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A critical look at Social Impact Evaluation of dam Construction by Revised SIMPACTS Software - a case Study of Alborz Dam in Northern Iran

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ABSTRACT: There is much discussion going on lately whether dam construction is economic or not in terms of social consequences. Accordingly, various techniques and software have been released to estimate the real social cost of dam construction among which, the Software SIMPACTS has been used extensively by researchers, worldwide. The present version of SIMPACTS software only focuses on adverse effects of hydropower dams regardless of their potential positive impacts. In order to fix the existing bugs, the software was modified by programming a new cost-benefit model in which the costs of power generation, irrigation and drainage, aquatics, and potable water as well as the benefits from electricity sales, elimination of pollutants, increased cultivated area, aquaculture practice and also prevention of flood in the area, were included. The obtained results revealed that the total costs of the Alborz Dam, including the costs added to the modified model, will raise from 164 US$/Mwh calculated by the original version of the software to US$ 1049 per MWh. Besides, total revenues resulting from the above mentioned variables added up to the model reaches US$ 1994 per MWh. Therefore, the cost over benefit ratio for construction of Alborz Dam is equal to 1.5. In other words, a sum of US$ 28 million would be expected as the annual net profit of the project which has totally been overlooked in the original model.

Key words: Modified version, SIMPACTS Software, Dam construction, Social impact assessment

INTRODUCTION

Social Impact Assessment (SIA) is a process to assess and manage the impacts of projects and public planning (Vanclay, 2000). There is not any common global definition on SIA. However, based upon one of the best definitions, it is an evaluation of analyzing, monitoring and managing process of social impacts resulting from a certain project (Vanclay, 2003; Vanderpool 1987). Dam-building can be pointed out as one of the most challenging social projects (Karbassi, 2013). Although dams have been built over 5000 years, large hydropower dams were developed with the advent of technology in the 20th century (Brismar, 2004). Since the early 1970s, large dams have been one of the most important debates in environmental engineering. Undoubtedly, large hydropower dams have many advantages such as clean water and renewable energy supply, flood control, increased agricultural products and also improved water supply systems for municipal water consumption purposes, etc. (Tilt *et al.,* 2009). On the contrary, there are also some negative environmental and socioeconomic impacts that should be well addressed prior to dam construction (Bridget, 2010; Fearnside, 2013; Brown *et al.*, 2009; Han *et al.*, 2008; Polimeni *et al.*, 2014; Koutsos *et al.*, 2010). With the publication of the reports in recent years about the environmental impacts of large dams by the World Commission on Dams (WCD), discussions on costs and benefits of water resources development projects have been initiated [WCD, 2000]. By studying a total of 125 large dams, the WCD has concluded that dams impose extensive adverse impacts on rivers, watersheds and ecosystems resulting in fundamental instability in the fulfillment of promised benefits, as well as ignored environmental issues and social costs (Eccleston, 2001). The SIA of dams has recently been the issue of global concern so as the increasing trend of relevant

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researches done in this field in the world confirms this claim.(Wang et al. (2013) proposed a framework to comprehensively assess the social impacts of large dams in the Upper-Mekong River, China through dividing the study area into three classes of wealth for the affected people, material, embodied, and relational, and to compare comprehensively the loss and compensation in each type of wealth. Wyrick et al. (2009) analyzed both physical and social impacts of the removal of two small dams in southern New Jersey, and integrated the two seemingly disparate concepts. They finally predicted that there will be limited effects to the hydrological and biological characteristics of the stream corridor. Large dams are criticized because of their negative environmental and social impacts (Lerer and Scudder, 1999). Beck et al. (2011) examined the impacts of dam projects in regions of the world such as the USA, China, and Southeast Asia that are at different stages of development to represent a development gradient from developed to developing, respectively (Monavari,2000). Scotta and Diaba in 1989 examined the social impacts of the Inanda Dam which is under construction on the Mgeni River in KwaZulu. The social impacts of dam construction could be assessed by a variety of methods and tools of which the Simpacts Software is the most widely-used. As a user-friendly, simplified tool, it estimates quantitatively the external costs caused by damages health, agricultural, forest and materials, air born and water pollution, solid waste, and different generating technologies to human health, crops and building (Liun *et al.,* 2007). Regardless of advantage of the software in valuating some important consequences of dam building, there is a need to examine whether the model output comply with the existing realities or not. This is the main hypothesis of this research supposed to be addressed comprehensively.

