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Minimising the Transportation Cost of an Oil Mill Company

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Abstract: ***It is very common in Ghana to transport products from sources to destinations by road, which can be seen in multiple business entities whose daily activities include manufacturing. The manufacturing sites, storage and final destinations are sometimes linked by road. Finding methods to reduce the transportation costs has always been an issue and it continues to affect the decision-making process of several establishments. In this study, the cost of transporting raw materials of an Oil Mill Company from its various farm gates (sources) to its various warehouses (destinations) is minimised using the transportation problem. The initial feasible solution is generated using the Least Cost and the Vogel Approximation Method, after which the Modified Distribution Method is then applied to determine optimality. From the optimal solution, the cost of transporting the raw materials from the various farm gates to the factory warehouses was obtained to be GH₵ 30351.45.***

Keywords: Transportation problem, optimal solution, Initial feasible solution, degeneracy

1. Introduction

The transportation problem is a particular form of a linear programming problem, which minimizes the cost of distributing goods from specific sources (warehouses) to distinct locations while meeting both supply and demand limitations [1]. Transportation model can be applied in areas such as personnel assignment, inventory control, financial planning, farm planning, work scheduling and transporting goods [2]. The Oil Mill Company under study, is a palm oil producing company concerned with refined oil trade with some companies and individuals nationwide. The company spends about GH₵53247.74 on transporting raw materials from the farm gates to their various warehouses. This high cost contributes to low profit achieved at the end of their financial year. It is the desire of the management of the company to minimise the cost of transporting raw materials in order to improve their financial records. According to [3], the French mathematician Monge formally established the transportation problem in 1781. The Soviet / Russian mathematician and economist Leonid Kantorovich made major advances in the field during the Second World War. Kantorovich [4] conducted a study on the ongoing version of the problem and later extended it to the problem of capacitated transport system [4]. This is widely studied in the literature of mathematical programming and engineering, most often referred to as the facility location and assignment problem. The issue of transport optimization can be described as a linear programming problem with a large-scale blended integer. [5] researched on a two-dimensional dynamic network routing model. The model uses heuristic techniques to fix issues of instability. The heuristics routing techniques are likened to the simulation of discrete events in the dynamic routing scheme. [6] utilized a linear programming module and management scientist transportation to help minimise Guinness Ghana limited transportation costs when their products were distributed to retailers from different warehouses. From the research, the same findings were achieved for both the linear programming module and the transportation module for management scientists in terms of the optimal solution. [7] also minimized the complete transportation cost of a beverage industry using the Regret Method and the U-V method. Quantitative manager for windows (QMW) was used for the analysis. It was realized that there is a great distinction between the lean and festive seasons in the monthly transportation cost. [8] also minimised the total transportation cost of Asuo Bomosadu Timber Sawmill Limited (A.B.T.S) using the Least cost method and the stepping stone method. This study, therefore, intends to employ the Least Cost Method, Vogel Approximation Method and the Modified Distribution Method to determine the optimal allocation of raw materials that will minimise the transportation cost of the Oil Mill Company.

2. Methods Used

2.1 Transportation Problem

The most significant and effective applications of linear programming problem are the physical allocation of goods, frequently known as transportation problem. The aim is to minimize the cost of transporting goods from one location to another so that each location's requirements are met and each supply place operates within its capability. However, the transportation problem can be formulated in the form of linear programming which has a lot of applications other than physical commodity allocation. Consider a commodity generated in different centres known as sources and demand in different locations. Each source's manufacturing capability (availability) and each destination's demand are known and fixed. The transportation problem considers the cost of transporting a unit of goods from each source to each location. The goods are to be transported from multiple shipping costs. This optimal distribution of the product to distinct locations from various sources is called the transportation problem [9].

2.2 Model Assumptions

The following are the assumptions considered in the transportation problem;

i. The model assumes that goods are moved conveniently from origin to destination.
ii. The transportation cost per unit commodity is certain.
iii. The cost per unit does not depend on the quantity being transported from source to destination.
iv. The transportation cost of transporting any number of units is proportional to any route.
v. The objective is to minimise the transportation cost for transporting commodities between two places

2.3 Model Formulation

Let m represents the sources and n represents the destinations. The following are notations that are needed in the mathematical formulation of a transportation problem;

$i =$ index for origins (supply points) $i = 1, 2...n$.
$j =$ index for destination (demand points) $j = 1, 2...n$.
$X_{ij} =$ the number of units to be distributed from source i to destination j.
Z = objective function
$s_i =$ supply from source i.
$d_j =$ demand at destination j.
$C_{ij} =$ cost per unit distributed from source i to destination j.

