of Land Available for Cultivation in Farm 2 is 30, which means that for each additional acre of land available in Farm 2, the net profit will increase by US $30.

The shadow price for Demand of Wheat is -247 which suggests that each acre decrease in the demand of wheat would decrease the objective function value by US $247. This indicates that the current Wheat allocation is excessive, and reduction is servicing of demand of wheat will have a positive impact on the profit. The same applies for Demand of Cotton where shadow price is -150.

(ii) Allowable Increase:

This value represents the maximum amount by which the constraint can be increased while still maintaining feasibility. It indicates the upper limit of how much the constraint can be relaxed or expanded without causing any issues. An increase within the allowable range would not violate any resource limitations or feasibility constraints of the problem.

(iii) Allowable Decrease:

This value shows the maximum amount by which a constraint can be decreased while still keeping the problem feasible. It indicates the lower limit of how much the constraint can be tightened or reduced without causing any issues. A decrease within the allowable range would not violate any resource limitations or feasibility constraints of the problem.

***Recommendations:***

*From the above analysis, the following recommendations can be proposed to the Farm Owner.*

***Recommendation 1: Utilize Available Land***

*The farm owner has 1,450 acres available for further cultivation, but only 1,250 acres is required for him to meet the seasonal demands. The farm owner could cultivate Wheat, Bean or Cotton in the unutilised land in Farm-1 (200 acres), as this would complement the deficit (if any) of Farm 1 or Farm 2. Also, he may also utilise a portion of the 200 acres for either agriculture, dairy or poultry farming. This will help diversify the produce and generate additional revenue.*

***Recommendation 2: Evaluate Expansion Opportunities***

*The farm owner could consider expanding cultivation on Farm 1 to utilize the available resources fully. For example, the allowable increase of production for Corn in Farm 1 is in Farm 1 is not limited, and Farm 1 has excess land available which can be utilized. Thus, the farm owner could increase production of Corn in Farm 1 without affecting the requirements of supply for the seasonal demand.*

***Recommendation 3: Focus on High-Profit Crops***

*While the reduced cost values for all crops are zero, indicating that net profit is already optimized, the farm owner should prioritize crops with an allowable increase of infinity. In this case, the farm owner should focus on cultivating Wheat, Bean, and Cotton in Farm 2 to potentially increase net profits.*

*These recommendations are based on the analysis of the available data and are intended to help the farm owner maximize profits. The farm owner should carefully consider these recommendations and make the decision that is best for their business.*

**Q2.**

**Reep Construction**

*Note: Due to limitations with Excel Solver, a sensitivity report couldn't be generated when the integer constraint was included in the model. Therefore, to proceed with solving the problem, the integer constraint was removed. It's worth noting that the optimal solution obtained with and without the integer constraint remains the same.*

**A. Objective:**

The objective is to minimize the cost of meeting the monthly trucking requirements for the new project of excavation and site preparation of a new rest area on the Pennsylvania Turnpike. The objective is to find the most cost-effective leasing strategy for acquiring additional trucks, while considering both short-term and long-term leasing options.

Bob Reep, the Founder and President of Reep Construction, wants to minimize the overall cost while ensuring that his company does not lay off any employees. This means that if the short-term leasing costs are higher but allow him to utilize his own drivers and maintain his no-layoff policy, he would prefer short-term leases.

Therefore, the objective is to determine the optimal combination of short-term and long-term leases that minimizes the total cost of acquiring the required number of trucks each month, considering the monthly lease costs, driver wages, and fuel costs.

