FACULTY OF COMPUTING
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TRANSPORTATION OPTIMIZATION FOR MIHARJA SHIPPING & TRANSPORT COMPANY WITH CHEMPRO USING TRANSPORTATION AND TRANSSHIPMENT MODELS

OPERATIONAL RESEARCH AND OPTIMIZATION (MCSD1133)

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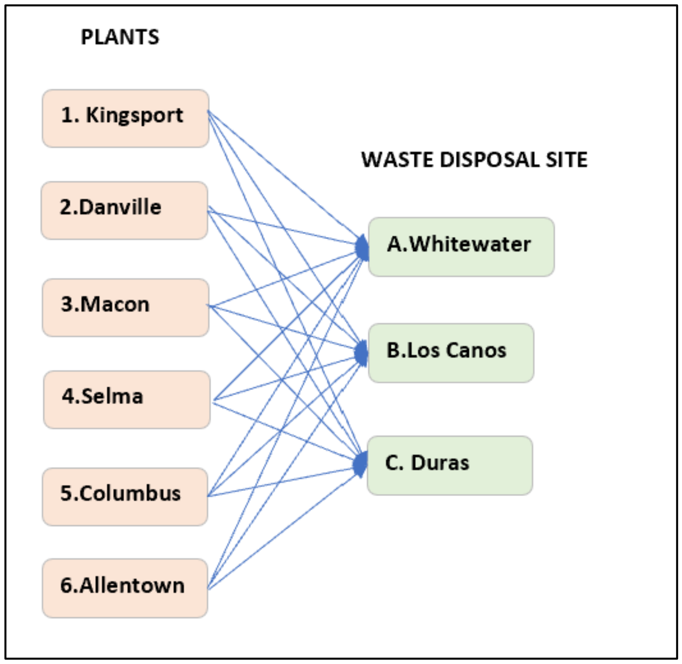
a) **Develop a transportation model for shipping the waste directly from the 6 plants to the 3 waste disposal sites. Solve the model and determine the optimal transportation cost.**



Transportation Network Routes

Shipping cost from plants to waste disposal sites			
Plant	**Waste Disposal Site**		
	Whitewater	Los Canos	Duras
1. Kingsport	12	15	17
2.Danville	14	9	10
3.Macon	13	20	11
4.Selma	17	16	19
5.Columbus	7	14	12
6.Allentown	22	16	18

Supply	
Plant	**Waste/Week (bbl)**
1. Kingsport	35
2.Danville	26
3.Macon	42
4.Selma	53
5.Columbus	29
6.Allentown	38
TOTAL	**223**

Demand	
Waste Disposal Site	**Maximum Demand**
A.Whitewater	65
B.Los Canos	80
C.Duras	105
TOTAL	**250**

Here we found that this transportation model is unbalanced with demand exceeding the available supply. To solve this, a dummy supply is added to achieve even distribution.

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Waste Disposal Site			
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1. Kingsport	12	15	17
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3.Macon	13	20	11
4.Selma	17	16	19
5.Columbus	7	14	12
6.Allentown	22	16	18
7. Dummy	0	0	0

Supply	
Plant	**Waste/Week (bbl)**
1. Kingsport	35
2.Danville	26
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5.Columbus	29
6.Allentown	38
7. Dummy	27
TOTAL	**250**

Demand	
Waste Disposal Site	**Maximum Demand**
A.Whitewater	65
B.Los Canos	80
C.Duras	105
TOTAL	**250**

Model Formulation

Decision Variables:

- xij: Number of barrels of waste shipped from plant i to disposal site j.
- i=1,2,3,4,5,6,7 to j=A,B,C

Objective Function:

Minimize, $Z = 12x_{1A} +15x_{1B} +17x_{1C} +14x_{2A} +9x_{2B} +10x_{2C} +13x_{3A} +20x_{3B} +11x3_{C} +17x_{4A} +16x_{4B} +19x_{4C} +7x_{5A} +14x_{5B} +12x_{5C} +22x_{6A} +16x_{6B} +18x_{6C} + 0x_{7A} +0x_{7B} +0x_{7C}$

Minimize the total transportation cost.

Subject to Constraints:

Supply Constraints: The amount of waste shipped from each plant should be equal its supply.

