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Optimal Strategic Solutions for Water Resources Development Problems in Niger Delta River Basin: Perspective on the Nexus between the Media and Civil Engineering

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Abstract

This study addressed Water Resources Development Problems in Niger Delta River Basin in Nigeria. The study, which was founded on Game Theory, employed the library method and utilised the linear programming method of game theory to solve management problems about cost apportionment. The objectives were to determine the net benefits under the topics of economic efficiency, regional economic redistribution, and social well-being; to assess fund apportionment to the purposes of irrigation, hydropower, and water supply, and to evaluate the financial benefit accruing to Niger Delta Basin on investment of ₦3.9 billion over three years. The study also analysed the place of the media in civil engineering. The study revealed that for optimal management, no allocation should go to water supply for the period under consideration. The results obtained also revealed that for the first three objectives to be optimised simultaneously, considering a three-year development fund of ₦3.9billion, the allocation should be such that ₦2.13billion should go to irrigated agriculture, ₦1.79billion to hydropower, while zero allocation should go to the water supply. Furthermore, the result of the analysis revealed that, if the fund is apportioned to the various purposes as proposed, a net financial benefit of ₦9.945billion is achievable by the basin under the worst possible conditions. Cost-sharing should always be based on logical and mathematical justifications. The study found that the media were not given their rightful place.It is recommended that the River Basin Development Authorities in Nigeria should ensure they intensify their efforts in record keeping to increase the reliability of data necessary for research. Also, the media should be considered in such civil engineering ventures. The government should set up an agency to monitor funds allocated to River Basin Authorities to avoid embezzlement and wastage.

Keywords: Development, Engineering, Media, Solution, River Basin, Water Resources

Introduction.

Water is an important ingredient of life; its uses transcends domestic, industrial, and agricultural utilization. It is meant for drinking, bathing, washing, transportation, irrigation among many other functions. In some areas where it is not readily available, solar-paneled powered boreholes are sunk to get water. Positing that the human cost of worsening scarcity of water is already fully apparent, Letzing and Berkley (2021) claim that about one out of every four people in the world doesn't have access to safely managed drinking water at home and that in a few years, about two-thirds of the global population will suffer water shortages.

Letzing and Berkley (2021) believe that lack of water is triggering violent conflict in places like India's Northern Plains, and creating new migrants and refugees who may contribute to further shortages wherever they resettle. This can be affirmed to be true also in Nigeria where scarcity of water is implicated as one of the reasons for regular clashes between farmers and cattle herders who invade the southern part of the country with their cattle in search of vegetation and water due to their scarcity in the northern part of Nigeria. The repercussion of water scarcity in any society can have progressively grievous effects on such a society if not addressed on time.

Despite the humongous amount spent on Nigeria's water sector by the government and international organizations, water scarcity persists. At present, the Ministry of Water Resources has proposed to borrow ₦287 billion ($700 million) for its Sustainable Urban and Rural Water Supply, Sanitation and Hygiene (SURWASH) program. According to Stephen (2021), the SURWASH program is expected to cover seven states and provide six million people with basic drinking water services. It will also provide 1.4 million people access to improved sanitation services, and deliver improved water sanitation and hygiene (WASH) services to 2,000 schools and health care facilities.

Water is a universal resource which, because of its free occurrence in nature, is often misused and taken for granted, particularly in third world nations where information is neither readily accessible nor disseminated to society (Anyata&Nwaiwu, 2000). It is important to note that the awareness created by the media about the disadvantages of wasting water through frequent reportage can encourage the public to make precautionary use of water.

Hitherto, Planning Engineers have considered benefits accruing from objectives outside economic efficiency as either too difficult, too abstract, or intangible to measure. However, the fact is that these other objectives are considered very vital by interest groups at the level of authorization. As such, the myth of immeasurability and intangibility of the benefit accruing from them must be discarded. Scientifically, all measures are relative. Therefore, immeasurability and intangibility cannot be absolute terms. Hence there must be a measure of benefit that exists.

With regards to optimization, most past works in multipurpose water resources development project planning have considered a single objective, which is economic optimization. This is not always the case in real-life situations. Other objectives can play significant roles alongside economic efficiency in the determining of development to be apportioned to various purposes involved in water resources projects. Such other objectives can be region economic redistribution, environmental quality improvement, social wellbeing, etcetera. These objectives are becoming increasingly important due to socio-political, ecological, health, and many other reasons. As such, they cannot be ignored in thorough planning.

A thorough analysis of benefits, in the light of, say a River Basin project, can show that tangible benefits are accruable by each purpose to vary concerning each objective. Moreover, this point can be buttressed by data available from such areas of learning as social statistics, medical geography, social welfare, ecology, environmental engineering, media, and others.

Given the foregoing, it becomes necessary in multipurpose water resource planning to consider not only economic efficiency but equally any other objective(s) that may be deemed necessary at the planning stage for explicit exhaustive and effective decision making. This is where the media, among others, come in. This is rightly affirmed by Onayiga (2016) who attests that the media have relationships with various sectors of society, and in all spheres of our national life; this includes civil engineering. Quanah (2019a) insinuates that this is the reason mass communication students have a good general education and basic knowledge of affairs that give them the competence to comment on varied issues, no matter the complexity.

The media shape public understanding of various issues, including civil engineering and water resources by making them major topics of discourse. The media can take time and energy to explain more of the specifics behind water resources management and optimal strategic solutions for water resources development problems, without boring the public with the engineering jargon that comes with it. This could result in a robust engagement of the people who are the beneficiaries of various water projects being embarked upon by the government. Through stimulated coverage by the media, the public can get to know about the different government policies on water that exists. By playing their information, education, mobilization, socialization, and dissemination of knowledge roles in the society, they interpret and break down policies that, ordinarily, the public may not be able to comprehend or understand.

Therefore, this study covered data acquisition from Niger Delta River Basin headquarters, Port Harcourt; determination of net benefits of the various objectives; data analysis and linear programming method of game theory; allocation of funds to the various purposes with game theory, and ascertaining the net financial returns to the basin on investment of ₦3.9billion over three years. It also attempted to bridge the gap between civil engineering and the media by highlighting the synergy that exists between journalism and engineering to erase and reshape the poor perception of the role of the media in civil engineering which has made the media to be excluded in engineering activities.

Description of Study Area

The study area is Niger Delta River Basin. It comprises Rivers and the Bayelsa States; and parts of the territory of Delta State, Nigeria, with a population of 7,315,565 million people (National Population Commission, 2006). Its headquarters is Port Harcourt, with area offices at Isiokolo in Ethiope East Local Government Area (LGA) of Delta State, and Igbogene in Yenagoa LGA of Bayelsa State.

