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SOCIOECONOMIC ANALYSIS OF THE POTENTIAL BENEFITS OF MODERNIZING HYDROMETEOROLOGICAL SERVICES IN THE LAO PEOPLE'S DEMOCRATIC REPUBLIC

WORLD BANK GROUP

GFDRR
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ABBREVIATIONS

BCA	benefit-cost analysis
BCR	benefit-cost ratio
CGEM	computable general equilibrium model
DMH	Department of Hydrology and Meteorology
DRM	disaster risk management
EI	effective implementation
EWS	early warning systems
GDP	gross domestic product
GNI	gross national income
GTAP	Global Trade Analysis Project
ICAO	International Civil Aviation Organization
IRR	internal rate of return
Lao PDR	Lao People's Democratic Republic
LRF	loss reduction factor
LRR	loss reduction ratio
MONRE	Ministry of Natural Resources and Environment
NHMSs	national hydrological and meteorological services
NPV	net present value
O&M	operations and maintenance
PV	present value
SEB	socioeconomic benefits
VOI	value of information
WTP	willingness to pay

EXECUTIVE SUMMARY

The Lao People's Democratic Republic (Lao PDR) is exposed to significant climate and disaster risks. The country's rapid economic development could put more people and assets at risk from natural hazards, if investments in risk reduction, planning and preparedness are not made. Floods, storms, and droughts are the most prevalent hazards and are expected to become more severe under the influence of climate change. Three of the five costliest natural disasters have taken place since 2009, including two floods in 2013. A preliminary financial risk assessment (World Bank 2012) estimated high annual economic losses for Lao PDR due to natural disasters, equivalent to 0.7 percent of gross domestic product (GDP). For floods alone, Lao PDR could face yearly average costs for emergency response of US$10 million, and these costs could exceed US$36 million once every 10 years on average (10 percent annual probability) (World Bank 2017). The poor suffer the brunt of the consequences in the aftermath of disasters, due to their overexposure, higher vulnerability, and reduced ability to recover.

Improving national capacity for multi-hazard early warning systems and weather, climate, and hydrological (hydromet) services is crucial to minimize growing economic losses from disasters, facilitate adaptation to climate change, and guide economic development across different sectors. Improved hydrometeorological information can bring many benefits to the general public across different productive and social sectors, making the economic analysis of its potential benefits a complex task. Rather than describing all the expected impacts of improved hydromet services, this analysis evaluates key expected benefits for which quantitative information can be obtained and conservative assumptions can be made. This allows the expected impacts to be attributable to the improvements in the hydromet services. Disasters related to water, especially floods, have played an important role in evaluating the improvement of hydrometeorological information. This study has not considered the numbers of deaths from an economic perspective, but only in terms of their social impacts. Some studies also estimate the economic value of life, such as value of statistical life. As this report has avoided valuing life in economic terms, the estimates presented in this study can be considered conservative.

The results of this analysis show that the contribution of hydrometeorological information to socioeconomic development in Lao PDR is expected to be very high, particularly due to the potential benefits for the energy and tourism sectors and their contribution to GDP. As part of this study, benefit-cost analysis (BCA) estimates were established for hydromet modernization in Lao PDR, using a 3 percent and 12 percent discount rate as lower and upper bounds and using the estimated annual benefits and costs as baseline. Table ES1 summarizes the results of the socioeconomic benefits calculations. Figure ES.1 shows the present value (PV) of benefits, which is estimated to be between US$186 million and US$375 million using a time horizon of 15 years and a 12 percent and 3 percent discount rate, respectively. Considering an additional 20 percent risk factor, as part of the sensitive analysis, the conservative PV of the expected benefits ranges between US$150 million and US$450 million. The results of this study support the conclusion that hydromet information is critically important for Lao PDR and that investments in the hydromet sector are expected to be highly profitable from socioeconomic perspective.

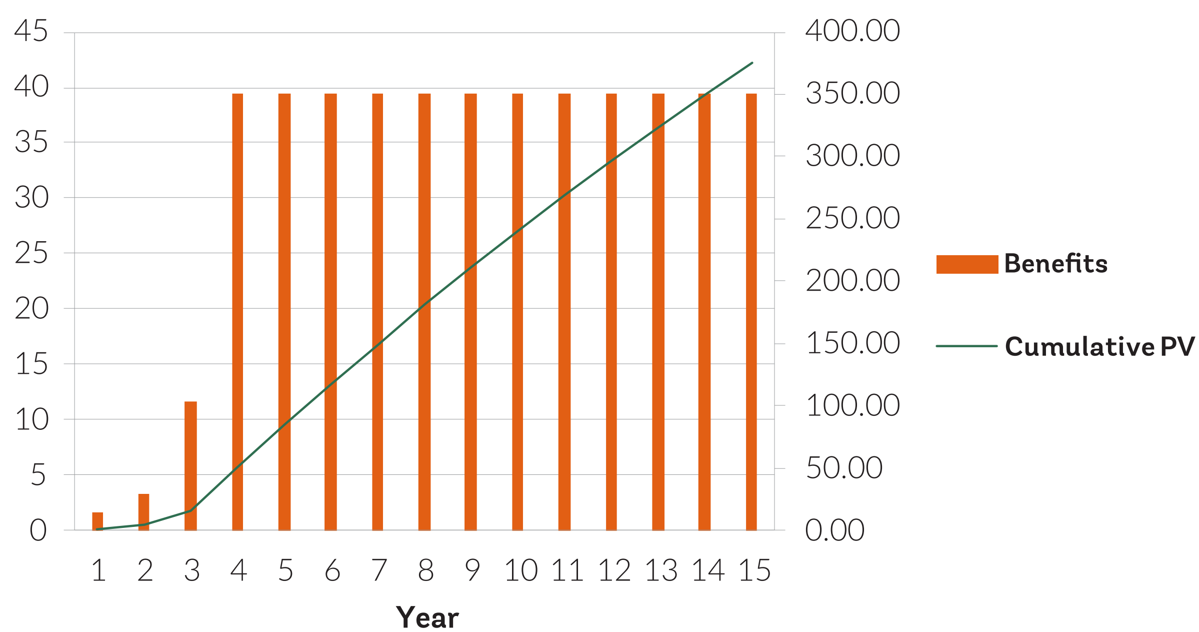
Table ES.1: Baseline Socioeconomic Benefits For Hydromet Modernization In Lao PDR *(actualized 15 years)*

	Benefit estimates (US$, millions)	
Discount rate (%)	3.0	12.0
Benchmarking survey	495.4	246.3
Benefits to general public (willingness to pay)	21.0	10.4
Increase in GDP (unblocked productivity)	329.8	164.0
DRM-avoided losses	24.3	12.1
Total PV benefits	375.1	186.5

Note: DRM = disaster risk management.

[a] Total PV benefits do not include benchmarking in order to avoid double counting of perceived and accounted values.

Figure ES.1: Socioeconomic Benefits Values For Hydromet Modernization In Lao PDR



INTRODUCTION

Lao People's Democratic Republic (Lao PDR) is exposed to significant climate and disaster risks. The country's rapid economic development could put more people and assets at risk from natural hazards, if investments in risk reduction, planning and preparedness are not made. Floods, storms, and droughts are the most prevalent hazards and are expected to become more severe under the influence of climate change. Three of the five costliest natural disasters have taken place since 2009, including two floods in 2013. A preliminary financial risk assessment (World Bank 2012) estimated high annual economic losses for Lao PDR due to natural disasters, equivalent to 0.7 percent of gross domestic product (GDP). For floods alone, Lao PDR could face yearly average costs for emergency response of US$10 million, and these costs could exceed US$36 million once every 10 years on average (10 percent annual probability) *(World Bank 2017)*.

The poor suffer the brunt of the consequences in the aftermath of disasters, due to their overexposure, higher vulnerability, and reduced ability to recover. Disasters further impoverish the poor and entrap them in the poverty cycle, with vulnerable households more likely to fall back into poverty following external shocks. In the aftermath of disasters, indebtedness, depletion of assets, and use of negative coping strategies affecting health and education, are common among highly vulnerable populations (Jha and Stanton-Geddes, 2013).

Weather, climate, and hydrological (hydromet) warning products and services, including early warnings for meteorological and hydrological hazards, are needed to make informed and timely decisions that avoid loss of lives and livelihoods, reduce property losses, and thus minimize disasters. There is overwhelming evidence that good early detection and warning systems, along with the ability to respond to hazards in a timely manner, have a significant economic benefit, and that the cost of inaction is often very large. For example, Hallegatte (2012) estimates the potential benefits of upgrading all developing country hydromet information production and early warning capacities to developed-country standards to be between US$4 billion and US$36 billion per year globally, with cost-benefit ratios between 4 and 36.

In Lao PDR, besides contributing to better preparedness to avoid disasters, better hydromet information would improve agricultural production and food security. It could also help the country manage water resources more effectively, including related to the energy sector, manage climate-sensitive health risks, anticipate and prepare for changes in disease vectors, better plan urban development (including the capacity to shelter and protect lives and livelihoods against floods), and better plan for adapting to climate change and variability. Significant are also the benefits for the aviation sector through contribution to safety, and to tourism.

The Department of Meteorology and Hydrology (DMH), under the Lao Ministry of Natural Resources and Environment (MONRE), is responsible for meteorological and hydrological observations, forecasting, and early warning of hydrological and meteorological hazards. DMH has an annual budget of US$300,000, personnel of 245, and a limited observation network given the size of the country. As part of its mandate, DMH provides hydromet information and services to a wide range of water resource planning and management activities. It also provides weather services to aviation and land transportation and supports decision making by providing climate outlooks.

While DMH provides a basic level of services, it cannot meet current and future needs for quality, upgrading, and maintenance or the demand for improved services and products. For example, DMH has only limited capacity to forecast flash floods, which constrains its ability to provide timely warning to the communities affected, and it has no capacity to receive user feedback. Lao PDR is currently implementing the Lao PDR Southeast Asia Disaster Risk Management Project, with World Bank financing, to reduce the impacts of flooding in Muang Xay and enhance the government's capacity to provide hydromet services and disaster response. Component 2 of this project—Hydromet Modernization and Early Warning Systems—is being implemented by DMH, and includes among other goals (i) strengthening early warning systems and service delivery systems, and (ii) modernizing the observing, forecasting, and communications systems.

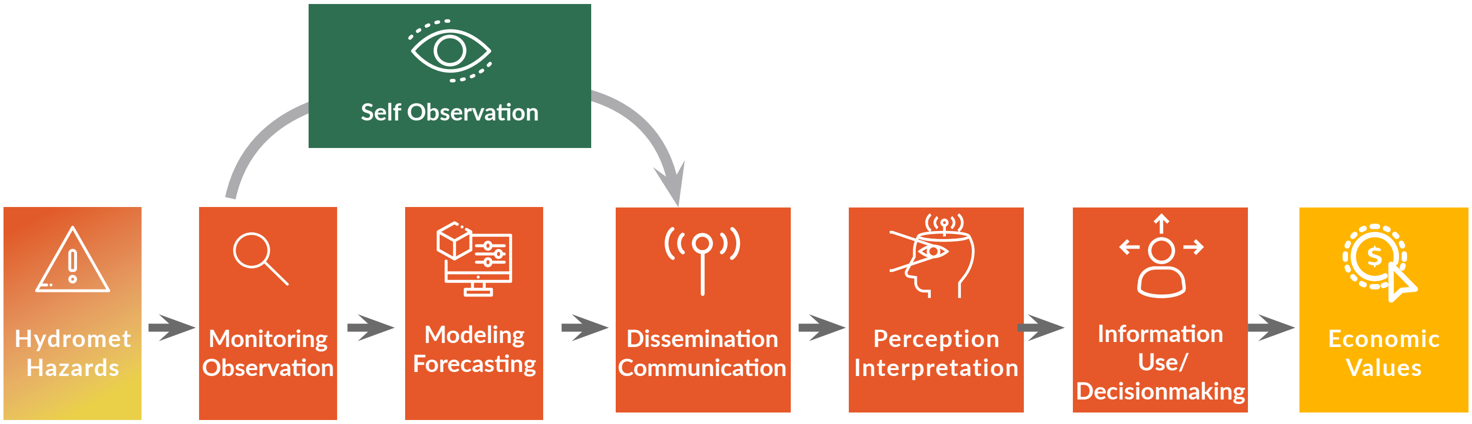
The current analysis has been undertaken in order to develop a socioeconomic assessment of the potential benefits of modernized national hydrological and meteorological services (NHMSs) and early warning systems (EWS) in Lao PDR. This report may provide decision makers with estimates of the benefits for different economic sectors of improved NHMSs and EWS. The findings from this assessment will assist the Government of Lao PDR and the World Bank in their dialogue and decision making on policy, infrastructure planning, and investments in NHMSs and EWS.