$x_{1A}+x_{1B}+x_{1C}$ =35 (1. Kingsport)

$x_{2A}+x_{2B}+x_{2C}$ =26 (2. Danville)

$x_{3A}+x_{3B}+x_{3C}$ =42 (3. Macon)

$x_{4A}+x_{4B}+x_{4C}$ =53 (4. Selma)

$x_{5A}+x_{5B}+x_{5C}$ =29 (5. Columbus)

$x_{6A}+x_{6B}+x_{6C}$ =38 (6. Allentown)

$x_{7A}+x_{7B}+x_{7C}$ =27 (7. Dummy)

Demand Constraints: The amount of waste received at each disposal site should meet its demand.

$x_{1A}+x_{2A}+x_{3A}+x_{4A}+x_{5A}+x_{6A}$=65 (A. Whitewater)

$x_{1B}+x_{2B}+x_{3B}+x_{4B}+x_{5B}+x_{6B}$=80 (B.Los Canos)

$x_{1C}+x_{2C}+x_{3C}+x_{4C}+x_{5C}+x_{6C}$=105 (C.Duras)

Non-negativity Constraints: The number of barrels shipped must be non-negative.

$x_{ij} \geq 0$ for all i,j

Results: The solution for this model formulation using Python is as below:

```
Route_1_A = 35.0
Route_2_C = 26.0
Route_3_C = 42.0
Route_4_A = 1.0
Route_4_B = 52.0
Route_5_A = 29.0
Route_6_B = 28.0
Route_6_C = 10.0
Route_7_C = 27.0
Optimal Direct Transportation Cost: 2822.0
```

Thus, the following table represents the optimal solution to the transportation problem.

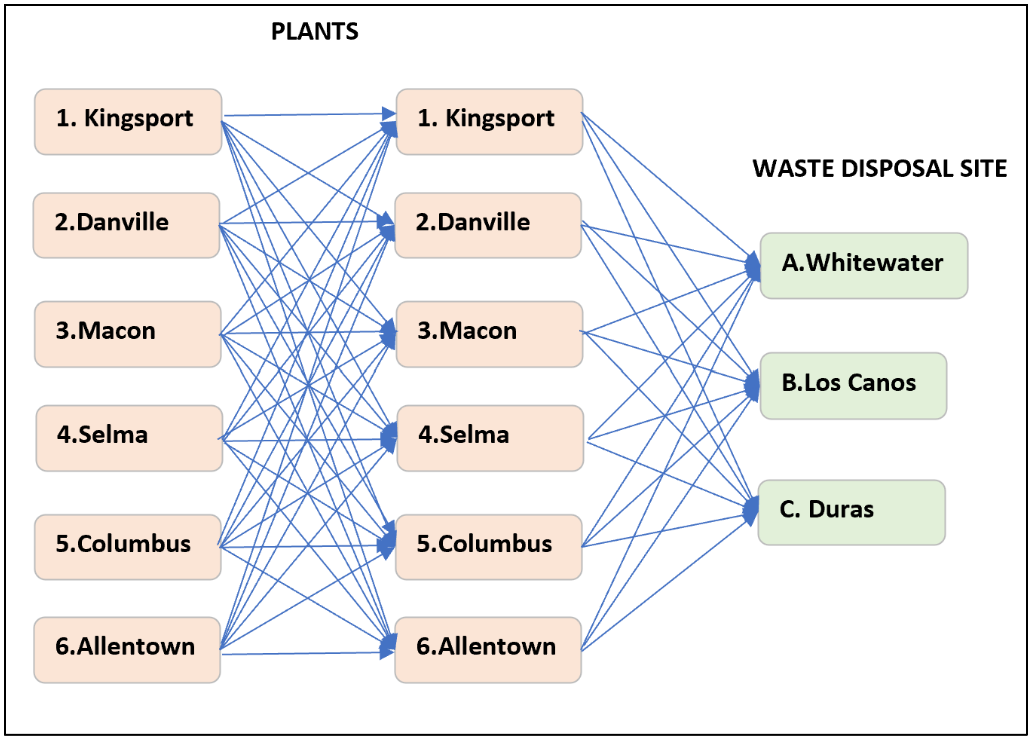
From	To	Shipment unit	Cost per unit	Shipment cost
1.Kingsport	A.Whitewater	35	$12	$420
2.Danville	C.Duras	26	$10	$260
3.Macon	C.Duras	42	$11	$462
4.Selma	A.Whitewater	1	$17	$17
4.Selma	B.Los Canos	52	$16	$832

5.Columbus	A.Whitewater	29	$7	$203
6.Allentown	B.Los Canos	28	$16	$448
6.Allentown	C.Duras	10	$18	$180
Total Cost				**$2822**

The overall cost of transportation for the best option is $2822, if Miharja carries garbage straight from plants to disposal facilities. This cost is calculated by considering the coefficients (shipping costs) and the optimal flow values for each route.