The linear programming problem representing the transportation problem is generally given by:

Minimise:

$$\begin{aligned} Z &= C_{11}X_{11} + C_{12}X_{12} + C_{13}X_{13} + ... + C_{1n}X_{1n} \\ &+ C_{21}X_{21} + C_{22}X_{22} + C_{23}X_{23} + ... + C_{2n}X_{2n} \\ &+ C_{31}X_{31} + C_{32}X_{32} + C_{33}X_{33} + ... + C_{3n}X_{3n} + ... \\ &+ C_{m1}X_{m1} + C_{m2}X_{m2} + C_{m3}X_{m3} + ... + C_{mn}X_{mn} \end{aligned} \quad (1)$$

Subject to:

Supply constraints

$$\begin{aligned} &X_{11} + X_{12} + X_{13} + ... + X_{1n} = s_1 \\ &X_{21} + X_{22} + X_{23} + ... + X_{2n} = s_2 \\ &X_{31} + X_{32} + X_{33} + ... + X_{3n} = s_3 \\ &. \\ &. \\ &. \\ &X_{m1} + X_{m2} + X_{m3} + ... + X_{mn} = s_m \end{aligned} \quad (2)$$

Demand constraints

$$\begin{aligned} &X_{11} + X_{12} + X_{13} + ... + X_{1m} = d_1 \\ &X_{21} + X_{22} + X_{23} + ... + X_{2m} = d_2 \\ &X_{31} + X_{32} + X_{33} + ... + X_{3m} = d_3 \\ &. \\ &. \\ &. \\ &X_{n1} + X_{n2} + X_{n3} + ... + X_{nm} = d_n \end{aligned} \quad (3)$$

$X_{ij} \geq 0$, (4)

for all $i = 1...m$ and $j = 1...n$ [2]

2.4 Least Cost Method

One of the techniques used to get the initial feasible solution for the transportation problem is the least cost technique. Here, the allocation starts with the minimum cost cell. The lesser cost cells are selected over the higher cost with the goal of having the least transportation cost. The least cost is regarded to generate better initial solution than the Northwest technique because it takes into account shipping cost while making the distribution, whereas the Northwest technique takes into account the availability and supply requirements and the allocation starts at the extreme left corner, regardless of shipping costs. The steps engaged in finding the initial feasible solution using the least cost technique are as follows:

Step 1: Determine the lowest cost in the transportation table.
Step 2: Look for the least value in a row and assign the optimum feasible quantity in the cell relating to the least value. If an allocation is made, then erase that row/column.
Step 3: Repeat steps 1 and 2 for a decreased shipping cost until all available quantities are distributed to the necessary locations. A tie can be broken arbitrarily if the minimum cost is not unique [10].

2.5 Vogel Approximation Method

The Vogel approximation technique is an iterative method computed to determine the initial feasible solution to the transportation problem. Like the least cost technique, shipping costs are also taken into account here, but in a comparative sense. The following are the steps involved in the Vogel's Approximation Method;

i. For both rows and columns, find the difference between the two least cost cells that are not allocated.
ii. Select the maximum difference between the rows and columns and select the one where the maximum quantity can be assigned, taking into account the minimum cost.
iii. Allocate the maximum amount in that row and column where the value is minimum within the demand and supply limit. Erase the satisfied row /column. Repeat the process until all criteria for demand and supply are met [10].

2.6 Modified Distribution Method

The modified distribution technique, also known as the MODI technique, offers the transportation problem with a minimum cost solution. Closed routes are taken for their assessment in the stepping stone technique as many as the unoccupied cells. In the MODI technique, on the contrary, only closed path is taken for the unoccupied cell with the greatest cost of chance. Determine an initial basic feasible solution using any one of the three methods given below:

- North West Corner Method
- Least Cost Method
- Vogel Approximation Method

i. Check whether the solution is non-degenerate by comparing the initial feasible solution to $m+n-1$ allocations. If non-degenerate, continue with step 2. If degenerate move to section 2.7 and resolve degeneracy and continue with step 2.
ii. Determine the values of dual variables, U_i and V_j, for the rows and columns respectively using the equation $C_{ij} = U_i + V_j$
iii. The opportunity cost for the unallocated cells is computed using the equation $D_{ij} = C_{ij} - (U_i + V_j)$
iv. Repeat the whole procedure until all D_{ij}'s ≥ 0 [10].

2.7 Degeneracy

A general transportation problem with m sources and n destinations needs the allocation of $m+n-1$ autonomous cells to test an optimal feasible solution. Degeneracy occurs when the total numbers of allocations are less than $m+n-1$ [10].