1. CONCEPTUAL APPROACH TO ECONOMIC VALUE

1.1 Hydrometeorological Information Value Chain

The hydrometeorological information value chain **(figure 1.1)** shows that value, in socioeconomic terms, is ultimately at the end of the process that starts with observations of weather, water, and climate elements and continues with decision-making and outcomes *(Lazo 2016)*. An arrow connecting "monitoring/observation" and "dissemination/communication" has been added to the general framework in **figure 1.1** to emphasize that some users do use observation data directly. Once information is created by an agency it must be disseminated and communicated through channels and in formats such that it can be obtained, understood, and used in stakeholder decision making to improve societal outcomes. Thus the value of accurate, timely, and relevant hydrological and meteorological information—including climatological information, forecasts, and warnings—is realized only if information can potentially be used in decision making to generate beneficial outcomes at the end of the process. Merely improving observations or forecasts—through improved technologies, for example—will not necessarily generate economic value unless the entire value chain process works to facilitate end-user decision making.

Figure 1.1: Simplified Hydromet Information Value Chain



Source: Based on Lazo 2016.

For the purposes of this analysis assessing economic benefits of improved hydromet services, it has been assumed that the improvements flow through as needed from product creation and dissemination to end-use and decision making. Thus the economic and social values that can derive from any project will require investing not only in hard infrastructure but also in all processes that ensure that outcomes are properly realized.

1.2 Value of information

The concept of "value of information" (VOI) captures the theoretical and applied methods in economics related to the use of hydromet products and services (i.e., hydromet information) to improve societal welfare. Beginning in the 1960s and drawing from the decision sciences and probability theory *(Savage 1954; Howard 1966; Macauley 2005)*, VOI approaches have dealt with questions such as "Prior to an event's occurrence, how does information influence the decision of whether or not to take action?" and "How much is the decision maker willing to pay for information about a potential event prior to making a decision?" The value of information thus relates to how individuals or economic agents can or will react to changes in the information available when they face a weather, climate, or water risk. There are several approaches for modeling decision making and the value of hydrometeorological information. The formal mathematical expression and empirical evaluation linking VOI to the expected outcomes of decisions can take many forms depending on the decision context and research methods. Common approaches include modeling decision making at the firm level based on profit maximization or loss minimization *(Suchman, Auvine, and Hinton 1981; Mjelde, Sonka, and Peel 1989)* or modeling decisions at the individual level in a utility-theoretic framework *(Hilton 1981; Mjelde Sonka, and Peel 1989; Murphy 1993; Johnson and Holt 1997)*.

1.3 Public goods and societal welfare

Economists have developed several methods for assessing the value of nonmarket goods and services so that these values can be included in decision making for policy (e.g., funding of national hydrometeorological services). Nonmarket methods include stated-choice methods that use surveys to elicit the economic values individuals place on goods and services that they don't pay for directly. We use estimates from nonmarket studies of the value of improved hydromet services for the current analysis. This approach involves eliciting individuals' willingness to pay (WTP)—essentially their consumer surplus if they had actually bought the service.

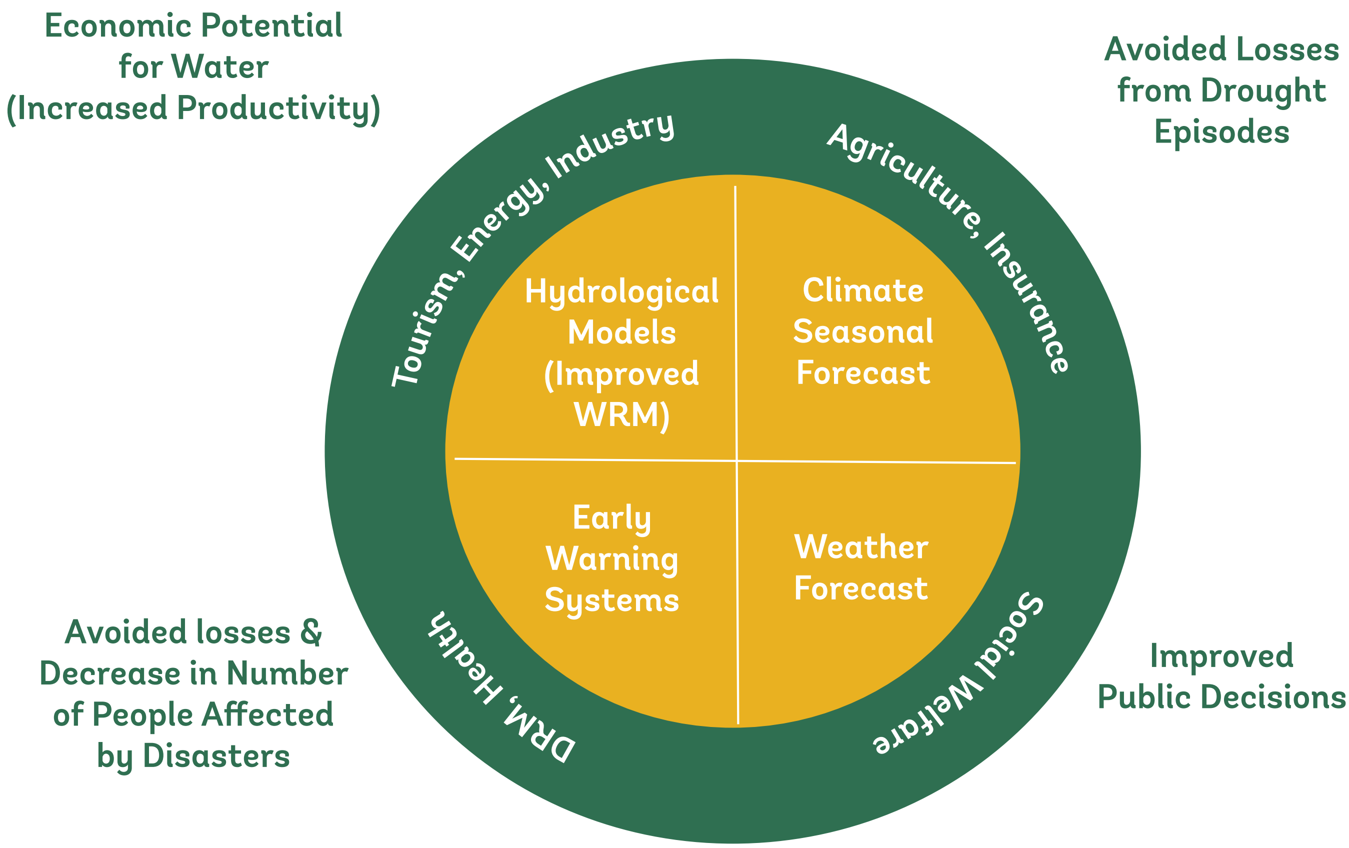
Technically, WTP is constrained by income levels (you cannot be willing to pay more than you have). Thus measuring WTP and aggregating such values should not sum to more than national GDP, which is a measure of the total income and production in an economy. There are ethical and equity issues raised by WTP, especially when considering WTP for something like the value of loss of life in different countries with significantly different income levels and thus different values of statistical life. A more complete discussion and explanation of economics related to the evaluation of benefits and costs of weather/water/climate information and of NHMSs can be found in WMO et al. *(2015)* and Lazo et al. *(2008)*.

2. SOCIOECONOMIC BENEFITS (SEB) EVALUATION CONTEXT IN LAO PDR

With around 70 percent of the Lao PDR population relying on subsistence agriculture for their livelihoods, climate effects—such as unpredictable rains, extended dry seasons, etc.—have a significant impact on the lives of people across the country *(UNDP 2010)*. In addition, the country is exposed to multiple hazards—most prominently floods—that have substantial repercussions in vulnerable communities. In this context, analyzing the contribution of NHMSs, and EWS in Lao PDR is very important and will shed light on the contribution of hydrometeorological information to economic development, human capacity, poverty reduction, and environment sustainability in the country.

Since hydrometeorological information is important to many sectors and generally brings benefits to society as a whole, its economic consequences are complex to analyze. Therefore, the proposed evaluation is not intended to provide an analysis of all the areas where hydromet information could be beneficial, but rather to focus on four key objectives: **(i)** a better characterization of seasonal climate information and its impact on agriculture, **(ii)** capacity building in hydromet services and its impact on productive sectors (e.g., tourism, energy, etc.), **(iii)** development of EWS for disaster risk management (DRM) and its impact on avoided losses (e.g., loss of human life, health losses, economic losses, etc.), and (iv) a general improvement of weather monitoring and forecasting and its impact on general public decisions. **Figure 2.1** summarizes the objectives considered in the economic analysis, linked to the main affected sectors and some specific impacts that may be analyzed.

Figure 2.1: Proposed conceptual framework for the economic analysis: Objectives analyzed, sectors affected, and examples of socioeconomic impacts for the analysis



Note: WRM=water resources management.

This report evaluates the aspects identified in this conceptual framework. On the one hand, there are direct economic effects affecting productive sectors—such as agriculture, tourism, energy, industry, insurance, etc.—that can be measured through market information. But on the other hand, there are other effects—such as deaths avoided, impacts on the general social welfare, improvement of conflicts, health effects, etc.—that also generate economic value even if they are not based on an economic activity. Therefore, we combine market and contingent valuation methods for the economic evaluation. There are many aspects we will not be able to quantify in this assessment, so qualitative information will also help to complete the whole picture of the benefit-cost analysis.

3. ESTIMATION OF BENEFITS

3.1 Benchmarking process: Stakeholders' perceptions of project impacts

In prior assessments of the value of hydromet services, the World Bank has used a benchmarking approach that provides order-of-magnitude estimates of the benefits of reducing damages from weather-related events through hydromet services *(World Bank 2008; Rogers and Tsirkunov 2013)*. A detailed description of the benchmarking process to evaluate hydrometeorological information can be found in Lazo *(2015)*. During the Multi-Stakeholders Workshop on Hydromet Services, co-organized by DMH and the World Bank and held in Vientiane, Lao PDR, on April 24, 2018, a benchmarking process was run to estimate how stakeholders perceived the potential impacts of hydrometeorological information. The steps of the methodology and the specific questionnaire used are detailed in annex 1 and annex 2 respectively.

Figure 3.1 shows the results for the perceived loss reduction ratio (LRR), representing the percentage of the potential to avert losses with an improved hydromet service. The average perception is that 25.3 percent of the weather/water/climate-related losses in the country may be averted by improving hydrometeorological information. The range for LRR has been from 20 percent to 60 percent in a range of World Bank benchmarking initiatives, so given the small sample, and in order to keep a conservative approach for calculating the benefits, the values above this range have not been considered for the analysis. In order to get more robust analysis in this ratio, it would be necessary to increase the sample (e.g., to include relevant local agencies). It would be also interesting to see how perception of loss reduction breaks down across the sectors represented by respondents, but we do not have enough data with the current sample to pursue this question. If the exercise is repeated in other workshops or similar initiatives in the country, a more accurate weighted average could then be generated based on sector contribution to GDP.

