

Simulation modeling using Markovian Decision theory in co-managing the competitive Anambra and Imo river basin

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Abstract

This work for purposes of efficiency aims at funding Anambra and Imo River Basin Development Authorities (RBDAS), namely RBDA 1 and RBDA 2, according to their net returns achieved on investment, since they operate within the same region of influence and are managed by a single board of directors. The RBDAS are competitively embarking on irrigated agriculture, water supply, hydroelectric power generation, flood control, drainage, navigation, recreation/tourism and erosion control. There is an expansion fund of ₦ 782.76 billion for full capacity utilization of the basin's assets involving 25 rivers in the South East Geopolitical region. The problem facing each of the RBDA is their strategy or optimal policy to maximize its net return per unit of investment on each of the developmental projects. On the other hand, the problem facing the management board is the ratio in which to share the funds available for expansion as to allow each of the RBDA to perform at an optimum level. Methodology involves methods and experiments. Data were collected from ABDAS, Ministries and Parastatal. When RBDA1 and RBDA 2 invest under the most unfavorable competition, it can assure itself of a net return ratio of 460/1000 respectively. Consequently, the management board will share the new fund (₦ 782.76 billion) available for expansion so as to allow each RBDA to perform at an optimum level according to the said ratio, which is the value of the Markovian Decision rule to ensure optimum efficiency. That is RBDA 1 gets ₦ 246.62 billion and RBDA 2 gets ₦ 536.14 billion.

Key words: expansion fund, Markov Decision, performance modeling

INTRODUCTION

A nation with the economic and great water resources potential of Nigeria cannot prosper without the benefits of resource development and utilization. The problems that beset the experimental phase must be fully assessed and remedial steps taken now to prevent a repeat in the next phase. In the definition of problem, most of the issues are decision problems for the decision maker regarding:

- (i) Several financial constraints were perhaps the main factor that prevented the take-off of some audacious projects planned by the RBDAS. At Anambra/Imo River Basin Development Authority Owerri, from 2007 to 2011, out of a total capital approval/allocation of ₦ 19.1 billion for capital projects, only ₦ 12.3 billion representing 64% was released by Government. This release of 64% occurred after the Authority had awarded contracts based on 100% of the expected capital fund. Consequently, the result of the above situation was the incompleteness of most projects and heavy debt incurred by the Authority (Eme 2012).

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- (ii) Continuous breakdown of machines, vehicle and plants and equipment as a result of age and inadequate funds hinders operation of the RBDAS. High outstanding liability profile includes: indebtedness to contractors, non-payment of first 28 days' wages to new employees and other staff claims (Federal Ministry of Water Resources 2010).
- (iii) Most personnel appointed to key positions at the creation of the basin authorities had no previous formal training or practical experience in watershed management (Ojiako 1989). Throughout the experimental period, planning and execution of developmental projects was based on inadequate data. Under these conditions, accurate appraisal of the project was bound to be hampered, an economic design of the facilities difficult, and an assessment of the optimal use of resources impaired. There were also disagreements between the planning engineer, other interested parties and the Government authority during project authorization (Devine 1966). This disagreement was around the optimization of one objective (economic efficiency) by the Government, instead of multi-objectivity for multi-purpose river basin projects (US Water Resources Council 1970a, 1970b; Marshal 1973).
- (iv) The two exiting methods in use for cost-sharing in multi-purpose water resources projects are: Remaining Benefit Method and Alternative Justifiable Expenditure Method. These two methods are plausible but do not exhaustively utilize all elements logically that can be considered in cost allocation (Ojiako 2001; Eme 2010a; US Water Resources Council 1977; Marglin 1967; Maass 1966; Marshal 1970).
- (v) The Authority presently covers five states that are within the South East Geopolitical Zone, this situation makes project citing, execution and monitoring very difficult as there is inadequate capital funding to execute projects in each of the states as well as there being an overlap of functions (Federal Military Government 1976).

The objective of this work is to determine the simulation of modeling the Markovian Decision for the new expansion fund to achieve full capacity utilization of the basin's assets. This study is useful because when the fund of ₦ 782.76 billion is released it will raise the staff strength of the Authority from 470 to 29,910 senior and junior staff within the region. The ratio of net returns per unit of investment of RBDA I and RBDA 2 is as given in Tables 1 and 2 below.

