International Journal of Sciences & Applied Research

www.ijsar.in

ANALYSES OF CUSTOMER'S POWER HOLDING COMPANY OF NIGERIA BILLING SYSTEM PREFERENCES USING THE CONCEPT OF GAME THEORY

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ABSTRACT

The factors influencing customers' preference on PHCN billing systems, using respondents from Alakahia, Rivers state were examined using the minimax principle of two players playing zero sum games. In order to gather the necessary data, questionnaires were distributed to the target population of sampled residence of Alakahia, taking into account the 8 factors that were identified as influencing residence's decisions between estimated and prepaid meter. In a two-player zero-sum game, the acquired data were analyzed using the minimax theorem. The best approach and the game's worth were identified. From the result, in the analysis of customers' preference on PHCN billing systems, using respondents from Alakahia, a saddle point exists at -23 (maximin value = minimax value). This implies that player A being Estimated billing prefers either strategy a_4 and a_8 representing 'not restricted to limited use of appliances' and 'best for commercial use' While player B being Prepaid meter billing prefers either strategy b_3 and b_7 representing 'more reliable power consumption' and 'more economical to meter. The value of the game is -23. This implies that in the analysis of customers preference to PHCN billing system, player B which denotes Prepaid billing system is favoured and preferable.

Keyword: Minimax principle, Zero sum games, Questionnaires, estimated and prepaid meter, Gamestrategy

1 INTRODUCTION

Game theory involves the study of strategic decision making in situations of conflict between two or more decision makers also known as players, with two or more decisions called strategies to choose from. Each player tends to have clear preferences among possible outcomes in which conflict and cooperation play important roles. The theory tends to identify the possible outcome of a game using what is known as Nash Equilibrium. The Nash equilibrium suggests that each player chooses its best strategy that gives it the highest payoffs.
When there is a direct conflict between multiple parties striving for the same outcome, this type of game is often a zero-sum game. The simplest game of any real theoretical interest is a two-person constant sum game of perfect information.

Game theory has been applied in different areas including electrical engineering mainly; in planning, scheduling ND marketing of electrical power (Liu et, Al., 2017).

Since the introduction of Game Theory, it has widely been applied in a wide range of applications in different fields like, engineering and Social fields including psychology, evolutionary biology, war, politics, economics, and business (Wang et, at., 2012). Despite its many advances, game theory is still a young and developing science.

Orumie(2017) used a two person zero sum game to investigate consumers choice of drinks in a competitive market. Udeme and Orumie (2021) studied patient's preference of health facilities for quality health care services in Akwa Ibom State using a Two Person Zero sum game in analyses. Orumie et, al. (2023) used the Game theory approach to study the analysis of students' choice of public and private institutions in Nigeria. Altman et al. (2006) studied the concept of the application of non-cooperative game theory in transportation system with extension to the network routing. Rosenthal (1973) presented a class of game theoretical model for routing in transportation network. Abhijit (2018) carried out a research on the application of game theory in medical consultation at Kolkata, India. Charles et al. (1997) in their study applied game theory in order to measure benefits of a shared decision making model for both physicians and patients that focused on life threatening illnesses in the disease process. Stavropoulou et al. (2008) carried out a study on conflict in the doctor-patient interaction and non-adherence using a game theory approach. Bettinger (2016) presented a study on game theory and mechanism design for cooperative competitive dilemmas between health care providers at California.

There have also been some interests in the use of game theory to develop prescriptive models of medical decision making according to Diamond et al. (1986).

Thus in this research, the researcher would adopt the concept of Two Persons Zero Sum Game Approach to determine the outcome of the preferences of PHCN Billing systems, since it is not just dependent on individual's choice but also on others.

