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| Photo displaying partial image of two pie charts on a canvas-textured page |
| Optimization Techniques  Group Assignment – Group 8 |
| |  |  |  | | --- | --- | --- | | Group 8 | April 22, 2018 | PGP BABI Bangalore – Section B | |

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1. **Case Study 1**

**Problem Statement**

* Find the Optimal March Shipment Schedule and its total transportation cost for each of the following:
  + Cotton
  + Polyester
  + Silk
* The company will be opening a silk-making department in the Nigeria Mill. Although it will not be completed for several months, a current capacity of 1000 bolts for that fabric might be used during March for an added one-time cost of $2000. Find the new optimal shipment schedule and the total cost for the fabric. Should the Nigeria mill process silk in March.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Mill | LA | Chicago | London | Mexico | Manila | Rome | Tokyo | NY |
| Bahamas | 2 | 2 | 3 | 3 | 7 | 4 | 7 | 1 |
| HK | 6 | 7 | 8 | 10 | 2 | 9 | 4 | 8 |
| Korea | 5 | 6 | 8 | 11 | 4 | 9 | 1 | 7 |
| Nigeria | 14 | 12 | 6 | 9 | 11 | 7 | 5 | 10 |
| Venezuela | 4 | 3 | 5 | 1 | 9 | 6 | 11 | 4 |

**Approach**

We shall solve this problem using Linear Programming techniques.

**Defining the Decision Variables**

We shall use the same decision variables for all 3 product lines solving them separately as there are no shared facilities or common constraints. Cost for shipping 1 bolt of any product line remains same.





**Determining the Objective Function**

It is a Minimisation (of cost) problem

Min ∫

(2 x BLA ) + ( 2 x BCH ) + ( 3 x BLO ) + ( 3 x BME ) + ( 7 x BMA ) + ( 4 x BRO ) + ( 7 x BTO ) + ( 1 x BNY)

+

( 6 x HLA ) + ( 7 x HCH ) + ( 8 x HLO ) + ( 10 x HME ) + ( 2 x HMA ) + ( 9 x HRO ) + ( 4 x HTO ) + ( 8 x HNY)

+

( 5 x KLA ) + ( 6 x KCH ) + ( 8 x KLO ) + ( 11 x KME ) + ( 4 x KMA ) + ( 9 x KRO ) + ( 1 x KTO ) + ( 7 x KNY )

+

( 14 x NLA ) + ( 12 x NCH ) + ( 6 x NLO ) + ( 9 x NME ) + ( 11 x NMA ) + ( 7 x NRO ) + ( 5 x NTO ) + ( 10 x NNY )

+

( 4 x VLA ) + ( 3 x VCH ) + ( 5 x VLO ) + ( 1 x VME ) + ( 9 x VMA ) + ( 6 x VRO ) + ( 11 x VTO ) + ( 4 x VNY )

**Laying out the Constraints for Answer 1 a ) Cotton**

Demand Constraints

( BLA + HLA + KLA + NLA + VLA ) = 500

( BCH + HCH + KCH + NCH + VCH ) = 800

( BLO + HLO + KLO + NLO + VLO ) = 900

( BME + HME + KME + NME + VME ) = 900

( BMA + HMA + KMA + NMA + VMA ) = 800

( BRO + HRO + KRO + NRO + VRO ) = 100

( BTO + HTO + KTO + NTO + VTO ) = 200

( BNY + HNY + KNY + NNY + VNY ) = 700

Supply Constraints

( BLA + BCH + BLO + BME + BMA + BRO + BTO + BNY ) <= 1000

( HLA + HCH + HLO + HME + HMA + HRO + HTO + HNY ) <= 900

( KLA + KCH + KLO + KME + KMA + KRO + KTO + KNY ) <= 1000

( NLA + NCH + NLO + NME + NMA + NRO + NTO + NNY ) <= 1000

( VLA + VCH + VLO + VME + VMA + VRO + VTO + VNY ) <= 1000

Note : Since Supply is greater than Demand, we have kept the Demand Constraint as “=” and the Supply Constraint as “<=”

