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Application of Game Theory in Solving Urban Water Challenges in Ibadan-North Local Government Area, Oyo State, Nigeria

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Abstract:- The significance of water in human life cannot be ignored, but in most of the developing countries; availability, provision and access to good water source to the citizens has post major challenges. The nature of water scarcity has been majorly attributed to seasonal factor and high population pressure. This study therefore aimed at developing a practical approach and mechanism to solving water challenges in urban areas in Nigeria by means of game theory. The findings revealed that majority of respondents lack access to portable or drinkable water from water agency and that regular water supply sources have been traced to be borehole or well which was provided by citizens in the community at a cost.

Applying the game theory approach, the outcome of the game indicates that the equilibrium value for the two players (the water agency and the residents) is ₦2,000 for 1,000 liters of water supply monthly. However, the payoff can be maiximised by every player (monetary values for the water agency and satisfactory water consumption for the residents). It is therefore importance that water agency should improve in the quality of their work in providing adequate water supply to the community to reduce or eradicate ailment arises from non availability of quality water.

Keywords:- *Cost Optimization, Game Model, Pipelines, Water Agency, Portable Water Component.*

I. INTRODUCTION

Game theory is applied in different disciplines; it found its first application in economics. To date game theoretical principles have been used, where other programming methods have failed, in the design of complex water management systems [1]. The nature of water scarcity has been majorly attributed to seasonal factor and densely populated pressure. Constant water supply sources have been traced to be borehole or well which are not unsusceptible to dryness and period of dryness has been found to be mainly as short as less than two months. In Ibadan North majority of people complain that water in this area is not suitable for drinking, that they rely on buying sachet water and borehole water for drinking. This indicates that majority of the residents lack access to portable/drinkable water, which could lead to outbreak of sickness and diseases resulting to untimely death.

For humans and all other creatures to survive, water is a necessary resource. Food supplies and adequate nourishment are also dependent on water. Prompt supply of "clean" and "portable" water is one of the most basic human needs, and one that is not met for more than half of the world's population [2]. Similarly, [3] stated that more than half of the world's population does not have access to adequate quantities of safe drinkable water, yet two out of three of the earth's surface is covered with water. Apparently, there is enough water around when we take the mighty rivers and the oceans into consideration, but it will be a gross mistake to take the process and management of these water resources for granted in the supply of "clean" and "portable" water for the use and consumption of human.

In addition to urbanization and pollution, many developing countries have significant water-related challenges. However, two major problems of developing countries are deterioration of water quality and shortage of water [2, 4]. Due to: temporally and spatially uneven distributed precipitation; exponentially increasing water consumption with increased population growth rate [5,6]; the resulting unsustainable water resources management practices caused by the loss of potential sources of fresh water [7], as well as rising temperature [8].

Nigeria, African's most populated country, with, with more than 200 million people, has limited water supply not only in the arid to semiarid north, but also in the southern region along the Atlantic Ocean. Lack of comprehensive planning and execution is the main problem facing water

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development in Nigeria [9]. The problem is probably the worst where citizens still need high quantities of improved water source stagnated at 47% from 1990 to 2006, but increased to 54% in 2010. According to [3], in 2006 access in urban areas decreased from 80% to 65% but then increased to 74% in 2010. However, due to differing definitions, indicators, and methodology used by various water corporations and authorities, inconsistent data exist about the availability of public water.

Moreover, the requirement to use diesel generators in order to pump and/or supply water for the general population drives up the operational costs of water agencies. In Nigeria, water production facilities are "rarely operated to capacity due to broken down of equipment, or lack of power or fuel for pumping."

These days, it is not unusual to witness people in both urban and rural areas frantically looking for water due to various issues [10]. Due to the lack of access to a safe water supply, the people are forced to look for alternative sources, which often require them to pay a third party a hefty fee for small-scale deliveries. In fact, the poorest people pay the highest costs for water, which is frequently tainted and contaminated [3]. These scenarios in Nigerian societies call for serious attention. Water problems are getting worse every day due to rapidly aging water management infrastructure, filthy waterways, and an expanding population. Millions of people in urban and rural regions of the country still do not have access to clean, portable, drinkable water [11]. However, there are four main types of issues related to urban water delivery in Nigeria: institutional, financial, commercial, and operational [3]. In Ibadan, like most major cities in Nigeria, urban water supply is confronted with these challenges, as citizens lack access to the system, the municipality does not provide water to their regions, or both [10].

