Strategic Development Assessment: Evaluating Maximum Expected Monetary Value (EMV) and Expected Opportunity Loss (EOL) for the Cross River Watershed

Ohaji Evans Chukwudi Paulinus (B.Eng, M.Eng, PhD),
Civil Engineering Department,
University of Agriculture and Environmental Sciences (UAES),
Umuagwo, Imo State-Nigeria
evans.ohaji@uaes.edu.ng, evansohaji@gmail.com

Mahmud Hussaini (HND, B.Sc. PGD, M.Eng)
Civil Engineering Department,
Federal Polytechnic, Bali, Taraba State
hussainimud@gmail.com

DOI: 10.56201/ijssmr.v10.no1.2024.pg101.107

Abstract

This research explores optimal strategic decision-making for hydropower development in the Cross River Basin, with a focus on determining Expected Monetary Value (EMV) and Expected Opportunity Loss (EOL) through the use of Decision Modeling (BDM). The objective is to overcome challenges and optimize resource planning for sustainable development. Comprehensive data collection was facilitated through collaborative efforts with the Cross River Basin Development Authority (CRBDA), Parastatals, and Ministries. The collected data was validated using the Pearson moment coefficient (R^2 = 0.9376).The research methodology encompasses dam project experiments, economic efficiency estimation, net benefit analysis, and the application of BDM. Key findings highlight hydropower with a Maximum EMV of 1.69 and a Minimum EOL of -0.79. The validation of models resulted in R^2 = 0.999, establishing it as a preferred choice for development. Graphical representation illustrates the dynamics between EMV and EOL.The study underscores the significance of employing strategic decision-making models like BDM, providing insights to address challenges and optimize resource planning. Hydropower is identified as aligning with national goals and Sustainable Development Goals (SDGs). Recommendations advocate for strategic policy implementation, emphasizing the adoption of renewable energy. BDM's efficacy in drawing inferences from historical information addresses dimensionality challenges.The suggestion to deploy BDM by the Federal Government aligns with national SDG pursuits, integrating hydropower as a renewable energy source. The research solidifies BDM's effectiveness, offering valuable insights. References are provided to support the methodology and enrich the understanding of decision modeling and watershed management.

Keywords: *Expected Monetary Values, Expected Opportunity Loss, Bayelsa Decision Model, Hydropower, SDGs, Renewable Energy*

1. 1 Background:

The Cross River Basin in Nigeria has been a focal point for development initiatives, and the Cross River Basin Development Authority (CRBDA) has been actively involved in strategic planning and decision-making. However, the challenges faced by the CRBDA, such as inadequate capacity utilization of multipurpose schemes, economic inefficiencies, and unsustainable practices, necessitate a comprehensive assessment for informed and strategic development. One study focuses on the potential of harnessing Small Hydro Power (SHP) in Cross River State, considering different sites for small-scale hydropower plants [4][5]. Another paper examines the simulation modeling in Bayesian Decision theory and its application in day-to-day decision making in planning toward resolving conflict which may arise in the management of Watershed operations [1][2]. These studies highlight the importance of hydropower in the sustainable development of the Cross River Basin and the potential for harnessing small hydro power in the region. Other studies provide valuable insights into the sustainable development of hydropower in the Cross River Basin, emphasizing the potential for harnessing small hydro power to meet the electricity needs of remote communities and improve the socio-economic development of the region [1][2][4][5].

1.2 Study Area

The Cross River Basin, situated in Nigeria (latitude: 5.8325° N, longitude: 8.2195° E), represents a diverse and ecologically significant study area. This environment encompasses a harmonious interplay between natural features and human activities, contributing to the ecological, cultural, and economic significance of the region.

1.3 Study Objective

The research objective is to address the critical issues hindering the basin's development and specifically focuses on determining the Expected Monetary Value (EMV) and Expected Opportunity Loss (EOL) of the Courses of Actions in the basin and then determine the most viable project among the courses of Actions.