Figure 3.1: Histogram of responses for LRR in the benchmarking process in Lao PDR

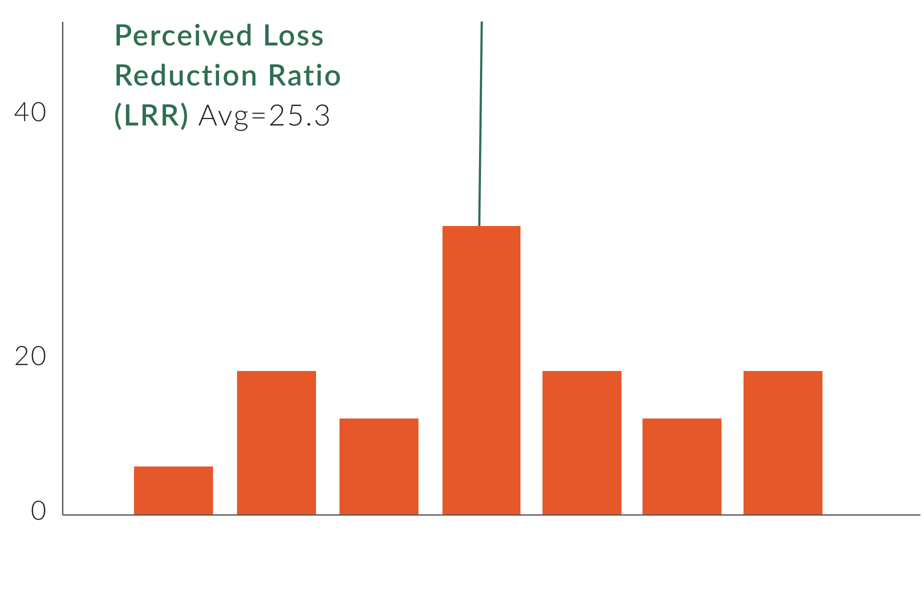


Table 3.1 is based on stakeholders' perceptions and shows order-of-magnitude estimates for the expected general impacts. The stakeholders' mean perception[4] for the region's vulnerability is about 0.55 percent of the national income (GDP). Considering the GDP for 2017, this means that consulted stakeholders perceive around US$87 million to be at risk for weather/water/climate-related events. Part of these losses may be averted if adequate information is available, but some of them would be unavoidable. Considering the average LRR in **figure 3.1**, the general impact of the project is perceived by stakeholders as almost US$22 million each year.

Table 3.1: Stakeholders' Perceptions of Project's General Impacts

	Current US$, millions[a]
GDP (2017)	15,900
Potential annual loss due to weather/water/climate	86.9
Benchmarking for annual impact of modernized hydromet service	21.9

a. Current US$ refers to the nominal value of U.S. dollars in the current year (in this case 2017).

3.2 Improved decisions for general public: Willingness to pay for EWS

In order to calculate the impact of the improved EWS in the country, a benefits transfer exercise has been conducted. A recent study for Vietnam (Nguyen et al. 2013) estimates the benefits to households of an improved cyclone warning service through the use of a discrete choice experiment survey with over 1,000 respondents conducted in 2011. The analysis examines issues with respect to preference heterogeneity, variation in benefit estimates based on analysis approaches, potential bequest and altruistic values, and impacts of value elicitation on benefit estimates. The Vietnam study's valuation focuses on improvements in tropical cyclone information. For the purpose of the preliminary analysis carried out for Lao PDR, it is assumed that non-cyclone-vulnerable populations in Lao PDR have comparable values for the range of other hazards subject to improved forecasts (i.e., flash floods, landslides, drought, extreme winds, etc.). Estimated household WTP was VND 100,000 to VND 168,000 in 2011 (Nguyen et al. 2013). As shown in **table 3.2**, the values for annual WTP converted into U.S. dollars are 4.44 to 7.46. Since the WTP measures have proved sensitive to income, we then use the ratio of gross national income (GNI) per capita in Vietnam and Lao PDR in the year of the study (2011) to convert the estimates of WTP at household level to estimates for Lao PDR, and finally aggregate the number of households in Lao PDR (CPC 2014) to reach an estimate of national WTP of US$3.6 million to US$6.1 million.

4 Mean perception refers to the average value of the respondents' estimate of the vulnerability ratio.

Table 3.2: Conversion of Vietnamese household WTP to Lao household WTP based on income ratio

	WTP estimate	Lower bound	Upper bound
Household WTP in 2011 (VND)		100,000	168,000
WTP (2011 US$)[a]		4.44	7.46
GNI per capita (US$)	Vietnam (2011)	2,150	
	Lao PDR (2011)	2,060	
Income ratio: Lao PDR/Vietnam		0.96	
Adjusted Lao WTP at household level (US$)		4.25	7.13
Number of households in Lao PDR		867,000	867,000
Total WTP at the country level (US$)		3,681,298.8	6,185,245.3

Source: GNI per capita is based on World Bank data, available at http://data.worldbank.org/indicator/NY.GDP.PCAP.CD; number of households in Lao PDR is from CPC (2014).

a. 1 VND = US$0.0000443951 (based on xe.com).

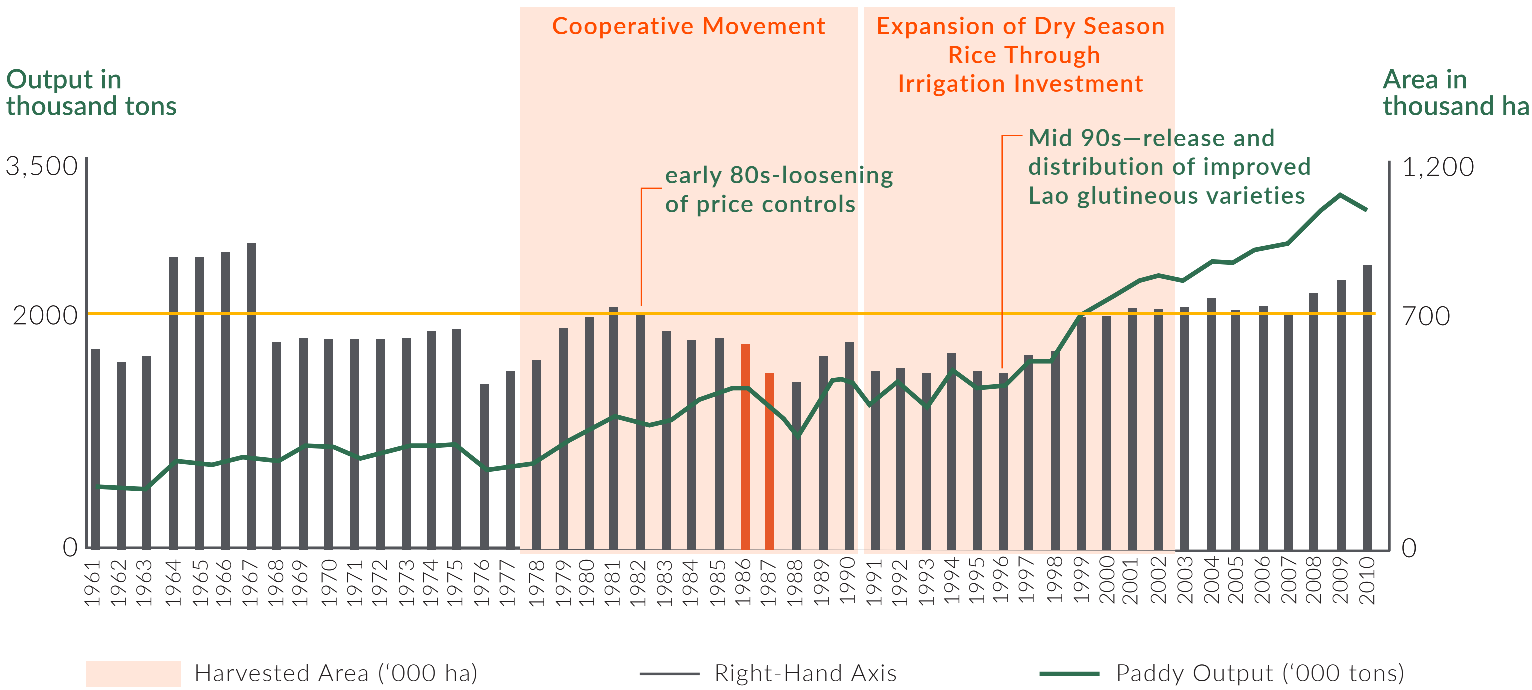
3.3. Benefits through the optimization of economic production

In order to estimate the impact of improved hydromet information and services, we need to analyze the sensitivity of Lao PDR's national economy to hydromet conditions. We consider three of the main sectors that use hydromet resources intensively in the country: (i) agriculture, (ii) energy, and (iii) aviation and tourism. The average changes in the productivity of these sectors have been reported and their effects in the economy as a whole have been computed using a general applied equilibrium model.

3.3.1 Agriculture: Changes in productivity (production function)

The changes in the marginal productivity of the agriculture sector have been reported through the estimation of production functions in a range of studies (Quiroga and Iglesias 2009; Quiroga and Suárez 2016; Iglesias et al. 2012) for a number of countries. The production function estimates the existing relationship among some combination of factors (labor, capital, energy, water, etc.) and the output or production levels obtained (Q). We consider an agricultural production function depending on endogenous factors (xi) (labor, capital) and exogenous factors (zi) (climate)—that is, Qi = f (zi, xi). The main advantage of this method is that it assumes a direct relationship between climate variables and crop yields. For the estimation of the production functions, the historical data from FAOSTAT (1961–2016) were analyzed. Figure 3.2 shows the data for rice production.

Figure 3.2: Lao PDR rice production and harvested area, 1961–2010



Source: Sayavong 2017; FAOSTAT, Food and Agriculture Organization of the United Nations, http://www.fao.org/faostat/en/#home.

Table 3.3 shows the estimated coefficients for temperature and precipitation elasticity for two types of crops in Lao PDR: rice and fruits[5]. For elasticity of the agricultural sector, a weighted average is used to take into account the contribution of those two crops to agricultural sector added value; the result is 0.024 percent of the total (that is, an increase of 1 percent in the total precipitation is estimated to increase the crop production by 0.024 percent).

Table 3.3: Production function for the agricultural sector

Dependent Variable	Crop Production Index	
Variables	Rice	Fruits
Average temperature *(Standard deviation for the estimated coefficent)*	-0.58 *(0.945)*	0.44 *(1.132)*
Precipitation *(standard deviation for the estimated coefficient)*	0.08 (0.118)	-0.05 (0.141)
R^2	0.97	0.98
F statistic	512.67	529.73
Probability	0.000	0.000

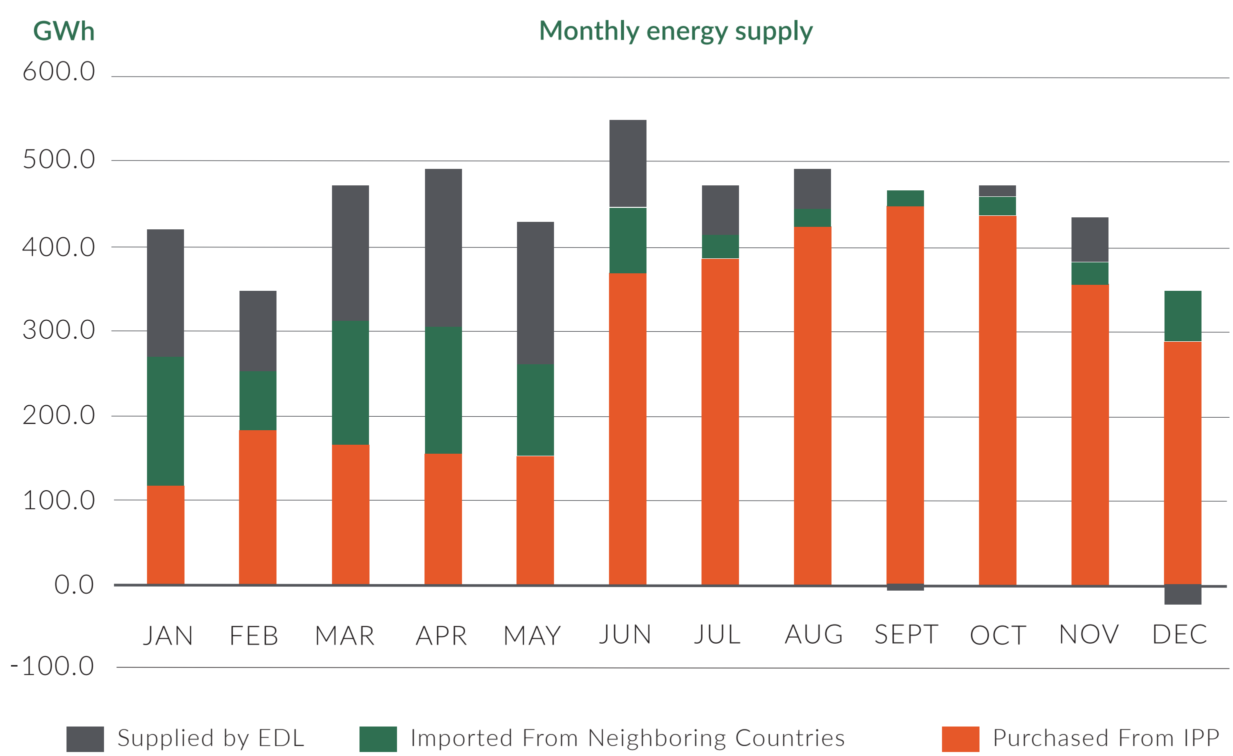
Source: FAOSTAT, Food and Agriculture Organization of the United Nations, http://www.fao.org/faostat/en/#home.