This study investigates the cost of connecting/accessing, sourcing water supply from the Oyo State Water Corporation (OYSWC) to proffer possible strategies in solving the water challenges.

In solving these challenges, this study adopted game theoretical models. Game theory is a valuable and effective method for simulating this kind of problem since it examines the tactics and equilibria of multiple agents in interdependent and interactive contexts [4,12].

The major challenges in accessing/connecting OYSWC water supply by majority of the residents are that water supplied by Oyo State Water Corporation (OYSWC) is not reliable; not good for consumption; and too expensive to connect and maintain. Also, inability to connect, because of: distance barrier/non-availability of the mains in their localities; unfunctional pump station; and disconnection because of road construction are other factors. However, 86% of the respondents stated that the OYSWC water supply could not be adequate.

II. REVIEW OF LITERATURES

Water distribution (WD) is an intermediate stage in the cycle of water production and supply. Indicator/marker posts, booster stations, distribution pipeline networks, valves, flow meters, chambers, and service reservoirs are all included. It is loop-safe and works like the branches of a tree, transporting resources from the base (waterworks and intake) to the trunk (rising and trunk pipeline mains) and finally to the leaves, or clients [13].

Unfortunately, modern WDNs are complex and difficult to manage due to increased level of urbanization, varying consumer demands, and limited resources. These management problems could be broadly classified into three categories: short-term; medium-term; and long-term.

Several studies have over time developed various categorizations of the difficulties facing the water industry and how they affect distribution. Technical, commercial, and administrative were the three that [14] mentioned. [15] identified three: climate change, management, and technical. [16] identified four categories: organizational, policy framework, commercial, and technical. But[17] found nine water supply-related issues that are pertinent to WD: urbanization and population growth; globalization and economic development; deteriorating infrastructure; privatization and governance; changes in public attitudes; developing technology; risks to critical infrastructure systems; growing fuel and energy expenses; and climate change.

Consequently, it may be said that WD issues are multifaceted, encompassing administrative, political, social, economic, environmental, and technical difficulties.

Among the many technical difficulties include leaks, outdated pipelines, improper technology, a workforce with insufficient training, poor design, construction, and operation, and deterioration of the water quality.

Therefore, it may be argued that there are a variety of WD problems, such as administrative, political, social, technical, environmental, and economic difficulties.

Technical issues can include difficulties with design, building, and operation; leaks; antiquated pipelines; inappropriate technology; a workforce lacking in the necessary skills; and declining water quality, to name a few.

- *Foreign and Domestic Debts*:

One aspect of Africa's problems is the amount of debt owed and/or the difficulty in obtaining loans from outside the continent. For example, the government of Ghana had to impose ban on foreign loans due to the country's massive foreign debt burden, which is estimated to be GHc63 billions ($18.5 billion approx.). This prevented the implementation of the second phase of the Nsawam Water Supply Rehabilitation and Expansion Project, which was supposed to increase the Nsawam distribution networks and for which €7 million in external funding had been acquired

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[13]. Some Nigerian states, like Lagos, Ondo etc, have taken on more debt than they are able to pay back, according to an economic analysis [13]. As such, the Nigerian Federal Government would not be able to ensure external loans to these states.

Lack of cost optimization: In developing nations, the sizes of reservoirs, valves, rising, trunk, and distribution main pipelines, among other components, must be restricted in order to save capital costs. In Nigerian towns, the majority of distribution mains now in use are only DN100 to DN150 mm in diameter, passing through streets that have trunk mains DN200 to DN250 mm in diameter [13]. Large capital cities have trunk main restrictions ranging from DN300mm to DN800mm. Even in globally integrated cities such as Lagos, trunk mains are limited to DN900mm to DN1200mm [13].

