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MODELING WATER RESOURCES ALLOCATION IN ANAMBRA-IMO RIVER BASIN

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ABSTRACT

Data were obtained from Mmam River and Aboine River Sub-basins of the Anambra-Imo River Basin. The sub-basins were considered along four subareas and five usage areas of community use, ecological, industrial, energy and loss/leakage mitigation. The study involved a minimization and reduced cost, linear programming simplex method as an aid in evaluating and describing the water resources allocation. The problem was solved using software, implementing the Tora Optimization system and simplex algorithm written in visual basic language. The model uses optimality and equity in minimizing allocation to various subareas with a view to reducing wastages and setting allocation limits within the available scarce water resources in the river basins. The optimal solutions were obtained subject to twenty-six material balance and capacity constraint for each river sub-basin, as well as more than twenty transformations and five iterations. The sensitivity and post-optimality analysis of the study provided a direct link between the model input and its output by a certain percentage or rate. The study showed that when compared with the existing method of water allocation; the proposed system resulted in more than 90% efficiency in water resource allocation.

Keywords: Optimality, Scarcity; Allocation, Water Resources.

1. INTRODUCTION

Water resource allocation entails making water available to users at particular points in space and time. It tends to allocate the available resources to various end- users who hold some entitlements. These entitlements could be for domestic use, irrigation, hydropower, industrial, environmental or other purposes (Garg, 2005). Due to changing environmental, social and development conditions, the utility functions of the decision makers and agencies could vary from time to time. Therefore, one of the greatest tasks for water resource managers is to match the balance between supply and demand of water (Agunwamba, 2001). Increased population growth, rapid economic growth and environmental degradation have resulted in increasing demand for water. Water is the most important resource of a country and of the entire society as a whole. This is because no life is possible without water. Water can be put to various uses (water allocation priorities) including: Running hydrometric turbines; Navigation of ships;

Recreation; Domestic use/drinking water; Irrigation; Agro-industries and non-agricultural industries; and, Ecology.

About 97% of the total water on earth, estimated to be 130 x $10^{15}m^3$, is contained in the oceans and is hence saline. Out of the remaining 3%, which is available is fresh water, about 2% is contained as ice on poles and 0.75% as ground water. Out of the remaining 0.25%, only about 0.01% is found available in lakes and rivers at any given time, as the rest occurs as glaciers and snow (Garg, 2005). From the foregoing it can be easily understood that the surface water which can really be utilized by the populace is generally very very small, being the quantity contained in lakes, or the ones flowing in rivers as surface runoff, caused by rainstorms and melting of snows. (Oteze, 1981). Even the surface runoff that flows in rivers, usually goes to waste, since it flows down to the oceans in the absence of proper storage. It is estimated that about 81% of the total annual surface runoff flowing in the rivers of the world, goes and joins the oceans and is thus not put to any worthwhile use and only a small quantity becomes available for human use (Oteze, 1981).

Two key factors lie at the centre of global concerns for the future availability of freshwater particularly safe drinking water, first, total withdrawals of fresh water have increased dramatically in recent time. In fact, the withdrawals have doubled over the past 40 years. As a result, groundwater aquifers are currently being depleted faster than they are being replenished (TWAS, 2002). Inefficient irrigation practices that have played such a large role in groundwater depletion not only waste water but degrade soil quality and reduce farm productivity placing the progress of enhanced agricultural production or green revolution at risk (TWAS, 2002).

The second key factor of concern has been the relentless rise in population in various parts of the world, particularly in developing countries. The global population is expected to increase by 1.5billion over the next 25 years (reaching some 8 billion people by 2005). If this population increase comes to pass, the amount of available fresh water per person per year will drop by 40 percent from more than 8000 cubic metres to about 5,000 cubic metres (TWAS, 2002). Nigeria's population of more than 140 million inhabitants going by the last census, is expected to increase tremendously in the next decade (Ogwueleka, 1999).