2.7.1 Resolving Degeneracy

One way of resolving degeneracy is to allocate a minute amount ε to one of the independent cells i.e., allocate a minute positive amount ε to the unoccupied cell with the lowest transportation costs, to make $m+n-1$ allocations. In other words, the allocation of ε must not have a closed loop or path. Once this is done, the test of optimality is applied [10].

3. Data Analysis and Results

3.1 Data Acquisition

The data used for the analysis is a secondary data collected from the Oil Mills Company. The cost of transporting products involves fuel consumption of vehicles, cost of labour and maintenance. Raw materials sources are called farm gates and the warehouses are called destinations. The data of the various farm gates and destinations with the respective codes are indicated in Table 1. Also, the network representation of the various sources and the destination for the study is shown in Figure 1.

Table 1: The Various Farm Gates, Destinations and Codes

Farm Gates	Codes	Destinations	Codes
North	-	Juaben Farms	Jua F
East	-	Juaben Farms	Jua F
West	-	Juaben Farms	Jua F
Krofofrom	Kro	Juaben Farms	Jua F
Nkyerepoaso	Nkye	Juaben East	Jua E
Abetenim	Abet	Juaben East	Jua E
Odoyefe	Odo	Juaben East	Jua E
Ofoase	Ofo	Juaben East	Jua E
Apemso	Apem	Juaben West	Jua W
Dumakwai	Duma	Juaben West	Jua W
Ntumkumso	Ntum	Juaben West	Jua W
Ankaasi	Ank	Juaben West	Jua W
Kasamu	Kasa	Atia	-
Kotei	_	Atia	-
Kubeasi	Kub	Atia	-
Duampompo	Duam	Atia	-
Boamadumasi	Boam	Odumasi	Odu
Boankra	Boa	Odumasi	Odu
New Koforidua	New K	Odumasi	Odu
Nnoboam	Nno	Odumasi	Odu
Bomfa	Bom	Individuals	Ind
Konongo	Kon	Individuals	Ind
Adumasa	Adu	Individuals	Ind