Electric power supply in Nigeria dates back to 1896 but with a functional electric utility company in 1929 called Nigeria Electricity Supply Company (NESCO), a privately owned power station (Onyi-Ogele, 2016) to Electricity Corporation Nigeria (ECN) in 1951 (Onochie, et, al, 2015) and the establishment of Niger Sam's Authority in 1962. ECN and NDA became National Electric Power Authority (NEPA) in 1972 and later to Power Holding Company of Nigeria (PHCN) and Nigeria Electricity Regulatory Commission (NERC) to regulate PHCN in 2005; with privatization in 2013, which comprises of 6 Generating Companies (GenCos), 11 distribution companies, and 1 Transmission Company (100% owned by Government). Despite the efforts of the Nigerian Government, Nigeria consistently face 'frequent power outrages with the attendant effect on the economic activities' (Ogunleye, 2016, as cited in Ohajianya, 2021) which is linked but not limited to poor management of the companies in getting sufficient equipment, poor and lack of implementation of government policies and incompetence of staff of DisCos . In other to attempt in cropping the rate of irregularities of the personnel of DisCos, NERC have abolished the estimated billing system and set the right prices for unmeter billing based on the tariff class per month. (Sanyaolu, 2020)

Nigeria Electricity Regulatory Commission (NERC) introduced the estimated billing system for electricity in 2012, as a way to make sure that unmetered consumers or consumers with faulty meters are billed by DisCos (Olarere, 2014). Despite the regulations set by NERC in Section 76

of the Electric Power Sector Reform Act of Nigeria, 2005, DisCos billings givens to the consumers are found not to be as stipulated. According to Anyaehie et, al,(2018), the DisCos are fond of not reading the analog meter regularly and as a result render outrageous bills to customers. The prepaid meter billing system is also adopted as a way to crop the high cost involved in the analog billing system (Alam et, al, 2016).

The preferences of consumers to PHCN billing systems is determined by the many factors such as: expenses involved in usage, reliability of power consummed, restriction to use of appliances, over billing, embarrassment from PHCN staff, disconnection and fees of reconnection etc. The prepaid billing has both the DisCos and the consumers advantages (Mhereag ,et, al, 2018). Nevertheless, DisCos still prefer the estimated billing system to the prepaid billing system (Thisday, 2019).

Therefore, the researchers aim to apply the two person zero sum game to study consumers' preference on PHCN billing system in Alakahia., and the main objectives are;To use this approach to determine the optimal strategy and the value of the game using the factors influencing consumers' preference on PHCN billing system in Alakahia. And as a result of the above, identify the PHCN billing system that gives the consumers best satisfaction using the game value

2 Scope and Delimitation of the study

This research work is centred on a Game Theory Approach to consumers' preference on PHCN billing system in Alakahia. The study used data got from both primary and secondary sources.Copiesof questionnaires were distributed to the customers residing at Alakahia, and the results collated. The individuals who have had access to different PHCN billing systems in Alakahia community in Obio/Akpor LGA of Rivers State are the targeted respondents. It is a community next to Choba, where the University of Port Harcourt is located.

3. Methodology / A Two-Person Zero-Sum Game

Traditional game theory addressed two-person zero-sum games, in which a participant's gains or losses are exactly balanced by the losses and gains of the other participant. In the 21st century, game theory applies to a wider range of behavioral relations, and it is now an umbrella term for the science of logical decision making in humans, animals, as well as computers. Modern game theory began with the idea of mixed-strategy equilibria in two-person zero-sum game and its proof by John von Neumann.

A game involving two persons is said to be a person game while if more than one person, it is called n-person game. When the sum of the game is zero that is, when the outcome (pafoff) is either a gain or loss for respective players, then it is a zero sum game. When a point of equilibrium also called saddle point is got, then the game is said to be a game with pure strategy but no saddle point, then it is a mixed strategy. Because games are rooted in conflict of interest, the optimal solution selects one more strategies for each player such that any change in the chosen strategies will not improve the payoff to either player. A pure strategy two person zero sum game can be solved using the minimax principle via the rule of dominance

The Minimax-maximin principle assumes that in a pure strategy two person zero sum game, the saddle point is the corresponding entry of the payoff matrix where the maximum of the row

minima is equal to the minimum of the column maxima

3.1Solution of Mixed Strategy Games

Games with mixed strategies can be solved by different solution methods such as: analytical method (probability theory technique by rule of dominance) graphical method and linear programming method (simplex method).