But still, the rest of the demand at disposal site Duras (27bbl), cannot be fully met due to insufficient supply. To account for this shortfall, a dummy route was introduced in the optimization model. Overall, the solution optimally allocates the transportation of waste to meet demand at disposal sites while minimizing the total transportation cost.

b) Develop a transshipment model in which each of the plants can be used as intermediate points to determine the optimal cost.



Transshipment Network Routes

The transportation model transforms into a transshipment model when each plant serves as an intermediary shipping point.. The additional decision variables included in the new model formulation as below:

<u>Model Formulation</u>

Decision Variables:

- x_{hi}: Number of barrels of waste shipped from plant *h* to intermediate plant *h*.
- x_{ij}: Number of barrels of waste shipped from plant *i* to disposal site *j*.

where

h=1,2,3,4,5,6

i=1,2,3,4,5,6,7 (the same 6 plants as *h* but additional of 1 dummy supply)

j=A,B,C

Objective Function:

Minimize, $Z = 6x_{12} + 4x_{13} + 9x_{14} + 7x_{15} + 8x_{16} + 6x_{21} + 11x_{23} + 10x_{24} + 12x_{25} + 7x_{26} + 5x_{31} + 11x_{32} + 3x_{34} + 7x_{35} + 15x_{36} + 9x_{41} + 10x_{42} + 3x_{43} + 3x_{45} + 16x_{46} + 7x_{51} + 12x_{52} + 7x_{53} + 3x_{54} + 14x_{56} + 8x_{61} + 7x_{62} + 15x_{63} + 16x_{64} + 14x_{65} + 12x_{1A} + 15x_{1B} + 17x_{1C} + 14x_{2A} + 9x_{2B} + 10x_{2C} + 13x_{3A} + 20x_{3B} + 11x3_{C} + 17x_{4A} + 16x_{4B} + 19x_{4C} + 7x_{5A} + 14x_{5B} + 12x_{5C} + 22x_{6A} + 16x_{6B} + 18x_{6C}$

Minimize the total transportation cost.

Subject to Constraints:

Supply Constraints 1: The amount of waste shipped from each plant should be equal its supply.

$x_{1A+}x_{1B}+x_{1C}$ =35 (1.Kingsport)

$x_{2A}+x_{2B}+x_{2C}$ =26 (2.Danville)

$x_{3A}+x_{3B}+x_{3C}$ =42 (3.Macon)

$x_{4A}+x_{4B}+x_{4C}$ =53 (4.Selma)

$x_{5A}+x_{5B}+x_{5C}$ =29 (5.Columbus)

$x_{6A}+x_{6B}+x_{6C}$ =38 (6.Allentown)

Supply Constraints 2: The amount of waste shipped from each plant should be equal its supply.

$x_{1A+}x_{1B}+x_{1C}$ =35 (1.Kingsport)

$x_{2A}+x_{2B}+x_{2C}$ =26 (2.Danville)

$x_{3A}+x_{3B}+x_{3C}$ =42 (3.Macon)

$x_{4A}+x_{4B}+x_{4C}$ =53 (4.Selma)

$x_{5A}+x_{5B}+x_{5C}$ =29 (5.Columbus)

$x_{6A}+x_{6B}+x_{6C}$ =38 (6.Allentown)

$x_{7A}+x_{7B}+x_{7C}$ =27 (7.Allentown)

Demand Constraints: The amount of waste received at each disposal site should meet its demand.

$x_{1A}+x_{2A}+x_{3A}+x_{4A}+x_{5A}+x_{6A}=65$ (A.Whitewater)

$x_{1B}+x_{2B}+x_{3B}+x_{4B}+x_{5B}+x_{6B}=80$ (B.Los Canos)

$x_{1C}+x_{2C}+x_{3C}+x_{4C}+x_{5C}+x_{6C}=105$ (C.Duras)

Transshipment Constraint: The amount of waste shipped from supply equal to amount received by demand

$\sum x_{hh} - \sum x_{ij} = 0$

Non-negativity Constraints: The number of barrels shipped must be non-negative.