As a result, the population's exponentially increasing water demand easily surpasses the trunk mains' flow carrying limits. Unfortunately, increasing flow in any WD pipeline network also increases overall head loss, depriving distant users of provision of potable.

Political challenges include among other things, a lack of political will, the politics of contract awards, and the absence of shared needs. A significant financial commitment to WD can only be made with political will, and most nations, developed or developing, lack this desire. The number of politicians, lawyers, and accountants working in Nigeria's water sector has been steadily increasing. However, knowledge in the investigation, design, construction, and operation of WD is required in this field.

Social Challenges: Since more than five years ago, WD has been owned by the African government [18]. However, privatization has proven successful in industrialized nations, which has prompted calls for its adoption in Nigeria and throughout Africa [18].

WD faces a number of administrative issues, including as determining and implementing appropriate pay and benefit structures to encourage engineers, managers, and employees; educating and retraining these individuals; providing appropriate tools and equipment; and creating more efficient work schedules. The capacity to collect and handle massive amounts of statistics on customers, supply, demand, tariffs, income, repair and maintenance, water quality, volume, pressure, pipeline materials and age, etc. are some more [13].

An abstract, defined as a formal explanation of a strategic situation, is what a game is. Any strategic interaction involves two or more players, or decision-makers, each of whom has two or more strategies; the choice of any player's approach determines the outcome. Among all the potential outcomes, each actor has well stated preferences, making it possible to assign commensurate outcomes (payoffs). Game theory is the rational examination of cooperative and conflictual situations. Formally speaking, it can be described as a theory of rational decision-making in conflictual contexts.

A renowned mathematician, John von Neumann and Oskar Morgenstern introduced game theory in 1944. Game theory has applied to water resource management problems during the past decade. [19] used game theory to analyse the interdependency among eight states and two provinces concerning water diversions from the Great Lakes.[20] used Nash product for the formulation of the objective function of reserviour water allocation model and used resiliency and vulnerability indices to evaluate the performance of optimization algorithms. [21] introduced the water distribution problem of the Mexican Valley and modeled as a three-person non-cooperative Game in which agriculture, industry, and domestic water users are the players and the total water amount supplied to the users were the payoff functions.

[22] uses a series of non-cooperative water resource games to investigate how game theory might be applied to conflict resolution and water resource management. He uses examples to show how water resource concerns have a dynamic structure and how important it is to take the game's evolutionary path into account when researching such issues.
In their study, [23] examined the utility of game theory in the distribution of water resources using simple two-by-two symmetric water resource games. They compared cooperative and non-cooperative game players using three different types of game theory images; the greatest reward is obtained when both players cooperate.

[24] studies the drainage basin of the Atrack River. After introducing a cooperative game amongst the beneficiaries and outlining their strategy, they analyze each player's "Shapley Value" and evaluate an efficient scenario. It was decided to expect increased national income, environmental improvement, and the best possible distribution of water resources in the northeastern provinces.

[25] analyze water-related conflicts and suggest mitigating measures in the Middle Tocantins Hydrographic Region by using potential conflict-generating agents. This allows for the identification of conflict scenarios and their corresponding levels of intensity (high, medium, and low). They came to the conclusion that improved communication could prevent a great deal of environmental damage and conflict. A committee is hereby suggested to be created to allow greater interaction between users.

III. METHODOLOGY

The importance of game theory as a tool in many different fields has been generally acknowledged. There are unique game models that are widely used in analyzing problems of environmental and natural resources.