**Note:**

1. Truck requirement is as follows:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Month | Month: 1st | Month: 2nd | Month: 3rd | Month: 4th |
| Trucks Needed | 10 | 12 | 14 | 8 |
| Trucks Available | 1 | 2 | 3 | 1 |
| Trucks To Be Leased | 9 | 10 | 11 | 7 |

1. The trucks that have been leased long-term are already available for use in this project, as Reep Construction signed a term-lease agreement with PennState Leasing a year ago. Therefore, the cost associated with leasing these trucks, which amounts to US$ 600, will not be factored into our decision-making process. These costs are being incurred regardless of whether the trucks are used in this specific project.
2. Fuel cost is considered an operating expenditure and will be taken into account, regardless of whether they choose a short-term or long-term lease.
3. Likewise, driver cost is also an operating expenditure that will be factored in for both Short Term and Long Term leases. Additionally, Reep Construction is committed to upholding its no-layoff policy, which means that their own drivers will be utilized even if it leads to higher costs. This policy acts as a constraint for the long-term lease option, as the available long-term leased trucks will be used for this project. While one might assume that the company has spare drivers who could be deployed for this project, the problem does not provide any data regarding the number of available spare drivers. Therefore, this option has been disregarded. Our decision-making process will consider the solution while taking into account these various costs associated with the project.

**B. Optimal Solution:**

The Optimal Leasing Plan is as follows. Note, that we are only determining the optimal solution for Short Term Lease, since Reep Constructions the trucks leased Long Term are already available for use in this project.

|  |  |  |
| --- | --- | --- |
| **No. of Trucks** | **Month Leased In** | **Length of Lease** |
| 2 | 1st | 3 Months |
| 7 | 1st | 4 Months |
| 1 | 2nd | 2 Months |
| 1 | 3rd | 1 Month |

The final solution considering Long Term and Short Term Lease is as follows:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Month Leased In** | | **1st** | **1st** | **2nd** | **3rd** |
| **Long Term Lease** | **No. of Trucks** | 1 | 2 | 3 | 1 |
| **Short Term Lease** | **No. of Trucks** | 2 | 7 | 1 | 1 |
| **Length of Lease** | 3 Months | 4 Months | 2 Months | 1 Month |

**C. Cost of Optimal Leasing Solution**

Leasing cost is minimized at US$ 233,400

We will look at Leasing Cost from two aspects:

1. With respect to the Optimal Solution
2. With respect to project as a whole

The break-down of all costs are as follows:

|  |  |
| --- | --- |
| **Fuel Cost** | |
| Fuel Cost/ Truck | 100 |
| Days/Week | 5 |
| Week/Month | 4 |
| **Monthly Fuel Cost/ Truck** | **2000** |

|  |  |
| --- | --- |
| **Driver Cost** | |
| Cost/Hour | 20 |
| Hours/Day | 8 |
| Days/Week | 5 |
| Week/Month | 4 |
| **Driver Cost/ Truck** | **3200** |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Cost of Long Term Lease** | **No. of Trucks** | | | |
| **1** | **2** | **3** | **1** |
| Lease Cost | 600 | 600 | 600 | 600 |
| Fuel Cost | 2,000 | 2,000 | 2,000 | 2,000 |
| Driver Cost | 3,200 | 3,200 | 3,200 | 3,200 |
| **Long Term Total Cost/ Truck for Optimal Leasing Plan** | **5,200** | **5,200** | **5,200** | **5,200** |
| **Long Term Total Cost/ Truck for Project as a Whole** | **5,800** | **5,800** | **5,800** | **5,800** |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Cost of Short Term Lease** | **No. of Trucks** | | | |
| **2** | **7** | **1** | **1** |
| Month Leased In | 1st | 1st | 2nd | 3rd |
| Length of Lease | 3 Months | 4 Months | 2 Months | 1 Month |
| Total Cost/ Truck/ Month | 16,500 | 20,800 | 12,000 | 6,400 |
| **Short Term Total Cost/ Truck for Optimal Leasing Plan** | **33,000** | **145,600** | **12,000** | **6,400** |

1. With Respect to the Optimal Solution:

Optimal Cost of the Pennsylvania Turnpike Excavation Project

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| No. of Trucks Leased Long Term | 1 | 2 | 3 | 1 |
| Fuel Cost | 5,200 | 5,200 | 5,200 | 5,200 |
| No. of Trucks Leased Short Term | 2 | 7 | 1 | 1 |
| Short Term Cost Associated including Driver Cost and Fuel Cost | 16,500 | 20,800 | 12,000 | 6,400 |
| **Optimal Cost of the Pennsylvania Turnpike Excavation Project** | **233,400** |  |  |  |

