# Optimisation of Production and Transportation Cost of Ashanti Foam Factory Limited, Ghana*

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## Abstract

Increasing global competition in the business world and heightened expectations of customers have forced companies to consider not only the pricing or product quality, but also reliability and timeliness of deliveries. The cost of production is the largest cost component in almost every manufacturing firm followed by transportation and inventory costs. This high cost of production and distribution is a major challenge to the management of Ashanti Foam Factory Limited and needs to make decisions on how to minimise costs so as to maximise profit. This has called for a study to explore ways to effectively manage production and transportation related problems of the company. In this study, Extended Vogel's Approximation Method was used to determine the feasible solution and the optimality was tested with Modify Distribution Method (MODI). With this, management could reduce production and transportation cost by 12.18 % and 42 % respectively.

**Keywords:** Transportation Problem, Feasible Solution, Optimality

## 1 Introduction

Increasing global competition in the business world and heightened expectations of customers have forced companies to consider not only the pricing or product quality, but also reliability and timeliness of deliveries.

Many researchers (Liu, 2003; Sriariyawat *et al.*, 2009; Hunjet *et al.*, 2002; Gorman, 2006; Eks,io'glu, 2002) have established that the cost of production is the largest cost component in almost every manufacturing firm followed by transportation and inventory costs.

Firms are to make decisions on production planning, inventory levels, and cost of transportation in each level of the logistics distribution networks in such a way that customers' demands are met promptly at a minimum cost (Okrah, 2012).

The production at Ashfoam involves a single homogeneous product, which is to be manufactured over a number of successive periods to satisfy pre-determined demands. Once manufactured, products can be transported to consumption centers or stores; both production cost and storage cost can be determined. On the average, the unit cost of production and transportation of product are GH¢415 and GH¢13 respectively. Management finds this to be too high. This has called for a study to explore ways to effectively manage production and transportation planning related problems of the company.

The study aims at developing a distribution plan for Ashfoam Ghana Limited, obtain the optimal monthly production schedule that meets customers' demand and determine optimal monthly haulage of products from sources (warehouses) to destinations (depots) that satisfies customers' demand.

The main model used in this study was Transportation Problem Model. Extended Vogel's Approximation Method (EVAM) was used to determine the Initial Basic Feasible Solution (IBFS); and, Modified Distribution Method (MODI) was also used to test for optimality.

## 2 Resources and Methods Used

### 2.1 Profile of Study Area

Ghana is a West African country bordering the Gulf of Guinea and located between latitude 5˚N and longitude 0° E. It is sandwiched by Burkina Faso, Cote d'Ivoire and Togo with a total boundary of 2 093 km. Ghana comprises 216 districts, with the capital city being Accra. The total population of Ghana is over twenty-seven million (27 098 246), with the two most populated cities being Accra (2.573M) and Kumasi (2.019M) (Anon., 2015a). The ten regions are divided into two major sectors: Southern and Northern sectors.

Ashanti Foam Factory Limited (Ashfoam Ghana Ltd) manufactures and exports polyurethane flexible foam, super deluxe mattress and pillows. The company has two plants, one in Accra (Gbawe) and the other in Kumasi (Ahensan). The Accra plant is in the southern sector of Ghana, whilst the Kumasi plant is in the northern sector.

The company has no inventory to begin with since units produced over the year are transported to the various depots before the beginning of the next production year. At the end of each month (after production has occurred and the current month's demand has been satisfied), an inventory cost of $3.3 per unit is incurred. The total production and transportation cost of the company at the end of the year are $25 427 853 and $625 482 respectively.

The growing population and improvement in the living standard of Ghana has over the years triggered demand for their products in almost all the ten regions of the country. Although, the cost of production at each plant is the same, the supply depots are scattered throughout the whole country. The regions which the two major plants supply to are shown in Fig. 1:

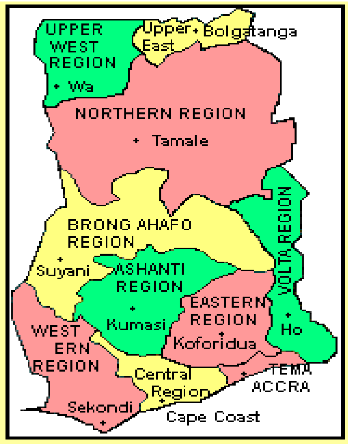


**Fig. 1 Map of Ghana Showing Various Regions (Anon., 2015a)**

## 2.2 Model Formulation

In this study, an Extended Vogel's Approximation method coupled with Modified Distribution method was applied to solve a transportation problem to determine the feasible region. The mathematical formulation of the transportation model depends on the ordinary VAM, but in an extended form taking into account all the necessary parameters.

