Risk and uncertainty analysis of natural environmental assets threatened by hydropower projects: case study from Sri Lanka

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This paper develops a methodology to analyse the risk and uncertainty associated with the decision to implement a hydropower project that threatens a series of waterfalls that are considered a unique natural environmental asset. The methodology to quantify the risk associated with that decision is developed using the principles of risk analysis. The objective of uncertainty analysis is defined with descriptions of proxy risk simulations that need to be carried out to describe the associated uncertainty. The interpretation of the results from the risk simulations and their use to estimate the level of confidence in the decision is described. A published case study on the estimation of bounds on the "economic value of waterfalls" from a reverse analysis is used to describe the methodology to quantify the risk and describe the uncertainty associated with the economic valuation of the threatened asset.

1. Introduction

When a unique series of waterfalls, considered a natural environmental asset by society, is threatened by a proposed new hydropower project, there invariably are disputes as to which should be sacrificed, the asset or the hydropower project. The problem is that there are no clear and easy methods to value these assets, which in most cases involve emotional issues. Contingent valuation is often cited as the only method available for direct valuation [Dixon et al., 1988; Markandya, 1992; Munasinghe, 1993; Munasinghe and Lutz, 1993; Meier and Munasinghe, 1994; ADB, 1996; Pearce and Warford, 1993; Winpenny, 1996; Rutherford et al., 1998].

An indirect method suggested in the literature is reverse analysis [ADB, 1996; Ranasinghe, 1997]. This method works backwards from the present value of net benefits at the required economic rate of return to determine the value of environmental impacts and/or losses that is acceptable in order to justify the project. This value for environmental impacts and/or losses on the threatened unique natural environmental asset is called the decision bound. In the absence of more reliable information, decision-makers are then forced to assume an economic value that they think is what society would value the unique asset at in arriving at the decision to implement or reject the project. Clearly, there is considerable risk and uncertainty associated with this decision.

The objectives of this paper are to develop a methodology to analyse risk and uncertainty associated with a decision to implement a hydropower project that threatens a unique natural environmental asset and to demonstrate the methodology by using an actual case study of a hydropower project that threatens a series of unique waterfalls in Sri Lanka.

This paper uses the case of waterfalls threatened by the proposed Upper Kotmale Hydropower Project (UKHP) in Sri Lanka to demonstrate the analysis of risk and uncertainty of the decision to implement a project when a unique natural environmental asset is threatened. According to the *Conceptual Design Report* [CEB, 1994a], the selected alternative for UKHP is a 150-MW capacity, run-of-river scheme generating 531.9 GWh annually with a regulation pond and concrete gravity dam. However, the *Environmental Impact Assessment Report* [CEB, 1994b] stated that implementing this alternative UKHP seriously impacts seven of the most scenic waterfalls in Sri Lanka.

2. Economic value of the waterfalls

Even though UKHP is a clear example of the conflict between the need for development and preservation of unique natural assets, the decision problem is that there are no clear and easy methods to value these assets. In most cases the preservation of the asset involves emotional issues, even though the asset may not be used directly by individuals or society.

According to Munasinghe [1993], a number of concepts of value and practical valuation techniques have been developed to trace the welfare impacts of environmental changes, which can result in measurable changes in production and/or changes in environmental quality. The value of the environment arises because people, either as individuals or as society, wish to consume it, and is due to its "use values" and "non-use values". Hence, the total economic value of an environmental resource/asset consisting of its use values and non-use values is defined as the basic concept of economic value [Munasinghe, 1993; ADB, 1996; Pearce and Warford, 1993; Pearce, 1992].

The use value which arise from physical personal use of the environmental resource/ asset is broken down further into "direct use value", "indirect use value" and "option value" [Munasinghe, 1993]. These categories can be illustrated by the following three examples in the case of waterfalls threatened by UKHP.

- Direct use values can be from use of water by local people for drinking and other needs, and use of waterfalls for generating hydro-electricity through small-scale power projects.
- Indirect use values can be from the amenity value enjoyed by those who visit the waterfalls, stability to prevent erosion and landslides, and maintenance of watershed that may benefit downstream agriculture.
- Option value can be from the amenity value of those who have not yet visited the waterfalls but would wish to visit them some time in the future. Even though option value is shown as a part of use value, in reality it is a value that falls between the use value and the non-use value. According to Munasinghe [1993], option value is based on how much individuals are willing to pay today for the option of preserving the asset for future personal direct and indirect use.