5 These are paddy rice and aggregated fruit crops according to the Food and Agriculture Organization of the United Nations (FAO) definition.

3.3.2 Energy: Differential costs of electricity in wet and dry season

For the energy sector, changes in productivity have been estimated through differences between the marginal cost of generating energy in the dry and the wet seasons. An increase in regulation and more integrated water management will contribute to a reduction in the differential elasticity. **Figure 3.3** shows the differences in monthly energy supply for the two seasons.

Figure 3.3: Monthly Energy Supply In Lao PDR (Gwh By Type of Source)



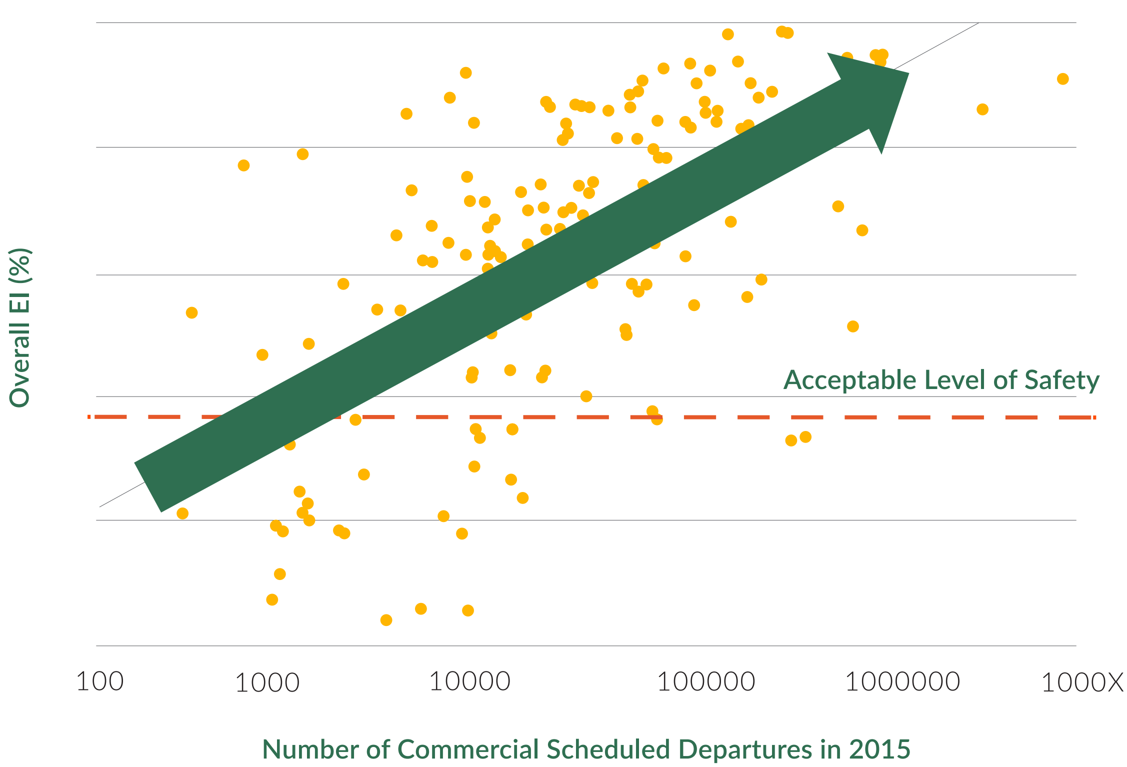
Source: Provincial Department of Energy and Mines; Electricite du Laos (EDL).

Note: IPP = independent power producer.

3.3.3 Aviation and tourism: Effect of increased safety

A strong and affordable global air transport network transcends continents, greatly expands local access to foreign supplies and markets, provides opportunities (especially for the tourist sector), and therefore increases GDP. The potential impact of safety on traffic demand can be estimated with an econometric model that uses an effective implementation (EI) score measured by the Continuous Monitoring Approach of the International Civil Aviation Organization (ICAO) Universal Safety Oversight Audit Programme as a proxy for safety performance. With all other factors affecting traffic being constant, this hypothetical analysis suggests that a 10 percent improvement in the EI of a country's safety oversight system might generate, on average, an additional 1.8 percent of aircraft departures from the country (IATA 2017); see **Figure 3.4**.

Figure 3.4: Economic Benefits of Aviation Safety



Source: IATA 2017.

Given the data provided by the model in **Figure 3.4**, and the fact that in the last 10 years an average of 34.6 percent of tourists visiting Lao PDR arrived by plane (TDD 2016), it is possible to estimate the potential benefits of improved aviation safety. The estimated elasticity comes to 0.18 percent of the revenues for the tourist sector. **Table 3.4** shows some important figures for the tourist sector and the estimated revenue from investments in aviation safety based on the IATA (2017) parameters.

Table 3.4: Estimated Revenue From Investments In Safety Aviation

Year	Number of tourist arrivals	Average length of stay for international tourists (days)	Revenue (current US$)	Mode of arrival: Air (%)	Estimated revenue from EI of safety (US$)a
2006	1,215,106	7	17,3249,896		163,191
2007	1,623,943	7	23,3304,695		236,105
2008	1,736,787	6.5	275,515,758		303,536
2009	2,008,363	7	267,700,224		286,278
2010	2,513,028	7	381,669,031		449,048
2011	2,723,564	7	406,184,338	48.8	496,067
2012	3,330,072	7.2	506,022,586	43	645,486
2013	3,779,490	8.4	595,909,127	32.4	760,146
2014	4,158,719	7.9	641,636,543	29.3	818,476
2015	4,684,429	7.5	725,365,681	28.4	925,281
2016	4,239,047	7.6	724,191,957	25.8	923,784

Source: TDD (2016).

a. Figure is for a 1 percent improvement in the EI of a country's safety oversight system.

3.3.4 GTAP computable general equilibrium model to measure the impact on GDP through international trade

The average weather/water/climate elasticity estimated for the agriculture, energy, and tourism sectors may be used to characterize the productive sectors' response in physical terms—e.g., tonnes of agricultural production, net sales in an industry, generation of electric energy, etc. However, in order to characterize the economic impact of these changes in productivity, it is necessary to consider the effect that they have through global market interrelationships. For this step, the assessment uses a computable general equilibrium model (CGEM).

CGEMs comprise a representation of most economic sectors, where countries are linked through the volume of trade, prices in international markets, and financial flows. A change in relative prices induces effects on the general equilibrium that are transferred to the economy as a whole. The partial equilibrium models also allow the estimation of the benefits of certain public policies or programs and can consider substitution processes in production and consumption through market balance conditions. But CGEMs also allow adjustment to other sectors; they are useful in considering the effects on growth of the economy as a whole, since they take into account the interactions between intermediate inputs and the markets for other goods and the link between factor remuneration and consumer income, among others. The CGEM considered for this analysis of changes in productivity and their impact on GDP is the model developed by the Global Trade Analysis Project (GTAP) and the GTAP8.5 database coordinated by the Center for International Trade Analysis of the Purdue University Department of Agricultural Economics (GTAP 2008). The GTAP model (Hertel 2012) has been used in numerous previous studies to analyze the economic consequences of hydromet impacts in many sectors. A complete and detailed description of the model and its assumptions can be found on the official project website.[6]

The aggregation that has been used for this study is shown in table 3.5. A social accounting matrix has been generated which comprises three regions, three sectors, and three productive factors. The regions are Lao PDR, a region encompassing the rest of South Asia, and another aggregate region encompassing the rest of the world. The sectors are agriculture, energy, and manufacturing and services (including tourism). The productive factors are labor, capital, and natural resources.

Table 3.5: Aggregation For The Gtap Social Accounting Matrix For This Study

Aggregation	GTAP code	
Regions	Lao PDR	Lao
	Rest of South Asia	mys, phl, sgp, tha, vnm, xse, bgd, ind, npl, pak,l ka, xsa
	Rest of world	aus, nzl, xoc, chn, hkg, jpn, kor, mng, twn, xea, khm, idn, can, usa, aut, bel, cyp, cze, dnk, est, fin, fra, deu, grc, hun, irl, ita, lva, ltu, lux, mlt, nld, pol, prt, svk, svn, esp, swe, gbr, che, nor, xef, alb, bgr, blr, hrv, rou, rus, ukr, xee, xer, kaz, kgz, xsu, arm ,aze, geo, bhr, irn, isr, kwt, omn, qat, sau, tur, are, xws, egy, mar, tun, xnf, ben, bfa, cmr, civ, gha, gin, nga, sen, tgo, xwf, xcf, xac, eth, ken, mdg, mwi, mus, moz, rwa, tza, uga, zmb, zwe, xec, bwa, nam, zaf, xsc, xtw, mex, xna, arg, bol, bra, chl, col, ecu, pry, per, ury, ven, xsm, cri, gtm, hnd, pan, slv, xca, xcb
Sectors	Agriculture	pdr, wht, gro, v_f, osd, c_b, pfb, ocr, ctl, oap, rmk, wol, frs, fsh, wtr
	Energy	coa, oil, gas, p_c, ely, gdt
	Manufacturing and services	omn, cmt, omt, vol, mil, pcr, sgr, ofd, b_t, tex, wap, lea, lum, ppp, crp, nmm, is, nfm, fmp, mvh, otn, ele, ome, omf, cns, trd, otp, wtp, atp, cmn, ofi, isr, obs, ros, osg, dwe
Production Factors	Natural resources	Land, Nat&Res
	Labor	skilled lab, unskilled lab
	capital	Cap

6 See Purdue University, "GTAP," https://www.gtap.agecon.purdue.edu.

For the effects on the sector, hydromet services have been considered as a productive factor implicitly included in natural resources. Changes in induced productivity have been introduced as an external shock in the GTAP model—i.e., the effect of the modernization plan to expand hydromet resources availability in Lao PDR and to increase the marginal productivity of each sector by the exact amount estimated for the elasticities. The shock variable was implemented as a technical progress that increases the marginal productivity of factor k, in region i, and sector j. This shock propagates in the GTAP model through the change in relative factor prices, which changes the supply of goods and therefore the relative prices of the final goods, in both the national and international markets. The model considers the competition between resources, so that productive shocks have been introduced at the same time, substitution of factors is allowed for, and workers or capital can change from one sector to another.

