From Risk to Resilience

Working Paper 7

Evaluating the Costs and Benefits of Disaster Risk Reduction under Changing Climatic Conditions : A Pakistan Case Study

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Cover: Settlement of vulnerable populations adjacent to flood prone Lai River. Rawalpindi, Pakistan.
Photo by Fawad Khan.

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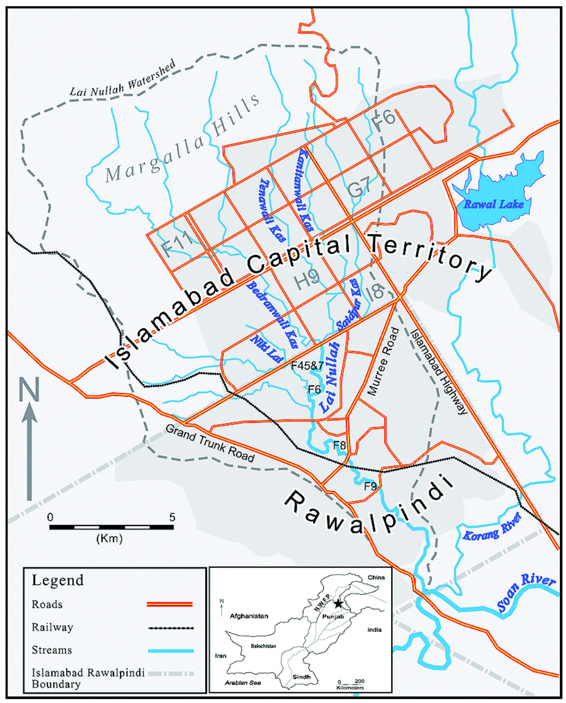
Introduction

Climate change and rising urban population density pose increasing risks in the Lai floodplain in the Rawalpindi/Islamabad conurbation in Pakistan (Figure 1). A recent flood in 2001 took 74 lives and caused damage estimated at PKR 7.73 billion (over USD 1 billion) (Khan and Mustafa 2007). Such events have drawn repeated attention of policy makers and residents along the Lai towards various options for proactive flood risk reduction.

This case study is designed to use both social and natural science tools to answer a set of basic questions on proactive risk reduction. The primary question is to determine whether and/or in what cases is proactive disaster risk reduction cost effective. Second, how can we compare the cost effectiveness of various proposed strategies to assist policy makers in making decisions? Finally, what are the limitations and risks in use of CBA for decision-making? Although political expediency and organizational biases tend to dominate policy level decision-making (Khan and Mustafa 2007), it is essential to see how compelling the economic justifications for the various strategies are. Such an analysis also helps compare competing demands on most appropriate use of the land by various interest groups such as real estate developers, environmentalists and local populations living along the Lai River and allows us to lend a lens of economic scale to such comparisons.

To answer the above questions the case study we have used a methodology that combines social science (cost-benefit analysis) with natural science (hydrological and climate modelling) to evaluate various strategies for risk reduction in the Lai flood basin. The methodology (see Risk to Resilience Working Paper No. 1: Cost-Benefit Analysis Methodology) incorporates

FIGURE 1 | Map of the Lai floodplain in the Rawalpindi/Islamabad conurbation in Pakistan



probabilistic climatic risk in determining benefits of risk reduction. Findings and tools developed in this area are expected to be highly replicable and relevant to developing world urban hazardscapes that have traditionally received lesser attention in the academic world but are omnipresent.

This case study starts with a description of the study area, the current risks faced by the local population, the evolution of various approaches debated for risk reduction, and the likely impacts of climate change in the area. Section three, discusses the parameters, assumptions and approaches in the application of cost-benefit analysis to the strategies selected for economic evaluation. Policy implications and advocacy potential of the analyses are discussed in Section five and, finally, broad conclusions from the case study are summarized in the last section.

Running through Islamabad/Rawalpindi conurbation in Pakistan, the Lai River offers important lessons about the geography of exposure and vulnerability in this flood prone area. The Lai Basin phenomenon is not uncommon in urban areas of the developing world. On its banks lives a growing urban poor population that has been neglected, even mistreated, by the city government. Elitist city planning has resulted in enclaves of unaffordable formal development. The poor are left with no choice but to reside in hazard prone areas. Along the Lai, their social, physical and economic vulnerability is enhanced by high exposure to flood damages. Rapid development of Islamabad in the upper reaches of Lai is constantly reducing the permeability of the catchment area and increased runoff in to the Lai. At the same time, global climatic change predicts more high intensity events, which would translate into higher flooding frequencies and intensities in the future.

Flood hazard in the Lai has attracted the attention of city managers since colonial times, starting in 1944 when British engineers proposed blasting the rock fall at the extreme southern end of the river before its confluence with the Soan River. Ever since technological solutions have dominated the discourse on reducing flood hazard in Lai.

These development plans included the Asian Development Bank (ADB) funded project to undertake channel improvements and removal of some encroachments in the floodplain, and the Japan International Cooperation Agency (JICA) funded installation of a telemetric flood warning system. JICA additionally funded studies on construction of a retention pond in the upper reaches of the Lai, diversion of the two western tributaries of the Lai into the neighboring Korang River, and construction of a flood spillway into the Korang (LEAD, 1999). Most recently, the government of Pakistan has proposed straightening and lining in concrete the Lai channel in its middle reaches and building an expressway along its banks as a flood control measure.

Residents of the floodplain see the a much wider range of hazards in their lives which includes health hazards such as unsafe drinking water and sanitation and consider provision of basic social services as a key proactive intervention to increase their resilience. Consistent with the view of the floodplain residents of the need for a multi-pronged approach to the multiple hazards in the Lai, those options that call for solid and liquid waste management along with prevention of encroachment on the floodplain, restoration of riparian ecology and turning the floodplain into a park after just and fair compensation to the existing residents are most desirable (Mustafam, 2005 and 2004.)