**Solution Question 1a:**

**Cotton**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Costs | LA | Chicago | London | Mexico | Manila | Rome | Tokyo | NY | Consumed | Constraints | Available |
| B | 0 | 300 | 0 | 0 | 0 | 0 | 0 | 700 | 1000 | <= | 1000 |
| H | 0 | 100 | 0 | 0 | 800 | 0 | 0 | 0 | 900 | <= | 2000 |
| K | 500 | 300 | 0 | 0 | 0 | 0 | 200 | 0 | 1000 | <= | 1000 |
| N | 0 | 0 | 900 | 0 | 0 | 100 | 0 | 0 | 1000 | <= | 2000 |
| V | 0 | 100 | 0 | 900 | 0 | 0 | 0 | 0 | 1000 | <= | 1000 |
| Consumed | 500 | 800 | 900 | 900 | 800 | 100 | 200 | 700 |  |  |  |
| Constraints | = | = | = | = | = | = | = | = |  |  |  |
| Available | 500 | 800 | 900 | 900 | 800 | 100 | 200 | 700 |  |  |  |

**Laying out the Constraints for Answer 1 b ) Polyester**

Demand Constraints

( BLA + HLA + KLA + NLA + VLA ) <= 1000

( BCH + HCH + KCH + NCH + VCH ) <= 2000

( BLO + HLO + KLO + NLO + VLO ) <= 3000

( BME + HME + KME + NME + VME ) <= 1500

( BMA + HMA + KMA + NMA + VMA ) <= 400

( BRO + HRO + KRO + NRO + VRO ) <= 700

( BTO + HTO + KTO + NTO + VTO ) <= 900

( BNY + HNY + KNY + NNY + VNY ) <= 2500

Supply Constraints

( BLA + BCH + BLO + BME + BMA + BRO + BTO + BNY ) = 3000

( HLA + HCH + HLO + HME + HMA + HRO + HTO + HNY ) = 2500

( KLA + KCH + KLO + KME + KMA + KRO + KTO + KNY ) = 3500

( NLA + NCH + NLO + NME + NMA + NRO + NTO + NNY ) = 0

( VLA + VCH + VLO + VME + VMA + VRO + VTO + VNY ) = 2000

Note : Since Demand is greater than Supply, we have kept the Demand Constraint as “<=” and the Supply Constraint as “=”

**Solution Question 1b:**

**Polyester**

| Costs | LA | Chicago | London | Mexico | Manila | Rome | Tokyo | NY | Consumed | Constraints | Available |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| B | 0 | 0 | 500 | 0 | 0 | 0 | 0 | 2500 | 3000 | = | 3000 |
| H | 0 | 0 | 2100 | 0 | 400 | 0 | 0 | 0 | 2500 | = | 2500 |
| K | 1000 | 1600 | 0 | 0 | 0 | 0 | 900 | 0 | 3500 | = | 3500 |
| N | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | = | 0 |
| V | 0 | 400 | 100 | 1500 | 0 | 0 | 0 | 0 | 2000 | = | 2000 |
| Consumed | 1000 | 2000 | 2700 | 1500 | 400 | 0 | 900 | 2500 |  |  |  |
| Constraints | <= | <= | <= | <= | <= | <= | <= | <= |  |  |  |
| Available | 1000 | 2000 | 3000 | 1500 | 400 | 700 | 900 | 2500 |  |  |  |

**Laying out the Constraints for Answer 1 c ) Silk**

Demand Constraints

( BLA + HLA + KLA + NLA + VLA ) <= 100

( BCH + HCH + KCH + NCH + VCH ) <= 100

( BLO + HLO + KLO + NLO + VLO ) <= 200

( BME + HME + KME + NME + VME ) <= 50

( BMA + HMA + KMA + NMA + VMA ) <= 400

( BRO + HRO + KRO + NRO + VRO ) <= 200

( BTO + HTO + KTO + NTO + VTO ) <= 700

( BNY + HNY + KNY + NNY + VNY ) <= 200

Supply Constraints

( BLA + BCH + BLO + BME + BMA + BRO + BTO + BNY ) = 0

( HLA + HCH + HLO + HME + HMA + HRO + HTO + HNY ) = 1000

( KLA + KCH + KLO + KME + KMA + KRO + KTO + KNY ) = 500

( NLA + NCH + NLO + NME + NMA + NRO + NTO + NNY ) = 0

( VLA + VCH + VLO + VME + VMA + VRO + VTO + VNY ) = 0

Note : Since Demand is greater than Supply, we have kept the Demand Constraint as “<=” and the Supply Constraint as “=”