3.1.1 Analytical method (probability theory technique by rule of dominance)

for a given payoff matrix without a saddle point, the optimum strategies for a reduced 2×2 payoff matrix can be solved analytically as seen in 3.1.4

3.1.2 A Two-person Sum Game with Pure strategies

In this, the matrix of a two sum game will be adopted and where a saddle point exists. The payoff matrix will be reduced by using the dominance principle and the minimax principle will be used to get the saddle point**.**

3.1.3 A Two-Person Sum Game with Mixed Strategies

Thestudy adopts a matrix method in a two-zero-sum game. In a situation that game has no saddle point or when the payoff matrix is a profit matrix for player A and a loss matrix for player B; the size of the given payoff matrix will be reduced by using dominance principles.

3.1.4 Analytical method (probability theory technique by rule of dominance)

If the game matrix is in the form of a square matrix, then optimal strategy solution as well as the value of the game may be obtained by the matrix method follows:

$$\boldsymbol{A} = \begin{bmatrix} \boldsymbol{a_{11}} \boldsymbol{a_{12}} \\ \boldsymbol{a_{21}}\ \boldsymbol{a_{22}} \end{bmatrix}$$

where A represents a matrix, a_{11} represents row 1 column 1 strategy, a_{12} represents row 1 column 2 strategy, a_{21} represents row 2 column 1 strategy, a_{22} represents row 2 column 2 strategy I

For example, to solve a zero-sum game with mixed strategies if a square payoff matrix is given by

Player B

Player A $\boldsymbol{A} = \begin{bmatrix} \boldsymbol{a_{11}} \boldsymbol{a_{12}} \\ \boldsymbol{a_{21}}\ \boldsymbol{a_{22}} \end{bmatrix}$

This means, for an 8x8 matrix, we have a matrix illustrated as follows:

Player B

Player A

$$\begin{pmatrix} a_{11} & a_{12} & a_{13} & a_{14} & a_{15} & a_{16} & a_{16} & a_{18} \\ a_{21} & a_{22} & a_{23} & a_{24} & a_{25} & a_{26} & a_{27} & a_{28} \\ a_{31} & a_{32} & a_{33} & a_{34} & a_{35} & a_{36} & a_{37} & a_{38} \\ a_{41} & a_{42} & a_{43} & a_{44} & a_{45} & a_{46} & a_{47} & a_{48} \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} & a_{56} & a_{57} & a_{58} \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & a_{66} & a_{67} & a_{68} \\ a_{71} & a_{72} & a_{73} & a_{74} & a_{75} & a_{76} & a_{77} & a_{78} \\ a_{81} & a_{82} & a_{83} & a_{84} & a_{85} & a_{86} & a_{87} & a_{88} \end{pmatrix}$$

The 8x8 matrix above will further be reduced to a 2x2 matrix using thedominance principle. we proceed as follows:

Assume there is no saddle point and the reduced matrix given below

Player B

Player A=$\begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{21} \end{bmatrix}$

Solving for P, we find $\boldsymbol{P} = \frac{\boldsymbol{a_{22} - a_{21}}}{\boldsymbol{a_{11} + a_{22} - (a_{12} + a_{21})}}$

Since there is no saddle point, ($a_{11} - a_{21}$) and ($a_{22} - a_{21}$) are either both positive or either both negative: hence, 0<p<1. Player A's average return using this strategy is

$V=a_{11}\boldsymbol{P} + a_{21}\ (1\text{-}p) = (a_{11}\ a_{22} - a_{12}\ a_{21})\ /(\ a_{11} - a_{12} - a_{21} + a_{22}\ )$

If Player B chooses the first column with probability q, means he uses strategies (q, 1-q), we equate his average losses when Player A uses row 1 and 2

$= a_{11}q + a_{12}\ (1\text{-}q) = a_{21}q + a_{22}\ (1\text{-}q)$

Hence $q = \frac{a22 - a12}{a11 - a12 - a21 + a22}$

Again, since there is no saddle point 0<p<1. Player B's average loss using this strategy is:

$V = a_{11}q + a_{12}(1-q) = \frac{a11a22 - a2\,a21}{a11 - a12 - a21 + a22}$

Thus, the following are used to find the optimal strategies for player A and B and the value of the game.