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➢ *Two-Person Zero-Sum Game Model:*

In this type of game, if one player wins, the other will lose because the total of their payoffs is always zero, that is $\sum_{i=1}^{2} \mu_i(s) = 0.$ A matrix $\lfloor a_{ij} \rfloor$ can be used to express such a game. Because the payoffs of player j are opposite to player i, it is usually just lists the payoffs of player i. A situation where multi-actors have conflicting interests or benefits, such as diverse water users in areas of water shortage, can be modeled by the two-person zero sum game.

$$A = \begin{bmatrix} a & -b & c \\ -a & b & -c \\ c & a & -b \end{bmatrix}$$

Fig 1 Two-Person Zero Sum Game

➢ *Prisoner's Dilemma Game Model:*

In this game, cooperation is rewarded, but there is also an incentive for each player to "free ride" on the actions of the others. In order to simulate joint decision-making scenarios where non-cooperation is consistently every player's dominant strategy, irrespective of player strategy, a two-person version of the prisoner's dilemma game is shown below [26]

$$\begin{array}{c} \rightarrow \\ \downarrow \begin{bmatrix} (4,4) & (1,5) \\ (5,1) & (3,3) \end{bmatrix} \downarrow \\ \rightarrow \end{array}$$

Fig 2 Game of Prisoners' Dilemma

The model is a highly helpful analytical tool for examining the conflicts between individual and group rationality [27]. Prisoner's dilemma models involves strategic behavior, it may be applied to any situation in which two entities could gain important benefits from cooperating or suffer from failing to do so, but find it difficult or expensive to coordinate their activities.

➢ *The Chicken Game Model:*

This model is typically used to simulate a scenario where one player occupies one resource while others would prefer to occupy another. There are typically several equilibria and no dominant strategy among the participants in this game.

$$\begin{array}{c} \rightarrow \\ \downarrow \begin{bmatrix} (4,4) & (3,*5) \\ (5,*3) & (2,2) \end{bmatrix} \downarrow \\ \rightarrow \end{array}$$

Fig 3 Chicken Game

➢ *Assurance Game Model:*

There are numerous equilibria in the assurance game as well. While the efforts of two players can produce a shared benefit, the contributions of one player are insufficient to yield a collective benefit.

$$\begin{array}{c} \leftarrow \\ \downarrow \begin{bmatrix} (4,*4) & (5,1) \\ (1,5) & (3,*3) \end{bmatrix} \downarrow \\ \rightarrow \end{array}$$

Fig 4 Assurance Game

Here, players lack a dominant strategy and instead rely on the expectations of other players. If one person cooperates, the other players usually have incentives to follow suit. In contrast, the other players have an incentive to not collaborate if one of them does not. This is a game where there exist risk and uncertainty.

➢ *Driving Force Game Model:*

If external or internal driving forces can eliminate risk and uncertainty in the assurance game, a more optimal result will achieved. The motivating factors typically allude to things like rules, laws, contracts, and other legally enforceable agreements. Economic techniques, such as taxes, fines, compensation, and so forth, are likewise these kinds of driving factors in accordance with those legislative ways. The players are motivated to choose cooperation by either internal or external factors.

➢ *Transforms of Games Models:*

An approach to solving the dilemma is to provide a system that can change the game's rules and encourage players to cooperate in order to achieve collective rationality [28]. Cooperation can emerge naturally via discussions or it might be shaped by external factors. In an attempt to totally eliminate non-cooperative conduct, players may create binding regulations. They act in this way because they understand that in the prisoners' dilemma game, repeated cooperation ultimately yields a significantly better result than desertion.

Additionally, in the event that the driving forces furnish additional comprehensive data regarding player conduct, severely penalize non-cooperative activity, and/or grant high subsidies to cooperative players, the assurance will be passed to the driving force game.

The study is conducted in Ibadan-North Local Government Area, Oyo State, Nigeria, which is situated at latitude 7° 24' 33" N and longitude 3° 53' 24" E. It's one of the biggest LGAs in Oyo State. This area is characterized by severe environmental conditions, prevalent high population concentrations, limited access to basic sanitary facilities and an appropriate water supply, and unsuitable housing plans. The data that was gathered was both qualitative and quantitative. using surveys, interviews, and observation to gather quantitative data. 500 residents who are 18 years and

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above were purposively selected based on the severity of water supply challenges. Also, the officials of the water agency were interviewed on the difficulties associated with the water supply in the area.

IV. DISCUSSION OF RESUTS

The study will offer practical advantages in several areas of water resources decision making. In this, the optimum strategy will be achieved between the water agency (OYSWC) and the residents by using game theoretical principles with due allowance to the various technical, economic and social conditions. Equilibrium value between players will also be achieved.