The non-use value which arises from non-physical non-personal use of the environmental resource/asset is broken down into "existence value" and "bequest value". Existence value is defined as the perceived value of the environmental asset unrelated either to current or optional use, while bequest value is defined as the value that people derive from knowing that others will be able to benefit from the asset in the future [Munasinghe, 1993]. Again, this can be illustrated by examples in the case of waterfalls of UKHP.

- Existence value can arise from the aesthetic value of the waterfalls in their present state.
- Bequest value can arise from the altruistic values of individuals' desire to preserve the waterfalls to be enjoyed by future generations.

Hence, the total economic value, given by TEV, can be written as:

$$TEV = UV+NUV = [DUV+IUV+OV] + [EV+BV] \quad (1)$$

where UV is use value, NUV is non-use value, DUV is direct use value, IUV is indirect use value, OV is option value, EV is existence value and BV is bequest value.

Theoretically, the use and non-use values can be measured by an individual's: maximum willingness to pay (WTP) to prevent the environmental damage or realise an environmental benefit; and/or minimum willingness to accept (WTA) compensation for accepting a specific degradation in environmental quality [ADB, 1996]. It is often argued that the appropriate measure of an environmental loss is not the WTP to prevent it, but instead the WTA compensation for accepting the environmental loss [Rutherford et al., 1998; Stirling, 1992]. Since WTA is more difficult to measure empirically, because it is often impossible to identify the upper bound on values, WTP is most often used in practice to assess benefits or damage.

When non-use motives are strong and non-use values are potentially large, as in the case of UKHP, the economic valuation has to rely on a technique called contingent valuation method (CVM). CVM is a survey-based method which can be used to estimate both use and non-use values of an environmental asset [ADB, 1996]. For example, the use values of the waterfalls can be estimated by employing indirect primary economic valuation methods such as hedonic pricing and travel cost [CEB, 1994a] and these values can be deducted from the contingent valuation of the waterfalls to obtain an estimate of the non-use values.

In this method, a hypothetical environmental change (e.g., for preservation of the majestic view of, or of public access to, the waterfalls) is presented in a survey and respondents are asked to quantify their WTP or WTA compensation for this environmental loss. Once values for a representative set of people have been determined, they are summed to estimate a total value based on the total number of affected individuals.

A main difficulty of CVM is the discrepancy between results generated by WTP and WTA for an environmental change/loss [Stirling, 1992]. Respondents generally cite significantly lower values for what they would be willing to pay in order to secure a particular environmental benefit than what they are willing to accept as compensation for its loss. This discrepancy tends to be greater with more "emotion-laden" issues [Stirling, 1992] (e.g., valuation of waterfalls threatened by UKHP is really a valuation of emotions). A direct consequence of using WTP as a measure to assess environmental losses will be significantly understated economic values [Winpenny, 1996; Rutherford et al., 1998; Stirling, 1992].

One of the most damning criticisms of CV, according to Winpenny [1996] is that people lack preferences for the environmental goods, sites or measures that they are questioned about. If these criticisms are valid, he claims it is a fundamental flaw of CV, which no amount of tinkering with methodology will eradicate. In addition it is stated that comparisons of hypothetical WTP and actual offers for private goods and charitable donations show large discrepancies, and that it is an uncomfortable reminder that CV measures what people say rather than what they do [Winpenny, 1996]. In similar vein, Stirling [1992] argues that so sensitive is CV to the subjective social and psychological circumstances of respondents and to the contexts of the studies themselves, that some have been led to conclude that the method becomes the message.

Hearne [1996] states that a major restriction on the use of CV is that the type of information provided is designed to answer questions that are not relevant to developing countries, especially in rural areas where environmental goods and services are important inputs into family production functions. For example, given the poverty levels

Table 1. Summary of the economic analysis for the selected alternative for UKHP

Discount rate	10 %
Present value of benefits (US$ million)	260.961
Present value of costs (US$ million)	224.152
Net present value (US$ million)	36.809
Benefit-cost ratio	1.16
Economic internal rate of return	11.47

in developing countries and limitations on government expenditure, the estimation of non-use values may not be appropriate because the value of environmental amenities is relatively less important than the value of environmental resources in the production process [Hearne, 1996].