Apart from Environmental Impact Assessment (EIA), no studies have been carried out on the SIA of dams in Iran particularly on valuation of the social impacts. In this study, an inventory of all anthropogenic activities in the basin of the Alborz Dam was initially prepared. After investigating all social aspects, a model was developed to predict the social impacts of the dam construction by modifying the original version of the Simpact Software. This was done by recognition of the existing bugs, imposing the required changes and adding some new indices to the model. Accordingly, the SIA analysis could be performed quantitatively with an estimations closer to the reality.

MATERIALS & METHODS

The Alborz Dam is situated between the latitude of 36° 13' 49.2" N (36.2303°) and the longitude of 52° 48' 38.1" E (52.8106°). The population density of the study area is equal to 33 people/km^2 and approximately 10000 people are exposed at risk of dam accident. The land uses forest and farmlands include around 40% and 59% of the entire study area, respectively (Tajziehchi *et al.,* 2013). As stated earlier, the present study is on completion of the article entitled “Quantification of Social Impacts of Large Hydropower Dams- a case study of Alborz Dam in Mazandaran Province, Northern Iran” written by Tajziehchi et al. (2013). Using the SIMPACTS Model, Tajziehchi and her colleagues estimated the external cost of the Alborz Dam equal to 164US$/MWh which is equivalent to 4.9 million dollars per year. This value cannot be invoked whereas it has not been estimated based upon a real cost-benefit analysis. Dam building has always been associated with a series of overt and covert benefits such as power generation, increased cultivated area, potable water supply, etc. encouraging decision makers to build new dams. Such benefits are totally neglected in the original version of the Software SIMPACTS. In this research, precise investigations revealed that there are some serious computational problems with the software which will be explained in the following.

In this research, power generation costs include initial investment in plant and dam, construction period interest, reinvestment to reconstruct the power plant within the study period, constant and variable repair and maintenance cost. The investment required for the construction of the dam and power plants are depreciated over their useful life. There are several methods for depreciation calculation of which the linear method was used in this study. Accordingly, it was supposed that the plant will be depreciated over 50 years. The residual value was set at zero. The annuity enterprise value of the plant was estimated to be US$ 721.671. All constant and current monetary amounts of repair and maintenance during the operational period were computed and added to the total costs. There are a series of operational constant monetary amounts such as charging cost, personnel salaries, irrigation of green space, etc. which are independent from production while some other types of costs such as repairs, replacement of parts, and oil changing are variable.The constant monetary amounts are associated with a nominal capacity and calculated in Kwh while the variable costs are dependent on power generation. These costs were included in the model as annual quantities. Assuming the payments are made in the middle of every year, the interest of the operational period was computed using the annual cash flow and discount rate. The annuity investment cost was also calculated.

In this model, the investment cost of a power plant with capacity of 10 MW was supposed to be 600 US$/ Kwh. Furthermore, the reconstruction cost was assumed to be necessary every other 25-year period which its current value is calculated by an annual discount rate of 10% (Eq. 1).

$$IDCF= a1\times(1+i)(cs_{-1})+0/5+a2\times(1+i)(CS_{-2})+0/5+......+ an\times(1+i)^{0/5}]-1 \quad (1)$$

Where;
IDCF= interest coefficient at the construction period of the plant, $a_1 \ldots a_{n=}$ Coefficients of annual payments during the constructional period of the plant (deductions), CS= constructional period (year), i= interest rate of constructional period (usually is considered equivalent to the annual discount as deductions)Considering the study period and reconstruction duration, it is required to consider a reinvestment rate, once for every other 25-year period. In this research, the study period was considered to be 50 years and the useful life of the plant and dam were respectively regarded to be 50 and 100 years. The reinvestment in the 25th year of the study period should be equivalent to 25% of the total initial investment which must be involved in computations. Accordingly, the coefficient of present investment value including the initial investment can be calculated as follows:

$$CIF= \mathbf{1} + \frac{\mathbf{SVF}}{(1+\mathbf{i})15} \quad (2)$$

Besides, the investment rate of dam within the study period was calculated by the Eq. 3.

