QUANTIFYING THE ENVIRONMENTAL IMPACT ON INDIVIDUALS' WELL-BEING IN RISK ANALYSIS

BY

MORTEZA TAVANAIE MARVI

THESIS

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Advisers:

Associate Professor Paolo Gardoni
Associate Professor Colleen Murphy
Associate Professor Arden Rowell

ABSTRACT

Catastrophes, such as the Deepwater Horizon oil spill, and the Chernobyl nuclear power plant explosion, exemplify how accidents that damage the environment affect society in ways that exceed human and property losses. Environmental damages caused by disasters are often continuous, influencing a broader portion of society, and might continually affect future generations moreso than the acute impacts associated with human health risks. As this paper demonstrates, policies in the United States and abroad affirm the importance of protecting the environment as a common asset for current and future members of society. The Environmental Impact Assessment (EIA) is a required common tool implemented by decision-makers to analyze the environmental impacts of their actions. Analysts around the world use various methods and techniques to assess the impacts of human actions on the environment. However, the effect of environmental impacts on individuals well-being is not sufficiently assessed in current EIA methodologies. Although current methodologies discuss how the environment may be changed by a particular human action, the scholarship does not sufficiently address questions related to how the affected environment can change human life. In response, this paper aims to improve the completeness of EIA methodologies by proposing a capability approach for assessing the effect of environmental impacts on humans well-being. Two human capabilities are specified to explicitly address the environmental impacts of human actions. Evaluating the proposed capabilities in EIA procedures can enrich and complement current EIA practices and more fully assess human actions impacts.

To my parents, for their love and support.

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Introduction

Accidents and failures affecting the environment, with or without significant direct human impacts, such as fatalities, sometimes influence society more than accidents and failures that do not have significant environmental impacts, despite a significantly high number of fatalities. According to reports, there were 11 fatalities in the Deepwater Horizon blowout of 2010 (National commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling 2011). Whereas, in the same year, a mining accident in Raleigh County, Montcoal, West Virginia caused more than two times the number of human deaths (29 fatalities) (United States Department of Labor website). Nevertheless, environmental impacts of oil spill catastrophes are so disastrous that society will remember it for a long time (Ismail, 2014). Other disasters, such as the Chernobyl nuclear power plant explosion, significantly influence humans and the environment. Although about 30 years passed since the accident, and society largely recovered from the grief associated with the massive number of direct and indirect causes of death related to the Chernobyl explosion, people remain incapable of enjoying the affected environment. Studies suggest that this inability will continue for many years (Marples, 1988). Such catastrophes draw researchers' attention to assessments of the impact of human actions on the environment, and how the affected environment impacts humans' well-being. Although such questions have been studied in various disciplines from various perspectives, such as ecology (Mendelssohn et al., 2012), economics (Liu et al., 2010), and law (Fourcade, 2011), assessing the environmental impacts of human actions on individuals' well-being is not fully addressed.

Assessing environmental impacts remains a focal point of policy decisions. Laws and regulations exist around the world to protect the environment prior to action by taking into consideration potential impacts (Noble, 2006. P.10). Decision-makers use quantitative methods

to select proper alternative actions (Wathern, 2013). Prior to 1970, cost-benefit analysis was the only criterion for action appraisal when the Environmental Impact Assessment (EIA) was presented concurrently with the National Environmental Policy Act (NEPA) (Wathern, 2013). In order to conduct an EIA, various methods and techniques were developed. For example, checklists, matrices, overlay mapping, networks, and simulation modeling methods are some conventional methods used in EIA processes (see Hanna, 2009, p.39; see Morris, 2009 for techniques). These methods evolved from a simple list of impacts to now accommodate for the complexity of the environment and uncertainty. It also attends to related impacts more broadly, such as human rights related to the environment (Anjaneyulu, 2011, p.34). Since 1970, many forms of impact assessment were developed to expand the influence of EIA. Examples include social impact assessment (SIA), health impact assessment (HIA), strategic environmental assessment (SEA), and recently, regulatory impact assessment (RIA), human rights impact assessment, and many other forms (Morgan, 2012). Some of these methods, such as SIA and HIA, tend to assess the influence of environmental impacts on human life.