Secondary data availability precluded analysis of health and related services in this study although they were termed high priority risks and among the key targets of risk reduction strategies identified by the community (Khan and Mustafa, 2007). The analysis also does not consider distributional aspects of costs and benefits because of the aggregate treatment of costs and benefits in CBA methodology. Qualitative analysis based on vulnerability indices showed varying level of resilience within communities living along Lai. Therefore, any decision based purely on CBA analysis would be misguided without qualitative assessments of the winners and losers in Lai flood basin, particularly if poverty reduction in the face of climate change and variability is the objective of the risk reduction strategy. However, pinpointing high vulnerability within the area would allow a much more cost effective approach resilience building strategies than those evaluated generically in this study.

Among the proposed interventions in the urban Lai basin in Pakistan, almost all options including relocation of exposed households are cost effective strategies (see Table 1). The various structural measures for river improvement especially those outside the densely populated areas tend to create the best returns in disaster risk reduction even though the investments are very large.

TABLE 1 | Summary results of cost-benefit analysis

Strategy/ Intervention	Net Present Value of Investment (PKR mill.)	Benefit Cost Ratio
Expressway/channel	24,800	1.88
JICA options (both)	3,593	9.25
- Community pond	2,234	8.55
- River improvement	1,359	25.00
Early warning	412	0.96
Relocation/restoration	15,321	1.34

Projects duration = 30 years, Social discount rate = 12%

The likelihood of a strategy being implemented tends to be constrained by the initial cost outlay despite its effectiveness and cost-benefit ratio in disaster risk reduction. The only strategy adopted so far in Lai has been the early warning system, which is partially because of its low cost and the availability of willing donor for the system. The channel improvement and expressway despite political will and backing was not launched due to the large initial investments, technical difficulties and a fluid political scenario where much larger short term interests like retention of political power and government at the federal and provincial levels were at stake.

Restoration of the wetlands by clearing the riverbanks of human encroachment was a theoretical scenario considered to see whether it was economically viable. It was deemed the most ecologically sound option, which could provide social amenity in the shape of recreational space on the banks of Lai. The very high cost of this measure does not mean that restoration is a bad idea but rather indicates high cost of reversibility of urban development strategies that result structural development in hazard prone areas.

Contrary to the general perception of effectiveness of soft measure, the over-designed early warning system in place is the only one with a benefit cost ration of less than one. This indicates that without careful consideration to various aspects (including economic) there is not a foolproof way of devising effective risk reduction strategies. The warning time is not enough to allow removal of household contents and commercial stock and a simpler system based on lesser dedicated infrastructure and more on already operational cell phone/sms could have been just as effective in saving lives at a much lower cost.

Each of the above options would need a different entity for implementation. For example, the community pond falls within Capital Development Authority and downstream river improvement in Chaklala Cantonment. For an optimal solution the analysis needs to be done at the Federal level or a body that is not committed to jurisdictions or line function such as roads, meteorology etc. From this analysis it is clear that CBA for proactive risk reduction would be best used by apex organizations like Planning Commission, National Disaster Management Authority or independent research organizations like Institute for Social and Environmental Transition (ISET).

The Case Location, Issues and Responses

Running through Islamabad/Rawalpindi conurbation, the Lai River offers important lessons about the geography of exposure and vulnerability in this flood prone area. The Lai Basin phenomenon is not uncommon in urban areas of the developing world. On its banks lives a growing urban poor population that has been neglected, even mistreated, by the city government. Elitist city planning has resulted in enclaves of unaffordable formal development. The poor are left with no choice but to reside in hazard prone areas. Along the Lai, their social, physical and economic vulnerability is enhanced by high exposure to flood damage. Findings and tools developed in this area are expected to be highly replicable and relevant to developing world urban hazardscapes that have traditionally received lesser attention in the academic world but are omnipresent.

The Lai[1] Basin drains a total area of 244 km^2 south of the Margalla hills, with 55% of the watershed falling within the Islamabad Capital Territory and the remaining portion within the downstream Rawalpindi Municipal and Cantonment limits (Figure 1). The stream has five major tributaries: Saidpur Kas, Kanitanwali Kas, Tenawali Kas, Bedranwali Kas and Niki Lai, in addition to twenty other minor tributaries. The maximum length of the Lai from its start to its final confluence with the Soan River does not exceed 45 kilometres, thereby allowing very little time for any flood warning in its middle reaches within the Rawalpindi municipal limits. The Rawalpindi/Islamabad conurbation is the fifth most populous urban area in Pakistan, with a combined population of 2.1 million, with 1.5 million residents in Rawalpindi and 0.6 million in Islamabad (GOP, 2000). About 400,000 out of the two million residents of the twin cities live in the 100-year floodplain along the Lai River (JICA, 2004). The conurbation is an important economic and transportation node connecting southern and eastern Pakistan with the northern Areas, Azad Kashmir (Pakistani Administered Kashmir), and the Northwest Frontier Province (NWFP). As the capital of Pakistan, Islamabad has all the administrative presence of the federal government, while Rawalpindi is the headquarters of the Pakistan Army, the most important institution in Pakistan.

[1] This spelling comes closest to the phonetic pronunciation of the name and is most widely used. Other spellings, e.g. Leh and Lei, are also in use.

The most exposed populations to the flood hazard are also the most vulnerable. The poorest residents of the modern, planned capital of Islamabad typically live in shanty towns along the tributaries of the Lai. The residents of these settlements predominantly belong to minority Christian communities, in addition to certain communities of Afghan refugees and other recent migrants from the other parts of Pakistan. In downstream Rawalpindi as well, the people living in the most exposed parts of the floodplain are also the poorest. The relatively better off are engaged in minor retail businesses, lower level government employment, and daily labour, while those who are worse off live closer to the banks of the Lai and are engaged in garbage collection, sanitation and begging.