The Niger Delta River Basin is located in the Niger Delta and the Gulf of Guinea at the passive continental margin near the western coast of Nigeria. The basin is very complex as it carries high economic value because it contains a very productive petroleum system. The Niger Delta River Basin is one of the largest sub-aerial basins in Africa. The total area of the Basin is 300,000km^2. The length of the Basin is 4,180km. The sub-aerial of the Basin is 75,000km^2

Statement of the Research Problem

The Niger Delta River Basin Development Authority (NDRBDA)is faced with many management challenges which include: lack of adequate funding, misplaced priority in the sharing of funds for water resources development authorities, and low generation of revenue for the federal government by the various river basins in Nigeria. The moribund nature of the river basins, coupled with the numerous problems they face have made them not live to their expectations; these informed parts of the reasons for this study.

Also, the managers of the river basins tend not to be guided in decision making, and this is resulting in wastages based on a lack of planning. Likewise, the media that can help incorporate decision making and opinion formulation seem not to be given a place of priority when it comes to civil engineering; whereas they can help civil engineers and water resources managers to optimally manage scarce resources and eliminate wastages. Additionally, there is a scarcity of research in the area of optimization, hence this work was intended to stimulate further studies in this area.

Objectives of the Study

The main objective of this study was to develop optimal solutions to management challenges in water resources development in the Niger Delta River Basin Authority. The other objectives were:

i. to determine the net benefits under the topics of economic efficiency, regional economic redistribution, and social well-being;
ii. to assess fund apportionment to the purposes of irrigation, hydropower, and water supply;
iii. to evaluate the financial benefit accruing to Niger Delta Basin on investment of ₦3.9 billion over three years, and
iv. to analyze the role the media can play in River Basin Authorities.

Review of Relevant Literature

TheoreticalPlacement

This paper finds support in Game Theory. According to Myerson (1991), Game Theory is the study of mathematical models of rational decision-makers' strategic interaction. When John von Neumann released *On the Theory of Games of Strategy* in 1928, he established game theory as a unique field (Neumann, 1928; Neumann, 1959). This theory can be applied in any branch of social science, as well as Logic, Systems Science, and Computer Science.

Brouwer's fixed-point theorem on continuous mappings into compact convex sets, which became a common approach in game theory and mathematical economics, is said to have been utilized in Von Neumann's original argument, according to Mirowski (1992). Von Neumann's 1944 book, *Theory of Games and Economic Behaviour*, co-authored with Oskar Morgenstern, followed his work. The book's second edition included an axiomatic theory of utility, reviving Daniel Bernoulli's ancient theory of utility (of money) as a separate subject. This 1944 book was the culmination of Von Neumann's work in game theory. The strategy for discovering mutually consistent solutions for two-person zero-sum games is described in this seminal paper. According to Leonard (2010), subsequent research concentrated mostly on cooperative game theory, which examines optimum tactics for groups of persons under the assumption that they can enforce agreements regarding suitable strategies among themselves.

Game Theory was developed to deal with zero-sum games, in which each player's earnings or losses are perfectly balanced by those of the other players. Game theory is now an umbrella name for the study of logical decision-making in people, animals, and computers in the twenty-first century. It applies to a wide variety of behavioral relations and is now an umbrella term for the science of logical decision-making in humans, animals, and computers.

For the fact that this work is about the mathematical study of optimizing agents, this theory applies. It can be used to share the costs of multifunctional water resource projects. The Remaining Benefit Method is one of the two methods now in use. These two strategies are conceivable, but they do not fully utilize all logically significant aspects in cost allocation.

As a result, it's safe to assume that optimizing multiple-purpose projects from a multi-objectivity perspective is likewise important. Then we may focus on using game theory to resolve any engineering disagreement that arises as a result of it. In general, the game theory may be used to make decisions in many aspects of water resource planning when the context is similar to that of a conflict scenario as seen in parlour games.

A Bird View of Optimisation

An optimisation problem consists of obtaining the best value (maximum or minimum) of a function formed by the decision variables for the system and the parameters representing the different weights of the decision variables. This function is called the objective function, and it is the heart of any optimisation technique (Wurbs, as cited in Guanah, 2019b). Similarly, Ojiako (as cited in Guanah, 2019b) presented how scientific planning of water resources development can be achieved using linear programming and simplex solution technique. The method is simple and takes account of all possible constraints likely to be encountered in water resources development planning in Nigeria. Emphasis was made on the need for even development of water resources in all river basin areas in the country.

A method of sharing the limited fund based on the asset financial requirement of each River Basin Development Authority (RBDA) for achieving partly in development was illustrated to take care of financial lapses on the budgetary allocation of the federal government to various RBDA's. In addition, a system of funding annually for each RBDA from its equitable shares of the budget allocation for a given period was also developed. The only objective considered in this paper was economic efficiency or economic optimisation.

The cost characteristics of water system elements are equally important to water resources engineering and the nature of cost functions associated with each component. Thus cost functions in water resources generally do not show marginal cost increase on which current economic theories are mostly based. Compared with operation and maintenance costs, most components of river systems involve huge investment costs. Such cost aspects of completed projects are therefore critical and make corresponding decisions economically rigid and merely irreversible (Otti&Nwafor, 2012).

River Basins and Water Resources Management

Water is a natural resource that is vital to all forms of life (Nyatuame, Owuau-Gyimah&Amphiaw, 2014; Biswas, 2004, 2008). Abundant as it may seem, water, in its clean state, is one of the rare elements in the world (Omole&Longe, 2008). Biswas (2008) notes that during the early 1980s, it became clear that the overall global water situation was not as good as it appeared. Jaspers (2003) shared a similar view when he said that throughout the world there is a broad consideration of water as a finite and vulnerable resource.

Al Radif(as cited in Guanah, 2019b) observes that water shortages are exacerbated by the geographically and temporally uneven distribution of precipitation. Herath and Ratnayake (2004) opine that scarce water resources are under continuous stress due to increasing water demands, increase in population, and economic development. Similarly, while referring to a recent report, Letzing and Berkley (2021) predict that water scarcity will be the biggest climate-related threat to corporate assets like factories within the next few decades.

Rahaman and Varis (2005) also argued in favour of the above when they opined that "an increasing number of countries are facing water stress"; i.e. when their annual water supplies drop below 1,700 cubic meters per person. UNESCO & Green Cross International (2003) report that despite this most river basins lack the mechanisms and institutions to manage water resource disputes.