Winpenny [1996] argues that it is no defence against these difficulties of CV to say "Some number is better than no number." Likewise, the argument that CV is the only method to estimate option and non-use (existence and bequest) values is a hollow defence if CV contains deep and irremediable flaws [Winpenny, 1996]. Therefore, the estimated economic value of the waterfalls will have a high degree of uncertainty, will be disputed and may not be reliable to the decision-maker.

Even though one could argue that the valuations are subjective, undervalued and/or unreliable, the important point is that there is some economic value to unique assets like the waterfalls. It is therefore not correct to argue that there is no economic value to the waterfalls threatened by the selected alternative for UKHP [CEB, 1994b] and ignore it in decision-making.

3. The case study

Present values for the selected alternative for UKHP, the 150-MW capacity run-of-river scheme generating 531.9 GWh annually, at the minimum acceptable rate of return (MARR) of 10 % for the economic analysis of UKHP are given in Table 1 [CEB, 1994a].

The positive net present value at 10 % indicates that the hydropower alternative is preferred to the next best thermal power alternative. This analysis assumed that there was no economic value for the waterfalls.

Even if there is some economic value to the waterfalls threatened by UKHP, the next important issue is whether it is practically possible to value these waterfalls. The discussion in the previous section highlighted the practical difficulties of CVM, indicating that any value estimated from a CVM may ulitmately not be reliable to the decision-maker.

Because of this difficulty in valuing the waterfalls, an innovative indirect method using a reverse analysis was developed [Ranasinghe, 1997]. This method works backward to determine the economic value that society has to place on the waterfalls to preserve them at the desired economic discount rate [Ranasinghe, 1997]. Then at a discount rate of 10 %, the decision-maker's choice is made as follows.

- If in the decision-maker's view, the economic value that society places on the waterfalls is less than US$ 77.5 million at 1994 prices (estimated decision bound), UKHP should be implemented. The reverse analysis to estimate this decision bound included valuations of the main non-waterfall environmental costs in implementing UKHP (resettlement costs, and mitigating and offsetting costs) and benefits equal to the avoided loss to the economy caused by air pollution in implementing the next best thermal alternative.
- If the economic value that society places on waterfalls is more than US$ 77.5 million, UKHP should not be implemented.

However, this decision bound implicitly assumes that the influence on a decision-maker to implement UKHP is the *same* as long as the supposed economic value that society places on the threatened waterfalls is lower than the decision bound. This assumption is however too simplistic for any rational decision-maker.

There is considerable risk and uncertainty associated with this decision as it is based on a proxy value for the actual economic value society places on these waterfalls. Secondly, there is always a chance that in reality the assumed value could have been the decision bound, thereby changing the decision-maker's preference. Thirdly, there is no certainty that the estimated decision bound is the actual indifference value of the society as it is dependent on the assumed discount rate for the economic analysis.

4. Risk analysis

According to Meier and Munasinghe [1994], the traditional and simple way of incorporating risk and uncertainty considerations in project-level benefit-cost analysis has been through sensitivity analysis. Using optimistic and pessimistic values for different variables can indicate which variables will have the most pronounced effects on benefits and costs [Munasinghe, 1993; Munasinghe and Lutz, 1993; Meier and Munasinghe, 1994]. It was noted that the sensitivity analysis does not reflect the probability of occurrence of the upper or lower values.

Munasinghe and Lutz [1993] state that risk can be treated probabilistically on the basis of known or estimated data, while uncertainty describes a situation where little is known about future impacts. Hence, no probabilities can be assigned to definite outcomes. However, according to Meier and Munasinghe [1994], uncertainty is especially important to environmental issues and plays an important role in environmental valuation and policy formulation [Munasinghe, 1993; Munasinghe and Lutz, 1993; Meier and Munasinghe, 1994]. This section will suggest a methodology to quantify the risk and describe the uncertainty associated with the decision to implement UKHP using the principles of risk analysis.

The objective of the risk analysis is to the determine the level of confidence in the decision to implement or reject the selected alternative for UKHP [CEB, 1994b]. The level of confidence in the decision is the probability at the point of indifference between the economic value that the society has to place on waterfalls to preserve them and the decision bound estimated from the quantification of risk of the extended benefit-cost analysis of the selected alternative for UKHP [CEB, 1994b]. In other words, the level of confidence is the probability when the decision bound is equal to the supposed economic value of the waterfalls estimated from a contingent valuation exercise or assumed by the decision-maker.