The National Water Resource Council, under the Federal Ministry of water Resources in Nigeria, has laid down the national water policy and the policy is reviewed from time to time. It considers and reviews water development plans as submitted by relevant water development agencies and the various River Basin authorities in the country (Agunwamba, 2001). Economic development and activities including agricultural, industrial and urban development are planned with regard to the constraints imposed by the configuration of water availability. There is a water zoning of the country and the economic activities are guided and regulated in accordance with such zoning (Akanmu et al, 2006). Some models in use in water allocation include:

(a) *Aquarius:* This is a state of the art computer model devoted to the temporal and spatial allocation of flows among competing water uses in a river basin. It uses exponential models of the form:

$$P = ae^{Q/b} \quad \ldots\ldots\ldots\ldots 1.0$$

With $a \geq o$ and $b \leq o$ to represent convex demand functions. It systematically examines the feasibility of reallocating unused or marginally valuable storage and releases, in favour of alternative or competitive uses, identifying tradeoffs between the various water users groups (Diaz, 2009).

(b) *Realm (Resource allocation Model):* The model uses a mode-link network to represent the river basin where modes represent the physical entities such as rivers, pipelines and canals, and links represent the connection between them

(James et al, 1996; Perera et al 2005). The realm is a network allocation model based on a combination of water balance combined with a linear optimization algorithm that enables the use of user-defined penalties to impose constraints and preferential resource use.

(c) *Multi-commodity Flow Model*: Water from different sources with different qualities are considered as distinct commodities which concurrently share a single water distribution system. It is for the regional water distribution system often represented as a network consisting of nodes and arcs. In general, in flow sources, water demand, reservoirs and hydraulic diversion structures arc represented by nodes, rivers, canals and pipes are represented by arcs (Diba et al, 1995).

Goulburn Simulation Model (GSM) and Murrary Simulation Model (MSM) are improvements of the Realm model that focuses primarily on regulated surface water allocation in space and time (Close, 2003). It is necessary therefore to adopt realistic policies and institutional arrangements that will ensure or enable water resources allocators or operators to control demand for water, apportion the available quantities along economically efficient lines and ensure that water is used more judiciously in various demand sectors. A comprehensive water allocation model should consider the conflicting issues facing water users as well as the changing water demand. In this paper, a system dynamics based model is presented by developing an optimal water allocation using Tora optimization system.

2. METHODS AND MATERIALS

Linear programming is a general model for optimum allocation of scarce or limited resources to competing activities under such assumptions as certainty, linearity, fixed technology and constant profit or cost per unit (Ewurum, 1995). Among the methods of solving linear programming problems are the graphical approach and the simplex method. The former is limited to those cases in which either the number of rows or the number of columns or the constraints is two or less. The simplex method rests on two concepts namely - Feasibility and Optimality.

The simplex method computations are particularly tedious, repetitive and above all, boring (Taha, 2007). The Tora Optimization system is an interactive user- guided option, with instant feedback; and allows one to decide the course of the computation in the simplex method without the burden of carrying out the boring Gauss-Jordan calculations (ibid). The search for the optimal solution starts from a basic feasible solution or program. The solution is tested for optimality and whenever it is optimal, the search is stopped. If the test of optimality shows that the current solution is not optimal, a new and better feasible solution is designed. Thus the iterative process is continued until an optimal solution has been attained (Agunwamba, 2001, Ewurum,1995).

The reliability of the research instrument was determined by a reliability test through the use of field surveys, where observed occurrences were made at a point in time and through data that are already existing. The observation surveys were obtained in the ten subareas in the river basins. This study involves survey research and has the basic characteristics of data collection through field survey and these were statistically analysed using Tora optimization system and simplex algorithm software. Secondary data were also collected from literature review which helped in corroborating the data obtained from the field survey. Detailed comparisons were made between the two sets of results. Findings revealed that the proposed system is better than the existing system.

The data were collected over a period of two years (2007-2009) through surveys to observe occurrences at a point in time in this case the survey was done at different points in time in cross-sectional areas. The aim is to enable the researcher not to manipulate or control any of the variables under investigation. Hence the need to observe occurrence. The important thing to note about these variance of cross-sectional design is that, they involved one-time observation through the number of variables as desired under study.

The research is novel, because none of the earlier researchers in this area employed the use of the Tora optimization system and simplex algorithm software, to the best of our knowledge; this becomes our contribution to knowledge. The change in the optimum solution when changes are made in the capacities of the usage areas were determined. The computed rates provide a direct link between the model input or resources and its output, that represents the unit worth of a resource, that is, the change in the optimal objective value per unit change in the availability of the scarce resources. This means that a unit change in capacity will change output by a commensurate percentage. Therefore criteria-related validity was employed which measures the extent to which a newly designed instrument (observation) was weighted against some established criteria. The sub-areas, are stationary with boundary conditions in the study areas and the issue of randomization does not rise.