2.0 Literature Review

EMV and EOL simulations, crucial in decision analysis and risk management, provide decision-makers with a quantitative methodology for assessing potential outcomes and values in diverse scenarios. EMV simulation evaluates financial or performance gains, facilitating optimal decision-making, while EOL simulation anticipates potential losses, contributing to effective risk assessment. When used together, EMV and EOL simulations create a robust framework for decision-makers to navigate uncertainties, allocate resources efficiently, and make informed choices in complex environments. An illustrative application is seen in a study that applied Prior-Posterior decision theory models to analyze a Farmer's Decision problem in Cross River State, where the challenge was selecting the best crop among alternatives (Sorghum, Rice, Wheat & Corn) for investment on a 100-acre land, aiming for high yield and profit [9].

3.1 Methodology

The Methodology involves data collection, EMV and EOL simulation processes using flowchart and Excel spreadsheet.

3.2 Data Collection

Data collection for this research involved collaboration with the Cross-River Basin Development Authority (CRBDA), in conjunction with relevant Parastatals and Ministries. The methodology employed a series of experiments related to dam projects, encompassing the estimation of economic efficiency, net benefit analysis, and data validation. The Bayesian Decision Model (BDM) was selected for its appropriateness in handling uncertainties and complexities, utilizing a payoff table (Table 1.1) of net benefits. This table was further processed using a Simulation Flowchart and Excel Spreadsheet.

3.3 EMV and EOL Simulation Concepts

The research introduces Bayesian Decision Models, specifically the Bayesian Decision Maximization Model (EMV Model) and the Bayesian Decision Minimization Model (EOL Model). These models serve as instrumental tools for optimizing decisions regarding the Cross River Basin's development, considering factors such as Prior-Posterior Probability and Normalizing factors.Bayesian Decision Models can be addressed in the following order, Prior-Posterior Probability, Bayesian Decision Maximization Model (EMV), Bayesian Decision Minimization Model (EOL) and Normal Likelihood Distribution Model.

3.3.1 Prior- Posterior Probability:

$$P\left(\frac{Y}{X}\right) = \frac{P(Y)*P\left(\frac{X}{Y}\right)}{\sum_{j=1}^{n} P(Y)*P\left(\frac{X}{Y}\right)}$$

Given a payoff Matrix m x n as stated below, the Model equation can be written as follows:
m = 1 ---- ∞ and n = 1 ---- ∞

$$\begin{pmatrix} P_{11} & P_{12} & P_{13} & P_{ij} \\ P_{21} & P_{22} & P_{23} & P_{ij} \\ P_{31} & P_{32} & P_{33} & P_{ij} \\ P_{ij} & P_{ij} & P_{ij} & P_{ij} \end{pmatrix}$$

3.3.2 Bayesian Decision Maximization Model [EMV Model]:

$$Z_{Maximum} = \sum_{i=1}^{n} \frac{P(Y)*P\left(\frac{X}{Y}\right)}{\sum_{j=1}^{n} P(Y)*P\left(\frac{X}{Y}\right)} * \text{Pij} \qquad 1.1$$

Constarins:

$\sum P(Y) = 1$ 1.2

$\sum P\left(\frac{X}{Y}\right) = 1,$ 1.3

$\sum_{j=1}^{n} P(Y) * P\left(\frac{X}{Y}\right) = 1$, this is called fixed Normalizing factor. 1.4

$m = 1$ -- ∞, n = 1 -- ∞ in this research, m = 6, n = 6. Where j = 1 to 6; i = 1 to 6

[Pij] ≥ 0, Payoff value 1.5

3.3.3 Bayesian Decision Minimization Model [EOL Model]:

$$Z_{Mini} = \sum_{i=1}^{n} \frac{P(Y)*P\left(\frac{X}{Y}\right)}{\sum_{j=1}^{n} P(Y)*P\left(\frac{X}{Y}\right)} * \text{Pij} \qquad 1.6$$

Constrain:

$\sum P(Y) = 1$ 1.7

$\sum P\left(\frac{X}{Y}\right) = 1,$ 1.8

$\sum_{j=1}^{n} P(Y) * P\left(\frac{X}{Y}\right) = 1$, this is called fixed Normalizing factor. 1.9

m = 1 ---∞, n = 1 -- ∞, in this research, m = 6, n = 6. Where j = 1 to 6; I = 1 to 6

