

Investment Decision Modeling for Transboundary Project Portfolio Selection

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Abstract

Joint activities for global water partnerships in regional development programs are usually facilitated by implementing transboundary water projects. Most projects are however hampered by the absence of a clear economic base for making investment decisions. In this paper, we propose a zero-one integer programming model to determine the optimal decisions for selection of project portfolios on transboundary waters; where project selection is based on several time periods in the future. The objective is to determine whether to undertake a project or not; so that the net present value of investment returns is maximized to support needy communities. A numerical example is presented for illustration; demonstrating the optimal choice of investment projects under budget constraints. The zero-one integer programming model provides a feasible solution for choice of transboundary project investment decisions; given the competing nature of capital budgets prior project implementation. The proposed model can be efficient; where limited funds among competing projects serve as a basis for project selection criteria; a decision for facilitation enhancement towards water partnership for regional development.

Keywords: Investment; modeling; project; portfolio; transboundary.

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1. INTRODUCTION

Transboundary water projects are vital for cities and the towns around the world; supporting the livelihood of vast numbers of people. The scientific base of such projects supports its rapidly increasing use as a vital management tool in the sustainable use of the world's water resources. The financial gap between cost of providing good water and sources of funding has raised greater public concern among policy makers worldwide; having long term budgetary implications. In evaluating and selecting project investment governing transboundary waters, a subset of a larger set of possible alternatives may be chosen subject to an overall limited budget. Therefore; innovative financing options appropriate to particular projects are deemed vital as well as the analysis of appropriate roles of donors and national awareness as stakeholders. The cooperation along transboundary waters often bring more benefits than expected; although frequently not fully perceived; considering the integrated water resource management projects along the trans boundaries worldwide. It is therefore necessary to understand the challenges and opportunities countries face in assessing financial resources necessary to ensure long term ability of sustaining water resources at sufficient levels of quantity and quality overtime. In practical terms, water management faces tremendous investment needs worldwide. This is crucial in order to meet a number of international development and natural resources management commitments. However, financial shortcomings are usually common in managing transboundary water

projects. This may be due to lack of financial capacity in some countries and regions of the world. This anomaly has led to situations in which challenges relating to the transboundary water resources are not sufficiently being addressed; leading to missed opportunities for cooperation. It is therefore critical to identify when financial resources are required in order to sustain transboundary water management be well captured as well as the potential resources to meet these financial needs. Therefore, sustainable funding models for development programs in transboundary water management are needed in order to foster a conducive environment for investment in sustainable water related infrastructure and services in order to boost current investment levels.

The paper is organized as follows: After reviewing the related literature in §2, the problem is described in §3. The model is thereafter formulated in §4; indicating the key notation and major assumptions taken. In §5, a numerical example is presented and solved using the zero-one integer programming model. The results obtained are discussed and interpreted; indicating the optimal decisions for selection of transboundary water projects in different regions. Lastly, conclusions and future research follow in §6.

2. Literature Review

The Transboundary water management has been attracted views from various scholars. Svensson, Prins et al ^[1] provided an analysis and diagnosis of water

governance at country level and a detailed action plan to address water governance gaps to attract funds. Cases of project funding and administrative decisions for reforming the water sector are thoroughly examined. A report compiled by UNECE [2] indicates how transboundary basins provide domestic water to sustain irrigation for agriculture, enable industries to function, generate electricity and support ecosystems. However, benefit assessments should be linked to basin investment planning efforts of such projects. In order to survive, transboundary water projects need to strengthen information exchange and management as Scheumann and Susanne [3] suggests. The project must in addition support the establishment of coordination and cooperation forums in order to promote the sustainable funding of river and lake basin organizations. A related report by UNECE [4] indicates how lack of sustainable funding models often prevents countries from deepening their cooperation. Many countries also face difficulties in financing transboundary water cooperation from national resources since often the benefits of transboundary cooperation are not explicitly known always and funding is often targeted to national and local water projects. Koeppele [5] points out the important challenges regarding financing of transboundary water cooperation. Lack of financial capacity, difficulty to invest in transboundary basins and lack of commitment of states to allocate financial resources to transboundary water cooperation and management.