- *Socio-Economic Distribution of Respondents*

This section gives the descriptive analysis of respondents' socio economic status. Out of the five hundred questionnaires administered only four hundred and sixty eight were returned. All the respondents were Nigerians of which 67% male and 33% female. The respondents were 35 ± 10 years old on average. The majority of responders were married (57%), had a postsecondary degree (78%), and worked or were employed as civil servants or public servants (63%). They made, on average, N47,500 ± N15,200 each month.

- *Status of Water Supply*

The study revealed that 68% of the respondents do not have access or connected to water supplied from the State Water Corporation (water agency), while 32% were connected to water supplied from the water agency. Out of the 32% connected, 13.4% got connected through the State Water Corporation (OYSWC) officials; while 18.6% of the respondents got connected through a technician without consulting the State Water Corporation. Also, the consistency of water supply from the OYSWC was revealed. 18.2% of the respondents stated that water supply by the OYSWC is seasonal, while 13.8% of them stated weekly. This indicates that water supply from the OYSWC is not consistency, thus, unreliable.

However, out of the 68% not connected to OYSWC, 20% and 48% were connected to borehole or well and private arrangement in sourcing water. This implies that nearly average of the residents sourced and/or bought water for consumption and usage. This indicates that the majority of the population uses other water suppliers, who provide it in little amounts and at a high cost. This supports the claim made by [3] that the less privileged people purchase water at the highest cost, which is frequently dirty and polluted. The implication of this is that majority of the residents are exposed to unpleasant, unsanitary and unhealthy living, which is contrary to the expectations of WASH (Water supply, Sanitation and Hygiene) [5, 6].

- *Water Scarcity and Survival Strategies*

The nature of water scarcity was revealed; majority of the respondents (81%) attributed water scarcity to seasonal factor (48%) and high population pressure (33%). Boreholes and/or wells were identified as regular sources of water supply, however 76% of respondents said that regular water sources were usually dry.

Period of dryness was found to be mainly as short as less than two months at 46%, while 38% and 16% at two months and at four months, respectively. Alternatives were sought after in order to ascertain the residents' survival strategies during dryness of water sources. The study found that 58% of the participants used to purchase water from private sources when it was dry. 12% of the respondents said they obtained free water from a nearby facility, and 24% said they hiked long distances to obtain water from any source. Out of all the responders, only 6% said they always had water, even throughout the dry season. Just 4% of the respondents had direct access to portable or potable water; the majority, 74%, claimed that the water in this location is unfit for human consumption and that they must purchase sachet water, while 22% must purchase borehole water.

This indicates that majority of the residents lack access to portable/drinkable water, which could lead to outbreak diseases resulting to untimely death.

- *Cost of Connecting/ Accessing, Sourcing and Maintaining Water Supply*

In this study, the cost of connecting/accessing, sourcing and maintaining water supply were sought after in order to proffer possible strategies in solving the water challenges identified. Out of the 32% connected to OYSWC water supplied, 22% stated that they paid ₦2,000 monthly (but not frequent) for the water supplied. While 10% responded that they have stopped paying, because they do not have access to the water supply anymore. Also, out of the 32% connected to OYSWC water supplied, 16% spent ₦50,000 on connection charges (includes: digging, piping and connecting) only. While 9% and 7% spent <₦50,000 and >₦50,000 on connection charges only. However, the cost estimates of connection/access to OYSWC water supply were carried-out variably in relation to the present monetary value.

Furthermore, majority (54 percent) of all the respondents estimated that they consumed 3,000 liters (3 kiloliter) of water monthly. While 24% consumed < 3,000 liters, 22% of the respondents consumed > 3,000 liters monthly. Similarly, majority (73%) of all the respondents estimated that they spent ₦4,000 on water expenses monthly. While, monthly, 17% and 20% spent <₦4,000 and >₦4,000 on water expenses respectively. However, for the purpose of comparison, the OYSWC officials were also interviewed to know the estimate of their water bills. The estimation of their water bills varies, depending on the household size and building size, however, ₦2,000 monthly per kiloliter was estimated for a household size of four (a single family unit). This implies that majority of the residents will be able to pay reasonable bill for OYSWC water supply monthly, if the source is reliable and efficient. In addition, the study revealed that majority of the respondents (71%) were not satisfied with the situations of water supply in this area, considering their comfortability and affordability in relation to the cost of

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connecting/accessing and sourcing water supply. As a result, urgent interventions are needed to ameliorate the situations of water supply in this area.