Table 3.6 shows the results from the GTAP model for changes in import and export value, added value, and GDP in response to the increase in hydromet services in the analyzed sectors in Lao PDR. The impacts include the adjustment to other sectors in the economy, since the model takes into account the interactions between intermediate inputs and the markets for other goods and the link between factor remuneration and consumer income, among others. In Lao PDR, it can be observed that the relatively low elasticity of the agricultural sector causes a reduction in its productivity, and the other sectors capture a greater number of resources and displace some of the benefits from the agricultural sector. Only 15 percent[7] of the potential increase has been computed as attributable to the project for the BCA.

Table 3.6: Change in Added Value in Response to a 1 Percent Increase in Hydrometeorological Services, By Sector and Region (%)

	Added value (% change)	Value of imports (% change)	Value of exports (% change)
Agriculture	-0.0455	0 .5310	-0 .5585
Energy	0 .0677	0 .0695	0 .2243
Manufacturing and services	0 .0205	-0 .0083	0 .1499
GDP change (%)	0 .0961		

7 Since a range of actions related to increased hydromet services are being developed in the region, it is probable that several projects will jointly contribute to improving water resources management, and so the joint potential will be larger. For the current hydromet modernization plan, a loss reduction factor of 15 percent is assumed, in keeping with other similar SEB analysis.

3.4 Mortality and material losses due to disasters

3.4.1 Mortality from natural disasters

Table 3.7 shows the number of deaths from floods and storms in Lao PDR between 1968 and 2016. The reported data show an average of more than five 5 deaths per year in years having a flood or storm event.

Table 3.7: Number of deaths from floods and storms in Lao PDR, 1968–2016

Year	Disaster type	Location	Number of deaths
1968	Flood	South, along Mekong River	2
1971	Flood	Vientiane	14
1978	Flood	Southern, central regions	31
1992	Flood	Whole country	10
1994	Flood	Xayaboury, Khammouane	7
1996	Flood	Huaphanh, Phongsaly, Luanprabang, Luangnamtha, Borikhamsay, Savanhnakheat, Vientiane, Khammuoane Provinces; Vientiane Capital	30
1997	Storm	Xayaboury	1
2000	Flood	Louang Namtha, Bolikhamxay, Kham Muane, Savannakhet, Champasak, Saravan, Vientiane	15
2002	Flood	Xiengkhuang, Bilikhamxay, Khammouan, Savannakhet, Champasak, Attapue	2
2002	Flood	Bolikhamsay, Savannakhet, Vientane, Khaman, Udomsay, Luang Prabang	2
2005	Flood	Oudomxay, Xayabuly, Vientiane Capital, Xiengkhuang, Vientiane Province, Bolikhamxay, Khammouan, Savannakhet, Xekong, Attapue	5
2006	Flood	Oudomxay, Luangnamtha, Luangprabang, Salavan, Attapue, Xiengkhuang	6
2006	Storm	Luangnamtha, Luangprabang, Champasak, Salavan, Xiengkhuang	5
2007	Flood	Vientiane Capital, LuangNamTha, Khammuane, Savannakhet, Saravane Provinces	2
2007	Storm	Luangnamtha, Oudomxay, Xiengkhuang, Xekong	1
2008	Flood	Luangprabang, Vientiane Capital, Bokeo, Vientiane Province, Bolikhanxay, Champasak, Layabaly, Huaphau, Luangnamtha, Khammanan, Xekong, Oudomxay, Phongsaly	13

2009	Flood	Attapeu, Xekong, Salavan, Savanakhet, Champasak	28
2011	Flood	Luangprabang, Vientiane Province, Khammouan, Vientiane Capital, Savanakhet, Champasak	30
2012	Flood	Houphan, Luangprabang	6
2013	Flood	Bolikhamxay, Xiengkhuang, Luangnamtha, Salavan, Xayabury	29
2014	Flood	Whole country	5
2014	Flood	Champasak, Soukkhoum District	1
2015	Flood	Nan District, Luang Prabang, Nafay Village	7
2016	Flood	Xayabuly (Sainyabuli), Louangphabang	6
2016	Flood	Xayaburi, Luang Prabang, Ouxomxay, Houaphanh, and Bokeo	1

Sources: Data compiled from national statistics reported to Mekong River Commission; annual flood reports; Budde Blog; Reliefweb; EM-DAT; Dartmouth Flood Observatory database; DesInventar; FloodList database; and Global Disaster Alerting Coordination System (GDACS) database.

3.4.2 Material losses from natural disasters

Table 3.8 shows the affected population and estimated material losses due to extreme weather in Lao PDR between 1966 and 2014. When no data are reported for the economic losses, the average value for an affected person is applied to the affected population for estimates. The analysis shows an average loss value of almost US$17 million per year due to extreme weather events.

Table 3.8: Affected population and estimated material losses due to extreme weather

Year	Location	Affected population	Estimated damages (US$, thousands; base 2002)
1966	N/A	72,000	140.7
1968	South, along Mekong river	9,600	19.4
1971	Vientiane	11,5000	4.6
1978	Southern, central regions	459,000	72,622.8
1984	N/A	2,000	316.4
1991	Khammouane, Savannakhet, Champasak	332,000	52,528.9
1992	Whole country	150	1,742.4
1994	Xayaboury, Khammouane	190,000	30,061.7
1995	Bokeo, Khammuane	1,180	186.7
1995	Luangnamtha	181	28.6
1995	Luangnamtha, other provinces	200,000	31,643.9

1995	Bolikhamxay, Savannakhet, Champasak, Sekong, Attapeu	391,400	61,927.2
1995	Central, southern regions	480,000	3,475.8
1996	Huaphanh, Phongsaly, Luanprabang, Luangnamtha, Borikhamsay, Savanhnakheat, Vientiane, Khammuoane Provinces; Vientiane Capital	420,000	25.3
1996	Savannakhet, Xayaboury, Khamuanne	19,751	3,124.9
1997	Borikhamxay, Khamuane, Saravane, Savannakhet	366,844	58,041.9
1997	Champasak, Phongsaly, Khammuane, Attapeu, Saravane, Savannakhet, Bolikhamxay	177,690	28,114.1
1997	Bokeo, Xayaboury	2,073	328.0
2000	Louang Namtha, Bolikhamxay, Kham Muane, Savannakhet, Champasak, Saravan, Vientiane	450,000	71,198.8
2001	Khammouane, Savannakhet, Champasak, Attapeu	453,000	71,673.5
2001	Phongsaly, Luangnamtha, Xayabouly, Vientiane Capital, Vientiane Province, Khammouan	109,947	17,395.8
2002	Xiengkhuang, Bilikhamxay, Khammouan, Savannakhet, Champasak, Attapue	325,962	51,573.6
2002	Bolikhamsay, Savannakhet, Vientane, Khaman, Udomsay, Luang Prabang	150,000	23,732.9
2004	Oudomxay, Bokeo, Houaphan, Vientiane Capital, Xiengkhuang, Vientiane Province, Bilikhamxay, Khammouan, Savannakhet, Salavan, Xekong	89,950	14,231.9
2005	Oudomxay, Xayabuly, Vientiane Capital, Xiengkhuang, Vientiane Province, Bolikhamxay, Khammouan, Savannakhet, Xekong, Attapue	186,423	29,495.8
2006	Oudomxay, Luangnamtha, Luangprabang, Salavan, Attapue, Xiengkhuang	103,434	4,535.1
2007	Vientiane Capiatal, LuangNamTha, Khammuane, Savannakhet, Saravane Provinces	159,463	25,230.2

2008	Luangprabang, Vientiane Capital, Bokeo, Vientiane Province, Bolikhanxay, Champasak, Layabaly, Huaphau, Luangnamtha, Khammanan, Xekong, Oudomxay, Phongsaly	243,342	38,501.5
2009	Attapeu, Xekong, Salavan, Savanakhet, Champasak	272,943	43,185.0
2010	N/A	10,851	1,716.8
2011	Luangprabang, Vientiane Province, Khammouan, Vientiane Capital, Savanakhet, Champasak	429,954	68,027.2
2012	Houphan,Luangprabang	14,518	2,297.0
2013	Bolikhamxay, Xiengkhuang, Luangnamtha, Salavan, Xayabury	15,671	2,479.5
2014	Whole country	92,165	14,582.3
2014	Bolikhamsai, Houphan, Khammoune, Luangnamtha Provinces	45,000	7,119.9
2016	Xayabuly (Sainyabuli), Louangphabang	4,977	787.5
2016	Xayaburi, Luang Prabang, Ouxomxay, Houaphanh, Bokeo	5,000	791.1

Sources: Data compiled from national statistics reported to Mekong River Commission; annual flood reports; Budde Blog; Reliefweb; EM-DAT; Dartmouth Flood Observatory database; DesInventar; FloodList database; and Global Disaster Alerting Coordination System (GDACS) database.

Note: IPP = independent power producer.

3.4.3 Avoided losses and mortality from natural disasters

The avoided losses calculated in the benefits analysis are represented by the LRR. There were calculated as 15 percent of the deflated accounted losses for the considered period with improved hydromet services. This figure is a lower than the range of values commonly used across World Bank studies which take into account 20 to 60 percent, particularly related to calculations for East Europe. Avoided mortality has not been computed in monetary units due to the controversy of some methods such as statistical value of life, highly dependent on people's incomes. However, the historical number of deaths presented in **table 3.7** clearly highlights the importance of the hydromet service to reduce loss of life due to disasters.

4. AGGREGATION: PRESENT VALUE OF BENEFIT

In order to aggregate the total benefits over time, it is necessary to actualize the values of benefits to the present value (PV). This step involves identifying the flows of resulting benefits in each year and using discounting to add these up to a single value (Beier 1990; Chapman 1992; Adler and Posner 2001; WMO et al. 2015). The PV of benefits is the cumulative value of benefits in a period expressed in discounted monetary units.

4.1 Choice of discount rate and time period

There was no specific government or agency direction on what discount rate to use in this SEB, and different analysts, countries, and agencies have different views on the correct discount rate. In a 2007 survey, Zhuang et al. (2007) studied discount rates used for public projects around the world and found rates from 2 percent to 15 percent, with lower rates more common in developed countries and higher rates more common in developing countries. Analysis conducted for multilateral development banks (e.g., the World Bank) tends to use discount rates in the higher range. The World Bank provides discount rate guidance in its Handbook on Economic Analysis of Investment Operations (Belli et al. 1998), noting that it has traditionally applied discount rates in the 10–12 percent range. Other major multilateral development banks (Asian Development Bank, Inter-American Development Bank, African Development Bank, and European Bank for Reconstruction and Development) also tend to use rates in this range (Zhuang et al. 2007). WMO et al. (2015) provides a more detailed discussion of the choice of discount rates. For purposes of our analysis, we use a 12 percent rate of discount as an upper bound and then conduct sensitivity analysis using a lower bound of 3 percent.

Our analysis indicates a five-year period for the primary investment in improving hydromet services. The benefits of any such project would presumably last much longer, and therefore we have chosen a 15-year analysis period to develop the aggregated SEB estimates. With a higher discount rate (e.g., 12 percent), benefits more than a couple decades out have minimal present value; thus truncating the analysis at 15 years is not likely to have a big impact on project decisions, and also allows a relatively short-run horizon, which is more informative when a high level of uncertainty is present. The maximum effectiveness rate of the plan is not achieved in a linear trend, but a path of accumulating improvements has been defined based on the actions proposed in the plan, considering a conservative rate of implementation (up to 60 percent at the end of the five-year period).

4.2 Values for SEB analysis

Table 4.1 summarizes the key variables for the SEB analysis, including project timing, benefits, and the discount rate. For all calculations, real values were applied that do not factor in inflation or potential changes in exchange rates. As mentioned before, a discount rate of 12 percent was applied as a baseline discount rate (following the World Bank's guidelines on economic analysis). However, a sensitivity analysis using a 3 percent discount rate captures the lower bound, and may reflect lower interest rates as Lao PDR continues to develop.