Therefore; financing of the projects needs to be more sustainable. In UNECE [6], the report indicates lack of financial resources, inadequate funding and financial mechanisms can impede transboundary water cooperation and basin development even if all states are committed to it. In order to strengthen the capacity of transboundary water management, a project was undertaken to create a framework for cross fertilization and exchange of experience between river basins and countries on regulatory, institutional, methodological and other aspects of integrated transboundary waters. This was proposed in the subsequent report UNECE. [7] In related literature, Lan [8] evaluated transboundary water development of lower Mekong river basin using a risk-based multi-criteria decision analysis approach. By implementing a risk-based assessment of the transboundary water, the study provides insights into the impacts of increasing risks to the ecosystem and human beings on the water development of the basin over time. The importance of promotion and guidance in transboundary ventures is explained by UNECE [9] report. The report provides a framework for guiding and promoting investments of transboundary significance in the Sio-Malaba-Malakasi (SMM) basin that is shared by Kenya and Uganda, Prioritization of projects take place through a bottom-up approach; first at district level and then at national level. Transboundary risks related to different criteria and objectives set by different countries are usually common. In a related article by Ganoulis, Kiolokytha et al [10], the authors provide multicriteria decision analysis (MCDA) as a decision support methodology for managing such risks. Three alternative methods are proposed in order to facilitate negotiations and the final decisions using modeling and composite programming. Considering the world bank report [11], the challenges and opportunities countries face in assessing financial resources for climate adaptation in transboundary river basins are explored. Understanding the special risks and complexities of transboundary river basin projects is critical to preparing bankable project proposals that can attract public and private financing partners. Onestini [12]

proposed measures to strengthen sustainable development through the update of the transboundary diagnostic analysis (TDA) development. The author undertakes a detailed situation analysis; addressing the issue of water quality and implementing projects on some of the most crucial issues of the basin. The agro-ecosystem management is equally vital in river basins. In a related report compiled by FAO [13], a project was done to adopt an integrated ecosystem approach for the management of land resources in the Kagera basin. The purpose of the project was to generate local, national and global benefits including restoration of degraded land, carbon sequestration and climate change adaptation and mitigation, protection of international water and other related goals. In Africa, the challenges and opportunities for financing transboundary water resources management and development are eminent according to the report SIWI-EUWI. [14] In this report, financing for water resources development and management is examined with special reference to transboundary water activities in Africa. Development outcomes, financing opportunities and a proposal for further study are presented. Stakeholder participation in transboundary water management is so crucial in the African context. In a related development, Eale and Malzbender [15] illustrated how governments have recognized the importance of managing and developing water resources in a sustainable way. This is done to ensure the long-term ability of water resources to be maintained at sufficient levels of quality and quantity. The world bank's technical report [16] for Nile basin initiative considers regional investment projects for the economic and social development of water resources, as well as for the improved management of water resource projects re selected, screened and national level project prioritization is done prior receiving funding approval. It requires making optimal use of the capacity that is available; as well as necessary structure and mechanisms in place for accelerated and smoother implementation of projects. In order to enhance conjunctive management of resources in transboundary waters, a project [17] was done to overcome the different barriers limiting effective utilization and production of shared aquifers in the upper riparian countries of the Nile development challenges and implementation approaches were identified in order to increase capacity for sustainable ground water management. In relation to project portfolio selection, Li, Qiu et al [18] studied the project portfolio selection problem for water security. In this article, a combined method is proposed with one-vote veto analytic hierarchy process to evaluate every project portfolio from various perspectives in order to address future increasing water demand and salinity intrusion.

Water supply-demand portfolio is further studied by Shabani, Gharneh and Niaki. [19] The authors use two objective functions; namely cost minimization and per capita water consumption where a portfolio approach based on the balance of water supply and demand is considered taking uncertainty into account. Additional literature transboundary water management considers water assessment program [20] where a global assessment of transboundary water bodies through a formalized consortium of partners was taken. The project provided a baseline assessment to identify and evaluate changes

in the water systems caused by human activities and natural processes; and the consequences' such have on development human populations. Transboundary waters under a delphi suggested by Krame, Rutting et al [21] similarly provide an external review as a basis for internal learning and recommendations for improvements with forward linking view to programme implementation. In this study, a qualitative assessment based on primary document analysis and semi-structure d interviews were conducted with relevant stakeholders. Treaty frameworks have also affected management of transboundary waters.