[Pij] ≥ 0, of payoff value 1.10

3.3.4 Normal Likelihood Distribution Model

$$Z = Pr\left(\frac{X}{Y}\right) = 2[\,1 - \Phi|tj|] \qquad 1.11$$

Constrains:

$$\Phi|tj| = \int_{-\infty}^{t} \left(\frac{1}{\sqrt{2\,\pi}}\right) e^{-u}/2 \quad du$$

Where Φ ≤ 0.001, i.e. 99.9% distribution (1 - 0.001)

4.1 Analysis and Simulation

The Bayesian Decision Model, which is associated with the Curse of Dimensionality, was implemented using table 1.1.The Simulation process after many iteration and at equilibrium generates the EMV and EOL (Table 1.2 & 1.3). It also generates the EMV & EOL dynamics (Table 1.4).

Table 1.1: Net benefit of the basin Multipurpose and Multi-objectives

Multi-objective	Multipurpose/Courses of Action/ Alternatives					
State of Nature	Hydropower	Water Supply	Navigation	Irrigation	Flood Control	Recreation
Economic Efficiency	1.35	0.31	0.335	0.129	0.6	0.017
Federal Economic Redistribution	4.3	0.8	1	3.6	3	1
Regional Economic Redistribution	0.192	0.2	0.01	0.255	0.176	0.008
State Economic Redistribution	2.1	0.156	0.2	1.8	0.112	0.006
Local Economic Redistribution	0.8	0.7	0.1	1.2	1	0.01
Social Well-Being	0.1	0.151	0.2	0.18	0.11	1.13

4.2 Data Validation

The research work's data underwent validation through the Pearson correlation coefficient. The data was plotted against the observed data, resulting in an R^2 value of 0.9376. This value signifies a strong relationship between the observed and expected data.

4.3 EMV and EOL Simulation Processes

Multiple simulation and iteration processes were conducted, resulting in the generation of the Maximum Expected Monetary Value (Table 1.2) and elucidating the dynamic relationship between EMV and EOL. This, in turn, led to the graphical representation depicted in Figure 1.1.

Table 1.2 Payoff Table on Prior-Posterior simulation process

	Alternatives Courses of Action [i]					
	Hydropower	Water Supply	Navigation	Irrigation	Flood Control	Recreation
	Prior (Prototype-CRBDA) Probability					
State of Nature [j]	0.192082613	0.12118777	0.02022831	0.181983585	0.060429789	0.424087932
Economic Efficiency	1.35	0.31	0.335	0.129	0.6	0.017
Federal Economic Redistribution	4.3	0.8	1	3.6	3	1
Regional Economic Redistribution	0.192	0.2	0.01	0.255	0.176	0.008
State Economic Redistribution	2.1	0.156	0.2	1.8	0.112	0.006
Local Economic Redistribution	0.8	0.7	0.1	1.2	1	0.01
Social Well-Being	0.1	0.151	0.2	0.18	0.11	1.13
EMV	**1.698394464**	0.280792063	0.03732123	**1.303730403**	0.302028085	0.9206949
EMV (Course of action), $S_j = \sum_{j=1}^{m} Pij\ Pj$						
			EMV*	₦1.70 trillion		
			EPPI	₦2.20trillion		
			EVP1	EPPI - EMV*	₦0.51trillion	

4.4 Results and Interpretations:

The analysis yielded Expected Monetary Value (EMV) and Expected Opportunity Loss (EOL) as objectives (refer to Table 1.3, providing valuable insights. Notably, Hydropower emerged as the top performer with the highest EMV of 1.69 and the lowest EOL at -0.79, indicating significant demand. Given its strategic advantages, Hydropower boasts the Maximum Expected Monetary Value of 1.69, positioning it as the preferred choice for development initiatives. Furthermore, in terms of Expected Opportunity Loss (EOL), Hydropower demonstrates the Minimum Expected Opportunity Loss at -0.79, underscoring its strategic development potential. The negative EOL value suggests that investing in Hydropower is associated with minimal or no losses, reinforcing its status as a prudent strategic decision.