**Solution Question 1c:**

**Silk**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Costs | LA | Chicago | London | Mexico | Manila | Rome | Tokyo | NY | Consumed | Constraints | Available |
| B | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | = | 0 |
| H | 100 | 100 | 0 | 0 | 400 | 0 | 200 | 200 | 1000 | = | 1000 |
| K | 0 | 0 | 0 | 0 | 0 | 0 | 500 | 0 | 500 | = | 500 |
| N | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | = | 0 |
| V | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | = | 0 |
| Consumed | 100 | 100 | 0 | 0 | 400 | 0 | 700 | 200 |  |  |  |
| Constraints | <= | <= | <= | <= | <= | <= | <= | <= |  |  |  |
| Available | 100 | 100 | 200 | 50 | 400 | 200 | 700 | 200 |  |  |  |

|  |  |
| --- | --- |
| Cotton's Total Cost | 15400 |
| Polyester's Total Cost | 40300 |
| Silk's Total Cost | 5000 |
| **Total Cost for March** | **60700** |

**Changing the Constraints for Answer 2 ) Supply from Nigeria for Silk**

Demand Constraints

( BLA + HLA + KLA + NLA + VLA ) <= 100

( BCH + HCH + KCH + NCH + VCH ) <= 100

( BLO + HLO + KLO + NLO + VLO ) <= 200

( BME + HME + KME + NME + VME ) <= 50

( BMA + HMA + KMA + NMA + VMA ) <= 400

( BRO + HRO + KRO + NRO + VRO ) <= 200

( BTO + HTO + KTO + NTO + VTO ) <= 700

( BNY + HNY + KNY + NNY + VNY ) <= 200

Supply Constraints

( BLA + BCH + BLO + BME + BMA + BRO + BTO + BNY ) = 0

( HLA + HCH + HLO + HME + HMA + HRO + HTO + HNY ) = 1000

( KLA + KCH + KLO + KME + KMA + KRO + KTO + KNY ) = 500

( NLA + NCH + NLO + NME + NMA + NRO + NTO + NNY ) = 1000

( VLA + VCH + VLO + VME + VMA + VRO + VTO + VNY ) = 0

Note : Since Supply has increased due to the Nigeria Mill, it is greater than Demand, hence we have kept the Demand Constraint as “=” and the Supply Constraint as “<=”

**Solution Question 2**

**Silk**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Costs | LA | Chicago | London | Mexico | Manila | Rome | Tokyo | NY | Consumed | Constraints | Available |
| B | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | <= | 0 |
| H | 100 | 100 | 0 | 0 | 400 | 0 | 200 | 200 | 1000 | <= | 1000 |
| K | 0 | 0 | 0 | 0 | 0 | 0 | 500 | 0 | 500 | <= | 500 |
| N | 0 | 0 | 200 | 50 | 0 | 200 | 0 | 0 | 450 | <= | 1000 |
| V | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | <= | 0 |
| Consumed | 100 | 100 | 200 | 50 | 400 | 200 | 700 | 200 |  |  |  |
| Constraints | = | = | = | = | = | = | = | = |  |  |  |
| Available | 100 | 100 | 200 | 50 | 400 | 200 | 700 | 200 |  |  |  |

|  |  |
| --- | --- |
| Cotton's Total Cost | 15400 |
| Polyester's Total Cost | 40300 |
| Silk's Total Cost (New) | 8050 |
| **Total Cost for March** | **63750** |

There is an “additional” cost of $ 3050 in terms of Transportation Cost

This is in addition to the one time cost of $ 2000 to make the capacity operational

Total increase in cost would be $ 5050, which is higher than the current Transportation cost for Silk & we are also not using up the full capacity

In the light of overall costs increasing by 100%, with just a 30% increase in capacity, our answer to the question would be

No, we should not process the Nigeria Mill Silk for March.