Let $x_{ij}$ be the quantity transported from the source, *i* to the destination, *j*. Suppose each plant has the capacity to supply an amount, $s_i$ to satisfy a required demand $d_j$ to *jth* destination at a cost $c_{ij}$ of *ith* source to *jth* destination, then the transportation problem for *m* sources and *n* destinations can generally be defined as:

**Minimise:** $$Z = \sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij} x_{ij}$$

**Subject to:**

$$\sum_{j=1}^{n} x_{ij} \le s_i, \quad \text{for } i = 1, 2, 3, \dots, m$$

$$\sum_{i=1}^{m} x_{ij} \ge d_j, \quad \text{for } j = 1, 2, 3, \dots, n$$

$$x_{ij} \ge 0, \quad \text{for all } i, j$$

The extended form of the transportation problem model for this study factoring into it the various plants, their respective destinations as well as the various depots can further be expressed as:

**Minimise:** $$Z = \sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij} x_{Aij} + \sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij} x_{Kij}$$

**Subject to:**

$$\sum_{j=1}^{n} x_{Aij} + \sum_{j=1}^{n} x_{Kij} \le s_i, \quad \text{for all i = 1, 2, 3,…, m}$$

$$\sum_{i=1}^{m} x_{Aij} + \sum_{i=1}^{m} x_{Kij} \ge d_j, \quad \text{for all j = 1, 2, 3,…, n}$$

$$x_{ij} \ge 0, \ \sum_{j=1}^{n} x_{Aij} \le a_i, \ \sum_{j=1}^{n} x_{Kij} \le b_i, \ \forall\, i, j$$

where

**Z**: Total transportation cost to be minimized;
$C_{ij}$: Unit transportation cost of the commodity from each plant *i* to destination *j* per month;
$X_{ij}$: Number of units of commodity sent from source *i* to destination *j* per month;
$a_i$: Level of supply at each source *i*;
$b_i$: Level of demand at each destination *j*;
$S_i$: Total production capacity of Ashfoam available to be supplied per month; and
$d_i$: Total monthly demand at both depot *j*.
The minimization cost functions formulated out of the transportation problem model is Equation (1): Subject to supply constraints Equation (2):

$$\left.\begin{aligned}
B: Z = {} & 14.0X_{A1,1} + 21.0X_{A1,2} + 23.0X_{A1,3} + 23.0X_{A1,4} + 10.5_{A1,5} + 11.0X_{A1,6} + 9.5X_{A1,7} \\
& + 8.5X_{A1,8} + 11.5X_{A1,9} + 5.6X_{A1,10} + 5.5X_{K2,1} + 12.0_{K2,2} + 14.5X_{K2,3} + 14.5_{K2,4} \\
& + 4.5X_{K2,5} + 9.5X_{K2,6} + 7.5X_{K2,7} + 7.5_{K2,8} + 14.0_{K2,9} + 10.5X_{K2,10} \\
C: Z = {} & 15.0X_{A1,1} + 23.0X_{A1,2} + 25.0X_{A1,3} + 25.0X_{A1,4} + 12.5X_{A1,5} + 12.0X_{A1,6} + 10.5X_{A1,7} \\
& + 8.5X_{A1,8} + 12.5_{A1,9} + 6.5X_{A1,10} + 8.5X_{K2,1} + 12.5_{K2,2} + 17.5X_{K2,3} + 17.5X_{K2,4} \\
& + 5.5X_{K2,5} + 13.0X_{K2,6} + 10.5X_{K2,7} + 10.5X_{K2,8} + 18.0X_{K2,9} + 12.5X_{K2,10}
\end{aligned}\right\} \quad (1)$$