While flood hazard is a recognized, most high profile risk in the floodplain by the decision makers of the city, the floodplain residents tend to place solid waste pollution in the river as a comparable priority (Mustafa, 2004; LEAD, 1997). In addition, raw sewage and medical and industrial waste dumped in the river is a major cause of olfactory and visual discomfort (Figure 2). Furthermore, water borne diseases are a major concern for women, who are the primary caregivers for the sick within households (Mustafa, 2005).

| FIGURE 2 | Raw sewage and solid waste draining into the Lai

Flood hazard in the Lai has attracted the attention of city managers since colonial times, starting in 1944 when British engineers proposed blasting the rock fall at the extreme southern end of the river before its confluence with the Soan River. The project was shelved because of the potential danger that the blasting posed to the foundations of the nearby railway bridges. Since that time, twenty-one different proposals were launched by various government agencies to address the flooding problem in the Lai Basin. More recently, these development plans included the ADB funded project to undertake channel improvements and removal of some encroachments in the floodplain, and the JICA funded installation of a telemetric flood warning system. JICA additionally funded studies on construction of a retention pond in the upper reaches of the Lai, diversion of the two western tributaries of the Lai into the neighboring Korang River, and construction of a flood spillway into the Korang (LEAD, 1999). Most recently, the government of Pakistan has proposed straightening and lining in concrete the Lai channel in its middle reaches and building an expressway along its banks as a flood control measure. Almost all of the twenty-one proposals, like the more recent ones, were heavily based on engineering solutions, ranging from complete diversion to turning the Lai into a concrete channel. The two exceptions were a proposal by the Rawalpindi Development Authority (RDA) for planting trees along the channel to prevent soil erosion and a proposal by the Rawalpindi Cantonment Board (RCB) in 1998 for solid waste management and encroachment removal. Not a single proposal was ever implemented, either partially or fully, until the two most recent ones.

In addition to the official proposals, a number of other interlinked options are also possible for flood risk reduction in the Lai, including:

- Removal of encroachment in the floodplain, only after equitable compensation.
- Ecological restoration of the watershed and creation of a/several recreation area(s) in the floodplain.
- Safe disposal of solid and liquid waste outside the Lai floodplain.
- Effective flood warning and communication.
- Mapping of the 100-year floodplain and public information.
- Construction of upstream ponds and check dams to slow flood onset.
- Construction of flood spillway towards the Korang River.

The option often mentioned by the floodplain residents was of preventing human encroachment into the floodplain and turning the floodplain into a park for recreation. Consistent with the view of the floodplain residents of the need for a multi-pronged approach to the multiple hazards in the Lai, those options that call for solid and liquid waste management along with prevention of encroachment on the floodplain, restoration of riparian ecology and turning the floodplain into a park after just and fair compensation to the existing residents are most desirable. For environmentally sensitive management of the Lai floodplain, an attractive utilitarian feature could be the provision of a corridor for non-motorized transport, such as bike tracks, and, contingent upon funding availability, even an elevated monorail corridor. The team of researchers working on the Lai has been particularly keen on advocating comprehensive floodplain management directed towards socially and ecologically friendly risk reduction with economic benefits.

The above options for risk reduction in the Lai basin must also be viewed in the context of climate change. We used a simplified downscaling technique and rainfall runoff model to investigate potential climate change impacts on the Lai. The rainfall runoff model incorporated a localized regression model utilizing the LOCFIT scheme (Loader, 1999). The model does not incorporate ponding, infiltration, overland flow or other factors commonly incorporated in traditional hydrologic models. The simplicity of the model is dictated by several factors including:

1) Lack of verified, daily rainfall and runoff data of statistically significant (if one applies traditional engineering metrics) length;
2) Lack of soil type/area data, channel roughness, etc.;
3) Time constraints; and
4) Uncertainty about the appropriate General Circulation Model (GCM) to use.

Given the above data limitations, precipitation results for the general region from the Canadian GCM were used for the period 2010 to 2050. The coefficients of correlation were derived between the historic simulated precipitation from the CGCM and the actual streamflow data since 1987. The modelling effort shows a shift in the timing and magnitude of rainfall (reflected in the streamflow predictions). August appeared to be a little drier, with lower streamflows. On the other hand, May and June had greater precipitation and higher streamflows. Since much of the precipitation that occurs in the basin during May-September is rainfall associated with convective activity, it is probably safe to say that either the number of storms will increase or the amount of rainfall per convective event will be increasing. This means that flooding events are likely to increase in May and June and decrease in August, with an increased possibility of rainfall in September. December also appears to exhibit an increase in precipitation, with possible minor flooding. These climate scenarios, despite the uncertainties associated with them, point to a need for greater attention to the issue of flooding, particularly with ongoing demographic and economic changes in the urbanized basin.

The Cost-Benefit Analysis

This section describes the parameters and relevant data used for risk reduction in all four scenarios, namely, warning system, concrete lining of the channel, construction of a dam in the upper reaches of the stream, and relocation of the most exposed population to higher ground. Along with the general assumptions and limitations, which are a part of the process of conducting a CBA, issues specific to each strategy are described individually under that approach. Following is an overview of the process adopted for conducting the CBA.

Risk

Flooding was the primary risk identified by the communities and in institutional shared learning dialogues (SLDs). The JICA study on comprehensive flood mitigation conducted after the 2001 floods proved to be a wealth of information. However, most of the data going into it was provided neither by JICA nor the local counterpart authorities (i.e. Federal Flood Commission) who remained skeptical of the analysis.