3. THE STUDY AREA I- MMAM RIVER SUB-BASIN

Mmam River sub-Basin is in the Anambra-Imo River Basin Development Authority's area of coverage. It is located on the border between, Enugu State and Anambra State; bordering Awlaw, Inyi and Akpugoeze towns all in Oji-River Local Government Area of Enugu State and Ufuma town in Orumba North Local Government Area of Anambra State.

The river flows along the Southern boundaries of Awlaw, Inyi and Akpugoeze towns and empties its water into the Eze River in Ugwuoba town. The basin, located in the middle reaches of the river is a commodity grain production base with developed irrigation farming. The well known Mmam forest reserve, stretches along the river banks, as well as sand excavation sites. Other privately owned cottage industries and enterprises stimulate and promote economic activities in the area.

Each of the communities is in a state of critical water balance; conflicts over water rights and use among the communities are becoming more severe and if unchecked could impede sustainable development. They could also endanger peace in the area and perhaps between the two states of Enugu and Anambra States in particular as well as between, communities and regions in general.

Table 1: Parameters and corresponding data for Mmam River Basin subareas

S/N	Item	Inyi	Awlaw	Akpugoeze	Ufuma
1	Population	45,600	18,561	31,022	40,242
2	Per capita usage at (270 lpcd) m^3/yr	4493880	1829186.6	3057218.	3965849.1
3	Established water quota (m^3/per/yr)	98.55	98.55	98.55	98.55
4	Area (10^4ha)	51.2	38.8	49.6	68.6
5	Ecological water reqt. per duty for crop (maize)	25cm	25cm	25cm	25cm
6	Water duty per ha (4) x (5)(m^3 – ha)	12.8	9.7	12.4	17.15
7	Industrial GDP x (N10,000)	50	16	46	78
8	Industrial water use (m^3/day)	2.5	1.5	1.5	2.5
9	Industrial water quota (m^3/yr)	912.5	547.5	547.5	912.5
10	Power generated/installed capacity (mw)	400	50	250	400
11	Efficiency, head factors	58860	58860	58860	58860
12	Water Quota (m^3)	6795.79	849.47	4247.37	6795.79
		4629588.3	849.47	4247.37	6795.79
13	Loses/leakages (15%)	694438.25	209125.54	477901.95	853283.61
	Total	5324026.6	21366291	3663915.0	6541841.0
14	Per capita (m^3/yr)	116.75	115.11	118.11	162.56
15	Policy use (population)	45600	18561	31022	40242

Source: Field Survey,2010.

3.1 THE STUDY AREA II- ABOINE RIVER SUB-BASIN

The Aboine River Sub-Basin is in the Anambra-Imo River Basin Development Authority's area of jurisdiction. It is located on the border between Benue State in the North and Ebonyi State in the South, with Enugu State in the centre. The river flows along the Northern East boundaries of Obolla-Afor, traversing Ikem town before emerging at Eha-Amufu town and discharging itself into the Nkalaha River in Nkalaha, Ebonyi State. Due to demand for water rights, conflicts usually arise. If unchecked, these could deteriorate and endanger peace, economic activities and development in the basin.

Table 2: Parameters and corresponding data for Aboine River Basin Subareas

S/N	*ITEM*	*OBOLLO-AFOR*	*IKEM*	*EHA-AMUFU*	*NKALAHA*
1	Population	33604	15749	59479	12650
2	Per capital use (at 270 lpcd) m^3/yr	3311674.2	1552064	5861064.2	1246657.5
3	Established water quota (m^3/per/yr)	98.55	98.55	98.55	98.55
4	Area (10^4ha)	27.4	24.5	30.4	21.4
5	Ecological water reqt. per duty for crop (Rice)	120cm	120cm	120cm	120cm
6	Water duty per ha (4) x (5)(m^3 – ha)	32.88	29.40	36.48	25.68
7	IndustrialGDP x (N10,000)	150	20	50	14
8	Industrial water use (m^3/day)	2.5	1.5	1.75	1.5
9	Industrial water quota (m^3/yr)	912.5	547.5	830.75	547.5
10	Power generated/installation capacity (mw)	40	20	50	20
11	Efficiency, head factors	58860	58860	58860	58860
12	Water Quota (m^3)	679.58	339.79	848.47	339.78
		3642066.3	**1846951.3**	**6227543.4**	**382344.8**
13	Loses/leakages (15%)	54630.95	277042.7	934131.5	57351.7
	Total	*4188376.2*	*2123994*	*7161674.9*	*439696.51*
14	Per capita (m^3/yr)	124.6	134.9	128.4	34.75
15	Policy use (population	33604	15749	59479	12650

Source: Field survey, 2010.