There are several terms used to describe an integrated process of assessing and managing water resources at the basin level. Most are variations on the terms integrated water resource management (IWRM), or river basin management (RBM). The concept of integrated river basin management has its roots in a collective effort to make water use economically productive, socially equitable, and environmentally sustainable to all users within the basin (Alaerts& Le Moigne, as cited in Mody, 2004). Also, Mody (2004) and Burton (2003), acknowledge that the idea of integrated management of land or the use of the river basin as the most suitable management unit is not new, but recently, it has become a principle accepted internationally.

According to the Global Water partnership- GWP (GWP, 2010), "Integrated Water Resources Management is a process which promotes the coordinated development of water, land and related resources, to maximise the resultant economic and social welfare equitably without compromising the sustainability of vital ecosystems" (p. 6).

River Basin Development Authorities in Nigeria

The realisation of the importance of adequate water management was responsible for the establishment of the River Basin Development Authorities- RBDAs (Cooky, 2012). The first basins in Nigeria were the River Niger and Lake Chad Basin Commissions during the first National Development Plan period of

1962 –1968. Today, there are 12 River Basin Development Authorities in Nigeria, and there is an agitation for the establishment of a 13th one in the southeast zone of the country. River Basin Development Authorities help in boosting agricultural extension, provision of dams for irrigation, power generation, rural feeder roads development, among others.

According to Aborisade (2021), River Basins Development Authorities are established to, among others, undertake comprehensive development of both surface and underground water resources for multipurpose use with particular emphasis on the provision of irrigation infrastructure and the control of floods and erosion and watershed management; construct, operate and maintain dams, dykes, wells, boreholes, irrigation and drainage systems and handover all lands to be cultivated under the irrigation schemes to the farmers; supply water from the Authority's Storage Schemes to all users for a fee; construct, operate and maintain roads and bridges linking project sites; and develop and keep up-to-date and comprehensive water resources master plan as well as water resources, water use, socio-economic and environmental data of the River Basin concerned.

Cost Sharing in Multi-purpose Projects

In the field of water resources management, there have been mounting concerns about how to split the total costs of a joint project among different users (Okada, as cited in Guanah, 2019b). This problem is termed "cost allocation". Cost allocation is the process of assigning to each purpose of a multi-purpose project an appropriate share of the total multiple-purpose cost. Enormous literature on this theme exists in the field of Water Resources Engineering.

The most well-known and commonly used is the Separable Cost Remaining Benefit method (SCRB). Though it is so widely applied, both theoretical and empirical studies have shown that the SCRB has some crucial drawbacks. The criticism that the conventional methods, including that SCRB, failed to handle the bargaining feature of cost allocation has provoked the development of a new approach in the water resources field.

This approach owes its theoretical basis to what has been developed as the theory of cooperative games (Loehman&Whinston; Suzuki & Nakayama; Bogardy&Szidarovsky; Okada, as cited in Guanah, 2019b). It was not until quite recently, however, that a systematic assessment has been made of the implications and applicability of a cluster of game-theoretic methods.

It is, however, worthy to know and note that cost allocation is inexact; no single correct approach or method exists. All cost studies involve judgments and should be viewed as a starting point (Beecher, Mann & Landers, as cited in Guanah, 2019b).

Research Methodology

Data Collection

The data for this study was obtained from the headquarters of the Niger DeltaRiver Basin Development Authority, Port Harcourt. The data collected are economic efficiency data, regional economic redistribution data, and social wellbeing data.

Economic Efficiency Data

As far as optimization is concerned, the economic efficiency of a water resources development resource project is achieved by economic optimisation of cost and benefit. On the other hand, economic optimisation is achieved by minimisation of a cost function or maximisation of benefit function, or both. Hence, instead of using a direct benefit/cost index as a measure of economic efficiency, economic optimisation is adopted with the application of Linear Programming (LP) to ensure enhanced economic efficiency which has been the sole objective considered in past work on optimisation involving LP.

This adjustment is necessary to use a common measure determining the outcome of both economic efficiency and other objectives, regional economic redistribution, and social wellbeing involved in multipurpose water resources development planning; the common measure being expressed in monetary terms. The factors that determine the benefits accruing to various purposes under economic efficiency as an objective varies with purposes as stated below.

a) Irrigation: Land value and agricultural yield
b) Hydroelectric power generation: Net returns from electrical energy sales
c) Water supply: Net returns from water rates

Regional Economic Redistribution Data

This is measured through benefits derivable from a water resources project by various benefiting localities within a region as a result of location and size of the project and concerning various (purposes). The factors determining the benefits are: Industrialisation, Urbanisation, Manpower Availability, and Improved property value. The benefits derivable as a result of the above factors are in the form of: Tax to regional authority from attracted infrastructures and roads; Servings on skilled service charge, and Enhanced property value, rent, and rate.

Social Wellbeing

When considering social wellbeing as a development objective in multipurpose resources planning, all factions that contribute towards fund furtherance of wellbeing in society are taken into consideration when determining the benefits that accrue to purpose involved in the development.

Such factors are: Food, shelter, and clothing; Industrial and collective security; Luxury and convenience; Health; Education; Harmonium family and community; Pleasant work and living conditions; Clean and stimulating Environment; certain level of culture, and certain level of morality of the above ten factors, the first five are the most important whereas the rest are incidental.

Benefits derivable as a result of the above five main factors are in the form of savings on food, shelter, and clothing; as a result of reduced theft, workers' strike and better security in industries, homes, and public places; on extra home luxury expenses; as a result of better health; as result of better family and community relations, improved level of culture and morality due to better education, and culture and morality due to better education. Therefore, the benefits accruing to each purpose, considering social well-being, is a summation of items (i) to (v) above concerning each specific purpose in the multipurpose water resources development.