METHODS

Methodology involves methods and experiments. Data were collected from ABDA, Ministries and Parastatals. The interpretation and presentation of results were based on simulation of Markov Decision as proposed by Hamdy (2008) and Eme (2010b, 2011, 2012).

The population figure of Anambra and Imo River Basin in 2018 was about 20 million people, based on the 2006 census. According to the Federal Military Government (1976) and Federal Ministry of Water Resources (2010) Anambra/Imo River Basin and Rural Development Authority is one of 12 river basins established in 1976 by Decree No: 25 of the then Military Government of President Olu-segun Obasanjo under the Federal Ministry of Agriculture and Water Resources. The Administrative Headquarter is located at Agbala in the Owerri North Local Government Area of Imo State. With the amended Decree No: 35 of 1987, the functions of the Authority were limited to the development of the water resources potentials of its catchments areas comprising the five states of Abia, Anambra, Ebonyi, Enugu, and Imo. These states involve 25 rivers in the region and fall within the South East Geopolitical Zone of Nigeria. In addition, this includes the development and ongoing maintenance of a comprehensive water resources master plan, which involves identifying all water resources requirements in the Authority's area of operation through adequate collection and collation of water resources, social economic and environmental data. The above functions are presently being reviewed to partly incorporate the agricultural functions which hitherto were excised from its function

Table 1 | The values of V_i^k (ratio of net returns per unit of investment) for RBDA I V_i^k

S	Irrigated Agriculture $i = 1$	Water Supply $i = 2$	Hydro-Electric Power Generation $i = 3$	Flood Control $i = 4$	Drainage $i = 5$	Navigation $i = 6$	Recreation $i = 7$	Erosion Control $i = 8$
1	0.46	0.46	0.47	0.39	0.39	0.53	0.51	0.45
2	0.42	0.43	0.53	0.38	0.44	0.34	0.36	0.42
3	0.42	0.46	0.47	0.39	0.39	0.53	0.51	0.45
4	0.46	0.43	0.47	0.39	0.39	0.53	0.51	0.45
5	0.46	0.46	0.53	0.39	0.39	0.53	0.51	0.45
6	0.46	0.46	0.47	0.38	0.39	0.53	0.51	0.45
7	0.46	0.46	0.47	0.39	0.44	0.53	0.51	0.45
8	0.46	0.46	0.47	0.39	0.39	0.34	0.51	0.45
9	0.46	0.46	0.47	0.39	0.39	0.53	0.36	0.45
10	0.46	0.46	0.47	0.39	0.39	0.53	0.51	0.42
11	0.42	0.43	0.47	0.39	0.39	0.53	0.51	0.45
12	0.42	0.46	0.53	0.39	0.39	0.53	0.51	0.45
13	0.42	0.46	0.47	0.38	0.39	0.53	0.51	0.45
14	0.42	0.46	0.47	0.39	0.44	0.53	0.51	0.45
15	0.42	0.46	0.47	0.39	0.39	0.34	0.51	0.45
16	0.42	0.46	0.47	0.39	0.39	0.53	0.36	0.45
17	0.42	0.46	0.47	0.39	0.39	0.53	0.51	0.42
18	0.46	0.43	0.47	0.39	0.44	0.53	0.51	0.45
19	0.46	0.43	0.47	0.39	0.39	0.34	0.51	0.45
20	0.46	0.43	0.47	0.39	0.39	0.53	0.36	0.45
21	0.46	0.43	0.47	0.39	0.39	0.53	0.51	0.42

in 1987. Most personnel employed in key positions at the creation of the basin authorities had no previous formal training or practical experience in watershed management (Ojiako 1989). In the water supply sector alone for example, the RBDAS needed 4,000 engineers and 20,000 technicians for their programmes within a decade, but only one tenth of these were then available (Okeke 1981).