Table 4.1: Key variables for SEB calculations for Lao PDR

Key Variables	Value
Project Timing	
Total project investment period	Years 1 to 5
Total SEB analysis period	15 years
Benefit estimates (annual US$, millions)	
Benchmarking survey	86.9
Benefits to general public (willingness to pay)	3.7
Increase in GDP (unblocked productivity)	57.9
DRM-avoided losses	4.2
Discount rate	
Base case	12%
Lower value for sensitivity analysis	3%

4.3 Baseline SEB analysis

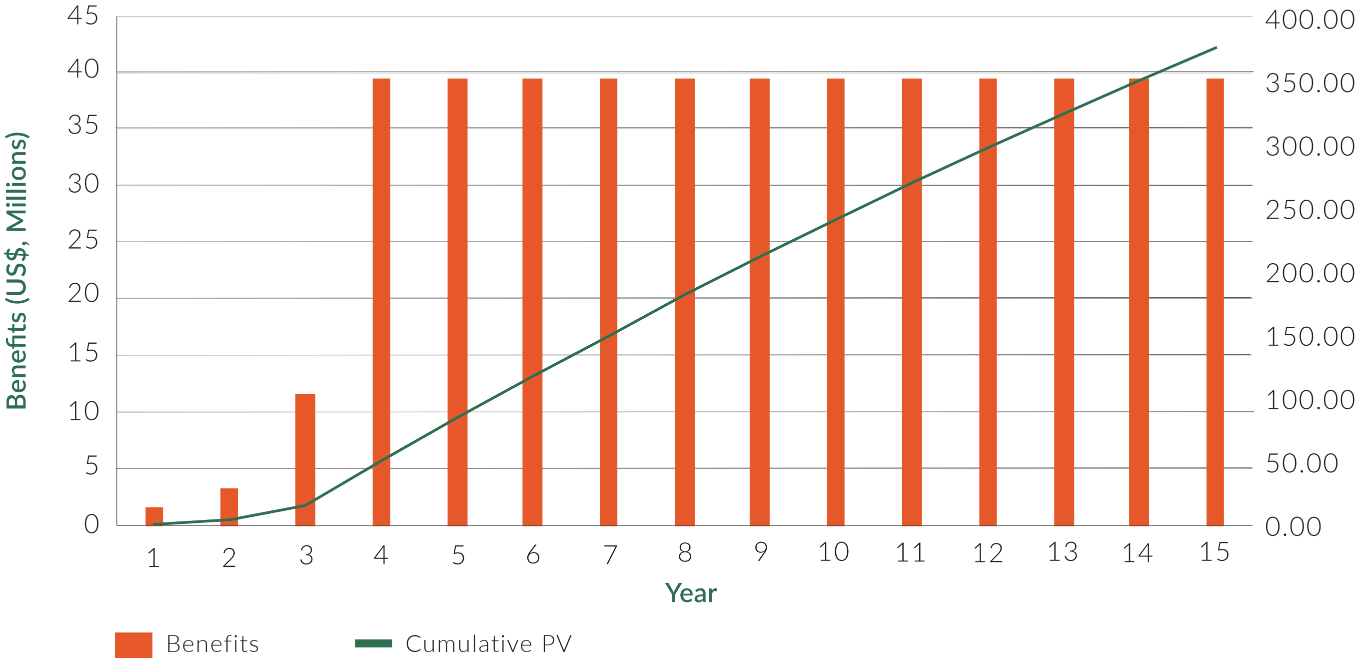
Using the 3 percent and 12 percent discount rates as lower and upper bounds, and with the estimated annual benefits and costs as baselines, ex ante BCA estimates were established for the hydromet modernization plan in Lao PDR. **Table 4.2** and **figure 4.1** show the results from the baseline SEB calculations. The present value of benefits is between US$186.5 million and US$375.1 million using a time horizon of 15 years and a 12 percent and 3 percent discount rate, respectively.

Table 4.2: Baseline SEB calculations for Lao PDR (actualized 15 years)

	Benefit estimates (US$, millions)	
Discount rate (%)	**3.0**	**12.0**
Benchmarking survey	495.4	246.3
Benefits to general public (willingness to pay)	21.0	10.4
Increase in GDP (unblocked productivity)	329.8	164.0
DRM-avoided losses	24.3	12.1
Total PV benefits[a]	375.1	186.5

a Total PV benefits do not include benchmarking in order to avoid double counting.

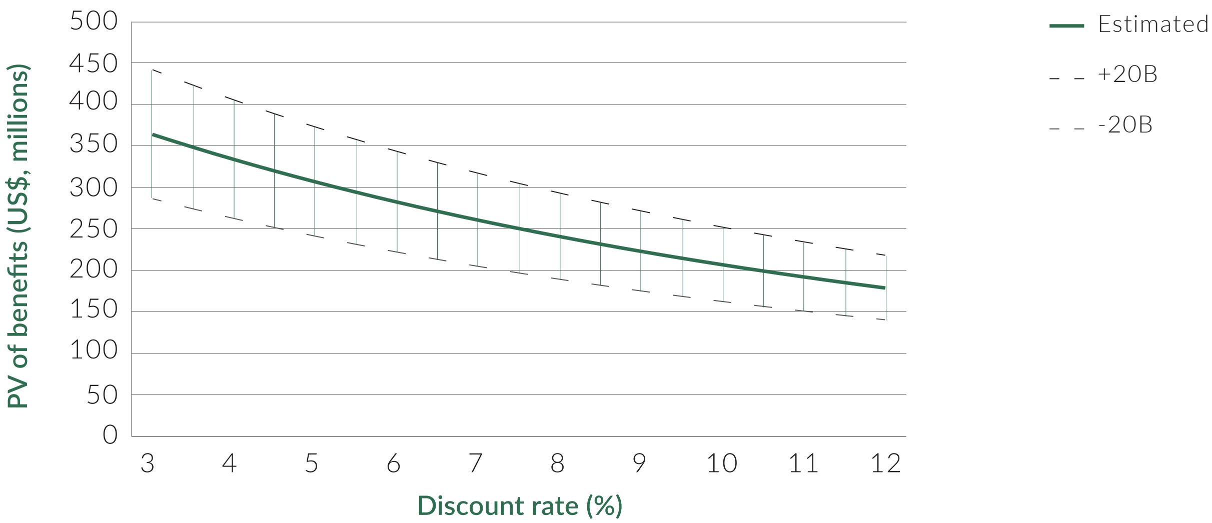
Figure 4.1: Socioeconomic Benefits Values



4.4 Sensitivity analysis

Given the uncertainty in several parameters used in the analysis, we undertake sensitivity analysis to see which factors may change the initial indication of the viability of a hydromet improvement project. Holding other project variables constant, we examine (i) the impact of the discount rate, (ii) a decrease of 20 percent in the benefit estimates (lower estimate), and (iii) an increase of 20 percent in the benefit estimates (upper estimate). **Figure 4.2** shows the PV of benefits from each of the three subsequent sensitivity analyses. The results show high SEB values even in a framework whose assumptions are conservative.

Figure 4.2: Present Value Of Benefits For Different Discount Rates (Sensitivity Analysis)



Note: -20B = decrease of 20 percent in the benefit estimates (lower estimate); +20B = increase of 20 percent in the benefit estimates (lower estimate).

5. CONCLUSION

The analysis shows that the contribution of hydrometeorological information to Lao PDR's socioeconomic development is expected to be very high, particularly due to the potential benefits for the energy and tourism sectors and their contribution to GDP. Disasters related to water, especially floods, have played an important role in evaluating the improvement of hydrometeorological information. This study has not considered the numbers of deaths from an economic perspective, but only in terms of their social impacts. Some studies also estimate the economic value of life, such as value of statistical life. As this report has avoided valuing life in economic terms, the estimates presented in this study can be considered conservative. Adding an additional risk factor of 20 percent, as part of sensitivity analysis, a conservative PV of the expected benefits ranges between US$150 million and US$450 million. The findings of the report lead to the conclusion that hydrometeorological information is critically important for Lao PDR and that hydromet investments in the country are expected to be highly profitable.

Related to the methodology and findings generated through this analysis, a number of limitations are noted in the given the time and available resources. Particularly notable is that reliable information on current and potential accuracy of hydro-met products and services after the modernization was not available at the time of this analysis, and neither specific investment cost estimations for coping with the modernization of the service. Other data limitations include the lack of primary information for general public willingness to pay, and a very short sample for the benchmarking analysis. A larger effort in engaging stakeholders in the benchmarking process, including both central and local levels, may provide a more accurate assessment of the stakeholders' perceptions of the potential benefits of improved hydromet services. At the same time, there are additional potential benefits that have not been considered in this study, and could be subject to further studies, including the potential value of climate information linked to longer and more reliable climate records (e.g., early warning systems for drought), potential value of contribution to global weather forecasting data and services, implications for climate change adaptation, potential applications for agricultural crop insurance, etc. These limitations strengthen the assertion that the estimates presented in this study are conservative and the total socioeconomic benefits of improved hydrometeorological services in Lao PDR could be much larger.

6. REFERENCES

Adler, M. D., and E. A. Posner, eds. 2001. Cost-Benefit Analysis: Legal, Economic, and Philosophical Perspectives. Chicago: University of Chicago Press.

Beier, G. 1990. "Economic Analysis in Project Appraisal." Discussion Paper, World Bank, Washington, DC.

Belli P., J. Anderson, H. Barnum, J. Dixon, and J. Tan. 1998. Handbook on Economic Analysis of Investment Operations. Washington, DC: World Bank.

Chapman, R. 1992. Benefit-Cost Analysis for the Modernization and Associated Restructuring of the National Weather Service. Washington, DC: National Institute of Standards and Technology, United States Department of Commerce.

CPC (Committee for Planning and Cooperation). 2014. The Household of Lao PDR Social and Economic Indicators: Lao Expenditure and Consumption Survey 2002/03. Vientiane, Lao PDR: National Statistical Centre.

Hallegatte, S. 2012. A Cost-Effective Solution to Reduce Disaster Losses in Developing Countries: Hydro-Meteorological Services, Early Warning, and Evacuation. Policy Research Working Paper 6058, World Bank, Washington, DC.

Hertel, T. W. 2012. "Global Applied General Equilibrium Analysis using the GTAP Framework." In The Handbook of Computable General Equilibrium Modeling, vol. 1B, edited by Peter Dixon and Dale Jorgenson, chap. 12. Kidlington, UK: North-Holland.

Hilton, R. W. 1981. "The Determinants of Information Value: Synthesizing Some General Results." Management Science 27: 57– 64.

Howard, R. A. 1966. "Information Value Theory." IEEE Transactions on Systems Science and Cybernetics (SSC-2): 22–26.

IATA (International Air Transport Association). 2017. "Aviation Benefits 2017." Industry High Level Group. https://www.iata.org/policy/Documents/aviation-benefits-%20web.pdf.

Iglesias, A., L. Garrote, S. Quiroga, and M. Moneo. 2012. "A Regional Comparison of the Effects of Climate Change on Agriculture in Europe." Climatic Change 112 (1): 29–46.

Jha, A. K., and Z. Stanton-Geddes. 2013. Strong, Safe, and Resilient: A Strategic Policy Guide for Disaster Risk Management in East Asia and the Pacific. Washington, DC: World Bank.

Johnson, S. R., and M. T. Holt. 1997. "Value of Weather Information." In Economic Value of Weather and Climate Forecasts, edited by R. W. Katz and A. H. Murphy, 75–107. Cambridge: Cambridge University Press.

Johnston, R. J., J. Rolfe, R. S. Rosenberger, and R. Brouwer, eds. 2015. Benefit Transfer of Environmental and Resource Values: A Guide for Researchers and Practitioners. Springer.

Lazo, J. K. 2015. Survey of Mozambique Public on Weather, Water, and Climate Information. NCAR Technical Note NCAR/TN-521+STR. Boulder, CO: National Center for Atmospheric Research. DOI: 10.5065/D6B56GS4.

2016. "Economic Assessment of Hydro-Met Services and Products: The Weather Information Value Chain." Working paper, National Center for Atmospheric Research, Boulder, CO.