Application of Game Theory in the allocation of Funds

The following are the methods of applying game theory as given by Hiller and Lieberman (1995):

a. Graphical Method: This method is useful for a game where the payoff matrix is of size 2 x n or m x 2 i.e. a game with mixed strategies that have only two un-dominated pure strategies for one of the players in the two-person zero-sum game. Optimal strategies for both the players assign non-zero probabilities to the same number of pure strategies. Therefore, if one player has only two strategies, the other player will also use the same number of strategies. Hence, this method is useful in finding out which of the two strategies can be used.

b. Matrix Method: If the game matrix is of a square matrix, then the optimal strategy mix, as well as the value of the game, may be obtained by the matrix method. The solution of a two-person zero-sum game with mixed strategies with a square payoff matrix may be obtained by using the following formulae:

$$\left.\begin{array}{l} \text{Player's optimal strategy} = \dfrac{[1 \quad 1]P_{adj}}{[1 \quad 1]P_{adj}\begin{bmatrix}1\\1\end{bmatrix}} \\[2ex] \text{Player's B optimal strategy} = \dfrac{[1 \quad 1]P_{cof}}{[1 \quad 1]P_{adj}\begin{bmatrix}1\\1\end{bmatrix}} \end{array}\right\} \quad \text{...... (2.1)}$$

Value of the game = (Player A's optimal strategies) x (Payoff matrix P_{ij}) x (Player B's optimal strategies)
Where P_{ij}= adjoint matrix, P_{cof}= cofactor matrix.

Player A's optimal strategies are in the form of a row vector and B's optimal strategies are in the form of a column vector.

c. Algebraic Method: This method is used to determine the probability of using different strategies by players A and B. This method has the disadvantage of being quite lengthy when the number of strategies for both players is more than two.

Consider a game where the payoff matrix is: $[a_{ij}]_{mxn}$. Let (p_1, p_2, …,p_m) and (q_1, q_2, …,q_m) be probabilities with which players A and B select their strategies (A_1, A_2,…A_m) and (B_1, B_2,…B_m) respectively. If V is the value of the game, then the expected gain to player A when player B selects strategies B1, B2,…B*n* one by one is given by the left-hand side of the following simultaneous equations respectively. Since player A is the gainer and expects at least V, therefore, we must have

		Player B			
Player A	B_1	B_1	B_1	probability	
A_1		a_{11}	a_{12}	a_{1n}	p_1
A_2		a_{21}	a_{21}	a_{22}	p_2
.					
probability	A_m	a_{21}	a_{m2}	A_{mn}	p_m

$$\left.\begin{array}{r} a_{11}p_1 + a_{12}p_2 + \ldots a_{m1}p_m \geq V \\ a_{12}p_1 + a_{22}p_2 + \ldots a_{m2}p_m \geq V \\ \\ a_{1n}p_1 + a_{2n}p_2 + \ldots a_{mn}p_m \geq V \\ \text{where } p_1 + p_2 + \ldots + p_m = 1; pi \geq 0 \text{ for all } i \end{array}\right\} \text{..... (2.1)}$$

Similarly, the expected loss to player B when player A selects strategies A_1, A_2,…A_m one by one can also be determined. Since player B is the loser player, therefore, he must have:

$$\left.\begin{array}{r} a_{11}q_1 + a_{12}q_2 + \ldots a_{m1}q_m \geq V \\ a_{12}q_1 + a_{22}q_2 + \ldots a_{m2}q_m \geq V \\ \\ a_{1n}q_1 + a_{2n}q_2 + \ldots a_{mn}q_m \geq V \\ \text{where } \quad q_1 + q_2 + \ldots + q_m = 1; qi \geq 0 \text{ for all } j \end{array}\right\} \text{...(2.2}$$

To get the values of p_i's and q_j's, the above inequalities must be considered as equations and are then solved for the given unknowns. However, if the system of equations so obtained is inconsistent, then, at least one of the inequalities must hold as strict inequality. The solution can then be obtained by applying the trial and error method.

d. **Linear Programming Method:** Game theory bears some relationship with linear programming. Two-person zero-sum games can also be solved by linear programming techniques. It has the additional advantage of being able to solve mixed strategy games of a larger dimension payoff matrix. To illustrate the transformation of a game problem to a linear programming problem, consider a payoff matrix of m x n size. Let a_{ij} be the element in the *i*th row and *j*th column of the game payoff matrix, and letting pi be the probabilities of m strategies (*i*= 1, 2,…,*m*) for player A. Then the expected gains for player A, for each of B's strategies will be

$$\sum_{i=1}^{n} p_i a_{ij}, \quad j = 1,2,\ldots,n \text{ ....(2.3)}$$

Player A aims to select a set of strategies with probability p*i*(*i* = 1, 2,…, *m*) on any play of game such that he can maximise his minimum expected gains. To obtain values of probability pi, the value of the game to player A for all strategies by player B must be at least equal to V. Thus to maximise the minimum expected gains, it is necessary that

$$\left.\begin{array}{r} a_{11}p_1 + a_{12}p_2 + \ldots a_{m1}p_m \geq V \\ a_{12}p_1 + a_{22}p_2 + \ldots a_{m2}p_m \geq V \\ . \\ . \\ . \\ a_{1n}p_1 + a_{2n}p_2 + \ldots a_{mn}p_m \geq V \\ \text{where } \quad p_1 + p_2 + \ldots + p_m = 1; pi \geq 0 \text{ for all } i \end{array}\right\} \text{.....(2.4)}$$

Dividing both sides of the inequalities and equation by V, the division is valid as long as V > 0, the direction of the inequality constraints must be reversed. But if V = 0, division would be meaningless. In this case, a constant can be added to all entries of the matrix ensuring that the value of the game (V) for the revised matrix becomes more than zero. After an optimal solution is obtained, the true value of the game is obtained by subtracting the same constant value. Let $p_i/V = x_i$, (≥ 0). Then we have

$$\left.\begin{aligned} &a_{11}p_1/V + a_{12}p_2/V + \ldots a_{m1}p_m/V \geq 1 \\ &a_{12}p_1/V + a_{22}p_2/V + \ldots a_{m2}p_m/V \geq 1 \\ &. \\ &. \\ &. \\ &a_{1n}p_1/V + a_{2n}p_2/V + \ldots a_{mn}p_m/V \geq 1 \\ &p_1/V + p_2/V + \ldots + p_m/V = 1 \end{aligned}\right\} \ldots\ldots (2.5)$$

Since the objective of player A is to maximise the value of the game, V which is equivalent to minimising 1/V, the resulting linear programming problem can be stated as

Minimise Z_p (= 1/V) = $x_1 + x_2 + \ldots + x_m$

Subject to the constraints

$$\left.\begin{aligned} &a_{11}x_1 + a_{12}x_2 + \ldots a_{m1}x_m \geq 1 \\ &a_{12}x_1 + a_{22}x_2 + \ldots a_{m2}x_m \geq 1 \\ &. \\ &. \\ &a_{1n}x_1 + a_{2n}x_2 + \ldots a_{mn}x_m \geq 1 \\ &x_1, x_2, x_m \geq 0 \\ &x_i = p_i/V \geq 0; i = 1, 2, \ldots, m \end{aligned}\right\} \ldots\ldots (2.6)$$