HOWEVER, we would like to get more information on the “Profit” per Bolt of Silk sold.

If the overall “Profit” on sales of additional Silk is greater than $ 5050, then we should utilise the opportunity to activate the Nigeria Mill.

1. **Case Study 2**

**Problem Statement**

AMARCO's planners want to determine how the three grades of aviation gasoline should be blended from the available input streams so that the specifications are met and income is maximized. Develop an LP Spreadsheet model of the company's problem.

**Objective Function**

**Maximization of the Income**

Amount of Gasoline A Produced\*Per unit Selling Price of Gasoline A + Amount of Gasoline B Produced\* Selling Price of Gasoline B + Amount of Gasoline C Produced\* Selling Price of Gasoline C

Amount of Gasoline A Produced = Amount of Alkalyte Used + Amount of Catalytic Cracked Gasoline Used + Amount of Straight Run Gasoline Used + Amount of Isopentane Used

Amount of Gasoline B Produced = Amount of Alkalyte Used + Amount of Catalytic Cracked Gasoline Used + Amount of Straight Run Gasoline Used + Amount of Isopentane Used

Amount of Gasoline C Produced = Amount of Alkalyte Used + Amount of Catalytic Cracked Gasoline Used + Amount of Straight Run Gasoline Used + Amount of Isopentane Used

**Constraints**

**Demand Constraints:**

* Amount of Gasoline A Produced >= Demand for Gasoline A
* Amount of Gasoline B Produced >= Demand for Gasoline B
* Amount of Gasoline C Produced >= Demand for Gasoline C

**Feed Stock Availability Constraints:**

* Amount of Total Alkalyte Used in Gasoline A, B and C <= Amount of Alkalyte Available
* Amount of Total Catalytic Cracked Gasoline Used in Gasoline A, B and C <= Amount of Catalytic Cracked Gasoline Available
* Amount of Total Straight Run Gasoline Used in Gasoline A, B and C <= Amount of Straight Run Gasoline Available
* Amount of Total Isopentane Used in Gasoline A, B and C <= Amount of Isopentane Available

**Reid Vapour Pressure Constraint**

* Obtained RVP of Gasoline A <= 7\*Amount of Gasoline A Produced
* Obtained RVP of Gasoline B <= 7\*Amount of Gasoline B Produced
* Obtained RVP of Gasoline C <= 7\*Amount of Gasoline C Produced
* Obtained RVP of Gasoline A = Amount of Alkalyte Used\*RVP of Alkalyte + Amount of Catalytic Cracked Gasoline Used\*RVP of Catalytic Cracked Gasoline + Amount of Straight Run Gasoline Used\*RVP of Straight Run Gasoline + Amount of Isopentane Used\*RVP of Isopentane
* Obtained RVP of Gasoline B = Amount of Alkalyte Used\*RVP of Alkalyte + Amount of Catalytic Cracked Gasoline Used\*RVP of Catalytic Cracked Gasoline + Amount of Straight Run Gasoline Used\*RVP of Straight Run Gasoline + Amount of Isopentane Used\*RVP of Isopentane
* Obtained RVP of Gasoline C = Amount of Alkalyte Used\*RVP of Alkalyte + Amount of Catalytic Cracked Gasoline Used\*RVP of Catalytic Cracked Gasoline + Amount of Straight Run Gasoline Used\*RVP of Straight Run Gasoline + Amount of Isopentane Used\*RVP of Isopentane