The flood hazard, return periods and depths have been based on JICA's estimation of various return periods (i.e. 5, 25, 50 and 100-year periods). Since JICA consultants had left accessible neither the software nor the data for its analysis, the research team decided to use its own model to fit the results that JICA had estimated based on the actual data from the 2001 flood. The team used a simpler steady state hydraulic model fine-tuned with critical on the ground measurements such as those for bridges, etc. As a result, the estimations came within acceptable range for a cost-benefit analysis based on secondary data. For a more forward looking analysis (for details refer Risk to Resilience Working Paper No. 1), the team tried various commonly used statistical distributions for flood modelling such as Gumbel and Pareto, finding the best fit with Log Pearson 3 and used it to extrapolate flood levels up to the 200-year return period.

Vulnerability

The basic vulnerability analysis was conducted using assets at risk and damage data from the flood of 2001. Since there was a three-fold difference between the official government figures and what JICA had calculated, it was deemed necessary to review the process of estimation. The government had calculated damage using compensation data and hence did not include huge losses that were not compensated. The JICA study did approximate the number of structures and assigned values taking citywide averages rather than look at the specific assets that were affected. It is reasonable to assume that the pattern of settlement and distribution of different types of infrastructure would be different from the city average on the banks of Lai. The area inhabited by lower income groups and the nature of the land is likely to be different because of its exposure to flood risk. Therefore, a triangulation of property values was conducted through interviews with real estate agents along the entire stretch of the floodplain to estimate realistic figures.

According to the real estate agents, around eighty per cent of the properties within 100 meters of the banks of the Lai are illegal and hence it was necessary to reconfirm the number of units along the river's banks. Readily available Google Earth imagery was used to ascertain actual assets at risk rather than estimations or official figures. Contour maps of flood depths for various return periods were superimposed on the Google Earth images to calculate the number of structures likely to be affected at different flood levels.

Procuring reasonably detailed contour maps for this analysis was extremely difficult. Official maps are considered classified because the Lai is close to the General Headquarters of the Pakistan military. The minimum size of maps required for a visual count of assets at risk was 1:50,000. The research team used the surveys done for a detailed design of the Lai expressway to make a raster and vector analysis of flood depth using ArcMap, ArcInfo and Adobe Illustrator software. This data was useful for plotting the damage estimations for floods below 100-year return periods as there is no historical damage data for these scenarios.

Depth-Damage Analysis

As there was no local data on depth-damage ratios, the team used data from various studies in the region and globally and then used what seemed to be reasonable estimates from Rawalpindi and corroborated them with anecdotal evidence found in qualitative surveys on the area. Average depths of the 2001 flood were used as the estimator for median damage figures and applied to other return periods.

Economic Effects

The impact of the 2001 flood is the only event that is well documented for damage caused. These figures were used to interpolate and extrapolate damages for other return periods using flood depths from hydraulic modelling, area of inundation and satellite imagery of the area.

The historical data on flood damage in 2001 had huge variations. The official government estimates were several times lower than those estimated through the JICA survey, which reached a figure of 53 billion rupees as opposed to 10-15 billion by official estimates (2000 PKR). The reason for this may be that the official estimate is based on a flat compensation on the basis of whether the houses damaged or destroyed were of *kuchha* or *pukka* construction only and not by the extent of actual damage. Also, there is a flat compensation for death depending on whether the person was the family breadwinner or not and for heads of cattle lost that can be verified through official documents only. Therefore, the study team used the JICA survey results rather than the official figures.

The surveys in the JICA study measured some indirect damage estimated from random surveys. This analysis tried to measure the damage caused by the disruption of business due to the closing of markets and factories and also that caused by damage to productive assets. The figures for these "flow" damages turned out to be to the tune of 35% of the total damages. Although the survey sample was not well designed and hence the results are not statistically significant, the value derived seems to be an underestimate when compared to the generic flood damage figures in other cases. Therefore, it was decided to use this figure as long as the analysis did not overestimate the benefits of risk reduction. Otherwise, not using indirect costs of floods would have been a gross underestimation of damage caused.

Environmental and ecological effects of floods were not included in the analysis due to lack of data. Nevertheless, the qualitative assessments and Shared Learning Dialogue (SLD) process clearly indicated that diseases and illnesses due to lack of sanitation and clean drinking water was one of the major costs to the local populations. There is also anecdotal evidence that some families had to stop sending their children to school or sent them to less expensive schools as a part of a coping strategy due to long-term losses to family incomes.

The environmental and social benefits of certain risk reduction strategies can be immense and therefore it is imperative to include these for better analysis of the alternatives. These are opportunity costs or benefits that are often overlooked in analysis for project selection. In the new expressway design for channel improvement, the base of the deepened river bed is also to be paved. This will have dire consequences to groundwater recharge in the city. For drinking water alone the lack of recharge will exacerbate the current decline of the average water tables from under 40 feet in 1980 to over 150 feet in 2003 due to groundwater overdraft (ADB 2005). Therefore, important issues that were not quantified are described in the following sub-sections which describe how the analysis for the four given options was structured. Besides the generic approach described above, the following subsections detail particular assumptions and challenges for using CBA in different scenarios.

Sheikh Rashid Expressway

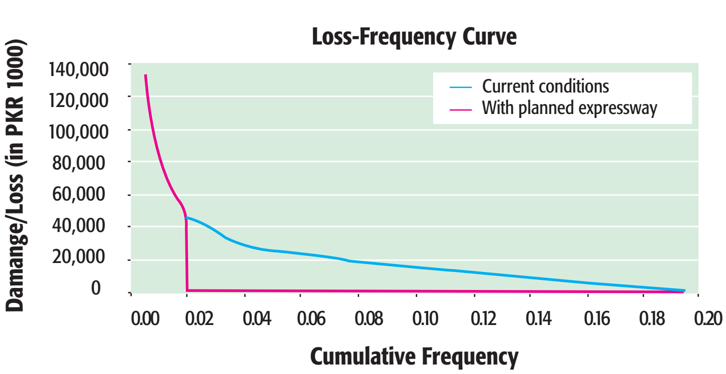
The Sheikh Rashid expressway was the most likely option for implementation until the recent elections after which the political forces behind the project were thrown out of power. This project was a hastily designed dual-purpose project that would provide flood protection through deepening and paving with concrete the section of the Lai that passes through the most densely populated areas of Rawalpindi. The second purpose of this project was to provide an expressway that joined Rawalpindi and Islamabad to ease the traffic burden between the two cities. The highway would also connect the old Army headquarters of the country with the new one being constructed upstream in Islamabad.