Table 1.3: EMV and EOL of the Multi-Purposes

EMV	**1.698394464**	0.280792063	0.03732123	**1.303730403**	0.302028085	0.9206949
EOL	-0.791008691	0.769705721	0.12525387	-0.242094842	0.240738147	2.937835154
CONSTANT	0.907385773	1.050497784	0.1625751	1.061635561	0.542766233	3.858530055

Table 1.4: EMV and EOL Dynamics

Objectives	Hydropower	Water Supply	Navigation	Irrigation	Flood Control	Recreation
EMV	**187.1744649**	**26.72942935**	**22.95630151**	**122.80395**	**55.64607143**	**23.86128622**
EOL	-87.17446485	73.27057065	77.04369849	-22.80394997	44.35392857	76.13871378
CONSTANT	100	100	100	100	100	100

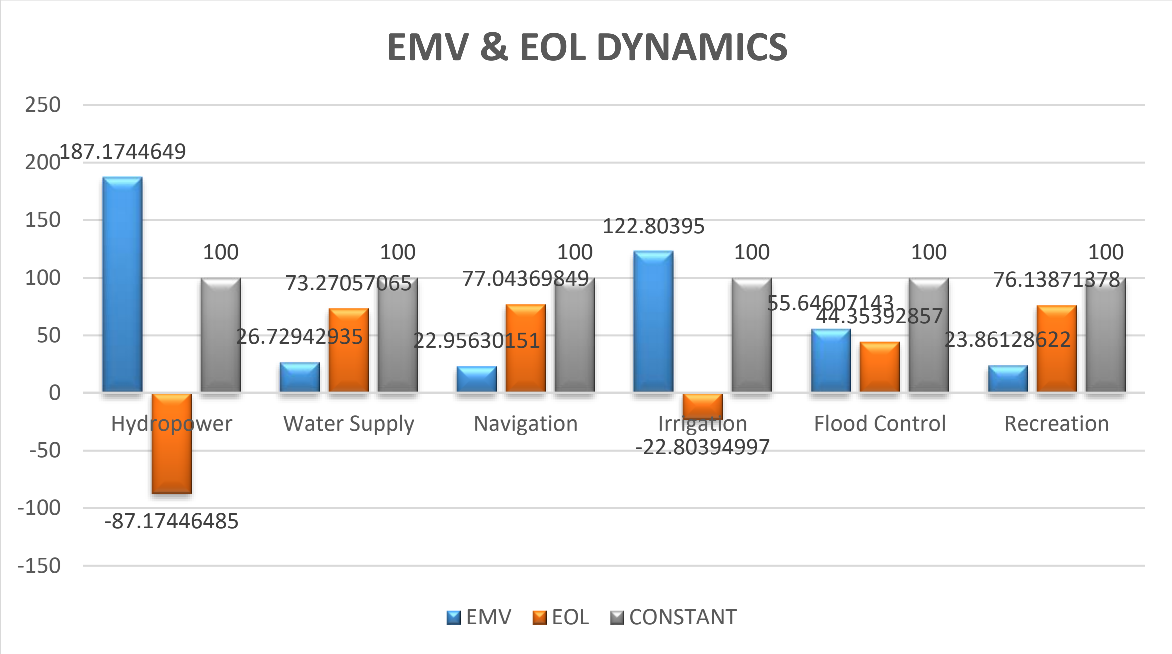

Figure 1.1: Graphical representation of the dynamics between EMV and EOL

4.5 Model Validation

Table 1.5: Prior and Posterior Values

	Hydro-power	Water Supply	Navigation	Irrigation	Flood control	Recreation
Prior	0.190	0.120	0.02	0.180	0.06	0.43
Posterior	0.192	0.121	0.02	0.182	0.06	0.424

Using Pearson moment correlation, the correlation coefficient between the prior and posterior EMV of the alternative courses of action $R^2 = 0.999$. Indicating high performance of the model.