Although researchers contributed to discussions about how the environment affects human life, limitations to such approaches and assessments remain. A recent approach relies on the concept of ecosystems. An "ecosystem" is defined as "a dynamic complex of plant, animal, and microorganism communities and their non-living environment interacting as a functional unit" (MEA, 2005a). Each ecosystem has some benefits for humans, and contributes to human well-being by providing a variety of goods and services or "ecosystem services" (MEA, 2005a). For instance, national forests regarded as an ecosystem can eliminate pollutants from the air and regulate air quality, which is considered as a crucial ecosystem service to humans from national forests. Furthermore, considerations of ecosystem services' changes in EIA can help decision-

makers to analyze systematically how environmental impacts of human actions affect the well-being of society. However, it is not sufficient to concentrate and evaluate ecosystem services alone. Ecosystem services are categorized as a *means* rather than *end* of human well-being. Thus, like other *means*, such as primary goods, the existence of ecosystem services cannot prove whether a person is able to use them in order to achieve his/her goals. For instance, consider two similar recreational parks with the same level of cultural ecosystem services. Despite such similarity, one park cannot be usable for part of society due to local barriers, such as social norms. For example, some social norms in particular locations of the Middle East make it difficult for women to perform physical and recreational activities in public parks. Thus, governments, like Iran, tried to remove such barriers by dedicating parks with special facilities for women alone (Tehran municipality website). In this situation, assessing ecosystem services does not reveal significant barriers and, moreover, gives a false impression of the recreational infrastructure of the city, although it is not a usable for part of society.

To overcome the problems discussed earlier, this paper proposes a capability approach for the assessment of environmental impact in risk analysis. "Capability" is a genuine opportunity for an individual to achieve a certain functioning (valuable state or activity) (Sen, 1993) that can be affected by the impact of human actions. In this paper, two capabilities are specified and discussed for suitability to capture environmental impacts on human well-being. Gardoni and Murphy (2006) proposed, when identifying and quantifying natural and human-made hazardous impacts on society, to gauge the changes of human capabilities in risk analysis. They suggest using two capabilities ("the capability to escape preventable morbidity" and "the capability to own property and maintain its integrity"), and by quantifying changes through proper indicators, it is possible to gauge societal impacts (Gardoni and Murphy, 2009). Although

their approach offers valuable opportunities for exploring the impacts of various hazards on human capabilities, its initial focus was not on environmental impacts as such. This creates an opportunity to explore how their framework can be extended to address environmental impacts.

The first part of this paper studies the EIA within a legal context to indicate regulatory requirements and expectations and to introduce the main agencies involved. Since the needs and concerns of a society are conveyed in its legal context and policies, exploring the policies related to the environment can indicate what people require, and their concerns about how to treat the environment. The second part is the introduction of the current EIA methodologies. By investigating how those requirements and concerns are currently addressed helps to further our understanding of the gaps and deficiencies that exist in current methods. The third part presents the capability approach as a solution for addressing a gap in current EIA methods. The features and characteristics of the capability approach, and the ways that it can be implemented in the EIA process, are mentioned in the third part as well. The fourth part is dedicated to discussions about the contribution of the proposed capability approach for increasing EIA effectiveness. The ability of the proposed capability approach to address some current concerns related to EIA practices is demonstrated in this part.

Legal Context

Prior to any efforts of development and improvement, recognizing the main players that influence the process of assessing environmental impacts is necessary. Every method and approach, at first, should address the necessities and concerns declared by the key players. The National Environmental Policy Act in the United States identified the first needs and requirements for the assessment of environmental impacts. Thus, the first part of this section is about the required measures clarified by this statute. Since Executive Orders also govern all actions of the US Federal agencies, executive order 13563 is discussed in the second part. One of the key points of this executive order relates to the implementation of cost-benefit analysis in the decision-making process. Considered as cost or benefit, environmental impacts exist within the scope of this executive order. The third part is a discussion about previous cases in the court of law and indicates how the environmental impacts are treated from that perspective. How the courts responded to such impacts can help to enhance our understanding in advance of how impacts should be assessed and treated.

National Environmental Policy Act (NEPA)

Although it commenced in the United States, the Environmental Impact Assessment (EIA) has changed the way of decision-making for enacting legislations, implementing policy and plans, and initiating development projects around the world (Wathern et al., 1988. p.3). Today, 191 nations and 193 members of the United Nations, as well as numerous bilateral and multilateral funding agencies, adopted the EIA procedure within the scope of analyzing their proposed actions (Morgan, 2012; Petts, 1999). The EIA, as a managerial tool, helps decision-makers to evaluate the likely consequences of their decisions on the environment, which may lead to mitigation measures or sometimes termination of the proposal (Jay et al., 2007).