When the decision bound of the economic value of the waterfalls estimated from the extended benefit-cost analysis of the selected alternative for UKHP [CEB, 1994b] is DB, it is given by:

$$DB = PV_B - PV_C + PV_{EB} - PV_{EC} \qquad (2)$$

where PV_B and PV_C are the present value of economic benefits and economic costs estimated in the economic analysis using the least-cost approach, and PV_{EB} and PV_{EC} are the present value of environmental benefits and environmental costs of the hydro power option without the economic value of the waterfalls [CEB, 1994b].

@RISK, a commercially available risk analysis package, is linked to the economic valuations of the extended benefit-cost analysis of the selected alternative for UKHP [CEB, 1994b] to conduct the risk analysis. In addition to the model for decision bound given by Equation (2), @RISK requires as input an identification of random variables in the model and description of the risk involved in the random variables in terms of their expected values, standard deviations and probability distributions (PDs).

Because of the lack of data, estimates for all the cost variables – present value of benefits which is the present value of costs of the next best alternative; present value of costs (see Table 1); annual air pollution costs; annual extended resettlement costs; and extended mitigating and offsetting costs – are assumed as the expected values. The standard deviations reflect the perceived risk and dispersion associated with the individual risky variables. The sensitivity of the uncertainty of the decision bound can be described through percentage changes in the standard deviations of these input variables as the standard deviations reflect the perceived risk in these variables. The expected values, standard deviations and probability distributions for cost variables are given in Table 2 [Ranasinghe, 1999].

Since estimates for both benefits and costs are in terms of costs in the least-cost analysis (see Table 1), all PDs of variables that have positive costs are assumed as lognormal distributions (LN). This is a reasonable assumption as the LN is positively skewed and on the positive scale, both being important characteristics when describing a cost variable. The variables for the two negative annual costs, which are overestimations in the preliminary resettlement plan, are assumed as normal distributions (N) for theoretical consistency [Ranasinghe, 1999].

The percentage change from the base-case standard deviation for the three critical variables, present value of economic benefits and costs, and annual air pollution costs, as given in Table 3, reflects six perceived pessimistic and optimistic uncertainty scenarios to explore the sensitivity of the uncertainty of the decision bound of the economic value of the waterfalls estimated from the selected alternative for UKHP [Ranasinghe, 1999].

Table 2. Expected values, standard deviations and PDs for the base case

Cost variable	Expected value (in US$ million)	Std. deviation (in US$ million)	PD
Present value of benefits	260.961	52.1922	LN
Present value of costs	224.152	44.8304	LN
Annual air pollution cost	9.2	2.3	LN
1996 Resettlement costs	0.126	0.0126	LN
1997 Resettlement costs	1.019	0.1019	LN
1998 Resettlement costs	0.943	0.0943	LN
1999 Resettlement costs	0.00275	0.0003	LN
2000 Resettlement costs	-0.3995	0.0399	N
2001 Resettlement costs	-0.26	0.026	N
1996 EMP costs	0.374	0.0374	LN
1997 EMP costs	0.224	0.0224	LN
1998 EMP costs	0.224	0.0224	LN
1999 EMP costs	0.224	0.0224	LN
2000 EMP costs	0.224	0.0224	LN

Seven Monte Carlo simulations of the model given by Equation (2) were carried out to quantify the uncertainty in DB using the present values at the discount rate of 10 %, the economic discount rate used in the feasibility study [CEB, 1994a] for the base case and the six pessimistic and optimistic uncertainty scenarios given in Table 3 (see Ranasinghe [1999] for details).

The expected value (E[DB]) and standard deviation (σ_{DB}) for DB, the decision bound of the economic value of the waterfalls estimated from the extended benefit-cost analysis of the proposed alternative for UKHP, are US$ 76.24 million and US$ 68.61 million respectively for the base case. The values of E[DB] and σ_{DB} for DB from the seven Monte Carlo simulations are given in Table 4. Both the expected value and the standard deviation converged to less than 0.5 % with 5000 iterations in all seven simulations. As more and more iterations are executed during a simulation, the generated distribution becomes more stable because the change in statistics which describes it becomes less and less.

The generated cumulative distribution function (CDF) for DB for the base case from the simulation illustrating the levels of confidence in the decision to implement UKHP given an economic value that society places on waterfalls is shown in Table 4 for the different scenarios.