Similarly, player B has a similar problem with the inequalities of the constraints reversed, i.e. minimise the expected loss. Since minimising of V is equivalent to maximising 1/V, therefore, the resulting linear programming problem can be stated as:

Minimise Z_q (= 1/V) = $y_1 + y_2 + \ldots + y_m$

Subject to the constraints

$$\left.\begin{aligned} &a_{11}y_1 + a_{12}y_2 + \ldots a_{1n}y_n \leq 1 \\ &a_{12}x_1 + a_{22}x_2 + \ldots a_{2n}y_n \leq 1 \\ &. \\ &. \\ &a_{m1}y_1 + a_{m2}x_2 + \ldots a_{mn}y_n \leq 1 \\ &y_1, y_2, y_n \geq 0 \\ &y_j = q_j/V \geq 0; j = 1, 2, \ldots, n \end{aligned}\right\} \ldots\ldots (2.7)$$

It may be noted that the LP problem of player B is the dual of LP problem for player A and vice versa. Therefore, the solution to the dual problem can be obtained from the primal simplex table. Since for both players $Z_p = Z_q$, the expected gain to player A in the game will be exactly equal to the expected loss to player B.

It should be noted that linear programming technique requires all variables to be non-negative and therefore to obtain a non-negative of vale V of the game, the data of the problem, i.e. a_{ij} I the payoff table should all be no-negative. If there are some negative elements in the payoff table, a constant to every element in the payoff table must be added to make the smallest element zero; the solution to this new game will give an optimal mixed strategy for the original game. The value of the original game then equals the value of the new game minus the constant.

Data Presentation, Analysis, and Discussion of Findings

Analysis of pre-processed data was based on the Linear Programming method of Game theory. The process involved converting the game problem into a linear programming problem. Thereafter, the simplex method was used to solve the problem. The following steps were followed:

a) Creating the initial tableau
b) Locating the pivot variables
c) Reducing the pivot element to one.
d) Employing Gaussian elimination operation on the other rows reduces all other entries of the pivot column to zeros.
e) Creating a new tableau
f) Checking for optimality. Optimality is reached when all entries in the reduced cost row (i.e. the $Z_j - C_j$ row) are all positives and zeroes.
g) Identifying optimal values.

Benefit Determination under the Objective of Economic Efficiency

Consider a N3.9 billion allocation for a strategic three-year plan for a multi-purpose water resources development involving irrigation, hydroelectric power generation, and water supply, where economic efficiency is to be optimised as an objective along with other objectives. The benefits accruing to each purpose is as determined:

a. Irrigation

Cost of land after irrigation: ₦1.71 billion

Cost of land before irrigation: ₦0.67 billion

Benefit from land: ₦1.04 billion

Agricultural yield after irrigation: ₦5.15 billion

Agricultural yield before irrigation: ₦3.26 billion

Benefit from agriculture ₦1.89 billion

Gross benefit from irrigation (₦1.04 billion + ₦1.89 billion) ₦1.93 billion

Cost of irrigation (separable of joint) ₦0.13 billion

Net benefit from irrigation ₦2.80 billion

b. Hydropower Generation

Returns from energy sales ₦5.29 billion

Capital cost ₦2.91 billion

Maintenance cost ₦0.13 billion

Net Benefit from Hydropower ₦2.25 billion

c. Water supply

Returns from Consumer water rates: ₦2.61 billion

Capital cost: ₦0.58 billion

Maintenance cost: ₦0.02 billion

Net benefit from water supply ₦2.01 billion

The summary table is shown below:

Table 1: Net Benefits under Economic Efficiency as an Objective

S/NO.	Purpose	Net Benefit (in billion naira)
1.	Irrigation	2.80
2.	Hydropower	2.25
3.	Water Supply	2.01

Benefit Determination under the objective of Regional Economic Redistribution

Consider a ₦3.9 billion development fund over three years for a multi-purpose water resources development involving irrigation, hydroelectric power generation, and water supply where regional economic redistribution is to be optimised as an objective along with other objectives. The benefits accruing to each purpose is as determined below:

a) Irrigation:

i) Tax on new industries attracted as a result of the inclusion of irrigated agriculture: ₦0.27B

ii) Savings on road-user cost as a result of new roads built due to irrigation development: ₦0.52B

iii) Savings on skilled labour due to attracted manpower as a result of the inclusion of irrigation in the development: ₦0.37B

iv) Increase in property value and rent as a result of the inclusion of irrigated agriculture in the development: ₦0.61B

Net benefit from irrigation= Summation of (i) to (iv) above = ₦1.77 billion

b) Hydropower generation:

i) Tax on new industries attracted as a result of the inclusion of hydropower development: ₦1.13 billion

ii) Savings on road-user cost as a result of new roads built due to the inclusion of hydropower in the development: ₦0.62 billion

iii) Savings on skilled labour due to attracted manpower as a result of the inclusion of hydropower in the development: ₦1.23 billion

iv) Increase in property value and rent as a result of the inclusion of hydropower in the development: ₦0.48 billion.

Net benefit from hydropower = Summation of (i) to (iv) above = ₦3.46 billion

c) Water Supply:

i) Savings on road-user cost as a result of new roads built due to the inclusion of water supply in the development: ₦0.73 billion

ii) Savings on skilled labour: ₦0.84 billion

iii) Tax on new industries attracted as a result of the inclusion of water supply in the development: ₦1.21 billion

iv) Increase in property value and rent as a result of inclusion water supply in the development: ₦0.49B

Net benefit of Water Supply =₦3.27 billion

The summary table is shown below:

Table 2: Net Benefits under Regional Economic Redistribution as an Objective

S/NO.	Purpose	Net Benefit (in billion naira)
1.	Irrigation	1.77
2.	Hydropower	3.46
3.	Water Supply	3.27

Benefit Determination under the Objective of Social Wellbeing

Consider a ₦3.9 billion development fund over three years for a multi-purpose water resources development involving irrigation, hydro-electric power generation, and water supply where social wellbeing is to be optimised as an objective along with other objectives. The benefits accruing to each purpose is as shown below:

a) Irrigation:

i) Savings as a result of reduced theft: ₦1.91 billion

ii) Savings as a result of improved health: ₦0.77 billion

iii) Savings on extra-home luxury expenses = ₦0.81 billion

Net Benefit of Irrigation = Summation of (i) and (ii) above = ₦3.49 billion

b) Hydropower:

i) Savings on food due to food preservation: ₦0.82 billion

ii) Savings due to better education: ₦1.14 billion

iii) Savings on extra-home luxury expenses: ₦0.78 billion

Net Benefit of Hydropower = ₦2.74 billion

c) Water Supply:

i) Savings as a result of improved health: ₦1.11 billion

ii) Savings on extra-home luxury expenses: ₦.67 billion

Net Benefit of Water Supply = ₦2.08 billion

The summary is as shown in the table below:

Table 3: Net Benefit under Social Wellbeing as an Objective

S/NO.	Purpose	Net Benefit (in billion naira)
1.	Irrigation	3.49
2.	Hydropower	2.74
3.	Water Supply	2.08

Table 4: Net Benefit Table for all Objectives/Purposes

Purpose	Objective		
	Economic Efficiency	Regional Economic Redistribution	Social Wellbeing
Irrigated Agriculture	2.80	1.77	3.49
Hydropower	2.25	3.46	2.74
Water Supply	2.01	3.27	2.08

RESULTS

Translating the results of the fore goings into a matrix table:

	B1	B2	B3	Minimum
A1	2.80	1.77	3.49	**1.7**
A2	2.25	3.46	2.74	**2.25**
A3	2.01	3.27	2.08	**2.01**
Maximum	**2.80**	**3.46**	**3.49**	

From the above,
maximin = 2.25; minimax = 2.80. Thus, miximin and minimax are not equal. Therefore, there is no saddle point. It should be noted that the value of the game, V should lie between the maximin and minimax values.

Let V be value of the game

p_1, p_2& p_3 = probabilities of selecting strategies A_1, A_2, & A_3 respectively; and q_1, q_2& q_3 = probabilities of selecting strategies B_1, B_2& B_3 respectively.

$$\left.\begin{array}{l} 2.80p_1 + 2.25p_2 + 2.0p_3 \geq V \text{ (if B uses strategy } B_1) \\ 1.77p_1 + 3.46p_2 + 3.27p_3 \geq V \text{ (if B uses strategy } B_2) \\ 3.49p_1 + 2.74p_2 + 2.08p_3 \geq V \text{ (if B uses strategy } B_3) \end{array}\right\} \text{.....4.1}$$

$p_1 + p_2 + p_3 = 1$; (probability condition); and $p_1, p_2, p_3, \geq 0$ (non-negativity condition)

Dividing each inequality and equality by V, we have:

$$\left.\begin{array}{l} 2.80p_1/V + 2.25p_2/V + 2.01p_3/V \geq 1 \\ 1.77p_1/V + 3.46p_2/V + 327p_3/V \geq 1 \\ 3.49p_1/V + 2.74p_2/V + 2.08p_3/V \geq 1 \\ p_1/V + p_2/V + p_3/V + p_4V + p_5V = 1/V; \\ \text{Let } p_1/V = x_1,\ p_2/V = x_2,\ p_3/V = x_3 \end{array}\right\} \text{.....4.2}$$

Therefore, the problem for player A becomes:
MinimiseZ$_{p=}$ $(1/V) = x_1 + x_2 + x_3$

Subject to the constraints:

$$\left.\begin{array}{l} 2.80x_1 + 2.25x_2 + 2.01x_3 \geq 1 \\ 1.77x_1 + 3.46x_2 + 3.27x_3 \geq 1 \\ 3.49x_1 + 2.74x_2 + 2.08x_3 \geq 1 \end{array}\right\} \text{......4.3}$$

$x_1, x_2, x_3 \geq 0$(non-negativity condition)

Player's B objective is to minimise his expected losses which can be reduced to minimising the value of the game, V. Hence the expected loss for player B will be as follows:

$$\left.\begin{array}{l} 2.80q_1 + 1.77q_2 + 3.49q_3 \leq V \\ 2.25q_1 + 3.46q_2 + 2.74q_3 \leq V \\ 2.01q_1 + 3.27q_2 + 2.08q_3 \leq V \end{array}\right\} \text{......4.4}$$

$q_1 + q_2 + q_3 = 1$ (probability condition)

Dividing through by V, we have:

$$\left.\begin{array}{l} 2.80q_1/V + 1.77q_2/V + 3.49q_3/V \leq 1 \\ 2.25q_1/V + 3.46q_2/V + 2.74q_3/V \leq 1 \\ 2.01q_1/V + 3.27q_2/V + 2.08q_3/V \leq 1 \\ q_1/V + q_2/V + q_3/V = 1 \\ \text{Let } q_1/V = y_1,\ q_2/V = y_2,\ q_3/V = y_3 \end{array}\right\} \text{.......4.5}$$

Therefore, the problem of B becomes:
MaximiseZ$_q$(= 1/V) = $y_1 + y_2 + y_3 + y_4 + y_5$

Subject to the constraints:

$$\left.\begin{array}{l} 2.80y_1 + 1.77y_2 + 3.49y_3 \leq 1 \\ 2.25y_1 + 3.46y_2 + 2.74y_3 \leq 1 \\ 2.01y_1 + 3.27y_2 + 2.08y_3 \leq 1 \end{array}\right\} \text{.......4.6}$$

$y_1, y_2, y_3 \geq 0$ (non-negativity condition)

It should be noted that problem of player A is the dual of the problem of player B. Therefore, the solution to the dual problem can be obtained from the optimal simplex table of the primal. To solve the problem of player B, slack variables are introduced to convert the inequalities to equalities. The problem therefore becomes:
MaximiseZ$_q$ $= y_1 + y_2 + y_3 + y + 0s_1 + 0s_2 + 0s_3$

Subject to the constraints:

$$\left.\begin{array}{l} 2.80y_1 + 1.77y_2 + 3.49y_3 + s_{1+} 0s_2 + 0s_3 = 1 \\ 2.25y_1 + 3.46y_2 + 2.74y_3 + 0s_1 + s_2 + 0s_3 = 1 \\ 2.01y_1 + 3.27y_2 + 2.08y_3 + 0s_1 + 0s_2 + s_3 = 1 \end{array}\right\} \text{......4.7}$$

$y_1, y_2, y_3, s_1, s_2, s_3, \geq 0$

Table 5: Initial Table

C_j / C_b	Basis	Solution Value (X_b)	1 y_1	1 y_2	1 y_3	0 s_1	0 s_2	0 s_3	Ra X_b/y_1
0	s_1	1	**2.8**	**1.77**	**3.49**	**1**	**0**	**0**	0.37 →
0	s_2	1	**2.25**	3.46	2.74	0	1	0	0.44
0	s_3	1	**2.01**	3.27	2.08	0	0	1	0.49
	Zj	0	**0**	0	0	0	0	0	
	Zj-Cj		**-1** ↑	-1	-1	0	0	0	

In the table above, C_j stands for the coefficient of the variables (decision and slack). y_1, y_2, and y_3 are the decision variables while s_1, s_2, and s_3 are the slack variables.