$$
\left.\begin{aligned}
B\ :\ & X_{A1,1}+X_{A1,2}+X_{A1,3}+X_{A1,4}+X_{A1,5}+X_{A1,6}+X_{A1,7}+X_{A1,8}+X_{A1,9}+X_{A1,10}\le 4029000\\
& X_{K2,1}+X_{K2,2}+X_{K2,3}+X_{K2,4}+X_{K2,5}+X_{K2,6}+X_{K2,7}+X_{K2,8}+X_{K2,9}+X_{K2,10}\le 7036000\\
C\ :\ & X_{A1,1}+X_{A1,2}+X_{A1,3}+X_{A1,4}+X_{A1,5}+X_{A1,6}+X_{A1,7}+X_{A1,8}+X_{A1,9}+X_{A1,10}\le 14098000\\
& X_{K2,1}+X_{K2,2}+X_{K2,3}+X_{K2,4}+X_{K2,5}+X_{K2,6}+X_{K2,7}+X_{K2,8}+X_{K2,9}+X_{K2,10}\le 15077000
\end{aligned}\right\}(2)
$$

And subject to demand constraints for B and C Equation (3):

$$
\left.\begin{aligned}
X_{A1,1}+X_{K2,1}&\le 5287\\
X_{A1,2}+X_{K2,2}&\le 3530\\
X_{A1,3}+X_{K2,3}&\le 2392\\
X_{A1,4}+X_{K2,4}&\le 2465\\
X_{A1,5}+X_{K2,5}&\le 8950\\
X_{A1,6}+X_{K2,6}&\le 5060\\
X_{A1,7}+X_{K2,7}&\le 4541\\
X_{A1,8}+X_{K2,8}&\le 4185\\
X_{A1,9}+X_{K2,9}&\le 4150\\
X_{A1,10}+X_{K2,10}&\le 10630,
\end{aligned}\right\}\quad(3)
$$

where A represents Accra plant, K, Kumasi plant, B, cost functions for the first six months (January to June) and C, cost functions for the next six months (July to December).

## 2.3 Model Assumptions

i. The activities of Accra and Kumasi operations are integrated.

ii. No breakdown in production and transportation facilities for the 2014 operational year.

iii. All depots are classified into the ten (10) corresponding regions of Ghana.

iv. Monthly production is made up of regular and overtime production.

## 2.4 Methodology

The method employed by this study to find the Initial Basic Feasible Solution for the Transportation Problem model is an Extended Vogel's Approximation Method (E-VAM) coupled with the Modified Distribution (MODI) Method. Although, there are several methods (Column Minimum Method (CMM), Row Minimum Method (RMM), North West-Corner Method (NWCM), Least Cost Method (LCM)) for determining the initial basic feasible solution for a given transportation problem model, Vogel's Approximation Method gives a much better Basic Feasible Solution (BFS) that is very close to optimality than the other methods (Utpal *et al*., 2014). The VAM thus leads to an allocation with fewer non-empty cells even in a degenerate case. The algorithm developed for E-VAM is based on the existing algorithm for Vogel's approximation.

### 2.4.1 Extended Vogel's Approximation Method (E-VAM) Algorithm

The Extended Vogel's Approximation Method makes use of the existing algorithm for VAM but with other constraint. The VAM algorithm used here is enumerated in the following steps:

Step 1. Identify two lowest costs in each row and column. Find the row difference and column difference for each cell;

Step 2. Identify the row or column with the largest cost difference and assign the maximum possible number of unit to the least cost route in that row or column;

Step 3. If the assignment in step two satisfies the demand at that destination, then delete the corresponding column. Otherwise delete the corresponding row when it exhausts the supply at the origin; and

Step 4. The procedure should be repeated until every supply and demand is exhausted or satisfied. Otherwise return to step one.