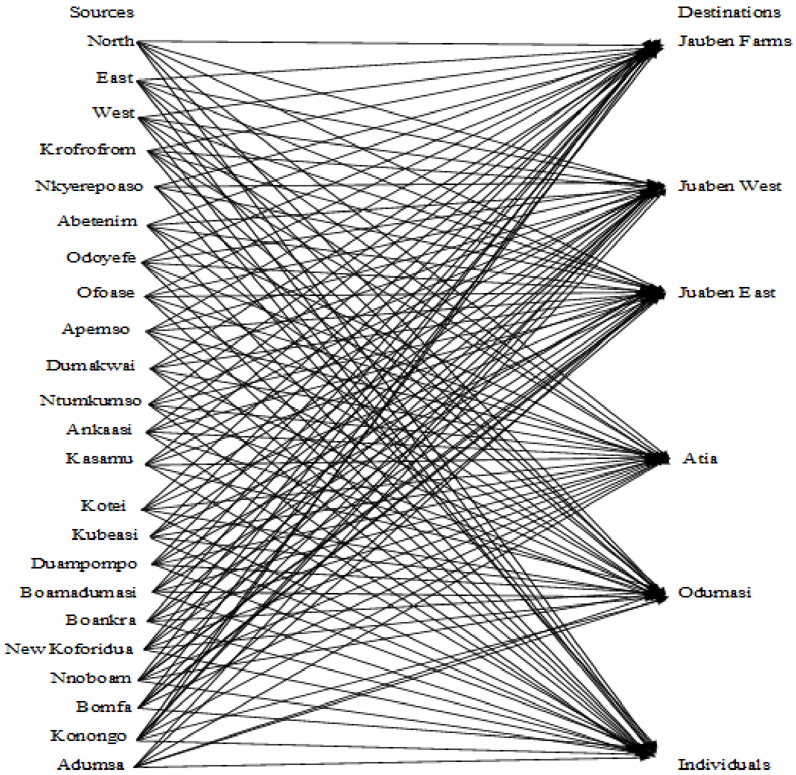

Figure 1: Network Representation of the Data of the Transportation Problem

Table 2: The Cost Transportation Tableau

Destination / Source	Atia	Odu	Jua E	Jua W	Jua F	Ind	Supply
North	83.08	95.19	53.02	40.08	1.67	11.69	387
East	81.41	93.52	51.35	42.17	2.51	10.86	360
West	86.01	92.69	55.95	37.58	2.92	12.53	378
Kotei	83.08	62.83	53.02	20.88	48.01	30.06	342
Ank	78.07	67.13	48.01	14.20	43.00	22.55	279
Apem	24.22	57.62	20.04	68.05	45.09	23.38	330
Kasa	53.44	60.12	41.33	6.68	20.04	15.87	249
Duma	50.10	58.29	38.83	4.18	16.70	13.36	304
Ntum	66.8	72.65	25.47	20.04	20.25	27.14	317
Abet	32.98	73.48	2.92	40.08	31.31	12.94	346
Ofo	36.74	77.24	6.68	43.42	34.24	16.70	340
Odo	40.92	70.96	16.28	54.69	44.67	25.05	311
*Nkye	42.17	75.57	10.86	47.60	38.83	22.55	353
Kro	34.24	67.64	17.54	55.53	35.91	29.23	322
Duam	5.85	46.27	35.91	87.68	64.3	43.42	323
Boam	10.02	43.43	40.08	88.51	68.47	47.6	304
Boan	11.27	29.23	41.33	74.32	57.2	48.85	319
Kub	10.86	44.23	40.92	94.93	69.31	48.43	328
Kon	47.60	4.18	10.04	59.29	72.65	46.76	305
New K	24.22	19.21	116.07	74.32	87.68	61.79	328
Nno	47.60	5.85	102.91	60.96	74.32	48.43	304
Bom	33.40	15.87	96.03	70.98	84.34	58.45	334
Adum	52.61	9.19	106.05	64.3	77.66	51.77	308
Demand	762	942	844	971	754	126	

Table 2 is the cost transportation tableau, indicating the demand and supply at the farm gates and the factory warehouses. From Table 2, the total demand is 4399 tonnes whereas the total supply is 7471 tonnes. The tableau is not balanced since the total supply exceeds the total demand (i.e. $\sum_{i=1}^{m} s_i > \sum_{j=1}^{n} d_j$) therefore a dummy column is created with a demand of 3072 as shown in Table 3.

Table 3: The Balanced Cost Transportation Tableau

Destination / Source	Atia	Odu	Jua E	Jua W	Jua F	Ind	Dummy	Supply
North	83.08	95.19	53.02	40.08	1.67	11.69	0	387
East	81.41	93.52	51.35	42.17	2.51	10.86	0	360
West	86.01	92.69	55.95	37.58	2.92	12.53	0	378
Kotei	83.08	62.83	53.02	20.88	48.01	30.06	0	342
Ank	78.07	67.13	48.01	14.20	43.00	22.55	0	279
Apem	24.22	57.62	20.04	68.05	45.09	23.38	0	330
Kasa	53.44	60.12	41.33	6.68	20.04	15.87	0	249
Duma	50.10	58.29	38.83	4.18	16.70	13.36	0	304
Ntum	66.8	72.65	25.47	20.04	20.25	27.14	0	317
Abet	32.98	73.48	2.92	40.08	31.31	12.94	0	346
Ofo	36.74	77.24	6.68	43.42	34.24	16.70	0	340
Odo	40.92	70.96	16.28	54.69	44.67	25.05	0	311
Nkye	42.17	75.57	10.86	47.60	38.83	22.55	0	353
Kro	34.24	67.64	17.54	55.53	35.91	29.23	0	322
Duam	5.85	46.27	35.91	87.68	64.3	43.42	0	323
Boam	10.02	43.43	40.08	88.51	68.47	47.6	0	304
Boan	11.27	29.23	41.33	74.32	57.2	48.85	0	319
Kub	10.86	44.23	40.92	94.93	69.31	48.43	0	328
Kon	47.60	4.18	10.04	59.29	72.65	46.76	0	305
New K	24.22	19.21	116.07	74.32	87.68	61.79	0	328
Nno	47.60	5.85	102.91	60.96	74.32	48.43	0	304
Bom	33.40	15.87	96.03	70.98	84.34	58.45	0	334
Adum	52.61	9.19	106.05	64.3	77.66	51.77	0	308
Demand	762	942	844	971	754	126	3072	

3.2 Model Formulation

Let X_{ij} be the number of units of palm fruit transported from farm gate i to warehouse j for the raw materials. Then the objective function can be written as