There were several issues with this approach. First, there was little experience of maintaining a paved channel in a perennial river prone to flooding without additional measures for water diversion. Second, although the middle section of the river was being designed to carry a 100-year return period flood, there was no modelling done for the effects of the section downstream from the project area, which has a much lower carrying capacity and thus already causes backwater effects in the river. Third, since this was a multi-purpose project, the benefits from transportation and increase in property value would have accrued as additional benefits that were not attributable to just flood prevention.

The issue of limiting channel enhancements to the expressway section in the middle reaches of Lai as opposed to the whole river has three implications for flood hazard:

i. Due to higher carrying capacity in the intervention reach there may be increased flooding downstream;
ii. Due to downstream backwater effects, the enhanced channel will likely not be able to carry the designed flow, thus reducing its flood reduction impacts; and,
iii. Slowing the water flow in the channel due to backwater effects mentioned above could cause heavy deposition in the channel area, reducing its depth and slope and ultimately bringing it back to its current position.

FIGURE 3 | **The loss-frequency curve for the planned expressway**



These effects were reflected in the analysis by reducing the risk reduction capacity of the channel to a 50-year return period from 100 years and incorporating a higher maintenance cost for upkeep of the channel than that suggested in the design documents (Figure 3).

To separate the flood prevention from transportation and other benefits, we incorporated the costs for the flood protection portion only and treated the road as a separate, stand alone project, although its construction is dependent on stabilization of the riverbanks with concrete. Taking this approach still leaves the opportunity cost of having the road, for which there may not be an alternative. The study team strongly recommends using much more environmentally friendly elevated mass transit in the Lai corridor which will not restrict the channel capacity and can also be used by poorer people living along the Lai, most of whom do not own cars.

Social benefits of flood prevention in terms of disease burden, psycho-social effects of trauma and long-term effects such as children dropping out of school because of post flood poverty were not included in the analysis because of lack of credible data for analysis. These benefits of risk reduction are also omitted in all the other scenarios and hence do not affect comparative analysis for selecting more economical options.

There were some alarming ecological effects of this project as it was designed because it would have stopped groundwater recharge in the areas of the river to be paved. Although not included in the mitigation strategy for reducing environmental damage, the design of the channel can be altered to allow infiltration of water without a substantial cost increase. Therefore, the cost of loss of groundwater recharge was not added to the analysis.

Despite all the issues, the "hard resilience" technical measure still yields a positive benefit-cost ratio of 1.88 at a commonly used discount rate of 12%. With lack of comparative strategies, a project like this would easily be approved in policy circles and it indeed was approved by the last government.

FIGURE 4 | Typical people transport along Lai

FIGURE 5 | Typical goods transport along Lai

JICA River Improvement Options

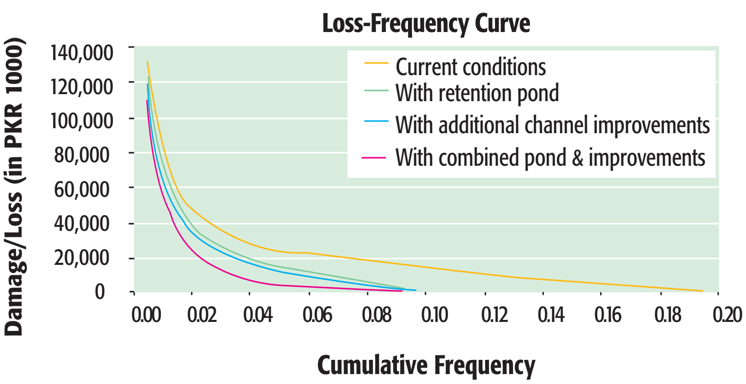
Among the options recommended by a JICA study for flood mitigation after the 2001 flood there were some comparable options for channel improvement. Two of these recommendations were the construction of a pond upstream of Rawalpindi in a park in Islamabad, and the straightening of a river bottleneck downstream of the densely populated area to increase flood flow and reduce backwater effects.

TABLE 2 | Estimated discharge by return period (m^3/sec)

Reference Point	Channel Capacity	5-yr	10-yr	25-yr	50-yr	100-yr
Kattarian Gawal Mandi	640 820	640 820	640 820	640 820	640 820	640 820
With Pond (Peak reduction of 190 m^3/sec for 25-yr and 240 m^3/sec for 100-yr)						
Kattarian Gawal Mandi				960 1,320	1,450 1,970	2,030 1,840
River Improvement (Increment flow capacity of 260 m^3/sec)						
Kattarian Gawal Mandi				890 1,250	1,210 1,920	2,010 2,700
Both measures (450 m^3/sec)						
Kattarian Gawal Mandi				700 1,060	1,190 1,710	1,770 2,460

Source: JICA, 2003 and interpolation by authors

| FIGURE 6 | Loss-frequency curve for JICA river improvement options



Since the modelling software was not available to the study team and the JICA country office was reluctant to provide the data, the following parameters from JICA study were used to estimate the risk reduction strategy (Table 2). If the model was available the team would have been able to generate results for a wider range of scenarios, rather than depend on the few results that were published in the report.