In the United States, the National Environmental Policy Act (NEPA) required the EIA since 1970 (Percival et al, 2009). The goal of the NEPA is to protect the human environment from irreversible and irretrievable damages. The term "human environment" was defined to refer comprehensively to both natural and physical environments and the interaction of humans with that environment (Regulations for Implementing the Procedural Provisions of the NEPA, 2005). Under NEPA, all federal agencies are required to:

> *Include in every recommendation or report on proposals for legislation and other major federal actions significantly affecting the quality of the human environment, a detailed statement by the responsible official on-*
>
> *(i) The environmental impact of the proposed action*
>
> *(ii) Any adverse environmental effects which cannot be avoided should the proposal be implemented*
>
> *(iii) Alternatives to the proposed action*
>
> *(iv) The relationship between local short-term uses of man's environment, and*
>
> *(v) The irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented. [42 U.S.C. §4332 (C).]*

As part of the NEPA, Congress established the Council on Environmental Quality (CEQ) within the Executive Office of the President (Whitehouse website). Among its missions and objectives, the CEQ assists federal agencies to implement the EIA and coordinate agencies' compliance with NEPA (Percival et al, 2009). CEQ has developed NEPA implementation guidelines to clarify many of the details of the NEPA process, and the guidelines have become the first recourse for any conflicts occurring between different entities associated with the implementation of NEPA.

Following NEPA, the American government established the U.S. Environmental Protection Agency (EPA) as an independent regulatory entity to ensure the implementation of NEPA and other environmental laws in the process of making new policies (EPA website). One of the EPA's missions, as it is mentioned on its website, is to collaborate with CEQ in developing and recommending new policies related to environmental protection.

Recognizing the steps that federal agencies follow in the procedures of EIA can elucidate how consequences of an action are required for assessment, and what criteria should be met in order to gain approval. Under CEQ and EPA, each federal agency must comply with the EIA process for its actions. CEQ clarified three levels of analysis for the EIA process in the "report on the NEPA" (Eleventh Recovery Act NEPA Report, 2011). The process of assessing environmental impacts can be terminated at each level if the analysis meets the certain criteria in that level; otherwise, it should continue in the next level with more detailed analysis. The three levels include Categorical Exclusion, Environmental Assessment, and Environmental Impact Assessment. A brief description of each level follows.

1. Categorical Exclusion (CE): The actions in this category are recognized by the CEQ and public review to have no individually or cumulatively significant environmental impact. Thus, there is no need for further analysis and documentation for those actions.

2. Environmental Assessment (EA): If the agency is not confident about the environmental effect of the proposed action, which was already not eligible for CE, then an EA is provided. An EA may be concluded with a finding of no significant impact (FONSI) or the necessity of providing an Environmental Impact Statement (EIS).

3. Environmental Impact Statement (EIS): When the proposed action is recognized to have a significant environmental impact, a comprehensive analysis of its impact should be

provided and documented in an Environmental Impact Statement (EIS). The NEPA review is finished in this step by the issue of a record of the decision (ROD).

As the definition of the above levels indicates, analyzing whether the proposed action causes "significant" impact is a key factor that the EIA process tends to answer at each level. Thus, the analysis continues to higher levels if the impacts are not clearly recognized as insignificant in a lower level. The term "significant" was defined by CEQ in the "Regulations for Implementing the Procedural Provisions of the NEPA" (2005). In these regulations, an evaluation of significance is required to study both context and intensity. By "context," the regulation means explicitly that the evaluation should be made in a variety of contexts, such as "society as a whole (human, national), the affected region, the affected interests, and the locality" for both short- and long-term impacts. By "intensity," the severity of impacts should be evaluated according to several considerations outlined in the CEQ regulations. As an example, the regulations require the consideration of both beneficial and detrimental impacts, uncertainty and unknown risks involved in the possible effects, and causes of cumulative significance in relation to other actions. Thus, the approaches for EIA aim to analyze such impacts in a variety of contexts, both short- and long-term, and should be capable of evaluating both beneficial and detrimental impacts while incorporating the issue of uncertainty about the future.

Cost-Benefit Analysis and Executive Order

To evaluate both beneficial and detrimental impacts, one of the well-known and accepted methods is cost-benefit analysis. Sec. 1502.23 of CEQ regulations (2005) mentions cost-benefit analysis as a tool to evaluate the consequences of environmentally different alternatives. However, CEQ makes it necessary to discuss "the relationship between cost-benefit analysis and any other analyses of unquantified environmental impacts, values, and amenities" in EIS, and

excludes “important qualitative consideration” from being monetized. This section of the regulation may be affected by the executive order 13563, which governs all agencies’ proposed and adopted regulations, including both CEQ and EPA.

