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Assessment and Estimation of Environmental Costs of Kasilian Dam

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Abstract: Despite the benefits of large dams, there are still concerns about their real benefits and environmental costs. Effects on social and natural ecosystems could be one of the most important external costs of dams' construction. The aim of this study is to identify the environmental and social costs of Kasilian hydropower Dam in Mazandaran Province, Iran, to reduce the negative consequences and move towards sustainable environmental development. In order to estimate the environmental costs, it is necessary to calculate the damaging and negative effects as well as the benefits of dam construction such that to calculate the net profit. Thus, this paper is one of the first efforts focusing on identifying the most important social and environmental impacts of dams' construction. Using the HECAM (Hydropower's Environmental Costs Analysis Model) software and considering the economic, social and environmental indicators, we estimated the benefit ratio to the cost of Kasilian hydroelectric dam to be about 3.5. We also found that land loss and electricity generation have the highest cost and the greatest profit associated with the lack of greenhouse gases, the water and electricity sale.

Key words: Environmental cost, hydropower, dam, HECAM.

Introduction

Due to climatic and geographic conditions in Iran, the flood events along with their large damage are witnessed every year. The flood event in Iran is not specific to a particular area and the whole country is affected by this phenomenon. For instance, in the northern regions of Iran, which have rivers with steep slopes and short lengths, annual floods lead to high losses of inhabitants and heavy damages (Ministry of Power, 2015). Dams provide reliable water resources, protect the surrounding areas from floods, and provide a clean energy. Although hydroelectric power (power generation by water) provides more advantages than two other major sources of power generation (i.e., fossil fuels and nuclear power), dams and water resources also cause some problems (Brismar, 2004).

The water issue has been highlighted in numerous international reports, including Water Security for Better Lives (OECD'S report). This report introduces the water

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security as a policy challenge and anticipates that until 2050, about 40% of the world's population will face severe water stress due to increased water demand, pollution and stresses (Hallaj, 2016). Therefore, the growth of human population, economic development and climate change, and needs for accessing the electricity highlight the necessity for renewable energy resources (Wallmo and Lew, 2011).

Iran with an average rainfall of 250 mm per year faces water shortage and non-uniform distribution of water resources. The dry climate in Iran has led to a great attention to dams' construction as an engineering method using new technologies to adjust and upgrade the water flow, crop operation, drinking, and other applications (Vanclay, 2003).

Hydropower is one of the renewable energies that will certainly play an important role in economic growth and social development in the future (Vanclay et al., 2015). Unlike the power generation systems, this kind of energy does not pollute the water and air. The former also leads to severe environmental damages including the changes in land use, natural habitats, and social life of people living in the periphery of the dam, which is identified as the most important consequences (Saeedi et al., 2006). In addition to the short-term benefits of large dams, there are plenty of hidden costs, including the actual cost of building a dam, resettlement, the loss of crops or livestock, etc. (Hainoun et al., 2010). Considering the effects of large dams including impacts on livelihoods, health, social systems and cultures, which are inseparable from their performance (Tilta et al., 2009) to achieve sustainable development, social and environmental impacts should be considered throughout the project's cycle (Lechner et al., 2017). Since 1978, according to the International Environmental Law, paying attention to the assessment of socioeconomic effects is as important as assessing the physical effects (Sousa et al., 2010).

Social Impact Assessment (SIA) is used as a mechanism for predicting the impacts and a decision-making tool in regulatory processes for considering the social impacts before making decisions. Moreover, social impact assessment still plays an important role in managing projects and it can be used to monitor and evaluate the benefits of implanting the project (Tajziehchi et al., 2013).

Bianca Dendena et al. analyzed the process of project approval and implementation of environmental policies integrate social and environmental issues by major international organizations in several countries. This survey puts emphasis on an integrated assessment process and explores an extensive programme of ESIA, in line with the potential social concerns of projects (Dendena and Corsi, 2015). Hamilton et al. (2015) explored and integrated the important aspects of environmental modelling, where they combined knowledge, data, methods and various perspectives to solve complex environmental problems. They outlined 10 key dimensions and examined how to integrate these dimensions in the integrated assessment process in several instances as case studies. Finally, they concluded that integration of management, stakeholder and nature issues is a necessary requirement and should be always considered (Hamilton et al., 2015).

Reid John and Junior Souse evaluated the uncertainty about Amazon's hydroelectricity development, the potential risks, and environmental issues surrounding the Belo Monte dam. In this study, in addition to the social and private costs of the dam construction project, they also identified the benefits of dam's construction, and significant risks and important fluctuations that could affect the final costs of electricity generation (de Souse et al., 2010). Tilt et al. (2008) cited a range of social effects between large-scale dams while examining the effects of large-scale dams, such as immigration and moving to another place, changes in the structure of economy and the recruitment system, impacts on people's health, gender and culture ratios, effects on transportation system, transportation and housing.