Minimise

$$
\begin{aligned}
Z = {} & 83.08X_{11} + 95.19X_{12} + 53.02X_{13} + 40.08X_{14} + 1.67X_{15} + 11.69X_{16} \\
& + 81.41X_{21} + 93.52X_{22} + 51.35X_{23} + 42.17X_{24} + 2.51X_{25} + 10.86X_{26} \\
& + 86.01X_{31} + 92.69X_{32} + 55.95X_{33} + 37.58X_{34} + 2.92X_{35} + 12.53X_{36} \\
& + 83.08X_{41} + 62.83X_{42} + 53.02X_{43} + 20.88X_{44} + 48.01X_{45} + 30.06X_{46} \\
& + 78.07X_{51} + 67.13X_{52} + 48.01X_{53} + 14.20X_{54} + 43.00X_{55} + 22.55X_{56} \\
& + 24.22X_{61} + 57.62X_{62} + 20.04X_{63} + 68.05X_{64} + 45.09X_{65} + 23.38X_{66} \\
& + 53.44X_{71} + 60.12X_{72} + 41.33X_{73} + 6.68X_{74} + 20.04X_{75} + 15.87X_{76} \\
& + 50.10X_{81} + 58.29X_{82} + 38.83X_{83} + 4.18X_{84} + 16.70X_{85} + 13.36X_{86} \\
& + 66.80X_{91} + 72.65X_{92} + 25.47X_{93} + 20.04X_{94} + 20.25X_{95} + 27.14X_{96} \\
& + 32.98X_{101} + 73.48X_{102} + 2.92X_{103} + 40.08X_{104} + 31.31X_{105} + 12.94X_{106} \\
& + 36.74X_{111} + 77.24X_{112} + 6.68X_{113} + 43.42X_{114} + 34.24X_{115} + 16.7X_{116} \\
& + 40.92X_{121} + 70.96X_{122} + 16.28X_{123} + 54.69X_{124} + 44.67X_{125} + 25.05X_{126} \\
& + 42.17X_{131} + 75.57X_{132} + 10.86X_{134} + 47.6X_{135} + 38.83X_{136} + 22.55X_{137} \\
& + 34.24X_{141} + 67.64X_{142} + 17.54X_{143} + 55.53X_{144} + 35.91X_{145} + 29.23X_{146} \\
& + 5.85X_{151} + 46.27X_{152} + 35.91X_{153} + 87.68X_{153} + 64.30X_{154} + 43.42X_{156} \\
& + 10.02X_{161} + 43.43X_{162} + 40.08X_{163} + 88.51X_{164} + 68.47X_{165} + 47.60X_{166} \\
& + 11.27X_{171} + 29.23X_{172} + 41.33X_{173} + 74.32X_{174} + 57.20X_{175} + 48.85X_{176} \\
& + 10.86X_{181} + 44.23X_{182} + 40.92X_{183} + 94.93X_{184} + 69.31X_{185} + 48.43X_{186} \\
& + 47.60X_{191} + 4.18X_{192} + 10.04X_{193} + 59.29X_{194} + 72.65X_{195} + 46.76X_{196} \\
& + 24.22X_{201} + 19.21X_{202} + 116.07X_{203} + 74.32X_{204} + 87.68X_{205} + 61.79X_{206} \\
& + 47.60X_{211} + 5.85X_{212} + 102.91X_{213} + 60.96X_{214} + 74.32X_{215} + 48.43X_{216} \\
& + 33.40X_{221} + 15.87X_{222} + 96.03X_{223} + 70.98X_{224} + 84.34X_{225} + 58.45X_{226} \\
& + 52.61X_{231} + 9.19X_{232} + 106.05X_{234} + 64.3X_{235} + 77.66X_{236} + 51.77X_{237}
\end{aligned} \tag{8}
$$

Subject to:

Demand constraints

$$
\begin{aligned}
&X_{11}+X_{21}+X_{31}+X_{41}+X_{51}+X_{61}+X_{71}+X_{81}+X_{91}+X_{101}+X_{111}+X_{121}\\
&+X_{131}+X_{141}+X_{151}+X_{161}+X_{171}+X_{181}+X_{191}+X_{201}+X_{211}+X_{221}+X_{231}=762\\
&X_{12}+X_{22}+X_{32}+X_{42}+X_{52}+X_{62}+X_{72}+X_{82}+X_{92}+X_{102}+X_{112}+X_{122}\\
&+X_{132}+X_{142}+X_{152}+X_{162}+X_{172}+X_{182}+X_{192}+X_{202}+X_{212}+X_{223}+X_{232}=942\\
&X_{13}+X_{23}+X_{33}+X_{43}+X_{53}+X_{63}+X_{73}+X_{83}+X_{93}+X_{103}+X_{113}+X_{123}\\
&+X_{133}+X_{143}+X_{153}+X_{163}+X_{173}+X_{183}+X_{193}+X_{203}+X_{213}+X_{223}+X_{233}=844\\
&X_{14}+X_{24}+X_{34}+X_{44}+X_{54}+X_{64}+X_{74}+X_{84}+X_{94}+X_{104}+X_{114}+X_{124}\\
&+X_{134}+X_{144}+X_{154}+X_{164}+X_{174}+X_{184}+X_{194}+X_{204}+X_{214}+X_{224}+X_{234}=971\\
&X_{15}+X_{25}+X_{35}+X_{45}+X_{55}+X_{65}+X_{75}+X_{85}+X_{95}+X_{105}+X_{115}+X_{125}\\
&+X_{135}+X_{145}+X_{155}+X_{165}+X_{175}+X_{185}+X_{195}+X_{205}+X_{215}+X_{225}+X_{235}=754
\end{aligned}
\tag{9}
$$