Macatangy and Clarke [22] explained this issue by seeking a method to advance how treaty frameworks might be developed in a way io support a market-based approach to ecosystem services and transboundary waters. In a related project by DELTA America [23], capacity for integrated water resources management was improved particularly in the context of transboundary water basin. The project was implemented to disseminate the lessons learned from various water resources management initiatives. Stakeholder participation is equally vital for sustainable transboundary water management. Earle and Malzbend[24] provided a reference tool which can provide input for the development of stakeholder strategies in transboundary water management. This was done to enhance the capacity of all institutional actors for effective participation in transboundary water cooperation; national and local service providers, private sector and the civil society. In a world water week report compiled by UNECE [25], a considerable financing gap for water related investments globally and securing funding for transboundary basins exists. Related challenges including increased real and perceived risks are also quite common. Although previous studies providerixh literature by scholars in §2, project portfolio selection of transboundary water investments that compete for limited budgetary funds leaves a gap for investigation. The zero-one integer programming model is therefore proposed to handle this problem.

3. Problem Description

The decision problem involves selection of the potential project investments on transboundary waters in regional areas; and a decision is sought whether or not to invest in a particular project. Since we cannot consider partial investment for transboundary projects, the problem becomes an integer program; where the decision variables are taken to be $X_{jr} = 0$ or 1 ; indicating that the j th project investment project in region r is rejected or accepted. The selected transboundary investment project must be worked on over a specified time horizon; but only limited funds are available to accomplish the possible project investments. The problem then seeks to determine which subset of projects in regional areas that are eligible for funding in order to maximize the Net Present Value (NPV),

4. Model Formulation

4.1 Notation

- n Total number of project investments on transboundary waters
- b_i Total amount of capital investment available in period i ($i = 1, 2, \dots, m$)
- r Region
- C_{jr} Present worth of all future profits

- from project j ($j = 1, 2, \dots, n$)
- d_{jr} Amount of capital required for project j ($j = 1, 2, \dots, n$) in region r
- X_{jr} Zero-one variable having a value one If project j is taken, zero otherwise

4.2 Constraints

The first constraint indicates that the total capital on all transboundary water project investments undertaken is less than or equal to the capital available.

$$\sum_{j=1}^n \sum_{r=1}^R d_{jr} X_{jr} \leq b_{jr}$$

($i=1, 2, \dots, m$ $r=1, 2, \dots, R$) (1)

The coefficient d_{jr} represents the net cashflow from transboundary project j in region r . If the project investment requires additional cash, then $d_{jr} > 0$; while if the project investment generates cash, then $d_{jr} < 0$. The right-hand side coefficient b_{ir} represent the incremental exogeneous cashflows. If additional funds are made available in period i , then $b_{ir} > 0$; while if funds are withdrawn in period i , then $b_{ir} < 0$. Therefore constraint (1) states that the funds for investment must be less than or equal to the funds generated from prior investments plus exogeneous funds made available. The second constraints indicates that the project investment j in region r must be rejected ($X_{jr} = 0$) or accepted ($X_{jr} = 1$)

$$X_{jr} = 0 \text{ or } 1 \quad (j=1, 2, \dots, n ; r=1, 2, \dots, R) \quad (2)$$

4.3 Objective Function

The objective function seeks to the maximize the Net Present Value (NPV) denoted by Z .
Maximize

$$Z = \sum_{j=1}^n \sum_{r=1}^R X_{jr} C_{jr} \quad (3)$$

4.4 Zero-One Integer Programming Model

Considering (1), (2) and (3), the associated zero-one integer programming model becomes:

Maximize

$$Z = \sum_{j=1}^n \sum_{r=1}^R X_{jr} C_{jr}$$

Subject to

$$\sum_{j=1}^n \sum_{r=1}^R d_{jr} X_{jr} \leq b_{jr}$$

$$X_{jr} = 0 \text{ or } 1$$

5. A Numerical Example

The study considers five (5) transboundary water projects in Nile region (region 1) and five projects in Kagera region (region 2) in Uganda. The available capital required and present worth of all future profits are indicated in Tables 1 and 2. The capital investment available (in million USD) = 35 for Nile region and 25 for Kagera region. The problem seeks to determine the transboundary projects that must be selected for funding in order to maximize the Net Present Value (NPV) of projects in Nile region and Kagera region.