In Iran, Tajziehchi et al. (2014) identified the social and environmental costs and benefits of Alborz Dam in Mazandaran province using the original version of SIMPACTS software and compilation of cost-benefit HECAM model.

The aim of the present research is to calculate the net profit of the Kasilian dam construction project in order to evaluate the total profit and loss of the social, economic and environmental impacts of the project using HECAM software. The results of this research can be utilized to take measures, considerations, and formulate necessary standards to reduce environmental concerns of the project for construction and operation of hydroelectric dams. Overall, this study provides some useful results for planners and designers of the country's development projects, environmental observers, and other relevant authorities.

Material and Methods

This research identifies important parameters in assessing, analyzing and monitoring the social and environmental damages of the project using the SIA approach. SIMPACT software estimates only the loss of agricultural land, forests, and greenhouse gas emissions, and ultimately calculates its external costs (Tajziehchi et al., 2014). Therefore, the evaluation of negative effects is limited and other positive effects, as well as some negative effects, have not been considered. In this connection, several effects have been performed using other tools. The new HECAM software is a developed model for the analysis of environmental and social costs of dams. Moreover, it has the ability to estimate the positive and negative effects and calculate the real costs of a dam. The surveyed indicators include the characteristics of the area, the technical characteristics of the studied dam, the population, and coverage of the land, the amount of greenhouse gas emissions, the production and sale of electricity, drinking water, flood, etc. (Tables 1 to 6). Each indicator has a numerical value in HECAM software.

Kasilian Reservoir Dam is located in Mazandaran Province and the lowest section of the Kasilian permanent River (Figure 1).

Table 1: The characteristics of the Kasilian dam

Name of facility	*Kasilian Dam*
Location/Description	Mazandaran Province
Dam Height (m)	98
Nominal Net Head (m)	58
Additional Head Correction (m)	-25
Plant Capacity (MW)	5
Average Plant Capacity Factor (%)	30
Region ID	1
Terrain Index (TI)	7
Type of Terrain	1
Average Terrain Incline (α°)	3
Average River Incline (β°)	2
Reservoir Inundated Area (Km^2)	20
Average Dam Failure Rate (FRD)	0.0001
Average Accident Warning Time (hr)	8