$$SVF = A(50) \times B(100) \quad (3)$$

Where;
SVF= the present value of the 50-year annuity cost of dam, A (50)= present value annuity factor within the period of 50 years calculated using the Eq. 4.

$$A(50)= \frac{i\times(1+i)^{50}}{(1+i)^{50}-1} \quad (4)$$

B(100)= annuity factor during a 100-year period estimated by the Eq. 5.

$$B(100)=\frac{(1+\mathbf{i})^{25}\_1}{\mathbf{i}\times(1+\mathbf{i})^{25}} \quad (5)$$

Consequently, the investment cost of the hydropower plant (FICH) and the dam investment cost (FICD) can be calculated in dollar by the following equations.

$$FICH = PGH \text{ x } FUCP \text{ x } [FUCP \text{ x } RF/(i+1)^{RY}] \text{ x } (1+IDCF) \text{ x } A(50) \quad (6)$$

$$FICD = PGH \text{ x } FUCD \text{ x } SVF \text{ x } (1+IDCF) \text{ x } A(50) \quad (7)$$

Wherein;
FICH= the investment cost of the plant, PGH= Installed capacity of the power plant (KW), FUCP= Plant construction costs (US$/KW), FUCD= Dam construction costs (US$/KW), RY= reconstruction period, and RF= reconstruction factor.
The constant and current monetary values of repair and maintenance were calculated using the Eqs. 8 and 9.

$$DFOM = PGH \text{ x } DFOMUC \quad (8)$$

$$FVOM = TEG \text{ x } FVOMUC \text{ x } 10^{2-} \quad (9)$$

Where;
DFOM= constant present value for repair and maintenance of the hydropower plant within the study period, FVOM= variable present value for repair and maintenance of the hydropower plant within the study period (C/Kwh), DFOMUC= constant annual repair and maintenance cost as per 1 KW of the total nominal capacity of the hydropower plant, and FVOMUC= variable repair and maintenance cost of hydropower plant as per Kwh of gross energy generation.
Finally, the total cost of power generation by the hydropower plant was calculated as follow:

$$TCP = FICH + FICD + DFOM + FVOM \quad (10)$$

Under the assumptions of the model, the total cost of power generation was estimated equal to 1234313 US$ per total power generation of 28820 Mwh.

As mentioned earlier, there were included revenues from dam building in the modified model to achieve more accurate estimates on the real social costs imposed. In this research, the total revenue from the hydropower plant construction was investigated in two categories of power selling and decreased greenhouse gas emission. In this research, the price of power selling in Iran was considered to be 5 cent/Kwh. It should be mentioned that the price is being raised in the country increasing the benefits from the dam construction in future. Considering the total energy generation of 28820 Mwh by the power plant and the power selling price of 5 cent/Kwh, the total revenue from power selling is expected to be 1441020 US Dollars. According to the global market selling price of carbon which is equivalent to 13-22 US$/ton, a value of 20 US$/ton was selected as the carbon price input data (Tavanir Co., 2013). The revenue from decreased greenhouse emission was calculated using the following equation.

$$Rev._{Pol.} = C_P \times T_{emis.} \quad (11)$$

Where;
$Rev._{Pol.}$= revenue from decreased pollutants, C_P= Carbon price, $T_{emis.}$= The total amount of CO_2 equivalent emissions in dollars

According to the global market selling price of carbon which is equivalent to 13-22 US$/ton, a value of 20 US$/ton was selected as the carbon price (Tavanir Co., 2013). Moreover, the Energy & Environment Software was used to convert the SO_X and NO_X to the CO_2 equivalent.

Establishment of irrigation and drainage system and the resulting increased cultivated areas are of other items negated in computations by the original SIMPACTS Model. The model assumes that the cost of water transmission including diversion tunnels and pumping is imposed once during the whole study period. Therefore, the present value of annuity cost together with annual cost of developed irrigation and drainage systems was calculated as follows:

$$TCI\&D = WTC \times A(50) \quad (12)$$

Where;
TCI&D: present value of annuity irrigation and drainage cost (US$), and WTC: water transmission cost (US$).
It is worth noting that the revenue of water transmission and drainage systems resulting in increased cultivated area of 10 types of crops were included in the model.

$$TBI\&D = \Sigma (A_i \times P_i \times Pr_i) \quad (13)$$

Where;
A_i= the cultivated area of the i[th] crop (km^2), P_i= the production yield of the i[th] crop ($tons/km^2$), and Pr_i= the price of the i[th] crop (US$/tons).