Player A's optimal strategy

$$.p1 = \frac{a22 - a21}{a11 - a12 - a21 + 22} \quad (1)$$

$$P2 = 1\text{-}p_1 \quad (2)$$

Therefore, P1 + P2 = 1

Player B's optimal strategy

$$q = (a_{22}\text{-}a_{21})/(\, a_{11} - a_{12} - a_{21} + a_{22}\,) \quad (3)$$

$$q_2 = 1 - q_1 \quad (4)$$

So that $q_1 + q_2 = 1$

$$.V = \frac{a11a22 - a21a12}{a11 - a12 + a22} \quad (5)$$

3.2 The Analysis of Data Using Payoff Matrix

The payoff matrix is illustrated below.

		Player B							
		b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8
Player A	a_1	$(a_1\text{-}b_1)$	$(a_1\text{-}b_2)$	$(a_1\text{-}b_3)$	$(a_1\text{-}b_4)$	$(a_1\text{-}b_5)$	$(a_1\text{-}b_6)$	$(a_1\text{-}b_7)$	$(a_1\text{-}b_8)$
	a_2	$(a_2\text{-}b_1)$	$(a_2\text{-}b_2)$	$(a_2\text{-}b_3)$	$(a_2\text{-}b_4)$	$(a_2\text{-}b_5)$	$(a_2\text{-}b_6)$	$(a_2\text{-}b_7)$	$(a_2\text{-}b_8)$
	a_3	$(a_3\text{-}b_1)$	$(a_3\text{-}b_2)$	$(a_3\text{-}b_3)$	$(a_3\text{-}b_4)$	$(a_3\text{-}b_5)$	$(a_3\text{-}b_6)$	$(a_3\text{-}b_7)$	$(a_3\text{-}b_8)$
	a_4	$(a_4\text{-}b_1)$	$(a_4\text{-}b_2)$	$(a_4\text{-}b_3)$	$(a_4\text{-}b_4)$	$(a_4\text{-}b_5)$	$(a_4\text{-}b_6)$	$(a_4\text{-}b_7)$	$(a_4\text{-}b_8)$
	a_5	$(a_5\text{-}b_1)$	$(a_5\text{-}b_2)$	$(a_5\text{-}b_3)$	$(a_5\text{-}b_4)$	$(a_5\text{-}b_5)$	$(a_5\text{-}b_6)$	$(a_5\text{-}b_7)$	$(a_5\text{-}b_8)$
	a_6	$(a_6\text{-}b_1)$	$(a_6\text{-}b_2)$	$(a_6\text{-}b_3)$	$(a_6\text{-}b_4)$	$(a_6\text{-}b_5)$	$(a_6\text{-}b_6)$	$(a_6\text{-}b_7)$	$(a_6\text{-}b_8)$
	a_7	$(a_7\text{-}b_1)$	$(a_7\text{-}b_2)$	$(a_7\text{-}b_3)$	$(a_7\text{-}b_4)$	$(a_7\text{-}b_5)$	$(a_7\text{-}b_6)$	$(a_7\text{-}b_7)$	$(a_7\text{-}b_8)$
	a_8	$(a_8\text{-}b_1)$	$(a_8\text{-}b_2)$	$(a_8\text{-}b_3)$	$(a_8\text{-}b_4)$	$(a_8\text{-}b_5)$	$(a_8\text{-}b_6)$	$(a_8\text{-}b_7)$	$(a_8\text{-}b_8)$

Below shows the analysis of the Customers preference on PHCN Billing systems (Estimated and prepaid) in Alakahia.

3.2.1 Below shows the analysis of the Customers preference on PHCN Billing systems (Estimated and prepaid) in Alakahia.

S/n	Items	Estimated	Prepaid
1	Less expensive to use	85	58
2	Less stressful in making payment	79	64
3	More reliable in power consumption	22	121
4	Not restricted to limited use of appliances	98	45
5	No over billing	90	53
6	No possible disconnection of wires and embarrassment by uncivil staff	24	119
7	More economical to maintain meter	21	122
8	Best for commercial use	99	44

For the purpose of this study,

Player A represents estimated billing in the row of the payoff matrix.
Player B represent Prepared meter in denoting the column payoff matrix.