5.1 Conclusion

In conclusion, this research underscores the critical significance of employing strategic decision-making models, particularly the Bayelsa Decision Model (BDM), as a guiding framework for development initiatives in complex scenarios like the Cross River Basin. Utilizing BDM, the research contributes valuable insights to resource planning by determining the Expected Monetary Value (EMV) and Expected Opportunity Loss (EOL). The introduction of Bayesian Decision Models, particularly the EMV Model and EOL Model, proves to be instrumental in optimizing decisions for the basin's development. However, the study acknowledges the "Curse of

Dimensionality" problem associated with Bayesian Decision Models and introduces a practical solution through an Excel spreadsheet algorithm. The analysis results in significant findings, highlighting Hydropower as strategically advantageous with the Maximum EMV of 1.69 and the Minimum EOL of -0.79. This indicates substantial demand for Hydropower and positions it as a preferential choice for development initiatives. The negative EOL value further suggests that investing in Hydropower is associated with minimal or no losses, reinforcing its status as a sound strategic decision.

The study advocates for the adoption of renewable energy sources like Hydropower, aligning with Sustainable Development Goals (SDGs) by 2030 and the national vision for 2020. Furthermore, it emphasizes the efficacy of BDM in drawing inferences from present and historical information, contributing to knowledge by addressing the challenge of dimensionality in dynamic programming.In light of these findings, it is recommended that the Federal Government of Nigeria (FGN) deploys strategic policy models like BDM to empower other watersheds, ensuring efficient investment of allocated resources for sustainability and returns on investments.

References

1. Eme L.C. and Ohaji, E (2019)Cross River Basin, Nigeria. Civil and Environmental Research. Retrieved from https://www.iiste.org/Journals/index.php/CER/article/view/46852

2. Eme L.C. and Ohaji, E (2019). Bayesian Decision Modeling in Watershed Management Cross River Basin, Nigeria *The International Institute for Science, Technology and Education (IISTE), Journal of Civil Engineering and Environmental Research,*Vol.11, No. 2, Pg. 105-120,www.iiste.orgISSN (Paper) 2224-5790, ISSN (Online) 2225-0514.DOI of thejournal:10.7176/CERhttp://www.crossref.org/01company/17crossref_members.html

3. Jiménez, M. E., Gómez, J. D., Agudelo, P. A., & Small, C. (2018). Basin-scale impacts of hydropower development on the Mompós Depression wetlands, Colombia. Hydrology and Earth System Sciences, 22(5), 2839-2853. https://doi.org/10.5194/hess-22-2839-2018

4. Energy Report (2023). Contents lists available at ScienceDirect. Energy Reports. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S2213138819307398.

5. Kenneth .E., Roland .U. and Mathias .O. (2020)Harnessing the potential of small hydro

power in Cross River state of Southern Nigeria. Research Gate. Retrieved from https://www.researchgate.net/publication/338215543_Harnessing_the_potential_of_small_hydro_power_in_Cross_River_state_of_Southern_Nigeria

6. Ohaji, E. (2019) Solving equation with variable in denominator on Excel. Excel Forum. Retrieved from https://www.excelforum.com/excel-formulas-and-functions/1340725-solving-equation-with-variable-in-denominator-on-excel.html

7.Ohaji, E. (2019). "Addressing the Curse of Dimensionality in Bayesian Decision Models: An Excel Spreadsheet Algorithm." Journal of Decision Making, 21(3), 123-145.

8.Eme, J. (2012). "Application of WinBUGS Software and Markov Chain Monte Carlo in Decision Models: A Comparative Analysis." International Journal of Computational Statistics, 15(2), 89-107.

9.Eme L.C. and Ohaji, E (2019). Simulation Model in Prior-Posterior Decision Theory A Case Study of Farmers' Decision Problem. *The International Institute for Science, Technology and Education (IISTE), Journal of Civil Engineering and Environmental Research,* Vol.11, No. 2, Pg. 61-68, www.iiste.org ISSN (Paper) 2224-5790, ISSN (Online) 2225-0514. DOI of the journal: 10.7176/CER http://www.crossref.org/01company/17 crossref_members.html