Coupled with the algorithm, the following conditions were also imposed:

i. $s_i > 0$, $\forall\ i = 1, 2, 3,\ldots, n$, and $d_j > 0$, $j = 1, 2, 3,\ldots, n$, that is should not be negative or zero at any instances;

ii. The difference $|s_i - d_j|$ should always be a minimum but not negative to satisfy both the customer and the organization; and

iii. $a_i \ge b_j \ge 0,\ and\quad Z = s_i(a_i) - d_j(b_i) > 0$

## 2.5 Model Validation

The formulated model was validated in two ways, first with respect to data and second with respect to the authenticity of the windows interface (POM-QM for windows (version 4)) used to simulate the model. The data for the study was acquired from Ashfoam Ghana Limited. A year-long secondary data (which comprises demand, production and transportation cost) was used to validate the model due to variation in prices of the product. The set of data used is shown in Table 1. The first set of data in Table 1, is on Production Capacity and Unit Cost of Production. The table shows the respective cost of production from January to December for each ware house (Accra and Kumasi warehouses) as well as the unit total cost for each month for the two warehouses. The second set of data is also on Monthly Demands at Various Depots. The expected monthly demand from January to December for each region (Depots) and the overall annual demand for each region are also shown in Table 2. The two sets of data were used to validate the model to achieve optimality. In ascertaining the authenticity of the windows interface used, POM-QM for windows (version 4) was used to run an existing data with known results from two different reference softwares (Lindo and Excel) and the three results compared. The data used for the validation was obtained from two different companies in Ghana (Guinness Ghana Ltd and GHACEM). From the results obtained, it can be inferred that there is no significant difference in the optimal solutions and the distribution plans of all the three softwares. It can thus be concluded that the POM-QM for windows (version 4) is reliable, and can be used to simulate the model. Tables 5 and 6, show the outputs obtained using POM-QM softwares.

## 3 Results and Discussion

Tables 3 and 4 show the results obtained when the formulated model in equations (1) - (3) was simulated with data from Ashfoam Ghana Limited. The result obtained, in Table 3, shows the Optimal Monthly Production Schedule for the company, whilst Table 4 gives the monthly Optimal Distribution Plan from January to December. Tables 3 and 4 were both used to explain the production and transportation schedule for the company. From Tables 3 and 4 it can be inferred that for the month of January Accra Plant should produce 1 235 000 units and distribute 70 000 units to Western Region, 290 000 units to Eastern Region, 275 000 units to Volta Region and 600 000 units to Greater Accra region. Also, in that same month, Kumasi Plant should produce 2 000 000 units and haul 340 000 units to Brong Ahafo Region, 420 000 units to Northern Region, 130 000 units to Upper East Region, 100 000 units to Upper West Region, 500 000 units to Ashanti Region, 200 000 units to Western Region and 310 000 units to Central Region.

**Table 1 The Production Capacity (in thousand) and Unit Cost of Production (Dollars)**

| MONTH / WHS | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ACC WHS | 2800 | 2800 | 2800 | 1840 | 1840 | 1840 | 3300 | 3300 | 3300 | 4500 | 4500 | 4500 | 37320 |
| KSI WHS | 2000 | 2000 | 2000 | 1400 | 1400 | 1400 | 2200 | 2200 | 2200 | 3200 | 3200 | 3200 | 26400 |
| COST | 410 | 410 | 410 | 425 | 425 | 425 | 440 | 440 | 440 | 455 | 455 | 455 | 5190 |

(Source: Anon., 2015b)

**Table 2 Expected Monthly Demands at Various Depots (Quantity)**

| MONTH / DEPOTS | Jan | Feb | Mar | Apr | May | Jun | *Jul* | *Aug* | Sept | Oct | Nov | Dec | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BA/R | 340 | 340 | 340 | 400 | 280 | 350 | *352* | *395* | 480 | 800 | 610 | 600 | 5287 |
| N/R | 420 | 250 | 250 | 180 | 180 | 180 | *320* | *320* | 320 | 370 | 370 | 370 | 3530 |
| UE/R | 130 | 195 | 115 | 120 | 135 | 152 | *135* | *150* | 150 | 300 | 400 | 410 | 2392 |
| UW/R | 100 | 100 | 120 | 111 | 132 | 132 | *250* | *255* | 270 | 270 | 340 | 385 | 2465 |
| AS/R | 500 | 500 | 500 | 360 | 360 | 360 | *900* | *900* | 1000 | 1020 | 1250 | 1300 | 8950 |
| W/R | 270 | 270 | 270 | 380 | 430 | 420 | *300* | *300* | 600 | 600 | 600 | 620 | 5060 |
| C/R | 310 | 310 | 283 | 283 | 300 | 300 | *500* | *420* | 420 | 420 | 525 | 470 | 4541 |
| E/R | 290 | 290 | 280 | 300 | 300 | 300 | *325* | *325* | 410 | 410 | 425 | 530 | 4185 |
| V/R | 275 | 275 | 275 | 310 | 310 | 310 | *335* | *335* | 395 | 395 | 415 | 520 | 4150 |
| G/R | 600 | 600 | 600 | 720 | 720 | 720 | *900* | *900* | 1200 | 1200 | 1340 | 1380 | 10630 |
| **Total** | 3235 | 3130 | 3033 | 3164 | 3147 | 3064 | *4317* | *4300* | 5155 | 5785 | 6275 | 6585 | 51190 |

