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Optimizing the Transportation of Potable Water to Kaura- Namoda and Its Surrounding Villages

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Abstract
The importance of potable water in life can never be over – emphasized. In this research paper, the transportation of potable water to Kaura – Namoda and its surrounding villages was optimized. Vogel's approximation method in Tora software package was used. The minimum cost of transporting potable water from two treatment plants to 9 different communities (11 reservoirs) was obtained. It was found that the total required water consumption per person per day of the communities is 12,212,796 liters. An optimal value of ₦223, 662.39k was obtained in transporting the required quantities of water to all the communities every day.
Keywords: Optimization, Transportation, Transshipment, Potable water

Introduction

Operations research is a discipline that deals with the application of advanced analytical methods to help make better decisions. It is often considered to be a sub-field of mathematics. In mathematics and computational science, optimization means the selection of the best element from some set of available alternatives (Dantzig, 1963). Operations Research has a long tradition in improving operations and especially in reducing costs (Rommert *et al.*, 2012). Optimization could be used in engineering to determine which equipment to be moved to which site in order to minimize cost (Bazaraa *et al*., 1990). 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).

Transportation model was first presented by Hitchock (1941) and it was further developed by Dantzig (1963). Transportation problem deals with minimum cost plan to transport a commodity from a number of sources to a number of destinations (Nesa, 1973). Reeb and Leavengood (2002) described transportation problem as selecting the shipping routes to be used and the number of desks to be shipped on each route so as to minimize total transportation cost. According to Uba, Abubakar and Abimbola (2013), the transportation problem is similar to the transshipment problem except that in the transportation problem, you can ship only from the supply node to the demand node. For the transshipment problem, it is possible to both ship – in aqnd ship – out of the same node. According to Advani and Tiwari (2006), transportation demands in urban areas continue to increase rapidly as a result of both population growth and changes in travel patterns. In the era of environment concerns and limited space available in cities, transport planners have to provide a system, which can ensure safe and clean mobility to all city residents in and outside the city. This requires planning a system, which is affordable, reliable and efficient from the users as well as operator's perspectives.

Charnes and kress (1993) opined that a linear programming model must be formulated for a transportation to be solved. After a linear programming is formulated, a transportation Tableau is now set after which any of North West corner rule method (NWCR), Least cost method (LCM) and vogel's Approximation method (VAM) of finding initial solution can be applied. Soji (2005) asserted that Vogel's approximation method 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 and Douglas (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 (Dick and Don, 1994).

Water can be said to be next to air in the list of the most important need of human beings. 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 (FGN, 2000). In spite of these low figures the average delivery to the urban population is only 32 liters 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 (FGN, 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.

Statement of the problem

Kaura – Namoda is a town located north of the capital of Zamfara state. In the future, any migration to and from the town will depend on many factors, including the adequacy of water supply system and any other facilities which might be established. The town has abundance land for development; kaura is growing in size, this leads to the need for its future water expansion works. Kaura and the communities surrounding it have been suffering from shortage of potable water and water related diseases for decades. The water provision system on ground pumps about 454,609 liters of water from the available treatment plant to a reservoir in the periphery of kaura daily. A booster pump is now used to pump the water from there to kaura town. The amount pumped per day is never enough for the population of kaura namoda, but people from nearby villages still come to struggle for the quantity they can get from the little. People and animals from nearby villages that have no option go to river to struggle for the water needed for their daily activities, hence, a need for this research. Water is an essential commodity everywhere and at any time. Lack of potable water is dangerous to the existence of human beings. The provision of potable water to the people in these communities will reduce the hardship they are going through on water scarcity. This will not only put an end to the water related diseases they have been suffering with for years, it will also provide a permanent solution to the problem of water scarcity in the rural areas in the study.

Materials and Methodology

Kaura Namoda water board was established in 1970 and started operation in 1972, the only treatment plant that transport water to the place is located at the south-eastern part of Kaura Namoda, along Birnin Magaji village. It is about 5km from the local government headquarter (Federal Ministry of Water Resources, 1993).

A dam is constructed at very close to the water treatment plant. The source of the water is the kuduwal stream, popularly known to inhabitants of the area i.e. Kogi, Agira and Tankware village. However, the primary source is Modomawa stream. Flow of water from the dam to the treatment plant is by gravity. 454,609 liters of water is pumped to three different reservoirs in the metropolis from the treatment plant every day.