The following notations are used for the considered strategies.
a_1- Less expensive to use for row 1 of player A
a_2- Less stressful in making payment for row 2 of player A
a_3-More reliable power consumption for row 3 of player A
a_4- Not restricted to limited use of appliances for row 4 of player A
a_5-No over billing for row 5 of player A
a_6-No possible disconnection of wires and embarrassment by uncivil staff for row 6 of player A
a_7- More economical to maintain meter for row 7 of player A
a_8- Best for commercial use for row 8 of player A
b_1- Less expensive to use for column 1 of player B
b_2- Less stressful in making payment for column 2 of player B
b_3-More reliable power consumption for column 3 of player B
b_4- Not restricted to limited use of appliances for column 4 of player B
b_5-No over billing for column 5 of player B
b_6-No possible disconnection of wires and embarrassment by uncivil staff for column 6 of

player B
b_7- More economical to maintain meter for column 7 of player B
b_8- Best for commercial use for column 8 of player B

	B1	B2	B3	B4	B5	B6	B7	B8
A1	(85, 58)	(85, 64)	(85,121)	(85, 45)	(85, 53)	(85,119)	(85,122)	(85, 44)
A2	(79, 58)	(79, 64)	(79,121)	(79, 45)	(79, 53)	(79,119)	(79,122)	(79, 44)
A3	(22, 58)	(22, 64)	(22,121)	(22, 45)	(22, 53)	(22,119)	(22,122)	(22, 44)
A4	(98, 58)	(98, 64)	(98,121)	(98, 45)	(98, 53)	(98,119)	(98,122)	(98, 44)
A5	(90, 58)	(90, 64)	(90,121)	(90, 45)	(90, 53)	(90,119)	(90,122)	(90, 44)
A6	(24, 58)	(24, 64)	(24,121)	(24, 45)	(24, 53)	(24,119)	(24,122)	(24, 44)
A7	(21, 58)	(21, 64)	(21,121)	(21, 45)	(21, 53)	(21,119)	(21,122	(21, 44)
A8	(99, 50)	(99, 64)	(99,121)	(99, 45)	(99, 53)	(99,119)	(99,122)	(99, 44)

	B1	B2	B3	B4	B5	B6	B7	B8
A1	27	21	-36	40	32	-34	-37	41
A2	21	15	-42	34	26	-40	-43	35
A3	-38	-42	-99	-23	-31	-97	-100	-22
A4	40	34	-23	53	45	-21	-24	54
A5	32	26	-31	45	37	-29	-32	46
A6	-34	-40	-97	-21	-22	-95	-98	-20
A7	-37	-43	-100	-24	-32	-98	-101	-23
A8	41	35	-22	54	46	-20	-23	55

a_7 is dominated, hence deleted to give

	B1	B2	B3	B4	B5	B6	B7	B8
A1	27	21	-36	40	32	-34	-37	41
A2	21	15	-42	34	26	-40	-43	35
A3	-38	-42	-99	-23	-31	-97	-100	-22
A4	40	34	-23	53	45	-21	-24	54
A5	32	26	-31	45	37	-29	-32	46
A6	-34	-40	-97	-21	-22	-95	-98	-20
A8	41	35	-22	54	46	-20	-23	55

b_8 is dominated hence deleted to give

	B1	B2	B3	B4	B5	B6	B7
A1	27	21	-36	40	32	-34	-37
A2	21	15	-42	34	26	-40	-43
A3	-38	-42	-99	-23	-31	-97	-100
A4	40	34	-23	53	45	-21	-24
A5	32	26	-31	45	37	-29	-32
A6	-34	-40	-97	-21	-22	-95	-98
A8	41	35	-22	54	46	-20	-23