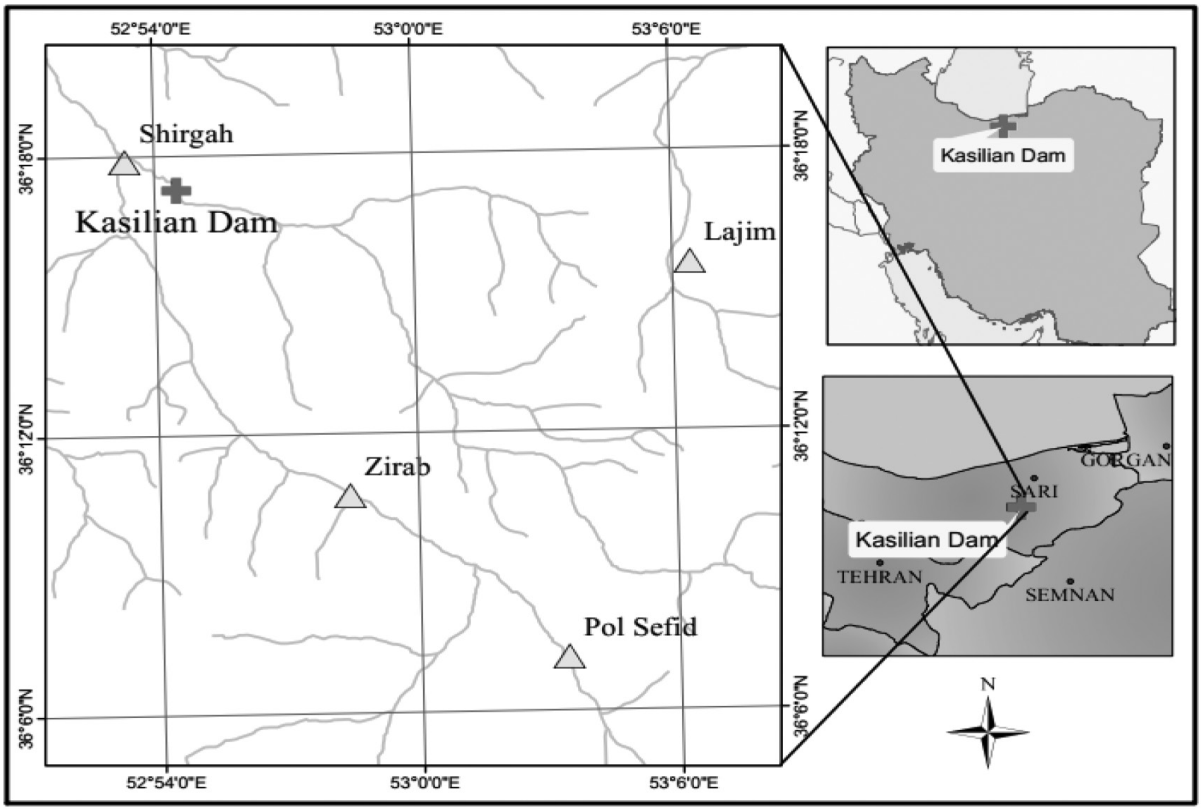

Figure 1: The overall picture of the plan according to the surrounding environment.

Population and Land Cover Part

The estimated population density in the river basin and displacement of the affected population are presented in Table 2.

Table 2: The data required for land use

Population Density in River Basin (Person/km^2)	33
Population at Risk in the Event (Persons)	10000
Share of People Resettled/compensated (%)	100
Land Cover: Forest (%)	40
Land Cover: Farmland(%)	59
Land Cover: Other (%)	1

Lack of Greenhouse Gases' Production Part

The characteristics of greenhouse gas emissions from Kasilian dam and power plant are represented in Table 3. The cost of carbon is about $ 12-35 (per ton), which is estimated to be $ 20 for this study according to the climatic conditions. There is no estimated cost for NOx and SOx in the global market. As a result, the income from environmental pollution savings is $ 225,788, which can be calculated as follows:

$$\text{Rev.Pol} = \text{CP} \times T_{emis}$$

where Rev.Pol is income from environmental pollution savings, CP = Carbon's cost and T_{emis} is total amount of environmental pollutants emissions.

Table 3: The data required for power plant Kasilian

CH_4 Emissions mean	18.7
CO_2 Emissions mean	170
GWP for Methane (GWP CH_4)	21
Price of Carbon	20

Electricity Part

Economic parameters of hydroelectric power plants are generally defined according to the costs and executive benefits. In this study, the fixed cost method was used rather than applying the inflation rates in the calculations. The main reason for avoiding the inflation rates is the uncertainty of this parameter in long-term studies and its inability to calculate the present value and cost benefits. Costs include fixed and variable components, which are shown in Table 4.

The fixed cost includes investment costs, fixed maintenance (mainly personnel) costs while the variable cost includes fuel, variable repairs, and maintenance (spare parts and repairs) costs. The constant component is calculated for kilowatts of pure net capacity and variable cost per kilowatt of net capacity throughout the year with a given production factor (net energy) and, in total, the cost criterion. The constant component is calculated for a kilowatt of pure net capacity and variable cost for per kilowatt of net capacity throughout the year with a proportional production factor (net energy), and it is totally assigned as a criterion for calculating the cost.

$$\text{THE (mwh)} = \text{PGH} \times \text{PFH} \times \text{AFH} \times 8760$$

where PGH (power plants rated capacity): 5 MW; PFH (annual generation capacity): 30%; AVFH (accessibility factor of power plants in a year): 94% and THE = (energy generated by power plants).

The annuity (or annual return of capital plus fixed and variable costs of operation in a year) is calculated using a fixed coefficient (pure energy) equal to the constant and variable present cost values.

Description of Cost Calculations

Production costs include the initial investment of dam plant, the profit of construction period, the re-investment for reconstruction of the power plant, and the fixed and variable installation and maintenance. Energy and power variables data are presented in Table 4.

Description of Income Calculations

Electricity Sales

The income from the sale of the produced electricity by the power plant is considered as an advantage of damming. The price of electricity sales is considered as $\frac{\text{Cents}}{\text{Kwh}}$. Definitely, this price is rising in the country, leading to the increased benefits of dam construction. Due to the amount of generated energy by this plant, the generated revenue from the sale of electricity is calculated to be $ 617,580.

Drinking Water

The benefit of constructing a dam for water transfer and calculating its profits should be taken into consideration at external cost. Therefore, in the HECAM model, some parts are calculated to enter the cost of water transfer in the dollar and ultimately, the annual cost of water transfer is calculated and the total generated revenue by this section is determined (Table 5).