RESULTS AND CONCLUSION

This study is useful because it will promote economic efficiency, local, state, regional and federal economic redistribution, massive employment of youth, social well-being of people, environmental quality improvement, growth of industrialization and a rise in Nigerian's Gross Domestic Product (GDP). It is important also because it will enable the Federal Government to quickly realize its vision 2020 among 20 world economies. The results of this study are interpreted as follows:

The Anambra River Basin was previously split from Imo River Basin Development Authority, but has now been remerged. It was found that, because of persistent management decision problems of the basin it could not stand alone as an Authority. Thus, it's incorrect decision making is hereby interpreted as that of the maximizer (RBDA 1), while Imo River Basin Development Authority's decision is interpreted as a minimizer (RBDA 2).

1. RBDA I is a maximizer whose pre-occupation is to find the best possible way to invest so as to achieve as high as possible a ratio of net return per unit of investment no matter what the state or condition of the system is.
2. On the other hand RBDA 2 is a minimizer which tries as much as possible to minimize cost per unit of investment so as to enhance its share of the new funding available for expansion.

Table 2 | The values of V_i^k (ratio of net returns per unit of investment) for RBDA 2

S	Irrigated agriculture i = 1	Water supply i = 2	Hydroelectric power generation i = 3	Flood control i = 4	Drainage i = 5	Navigation i = 6	Recreation i = 7	Erosion control i = 8
1	0.47	0.47	0.48	0.40	0.40	0.54	0.52	0.46
2	0.43	0.44	0.53	0.39	0.45	0.35	0.39	0.43
3	0.43	0.47	0.48	0.40	0.40	0.54	0.52	0.46
4	0.47	0.44	0.48	0.40	0.40	0.54	0.52	0.46
5	0.47	0.47	0.53	0.40	0.40	0.54	0.52	0.46
6	0.47	0.47	0.48	0.39	0.40	0.54	0.52	0.46
7	0.47	0.47	0.48	0.40	0.45	0.54	0.52	0.46
8	0.47	0.47	0.48	0.40	0.40	0.35	0.52	0.46
9	0.47	0.47	0.48	0.40	0.40	0.54	0.39	0.46
10	0.47	0.47	0.48	0.40	0.40	0.54	0.52	0.43
11	0.43	0.44	0.48	0.40	0.40	0.54	0.52	0.46
12	0.43	0.47	0.53	0.40	0.40	0.54	0.52	0.46
13	0.43	0.47	0.48	0.39	0.40	0.54	0.52	0.46
14	0.43	0.47	0.48	0.40	0.45	0.54	0.52	0.46
15	0.43	0.47	0.48	0.40	0.40	0.35	0.52	0.46
16	0.43	0.47	0.48	0.40	0.40	0.54	0.39	0.46
17	0.43	0.47	0.48	0.40	0.40	0.54	0.52	0.43
18	0.47	0.44	0.48	0.40	0.45	0.54	0.52	0.46
19	0.47	0.44	0.48	0.40	0.40	0.35	0.52	0.46
20	0.47	0.44	0.48	0.40	0.40	0.54	0.39	0.46
21	0.47	0.44	0.48	0.40	0.40	0.54	0.52	0.43

3. Solving the manager's problem with an infinite stage simulation model using the exhaustive enumeration method of Markovian Decision theory. Table 3 shows a solution of the computation given above for the RBDA I maximum problem as a decision to maintain regardless of the state of the system.

The manager's problem is solved using an infinite stage simulation model with the exhaustive enumeration method of the Markovian Decision theory. We have the following solution for RBDA 2's minimum problem as a decision to minimize whenever the system is in state 8 (very poor, Table 4).

Table 3 | The solution is shown for the RBDA I maximum problem as a decision to maintain regardless of the state of the system

S/N	Developmental projects for investment	Solution for RBDA 1 maximum problem
1	Irrigated agriculture	$(\pi_1^S) = 0.1248$
2	Water supply	$(\pi_2^S) = 0.0948$
3	Hydroelectric power generation	$(\pi_3^S) = 0.1269$
4	Flood control	$(\pi_4^S) = 0.1557$
5	Drainage	$(\pi_5^S) = 0.1689$
6	Navigation	$(\pi_6^S) = 0.1687$
7	Recreation/Tourism	$(\pi_7^S) = 0.0984$
8	Erosion control	$(\pi_8^S) = 0.0617$
	Expected yearly revenue	(E) = 0.41 or 41%

