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Transportation Problem for a Beverage Firm in Kumasi, Ghana

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Abstract
This paper seeks to find the optimal transportation cost of a beverage firm in Kumasi-Ashanti Region, Ghana, using POM-QM for Windows 4 (Software for Quantitative Methods, Production and Operation Management by *Howard J. Weiss*) with Vogel's Approximation Method (VAM) as the initial method. An administered questionnaire was used for data collection from the firm. The results of the analysis revealed that, optimal transportation cost of the beverage firm is GH¢3, 174635.00 if it transports 769785, 615410 and 1014805 numbers of cases of bottles with drinks from Plant 1 to Accra, Tamale and Kumasi respectively. Again, if they transport 667887, 698463, and 633650 numbers of cases of bottles with drinks to Accra, Techiman and Sunyani from Plant 2, and also from Plant 3, with 11273 and 988727 number of cases of bottles with drinks to Accra and Koforidua respectively.

The company's transportation cost will reduce from GH¢3,209,897.86 to GH¢3, 174635.00 if it transports beverage (in cases) from the sources to the various destinations as in the optimal tableau (, Appendix 1, Table 3). It is believed that if the beverage firm applies this mathematical model then, it can save as much as GH¢35262.86 equivalent to US$ 11,020.00 which could be used in other areas of the firm to boost production.

Keywords: Transportation, Beverage firm, Optimal Tableau, Production, Optimal transportation cost.

Introduction

The production and transportation have crucial role simultaneously to balance the overall supply chain of manufacturing companies. Whenever any product is produced by industry it has to reach to its end users. Consumers may lie far away from the industry. Therefore, transportation is essential to keep the end users in access of various goods and services produced. Transportation maintains the flow of production and consumption regularly, thus causing nation to develop and improve. Transportation makes goods and services available at where and when they are needed by consumers and this eventually expands trade. The performance of a company depends both on its technological expertise and its managerial and organizational effectiveness. Transportation management is an important part of the process for manufacturing companies or firms.

Akot-Danso (2009) is of the view that transportation plays a vital role in life of region. It is that aspect of economic activity which provides for the carriage of goods and persons from one place to another. The transportation system of a country therefore is the circulatory system of that area. The networks of transportation in a country, thus, form the veins and arteries through which the activities of the country take place. One of the most important features of transportation, therefore, is that, it is important element in production and services. This is because production is not complete until the finished goods get to the final consumer.

Transportation problem is concerned with distributing any commodity from any group of supply centers called sources to any group of receiving centers called destinations, in such a way as to minimize the total distribution cost. Transportation entails the allocation of finished product so as to satisfy customer demands over a specific time horizon. As such transportation problems are inherently optimization problems where the objective is to develop a plan that meets demand at minimum cost or that fills the demand that maximize profit subject to constraints. In real world application, the supply and demand quantities in transportation problem are sometimes hardly specified precisely because of changing economic conditions.

Transportation providers utilize resources to make possible the physical movement of the goods, and they must recover the cost of providing this service -transportation cost. To be more specific, "transportation cost includes the rates, minimum weights, loading and unloading facilities, packaging and blocking, damage in transit, and special services available from a carrier -for example, stopping in transit" (Coyle, et al., 2003, p. 342)

Saumis et al; (1991) considered a problem of preparing a minimum cost transportation plan by simultaneously solving the following two sub-problems: first the assignment of units available at a series of origins to satisfy demand at a series of destinations and second, the design of vehicle tours to transport these units, when the vehicle has to be brought back to their departure point. The original cost minimization mathematical model was constructed, which is converted into a relaxed total distance optimization, then finally vehicle problem, and an empty vehicle problem.