- *Challenges in Accessing/Connecting OYSWC Water Supply*

The study found out the major challenges in accessing/connecting OYSWC water supply. Majority of the respondents (82%) stated that there is no need for it, because their water supply is: not reliable; not good for consumption; and too expensive to connect and maintain. Others (18%) stated that inability to connect, because of: distance barrier/non-availability of the mains in their localities; unfunctional pump station; and disconnection as a result of road construction. However, 86% of the respondents stated that the OYSWC water supply could not be adequate enough to meet their monthly needs. While only 14% testified that it could be enough to meet their monthly needs. This indicates that the OYSWC water supply is not adequate enough to meet the residents' needs. Also, the OYSWC officials were interviewed to know their challenges in carrying their mandates. All the challenges stated were similar to the ones identified by [3], these are: financial; operational; commercial; and institutional challenges.

➢ *Game Model for the Study*

From the perspective of game theory, human societies and nature are full of games. For examples, the game can be between: human and rain, rivers, lakes and animals; human and human; animals and animals; plants and plants; animals and plants; or their habitats, and so on [4]. However, in this study, the game involved is classified as human and human game (HH-G). That is, the game between the water agency (OYSWC) and the residents. The HH game is a social game and strategic game. Hence, strategic games were adopted.

An extremely variety of circumstances on conflicts and challenges have been modeled as strategic games [4, 29-33].

- *Here is how the Strategic Game, also Known as the Normal Game, was Defined:*

$$G = (N,\ (S_i),\ (U_i))$$

Where $N = \{1, 2, \cdots, n\}\}$ set of players $S_i = \{S_1,\ S_2,\ \cdots, S_n\ \}$ is the strategies profile of player i and $U_i = \{U_1,\ U_2,\ \cdots, U_n\ \}$ is the payoff function of player *i*.

Strategic (or normal) games are usually applied to model the static (or simultaneous-move) games in which every player chooses a strategy simultaneously. The strategy profile of all the players determines the payoff of every player. Static games can be either with complete information or with incomplete information. Simultaneous choice does not mean that one player chooses the strategy with other players at the same time, but it just means that a player does not know the choice of the others. The simple model of a strategic game is a two-person game, which can be constructed as a bi-matrix:

$$G = \begin{array}{c} \\ S_1 \\ S_2 \end{array} \begin{array}{c} \begin{array}{cc} \multicolumn{2}{c}{2} \\ P_1 & P_2 \end{array} \\ \begin{bmatrix} (a,\ a) & (b,\ c) \\ (c,\ b) & (d, *d) \end{bmatrix} \end{array} 1$$

The water agency, OYSWC, (Player 1), and the residents, Player 2, are the two players in this study, according to the matrix. Both Player 1 and Player 2 have two strategies: S1 (N2,000 per month) and S2 (for 1,000 liters), and P1 (N4,000 per month) and P2 (for 3,000 liters). Each of the four cells, which stand for the four possible outcomes, has a pair of letters. The first number in each matrix cell represents the value or payoff that Player 1 (the water agency) could obtain at the end of the game through possible interactions (N4,000), and the second number is what Player 2 (the residents) could obtain at the end of the game (3,000 liters of water).