4. METHODS AND MATERIALS

4.1 THE MODEL

The optimization problem is one requiring the determination of the optimal (minimum) value of a given function called the objective function, subject to a set of stated restrictions or constraints placed on the variables concerned. Optimization, therefore is the process of seeking the best value, condition or solution to a problem subject to the given constraint. In optimization, we first describe a given system in terms of a mathematical model of the form:

$$\text{Min } Z = \sum_{j=I}^{5} \sum_{i=I}^{4} C_{ij} X_{ij} \quad \ldots\ldots\ldots (1)$$

Subject to the constraints:

$$\sum a_{ij} x_{ij} \geq b \ldots\ldots\ldots (2)$$

Where:

C_{ij}, a_{ij} are coefficients,

X_i represents that quantity of the variable i that produces the optimum value for the criterion,

b= the given limit or restriction; i = the subareas and j = the sectoral allocations.

The above equations may be written out in full to facilitate understanding. Substituting the coefficients from data collected from the areas of study into the equation, the above expressions become as follows for the Mmam river basin parameters:

The objective function:
Min $Ƶ = 116x_1 + 115x_2 + 118x_3 + 163x_4$ ……………………………….(3)
While the model solution is as follows

4.1.1 THE MODEL SOLUTIONS

Min $Ƶ = 45600x_{11} + 18561x_{12+} \quad 31022x_{13} + 40242x_{14} + 51.2x_{21} + 38.8x_{22} + 49.6x_{23} + 68.6x_{24} + 50x_{31} + 16x_{32} + 46x_{33} + 78x_{34} + 400x_{41} + 50x_{42} + 250x_{43} + 400x_{44} + 15.2_{51}$

$11.3x_{52} + 15.4x_{53} + 21.2x_{54}$ … (4)

Subject to:

$$X_{11} + X_{12} + X_{13} + X_{14} \geq 135400$$
$$X_{21} + X_{22} + X_{13} + X_{24} \geq 200$$
$$X_{31} + X_{32} + X_{33} + X_{34} \geq 180$$
$$X_{41} + X_{42} + X_{43} + X_{44} \geq 1000$$
$$X_{51} + X_{52} + X_{53} + X_{54} \geq 60 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$
$$X_{11}, X_{12}, X_{13}, X_{14}, X_{21}, X_{22}, X_{23}, X_{24}, X_{24}, X_{31}, X_{32}, X_{33}, X_{34}, X_{41}, X_{42}, X_{43}, X_{44}, X_{51},$$
$$X_{52}, X_{52}, X_{54}, \geq 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . (6)$$

Similarly for the Aboine river basin parameter, the coefficients from collated data from the area of study, when substituted in the equation and expanding the mathematical model becomes:

The objective function:

Min $Ƶ = 125x_1 + 135x_2 + 128x_3 + 35x_4$…………………………….(7)
Min $Ƶ = 33604x_{11} + 15749x_{12}+59474x_{13} + 12650x_{14} + 27.4x_{21} + 24.5x_{22} + 30.4x_{23} + 21.4x_{24} + 150x_{31} + 20x_{32} + 50x_{33} + 14x_{34} + 40x_{41} + 20x_{42} + 50x_{43} + 20x_{44} + 16.3_{51}$

$17.6x_{52} + 15.7x_{53} + 4.5x_{54}$ … … … … … … … … … (8)

Subject to:

$$X_{11} + X_{12} + X_{13} + X_{14} \geq 121400$$
$$X_{21} + X_{22} + X_{23} + X_{24} \geq 100$$
$$X_{31} + X_{32} + X_{33} + X_{34} \geq 230$$
$$X_{41} + X_{42} + X_{43} + X_{44} \geq 130$$
$$X_{51} + X_{52} + X_{53} + X_{54} \geq 50 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

5. RESULTS AND DISCUSSION

The problem was solved using Tora Optimization system and simplex algorithm software. The file ampl. Ex 2. 3-1. Txt or Solver Ex. 2.3.1 Xls and Tora optimization system, windows version 2.00 were applied. The findings are in line with the objectives of the study. The optimal results of water resources allocation in all the cases are as shown in table 3 in the

Mmam River Basin and Table 4 for Aboine River Basin. The optimization system has therefore allocated limits in the subareas of the river basins considered.