Firms enter product markets to distribute final goods with the goal of minimizing distribution costs (Connor & Schiek, 1997). Product markets are also the source of final demand (Henderson & McNamara, 2000). Closeness to product markets is more important for demand- oriented food processing firms because most of the total production costs of these firms are associated with distribution of final products (Henderson & McNamara, 2000)

Firms typically outsource a variety of activities in order to achieve specific objective, which includes reducing costs (Aimi, 2007; Jiang, Frazier, & Prater, 2006; Lau & Zhang, 2006), improving product quality (Bardhan, Whitaker, & Mithas, 2006), improving flexibility (Lau & Zhang, 2006), increasing market coverage (Skjoett-Larsen, 2002), or perhaps to gain ready access to additional capacity (Linder, 2004; Mason, Cole, Ulrey, & Yan, 2002). According to Elliott (2006, p. 22), however, "in most cases the objective of outsourcing is a targeted 20% cost reduction, with actual savings coming from direct labor and variable costs."

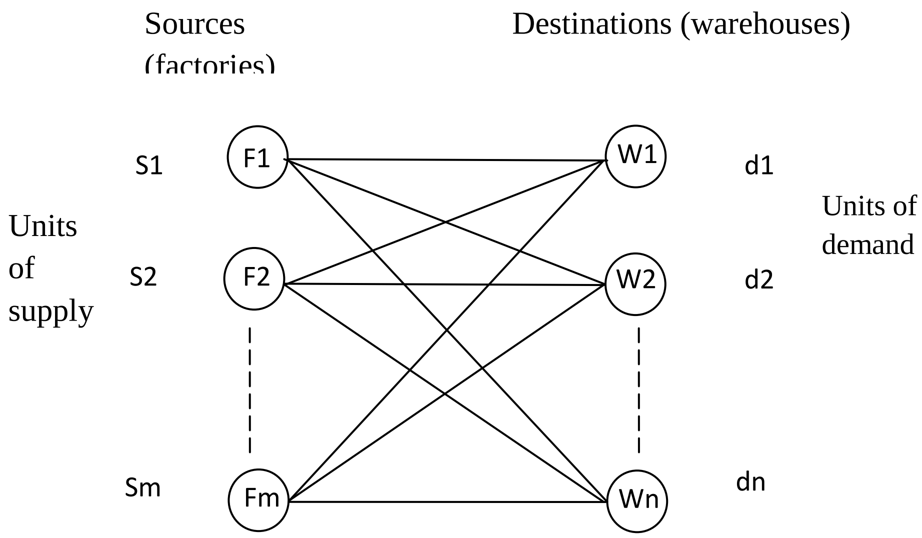
Business and Industries are practically faced with economic optimization such as cost minimization of non-economic items that are vital to the existence of their firms. Transportation problem is a Linear Programming problem that is concerned with the optimal pattern of the distribution of goods from several points of origin to several different destinations, with the specified requirements at each destination.
Transportation problem is a linear programming problem based on a network structure consisting of a finite number of nodes and arcs attached to them. Lui(2003). In transportation problem, when the demand and supply quantities are varying, a pair of mathematical problem is formulated to calculate the objective value. The derived result is also in range, where the total transportation cost would appear. In addition to allowing for simultaneous changes in supply and demand values, the total cost bounds are calculated directly. Due to the structure of the transportation problem, the largest total transportation cost may not occur at the highest total quantities shipped. Since the total cost bounds are derived, it would be beneficial to decision making.
Transportation problems faced by government or a business firm, are not balanced, thus, supply is less than demand and vice-versa due to paucity of funds. Sometimes, it becomes necessary to transport a certain percentage of commodities (demand) irrespective of the transportation cost. Almost all decision makers dealing with transport management are interested in minimization of total transportation cost and total time to each destination.
In this paper, transportation cost is the expenses involved in moving the finished products from the sources to the various warehouses in allocation of finished products so as to satisfy customers' demands over a specific time horizon. The objective of this study seeks to find the optimal transportation cost of a beverage firm in Kumasi-Ashanti Region, Ghana, using POM-QM for Window 4 (Software for Quantitative Methods, Production and Operation Management by *Howard J. Weiss*) with Vogel's Approximation Method (VAM) as the initial method.

