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Transshipment Optimization of Potable Water to Some Rural Areas in Gombe State Using Equal Demand from Two Created Depots.

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ABSTRACT: The importance of potable water in human's life can never be over-emphasized. In this research paper, the transshipment of potable water to some rural areas in Gombe state using equal demand from two water depots is optimized. Vogel's approximation method, North West Corner rule method and Least cost method of solving transportation problem are compared. The transshipment output from Tora, Excel Solver and Management Scientists programming packages are also compared. The minimum cost of transshipping water from two water factories to various communities in sixteen towns of Gombe state through two created depots was obtained. It was found that Vogel's approximation method produced the best result in this problem. Tora and Management Scientist programming packages produced the same optimal value of ₦177929.28315k, using the parameters in this paper.

Keywords: Linear programming problem, Optimization, Transportation, Transshipment and Optimal value.

Introduction

Operations Research has a long tradition in improving operations and especially in reducing costs (Rommert *et al.*., 2012). In mathematics and computational science, optimization means the selection of the best element from some set of available alternatives (Dantzig, 1963). It also means solving problems in which one seeks to either minimize or maximize a real function by systematically choosing the values of real or integer variables from within an allowed set (Winston, 1991). In applications, optimization is used in engineering and economics (Bazaraa *et al.*, 1990). However, in optimization, when commodities pass from destination to destination or from source to source, a transshipment problem is formed (Hamdy, 2007). Transshipment in the other hand means shipment of commodities among sources and destinations. While commodities can be directly shipped to destinations in transportation problem, the commodities can be transported from one or more trans-shipment points in transshipment problem.

Charnes and Kress, (1993) opined that a linear programming model must be formulated for a transportation problem to be solved. After a linear programming model is formulated, a transportation tableau is now set after which any of the mentioned methods of finding an initial solution can be applied. Soji (2005) asserted that Vogel's approximation method (VAM) makes allocation based on a rational approach – minimization of the penalty (or opportunity) cost. North West Corner Rule method involves working diagonally across the routes from the top left-hand to the bottom right-hand (South-East) corner. Allocation can start from the upper left-hand corner of the given transportation matrix, satisfying the individual destination requirements and exhausting the origin capacities one at a time. According to Parsons et al. (1995), economists tend to equate least-cost method with cost-effectiveness analysis, a subset and simplification of a complete analysis of benefits and costs that is appropriate when an analyst can assume, as a rough approximation that benefits remain constant alternatives. If all alternatives provide the same benefits, then benefit-cost analysis reduces to determining the project with the least cost.

Water can be said to be next to air in the list of the most important need of man. Despite the considerable investment of Governments in Nigeria over the years in this essential human requirement, a large population still does not have access to water in adequate quantity and quality. It is estimated that only 48% of the inhabitants of the urban and semi-urban areas of Nigeria and 39% of rural areas have access to potable water supply (NWSP, 2000). In spite of these low figures the average delivery to the urban population is only 32 litres per person per day and that for rural areas is 10 liters per person per day which is below the United Nations standard. The quality in most cases is suspected to be poor (NWSP, 2000). Various reasons responsible for this situation includes poor planning, inadequate funding, insufficient relevant manpower, haphazard implementation etc, and above all the lack of a national policy for water supply.

The role of transshipment model in communities and companies can never be over – emphasized. United States of America used least cost planning in developing electric utility industry as a method for selecting the most cost – effective measures for meeting projected increases in demand for electricity (Parsons *et al.*, 1995). Of course, there is a clear relationship between the electricity and transportation facilities. But nobody has told us the best out of the three methods and the yard stick used to determine the best. This research will come out with the best method of solving a transportation problem among the three mentioned above. The research will show us the minimum amount to be spent on giving sixteen communities potable water. This will help the stakeholders in planning and budgeting for giving them portable water as early as and when due. Companies, communities and researchers stand to know what to apply when solving a transportation problem of which kind. So that time and resources can be saved for better things. Water is life. Dukku and the communities surrounding it have been battling with guinea worm for decades. Though, there is an international intervention for now. The areas are still under surveillance. But the truth remains that the problems they have are two; Shortage of water and guinea worm. The only thing that can help in fighting the two scourges at once is the provision of potable water for these communities. However, in producing the potable water, this research will help in optimizing the cost of transshipping the potable water to all the affected communities.

