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Modeling Investment Portfolio Selection for Disaster Risk Reduction Projects

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***Abstract**: Investment projects for disaster risk reduction must ensure protection of lives and livelihoods of communities and individuals in affected areas. Several projects are however hampered by the absence of sound budgetary plans to facilitate activities for emergency response management. In this paper, we propose a zero-one integer programming model to determine the optimal decisions for project portfolio selection towards disaster risk reduction in prone regions; 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 under budget constraints. A numerical example is presented for illustration; demonstrating the optimal choice of projects in disaster prone regions. The zero-one integer programming model provides a feasible solution; 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 towards disaster risk reduction.*

Keywords: *budget; disaster risk; modeling; project; portfolio*

1. Introduction

In many parts of our global world, poorly planned and managed urban development, environmental degradation, poverty and inequality have driven levels of disaster risk to higher heights. This phenomenon poses a critical threat to economic development, social welfare and environmental health. It is always prudent for governments to manage their disaster risks amidst budgetary, political and social contexts in order to set policy indicators for disaster risk management so as to build disaster resilient communities and nations of the future. Priorities must be set whether to ensure that disaster risk reduction is a national and local priority with a strong institutional basis for implementation, identify, assess and monitor disaster risks so enhance early warning, use knowledge, innovation and education to build a culture of safety and resilience at all levels, reducing the underlying risk factors and strengthening disaster preparedness for effective response at all levels. The financial sector especially banks must strengthen resiliency when a disaster occurs. Financing for recovery, rehabilitation and reconstruction is important for many companies; especially small and medium enterprises. Banks are supposed to prioritize what should be financed and take the lead in steering the early recovery of regional economies. Banks can also play an important role in facilitating disaster risk prevention and reduction by providing lower interest loans to promote a resilient built environment.

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 disaster risk reduction projects in prone regions. Lastly, conclusions and future research follow in §6.

2. Literature Review

Marc Gordon [1] examined the funding of recent analysis undertaken by United Nations office for disaster risk reduction by exploring how national governments seek to incorporate disaster risk management considerations into public investment portfolios. This was done to enable formulation of strategies for disaster risk management as an integral part of more comprehensive fiscal risk management policies that must be embrace by ministries in various countries. Guiding notes can also cat tools for mainstreaming disaster risk reduction as Benson and Twigg[2] suggest. In this article, the authors provide guiding notes for use by development organizations in adopting project appraisal and evaluation tools to mainstream disaster risk reduction into their development work in hazard prone countries. This work is also of relevance to stakeholders involved in climate change adaptation. Critical factors contributing to the successful mainstreaming of disaster risk reduction into development policy and practice are analyzed. As a strategy to finance disaster risk reduction, Kellet, Caravani and Pichon[3] illustrate how lack of local level of financing is a weakness shared across countries; including those that have made progress in several areas, including those that have made progress in several areas. In most countries, the engagement of non-government actors and their financing is not clear. Therefore more needs to be done to integrate and leverage different sources of investments in disaster risk reduction. However, from the examination of the available country level literature, it is not possible to establish how each country is reducing its disaster risk; and how financing contributes to that effectiveness. In a related development, Spackova and