Table 4 | The solution is shown for RBDA 2 minimum problem as a decision to minimize whenever the system is in state 8 (very poor)

S/N	Developmental Projects for Investment	Solution for RBDA 2 minimum problem
1	Irrigated agriculture	$(\pi_1^S) = 0.0193$
2	Water supply	$(\pi_2^S) = 0.0441$
3	Hydroelectric power generation	$(\pi_3^S) = 0.0671$
4	Flood control	$(\pi_4^S) = 0.0876$
5	Drainage	$(\pi_5^S) = 0.1158$
6	Navigation	$(\pi_6^S) = 0.1279$
7	Recreation/Tourism	$(\pi_7^S) = 0.2292$
8	Erosion control	$(\pi_8^S) = 0.3092$
	Expected yearly revenue	(E) = 0.46 or 46%

The interpretation of the above results are as follows: (A) RBDA 1 should in order to maximize its performance with regards to net return per unit of investment, invest as follows in [Table 5](#):

Table 5 | For RBDA 1 to maximize its performance with regards to net return per unit of investment, should invest as shown

S/N	Developmental projects for investment	Maximization of net return per unit of investment for RBDA 1
1	Irrigated agriculture	12.48% of investment
2	Water supply	9.48% of investment
3	Hydroelectric power generation	12.69% of investment
4	Flood control	15.57% of investment
5	Drainage	16.89% of investment
6	Navigation	16.87% of investment
7	Recreation/Tourism	9.84% of investment
8	Erosion control	6.17% of investment

When RBDA 1 invests as above, it can assure itself of net return ratio of 460/1000, even under the most unfavorable competition or condition.

(B) RBDA 2 should, in order to enhance its share of the new fund available for expansion with respect to minimization of cost per unit of investment, invest as shown in [Table 6](#).

When RBDA 2 invests as shown, it can assure itself of a net return ratio of 460/1000, even under the most unfavorable competition or condition.

Table 6 | For RBDA 2 to enhance its share of the new funds available for expansion with respect to minimization of cost per unit of investment, should invest as shown

S/N	Developmental Projects for investment	Minimization of cost per unit of investment for RBDA 2
1	Irrigated agriculture	1.93% of investment
2	Water supply	4.41% of investment
3	Hydroelectric power generation	6.71% of investment
4	Flood control	8.76% of investment
5	Drainage	11.58% of investment
6	Navigation	12.79% of investment
7	Recreation/Tourism	22.92% of investment
8	Erosion control	30.92% of investment

The new expansion fund of ₦ 782.76 billion is to be shared partly to promote the full capacity utilization of the Anambra/Imo's 25 rivers in the basin, and enhance its share of the new fund available for expansion, due to its minimization of cost per unit of investment of each of the purposes (developments) by the RBDA 2.

Consequently, the management board will share the new fund (₦ 782.76 billion) available for expansion so as to allow each RBDA to perform at an optimum level according to the ratio 460/1000 (RBDA 1 to RBDA 2), which is the value of the Markovian Decision, to ensure optimum efficiency. That is RBDA 1 gets ₦ 246.62 billion and RBDA 2 gets ₦ 536.14 billion.

- (i) Presently the Anambra/Imo River Basin Authority has 367 senior staff and 103 junior staff, making a total of 470 employees during the period from 2007 to 2011 with a total fund release of ₦ 12.3 billion (33rd Audited Report).
- (ii) When the new expansion fund of ₦ 782.76 billion is released it will raise the staff strength of the Authority from 470 to 29,910 members of senior and junior staff within the region.

In conclusion, aside from massive increase of employment for engineers, technologists, technicians, artisans, administrative staff, etc. in the local, state and federal Ministries of Water Resources, Ministries of Agriculture, National Electric Power Authorities, Ministries of Transport/Tourism, Ministries of Environment, Mining Companies, Ministries of Works and Housing, etc, the study will also cause growth of industrialization, which will raise Nigeria's GDP and reduce carbon dioxide emissions per unit of GDP by 40 to 50% by the inclusion of hydropower in the development plans.

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