The transshipment problem is similar to the transportation problem except that in the transshipment problem, it is possible to both ship in and ship out of the same node. For the transportation problem, you can ship only from supply node to demand nodes. For the transshipment problem, you can ship from one supply node to another or from one demand node to another. Actually, designating nodes as supply points or demand nodes becomes confusing when you can ship both in and out of a node. One important point to consider in transshipment is that products sometimes be shipped into one node at a very low cost and then transshipped to other nodes. In some situations, this can be less expensive than direct shipment. Tai-Hsi *et al.* (2002) opined that in some logistic environments, managers must make decisions such as location for distribution centers, allocation of customers to each service area, and transportation plans connecting customers. The location-routing problems can find the optimal number and locations of the distribution centers, simultaneously with the vehicle schedules and distribution routes so as to minimize the total system costs. According to (Nabil *et al.*, 2004), transshipments can be recognized as the monitored movement of material among locations at the same echelon. It affords a valuable mechanism for correcting the discrepancies between the locations' observed demand and their on-hand inventory. Subsequently, transshipments may reduce costs and improve service without increasing the system-wide inventories. The transshipment problem acknowledges that it may be cheaper to ship through intermediate points before reaching the final destinations (Houthakar, 1985). This concept is therefore more general than that of the regular transportation model, where direct shipments are only allowed between a source and a destination.

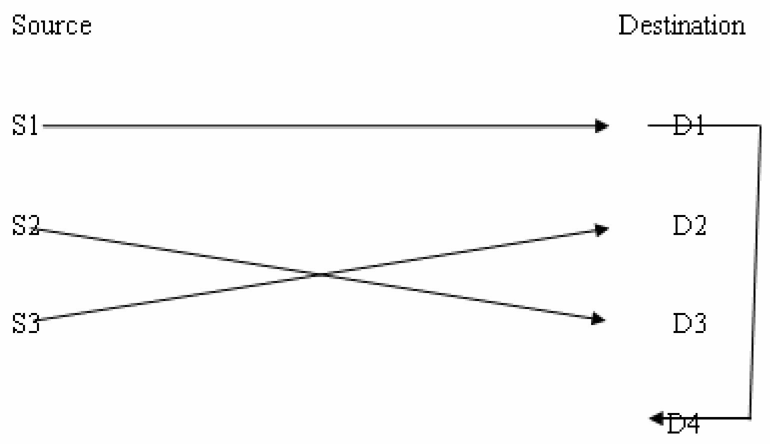

Figure 1: Transshipment of commodities from three sources to four destinations.

Figure 1 above shows the trans-shipment problem of commodities from three sources to four destinations. What makes the figure above a transshipment problem is that a destination is playing a dual role. Destination one is not just a destination point, it is also a source point for destination four.

Public Water Supply started in Nigeria early this century in few towns under the management of the lowest administrative level (NWSP, 2000). Amongst the early beneficiaries of these facilities were Kano, Ibadan, Enugu Lagos, Calabar, Abeokuta and Ijebu Ode. Then, the schemes were maintained with revenue from water rate collection with virtually no operational subvention from government. When Regional Governments were created in the early 1950s, the water supply undertakings continued to maintain the schemes but the financial and technical responsibilities for developing new water schemes were taken over by the Regional Governments who also assigned supervisory high level manpower (Water Engineers and Superintendents) to the water supply undertakings. For the period of the assignment, all the allowances and part of the salaries of these officers were paid from revenue generated from their water rate, while these officers still retained their employments and seniorities in the Regional Service. With the growing demand and increasing cost, it became necessary for the Regional Governments to secure loans. All the Regions were requested to set up independent bodies i.e. Water Corporations/Boards to develop, operate and manage the water supply undertakings. The first Water Corporation was formed in 1966 by the then Western Region with all the public water supply undertakings in the region, including their staff, assets and liabilities taken over by the Water Corporation. The staff of the Water Division of the Ministry of Works was also transferred to the new corporation. All the thirty-six (36) States of the Federation and the Federal Capital Territory have Water Boards/Corporations or Public Utilities Boards managing their public water supply systems. Their efforts are supplemented in many cases by Local Governments and Non-governmental organizations who supply water to small villages in their areas of jurisdiction. In 1976, the Federal Government got involved in water supply when the Federal Ministry of Water Resources and the eleven (11) River Basin Development Authorities (RBDAs) were created to manage the water resources of the country and to provide bulk water, primarily for irrigation and water supply. The Federal Ministry also undertakes basic Hydrological Data Collection and Storage for National Planning purposes. Other agencies involved in public water supply, as aid or loan programmes are the United Nations Children's Fund (UNICEF), United Nation Development Programme (UNDP) and a number of other bilateral, multilateral and External Support Agencies.