Therefore, the Optimal Leasing Plan Cost is US$ 233,400

1. With respect to Project as a Whole:

The overall cost of the project will include the Long Term Lease Cost as well. This cost is calculated primarily to determine the profitability of the project. By considering the Long Term Lease Cost, we account for the fact that these trucks could have been utilized for other projects, potentially generating additional revenue by increasing productivity. However, since no specific data is available regarding the potential revenue or opportunity cost associated with using the trucks for other projects, we will exclude this factor when calculating the cost of the current project.

Therefore, the total cost of the project as a whole is US$ 237,600

**D. Binding and Non-Binding Constraints:**

Binding Constraints: The following constraints are binding, meaning the allocation was fully utilized.

|  |  |
| --- | --- |
| **Name** | **Constraints** |
| Trucks Needed in Month 1 | 10 |
| Trucks Needed in Month 2 | 12 |
| Trucks Needed in Month 3 | 14 |
| Trucks Needed in Month 4 | 8 |

The trucks requirement for each month are all binding constraints.

Non-Binding Constraints: The following constraints are non-binding, meaning the allocation was withing the limit but not fully utilized.

**E. Sensitivity Analysis:**

Variables in Objective Function:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Lease Structure** | **Short Term Lease Trucks** | **Reduced Cost** | **Total Cost/ Truck** | **Allowable Increase** | **Allowable Decrease** | ***Lower Limit*** | ***Upper Limit*** |
| Leased in the 1st Month for 1 Month | 0 | 3,900 | 6,400 | 1E+30 | 3,900 | *2,500* | *∞* |
| Leased in the 1st Month for 2 Months | 0 | 3,900 | 10,000 | 1E+30 | 3,900 | *6,100* | *∞* |
| Leased in the 1st Month for 3 Months | 2 | 0 | 12,500 | 3,900 | 1,300 | *11,200* | *16,400* |
| Leased in the 1st Month for 4 Months | 7 | 0 | 14,800 | 1,300 | 1E+30 | *-∞* | *16,100* |
| Leased in the 2nd Month for 1 Month | 0 | 2,800 | 6,400 | 1E+30 | 2,800 | *3,600* | *∞* |
| Leased in the 2nd Month for 2 Months | 1 | 0 | 10,000 | 2,800 | 3,900 | *6,100* | *12,800* |
| Leased in the 2nd Month for 3 Months | 0 | 3,800 | 12,500 | 1E+30 | 3,800 | *8,700* | *∞* |
| Leased in the 3rd Month for 1 Month | 1 | 0 | 6,400 | 1,300 | 2,800 | *3,600* | *7,700* |
| Leased in the 3rd Month for 2 Months | 0 | 1,300 | 10,000 | 1E+30 | 1,300 | *8,700* | *∞* |
| Leased in the 4th Month for 1 Month | 0 | 4,100 | 6,400 | 1E+30 | 4,100 | *2,300* | *∞* |

(i) Reduced Cost:

The Reduced Cost for each variable in represents the amount by which the Total Cost/ Truck should decrease to add a truck from that lease structure in the optimal solution.

|  |
| --- |
| **Lease Structure where the Reduced Cost is US $0** |
| Leased in the 1st Month for 3 Months |
| Leased in the 1st Month for 4 Months |
| Leased in the 2nd Month for 2 Month |
| Leased in the 3rd Month for 1 Month |

The lease structure where the Reduced Cost is US $0 means that there would be no decrease in the total cost if the one additional truck is leased with that lease structure. This variable is already at its optimal number in the current solution.

|  |  |
| --- | --- |
| **Lease Structure with some Reduced Cost** | **Reduced Cost** |
| Leased in the 1st Month for 1 Month | 3,900 |
| Leased in the 1st Month for 2 Months | 3,900 |
| Leased in the 2nd Month for 1 Month | 2,800 |
| Leased in the 2nd Month for 3 Months | 3,800 |
| Leased in the 3rd Month for 2 Months | 1,300 |
| Leased in the 4th Month for 1 Month | 4,100 |

For lease structures with some Reduced Cost, it means to add one truck from that lease structure into the optimal solution the Total Cost/ Truck will have to reduce by that many dollars.