Since there is no other explanation, the result with an asterisk (*) in the cells is the equilibrium result. Typically, Player 1 (the row player) strategies are represented by the rows of the matrix, and Player 2 (the column player) plans are represented by the columns. The game matrix for this study is simply expressed as:

$$G = \begin{array}{c} \\ S_1 \\ S_2 \end{array} \begin{array}{c} \begin{array}{cc} \multicolumn{2}{c}{2} \\ P_1 & P_2 \end{array} \\ \begin{bmatrix} (2) & (1) \\ (4) & (3)\ (*d) \end{bmatrix} \end{array} 1$$

$$G = (2*3) - (4*1)$$
$$G = (6) - (4)$$

- *Outcome of the Game is : 2*

The outcome of the game (2) indicates that the equilibrium value for the two players (the water agency and the residents) is ₦2,000 for 1,000 liters of water supply monthly. However, each of the players can maximize his payoff (monetary values for the water agency and satisfactory water consumption for the residents). Relatively, the game model provides mathematical illustration of the critical need to fund the necessary investment on water supply infrastructure for social rehabilitation and economic development. To achieve this, the water agencies have to be commercially oriented. They have to treat the water users (the residents) as customers, not as consumers. Commercially, Customers' complaints are typically given the attention they deserve which in-turn makes the customers (the residents) to willing-fully pay their water bills.

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V. CONCLUSION

Game theory application provides useful benefits in various domains of water resource decision making. Although, the theory found its first practical application in economics [34], but it has been widely adopted in various aspects of sciences. In this study, through the application of game theory, optimum strategy was achieved between the water agency (OYSWC) and the residents by using game theoretical principles with due allowance to the various technical, economic and social conditions. Equilibrium value for the two players is ₦2,000 for 1,000 liters of water supply monthly, with each player having the strategies to maximize his playoff.

However, to address water challenges holistically, the study is of the opinion that water improving infrastructure needs to be prioritized, as well as proper commercialization of the water sector. International financiers and donor agencies will be needed to complement the funds received to the sector which is handicapped by: inaccurate billing and collection; high and steadily increasing operating costs. Also, accurate customer's data are needed (customers' database), accompany with competent staff, which will improve everything from billing to water collection in their commercial operations.

In conclusion, water is a limited and delicate resource that is necessary for development, the environment, and life itself. It has a close connection to both social and economic growth. Water resources are essential to human survival because water is necessary for life. It is part of the five essential needs for human beings: air, water, food, light, and heat. A common factor among the other four is water. Water, therefore, constitutes a significant component of all living things, including humans, so to say that it is life is not an understatement. Its social and economic values, however, should not be undervalued based on its fundamentals.

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APPENDIX

Table 1 Socio-Economic Distribution of Respondents

Gender of Respondents			
	Frequency	**Percentage**	**Cumulative %**
Male	315	67%	67%
Female	153	33%	100%
Total	468	100	
Age of Respondents			
	Frequency	Percentage	Cumulative %
18-30years	168	36%	36%
31-43years	225	48%	84%
44-56years	42	9%	93%
57-69years	33	7%	100%
Total	468	100	
Marital Status of Respondents			
	Frequency	Percentage	Cumulative %
Single	102	22%	22%
Married	268	57%	79%
Separated/Divorced	75	16%	95%
Widow(er)	24	5%	100%
Total	468	100	
Educational Level of Respondents			
	Frequency	Percentage	Cumulative %
No-formal Education	--	--	0%
Primary Education	--	--	0%
Secondary Education	102	22%	22%
Tertiary Education	366	78%	100%
Total	468	100	
Occupation of Respondents			
	Frequency	Percentage	Cumulative %
Student	27	6%	6%
Unemployed	33	7%	13%
Self-employed	105	22%	35%
Public/Civil Servant	294	63%	98%
Retired	9	2%	100%
Total	468	100	
Monthly Income of Respondents			
	Frequency	Percentage	Cumulative %
₦40,000 and below	123	26%	26%
₦40,001 – ₦60,000	201	43%	69%
₦60,001 – ₦80,000	99	21%	90%
₦80,001 – ₦100,000	33	7%	97%
Above₦100,000	12	3%	100%
Total	468	100	

Source: Authors' Field Survey, 2023.

Table 2 Socio-Economic Distribution of Respondents

Domain	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Age of Respondents	27	69	34.67	10.35
Monthly Income (NGN '000)	20	105	47.50	15.20

Source: Authors' Field Survey, 2023.