Gombe state water board was created in 1996. It is saddled with the responsibility of providing potable water for people within Gombe metropolis. The state government created a water treatment plant and a dam at Dadinkowa. At the dam, rain water is been harvested and kept in the dam. The river gongola passes through the dam and from there, water is been sent to the treatment plant. It is from there; water is pumped to different reservoirs and to different places within the metropolis. Gombe state water board is not to serve Dukku local government area and its environs water. It is the duty of the local government to provide the people of Dukku with potable water; though with the assistance of the state government. Though other parts of the state has problem of water, but it is not as serious as Dukku town and its environs. They cannot harvest rain water because of one of two reasons;

i. The surface of the ground is too hard, it cannot retain water. Therefore, rain water flows to other lands where water can sink into the ground.

ii. The underneath of the ground is too soft; water that goes down goes to settle at other places because the ground cannot retain water.

Nigeria is divided into six main Hydrological basins. Geographically, in the far south are low-lying swamp forests, followed in a northerly direction by generally flat dense rain forests, hilly shrub lands in the middle belt, relatively flat savannah grasslands and semi-arid areas in the far north. The central part of the country is marked by crystalline rock outcroppings and gently rolling hills. The average rainfall is about 500 mm/year in the north occurring (April through September), increasing to about 3,000 mm/year in the south occurring (March through October). The country is noted for its two major river systems: the Niger entering the country from the northwest, and the Benue entering from the Northeast which together with their many tributaries drains half the land area of the country. The two rivers meet at Lokoja and then move in a southerly direction into an extensive delta before discharging into the Atlantic Ocean. Other rivers flow directly into the Ocean or into Lake Chad. Many rivers in the north are intermittent, having water in them only in the rainy season, but the majority of the rivers in the south are perennial, flowing all year round, and are important sources of drinking and irrigation water for the surrounding communities. About 60% of the country is underlain by crystalline rocks, 20% by consolidated sedimentary materials, and 20% by unconsolidated sedimentary materials. Static water levels in water wells range between zeros in parts of the coastal alluvium to 200 meters in some sedimentary areas. Crystalline rock areas are found in many parts of the north, well yields are unpredictable; where sufficient depth of weathering exists, the area may be suitable for operation (minimum yield of 10 litres per minute), but only at specific localities where deep weathering and underlying fractures coincide are yields likely to be sufficient for motorized schemes. Groundwater quality in the country is good. Only in some areas are iron, nitrate or fluoride concentrations above recommended WHO levels. The corrosiveness of groundwater is also an important consideration in choosing materials for water supply equipments. Using pH as an index of corrosion potential, about 20% of the country is underlain by highly corrosive ground water (pH < 6.5), 40% by moderately corrosive groundwater (pH 6.5 to 6.8), and the remaining 40% by non-corrosive ground water (pH > 6.8).

However, groundwater is said to be well suited to rural water supply in sub-Saharan Africa (SSA). The characteristic of groundwater differs from that of surface water in many ways. Groundwater responds slowly to changes in rainfall and the impacts of droughts are often buffered (Calow *et al.*., 1997). In areas that has a long dry season; groundwater is still available when sources such as rivers and streams have run dry. Groundwater is generally uncontaminated microbiologically and to a certain extent, it is naturally protected from pollution. The resource can be cheap to develop, since large surface reservoirs are not required and water sources can usually be developed close to the demand (UNEP, 1996). These characteristics make groundwater well suited to the more demand responsive and participatory approaches that are being introduced into most rural water programmes. Any where groundwater is readily available; wells and boreholes can be dug using mainly social criteria and hydro geological considerations. However, problems arise in areas where communities have difficult geological conditions which make groundwater to be limited and/or hard to find in such communities. To site wells and boreholes in such areas will definitely lead to dry wells and boreholes. In order to have successful and sustainable rural water supply project, it is essential to understand the hydro geological environment of the project area.

Materials and Methodology

Real – life data were obtained from National Population Commission. A linear programming model was formulated from the data, after which a transportation tableau was set up. The programming packages mentioned above were used in finding an optimal solutions of the problem formulated.

Sixteen towns and villages were involved in the study. Two were used as a water factory (Barri and Wuro Tara), while two were also used as depots (Dukku and Bozon Sholwa). The population of all the towns and villages involved were obtained from National Population Commission. The only available population census was done in 1991. However, it had projection of up to 1996. There was a population growth of 2.89% between 1996 and 2006 and a population growth of 3.2% between 2006 and 2012. Below is a table showing the population of the towns and villages used in the study.