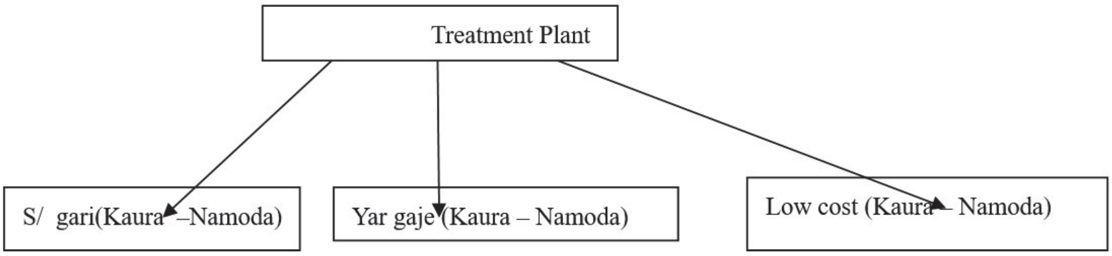

Figure 1: The existing system of water supply to Kaura Namoda.

The pumping machines to be used for this paper can pump 1,000,000 liters of water to 19km, using a drum of diesel. A drum of diesel in the filling stations cost ₦57,250: 00k. But in the black market, it is about ₦68,700:00k. ₦64,120: 00k per drum of diesel is used in this research. Two treatment plants and eleven towns and villages were involved in study. The estimated population of all the towns and villages involved were obtained from Kaura-Namoda water board. The communities are: Agira, Kogin-Abdu, Tankware, Yar gaje (Kaura namoda), Garbawa, Ginjime, Banga, Low cost (Kaura namoda), Kadarbe, Badawa, Kaura namoda.

Table 1: Required water consumption per person per day

Area	Population	Required water consumption per person per liter in a day
Urban Area	Above 20,000 People	120 Liters
Semi- Urban Area	5,000 – 20,000 People	60 Liters
Rural Area	Less than 5,000 people	30 Liters

The National Water supply and sanitation policy (2007) stated that separate water supply and sanitation consideration should be made to match the three socio – economic profiles of the population as indicated in table 1 above.

Table 2: Distances from the treatment plants to the communities.

Towns and Villages	Treatment Plant 1 (TP 1)	Treatment plant 2 (TP 2)
Agira	4km	6km
K/Abdu	3km	5km
Tankware	3km	4km
Yar gaje (Kaura namoda)	5km	6km
Garbawa	5km	3km
Ginjime	6km	3km
K/Namoda	5km	7km
Banga	6km	4km
Low cost (Kaura namoda)	6km	5km
Kadarbe	5km	3km
Badawa	7km	4km

Using the required water consumption per person per day of National Water supply and sanitation policy (2007), the demand of each community is obtained as shown in the table below.

Table 3: The total demand of each community

S/N	COMMUNITY	POPULATION	AREA TYPE	DEMAND (LITRES)	DEMAND (LITERS) + 15%
1	K/NAMODA	67635	URBAN	8116200	9333630
2	AGIRA	6827	SEMI-URBAN	409620	471063
3	K/ABDU	5696	SEMI-URBAN	341760	393024
4	TANKWARE	7936	SEMI-URBAN	476160	547584
5	BANGA	9583	SEMI-URBAN	574980	661227
6	L/COST (K/N)	5296	SEMI-URBAN	317760	365424
7	KADARBE	2565	RURAL	76950	88493
8	BADAWA	3487	RURAL	104610	120302
9	YARGAJE (K/N)	2573	RURAL	77190	88769
10	GARBAWA	2385	RURAL	71550	82283
11	GINJIME	1768	RURAL	53040	60997
TOTAL					12212794

Method

Real - life data were obtained from zamfara state water board. A linear programming model was formulated from the data. A transportation tableau was set up. Vogel's approximation method in TORA package was used to optimize the formulated linear programming problem. TORA package is used to obtain the optimal solution of the problem formulated.

Analysis of Transportation of Water from treatment plants to the proposed Areas

In this analysis, we look at the transportation of water from the treatment plants to the proposed communities. Below is a transportation table showing the demand and supply of the treatment plants to these communities;

Table 4: Transportation Tableau of the proposed treatment plants and communities

Demand	9333630	471063	393024	547584	661227	365424	88493	120302	88769	82283	60997	12212796
Tp2	0.02362	0.02025	0.01687	0.01350	0.01350	0.01687	0.01012	0.01350	0.02025	0.01012	0.01012	6106398
Tp1	0.01687	0.01350	0.01012	0.01012	0.02025	0.02025	0.01687	0.02362	0.01687	0.01687	0.02025	6106398
	K/Namoda	Agira	K/Abdu	Tankware	Banga	Low cost (Kaura namoda)	Kadarbe	Badawa	Yar gaje (Kaura namoda)	Garbawa	Ginjime	Supply

A linear programming model from the transportation table above was formulated.