Executive Order 13563 clarifies the general principles of regulation in section 1 (2011). Several requirements of this EO could affect EIA in federal agencies. At first, protecting “public health, welfare, safety, and the environment” is enforced by regulatory systems while trying to improve “economic growth, innovation, competitiveness, and job creation.” Second, increasing levels of predictability and decreasing levels of uncertainty are desired. And third, considering costs and benefits of regulations, both quantitative and qualitative, is required. By this EO, each agency must ensure that the benefits of its regulation justify its costs prior to the proposal or adoption, also taking into consideration the fact that some benefits and costs are difficult to quantify. Thus, the environmental costs and benefits of proposed regulations should be analyzed to ensure that benefits outweigh costs.

Cost-Benefit Analysis (CBA), regardless of being an accepted quantification method, has limitations. Rowell (Berkshire encyclopedia) enumerated four main challenges of CBA. First, it tends to monetize all costs and benefits; however, some impacts are nonmonetary, such as environmental effects. Although decision-makers try to monetize those impacts, using willingness to pay or contingent valuation, those techniques can be biased against goods that are difficult to evaluate on the open market (including environmental goods). Second, monetizing some human goods, such as the environment, may lead to an underestimation of value. Third, the method does not address inequity and distribution of costs and benefits to different races, classes, genders, and other factors of society. Fourth, in order to account for costs and benefits scattered over time, CBA usually employs a discount rate to calculate the present value of monetary costs

and benefits. Adopting a suitable discount rate is controversial and decision-makers struggle with this challenge.

Court Cases

Also, how courts of law address damages to the environment reveals specific concerns related to the environment and the responsibilities expected from the involved entities in an action. A study of previous events and cases elaborates how people respond to environmental damage, what factors of the environment are crucial for society, and which responsibilities toward the environment are included in every action. Entities involved in an action, such as federal agencies and various firms, should know about those concerns and responsibilities in advance, and consider them in their decision making process. Reviewing cases filed that relate to environmental impacts and damages indicates that involved entities tolerated significant costs to compensate for damages. For example, $2 billion was reported as the cleanup cost of Alaska spent by the Exxon Corporation; while, an additional $1 billion was agreed to be paid for the public's natural resources damages, and $125 million was determined as a criminal fee (Fourcade, 2011). Thus, an environmental assessment of the actions should identify concerns that prompt considerable costs in the cases of accident, evaluate probable impacts related to them, and propose proper actions to avoid or mitigate negative impacts.

Regardless of its deficiencies, quantifying and monetizing environmental goods is a common approach for determining compensation in a court of law. When an accident damages the environment, culpable entities are responsible for providing financial relief to the suffered environment and society in addition to the cost of conventional recovery and restoration. As mentioned earlier, a considerable portion of what Exxon spent was related to environmental damages compensation. However, the trial of the Amoco Cadiz oil spill disaster, which released

six times the amount of oil than the Exxon Valdez, and in a more populated area, concluded a payment of $61 million as total compensation (Fourcade, 2011). This significant discrepancy was mainly due to the different understanding of the environment and the way of valuing nature, Fourcade (2011) argued.

Prior to any quantification and valuation of damages, identifying what genuinely has been tarnished is essential. Being insightful of the environment and its damages induced the less populated environment affected by the Exxon Valdez to be valuated higher than the environment affected by the Amoco Cadiz. Considering the environment beyond its physical damages and accounting for the loss of noneconomic consumption of the affected environment in the Exxon Valdez case implies that society perceives environmental benefits as more than just utility. The passive use value estimated in this case implies that people care about an area that they may never have a chance to use for any purpose; yet, they want to keep the opportunity of using it available for future generations and themselves.

Quantifying and valuating nonmarket goods, such as the environment and opportunities of enjoying it, has been a controversial task. Although some environmental goods are incommensurate with money, partial valuation, which involves a willingness to pay, is recommended as compensation for at least those portions of the environment that are capable of being monetized (Rowell, 2012). In practice, willingness to pay and a contingent valuation has been used to determine compensation for environmental damages. In the Exxon Valdez oil spill case, $2.8 billion was calculated by using a willingness to pay to estimate the lost "passive use values" of Prince William Sound in Alaska; although, this amount was settled for $900 million and an additional $100 million in the case of occurrences of unforeseen damages in the long-term future (Fourcade, 2011).