Supply constraints

$$
\begin{aligned}
&X_{11}+X_{12}+X_{13}+X_{14}+X_{15}+X_{16}=387\\
&X_{21}+X_{22}+X_{23}+X_{24}+X_{25}+X_{26}=260\\
&X_{31}+X_{32}+X_{33}+X_{34}+X_{35}+X_{36}=378\\
&X_{41}+X_{42}+X_{43}+X_{44}+X_{45}+X_{46}=342\\
&X_{51}+X_{52}+X_{53}+X_{54}+X_{55}+X_{56}=279\\
&X_{61}+X_{62}+X_{63}+X_{64}+X_{65}+X_{66}=330\\
&X_{71}+X_{72}+X_{73}+X_{74}+X_{75}+X_{76}=249\\
&X_{81}+X_{82}+X_{83}+X_{84}+X_{85}+X_{86}=304\\
&X_{91}+X_{92}+X_{93}+X_{94}+X_{95}+X_{96}=317\\
&X_{101}+X_{102}+X_{103}+X_{104}+X_{105}+X_{106}=346\\
&X_{111}+X_{112}+X_{113}+X_{114}+X_{115}+X_{116}=340\\
&X_{121}+X_{122}+X_{123}+X_{124}+X_{125}+X_{126}=311\\
&X_{131}+X_{132}+X_{134}+X_{135}+X_{136}+X_{137}=353\\
&X_{141}+X_{142}+X_{143}+X_{144}+X_{145}+X_{146}=322\\
&X_{151}+X_{152}+X_{153}+X_{153}+X_{154}+X_{156}=323\\
&X_{161}+X_{162}+X_{163}+X_{164}+X_{165}+X_{166}=304\\
&X_{171}+X_{172}+X_{173}+X_{174}+X_{175}+X_{176}=319\\
&X_{181}+X_{182}+X_{183}+X_{184}+X_{185}+X_{186}=328\\
&X_{191}+X_{192}+X_{193}+X_{194}+X_{195}+X_{196}=305\\
&X_{201}+X_{202}+X_{203}+X_{204}+X_{205}+X_{206}=328\\
&X_{211}+X_{212}+X_{213}+X_{214}+X_{215}+X_{216}=304\\
&X_{221}+X_{222}+X_{223}+X_{224}+X_{225}+X_{226}=334\\
&X_{231}+X_{232}+X_{234}+X_{235}+X_{236}+X_{237}=308
\end{aligned}
\tag{10}
$$

3.3 Computational Procedure

Due to the large size of the data, manual computation would have been tedious; therefore the QM software for windows was used. The software starts by using any of the methods stated in sections 2.4 and 2.5 to find the initial feasible solution and then continues to find the optimal solution using the modified distribution method.

Table 4: Computational Results-Least Cost Method

solution value = $129865.1	Atia	Odumasi	Juaben E	Juaben W	Juaben F	Ind	Dummy
North	(115.8)	(98.95)	(50.1)	(-11.27)	(-32.56)	(-2.92)	387
East	(114.13)	(97.28)	(48.43)	(-9.18)	(-31.72)	(-3.75)	360
West	(118.73)	(96.45)	(53.03)	(-13.77)	(-31.31)	(-2.08)	378
Kotei	(115.8)	(66.59)	(50.1)	(-30.47)	(13.78)	(15.45)	342
Ankaasi	(110.79)	(70.89)	(45.09)	(-37.15)	(8.77)	(7.94)	279
Apemso	(56.94)	(61.38)	(17.12)	(16.7)	(10.86)	(8.77)	330
Kasamu	(86.16)	(63.88)	(38.41)	(-44.67)	(-14.19)	(1.26)	249
Dumakwai	(82.82)	(62.05)	(35.91)	(-47.17)	(-17.53)	(-1.25)	304
Ntumkumso	(99.52)	(76.41)	(22.55)	(-31.31)	(-13.98)	(12.53)	317
Abetenim	(65.7)	(77.24)	220	(-11.27)	(-2.92)	(-1.67)	126
Ofoase	(65.7)	(77.24)	340	(-11.69)	(-3.75)	(-1.67)	(-3.76)
Odoyefe	(63.2)	(64.28)	(2.92)	(-7.1)	254	57	(-10.44)
Nkyerepoaso	(66.95)	(71.39)	284	(-11.69)	(-3.34)	69	(-7.94)
Krofofrom	(65.28)	(69.72)	(12.94)	(2.5)	322	(12.94)	(-1.68)
Duampompo	323	(11.46)	(-5.58)	(-2.24)	(-8.5)	(-9.76)	(-38.57)
Boamadumasi	304	(4.45)	(-5.58)	(-5.58)	(-8.5)	(-9.75)	(-42.74)
Boankra	(21.02)	(10.02)	(15.44)	141	178	(11.27)	(-22.97)
Kubeasi	135	(4.41)	(-5.58)	193	(-8.5)	(-9.76)	(-43.58)
Konongo	(72.38)	305	(-.82)	( )	(30.48)	(24.21)	(-7.94)
New Koforidua	(33.97)	( )	(90.18)	328	(30.48)	(24.21)	(-22.97)
Nnoboam	(70.71)	304	(90.38)	( )	(30.48)	(24.21)	(-9.61)
Bomfa	(46.49)	25	(73.48)	309	(30.48)	(24.21)	(-19.63)
Adumasa	(72.38)	308	(90.18)	( )	(30.48)	(24.21)	(-12.95)