Lazo, J. K., R. S. Raucher, T. J. Teisberg, C. J. Wagner, and R. F. Weiher. 2008. "Primer on Economics for National Meteorological and Hydrological Services." World Meteorological Organization Voluntary Cooperation Program and National Center for Atmospheric Research, Societal Impacts Program, Boulder, CO. https://www.wmo.int/pages/prog/amp/pwsp/documents/Primer_on_Economics_for_NMHS_2008_01.pdf.

Macauley, M. 2005. "The Value of Information: A Background Paper on Measuring the Contribution of Space-Derived Earth Science Data to National Resource Management." Discussion Papers dp-05-26, Resources for the Future.

6. REFERENCES (CONTINUED)

Mjelde, J. W., S. T. Sonka, and D. D. Peel. 1989. "The Socioeconomic Value of Climate and Weather Forecasting: A Review." Research Report No. 89-01. Midwestern Climate Center, Climate and Meteorology Section, Illinois State Water Survey, Champagne, IL.

Murphy, A. H. 1993. "What Is a Good Forecast? An Essay on the Nature of Goodness in Weather Forecasting." Weather and Forecasting 8: 281–83.

Nguyen, T. C., J. Robinson, S. Kaneko, and S. Komatsu. 2013. "Estimating the Value of Economic Benefits Associated with Adaptation to Climate Change in a Developing Country: A Case Study of Improvements in Tropical Cyclone Warning Services." Ecological Economics 86 (2013): 117–28. http://dx.doi.org/10.1016/j.ecolecon.2012.11.009.

Quiroga, S., and A. Iglesias. 2009. "A Comparison of the Climate Risks of Cereal, Citrus, Grapevine and Olive Production in Spain." Agricultural Systems 101: 91–100.

Quiroga S., and C. Suárez. 2016. "Climate Change and Water Scarcity Effects on the Rural Income Distribution in the Mediterranean: A Case Study for Spain." Natural Hazards and Earth System Science (special issue on climate change, extreme events, and hazards in the Mediterranean region) 16: 1–17.

Rogers, D. P., and V. V. Tsirkunov. 2013. Weather and Climate Resilience: Effective Preparedness through National Meteorological and Hydrological Services. Directions in Development. Washington, DC: World Bank.

Rosenberger, R. S., and J. B. Loomis. 2003. "Benefit Transfer." In A Primer on Nonmarket Valuation, edited by P. A. Champ, K. J. Boyle, and T.C. Brown, chap. 12. Dordrecht, Netherlands: Kluwer Academic Publishers.

Savage, L. 1954. The Foundations of Statistics. New York: John Wiley & Sons.

Sayavong, V. 2017. "Productivity and Technical Inefficiency of Paddy Rice Production in Laos: A Case Study of Farm Household Survey." EADN Working paper no. 118, East Asian Development Network.

Suchman, D., B. A. Auvine, and B. H. Hinton. 1981. "Determining Economic Benefits of Satellite Data in Short-Range Forecasting." Bulletin of the American Meteorology Society 62: 1458–65.

TDD (Tourism Development Department). 2016. "Statistical Report on Tourism in Laos 2016." Ministry of Information, Culture and Tourism, Vientiane, Lao PDR.

UNDP (United Nations Development Programme). 2010. "National Strategy on Climate Change of the Lao PDR." http://www.la.undp.org/content/lao_pdr/en/home/library/environment_energy/climate_change_strategy.html.

WMO (World Meteorological Organization), WBG (World Bank Group), GFDRR (Global Facility for Disaster Reduction and Recovery) and USAID (United States Agency for International Development). 2015. Valuing Weather and Climate: Economic Assessment of Meteorological and Hydrological Services. World Meteorological Organization, World Bank Group, Global Facility for Disaster Reduction and Recovery, and United States Agency for International Development. WMO no. 1153.

World Bank. 2008. "Weather and Climate Services in Europe and Central Asia: A Regional Review." World Bank working paper 151, World Bank, Washington, D.C.

2012. Main Report. Vol. 1 of Advancing Disaster Risk Financing and Insurance in ASEAN Member States: Framework and Options for Implementation. Washington, DC: World Bank. https://openknowledge.worldbank.org/handle/10986/12627.

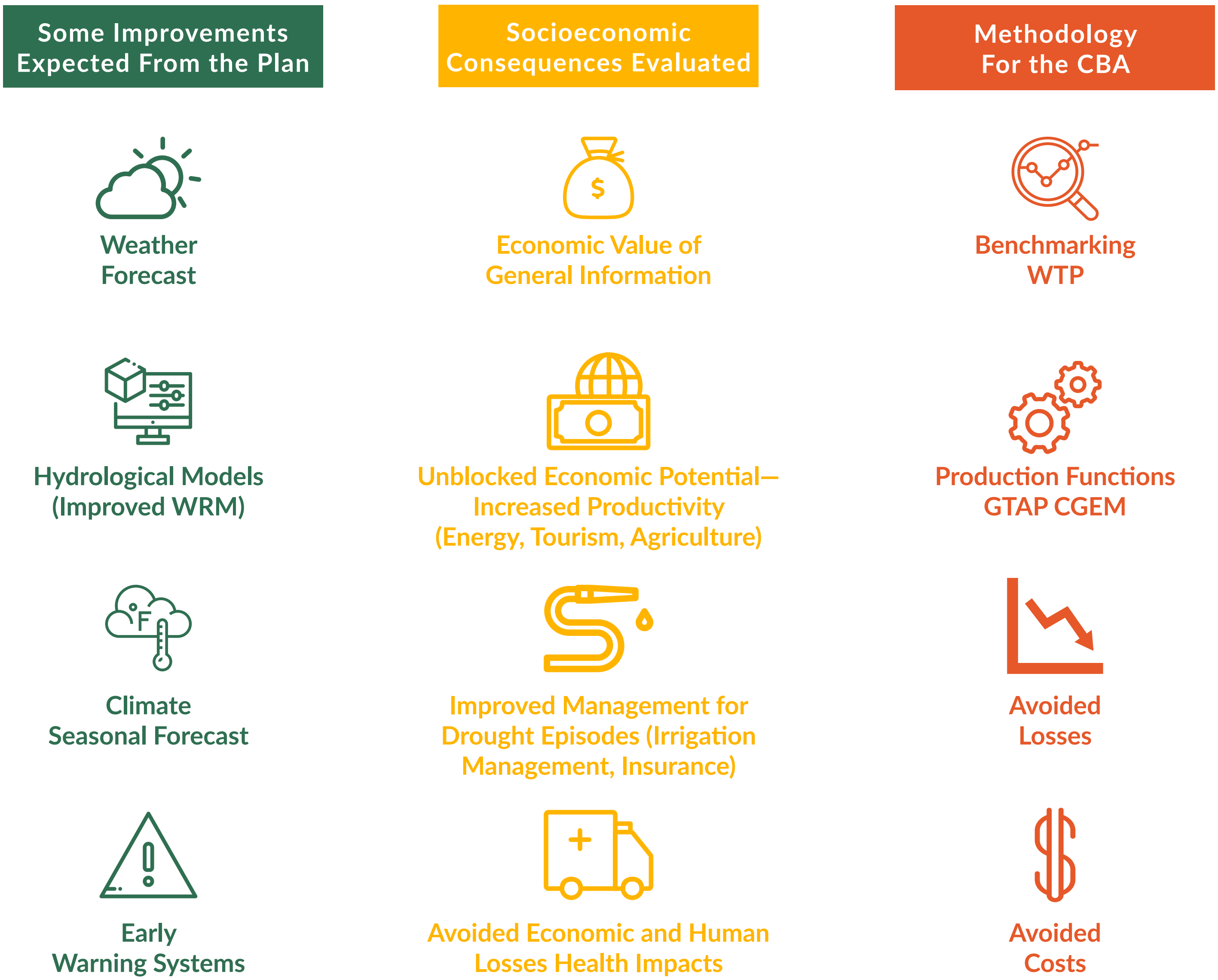
2017. "Disaster Risk Finance Country Diagnostic Note: Lao PDR." http://www.rcrc-resilience-southeastasia.org/wp-content/uploads/2017/12/world_bank_et_al._2016._lao_pdr_disaster_risk_financing_draft-diagnostc-report.pdf.

Zhuang, J., Z. Liang, T. Lin, and F. de Guzman. 2007: "Theory and Practice in the Choice of Social Discount Rate for Cost-Benefit Analysis: A Survey." ERD Working Paper no. 94, Manila, Philippines, Asian Development Bank.

ANNEX 1. METHODOLOGY FOR IMPACT ASSESSMENT

Figure A1.1 outlines the methodologies proposed for evaluating each of the aspects mentioned in the conceptual framework. A detailed description of the methods proposed is presented in the subsequent sections.

Figure A1: Proposed Economic Methods For The Evaluation Of Socioeconomic Impacts



Note: WRM = water resources management.

A1.1. Benchmarking for the impacts of improved hydrometeorological forecasting

Benchmarking is carried out by first using data and estimates from other countries and expert judgment to define and adjust two benchmarks for each country: (i) the average annual direct economic losses caused by hydromet hazards as a share of GDP; and (ii) the potential changes in annual losses with modernization as a percentage of the total level of losses. In a second step, these factors may be adjusted to account for country-specific estimates of weather and climate conditions, structure of the economy, and other factors. These factors will be a function of the weather dependency of the economy (i.e., national economic structure and hydrometeorological vulnerability) and the current and potentially improved quality of hydromet products and services (i.e., the efficiency of hydromet services with and without modernization). For the Europe and Central Asia (ECA) region, the World Bank reviewed a series of studies conducted in several countries and concluded that mean annual losses from hydromet hazards and events vary between 0.1 percent to 1.1 percent of GDP, and that the share of preventable or prevented losses ranges from 20 percent to 60 percent of total weather- and climate-related losses.

We followed the steps listed below to run a benchmarking process for this specific project:

STEP 1 Identify the relevant stakeholders for the new integrated water information system.

STEP 2 Organize a stakeholders' meeting to implement the process.

STEP 3 Evaluate the quality of the ex ante information system *(stakeholders' perception on a scale of 1 to 10).*

STEP 4 Evaluate the vulnerability to water impacts *(stakeholders' perception on a scale of 1 to 5).*

STEP 5 Estimate the average annual value of damages or problems related to hydrometeorology (stakeholders' perception based on a percentage of GDP, with options based on levels of vulnerability to hydrometeorology)

STEP 6 Rate the quality of the information after the implementation of the project (stakeholders' perception on a scale of 1 to 10)

STEP 7 Assign a damage reduction factor (stakeholders' perception expressed as a percentage).

An estimate of potential benefits of the new system can be calculated from these outputs.

A1.2. Benefits transfer for general public willingness to pay

An estimation approach for contingent evaluation of some aspects of social welfare is a common method for valuing nonmarket goods and services. This approach is known as benefits transfer because it transfers the results of existing valuation studies, correcting and adjusting for the current context (Johnston et al. 2015; Rosenberger and Loomis 2003; WMO et al. 2015).

This is the best and most feasible valuation approach when time and resources are not available for primary data collection and analysis. A number of cautions are relevant when using benefits transfer, however, particularly as there is a limited literature on economic values of improved weather forecasting in developing countries. We propose using the lower bound in the existing literature. The approach proposed here is a unit-value approach using adjustments based on differences in national income (assuming WTP to be in a linear relationship with income).

A1.3. Production functions and GTAP general equilibrium model for changes in water productivity (productive sectors)

In order to estimate the impact of improved hydromet services in the productive sectors, we need to analyze the impact of water productivity on Lao PDR's national economy. We consider the main sectors that are intensive in use of water resources in the country—i.e., agriculture, energy, tourism, etc. The average changes in the productivity of these sectors have been reported and their effects in the economy as a whole have been computed through an analysis of CGEM.