Table 4: The data required for energy and cost characteristics

Section	*Input data*	
Cost Characteristics	GNP of country($US per Capita)	6900
	PPPGNP of country($US per Capita)	13072
	Cost of forest($US per Capita)	6656000
	Cost of farmland($US per Capita)	4993200
	Cost of other land($US per Capita)	637880
	Fraction of land costs internalized (Fraction)	1
	Economic lifetime of Project	50
	Interest Rate for Cost Levelization (%)	10
Energy	Accessibility Factor (%)	94
	Annual Interest Rate of Investment (%)	10
	Lifetime of Plant (Year)	50
	Lifetime of Dam (Year)	100
	Investment in Plant ($/KW)	600
	Investment in Dam ($/KW)	400
	Fixed Maintenance Costs($/KW in Year)	1.958
	Non-Fixed Maintenance Costs($/KW)	0.00026
	Plant Reconstruction Costs (% of Investment)	25
	Plant Reconstruction Period (Year)	25
	Plant Construction Period (Year)	4
	Dam Construction Period (Year)	5
	Electricity Price (Cents/KWh)	5
	CO_2 Emission in Thermal Plant (gr/KWh)	912.152
	SOx Emission in Thermal Plant (gr/KWh)	3.142
	NOx Emission in Thermal Plant (gr/KWh)	2.795

Table 5: The data required for drinking water

Cost of water transfer ($ US)	281250
Fixed maintenance costs ($ US)	700
Cost of needed materials ($ US)	800
Increase the volume of produced water (m^3)	2500
Water price ($ US/m^3)	0.5

Flood Part

In order to estimate the Kasilian River's flood, watering statistic of the maximum instantaneous discharge rate of Kasilian-Shirgah Station was used during the period of 51 water years ending at 2006-2007 (Table 6).

Table 6: The data required for flood reduction (unit value)

Flood damage ($ US/Return Period)	95000
Return period of flood (Year)	30
Benefit of flood mitigation ($ US/Year)	3166
Annual energy production (KWh)	5256000

Results and Discussion

As mentioned earlier, HECAM software as an updated version of the International Atomic Energy Agency's software was applied to calculate the costs and benefits of the Kasilian hydroelectric dam. Accordingly, all indices related to the actual costs of the Kasilian hydroelectric dam, including electricity production, population displacement, loss of agricultural and forest land, and greenhouse gas emissions, are calculated after determining the required values (Table 7 and Figure 2). Clearly, economic and social environment damages will be about $ 61,6621 in case of constructing the Kasilian dam and power plant for production of every MW of electricity. Land damage, which is the largest part of environmental costs, is about $ 665,000 with the smallest part belonging to the lack of life loss (products and resettlement).

Table 7: The results of all effective variables of Kasilian dam and power plant in HECAM software

Physical impacts	Loss of land (km^2)	Forest		8
		Farmland		11.8
		Other		0.2
		Total		215
	Displacement and resettlement (person)	Displaced people		2470
		Resettled people		0
	Loss of life (Accident)	Loss of per failure		37.7
		Expected loss of life		0
	Emission during operation (metric tons/year)	CH_4	Low	30
			Mean	360
			High	800
		CO_2	Low	3000
			Mean	35960
			High	80000
	Total emission (metric tons/year)	CH_4	Low	30
			Mean	374
			High	800
		CO_2	Low	3000
			Mean	3400
			High	80000
	GHG (in carbon equivalents)	Low		990
		Mean		3069.3
		High		26400
Economic impacts		Total damage cost		22.7
	Displacement of people (million $)	External cost	Displaced not resettled/compensated	0
	Loss of life (Accident)	External Annual damage cost (million $/year)		0
		External cost of loss of life (million $/Mwh)		0.2
	Loss of agriculture and Livestock production	External Annual damage cost (million $/year)		0
		External cost of loss of life (million $/Mwh)		0
	Cost of emission	External Annual damage cost (million $/year)		0.1
		External cost of loss of emission (million $/Mwh)		4.7
	Total External Cost Per Mwh			4.9

In order to calculate the profits from the construction of the Kasilian hydroelectric dam, the options related to electricity and drinking water sale's indices, income from pollution elimination, and flood prevention were investigated. As shown in Figure 3, the total revenue is $ 2,879,683.5 and the greatest benefit from the construction of Kasilian dam and power plant relates to reducing the polluting gases and selling the electricity (Figure 4). Hence, the ratio of benefit to the calculated cost of the Kasilian dam's and power plant construction is 3.5, indicating a relatively high justification of dam construction. In fact, benefit minus the cost is equal to $ 3.5 million in net profit or the generated net annual profit by the project, which is obtained by HECAM software and is generally ignored in the SIMPACT model.