Table 1: Populations of the towns and villages.

Communities	(population as at) 1991	1996 (Projection)	2006 (2.89 % growth)	2012 (3.2 % growth)
BARRI (FACTORY)	1915	2210	2274	2347
ZANGE	899	1038	1068	1102
KUNI	947	1093	1125	1161
WALOJI	754	870	895	924
DIRRI	659	761	783	808
DASHI	1162	1341	1380	1424
NAKUJA	1182	1364	1403	1448
SHABEWA	547	631	649	670
DUKKU (DEPOT)	12147	14021	14426	14888
BUL - BUL	1120	1293	1330	1373
SHALLUDE	782	903	929	959
SHUWE	546	630	648	669
SUKA	1079	1245	1281	1322
JONDE	995	1148	1181	1219
B/ SHULWA (DEPOT)	1678	1937	1993	2057
WURO TARA (FACTORY)	319	368	379	391

The National Water Supply and Sanitation Policy (2000) stated that separate water supply and sanitation consideration should be made to match the three socio – economic profiles of the population. 30 litres per person per day in the rural areas, 60 litres per person per day in the semi-urban areas and 120 litres per person per day in the rural areas.

Table 2: The demand of each community

Communities	Population		Demand (Liters)	Demand+ 10% (Liters)
BARRI (FACTORY)	2347	Rural Area	70399	77439
ZANGE	1102	Rural Area	33065	36372
KUNI	1161	Rural Area	34817	38299
WALOJI	924	Rural Area	27714	30485
DIRRI	808	Rural Area	24241	26666
DASHI	1424	Rural Area	42717	46989
NAKUJA	1448	Rural Area	43450	47795
SHABEWA	670	Rural Area	20100	22110
DUKKU (DEPOT)	14888	Semi - Urban Area	893271	982598
BUL - BUL	1373	Rural Area	41188	45307
SHALLUDE	959	Rural Area	28765	31642
SHUWE	669	Rural Area	20068	22075
SUKA	1322	Rural Area	39659	43625
JONDE	1219	Rural Area	36569	40226
BOZAN SHULWA (DEPOT)	2057	Rural Area	61703	67873
WURO TARA (FACTORY)	391	Rural Area	11723	12895
			TOTAL	1572396

10% of the demand is added to each community. This is to cater for the needs of their domestic animals and projects like buildings etc. The pumping machines to be used can pump 1000000 liters of water to 19km, using a drum of diesel. ₦50, 000:00k per drum of diesel is used in this research.

RESULTS AND DISCUSSION

ANALYSIS OF TRANSSHIPMENT OF WATER FROM BARRI AND WURO TARA TO DUKKU AND BOZON CHOLWA WITH EQUAL DEMANDS.

A linear programming model is formulated as below:

Minimize $Z = 0.08947x_{11} + 0.15000x_{12} + 0.00079x_{13} + 0.11579x_{14} + 0.02632x_{21} + 0.08684x_{22} + 0.011579x_{23} + 0.00079x_{24}$

Subject to:

$X_{11} + X_{12} + X_{13} + X_{14} = 786198$

$X_{21} + X_{22} + X_{23} + X_{24} = 786198$

$X_{11} + X_{21} = 741031$

$X_{12} + X_{22} = 741031$

$X_{13} + X_{23} = 77439$

$X_{14} + X_{24} = 12895$

Using TORA, the three methods produced the same value of ₦128684.56267k. But Vogel's approximation method obtained its own in one iteration. North West corner rule produced its own after three iterations and Least cost method obtained the same optimal cost in two iterations. The transportation of water from one place to the other was common in all the three methods.

Using EXCEL SOLVER, the same optimal value of ₦128684.56267k was obtained as in TORA. However, in EXCEL SOLVER, Wuro tara transshipped 0.00000000000017 liter of water to Barri, a quantity that is negligible. It is believed that it does its own work in one iteration.

Using MANAGEMENT SCIENTIST, the same optimal value of ₦128684.56267k was obtained.

ANALYSIS OF TRANSSHIPMENT OF WATER FROM THE WATER DEPOTS (DUKKU AND BOZON CHOLWA) WITH EQUAL SUPPLY TO THE OTHER COMMUNITIES.

A linear programming model is formulated as below.