5.1 MODEL ANALYSIS

The solution obtained were as follows: Ƶmin = $2357.23m^3$, X_1 = 1.41, X_2 = 1.48; X_3 = 1.24 and X_4 = 0.13 and R_x = 18.56. The solutions satisfied all the demand subareas and the usage areas. An excess of $185.6m^3$ of water (7.87%) of the total minimum optimal solution was observed. The optimal results of water resource allocation in all the subareas and usage areas are shown in Table 3.

Table 3: Computed values for subareas sectoral allocation for Mmam River Basin

	Usage areas	*Allocation limits and subareas*				
		Inyi (X_1)	*Awlaw* (X_2)	*Akpugoeze* (X_3)	*Ufuma* (X_4)	*Total Amts* $(m^3 x\ 10^2)$
1	Consumption & domestic use	64296	27470.28	38467.28	5231.46	135465.02
2	Ecological use	72.192	57.42	61.05	8.918	200.03
3	Industrial use	70.50	23.68	57.84	10.14	162.16
4	Energy use	564	74	310	52	1000
5	Losses/leakages mitigation	21.43	16.72	19.096	2.756	60.02
	Total	*65024.122*	*27642.1*	*38915.266*	*5305.274*	*136887.23*

Source: Field Survey, 2010

Table 4: Computed values for subarea sectoral allocations for Aboine River Basin

	Usage areas	Allocation limits and subareas				
		Obollo-afor(X_1)	Ikem(X_2)	EhaAmufu (X_3)	Nkalah a(X_4)	Total Amts $(m^3\ x\ 10^2)$
1	Consumption & domestic use	32931.92	11024.3	63637.18	13915	121508.4
2	Ecological use	26.852	17.15	32.528	23.54	100.07
3	Industrial use	147	14	53.5	15.4	229.9
4	Energy use	39.2	14	53.5	22	128.7
5	Losses/leakage s mitigation	15.974	12.32	16.799	4.95	50.04
	Total	33160.946	11081.77	63793.507	13980.89	122017.11

Source: Field Survey, 2010.

The optimum solution of Ƶmin= $530.53m^3$ gives X_1 = 0.98; X_2 0.79; X_3 = 1.07; X_4 = 1.10 and R_x = 1.38. Having established allocation limits, the starting order for allocations of water is then decided. A priority regime establishes how water intakes from a river are to be restricted. This can be specified in a regional plan and implemented through consent or laws.
Table 3.1shows that the total minimum optimal values for each subareas sectoral allocation for Mmam River Basin were obtained using the algorithm software. Each of the usage areas as well as the subareas had values obtained using the model analysis. An excess of 185.6m3 of water, or 7.8 percent, of the total minimum optimal solution was obtained.

Similarly, table 4 that computed values for subarea sectoral allocations for Aboine River Basin shows a total allocation of 122017.11m3 of water. Also, all the usage areas as well as the subareas have allocations of water using the model analysis. An excess of 13.8m3 of water was also obtained. Tables 5 and 6 analyses the performance of the model when varying some parameters in the optimum result. The post optimal analysis helps in the gathering of more additional information. It is used as a means of rating the variables in order of relative importance, as it will help managers and planners to evaluate both short and long term implications of their decision (Pappas et al, 1983).

Table 5: Changing capacity of the energy usage area

Coefficient for X_{41} = 800MW and RHS = 800; $X_{42} = X_{43} = X_{44} = 0$					
Basic	X_1	X_2	X_3	X_4	Solution
Zmin	0.00	0.00	0.00	- 593494.67	46652.71
R_{x5}	0.00	0.00	0.00	- 5937.01	457.88
R_{x6}	0.00	0.00	0.00	2.31	3.99
X_3	0.00	0.00	1.00	1.98	2.75
X_1	1.00	0.00	0.00	0.00	1.00
X_2	0.00	1.00	0.00	-0.83	0.22

Source: Field Survey, 2010.