**Octane No. Constraint**

* Obtained Octane No. of Gasoline A >= 80\* Amount of Gasoline A Produced
* Obtained Octane No. of Gasoline B >= 91\* Amount of Gasoline B Produced
* Obtained Octane No. of Gasoline C >= 100\* Amount of Gasoline C Produced
* Obtained Octane No. of Gasoline A = Amount of Alkalyte Used\*Octane No. (TEL 0.5) of Alkalyte + Amount of Catalytic Cracked Gasoline Used\* Octane No. (TEL 0.5) of Catalytic Cracked Gasoline + Amount of Straight Run Gasoline Used\* Octane No. (TEL 0.5) of Straight Run Gasoline + Amount of Isopentane Used\* Octane No. (TEL 0.5) of Isopentane
* Obtained Octane No. of Gasoline B = Amount of Alkalyte Used\*Octane No. (TEL 4) of Alkalyte + Amount of Catalytic Cracked Gasoline Used\* Octane No. (TEL 4) of Catalytic Cracked Gasoline + Amount of Straight Run Gasoline Used\* Octane No. (TEL 4) of Straight Run Gasoline + Amount of Isopentane Used\* Octane No. (TEL 4) of Isopentane
* Obtained Octane No. of Gasoline C = Amount of Alkalyte Used\*Octane No. (TEL 4) of Alkalyte + Amount of Catalytic Cracked Gasoline Used\* Octane No. (TEL 4) of Catalytic Cracked Gasoline + Amount of Straight Run Gasoline Used\* Octane No. (TEL 4) of Straight Run Gasoline + Amount of Isopentane Used\* Octane No. (TEL 4) of Isopentane

**Marketing Constraint**

* Amount of Gasoline A Produced >= Amount of Gasoline B Produced

**Solution using Excel Solver:**

We will use Linear Programming method to solve the problem

**Data Sufficiency**

| Feedstocks | Alkylate | Catalytic Cracked Gasoline | Straight Run Gasoline | Isopentane |
| --- | --- | --- | --- | --- |
| Reid Vapour Pressure | 5 | 8 | 4 | 20 |
| Octane No. (0.5 TEL) | 94 | 83 | 74 | 95 |
| Octane No. (4 TEL) | 107.5 | 93 | 87 | 108 |
| Available (Bbl per day) | 14000 | 13000 | 14000 | 11000 |
| Value ($/Bbl) | 17 | 14.5 | 13.5 | 14 |

**Solution**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| FeedStocks | Gas A | Gas B | Gas C | Used | Constraint | Barrels Available |
| Alkalyte | 1435 | 0 | 6165 | 7600 | <= | 14000 |
| CCG | 0 | 9750 | 3250 | 13000 | <= | 13000 |
| SRG | 9217 | 3250 | 1533 | 14000 | <= | 14000 |
| Isopentane | 2348 | 0 | 1052 | 3400 | <= | 11000 |
| Amount produced | 13000 | 13000 | 12000 | 38000 |  |  |
| Constraint | >= | >= | >= |  |  |  |
| Demand | 12000 | 13000 | 12000 |  |  |  |

**Reid Vapour Pressure Constraint**

|  |  |  |  |
| --- | --- | --- | --- |
| Constraint on Reid VP | Gas A | Gas B | Gas C |
| Octane Number Obtained | 91000 | 91000 | 84000 |
| Constraint | >= | >= | >= |
| Maximum Reid VP required | 91000 | 91000 | 84000 |

**Octane No. Constraints**

|  |  |  |  |
| --- | --- | --- | --- |
| Constraint on Octane Number | Gas A | Gas B | Gas C |
| Octane Number Obtained | 1040000 | 1189500 | 1211982.609 |
| Constraint | <= | <= | <= |
| Minimum Octane number required | 1040000 | 1183000 | 1200000 |

**Marketing Constraint**

|  |  |
| --- | --- |
| Amount A produced | 13000 |
| Constraint | >= |
| Amount B produced | 13000 |

**Objective Function**

|  |  |
| --- | --- |
| Product Income | $ 601,000.00 |

After applying, Simplex LP method in solver we were able to derive the maximum product income from Gasoline A, B and C which is coming out to be USD 601,000. To achieve this value, we will need to produce 1000 Bbl quantity over the demanded quantity of Gasoline A.