Minimize $Z = 0.08158x_{11} + 0.04474x_{12} + 0.05263x_{13} + 0.11316x_{14} + 0.01842x_{15} + 0.01053x_{16} + 0.00526x_{17} + 0.00079x_{18} + 0.01579x_{19} + 0.02105x_{110} + 0.03684x_{111} + 0.06316x_{112} + 0.10000x_{113} + 0.06053x_{114} + 0.14211x_{21} + 0.10526x_{22} + 0.09757x_{23} + 0.05263x_{24} + 0.07105x_{25} + 0.07105x_{26} + 0.06579x_{27} + 0.06053x_{28} + 0.04474x_{29} + 0.03947x_{210} + 0.02368x_{211} + 0.12368x_{212} + 0.07895x_{213} + 0.00079x_{214}$

Subject to:

$X_{11} + X_{12} + X_{13} + X_{14} + X_{15} + X_{16} + X_{17} + X_{18} + X_{19} + X_{110} + X_{111} + X_{112} + X_{113} + X_{114} = 741031$

$X_{21} + X_{22} + X_{23} + X_{24} + X_{25} + X_{26} + X_{27} + X_{28} + X_{29} + X_{210} + X_{211} + X_{212} + X_{213} + X_{214} = 741031$

$X_{11} + X_{21} = 36372$

$X_{12} + X_{22} = 38299$

$X_{13} + X_{23} = 30485$

$X_{14} + X_{24} = 26666$

$X_{15} + X_{25} = 46989$

$X_{16} + X_{26} = 47795$

$X_{17} + X_{27} = 22110$

$X_{18} + X_{28} = 982598$

$X_{19} + X_{29} = 45307$

$X_{110} + X_{210} = 31642$

$X_{111} + X_{211} = 22075$

$X_{112} + X_{212} = 43625$

$X_{113} + X_{213} = 40226$

$X_{114} + X_{214} = 67873$

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

Using TORA, North – West Corner Rule produced an optimal value of ₦49244.72048k after five iterations; Least Cost Method produced the same optimal value in six iterations. Vogel's approximation method produced the same optimal value in one iteration.

Using EXCEL SOLVER, an optimal value of ₦49244.72048k was obtained. But it transshipped 0.00000000000025 litre of water from Dukku to Dirri. 0.00000000000083 litre from Bozon Cholwa to Kuni, 0.00000000000055 litre from Bozon Cholwa to Shabewa and 0.00000000000012 litre from Bozon Cholwa to Suka. Though the quantities are very negligible, the transshipments made no sense.

Using MANAGEMENT SCIENTIST, the same optimal value of ₦49244.72048k was obtained;

DISCUSSION OF RESULTS

Considering the LPP, North-West Corner Rule method produced an optimal value of ₦128684.56267k after 3 iterations, Least Cost method produced the same value after 2 iterations but Vogel's approximation method produced the same optimal value after one iteration. Clearly, Vogel's approximation method though produced the same optimal value but in a shorter number of iteration. Therefore, Vogel's approximation method can be taken for the best in solving the LPP.

Comparing the packages, the result obtained by vogel's approximation method can be used to represent the result of Tora. However, the three packages obtained the same optimal value of ₦128684.56267k. the only observation here is that Excel Solver transported 0.00000000000017 litre of water from Wuro Tara to Barri. Though the quantity is negligible, such transportation makes no sense.

Considering the second LPP, North-West Corner Rule method produced an optimal value of ₦49244.72048k after 5 iterations, Least Cost method produced the same optimal value after 6 iterations but Vogel's approximation method produced the same optimal value after one iteration. Clearly, vogel's approximation method though produced the same optimal value but in a shorter number of iteration. Vogel's approximation method is the best for solving the LPP.

Comparing the packages, the result obtained by vogel's approximation method can be used to represent the result of Tora. However, the three package obtained the same optimal value of ₦49244.72048k. excel Solver transshipped 0.00000000000025 litre of water from Dukku to Dirri, 0.00000000000083 litre from Bozon Cholwa to Shabewa and 0.00000000000012 litre from Bozon Cholwa to Suka. Though the quantities are negligible, such transshipments makes no sense.

CONCLUSION

It can be concluded that Vogel's approximation method produced better results than the other methods; Tora package produced the best optimal value in solving this problem. However, the best optimal values produced are ₦128684.56267k for the transshipment of water from the factories to the water depots and ₦49244.72048k for the transshipment of water from the water depots to the other communities. This gives a total optimal value of ₦177929.28315k.

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