The Reduced Cost provides important information about the sensitivity of the optimal solution to changes in the availability and cost of truck leases, and can help Reep Construction identify which lease structures are most critical to the optimal solution and which can be adjusted without significantly affecting the total cost.

(ii) Allowable Increase:

Allowable Increase indicates the maximum amount by which the Total Cost for a truck in each lease structure can increase while still maintaining the optimality of the current solution.

|  |
| --- |
| **Lease Structure where the Allowable Increase is Infinity** |
| Leased in the 1st Month for 1 Month |
| Leased in the 1st Month for 2 Months |
| Leased in the 2nd Month for 1 Month |
| Leased in the 2nd Month for 3 Months |
| Leased in the 3rd Month for 2 Months |
| Leased in the 4th Month for 1 Month |

For leases where the Allowable Increase is listed as infinity, suggests that the Total Cost/ Truck can increase without bound while still maintaining the optimality of the solution. Therefore, there are no specific restrictions on the cost increase for these lease options. However, this is not to be encouraged, since our costs have the potential to increase to no limit.

|  |  |
| --- | --- |
| **Lease Structure with some Allowable Increase** | **Allowable Increase** |
| Leased in the 1st Month for 3 Months | 3,900 |
| Leased in the 1st Month for 4 Months | 1,300 |
| Leased in the 2nd Month for 2 Months | 2,800 |
| Leased in the 3rd Month for 1 Month | 1,300 |

For leases where the Allowable Increase is listed with some value in dollars, suggests that the Total Cost/ Truck can increase only by that value while still maintaining the optimality of the solution. Any further increase will change the optimal solution. This provides Reep Construction with an upper limit while negotiating lease cost with the vendor.

(iii) Allowable Decrease:

Allowable Decrease indicates the maximum amount by which the Total Cost for a truck in each lease structure can decrease while still maintaining the optimality of the current solution. It provides insights into the flexibility and potential cost savings associated with different leasing options.

For a truck leased in the 1st Month for 4 Months, the Allowable Decrease indicates that the Total Cost/ Truck can decrease without bound while still maintaining the optimality of the solution. Therefore, there are no specific restrictions on the cost reduction for these lease options.

|  |  |
| --- | --- |
| **Lease Structure with some Allowable Increase** | **Allowable Decrease** |
| Leased in the 1st Month for 1 Month | 3,900 |
| Leased in the 1st Month for 2 Months | 3,900 |
| Leased in the 1st Month for 3 Months | 1,300 |
| Leased in the 2nd Month for 1 Month | 2,800 |
| Leased in the 2nd Month for 2 Months | 3,900 |
| Leased in the 2nd Month for 3 Months | 3,800 |
| Leased in the 3rd Month for 1 Months | 2,800 |
| Leased in the 3rd Month for 2 Months | 1,300 |
| Leased in the 4th Month for 1 Month | 4,100 |

For leases where the Allowable Decrease is listed with some value in dollars, suggests that the Total Cost/ Truck can be decreased only by that value to maintain the optimality of the solution. Any further reduction will change the optimal solution. This provides Reep Construction with an lower limit while negotiating lease cost with the vendor.

From the Lower Limit - Upper Limit columns, a range to negotiate leasing costs can be ascertained to maintain the same optimal leasing plan.