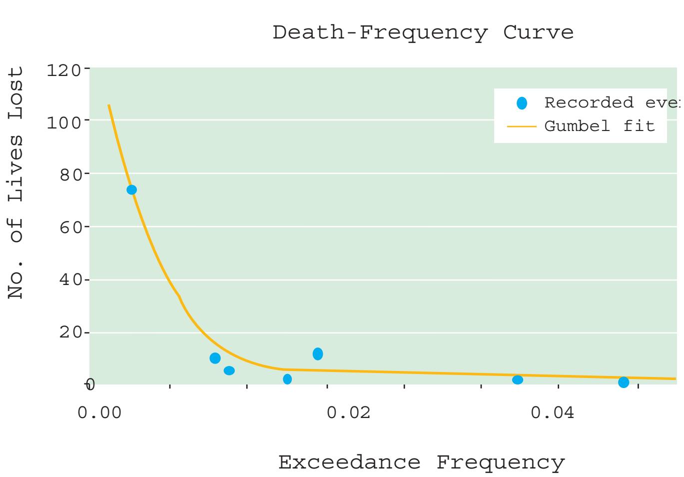
The risk reduction for various flood intensities was calculated through the decrease in flooded area and subsequent reduction in damage. This strategy yields the best benefit-cost ratio of the four strategies reviewed and is higher by several orders of magnitude.

There are several reasons for this outcome. First, the analysis appeared technically sound and took into consideration the river morphology for optimization. Second, the approach makes interventions in sparsely or non-populated areas of the city, which are either government owned or of low value. Third, due to the nature of the analysis and availability of more accurate data, the CBA process is very well suited to measure the tangible benefits from engineering based solutions. This does not mean that other measures such as improvement in social services such as drinking water and sanitation cannot give better ratios. The required data for such analysis was not and the research project did not have resources to collect primary data to conduct CBA on health related benefits and costs.

Early Warning System

An early warning system was proposed as a "soft resilience" or non-structural intervention. Although the cost of this measure is considerable, the ensuing benefits are low because of the short response time of the Lai River in which only lives and perhaps some movable property can be saved. Unlike physical damage data, loss of life in various flood periods is well documented in newspapers. We carried out a newspaper research on the number of lives lost during various floods and plotted them against return periods estimated by the flood heights or discharges reported in various sources. This resulted in the following curve fitted to a Gumbel distribution (Figure 7).

| FIGURE 7 | Loss of life frequency curve for Lai floods



Integration of the curve yielded an average of 3.34 loss of lives per annum due to floods. The cost of saving lives came out to be around PKR 3 million (USD 44,000) per life. This does not mean much in absolute values, as putting an estimate on the value of a life is a matter of much debate and raises moral issues. However, for comparing risk reduction strategies this number can be very useful in making decisions. For example, one may compare this number to the number of lives saved through investment in basic services such as neo-natal health and provision of clean drinking water and sanitation. Although such data were not available for the Lai area population, there was a strong demand for basic services from the poorer communities as a major risk reduction strategy.

For further analysis, we also included an upper limit on household and business contents that can be removed. For this purpose, we assumed that 20% of the value of all household contents and 2% of the value of warehouse stocks can be removed in the short warning time provided by the system. With these assumptions, the benefit-cost ratio became marginally positive, although it is still very low. Although this was a "soft" strategy, the main thrust of the project was on sophisticated telemetric hardware and expensive technology. It was learned during field visits that despite multiple sophisticated control stations, communication and evacuation strategies were still not developed, indicating the strong focus on equipment alone. Moreover, the institutional setup for the system is highly complex and the front-end response agencies, such as the fire department and the voluntary civil service, have very low capacity compared to the requirements for such an evacuation.

A simpler, lesser high-tech system reliant on a short messaging service to all cell phone holders would have had significantly lower costs and much higher communication outreach. Such strategies have already proved highly effective in many similar countries (Aditya, 2007).

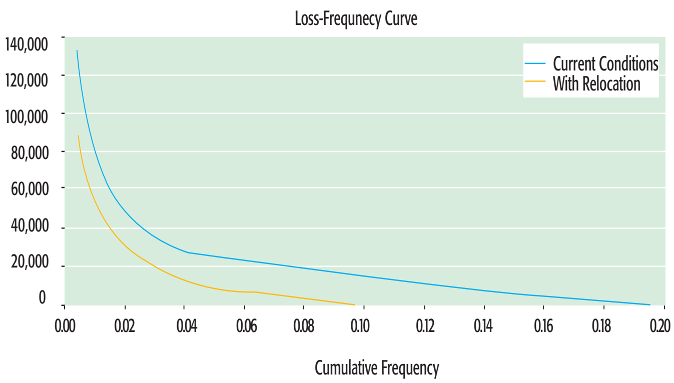
Relocation and Restoration of Floodplain (Hypothetical)

One of the more unconventional strategies for Lai flooding that has frequently been discussed, though never examined, is the ecological restoration of the Lai floodplain. This strategy would entail the relocation of people out of the floodplain and opening up space around the river for vegetation growth and recreational areas. For a stylistic economic analysis, the study team decided to perform a CBA on clearing all housing within 100 meters of both banks of the Lai. The cost of this measure was calculated based on market value of building units and the benefits from the reduction in flood damage. The damage is reduced by buildings and people being moved out of harm's way, but also by the associated clearing of part of the floodplain flow area such that water levels and thus flooded areas are reduced.

This approach also yielded a very low benefit-cost ratio compared to river improvement measures. The main damage averted was that to the houses that were removed while the increased channel capacity actually had little effect on the reduction of the floodplain area. The high cost and density of urban infrastructure once again was driving the results of the analysis.

There are ecological benefits to river restoration but relocation alone will not be enough and enormous investment and coordination will be required to rehabilitate the wetland. It will entail provision of piped sanitation to all households in

| FIGURE 8 | **Loss-frequency curve with relocation**



Islamabad and Rawalpindi and convincing the Capital Development Authority to treat all its sewage before dumping it into the Lai. A complete solid waste management collection and disposal system would also be needed in the twin cities.