From Table 4, the least cost method yielded GH₵129865.10 as the initial feasible solution.

Table 5: Computational Results-Vogel Approximation Method

solution value = $47164.59	Atia	Odumasi	Juaben E	Juaben W	Juaben F	Ind	Dummy
North	(130.82)	(109.56)	(53.85)	(3.75)	387	(21.86)	(11.69)
East	(128.31)	(107.05)	(51.34)	(5)	360	(20.19)	(10.85)
West	(132.5)	(105.81)	(55.53)	371	7	(21.45)	(10.44)
Kotei	(119.13)	(65.51)	(42.16)	(-27.14)	(34.65)	(28.54)	342
Ankaasi	(114.12)	(69.81)	(37.15)	(-33.82)	(29.64)	(21.03)	279
Apemso	(60.27)	(60.3)	(9.18)	(20.03)	(31.73)	(21.86)	330
Kasamu	(130.83)	(104.14)	(71.81)	249	(48.02)	(55.69)	(41.34)
Dumakwai	(129.99)	(104.81)	(71.81)	304	(47.18)	(55.68)	(43.84)
Ntumkumso	(102.85)	(75.33)	(14.61)	(-27.98)	(6.89)	(25.62)	317
Abetenim	(76.97)	(84.1)	341	5	(25.89)	(19.36)	(7.94)
Ofoase	(76.97)	(84.1)	340	(-.42)	(25.06)	(19.36)	(4.18)
Odoyefe	(76.97)	(73.64)	(5.42)	(6.67)	(31.31)	(23.53)	311
Nkyerepoaso	(78.22)	(78.25)	163	(-.42)	(25.47)	(21.03)	190
Krofofrom	(70.29)	(70.32)	(6.68)	(7.51)	(22.55)	(27.71)	322
Duampompo	323	(7.05)	(-16.85)	(-2.24)	(9.04)	( )	(-41.9)
Boamadumasi	304	(.04)	(-16.85)	(-5.58)	(9.04)	(.01)	(-46.07)
Boankra	(47.32)	(31.91)	(30.47)	(26.3)	(43.84)	(47.33)	319
Kubeasi	135	25	(-16.85)	42	(9.04)	126	(-46.91)
Konongo	(76.79)	305	(-7.68)	(4.41)	(52.43)	(38.38)	(-6.86)
New Koforidua	(60.27)	(21.89)	(105.21)	(26.3)	(74.32)	(60.27)	328
Nnoboam	(75.12)	304	(83.52)	(4.41)	(52.43)	(38.38)	(-8.53)
Bomfa	(69.45)	(18.55)	(85.17)	(22.96)	(70.98)	(56.93)	334
Adumasa	(76.79)	308	(83.32)	(4.41)	(52.43)	(38.38)	(-11.87)

From Table 5, the Vogel approximation yielded GHȻ47164.59 as its initial feasible solution, which is the least of the initial solutions obtained from the two methods. The modified distribution method was then applied to obtain the optimal solution as shown in Table 6.

Table 6: Computational Results-Modified Distribution Method

solution value = $30351.45	Atia	Odumasi	Juaben E	Juaben W	Juaben F	Ind	Dummy
North					387		
East					234	126	
West					133		245
Kotei							342
Ankaasi				279			
Apemso							330
Kasamu				249			
Dumakwai				304			
Ntumkumso				139			178
Abetenim			346				
Ofoase			340				
Odoyefe							311
Nkyerepoaso			158				195
Krofofrom							322
Boamadumasi	304						
Boankra							319
Kubeasi	135						193
Konongo		305					
New Koforidua							328
Nnoboam		304					
Bomfa		25					309
Adumasa		308					

From Table 6, the modified distribution method yielded GHȻ 30351.45 as the optimal solution. Table 7 shows shipment, cost per shipment and shipment cost.