C_b represents the objective function coefficients of the variables in the basis. The term basis is simply a collection of variables that are currently in the solution set. The solution value (X_b) gives the initial values on the right-hand side of the linear programming problem. The (X_b) column gives values of the solution variable as the iteration progresses.

Zj-Cj which could be termed the reduced cost row gives the net change in the objective function coefficient.
The arrow pointing upward indicates the pivot or incoming column while that pointing towards the left shows the pivot row. The intersection of the pivot column and the pivot row gives the pivot element. The table also reveals that the initial solution starts from the origin.

Table 6: 1st Iteration

C_j / C_b	Basis	Solution Value (X_b)	1 y_1	1 y_2	1 y_3	0 s_1	0 s_2	0 s_3	Ra X_b/y_1
1	y_1	0.36	1	**0.63**	1.25	0.36	0	0	0.37
0	s_2	0.189	0	**2.04**	**-0.06**	**-0.8**	**1**	**0**	**0.44** →
0	s_3	0.28	0	**2**	-0.43	-0.72	0	1	0.49
	Zj	0.36	1	**0.63**	1.25	0.36	0	0	
	Zj-Cj		0	**-0.37** ↑	0.25	0.36	0	0	

Here, y_2 is the pivot column, and s_2 the pivot row. 2.04 is the pivot element.

Table 7: Optimal Solution Table

C_j C_b	Basis	Solution Value (X_b)	1 y_1	1 y_2	1 y_3	0 s_1	0 s_2	0 s_3
1	y_1	0.3	1	0	1.27	0.61	-0.31	0

1	y_2	*0.0926*	*0*	*1*	*-0.03*	*-0.4*	*0.49*	*0*
0	s_3	*0.09*	*0*	*0*	*-0.36*	*0.07*	*-0.98*	*1*
	Zj	*0.3928*	*1*	*1*	*1.24*	*0.22*	*0.18*	*0*
	Zj-Cj		*0*	*0*	*0.24*	*0.21*	*0.18*	*0*

From the table above, since all the elements of *Zj-Cj* row are zeroes and non-negatives, optimality is said to have been reached. Therefore, the optimal solutions include:

i) For Player B
$y_1 = 0.3$
$y_2 = 0.0926$
$y_3 = 0$

ii) For Player a
$s_1 = x_1 = 0.22$
$s_2 = x_2 = 0.18$
$s_3 = x_3 = 0$;

and the expected value of the game V = 1/Z = 1/0.3926
V = 2.55

Converting these solution values into the original values, we have:
From $y_1 = q_1/V$
$q_1 = y_1 \text{ x } V = 0.3 \text{ x } 2.55 = 0.765$
$q_2 = y_2 \text{ x } V = 0.0926 \text{ x } 2.55 = 0.236$
$q_3 = y_3 \text{ x } V = 0 \text{ x } 2.55 = 0$
$p_1 = x_1 \text{ x } V = 0.21 \text{ x } 2.55 = 0.536$
$p_2 = x_2 \text{ x } V = 0.18 \text{ x } 2.55 = 0.459$
$p_3 = x_3 \text{ x } V = 0 \text{ x } 2.55 = 0$

Allocation of Cost to the Various Purposes

From the above, if we consider a scenario where N3.9 billion is to be spent on multi-purpose/multi-objective water resources development, to simultaneously optimise the objectives even under the worst possible conditions, the allocation should be as demonstrated in the table below:

Table 8: Cost Allocation Table

S/No.	Purpose	Probability	Allocation (in billion naira)
1.	Irrigation	$p_1 = 0.561$	p_1x 3.9 = 0.545 x 3.9 = N2.13
2.	Hydropower	$p_2 = 0.459$	p_2 x 3.9 = 0.459 x 3.9 = N1.79
3.	Water Supply	$p_3 = 0$	p_3 x 3.9 = 0x 3.9 = 0

Also, if the allocation is made as illustrated, under the worst condition of conflicting objectives, the basin can make a financial gain of N9.945 billion on investment of the said sum.

The synergy between the Media and Civil Engineering

The media, made up of the mainstream media like the newspaper, magazine, radio, and television, and the social media arm which has social media platforms like Pinterest, Google+, Tumblr, Facebook, Instagram, WhatsApp, Twitter, Snapchat, Blogs, SoundCloud, Hulkshare, 2go, Zoom, Russian SM Vkontakte, Flickr, Facebook Messenger, Tencent, Telegram, Tik Tok, Skype, LinkedIn, Evernote, YouTube, Foursquare, Yelp, MySpace. XING and kununu (A specific European Social Media phenomenon widely used in German-speaking countries) and others have always had a significant place in civil engineering. The journalist, being a "learned person" that knows something about everything and thrives to know everything about something, has an idea about civil engineering just as he has about other disciplines, fields, and professions

It is worthy to note that Nigeria's government's National Water Resources Institute has as part of its duties spelled out, under section 2 of the National Water Resources Institute Act (C.A.P 2841), among other things, to establish and maintain a water resources library, documentation and conference center; publish or sponsor the publication of water resources journals, and promote co-operation in water resources development management with similar bodies in other countries and with international bodies connected with water resources management and operations. These assignments fall under the jurisdiction of the media, hence making the media relevant, not only in the engineering discourse but specifically in the water resources narratives.

Civil Engineering will always need the media in its operations. The media increase awareness of developments and latest advancements in different areas of civil engineering, promote, share, discuss various new issues, share insights and best practices to achieve success in civil engineering. They also report on research related to the broad spectrum of civil engineering with similar emphasis on all topics. The media do not only disseminate the latest original research, achievements, and developments in many areas of civil engineering and management but also serve as podia for Civil Engineering and other professional communities to present and discuss matters of major interest like new developments in civil regulations.

The media have positive roles they can perform with regards to their relationship with civil engineering as per information dissemination and enlightenment of the communities about engineering activities. They do contribute to the development of civil engineering via radio or television programs, feature articles in newspapers and magazines on various aspects of civil engineering. Civil engineers are sometimes invited for talk shows and interviews on radio and television where they have the ample opportunity to delve into grey areas in engineering, breaking them down for viewers and listeners to understand.