Another issue with this approach is its implementation. Pakistan still follows outdated and unjust resettlement laws from the colonial period framed in the 1890s. Because of this, resettlement has been a money minting business for bureaucracy and works against the poor and powerless. For example, around the Lai 80% of the most exposed housing is illegal and hence the most physically vulnerable would not be compensated. Moreover, most of the people living in these houses are tenants rather than owners, which further lowers the chance of reducing the vulnerability of those who deserve the most assistance.

The benefit-cost ratio, however, remains positive. Cost of basic services not included would yield their own benefits in terms of health and recreational value and biodiversity of the wetland. This lower benefit-cost ratio does not imply that rehabilitation is not a cost effective strategy but is rather indicative of the sunk costs accrued because of bad city planning and development strategies which are very costly to reverse.

The Policy and Programme Context

The institutional landscape of the Lai is characterized by complex, multiple, fragmented jurisdictions. At the macro-scale, the upper basin is under the federally controlled Capital Development Authority (CDA) and its various directorates, e.g. for water supply, sanitation, and environmental management. The middle basin falls under the local Rawalpindi *Tehsil* Municaipal Administration (TMA) as well as the provincially controlled Rawalpindi Development Authority (RDA). The lower basin is again under federally controlled Rawalpindi and Chaklala Cantonment Boards (RCB and CCB) and their various departments. The assorted stakeholder institutions within the Lai Basin display all the specialized bureaucratic structures and disciplinary backgrounds, from public administrator to civil engineers, particular to a modernist state apparatus. Bureaucratic objectives are disconnected and uncoordinated: the Sanitation directorate of the CDA is preoccupied with solid and liquid waste disposal, while the Relief Commissioner of Rawalpindi focuses solely on floods. In the context of the federalist structure of Pakistan with an emphasis on provincial autonomy, is no mechanism for the provincial and federal institutions to have operational or even policy coordination vis-à-vis the Lai. The messy substantive interlinkages between issue areas, although widely recognized, do not and supposedly *must* not distract the public servants from their assigned tasks.

The assessed interventions, therefore, geographically fall with various agencies and there would be no reason for any of the agencies to conduct a comparative CBA. The highway project was to be implemented by the RDA in the middle reaches of Lai. The JICA recommended pond would falls in CDA territory and the channel improvement with Chaklala Cantonment Board and Pakistan Railways. With a stand alone CBA most strategies and options would get a green signal from their planning authorities. The over-designed and costly early warning system would not have passed the CBA criterion but then saving lives alone would have justified it. Therefore, the stand alone CBA in a single jurisdiction or a technical line agency would bring little improvement in selecting the most cost effective measure.

In the context of the Lai, where the local, provincial, and federal levels are all important stakeholders, simply by virtue of the basin's geography, any comprehensive floodplain management initiative of necessity will be dominated most by the federal government followed by the provincial and local levels, respectively. This can be good news for the CBA methodology as federal institutions such as the 'Planning Commission' are largely staffed by people trained in economics, who are familiar and experienced in the methodology and are likely to make the best use of it for comparing multiple projects. More recently, National Disaster Management Authority (NDMA) has also been formed to serve as a coordination body at the federal level between different provincial institutions, but it is still in its infancy with an ambitious mandate but little constitutional cover for its enabling legislation and little technical capacity. The provincial Planning and Development (P&D) Departments, also have substantial human resources at their disposal, which can be consumers of the CBA methodology for project selection. Although, ideally it ought to be the local governments, which should be at the forefront of project selection and implementation their limited human resources and geographical jurisdictions are unlikely to use the CBA methodology.

Local and international advocacy groups, academia and other research institutes can however use CBA as a tool for advocacy at all levels. Since all decision makers and governments operate in political contexts, it is often the politics of an intervention rather than the economics of it that drive the decision-making. The politicized decision-making can be tempered by the economic test of CBA, and then too when it is used to *compare* multiple options with consistent assumptions about discount rates and future scenarios informing the analysis across different projects.

The CBA methodology can be susceptible to abuse in the risk reduction context. Apart from the technical difficulties of actually quantifying and monetizing levels of exposure to hazards whose probability and consequences are often highly uncertain, there is a fundamental ethical issue posed by this financial based method for assessing hazard exposure. Measured in dollar (or rupee) terms the consequences of a given event will always be higher if it affects richer people. Financially based tools, like cost-benefit analysis, are blind to the distributional effects and to the consequences for the worst off, which are central to the Rawlsian conceptions of justice (Johnson et al., 2007). Therefore it is all the more important that CBA analysis be coupled with vulnerability analysis, such as the Vulnerabilities and Capacities Index (VCI) proposed by Mustafa et al. (2008) to have a sufficient understanding of the patterns of differential vulnerability in the target area. Using the index we found a range of vulnerability among the residents affected by Lai and any intervention to make them more resilient would not be possible without identifying these groups and the specific causes for their disposition.

Conclusions

Our analysis based on secondary data show that all four interventions for flood risk reduction have a favorable benefit/cost ratio, indicating economic efficiency proving that pro-active risk reduction among densely populated urban poor can indeed be cost effective. However, there is a wide difference between these ratios, with some of the interventions proposed by JICA have by far the greatest impact on flood peak reduction. The CBA tool is extremely useful in comparing two similar technology based strategies where the concrete paving of the channel in the midsection is far less economically beneficial than channel improvement in the lower reaches.

Due the short length of the Lai and over design of the project in terms of costly equipment, the early warning system does not have a favorable benefit cost ratio. In terms of cost per life saved, it would not compare with improvement of basic services like health, water and sanitation. Using newer technologies for outreach such as Short Messaging Services on cell phones and fewer telemetry stations a very cost effective system could have been developed. Despite the lack of cost effectiveness the lower scale of investment made it the most viable project in terms that it was implemented. The CBA tool was extremely useful in highlighting this short-coming of the designed project, whereas, generally most early warning systems are considered to be worthwhile investments.