Methodology
The data used in this study is obtained from a self administered questionnaire designed by the researchers in the firm to extract from the company, information on their level of supply at each source, level of demand at each destination and the unit transportation cost from each source to each destination as in (Appendix 2 Tables). The analysis was based on the information from the management of the firm. The total supply was 5400000 cases of drinks from three different plants and transported to six different depots (warehouses) with total demand of 5876382 cases of drinks. The total transportation cost was given as GH¢3,209,897.86 and the unit transportation cost of a case of drink from a source to a destination as found in (Appendix 1, table 1). Since the total demand exceeds total supply by 476382 cases, a fictitious source (supply) was created such that the unit cost from this source to every depot is zero to produce a balanced transportation tableau.
We therefore formulate the linear programming problem based on the above information to minimize the firm's transportation (distribution) cost.

Modeling Technique
The transportation model is thus a linear programming problem that can be solved by the regular simplex method, but of special structure. A balanced transportation problem is where the total supply equals to the total demand. POM-QM for Windows 4 (Software for Quantitative Methods, Production and Operation Management) was used to implement the transportation algorithm in this paper with the Vogel's approximation method (VAM) as the initial method. The transportation model seeks the determination of a transporting plan for a single commodity from a number of sources (factories) to a number of destinations (warehouses).The data of the model should include;

i. The level of supply at each source and amount of demand at each destination.
ii. The unit transportation cost of the commodity from each source to each destination.

The objective of the model is to determine the amount to be transported from each source to each destination such that the total distribution cost is minimized.
The transportation model can be considered as a network with M sources (factories) and N destinations (warehouses). The basic assumption is that the transportation cost on a given route is directly proportional to the number of units transported.



Network flow model of transportation problem

A factory or warehouse is represented by a node. An arc joining a factory and a warehouse represents the route through which the commodity is transported. The amount of supply at factory i is S_i and the demand at warehouse j is d_j and the unit of transportation cost between factory i and warehouse j is C_{ij}. Let Y_{ij} represent amount transported from factory i to warehouse j, clearly $Y_{ij} \geq 0$ and the linear programming model representing the transportation problem is given as:

Minimize $$\sum_{i=1}^{m} Y_{ij} = d_j,\ j = 1, 2, 3 \ldots \text{n}$$

Subject to $$\sum_{j=1}^{n} Y_{ij} \leq S_i, \text{i} = 1, 2, 3 \ldots \text{m}$$

$$\sum_{i=1}^{m} Y_{ij} \geq d_j, \text{i} = 1, 2, 3 \ldots \text{n} \qquad Y_{ij} \geq 0 \ \text{for all i and j}$$

The first set of constraints required that the sum of the product from a factory cannot exceed its supply; and the second set stipulates that the sum of the product to the warehouse must satisfy its demand.

ie. $$\sum_{i=1}^{m} S_i = \sum_{j=1}^{n} d_j$$

Proof

$$\sum_{j=1}^{n} Y_{ij} = S_i, \mathrm{i} = 1, 2, 3 \ldots \mathrm{m}$$

$$\sum_{i=1}^{m} Y_{ij} = d_j, \mathrm{j} = 1, 2, 3 \ldots \mathrm{n}$$

Summing the first constraints over i, We obtain

$$\sum_{j=1}^{n}\sum_{i=1}^{m} Y_{ij} \leq \sum_{i=1}^{m} S_i$$

(1)

Also summing the second constraints over j,

We obtain

$$\sum_{j=1}^{n}\sum_{i=1}^{m} Y_{ij} \geq \sum_{j=1}^{n} d_j \qquad (2)$$

This follows from (1) and (2) that $\sum_{i=1}^{m} S_i = \sum_{j=1}^{n} d_j$

When the total supply equal the total demand the resulting formulation is called a balanced transportation model. It differs from the above model only in the fact that all the constraints are equations.