Table 5 shows the solution of changing the capacity of subarea X_{41} to 800mw while the other subareas are allocated zero capacities. Let the Energy Use Parameter for subarea X_1 change its capacity to 800mw while the other subareas are allocated no power stations or capacities. This demonstrates the general idea of the analysis, as the right hand-side (RHS) of the constraints will change, as well as the unit cost or the coefficient of the objective function in relation to the energy usage area. Some conclusions can be deduced:

- As the capacity of the allocated subareas increased from 400mw to 800mw with zero allocation to other subareas, the surplus or excess variable increased to 461.87m^3. This is (95.98%) increase in unutilized water.
- This capacity change alters the optimality table and no water is allocated to subarea X_4 in the changes in the original objective coefficients. This agrees with Akanmu et al (2006) which states that economic activities are guided and regulated in accordance with imposed constraints.

Table 6: Changing capacity of the industrial use

Coefficient for X_{31} = 0 and X_{34} = 0; RHS = 62					
Basic	X_1	X_2	X_3	X_4	Solution
Zmin	0.00	-350918.31	0.00	0.00	235697.31
Rx_5	0.00	-3511.22	0.00	0.00	2348.23
Rx_6	0.00	2.32	1.00	1.00	4.15
X_3	0.00	0.35	1.00	0.00	1.35
x1	1.00	0.00	0.00	0.00	1.00
X_4	1.00	1.00	0.00	1.00	1.13

Source: Field Survey, 2010.

In Table 6 the idle water not allocated in the optimal compulation due the changes in the industrial use for subareas X_{31} and X_{34} amounted to 2352.38m^3. In an area of water scarcity. A 99.21% increase from the initial optimal solution was observed due to the changes in the industrial use area. This means that changes in the objective function coefficients can affect the optimality of the problem. Furthermore, this capacity change has resulted in aggravating the already scarce resources for subareas X_2, as no water is allocated to this area in the new sensitivity analysis optimality.

The change in the optimum solution, when changes are made in the capacities of the usage areas were shown above in tables 3.3 and 3.4. The computed rates provide a direct link between the model input or resources and its output, that represents the unit worth of a resource. That is, the change in the optimal objective value per unit change in the availability of the scarce resources. This means that a unit increase or decrease in capacity will increase or decrease output by a certain percentage or rate. This aligns with the other authors on the effect of increased population on water, which TWAS (2002) says will bring about a tremendous increase in water demand. This will then affect people in many ways as other demand sections of the economy such as irrigation, industries, ecology, energy sectors, may not have the required water allocation for them. This may result in social unrest warranting loss of properties and age long acquired wealth, injuries, loss of social system and sometimes death.

The real option then is to reduce the consumption of resources perhaps by making the allocation process more efficient (Taha, 2007). This work applies to the Mmam River and Aboine Rivers Basins of the Anambra-Imo River Basin Development Authority. The river basins were considered. Four subareas and five usage areas of community use, ecological, industrial energy and losses/leakage mitigation. The study proposes a minimization and reduced cost, linear programming simplex method as an aid in evaluating and describing the water resource allocation. The model was solved using the Tora optimization system and simplex algorithm written in Visual Basic language. The model uses optimality and equity in minimizing allocation to various subareas with a review to reducing wastages and setting allocation limits. Within the available scarce water resources in the river basins.

Sensitivity and post-optimal analysis of varying capacities of the river basins to the optimal values were also investigated. The optimal solutions were obtained when the more than twenty transformations and five iterations provided values for the respective subareas, while providing minimum (Zmin) values of 2357.23m^3 and 530.53m^3 respectively for Mmam River Basin and Aboine River Basin. This model therefore helps in facilitating and improving on decision making required by water allocators and policy maker sin the water sector, to achieve their organizational goals. The engineer is equally provided with a quantitative basis for decision making and enhanced ability to make long range plans and develop broad strategies.

5.2 POST OPTIMAL AND SENSITIVITY ANALYSIS

The change in the optimum solution when changes are made in the capacities of the usage areas were determined. The computed rates provide a direct link between the model input or resources and its output, that represents the unit worth of a resource, that is, the change in the optimal objective value per unit change in the availability of the scarce resources. This means that a unit change in capacity will change output by a commensurate percentage. Although a unit worth of resource is an apt description of the rate of change of the objective function, the technical name: dual or shadow price is now standard in the linear programming literature and all software packages (Taha, 2007).