The number of iterations required to generate stable distributions varies, depending on the model being simulated

Table 3. Percentage change of the base-case standard deviations

Symbol	Pessimistic			Optimistic		
	P-1	P-2	P-3	O-1	O-2	O-3
Present value of benefits (%)	50	50	50	-50	-50	-50
Present value of costs (%)	50	50	50	-50	-50	-50
Annual air pollution cost (%)	0	20	-20	0	20	-20

Table 4. Results from the simulations

Moments (US$ mil)	Base case	Pessimistic			Optimistic		
		P-1	P-2	P-3	O-1	O-2	O-3
E[DB]	76.24	76.31	75.86	78.01	76.97	77.43	77.65
σ_{DB}	68.61	104.67	102.41	101.58	34.75	34.78	34.13
EV of the waterfalls (US$ mil)	Level of confidence (%)	Level of confidence (%)	Level of confidence (%)	Level of confidence (%)	Level of confidence (%)	Level of confidence (%)	Level of confidence (%)
0	87	78	78	79	98	98	99
10	84	75	75	76	97	97	97
20	80	72	71	72	95	95	95
30	75	68	67	69	91	91	91
40	70	64	63	64	86	86	86
50	65	60	60	61	78	79	79
60	58	56	55	57	68	69	69
70	52	53	51	52	57	58	59
77.5	48	49	48	49	48	49	50

and the distribution functions in that model. According to Ranasinghe and Russell [1992], the error band of the generated CDF from a simulation of 5000 iterations is about 2 % at 95 % confidence level. The error band is the accuracy to which the CDF generated from the simulation approximates to the unknown CDF of DB and at 95 % confidence level, the error band brackets the unknown CDF in 95 % of all simulation samples [Ranasinghe and Russell, 1992].

The levels of confidence in the decision to implement UKHP when the decision bound is equal to a supposed economic value (EV) of the waterfalls in US$ million, either estimated from a contingent valuation exercise or assumed by the decision-maker, are also given in Table 4. In other words, it is the association of a level of confidence in the decision to implement UKHP, given an economic value that society places on waterfalls, to each of the different uncertainty scenarios.

The values of the levels of confidence show that when the supposed economic value that society places on waterfalls is low, the confidence in the decision to implement UKHP is high. Clearly, that supposed value is the most uncertain and contentious variable in the decision. However, the decision bound that was estimated for prudent decision-making implicitly assumed that the influence on the decision-maker of the supposed economic value that society places on waterfalls is the *same* as long as it is lower than the decision bound (i.e. US$ 77.5 million in 1994 prices [CEB, 1994b]).

What the uncertainty analysis is showing is that that assumption is too simplistic. As common sense dictates, the influence on the decision-maker to reject UKHP will be high when the supposed value that society places on waterfalls is high. For example, if a decision-maker thinks that the economic value of the waterfalls is US$ 70 million, the decision bound approach dictates that UKHP should be implemented. The decision-maker on the other hand would be reluctant because the economic value of the waterfalls is high enough to make a decision error. The uncertainty analysis shows that this error is about 48 % in the base case with sensitivity between 41 % and 49 %, depending on the uncertainty scenario. Hence, the decision-maker's reluctance is justified.

The values for levels of confidence show a greater variability for the different scenarios when the supposed economic value that society places on the waterfalls is low. Low economic values encourage implementation of the proposed UKHP alternative while high economic values discourage implementation. Any decision to implement the current UKHP based on a low economic value of the waterfalls would therefore contain a lot of uncertainty.

Even at a low economic valuation of the waterfalls, such as US$ 20 million, it is conceivable that other hydro options, not as economically feasible as the proposed CEB option but which could preserve all or some of the waterfalls, could become feasible. Given such a possibility, the level of confidence in implementing the CEB option would only be around 80 % (i.e. the probability of decision error could be as high as 20 %) even at an economic value of US$ 20 million for the waterfalls. Even if the decision-maker was to assume that there was no economic value of the waterfalls, it is conceivable that the decision error could be as high as 22 %, if in reality the project faced the assumed uncertainty scenarios. In other words, the probability of error of the decision bound on the implementation or rejection of UKHP being US$ 0 (zero) is between 1 % and 22 % for the assumed scenarios.