Thus

$$\sum_{j=1}^{n} Y_{ij} = S_i, \mathrm{i} = 1, 2, 3 \ldots \mathrm{m}$$

$$\sum_{i=1}^{m} Y_{ij} \geq d_j, \mathrm{i} = 1, 2, 3 \ldots \mathrm{n}$$

If $\sum_{i=1}^{m} S_i = \sum_{j=1}^{n} d_j$ the problem is said to be balanced

$$\sum_{j=1}^{n} Y_{ij} = S_i, \mathrm{i} = 1, 2, 3 \ldots \mathrm{m}$$

$$\sum_{i=1}^{m} Y_{ij} \geq d_j, \mathrm{i} = 1, 2, 3 \ldots \mathrm{n}$$

Suppose for some a we have $\sum_{j=1}^{n} Y_{ai} < S_a$

Then $\sum_{j=1}^{n} d_j \leq \sum_{i=1}^{m}\sum_{j=1}^{n} Y_{ij} < \sum_{i=1}^{m} S_i$

Therefore $$S_i = \sum_{j=1}^{n} Y_{ij}$$

Also suppose that for some b

$$db = \sum_{i=1}^{m} Y_{ij}$$

Then $$\sum_{i=1}^{m} d_b < \sum_{j=1}^{n}\sum_{i=1}^{m} Y_{ij} \leq \sum_{i=1}^{m} S_i$$

Therefore $$d_j = \sum_{i=1}^{m} Y_{ij}$$

Otherwise the model is said to be unbalanced. However, a transportation model can always be balanced by adding either dummy source (factory) or destination (warehouse) with a unit transportation cost of zero. This is one of the special structures of the transportation model.

The Balanced Problem

The balanced transportation problem may be written as

Minimize $$\sum_{i=1}^{m}\sum_{j=1}^{n} C_{ij} Y_{ij}$$

Subject to

$$\sum_{j=1}^{n} Y_{ij} = S_{i,}\ \mathrm{i} = 1, 2, 3 \ldots \mathrm{m}$$

$$\sum_{i=1}^{m} Y_{ij} = d_{j,}\ \mathrm{i} = 1, 2, 3 \ldots \mathrm{m}$$

	W_1	W_2		W_n	Supply
S_1	C_{11}	C_{12}		C_{1n}	S_1
	Y_{11}	Y_{12}		Y_{1n}	
S_2	C_{21}	C_{22}	- - - -	C_{2n}	S_2
	Y_{21}	Y_{22}	- - - -	Y_{2n}	
	-	-		-	
	-	-		-	
	C_{m1}	C_{m2}	- - - - -	C_{mn}	
	Y_{m1}	Y_{m2}	- - - -	Y_{mn}	
Demand	d_1	d_2		dn	

There is a row for each source and a column for each warehouse. The supplies and the demands of these are shown for the right and below respectively. The unit costs are shown in the upper right hand corners of the cells.

We observe that

i. The coefficient of each variable Y_{ij} in each constraint is either 1 or 0.
ii. The constant on the right hand side of each constraint is an integer.
iii. The coefficient matrix A has a certain pattern of 1's and 0's.

It can be shown that any linear programming problem with these properties has the following properties:
Thus if the problem has a feasible solution then there exist feasible solution in which all the variables are integers. It is this property on which the modification of the Simplex method that provides efficient solution algorithms is based.

We note the following (m + n) conditions

$$\sum_{j=1}^{n} Y_{ij} = S_{i,}\, \mathrm{i} = 1, 2, 3 \ldots \mathrm{m}$$

$$\sum_{i=1}^{m} Y_{ij} = d_{j,}\, \mathrm{i} = 1, 2, 3 \ldots \mathrm{n}$$

are not independent since $\sum_{i=1}^{m} S_i = \sum_{j=1}^{n}\sum_{i=1}^{m} Y_{ij} = \sum_{j=1}^{n} d_j$

Thus the effective number of constraints on the balanced transportation problem is m+n-1.

We therefore expect a basic feasible solution of the balanced transportation problem to have (m+n-1) non negative entries.

Finding an Initial Basic Feasible Solution using Vogel's Approximation Method (VAM)

The Vogel's Approximation method is the method seems to produce optimal solution quiet often. First calculated the penalty cost for each row or column by subtracting the smallest cost from the next smallest cost element. Find the row or column which has the highest penalty cost (breaks ties arbitrarily). Allocate as much as possible to this cell as the row supply or column demand will allow. This implies that either a supply is exhausted or a demand is satisfied. In either case delete the row of the exhausted supply or the column of the satisfied demand. Calculate new row and column penalties for the remaining rows and column and repeat the process until a basic feasible solution is found. Vogel's Approximation method leads to an allocation with fewer than (m+n-1) non-empty cells even in the non-degenerate case. To obtain the right number of cells in the solution, we add enough zero entries to empty cells, avoiding the generation of circuits among the cells in the solution.