Apart from inherent application of dams in prevention of river flooding, they have created favorable conditions for fish farming that can be a good source of income for local communities. This has completely been neglected in the original model of SIMPACTS. In the present study, the cost of constructing fish ponds and annual upkeeps were initially estimated using the Eq. 14.

$$TCF = TIF \times A(50) + FVOM + DVOM \quad (14)$$

Where;
TCF= annual cost (US$), TIF= the cost of pool construction and required installations (US$),FVOM= annual upkeep cost (US$),DVOM= the annual cost of required materials (US$), and A(50)= annuity factor for a period of 50 years. In this model, the revenue from fish farming was calculated for a total of 10 types of fish based upon the following equation.

$$TBF = \Sigma (FP_i \times FPr_i) \quad (15)$$

Wherein;
TBF= annual aquaculture revenue (US$), FP_i= production yield of the fish of i[th] type (tons), and FPr_i= the price of the fish of i[th] type (US$/tons).
Flood control is of important functions of dam building which was included in the modified model in the form of the following equation:

$$TFDC = FDC \times [1 + \frac{1}{(1+i)^{30}} \times \frac{A(30)}{A(20)}] \quad (16)$$

TFDC= the present value of annual flood damage (US$)
FDC= Damage caused by flooding within a certain period assumed to be 30 years in this research Potable water supply, in most cases, is of utmost objectives of dam building in dry areas. In this research, the cost of water transmission as well as annual upkeeps of the equipment was calculated as the present value of annuity water transmission cost.

$$TCSF = TISF \times A(50) + FOMSF + VOMSF \quad (17)$$

Where;
TCSF= annual cost of water transmission (US$),TISF= the cost of water transmission construction and installations (US$),FOMSF= annual upkeep cost of water transmission installations, VOMSF= annual cost of required materials (US$), and A(50)= annuity factor within the study period.
On the contrary, the annual revenue from selling potable water was separately computed using the Eq. 18.

$$T_{Rev.} = Incr._w \times W_S \quad (18)$$

Where;
$T_{Rev.}$= total annual income from selling drinking water, $Incr._w$= Increased marketable water supplied (m^3), and W_S= water selling rate (US$/$m^3$)

RESULTS & DISCUSSION

As mentioned earlier, underestimating real cost of dam construction as well as lack of attention to the resulting benefits are of major criticisms of the original SIMPACTS Software. Detailed costs and revenues of Alborz Dam neglected in the original model are here discussed in details. As a result of water supply, the area of cultivated lands will be expanded and this will cuse increased yield of agricultural and horticultural crops at downstream of the dam. Table 1 gives the

Table 1. Agricultural and horticultural crops cultivated as a result of increased farmland areas at downstream of Alborz Dam

No.	Crop	Weight (ton)	Cultivated area (ha)	Gross value of production US$(in this study US$1 is equal to 25000 Rials)
1	Rice	95000	41470	127018640
2	Grains	13700	2733	2999720
3	Oilseeds	4600	1822	2053240
4	Vegetables	55000	2112	4928560
5	Forage	567000	10554	8881040
6	Citrus fruits	112700	5797	15779120

Table 2. Total costs of Alborz dam construction in separation of affected sectors

Applied model	damages	Cost per unit	Total costs (US$)
Original	Reservoir and environmental dames	1005.80	30837951
Modified	Power generation	42.83	1234313
	Irrigation and drainage	3.29	100859
	Aquaculture	0.22	6809
	Potable water	0.10	3013
	Total cost neglected	43.87	1344994
	Total costs	1049.67	32182945