Newspapers also do interview engineers and go ahead to write feature and opinion articles on civil engineering. The media promote, sell, distribute, and project what civil engineering produces without which the society will not benefit from them. They help to interpret engineering 'jargons' for the ordinary man on the street to understand and make them aware of new civil engineering technologies.

No matter how lofty a project, innovation or service may be, be it engineering projects, or any other project or services, they remain useless until the people who are meant to benefit from them get to know about their existence. This is where the media come in to create awareness about the existence of such projects or services, because, "…until the media is involved, no matter or issue revolves; every issue remains docile until the media choose to activate it and cause it to be matters of national discourse" (Guanah, 2017, p. 8). This also reconfirms the relevance of the diffusion innovation theory in a study like this.

There was a reported case of a village that has been provided with a Water borehole, but the women still trekked kilometers away to the stream to fetch water for their domestic needs. Well, they might have preferred to go that distance to utilise the opportunity to gossip among themselves, but the fact remains that the media needed to have been used to enlighten them more about the advantages of using the borehole treated water over the Cholera and Guinea worm prone stream water.

The role of the media is always important in projecting civil engineering outcomes. Nebo (2014) echoes, "We cannot pretend to seek an education system that is viable and encouraging for learning while ignoring the fundamental infrastructural requirements necessary to support the intended growth for both teachers and students" (p.23). Any nation that has a bulk of illiterate can hardly experience development. Likewise, no development campaign can have headway where development messages are not effectively passed to the supposed beneficiaries of such development projects.

While identifying innovation and collaboration as two factors that have often held the construction industry back Hall (2018), singled out collaboration as an area civil engineers, in general, need to improve on. He mentions that the Government Construction Strategy in 2011 presented a quite poor impression of the state of collaborative construction due to poor communication within the sector as one of the reasons for this. He emphasises the importance of collaboration in civil engineering among the different groups involved in a project.

Although he did not mention the media categorically in these groups, the fact remains that it is effective communication, which could be achieved through the media (especially social media), that can make this collaboration work and succeed because communication is vital in all human endeavours. Social media can be used to create strong lines of communication involving key representatives of each group, who then translate information to their respective teams.

The media make communication at all levels exceptionally simple, noteworthy, significant, make life easier, and also fill and close communication gaps. Hall (2018) attests that early and regular communication is the most important factor among the three key elements that can help increase the quality of collaboration during construction and civil engineering projects.

Reechoing the benefits of the digital revolution to the efficiency, management, and security of civil engineering projects, keeping everyone informed of real-time progress, and improving communication, Hall (2018) affirms that their teams on-site track their information on iPads with robust project management applications. Hall (2018) concludes that "the development of systems like Building Information Modelling (BIM) too, have improved the viability of collaborative working by encouraging communication in the early stages of a project and keeping vital information in one location. It represents a culture shift for many firms, but these innovations are rapidly increasing our ability to cooperate during projects" (p. 3).

One of the main functions the media perform in society is to inform the people about the latest happening around them and the world, including the goings in the engineering sector. This has warranted the formation of dedicated TV & radio channels, house journals, newspapers, and magazines to intimate people about current happenings.

There are numerous highly targeted top executives, Construction & Civil Engineering magazines that have been established to offer readers a unique combination of successful business change case studies, reports on major projects, and real-world management advice, put together in non-technical, well-written, and well-designed formats. According to Construction and Civil Engineering magazine - CCE (2021), these magazines provide a variety of article topics combined with carefully chosen business success stories that give real-life insight into what makes a company in this sector not only survive but thrive.

Some of these magazines include Engineering News-Record Magazine (ENR), Building Design Construction Magazine, Equipment World Magazine, Construction Review Online Magazine, Construction News Magazine, Construction Equipment Magazine, Building Magazine, On-Site Magazine (Canada's Construction Magazine), Civil Engineering Bulletin, Civil Engineering Magazine (ASCE), India's, Civil Engineering and Construction Review, Civil Engineering and Construction Review, Civil engineering news, Civil Engineering magazine archive, Structural engineering magazine, Top construction magazines the UK, Construction magazine the USA, Construction management magazine, and ASCE civil engineering magazine, among others (Google.com, 2021).

Institution of Civil Engineers- ICE (2021) emphasises that communication channels, invariably the media, can be used to engage the public and to get messages out about civil engineering because communication continues to be central to the effective delivery of public infrastructure. For instance, ICE (2021) opines that when social media are used effectively, they provide "a vital channel for civil engineers to keep the public informed during disruption and to communicate the benefits to the public of a particular project" (p.2). ICE (2021) also posits that social media can be utilised in effectively telling civil engineering stories that can capture the public's imagination and inspire the next generation of civil engineers.

To buttress her argument of the importance of the media in civil engineering, ICE (2021) recalls how social media ensured an anxious public and politicians were kept informed during the closure of the Forth Road Bridge to repair a fractured truss end link. It recounts that Engineers became the heroes of the hour as images of them suspended 54m above the water in challenging winter conditions went viral. The images showed civil engineering on a global stage.

Conclusion
This study has been on Optimal Strategy Solution to Water Resources Problems in Niger Delta River Basin. It employed the linear programming method of game theory to solve management problems about cost apportionment. The study revealed that for optimal management, no allocation should go to water supply for the period under consideration.

For the three purposes to be optimised simultaneously, the development fund of ₦3.9 billion should be apportioned to the various purposes as follows: ₦2.13 billion should go to irrigated agriculture, ₦1.79 billion to hydropower, and zero allocation to the water supply. The basin can make a huge financial net benefit of up to ₦9.945 billion if the development funds are allocated as demonstrated. The value of the game is 2.55 which falls between the minimax and maximin values. This authenticates the mathematical process employed.

The study also argues that the media have significant roles to play in civil engineering, just like in other fields of human endeavor. Even though the strong link between civil engineering and the media are quite spelled out, unfortunately, they were not utilized in the optimisation project of this study

Recommendations

i. Rather than yearly allocations, disbursement of funds to the river basins should be on, at least, a quarterly basis.
ii. Cost-sharing should always be based on logical and mathematical justifications.
iii. The River Basin Development Authorities in Nigeria should ensure they intensify their efforts in record keeping to increase the reliability of data necessary for research.
iv. Future research should be encouraged in the area of optimisation to ensure that scarce resources are not wasted.
v. Government should set up an agency to monitor funds allocated to the river basin authorities to avoid embezzlement and wastage.
vi. The media should be involved in all cases of civil engineering where they are found useful.

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