POM-QM (Software for Quantitative Methods, Production and Operation Management by *Howard J. Weiss*) was then used based on Vogel's Approximation Method (VAM) as the initial method to find the optimal transportation cost of the firm.

Results

The optimal tableau shown that, the Firm should transport beverage from the sources to the specific destinations with the exact number of cases of drinks as indicated in the Optimal tableau (Appendix 1,Table 3) so that its total transportation cost will be GH¢ 3,174,635.00. Any attempt to change the number of cases or the destinations, the firm will incur more transportation cost than the optimal transportation cost given by the software.

Discussion

The table 2 of (Appendix 1) depicts the results of the firm's balanced tableau. A fictitious source whose capacity is strictly the excess of demand over supply and that the unit cost from source to every warehouse is zero was created to produce a balanced transportation tableau for the POM- QM for Windows 4 to solve the problem to obtain the optimal tableau, (Appendix 1, Table 3).

The final (optimal) tableau shows the number of cases of drinks that should be transported to the various depots and from which source in order to minimize the total transportation cost. The dummy source helped in balancing the problem so as to solve and not to distribute to any destination (depot). Thus 769785, 615410 and 1014805 should be transported from Plant 1 to Accra, Tamale and Kumasi respectively. Again 667887, 698463, and 633650 cases of drinks should go to Accra, Techiman and Sunyani from Plant 2. And from Plant 3, 11273 and 988727 number of cases of drinks should be transported to Accra and Koforidua respectively. Distribution of beverage in this order to the various depots bring the total transportation cost to GH¢3174635.00. Any attempt to change the number of cases or the destinations, the firm will incur more transportation cost than the optimal transportation cost given by the software in optimal tableau.

Akot-Danso (2009) said production is not complete until the finished goods get to the final consumer. Firms enter product markets to distribute final goods with the goal of minimizing distribution costs (Connor & Schiek, 1997). Closeness to product markets is more important for demand- oriented food processing firms because most of the total production costs of these firms are associated with distribution of final products (Henderson & McNamara, 2000)
So the transportation cost should be minimal in that the consumer will be satisfied with the price of the drinks at wherever he/she found himself or herself.

Conclusion

This paper sought to find the optimal transportation cost of a beverage firm in Kumasi-Ashanti Region, Ghana, using POM-QM(Software for Quantitative Methods, Production and Operations Management) with Vogel's approximation method (VAM) as the initial method. An administered questionnaire was used for data collection from the firm. The results of the analysis revealed that, optimal transportation cost of the beverage firm is GH¢3, 174635.00 if it transports 769785, 615410 and 1014805 numbers of cases of drinks from Plant 1 to Accra, Tamale and Kumasi respectively. Again, if they transport 667887, 698463, and 633650 numbers of cases of bottles with drinks to Accra, Techiman and Sunyani from Plant 2, and also from Plant 3, with 11273 and 988727 number of cases of bottles with drinks to Accra and Koforidua respectively.

The company's transportation cost was reduced from GH¢3,209,897.86 to GH¢3, 174635.00 if it transports beverage (in cases) from the sources to the various destinations as in the optimal tableau (table 3). It is believed if the beverage firm applies this mathematical model then, the firm can save as much as GH¢35262.86 equivalent to US$ 11020.00which could be used in other areas of the firm to boost production.

The manufacturing firm should reduce the needless cost which is losses in the conversion process to improve the productive time; they have to afford to produce and transport an output with minimum unit cost for sustaining the profit for business survival too.