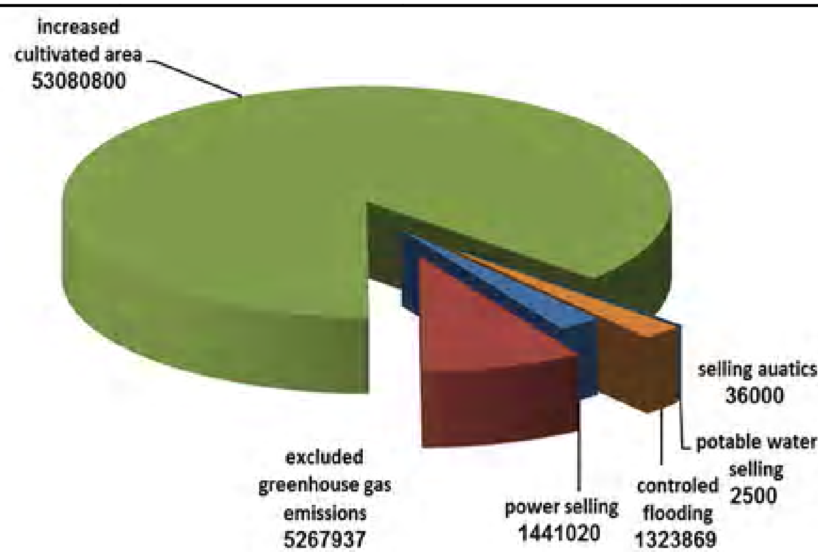

Fig. 1. Total revenues expected from construction of Alborz Dam (US$)

type of the agricultural and horticultural crops cultivated.As the table suggests, the area of the cultivated land will be increased 64488 ha, in total. The profits from selling these crops will be equal to US$ 161660800.

Based on the obtained results, it is expected that a total area of 12 ha of orchards will be flooded. Including a damage of 56000 US$/ha, the total damage caused by loss of orchards will be equal to 672000 US$. The total damages of the 1200ha flooded woodlands was estimated to be 4320000 US$; 36000 US$/ha. The research findings revealed that construction of Alborz Dam will cause a flood mitigation of approximately 455 m3/s. This will protect 955.7 ha of downstream lands from being flooded. Accordingly, the profit of flood control at downstream areas is estimated equal to 1.3 million dollars equivalent to 45.9 US$/Mwh. As estimated by the original model, construction of Alborz Dam will impose a total cost of 30837951 US$ to the environment. Further investigations revealed that there are some other costly activities that should be included in the final computations. An inventory of the neglected costs is provided in Table 2. As the results indicated, a cost of 1344994 US$ has been overlooked by the original software of which 91.77% belongs to power generation. The cost of irrigation and drainage (with a share of 7.49%) and aquaculture (with a share of 0.5%) were detected as two costly activities neglected.

Total estimated revenues from construction of Alborz Dam are depicted in Fig. 1. The obtained results indicated that the largest source of expected revenue is earned by increased cultivated area comprising 86.80% of the total revenue while the lowest proportion of total (0.004%) belongs to potable water selling. Constituting 8.61% of the total revenue, the profit of excluded greenhouse gas emissions is the second leading cause of earnings by the dam. The revenues from selling fishery products with a share of 0.058%, controlled flooding with a share of 2.16% and generated power with a share of 2.35% include next occupied priorities, respectively.

In overall, total costs and revenues estimated by the modified software were equal to 32182945 US$ and 61152127 US$, respectively. In other words, there is expected to gain a net profit of 28969181 US$ by the Alborz Dam. This will be equivalent to a benefit over cost ratio of 1.90.

CONCLUSION

According to the study by Tajziehchi et al. (2013), the external social cost of Alborz Dam was estimated to be 164 US$/Mwh equivalent to 0.16 US$/Kwh or 4.9 million dollars per year. This value has been derived from a merely cost analysis by the SIMPACTS Software. Further investigations revealed that the model output could not be an accurate estimation of the real social costs because there other types of expenses such as power generation, irrigation and drainage installations, aquaculture system upkeeps, and potable water supply systems as well as the benefits from electricity sales, elimination of pollutants, increased cultivated area, fish selling, potable water selling and prevented flooding that have totally been neglected by the original model. Therefore, the software was modified in this research in which the identified bugs were fixed. According to the findings of the modified version, the estimated cost of 0.16 US$/Kwh by the original model was raised to 1 US$/Kwh. Including the added up expenses in the modified model, the total cost of Alborz Dam reaches to 1049 US$/Mwh and the total revenue is estimated to be 1994 US$/Mwh. In other words, benefits over cost ratio for construction of Alborz Dam is equal to 1.5.

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