Changes in productivity (production function)

The changes in the marginal productivity of the productive sectors are analyzed on the basis of the available information on production and inputs used. Production function estimates consider the existing relationship among some combination of factors (labor, capital, energy, water, etc.) and the output or production levels obtained (Q). We consider an agricultural production function depending on endogenous factors (xi) (labor, capital) and exogenous factors (zi) (climate)—that is, Qi = f (zi, xi). The main advantage of this method is that it assumes a direct relationship between climatic variables and crop yields.

Use of GTAP CGEM to measure the impact on GDP through international trade

The average water elasticity estimation for the productive sectors may be used to characterize the productive sectors' response in physical terms—i.e., tonnes of agricultural production, net income from tourism, etc. However, in order to characterize the economic impact of these changes in productivity, it is necessary to consider the effect that they have through market interrelationships. For this purpose, a CGEM has been used. GGEMs comprise a representation of most economic sectors, where countries are linked through the volume of trade, prices in international markets, and financial flows. A change in relative prices induces effects on the general equilibrium that are transferred to the entire economy. The partial equilibrium models also allow the estimation of the benefits of certain public policies or programs and can consider substitution processes in production and consumption through market balance conditions. But CGEMs also allow adjustment to other sectors; they are useful in considering the effects on growth of the economy as a whole, since they take into account the interactions between intermediate inputs and the markets for other goods and the link between factor remuneration and consumer income, among others.

A1.4. Avoided losses

In this study, future savings, in terms of avoided losses, may be computed for a number of improved decisions, such as DRM, health consequences, or direct expenses avoided. Different methods will be used depending on the available information. Some of the methods used to arrive at the estimated benefits include market prices, direct property damage losses, or benefits transfer, as mentioned previously.

A1.5. Proposal on the methodology for benefit-cost analysis (aggregation)

Aggregation means comparing the total benefits over time to the total costs over time. In economics and policy analysis this is called benefit-cost analysis (or cost-benefit analysis in some countries); it involves identifying the flows of costs and resulting benefits in each year and using discounting to add these up to a single value (Beier 1990; Chapman 1992; Adler and Posner 2001; WMO et al. 2015). This value can be presented as the net present value (NPV), benefit-cost ratio (BCR), or internal rate of return (IRR). The NPV is benefits minus costs expressed in discounted present value terms. Calculating NPV consists of discounting future cash flows to take into account discount rates considering the real interest rate. **The NPV can be obtained as follows:**

$$NPV = \Sigma \{BN/(1 + r)^N$$

In this equation, BN is the net period cash flow during the year N, r is the real interest rate (discounted for inflation), and N is the number of years considered for the evaluation of the project. The real interest rate (percentage) is the lending interest rate adjusted for inflation as measured by the GDP deflator. The real interest rate will be based on the World Bank database for the period 2011–2016; and a sensitivity analysis with respect to the discount rate will be carried out.

The BCR is the ratio of the discounted benefits to the discounted costs. The IRR is the implied rate of return on investment funds. Each approach uses the same benefit and cost information but summarizes them differently. An NPV greater than zero, a BCR greater than 1, and an IRR greater than the applicable discount rate all suggest that a project is worth doing (i.e., overall the project increases societal welfare).

ANNEX 2. BENCHMARKING QUESTIONNAIRE: ORDER OF MAGNITUDE DRM BENEFITS IN LAO PDR

Objective: Develop an estimated order of magnitude for the benefits of DMH, focused on the potential capacity of the hydromet service to avoid losses related to water/weather/climate.

Step 1: Subjective evaluation of vulnerability of the region to impacts related to water/weather/climate

Indicate below your personal evaluation of vulnerability (from 1 to 5).

1	2	3	4	5

Step 2: Personal perception of annual average damages related to national income (GDP)

According to the World Bank, GDP in Lao PDR is about US$15.91 billion. This is the total monetary value for all the goods and services produced in the country in one year. Based on your evaluation in step 1 of the vulnerability of the region to water/weather/climate, provide a perceived estimation of annual average value of damages in Lao PDR with respect to the national income (gross domestic product) as below:

1. 0.2% of GDP (0.002)
2. 0.4% of GDP (0.004)
3. 0.6% of GDP (0.006)
4. 0.8% of GDP (0.008)
5. 1% of GDP (0.010)

1	2	3	4	5

Step 3: Step 3: Assignment of a reduction factor for damages or losses Assignment of a reduction factor for damages or losses

Now think about how much damages may be reduced on average as a result of improvements in the information that DMH provides through its products and services. We will refer to that as the loss reduction factor (LRF).

In selecting a LRF, you should consider the ability of the population, firms, and public institutions such as emergency services to respond when they have improved information. For example, if the losses are mainly concentrated in buildings and infrastructures, the loss reduction factor should be low. If the opposite is true, and losses mainly affect human beings, crops, or livestock, the potential for reducing the losses should be high.

Please indicate your subjective estimation of the reduction in losses or damages (expressed as a percentage) as a result of improved DMH information:

LRF: ___%

ANNEX 3. BENEFIT-COST ANALYSIS FOR LAO PDR SOUTHEAST ASIA PROJECT

Component 2

BCA consists of comparing total benefits over time to total costs over time. This value can be presented as the NPV or the BCR. The NPV is benefits minus costs expressed in discounted present value terms. The BCR is the ratio of the discounted benefits to the discounted costs. Each approach uses the same benefit and cost information but summarizes them differently. An NPV greater than zero or a BCR greater than 1 suggest that a project is worth doing (i.e., overall the project increases societal welfare). This analysis was applied to Component 2 of the Lao PDR Southeast Asia Disaster Risk Management project.

A3.1. Costs

For the purposes of using BCA to assess the potential economic benefits of Component 2, we assume that information flows optimally as needed, from product generation to dissemination to end-use. Thus the economic and social values that can be derived from any investment will require expenditures not only on hard infrastructure but also on the entire value creation process to ensure beneficial societal outcomes. Investments should thus include sufficient initial and ongoing expenditures on personnel, operations, and maintenance, as well as on information dissemination and communication for appropriate reception, understanding, and use of information and for decision making (as indicated in figure 1.1 showing the hydromet information value chain) (Lazo 2016).

The costs are assumed to be US$10 million, based on the budget of the modernization plan for the whole period of the project (five years). In addition to the initial investment, factors for capital replacement and upkeep (e.g., to account for depreciation) and for operations and maintenance (O&M) are considered to be 10 percent during the entire period. Experience suggests that the incremental O&M costs are equivalent to approximately 10 to 15 percent of the investment budget. As DMH in Lao PDR is a small service, we use the lower value in this study.

A3.2. Values for BCA analysis

Table A3.1 summarizes the key variables for the benefit-cost analysis, including project timing, costs, benefits, and the discount rate. For all calculations, real values were applied that do not factor in inflation or potential changes in exchange rates. A discount rate of 12 percent was applied as a baseline (following the World Bank's guidelines on economic analysis). However, a sensitivity analysis using 3 percent discount rate captures the lower bound and may reflect lower interest rates as Lao PDR continues to develop.

Table A3.1: Key variables for benefit-cost calculations in Lao PDR

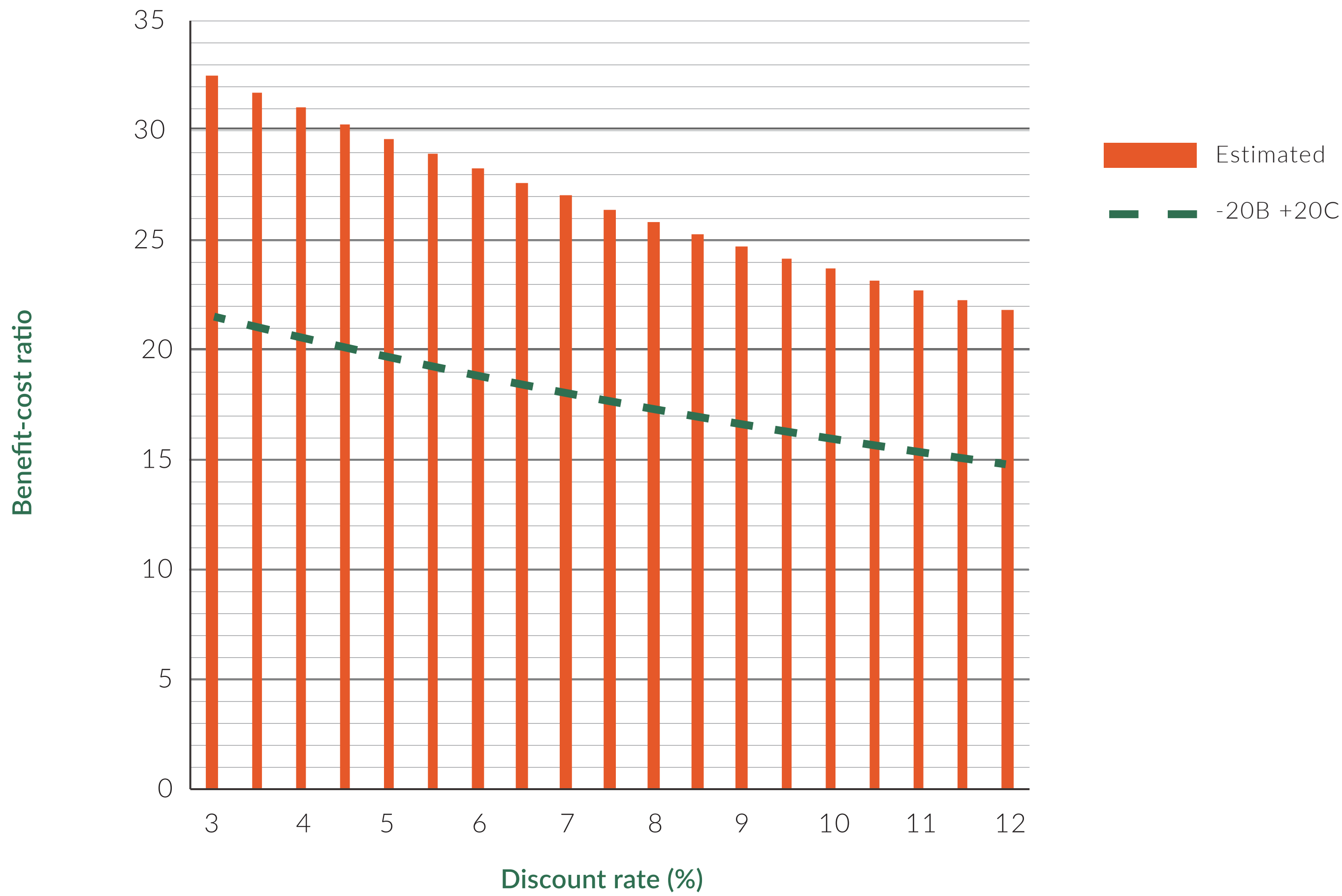
Variables	Value
Project Timing	
Total project investment period	Years 1 to 5
Total BCA analysis period	15 years
Project costs (US$, millions)	
First-year cost of investment	2.0
Total cost of investment (5 years)	10
Annual maintenance and operational costs (from year 1)	0.2
Discount rate	
Base case	12%
Lower value for sensitivity analysis	3%

Note: Benefits considered are those presented in section 4 of this report.

A3.3. Benefit-cost analysis

The BCR has been computed for the baseline and the lower estimate scenario described above; the results are shown in figure A3.1. There is an important source of uncertainty in the discount rate considered, and for that reason significant variations in the discount rate—from 3 percent to 12 percent—have been considered for the sensitivity analyses. It can be observed that in all cases the project shows benefits that exceed costs, since the cost-benefit ratio is greater than 1 for the lower estimate scenario and for any discount rate considered. For this reason, and because the assumptions in this report are based on the conservative lower bound, the expected benefits of this project are considered robust to the possible sources of uncertainty.

Figure A3.1: Benefit-Cost Ratio for Component 2 Response to Discount Rate Changes



Note: Estimated values are the baseline estimations; the red line shows a lower-estimate scenario (20 percent less benefits than baseline and 20 percent more costs).

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