5. Discount rate

The suitability of the discount rate assumed for decision-making in the feasibility analysis given the very low economic rate of return (EIRR) of the proposed alternative to UKHP [CEB, 1994a; b] is an important issue that cannot be ignored. The proposal to implement UKHP and thereby sacrifice the waterfalls based on a decision bound is highly dependent on the selected discount rate for the extended benefit-cost analysis.

The economic analysis of the selected UKHP option [CEB, 1994a], which initially ruled that it was the most feasible (see Table 1), also showed that the EIRR of this alternative was 11.47 %. The break-even of the alternative is only 1.47 % more than the minimum acceptable rate of return (MARR). In other words, had the discount rate been 11.5 % (or higher), or the perceived opportunity cost of capital of society been 1.5 percentage points (15 %) more than the assumed value, this option would not have been economically feasible even from the least-cost method. Then, there would be no question of implementing this option or sacrificing the seven waterfalls.

Hence, a more realistic proxy value for the economic value that society places on the waterfalls to preserve them is the incremental economic value of hydropower generation. In other words, we have to consider the decision bound at EIRR, the rate at which the decision between hydropower (best option) and thermal power (assumed next best option) generation is economically indifferent. A “with project” analysis at a discount rate of 11.47 % shows that the decision bound to implement UKHP or preserve the waterfalls by rejecting the proposed alternative is about US$ 31.7 million [Ranasinghe, 1999].

A risk simulation of 5000 iterations of the base-case values was carried out at EIRR (i.e., at a discount rate of 11.47 % instead of at 10 %) to study the impact of the incremental economic value of hydro power generation. Then, the expected value (E[DB]) and the standard deviation (σ_{DB}) for DB, the decision bound, were US$ 31.54 million and US$ 55.54 million respectively. Both the expected value and the standard deviation converged to less than 0.5 % with 5000 iterations.

The generated CDF from the simulation for DB for the base case at a discount rate of 11.47 % illustrating the levels of confidence in the decision to implement UKHP given an economic value that society places on waterfalls showed that the level of confidence in implementing the CEB option is only around 72 % (i.e., the probability of decision error could be as high as 28 %) when assuming that there is *no* economic value for the waterfalls. Even at a low economic value of US$ 20 million for the waterfalls, the level of confidence in the decision to implement UKHP is about 58 % and conversely the decision error could be as high as 42 % [Ranasinghe, 1999].

6. Conclusions

The objective of this paper was to develop a methodology to analyse the risk and uncertainty associated with the decision to implement an infrastructure project that threatens a unique natural, environmental or cultural asset. As a result of this study the following conclusions can be drawn.

- The total economic value of the waterfalls consists of their use values, which arise from physical personal use, and non-use values, which arise from non-physical non-personal use.
- The appropriate direct economic valuation method to value a unique natural environmental asset such as waterfalls is the CVM. The appropriate measure of the environmental loss is the WTA compensation for accepting the environmental loss, and not the WTP to prevent it. However, most often CVM uses WTP to assess benefits or damage, because WTA is more difficult to measure empirically. Then the economic value from WTP is understated.
- Because of the practical difficulty of valuing threatened assets directly, the decision bound estimated from reverse analysis of the extended benefit-cost analysis is a good starting-point for the analysis of the value of waterfalls threatened by the hydropower project [Ranasinghe, 1997].
- The level of confidence in the decision to preserve the waterfalls is the probability at the point of indifference between the economic value that society has to place on the asset to preserve it and the risk quantification of the estimated decision bound.
- The risk analysis showed that the assumption that the influence on the decision-maker to implement UKHP, on the basis of the supposed economic value that society places on waterfalls, is the same as long as it is lower than the decision bound, was too simplistic as the influence on the decision-maker to reject UKHP is high when the supposed value that society places on waterfalls is high and vice versa.
- Even if the decision-maker is to assume that there is *no* economic value of the waterfalls, as was done in the economic analysis, the probability of the decision error in implementing UKHP could still be as high as 22 %.
- A more realistic proxy value for the economic value that society places on the waterfalls to preserve them

is the incremental economic value of hydropower generation estimated when the MARR is equal to the EIRR. Against the incremental economic value of hydropower generation at EIRR, if the decision-maker is to assume that there is no economic value of the waterfalls, then the decision error is about 28 %.

- The uncertainty associated with a decision to implement UKHP is too high, given the policy objective in Sri Lanka of minimising the adverse effects on the environment in hydropower generation, for a prudent decision-maker to approve the proposed UKHP alternative. ■

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