x_{hi} and $x_{ij} \geq 0$ for all *h*, *i*, and *j*

Results: The solution for this model formulation using Python is as below:

```
Optimal Transshipment Plan:
Ship 16.0 barrels from Kingsport to Kingsport (Route 1)
Ship 19.0 barrels from Kingsport to Macon (Route 1)
Ship 26.0 barrels from Danville to Danville (Route 1)
Ship 42.0 barrels from Macon to Macon (Route 1)
Ship 17.0 barrels from Selma to Macon (Route 1)
Ship 36.0 barrels from Selma to Columbus (Route 1)
Ship 29.0 barrels from Columbus to Columbus (Route 1)
Ship 38.0 barrels from Allentown to Allentown (Route 1)
Ship 16.0 barrels from Kingsport to Los Canos (Route 2)
Ship 26.0 barrels from Danville to Los Canos (Route 2)
Ship 78.0 barrels from Macon to Duras (Route 2)
Ship 65.0 barrels from Columbus to Whitewater (Route 2)
Ship 38.0 barrels from Allentown to Los Canos (Route 2)
Ship 27.0 barrels from dummy to Duras (Route 2)

Total Transshipment Cost: $2630.0
```

Hence, the most efficient resolution for this transshipment issue can be summarized in the subsequent table..

From Plants	To Intermediate Plants	Shipment unit	Cost per unit	Shipment cost	Total
1.Kingsport	1.Danville	16	$6	$96	$597
2.Danville		26	$0	$0	
6.Allentown		38	$7	$266	
1.Kingsport	3.Macon	19	$4	$76	
3.Macon		42	$0	$0	
4.Selma		17	$3	$51	
4.Selma	5.Columbus	36	$3	$108	
5.Columbus		29	$0	$0	

From Intermediate Plants	To Waste Disposal Sites	Shipment unit	Cost per unit	Shipment cost	Total
1.Danville	B.Los Canos	80	$9	$720	$2033
3.Macon	C.Duras	78	$11	$858	
5.Columbus	A.Whitewater	65	$7	$455	
				TOTAL	**$2630**

When transshipping waste within Miharja's plants and subsequently to disposal sites, the total transshipment cost for the optimal solution amounts to $2630. This cost is computed by taking into consideration the coefficients (shipping costs) and the optimal flow values for each route. Again, the remaining demand at the disposal site for Duras (27 barrels) cannot be entirely fulfilled due to inadequate supply. Hence, a dummy route was incorporated into the optimization model.

c) Interpret the results and determine the best model for Sally to be implemented

a) Direct Transportation Model

From Plants	To Disposal Sites	Shipment unit	Cost per unit	Shipment cost
1.Kingsport	A.Whitewater	35	$12	$420
2.Danville	C.Duras	26	$10	$260
3.Macon	C.Duras	42	$11	$462
4.Selma	A.Whitewater	1	$17	$17
4.Selma	B.Los Canos	52	$16	$832
5.Columbus	A.Whitewater	29	$7	$203
6.Allentown	B.Los Canos	28	$16	$448
6.Allentown	C.Duras	10	$18	$180
Total Cost				$2822

b) Transshipment Model

From Plants	To Intermediate Plants	Shipment unit	Cost per unit	Shipment cost	Total
1.Kingsport	1.Danville	16	$6	$96	
2.Danville		26	$0	$0	
6.Allentown		38	$7	$266	
1.Kingsport	3.Macon	19	$4	$76	
3.Macon		42	$0	$0	$597
4.Selma		17	$3	$51	
4.Selma	5.Columbus	36	$3	$108	
5.Columbus		29	$0	$0	
From Intermediate Plants	To Waste Disposal Sites	Shipment unit	Cost per unit	Shipment cost	Total
1.Danville	B.Los Canos	80	$9	$720	
3.Macon	C.Duras	78	$11	$858	$2033
5.Columbus	A.Whitewater	65	$7	$455	
				TOTAL	$2630

Upon analyzing the results, optimal cost for direct transportation from plants to disposal sites is $2882. Conversely, employing a transshipment strategy within each plants before onward transportation to disposal sites yields a total cost of $2630. From a cost perspective alone, the transshipment model appears as the more advantageous choice by presenting a solution with a lower optimal cost compared to the direct transportation model. This translates to a weekly cost savings of $192 for Miharja which is significant amount of cost that can be reduce.

In summary, the transshipment model stands as the best choice for Sally to implement in achieving cost efficiency with a noticeably reduced optimal cost.