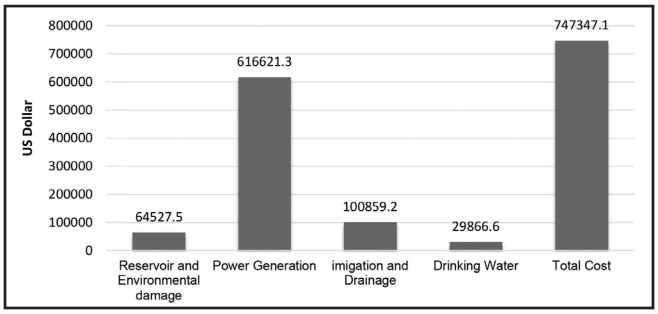

Figure 2: Environmental costs of Kasilian hydroelectric dam.

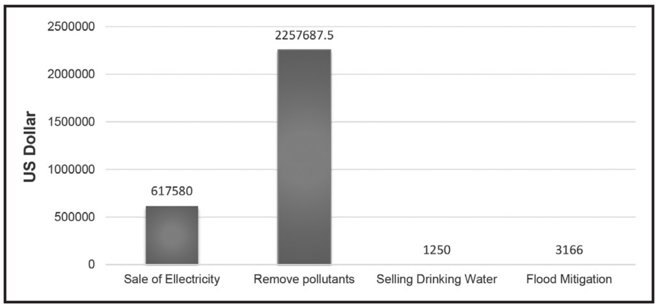

Figure 3: Environmental benefits of Kasilian hydroelectric dam.

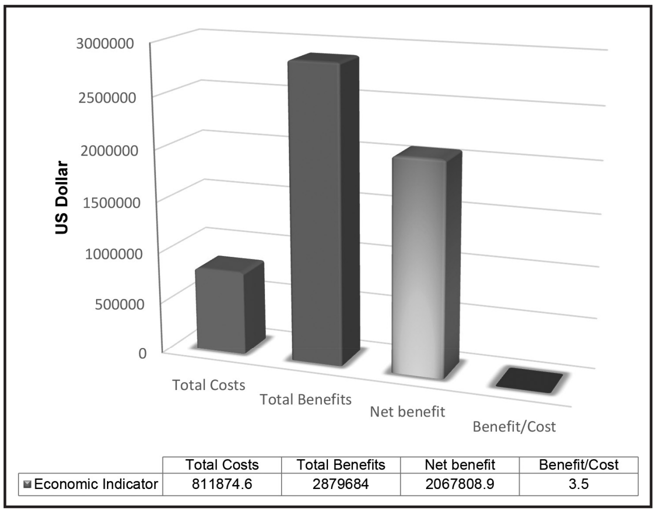

Figure 4: Total costs and benefits of Kasilian hydroelectric dam.

According to the above cases, it can be figured out that the results from HECAM software's calculations for constructing the Kasilian dam and power plant are in the same direction. As their results also show, in general, the highest costs are related to the loss of lands and agricultural products, resettlement, and electricity generation, in the order of their appearance. In comparison, the most profits from the construction of the dam and power plant are related to electricity sales, reduction of polluting gases, irrigation, and drainage and flood control, in the order of their appearance.

Besides, the results of this study, assuming the carbon cost of $ 20 per ton of carbon dioxide, and results from Tajziehchi studies have the same direction, suggesting an increase in carbon price is accompanied with an ascending increase in reservoir damages and environmental risks. Overall, the present study outlines the importance of assessing the environmental benefits and costs of building large dams in order to make proper decisions, control and manage the consequences.

Conclusion

The dam construction area, and especially the affected population by the project, suffer from various damages including the loss of agricultural and forest lands due to the construction of the dam. Accordingly, it is necessary to specify the size of environmental damages and provide a special programme to reduce them. Moreover, external costs also increase by adding the power system's development, which can significantly affect the benefits of the project. Generally, solving environmental problems requires considering an integrated approach. Hence, for an integrated assessment of the social and environmental impacts (ESIA), an instruction should be provided by the EU such as the EIA and SIA.

The HECAM model tries to calculate the real cost of dams alongside their profits by quantifying the covered environmental effects and emphasizing the social, economic and cultural aspects of large dams. Considering the successful implementation of this modelling in two cases (i.e., dam and power stations of Alborz and Kasilian), it can be concluded that this model has a high ability to demonstrate the social and environmental impacts of dams. The results of this model will be of great assistance in an effective assessment of environmental impacts on water resource development and dam construction projects and to make an appropriate decision and create some environmental guidelines and plans appropriate for dam and power projects.

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