The dual or shadow prices/rates are shown to be valid. This is because the changes in the right-hand sides of the constraints satisfy all the feasibility conditions when the changes are simultaneous or within the feasibility ranges when the changes are made individually. In most real-life situations, the price or cost per unit may not be a viable option because its value is dictated by market conditions. The real option then is to reduce the consumption of resources perhaps by making the allocation process more efficient (Taha, 2007). The existing system uses domestic ration water supply, where quota and size are the parameters of consideration. The population and land area comprising the size. It shows that 136887.2m^3 of water as compared to 13388258m^3 of water is the desired optimal allocation to achieve fairness and efficiency in the usage areas and the subareas of the Mmam River Basin. Close to 98% optimal efficiency is achieved in this regard.

Table 7: Comparison of optimal results with existing results for Mmam River Basin

Item	Existing system	Proposed system
Total allocation input	13388258m^3	136887.2 m^3
No of usage areas	4	4
No of subareas	4	4

Source: Field Survey, 2010.

Table 8 shows that 122017.11 m^3 is the value of the proposed system as against 11,986726 m^3 that the existing system provides. The reduced consumption is due to efficient and optimal application of the resource. The resulting allocation is 98.9% improvement against the existing system. The facility layout of the proposed system in table 3.5 and 3.6 are cost effective. Cost overrun in the operation was brought to the barest minimum based on recommended and approved per capita usage of the scarce resources. Therefore better efficiency was attained in the scheduling of the scarce resources, as a result of control management. The existing system is not desirable in futuristic terms, in view of the inherent wastages of the scarce resource which is likely going to put a large number of the population at risk without water and its related activities.

Table 8: Comparison of optimal results with existing results for Aboine River Basin

Item	Existing system	Proposed system
Total allocation	11,986726m^3	122017.11 m^3
No of usage areas	4	4
No of subareas	4	4

Source: Field Survey, 2010.

6. CONCLUSION AND RECOMMENDATIONS

One of the greatest tasks for water resource managers is to match the balance between supply and demand of water (Agunwamba, 2001). Increased population growth, rapid economic growth and environmental degradation have resulted in increasing demand for water. It is therefore necessary to adopt realistic policies and institutional arrangements that will ensure or enable water resources allocations and operators to control demand for water, by apportioning the available quantities along economically efficient lines and ensure that water is used efficiently in various demand sectors. Given the known allocation limits, the model can fulfill an optimum allocation plan that includes appropriate timing and volumes of water distribution in each subarea and minimize the economic losses. A water meter at points of water use, allows the monitoring of water use on the basis of consumption figures, assess a presumably water rate fee. Comparing bulk water meter readings at the reservoirs with the total of consumer meter reading gives an insight in the functioning of the system and allows monitoring of leakages and losses.

The allocation and distribution of water while considering water losses through human inadequacies and leakages while applying the principles of Operations Research, provides the engineer with versatile, powerful and useful basis for decision making especially in cases of scarce and limited resources like water. This models' attempt to allocate the scarce resources in the Mmam River Basin and Aboine River Basin respectively, will result in effective water allocation to the subareas in the river basins and reduce regional, interstate and subareas conflicts and encourage efficient use of water.

Consequently from the findings, the developed model is an efficient and sustainable approach to efficient and sustainable approach to efficient use of resources and hence raise the performance level of organizations. Since the model will support engineers as they seek to clarify strategy, communicate strategy and challenge assumptions. In today's competitive global market, quality services – a derivative of the level of efficiency, remains a key differentiating factor for superior performance. The binding constraints used in the linear programming model while ensuring equitable distribution of the scarce – water and losses minimized, provides valuable guidance in equitable distribution and optimal utilization of the scarce resources by various communities that make up a river basin. The analysis indicates that the river basin management and the extra contribution could benefit from increasing by one unit, the amount of the scarce resources, thereby utilizing the limited resources to best advantages. This will also help to sensitize Nigerians on the need to develop and practice the culture of implementing sets standards, limits, policy rules and regulations while the policy making body could have a policy rethinking in collaboration with the river basin basin management authorities.

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