**(Source: Anon., 2015b)**

**Table 3 Optimal Monthly Production Schedule for Ashfoam Ghana Limited**

| Optimal Monthly Production Schedule for Ashfoam Ghana Limited Solution | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Optimal solution value = $22331470 | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEPT | OCT | NOV | DEC | DUUMY |
| JAN (ACC PLT) | 1235 | | | | | | | | | | | | 1565 |
| FEB (ACC PLT) | | 1130 | 1397 | | | | | | | | | | 273 |
| MAR (ACC PLT) | | | | 2800 | | | | | | | | | |
| APR (ACC PLT) | | | | | 1840 | | | | | | | | |
| MAY (ACC PLT) | | | | | | | 1840 | | | | | | |
| JUN (ACC PLT) | | | | | | 1664 | | | | | | | 176 |
| JUL (ACC PLT) | | | | | | | | | | | | | 3300 |
| AUG (ACC PLT) | | | | | | | | 2100 | | | | | 1200 |
| SEPT (ACC PLT) | | | | | | | | | 2955 | | | | 345 |
| OCT (ACC PLT) | | | | | | | | | | 2585 | | | 1915 |
| NOV (ACC PLT) | | | | | | | | | | | 3075 | | 1425 |
| DEC (ACC PLT) | | | | | | | | | | | | 3385 | 1115 |

**Table 4 Monthly Optimal Distribution Plan Solution for January to December**

**JANUARY Solution**

| THE MONTHLY OPTIMAL DISTRIBUTION PLAN Solution | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Optimal solution value = $26477.5 | BA/R | N/R | UE/R | UW/R | AS/R | W/R | C/R | E/R | V/R | G/R |
| ACC WHS | | | | | | 70 | | 290 | 275 | 600 |
| KSI WHS | 340 | 420 | 130 | 100 | 500 | 200 | 310 | | | |

**FEBRUARY Solution**

| Optimal solution value = $25240 | BA/R | N/R | UE/R | UW/R | AS/R | W/R | C/R | E/R | V/R | G/R |
|---|---|---|---|---|---|---|---|---|---|---|
| ACC WHS | | | | | | | | 255 | 275 | 600 |
| KSI WHS | 340 | 250 | 195 | 100 | 500 | 270 | 310 | 35 | | |

**MARCH Solution**

| Optimal solution value = $10556 | BA/R | N/R | UE/R | UW/R | AS/R | W/R | C/R | E/R | V/R | G/R |
|---|---|---|---|---|---|---|---|---|---|---|
| ACC WHS | | | | | | | | | | 0 |
| KSI WHS | 340 | | | | 500 | 233 | 283 | 280 | | |

**APRIL Solution**

| Optimal solution value = $6454.5 | BA/R | N/R | UE/R | UW/R | AS/R | W/R | C/R | E/R | V/R | G/R |
|---|---|---|---|---|---|---|---|---|---|---|
| ACC WHS | | | | | | | | | | 0 |
| KSI WHS | 177 | | | | 900 | | | | | |

**JUNE Solution**

| JUNE Solution | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Optimal solution value = $24391 | BA/R | N/R | UE/R | UW/R | AS/R | W/R | C/R | E/R | V/R | G/R |
| ACC WHS | | | | | | 334 | | 300 | 310 | 720 |
| KSI WHS | 350 | 180 | | 124 | 360 | 86 | 300 | | | |