Minimize $Z = 0.02025x_{11} + 0.01350x_{12} + 0.010121x_{13} + 0.01012x_{14} + 0.02025x_{15} + 0.02025x_{16} + 0.01687x_{17} + 0.02362x_{18} + 0.01687x_{19} + 0.01687x_{110} + 0.02025x_{111} + 0.02362x_{21} + 0.02025x_{22} + 0.01687x_{23} + 0.01350x_{24} + 0.01350x_{25} + 0.01012x_{26} + 0.01012x_{27} + 0.01350x_{28} + 0.02025x_{29} + 0.01012x_{210} + 0.01012x_{211}$

Subject to:

$X_{11} + X_{12} + X_{13} + X_{14} + X_{15} + X_{16} + X_{17} + X_{18} + X_{19} + X_{110} + X_{111} = 6106398$

$X_{21} + X_{22} + X_{23} + X_{24} + X_{25} + X_{26} + X_{27} + X_{28} + X_{29} + X_{210} + X_{211} = 6106398$
$X_{11} + X_{21} = 9333630$
$X_{12} + X_{22} = 471063$
$X_{13} + X_{23} = 393024$
$X_{14} + X_{24} = 547584$
$X_{15} + X_{25} = 661227$
$X_{16} + X_{26} = 365424$
$X_{17} + X_{27} = 88493$
$X_{18} + X_{28} = 120302$
$X_{19} + X_{29} = 88769$
$X_{110} + X_{210} = 82283$
$X_{111} + X_{211} = 60997$
$x_{ij} \geq 0$ for all i,j

Using Tora, the following results were obtained.

Table 5: The result obtained in the transportation of water from the two treatment plants to the proposed communities.

From	To	Amount shipped	Objective Coeff.	Obj. contribution
TP1	K/Namoda	5242311	0.01687	88437.78657
TP2	K/Namoda	4091319	0.02362	96636.95478
TP1	Agira	471063	0.01350	6359.3505
TP1	K/Abdu	393024	0.01012	3977.40288
TP2	Tankware	547584	0.01350	7392.384
TP2	Banga	661227	0.01350	8926.5645
TP2	Low cost (Kaura namoda)	365424	0.01687	6164.70288
TP2	Kadarbe	88493	0.01012	1492.87691
TP2	Badawa	120302	0.01350	895.54916
TP2	Yar gaje (Kaura namoda)	88769	0.02025	1624.077
TP2	Garbawa	82283	0.01012	832.70396
TP2	Ginjime	60997	0.01012	1235.18925

Discussion of results

From the results obtained above, it can be seen that ₦88437.78657 will be used in transporting 5242311 liters of water from treatment plant 1 to Kaura – Namoda, and ₦96636.95478 will be used in transporting 4091319 liters of water from treatment plant 2 to Kaura – Namoda. ₦6359.3505 will be used in transporting 471063 liters of water from treatment plant 1 to Agira, ₦3977.40288 will be used to transport 393024 liters of water from treatment plant 1 to K/Abdu, ₦7392.384 will be used to transport 547584 liters of water from treatment plant 2 to Tankware. ₦8926.5645 will be used to transport 661227 liters of water from treatment plant 2 Banga, ₦6164.70288 will be used in transporting 365424 liters of water from treatment plant 2 to Low cost (Kaura namoda), ₦895.54916 will be used in transporting 88493 liters of water from treatment plant 2 to Kadarbe, ₦1624.077 will be used in transporting 120302 liters of water from treatment plant 2 to Badawa, ₦1797.57225 will be used in transporting 88769n liters of water from treatment plant 2 to Yar gaje (Kaura namoda), ₦832.70396 will be used to transport 82283 liters of water from treatment plant 2 to Garbawa, ₦617.28964 will be used in transporting 60997 liters of water from treatment plant 2 to Ginjime. This gives a total optimal value of ₦223662.338120.

Summary

The importance of providing potable water for these communities can never be over emphasized. In this research work, the existing system of Kaura – Namoda water supply was studied. Addition of one treatment plant was proposed in order to provide adequate potable water to Kaura – Namoda town .A linear programming problem was formulated. The formulated objective function was solved using Vogel's approximation method in TORA software package to find the optimal solution for transporting water from the two treatment plants to Kaura – Namoda and the other communities. The optimal value obtained was ₦223662.3381120k.

Conclusion

In conclusion, from the result of the analysis, potable water will be transported to Kaura – namoda and the surrounding communities. The optimal value of ₦223662.338120k would be expended daily in the transportation of water from the treatment plants to Kaura Namoda and the communities.

Recommendations

- Government should relate with research institutions or researchers to find out the best channel of transporting water so that the cost is minimized
- Stakeholders should put hands together in the realization of the project. This will not only provide potable water to the communities, it will also prevent the people of the communities from water related diseases.
- For further studies, the scope of this research work should be expanded to cover more communities in the area.

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