Many conservationists and locals of Rawalpindi would like to see Lai restored to its natural state. The CBA analysis shows that although the results are still positive the cost of restoration (through relocation) is the highest of all strategies. There are also other multiple issues of untreated sewage from both Islamabad and Rawalpindi, and solid waste from the localities around Lai being dumped in river. Installing and enforcing water treatment in so many administrative jurisdictions is a task, which is yet to be achieved in South Asia. These heavy costs and issues do not mean that rehabilitation of urban wetlands is bad idea but rather indicate the high cost of reversibility of urban planning and growth in sensitive ecosystems such as wetlands.

In the case of Lai, rehabilitation is complicated further by the archaic relocation laws that tend to benefit the richer and go against the poor. Most of the people living along Lai rent their houses and landlords are compensated. In addition, a large portion of the houses are encroaching public property, which makes them illegal, and hence the owners are unable to claim benefits. In terms of cost of land, CDA has the mandate to develop new housing and owns large tracts of land for low cost housing. If the houses along Lai were to be exchanged for units upstream then the prospect of relocation would become even more feasible as the authorities would have to pay for land development only and not cost of the land. This would have to be done under a special project with more pro-poor policies and procedures.

The CBA process has made it possible to compare similar approaches for cost effectiveness and lent a sense of proportion to softer approaches in risk reduction that tend to focus more on people rather than the hazard. The process has also highlighted the shortcomings of the tool in assessing people-centered resilience building. Due to lack of distributional aspects in the analysis, it is extremely important to use more qualitative tools that focus on the differential effects of various approaches on the poor and the vulnerable. If one were to focus on resilience building and number of people rather than amount of capital then such an analysis would yield even better results.

Despite the shortcomings, the tool has established that one form of river improvement is much better than the other and secondly that the early warning system could have been made much more cost effective, had one done some benefit cost analysis on it. Use of CBA with its known limitations leads to tangible results in some cases and calls for further analysis in others.

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Annex I: Working Paper Series

Working Paper Number	Title	Lead Authors	Focus
WP 1	The Cost-Benefit Analysis Methodology	Reinhard Mechler (IIASA)	CBA methods
WP 2	Pinning Down Vulnerability: From Narratives to Numbers	Daanish Mustafa (KCL); Sara Ahmed, Eva Saroch (ISET-India)	VCI methods
WP 3	Downscaling: Potential Climate Change Impacts in the Rohini Basin, Nepal and India	Sarah Opitz-Stapleton (ISET); Subhrendu Gangopadhyay (University of Colorado, Boulder)	Climate downscaling methods
WP 4	Evaluating Costs and Benefits of Flood Reduction Under Changing Climatic Conditions: Case of the Rohini River Basin, India	Daniel Kull (IIASA); Praveen Singh, Shashikant Chopde (WII); Shiraz A. Wajih (GEAG)	India floods
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WP 6	Costs and Benefits of Flood Mitigation in the Lower Bagmati Basin: Case of Nepal Tarai and North Bihar, India	Ajaya Dixit, Anil Pokhrel (ISET-Nepal); Marcus Moench (ISET)	Nepal Tarai and North Bihar floods
WP 7	Pakistan Case Study: Evaluating the Costs and Benefits of Disaster Risk Reduction under Changing Climatic Conditions	Fawad Khan (ISET-Pakistan); Daanish Mustafa (KCL); Daniel Kull (IIASA)	Pakistan (urban) floods
WP 8	Moving from Concepts to Practice: A Process and Methodology Summary for Identifying Effective Avenues for Risk Management Under Changing Climatic Conditions	Marcus Moench (ISET); Sara Ahmed (ISET-India); Reinhard Mechler (IIASA); Daanish Mustafa (KCL); Ajaya Dixit (ISET-Nepal); Sarah Opitz-Stapleton (ISET); Fawad Khan (ISET-Pakistan); Daniel Kull (IIASA)	Methodology summary
WP 9	Understanding the Costs and Benefits of Disaster Risk Reduction under Changing Climatic Conditions	Marcus Moench (ISET)	Summary report

Annex II: Acknowledgements

This paper provides insights from an evaluation of the costs and benefits of disaster risk reduction and adaptation to climate change in South Asia. The report is based on a set of work undertaken in the Nepal Tarai, Eastern Uttar Pradesh, and Rawalpindi, Pakistan. The progamme as a whole is financed by DFID and has been undertaken in conjunction with related activities supported by IDRC, NOAA and ProVention. The support of all these organizations is gratefully acknowledged. Numerous organizations and individuals have contributed in a substantive way to the successful completion of this report. The core group of partners undertaking field work and analysis included: Reinhard Mechler, Daniel Kull, Stefan Hochrainer, Unmesh Patnaik and Joanne Bayer from IIASA in Austria; Sara Ahmed, ISET Associate, Eva Saroch; Shashikant Chopde, Praveen Singh, Sunandan Tiwari, Mamta Borgoyary and Sharmistha Bose of Winrock International India; Ajaya Dixit and Anil Pokhrel from ISET-Nepal; Marcus Moench and Sarah Opitz-Stapleton from ISET; Syed Ayub Qutub from PIEDAR, Pakistan; Shiraz A. Wajih, Abhilash Srivastav and Gyaneshwar Singh of Gorakhpur Environmental Action Group in Gorakhpur, Uttar Pradesh, India; Madhukar Upadhya and Kanchan Mani Dixit from Nepal Water Conservation Foundation in Kathmandu; Daanish Mustafa from King's College London; Fawad Khan, ISET Associate and Atta ur Rehman Sheikh; Subhrendu Gangopadhyay of Environmental Studies Program, University of Colorado, Boulder. Shashikant Chopde and Sonam Bennett-Vasseux from ISET made substantive editorial and other contributions to the project. Substantive inputs from field research were also contributed in India, Nepal and Pakistan by numerous dedicated field staff and individuals in government and non-government organizations as well as the local communities that they interacted with.

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