**AUGUST Solution**

| AUGUST Solution | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Optimal solution value = $41005 | BA/R | N/R | UE/R | UW/R | AS/R | W/R | C/R | E/R | V/R | G/R |
| ACC WHS | | | | | | 300 | 240 | 325 | 335 | 900 |
| KSI WHS | 395 | 320 | 150 | 255 | 900 | | 180 | | | |

**OCTOBER Solution**

| OCTOBER Solution | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Optimal solution value = $55787.5 | BA/R | N/R | UE/R | UW/R | AS/R | W/R | C/R | E/R | V/R | G/R |
| ACC WHS | | | | | | 580 | | 410 | 395 | 1200 |
| KSI WHS | 800 | 370 | 300 | 270 | 1020 | 20 | 420 | | | |

**NOVEMBER Solution**

| NOVEMBER Solution | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Optimal solution value = $60782.5 | BA/R | N/R | UE/R | UW/R | AS/R | W/R | C/R | E/R | V/R | G/R |
| ACC WHS | | | | | | 600 | 295 | 425 | 415 | 1340 |
| KSI WHS | 610 | 370 | 400 | 340 | 1250 | | 230 | | | |

**DECEMBER Solution**

| DECEMBER Solution | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Optimal solution value = $64062.5 | BA/R | N/R | UE/R | UW/R | AS/R | W/R | C/R | E/R | V/R | G/R |
| ACC WHS | | | | | | 620 | 335 | 530 | 520 | 1380 |
| KSI WHS | 600 | 370 | 410 | 385 | 1300 | | 135 | | | |

**Table 5 POM-QM Transportation Output of Guinness Gh. Ltd., July 2007-June 2008**

| **OPTIMALVALUE =$ 245498.9** | FTA | RICKY | OBIBAJK | KADOM | NAAT | LESK | DCEE | JOAMA | KBOA |
|---|---|---|---|---|---|---|---|---|---|
| ACH | 465 | | 451 | | 260 | 122 | | | |
| KAS | | 605 | | 338 | | 61 | 282 | 127 | 535 |

**Table 6 POM–QM Transportation Output of Ghacem Ltd.**

| **OPTIMAL VALUE=15670320** | MK1 | MK2 | MK3 | MK4 | MK5 | MK6 | MK7 | MK8 | MK9 |
|---|---|---|---|---|---|---|---|---|---|
| PLANT1 | | 51 510 | 205600 | | | | 34220 | 0 | 461720 |
| PLANT2 | 28010 | | | 34820 | 376560 | 90820 | | 6 360 | |
| DUMMY | | | | | | | | 2 000 | |

For the month of February, Accra Plant should produce 1 130 000 units and haul to Eastern Region 255 000 units, Volta Region 275 000 units and 600 000 units to Greater Region. Again, Kumasi Plant on the other hand, should produce 2 000 000 units in order to meet customers' demand and ship 340 000 units to Brong Ahafo Region, 250 000 units to Northern Region, 195 000 units to Upper East Region, 100 000 units to Upper West Region, 500 000 units to Ashanti Region, 270 000 units to Western Region, 310 000 units to Central Region, and 35 000 units to Eastern Region. This scenario continues for the subsequent months. It was also realised that there were no production and supply in the months of April and May at both Accra and Kumasi Plants. This is due to the fact that the proposed model takes into account the stock at various depots before production and supply commence.

Thus, the optimal annual cost for production was found to be $22 331 470 and that of transportation was $362 744.

## 4 Conclusions and Recommendation

### 4.1 Conclusions

The research work sought to reduce the transportation and production cost of Ashfoam Ghana Ltd. This was achieved by the use of Extended Vogel Approximation Method to reduce production and transportation cost, and at the same time satisfy the customers demand. With this scheduling plan, the company will reduce its production and transportation cost by 12.18% and 42% respectively. The application of the model also shows the optimal way to transport goods from the ware to the depots to meet customers' demand.

### 4.2 Recommendation

It is recommended that management of Ashfoam Ghana Limited adopt the proposed model for optimizing production to meet the required demand at minimal cost.


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