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Straub [4] show how overall budget for risk reduction measures is limited where an optimal allocation of resources among different subsystems is necessary. The authors formulate this problem as a hierarchical decision problem; where the general rules and decisions on the available budget are made at a central level. It is shown that the marginal cost criterion provides optimal solutions in such hierarchical optimization. Disaster risk financing is further examined in OECD [5] report. The report provides an overview of the disaster risk assessment and financing practices of a broad range of economies relative to the guidance elaborated in G20/OECD framework for disaster risk assessment and financing. The report provides an overview of the approaches that the economies facing various levels of disaster risk and economic development have taken to manage the financial impact of natural and man-made catastrophes. In a related report assessing financial risk protection by IBRD [6], guidance is given on how to conduct a diagnostic exercise in a systematic and comprehensive manner b analyzing the economic, fiscal and social impact disasters, assessment of the current approach to disaster risk finance, review of domestic insurance and capital markets, funding gap analysis and devising options for improved financial protection. Disaster risk reduction as outlined in ISDR [7] report indicates some of the barriers to integration and makes recommendations on how they can be addressed. The analysis presented includes seven pacific island countries .Criteria were developed to help identify areas that would provide the most useful experience and other information on the policies and institutional arrangements, responsibilities and operational services. A related report by UNDP[8] evaluated relevance of projects and how such project compliments fit into the UNDP;s priorities in Sri Lanka, how consistent they were to project components with the Hyogo framework for action and roadmap documents and how they reflect the national priorities and needs. UNDP has a major role to play and has formulated seven projects with different schemes to achieve these objectives. The office of evaluation and oversight (OVE) in association with International development bank presented a report [9] that evaluates the involvement of Inter-American Development Bank (IDB) in disaster risk management (DRM) as it relates to climate change in Latin America and the Caribbean (LAC).The paper firs describes the state of natural disaster risk in the region including the sources of risk and the most vulnerable areas and people. Next, it looks at LAC’s progress in reducing disaster risk and examines the major challenges that still confront the region. Van der Honert [10] provided a framework for selecting a set of mitigation options within a limited budget. The author indicates how project selection about natural disaster mitigation options needs to trade off benefits offered by the alternative investments; and such costs include capital and on-going operational costs as well as the intangible costs such as impact of the project on visual landscape. Rosalind, Mabey and Levick[11] set out recommendations on how the main sustainable finance initiatives underway can support a major reduction in disaster risk. The authors consider physical climate together with disaster risk caused by natural hazards. The analysis builds on insights from 25 stakeholders from the private. Public and non-profit sectors as well as European Commission. Three major areas are explored; including long term thinking, reorienting capital flows and mainstreaming sustainability into risk management. Disaster risk reduction (DRR) finance and opportunities examined by Watson, Caravani , Mitchell et al [12] provide a clear overview of the needs and trends in DRR finance, the available cjannels and a narrative to capture the attention of decision makers and stakeholders in advance of the Sendai World conference on Disaster Risk Reduction. A toolkit developed by Meenan, Ward and Muir [13] provides practical guidance on how to choose which disaster risk finance instruments for which circumstances; mainly for policymakers in developing countries who are responsible for disaster risk management at national, regional and local levels. Is also intended to assist the development and humanitarian community who support developing country policy makers in disaster risk management. Additional work by the world bank group examine the developmental and financial cost of natural disasters, disaster risk financing and insurance tools for financial protection and looks into the future. In the second part of the report, an operational framework for disaster risk financing and insurance is explored. Gerald and Dorothy [15] contribution examines linkages between disaster risk reduction and livelihoods. In this report, existing literature on disaster risk reduction is explored which though diverse; presently reveals little insight on the potential livelihood estimation of DRR. More gaps in knowledge and programming than prescriptions for protecting livelihoods are shown. Therefore livelihoods and DRR need to be deepened through more comprehensive research, in-depth case studies and innovative evaluations in order to reduce the cost of disasters in lives lost and livelihoods destroyed.

3. Problem Description

The decision problem involves selection of potential project investments for disaster risk reduction in prone areas; and a decision is sought whether or not to invest in a particular project. Since we cannot consider partial investment for projects, the problem becomes an integer program; where the decision variables are taken to be X_{jr}= 0 or 1; indicating that the i^{th}project investment in region r is rejected or accepted. The selected project must be worked on over a specified time horizon; but only limited funds are available to accomplish the possible project investments for disaster risk reduction. 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*

p Total number of project investments for disaster risk reduction

B_i Total amount of capital investment available in period i (i= 1,2,…… m)

r Region

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W_{jr} Present worth of all future profits from project j (j = 1,2,…….,n)
D_{jr} Amount of capital required for project j (j = 1,2,….,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 disaster risk reduction 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,…m r=1,2,……R) (1)