5.1 Zero-One Integer programming Model for Nile Region

Maximize

$$Z = 8X_{11} + 8X_{21} + 3X_{31} + 5X_{41} + 5X_{51}$$

subject to:

$$10X_{11} + 15X_{21} + 6X_{31} + 8X_{41} + 7X_{51} \leq 35$$

$$X_{jr} = 0 \text{ or } 1$$

5.2 Zero-One Integer programming Model for Kagera Region

Maximize

$$Z = 10X_{12} + 5X_{22} + 3X_{32} + 2X_{42} + X_{52}$$

subject to:

$$11X_{12} + 5X_{22} + 2X_{32} + 4X_{42} + 3X_{52} \leq 25$$

$$X_{jr} = 0 \text{ or } 1$$

5.3 Results and Discussion

Solving the zero-one integer programming models in §5.1 and §5.2, the following results are obtained for the two regions

Nile Region

$$X_{11} = 1 \quad X_{21} = 1 \quad X_{31} = 0 \quad X_{41} = 1$$

and $X_{51} = 0$ with maximum profits of 33 million dollars (\$)

Note:

$$10X_{11} + 15X_{21} + 6X_{31} + 8X_{41} + 7X_{51}$$

$$= 10(1) + 15(1) + 6(0) + 8(1) + 7(0)$$

$$= 33 \text{ million dollars } (\$)$$

Kagera Region

$$X_{12} = 1 \quad X_{22} = 1 \quad X_{32} = 0 \quad X_{42} = 1$$

and $X_{52} = 1$ with maximum profits of 23 million dollars (\$)

Note:

$$11X_{12} + 5X_{22} + 2X_{32} + 4X_{42} + 3X_{52}$$

$$= 11(1) + 5(1) + 2(0) + 4(1) + 3(1)$$

$$= 23 \text{ million dollars } (\$)$$

Results indicate that the available 35 million dollars (\$) for Nile region can be allocated to river basin development (project investment 1), waterways feasibility (project investment 2) and integrated water supply (project investment 4), Regional water observatory (project investment 3) with flood and drought reduction (project investment 5) are dropped. This decision results in a maximum profit of $(10 + 15 + 8) = 33$ million dollars (\$) for the decisions taken.

Table 1
Capital requirements (in million USD) and present worth (in million USD) of all future profits for transboundary water project investments in Nile region

REGION 1 Nile region(r=1)		
Transboundary water project investment (j)	Amount of capital required (d _{jr})	Present worth pf future profits (C _{jr})
River basin development (1)	10	8
Waterways feasibility (2)	15	8
Regional water observatory (3)	6	3
Integrated water supply (4)	8	5
Flood and drought reduction (5)	7	5
Capital Investment Available (in million USD) = 35		

Table 2

Capital requirements (in million USD) and present worth (in million USD) of all future profits for transboundary water project investments in Kagera region

REGION 2 Kagera region(r=2)		
Transboundary water project investment (j)	Amount of capital required (d_{jr})	Present worth pf future profits (C_{jr})
Transboundary water supply (1)	11	10
Regional water sanitation (2)	5	5
Infrastructure for climate change (3)	4	3
Regional water supply (4)	4	2
Geo-aquifer system (5)	3	1
Capital Investment Available (in million USD) = 25		

Considering Kagera region, results indicate that the available 25 million dollars (\$) can be allocated to transboundary water supply (project investment 1), regional water sanitation (project investment 2), regional water supply (project investment 4) and Geoaquifer system (projects investment 5). Infrastructure for climate change (project investment 3) is dropped. This decision results in a maximum profit of $(11 + 15 + 4 + 3) = 23$ million dollars (\$) for the decisions taken. We note that the capital left over of 2 million dollars (\$) is insufficient to invest in the dropped project investment 3; with higher capital requirements.

6. Conclusion.

As a solution to project portfolio selection, transboundary project investments under constrained capital expenditure, computational efforts of using zero-one integer programming provide promising results. The available capital can be optimally allocated in order to maximize profits; given the competing nature of funding among transboundary water projects.

6.1 Future Work

The proposed model has considered independent projects of transboundary waters as a criterion for project portfolio selection. It would be worthwhile to extend the proposed model in order to handle cases of concurrent projects during execution within the regions considered. Model extensions are also sought in order to handle cases of project dependence as well as mutually exclusive projects for transboundary water management.

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