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APPENDIX 1

Table 1. The total number of cases of drinks with different labels distributed over the various depots for six months and the unit transportation cost of each case. (Data from the firm)

	ACCRA	TAMALE	KUMASI	TECHIMAN	KOFORIDUA	SUNYANI	SUPPLY
PLANT 1	0.9	1.0	0.2	0.34	0.52	0.34	2400000
PLANT 2	1.0	1.0	0.2	0.31	0.57	0.31	2000000
PLANT 3	1.0	1.12	0.2	0.32	0.5	0.3	1000000
DEMAND	1925327	615410	1014805	698463	988727	633650	

Table 2.The Firm's Balanced Tableau

	ACCRA	TAMALE	KUMASI	TECHIMAN	KOFORIDUA	SUNYANI	SUPPLY
PLANT 1	0.9	1.0	0.2	0.34	0.52	0.34	2400000
PLANT 2	1.0	1.0	0.2	0.31	0.57	0.31	2000000
PLANT 3	1.0	1.12	0.2	0.32	0.5	0.3	1000000
DUMMY	0	0	0	0	0	0	476382
DEMAND	1925327	615410	1014805	698463	988727	633650	

Table 3.The Optimal Tableau

Using the POM- QM for Windows 4, the optimal transportation tableau is shown as below.

MINIMUM TRANSPORTATION COST Solution						
Optimal Solution Value = GH¢ 3174635.00	ACCRA	TAMALE	KUMASI	TECHIMAN	KOFORIDUA	SUNYANI
PLANT 1	769785	615410	1014805			
PLANT 2	667887			698463		633650
PLANT 3	11273				988727	
DUMMY	476382					

APPENDIX 2

INFORMATION FROM THE FIRM

Table 1: TRANSPORTATION COST PER CASE

	ACCRA	TAMALE	KUMASI	TECHIMAN	KOFORIDUA	SUNYANI
PLANT 1	0.9	1.0	0.2	0.34	0.52	0.34
PLANT 2	1.0	1.0	0.2	0.31	0.57	0.31
PLANT 3	1.0	1.12	0.2	0.32	0.5	0.3

Table 2: TOTAL TRANSPORTATION COST = 3209897.00 Ghana Cedis

SUPPLY FROM THE PLANTS

PLANT 1	2000000
PLANT 2	2000000
PLANT 3	1000000

Table 3: DEMAND FROM THE DEPOTS

ACCRA	TAMALE	KUMASI	TECHIMAN	KORIDUA	SUNYANI
1925327	615410	1014805	698463	988727	633650

Table 4: THE NUMBER OF CASES OF DRINKS WITH DIFFERENT LABELS DISTRIBUTED OVER THE VARIOUS DEPOTS FROM JULY TO DECEMBER, 2013.

FES L

	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
ACCRA	1900	1923	1997	2033	2134	1044
TAMALE	780	780	700	860	780	------
KUMASI	1400	1460	1500	1467	1506	155
TECHIMAN	400	441	413	414	400	19
KOFORIDUA	500	539	544	562	545	55
SUNYANI	270	320	310	280	300	20

Table 5: FES S

	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
ACCRA	148600	148600	148776	148775	148688	150343
TAMALE	41000	41092	41200	41184	43764	47712
KUMASI	78000	75668	78830	76835	78840	98609
TECHIMAN	59368	59300	59000	59435	59735	89544
KOFORIDUA	88908	78145	80325	89816	88908	106253
SUNYANI	63800	63600	64200	64000	63600	78500

Table 6: SL

	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
ACCRA	165000	165997	165499	165515	166725	191828
TAMALE	57054	57000	57123	60101	61235	63045
KUMASI	83773	84187	86154	86316	88000	92105
TECHIMAN	48292	51116	49118	52993	53287	55188
KOFORIDUA	69830	71928	72143	80233	82998	85495
SUNYANI	37235	38183	36992	38313	38427	45400

APPENDIX 3

Kumasi polytechnic
Faculty of applied science
Department of mathematics and statistics
The purpose of this questionnaire is to Research on the Transportation Cost of a Beverage firm in Kumasi.

1. How many plants act as sources?
2. What are the average capacities of the plants?
3. Name six major distribution centers
4. Give the average monthly demand at the distribution centers
5. Provide the number of cases of drinks with different labels distributed over the various depots from July to December, 2014.
6. Provide the transportation cost per case from a source to a destination