a_3 is dominated thus, deleted to give

	B1	B2	B3	B4	B5	B6	B7
A1	27	21	-36	40	32	-34	-37
A2	21	15	-42	34	26	-40	-43
A4	40	34	-23	53	45	-21	-24
A5	32	26	-31	45	37	-29	-32
A6	-34	-40	-97	-21	-22	-95	-98
A8	41	35	-22	54	46	-20	-23

b_4 is dominated hence, deleted to give

	B1	B2	B3	B5	B6	B7
A1	27	21	-36	32	-34	-37
A2	21	15	-42	26	-40	-43
A4	40	34	-23	45	-21	-24
A5	32	26	-31	37	-29	-32
A6	-34	-40	-97	-22	-95	-98
A8	41	35	-22	46	-20	-23

a_6 is dominated hence, deleted to give

	B1	B2	B3	B5	B6	B7
A1	27	21	-36	32	-34	-37
A2	21	15	-42	26	-40	-43
A4	40	34	-23	45	-21	-24
A5	32	26	-31	37	-29	-32
A8	41	35	-22	46	-20	-23

a_2 is dominated hence, deleted to give

	B1	B2	B3	B5	B6	B7
A1	27	21	-36	32	-34	-37
A4	40	34	-23	45	-21	-24
A5	32	26	-31	37	-29	-32
A8	41	35	-22	46	-20	-23

b_5 is dominated hence, deleted to give

	B1	B2	B3	B6	B7
A1	27	21	-36	-34	-37
A4	40	34	-23	-21	-24
A5	32	26	-31	-29	-32
A8	41	35	-22	-20	-23

a_1 is dominated hence, deleted to give

	B1	B2	B3	B6	B7
A4	40	34	-23	-21	-24
A5	32	26	-31	-29	-32
A8	41	35	-22	-20	-23

b_1 is dominated hence, deleted to give

	B2	B3	B6	B7
A4	34	-23	-21	-24
A5	26	-31	-29	-32
A8	35	-22	-20	-23

a_5 is dominated hence, deleted to give

	B2	B3	B6	B7
A4	34	-23	-21	-24
A8	35	-22	-20	-23

b_2 is dominated hence, deleted to give

	B3	B6	B7
A4	-23	-21	-24
A8	-22	-20	-23

b_6 is dominated hence, deleted to give

	B3	B7	row min
A4	-23	-24	-24
A8	-22	-2	-23 maximin
Col Max.	-22		-23 minimax

A saddle point exists at -23 (maximin value = minimax value).
The value of the game is -23. This implies that player B which denotes Prepaid billing system is favoured since a negative value was got.

4. SUMMARY AND CONCLUSION

4.1 Summary

This is concerned with the use of two-persons zero sume game in the analysis of customers' preference on PHCN billing systems, using respondents from Alakahia, Rivers State.

Game Theory involves the study of strategic decision making in situations of conflict between two or more makers known as players with two or more decisions called strategies, to choose out of. According to Nash Equilibrium, each player chooses its best strategy that gives the highest payoffs.

When the game involves two persons, it is called two persons game and if more than two, n-persons game. Zero sum game is involved when the sum of the payoffs is zero. In two person zero sum game, the gain of player A is the loss of player B and vice versa. Using the minimax-maximin principle, in a pure strategy, the Game would have a saddle point also called equilibrium point, when the maximin of the rows is equal to the minimax of the columns and if otherwise, a mixes strategy is involved, in which the game is called a probabilistic game, where any of analytical method (probability theory technique by rulemof dominance), graphical method, or simplex method can be used.

4.2 Conclusion

From the result, in the analysis of customers' preference on PHCN billing systems, using respondents from Alakahia, Rivers State, using two-persons zero sum game, a saddle point exists at -23 (maximin value = minimax value). This implies that player A being Estimated billing prefers either strategy a4 and a8 representing 'not restricted to limited use of appliances' and 'best for commercial use' While player B being Prepaid meter billing prefers either strategy b3 and b7 representing 'more reliable power consumption' and 'more economical to meter meter'

The value of the game is -23. This implies that in the analysis of customers preference to PHCN billing system, player B which denotes Prepaid billing system is favoured since a negative value was got.

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