Constraints:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Constraints** | **Final Value** | **Shadow Price** | **Constraint RHS** | **Allowable Increase** | **Allowable Decrease** | ***Lower Limit*** | ***Upper Limit*** |
| Trucks Needed in Month 1 | 10 | 2,500 | 10 | 1 | 2 | *8* | *11* |
| Trucks Needed in Month 2 | 12 | 3,600 | 12 | 1 | 1 | *11* | *13* |
| Trucks Needed in Month 3 | 14 | 6,400 | 14 | 1E+30 | 1 | *13* | *∞* |
| Trucks Needed in Month 4 | 8 | 2,300 | 8 | 2 | 7 | *1* | *10* |

(i) Shadow Price:

This is the marginal value, which represents the amount of change in the Total Cost/ Truck with respect to a adding or reducing one truck from the required trucks each month.

|  |  |
| --- | --- |
| **Truck Requirement** | **Value Increase/ Decrease by Adding/ Reducing Requirement of 1 Truck** |
| Trucks Needed in Month 1 | 2,500 |
| Trucks Needed in Month 2 | 3,600 |
| Trucks Needed in Month 3 | 6,400 |
| Trucks Needed in Month 4 | 2,300 |

Shadow Prices are present for all four months. This means that if there is an increase in the number of trucks needed in any of these months by one, the cost of meeting the monthly trucking requirements would increase by that many dollars (corresponding value). Similarly, a decrease in the number of trucks needed in that month by one would result in a cost reduction by that many dollars.

(ii) Allowable Increase:

This refers to the maximum amount by which truck requirement can be increased while still maintaining the current optimal solution.

Trucks needed in Month 3 are 14, and as per the analysis the Allowable Increase is a very large value (infinity), which

indicates that the constraint on the number of trucks needed in month 3 is not binding or critical. It can be increased by any amount without affecting the optimal solution.

|  |  |
| --- | --- |
| **Truck Requirement** | **Allowable Increase** |
| Trucks Needed in Month 1 | 1 |
| Trucks Needed in Month 2 | 1 |
| Trucks Needed in Month 4 | 2 |

In the case of the above months, the Allowable Increase shows that increasing the requirements by these numbers will not affect the optimal solution. Any additional requirements over and above this limit will change the solution.

For example, if Reep Construction faces a truck break-down, and has not accounted for the same in their total requirements, they can add these many additional trucks in the corresponding months without changing the solution.

(iii) Allowable Decrease:

This refers to the maximum amount by which truck requirement can be decreased while still maintaining the current optimal solution.

|  |  |
| --- | --- |
| **Truck Requirement** | **Allowable Decrease** |
| Trucks Needed in Month 1 | 2 |
| Trucks Needed in Month 2 | 1 |
| Trucks Needed in Month 4 | 1 |
| Trucks Needed in Month 4 | 7 |

The Allowable Decrease shows that decreasing the requirements by these numbers will not affect the optimal solution. Any reduction in requirements over and above this limit will change the solution.

***Recommendations:***

*From the above analysis, the following recommendations can be proposed to the Farm Owner.*

***Recommendation 1: Cost-Benefit Analysis***

*While Reep Construction is committed to its no-layoff policy, it's crucial to conduct a cost-benefit analysis to assess the financial impact of using their own drivers versus the cost of short-term leases that include drivers. Although using their own drivers may be preferred for maintaining company policies, the analysis should consider the hourly wages of the drivers, fuel costs, and the cost difference between leasing with and without drivers. If the cost savings from short-term leases with drivers outweigh the expenses associated with using their own drivers, Reep Construction should consider adjusting their approach to align with cost-effectiveness.*

*The Optimal Leasing if no-layoff policy is removed,*

|  |  |  |
| --- | --- | --- |
| ***No. of Trucks*** | ***Month Leased In*** | ***Length of Lease*** |
| *2* | *1st* | *3 Months* |
| *8* | *1st* | *4 Months* |
| *2* | *2nd* | *2 Months* |
| *2* | *3rd* | *1 Month* |

*And the cost associated with this plan is US$ 236,200 which is higher. However, the overall project cost also comes down to US$ 236,200.*

***Recommendation 1: Contingency Planning***

*It's important for Reep Construction to have contingency plans in case of unforeseen circumstances, such as truck breakdowns or unexpected changes in project requirements. The allowable increase values provide an indication of the maximum number of additional trucks that can be added without affecting the optimal solution. Reep Construction should factor in a buffer by leasing a few extra trucks to account for potential contingencies, ensuring they have the flexibility to adapt to unexpected situations without impacting project timelines or incurring excessive costs.*