Table 7: Shows Shipment, Cost per shipment and Shipment cost

From	To	Allocation	Cost per unit (GHȻ)	Allocation cost (GHȻ)
North	Juaben Farms	387	1.67	646.29
East	Juaben Farms	234	2.51	587.34
East	Individuals	126	10.86	1368.36
West	Juaben Farms	133	2.92	388.36
West	Dummy	245	-	-
Kotei	Dummy	342	-	-
Ankaasi	Juaben West	279	14.2	3961.8
Apemso	Dummy	330	-	-
Kasamu	Juaben West	249	6.68	1663.32
Dumakwai	Juaben West	304	4.18	1270.72
Ntumkumso	Juaben West	139	20.04	2785.56
Ntumkumso	Dummy	178	-	-
Abetenim	Juaben East	346	2.92	1010.32
Ofoase	Juaben East	340	6.68	2271.2
Odoyefe	Dummy	311	-	-
Nkyerepoaso	Juaben East	158	10.86	1715.88
Nkyerepoaso	Dummy	195	-	-
Krofofrom	Dummy	322	-	-
Duampompo	Atia	323	5.85	1889.55

Boamadumasi	Atia	304	10.02	3046.08
Boankra	Dummy	319	-	-
Kubeasi	Atia	135	10.86	1466.1
Kubeasi	Dummy	193	-	-
Konongo	Odumasi	305	4.18	1274.9
New Koforidua	Dummy	328	-	-
Nnoboam	Odumasi	304	5.85	1778.4
Bomfa	Odumasi	25	15.87	396.75
Bomfa	Dummy	309	-	-
Adumasa	Odumasi	308	9.19	2830.52

From Table 6, the maximum allocation is 387 tonnes, from North to Juaben Farms, whereas the minimum allocation is 25 tonnes, from Bomfa to Odumasi. The optimal transportation cost for the oil mills company is GH₵ 30351.45.

4. Conclusions and Recommendation

The study formulated the objective function of a transportation problem of an oil mill company as indicated in equation (8) and also established the optimal allocation as indicated in Table 6 in order to minimize the transportation cost. From the study, the cost of transporting raw materials from the various farm gates to the factory warehouses was obtained to be GH₵ 30351.45 which in effect saved the company an amount of GH₵ 22896.29 as compared to what they recorded during 2018 financial period. The Oil Mill management should employ the allocations in Table 6 in their daily schedule to minimise the cost involved in transporting the raw materials to the various warehouses.

References

[1] Issaka, H. (2010), "Transportation Problem with Volume Discount on Shipping Cost", Unpublished MSc. Project Report, Kwame Nkrumah University of Science and Technology, 79 pp.
[2] Otoo, H. (2018), "Mathematical Programming", Unpublished BSc. Lecture Notes, University of Mines and Technology, Tarkwa, 49 pp.
[3] Yinfang, S. (2011), "Multivariate Monge-Kantorovich Transportation Problem" Journal of Mathematics Research, Vol. 3, No. 2, pp. 66-71.
[4] Kantorovich, L. V. and Gavurin, M. K. (1949), "Application of Mathematical Methods to Problems of Analysis of Freight Flows", Problems of Raising the Efficiency of Transport Performance, pp. 110-138.
[5] Martin, L., Craveirinhna, J., Climaco, J. N. and Gomes, T. (2005). "On a Bi-dimensional Dynamic Alternative Routing Method" European Journal of Operational Research, Vol. 166, No. 3, pp. 828-842.
[6] Asare A. (2011), "Transportation Problem", Unpublished MSc. Project Report, Kwame Nkrumah University of Science and Technology, 104 pp.
[7] Ablordepey, V. (2012), "The Transportation Problem of a Beverage Industry: A Case Study of Accra Brewery Limited", Unpublished MSc. Project Report, Kwame Nkrumah University of Science and Technology, 94 pp.
[8] Ayisi, F. (2018), "Minimising the Transportation Cost of Asuo Bomasadu Timber Sawmill Limited", Unpublished BSc. Project Report, University of Mines and Technology, Tarkwa, 40 pp.
[9] Owusu-Boahene, R. (2016), "Modelling Transportation Problems in the Timber Industry: A case of Asuo Boosadu Timber Sawmill Limited (A.B.T.S) Berekum", Unpublished Dissertation, Kwame Nkrumah University of Science and Technology, 80 pp.
[10] Gupta, K. P. (2014), "Problems in Operations Research", S. Chand and Company Pvt. Limited, Vol. 27, No. 7, pp. 254-267.

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