The coefficient D_{jr} represents the net cash flow from disaster risk reduction 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_{jr} represent the incremental exogenous cash flows. If additional funds are made available in period i, then $B_{jr} > 0$; while if funds are withdrawn in period i, then $B_{jr}, < 0$. Therefore constraint (1) states that the funds for investment must be less than or equal to the funds generated from prior investments plus exogenous funds made available. The second constraints indicates that the project investment j in region r must be rejected ($X_{jr} = 0$) or accepted ($X_{jr} = 1$)

$X_{jr} = 0$ or 1
(j=1,2,…n ; r=1,2,…R) (2)

4.3 *Objective Function*
The objective function seeks to maximize the Net Present Value (NPV) denoted by Z.

Maximize

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

4.4 *Zero-One Integer Programming Model*
Considering (1) , (2) and (3), the associated zero-one integer programming model becomes:

Maximize

$Z = \sum_{j=1}^{n}\sum_{r=1}^{R} X_{jr}\,W_{jr}$
Subject to

$$\sum_{j=1}^{n}\sum_{r=1}^{R} D_{jr}\,X_{jr} \leq B_{jr}$$

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

5. A Numerical Example

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

5.1 *Zero-One Integer programming model for western region*
Maximize
$Z = 8\,X_{11} + 8\,X_{21} + 3\,X_{31} + 5\,X_{41} + 5\,X_{51}$ subject to:
$10\,X_{11} + 15\,X_{21} + 6\,X_{31} + 8X_{41} + 7\,X_{51} \leq 35$
$X_{jr} = 0$ or 1

5.2 *Zero-One Integer programming Model for northern region*
Maximize
$Z = 10\,X_{12} + 5X_{22} + 3X_{32} + 2X_{42} + X_{52}$
subject to:
$11X_{12} + 5X_{22} + 2X_{32} + 4X_{42} + 3X_{52} \leq 25$
$X_{jr} = 0$ 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

Western region
$X_{11} = 1$ $X_{21} = 1$ $X_{31} = 0$ $X_{41} = 1$
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 million dollars ($)
Northern region
$X_{12} = 1$ $X_{22} = 1$ $X_{32} = 0$ $X_{42} = 1$
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 million dollars ($)

Results indicate that the available 35 million dollars ($) for western region can be allocated to flood reduction (project investment 1), climate change mitigation (project investment 2) and evacuation centers for hazard prone areas (project investment 4). City disaster resilience (project investment 3) with disaster reduction education (project investment 5) are dropped. This decision results in a maximum profit of (10 + 15 + 8) = 33 million dollars ($) for the decisions taken.

Considering northern region, results indicate that the available 25 million dollars ($) can be allocated to building materials and methods testing (project investment 1), strengthening meteorological operations (project investment 2), safety improvement of facilities (project investment 4) and agricultural sustenance (projects investment 5). Strengthening community resilience (project investment 3) is dropped. This decision results in a maximum profit of (11 + 15+4 + 3) = 23 million dollars ($) 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 for disaster risk reduction in regions 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 projects for disaster risk reduction.

6.1 *Future Work*

The proposed model has considered independent projects of disaster risk reduction 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 disaster risk reduction.

Table 1

Capital requirements (in million USD) and present worth (in million USD) of all future profits for disaster risk reduction projects in regions

Western region (r=1)			Northern region (r=2)		
Disaster risk reduction project investment (j)	Amount of capital required (D_{jr})	Present worth of future profits (W_{jr})	Disaster risk reduction project investment (j)	Amount of capital required (D_{jr})	Present worth of future profits (W_{jr})
Flood reduction (1)	10	8	Building materials and methods testing (1)	11	10
Climate change mitigation (2)	15	8	Strengthening metrological operations (2)	5	5
City disaster resilience (3)	6	3	Strengthening community resilience (3)	4	3
Evacuation centers for hazard prone areas (4)	8	5	Safety improvement of facilities (4)	4	2
Disaster risk reduction education (5)	7	5	Agricultural sustenance (5)	3	1
Capital Investment Available (in million USD) = 35			Capital Investment Available (in million USD) = 25		

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