As previously discussed, EIA tries to protect the human environment: what is valuable in the environment, whether natural or physical, as well as the interaction between humans and the environment. The aforementioned judicial cases, especially Exxon Valdez, clarify such values and interactions. Almost none of the participants in the contingent valuation survey for the Exxon Valdez case had a chance of using the affected area (Fourcade, 2011); however, they expressed a considerable level of desire for maintaining the opportunity of enjoying it. This indicates that the interaction between humans and the environment, which has to be protected by EIA, goes beyond the mere use of environmental goods. Such interaction and opportunity should be defined in a way that can be readily manipulated within the scope of EIA, be meaningfully quantified, and be communicated among and understood by various people and entities involved. In the next section, the clarification of human-environment interaction is discussed through the concept of ecosystem services. And, how analyzing the changes in ecosystem services can improve EIA by addressing the aforementioned concerns will be explained.

The Role of the Environment on Human Well-Being

Since the enactment of NEPA, various methodologies were developed and used in theory and practice. Checklists, matrices, networks, and overlays can be mentioned as examples of conventional EIA methodologies. Although, practitioners may develop and implement their own approaches (Wathern, 2013; Caldwell et al., 1982). One of the main deficiencies of current methods is the minimal consideration of ecosystem services concepts in EIA (Baker et al., 2013; Honrado et al., 2013). Defined as benefits provided by the environment to society, "ecosystem services" can be used to explain the interaction between the environment and human well-being; thus, EIA can take utilize this concept to bolster its theory and practice (Rosa and Sánchez, 2015; Slootweg et al., 2010; Landsberg et al., 2011).

Protecting human environments as required by the NEPA entails identifying the interaction between human well-being and the environment. As discussed earlier, the term "human environment" refers to the interaction between people and natural and physical environments. By definition, a natural system of living factors functioning together with non-living factors in an area forms the ecosystem of that area. Therefore, human-environment interaction can be clarified and explained by the services that an ecosystem provides for humans. The Economics of Ecosystems and Biodiversity (TEEB, 2010) consider every "direct and indirect contributions of ecosystems to human well-being" as an ecosystem service. Thus, ecosystem services encompass all necessary goods (such as food), life-supporting processes (such as water purification), and life-fulfilling conditions (such as beauty) (Daily et al., 2009) that can be affected by human activities; while, those activities themselves depend on ecosystem services (Rosa and Sánchez, 2015). This cyclic interaction between human and ecosystem makes it essential to consider the probable "significant positive or negative impacts on ecosystem

services, and consequently on human well-being" in any decision-making tool for planning or strategy development, like EIA (Honrado et al., 2013).

NEPA refers to "significant", "irreversible", or "irretrievable" damages to the human environment, and these can be analyzed by studying significance, reversibility, and retrievability of probable changes in ecosystem services caused by the proposed action. EIA traditionally analyzes effects on biodiversity, soil, water, air, climate, landscape, and other components of the environment; while, if ecosystem services can influence human well-being, they should be considered as a pivotal part of the decision-making processes, including EIA (Honrado et al., 2013). Thus, the level of contribution of each component in changes to ecosystem services can determine the significance of the changes of the component. To gauge the level of influence and significance, quantifying probable impacts on ecosystem services is needed. Comparing the quantified probable impacts with acceptable and tolerable thresholds and the likelihood of exceeding those thresholds indicate the magnitude of impacts' significance. As Murphy and Gardoni (2008) argued, acceptable and tolerable thresholds should be based on societal impacts of a hazard. Not only the probability of exceeding those thresholds should be kept sufficiently low, but also the social consequences and impacts of the hazard should be evaluated and perceived as acceptable/tolerable. In this regard, it is necessary to evaluate the impacts of a hazard broader than the components of the environment. What those environmental components can provide as well as what may be disturbed by the probable changes in each component should be evaluated.

In the CBA required by EO 13563, positive and negative impacts on ecosystem services can be considered for comparing the costs and benefits of a proposed action. According to Braat and Brink (2008), while the loss of non-market ecosystem services can be considered to be costs,

preserving them can be regarded as benefits – a source of costs and benefits which is generally ignored in decision-making processes. Thus, Braat and de Groot (2012) noted that it is essential to include non-market costs and benefits of ecosystem services in decision-making processes. In order to take ecosystem services into account, much consideration has been made for monetizing ecosystem services (see De Groot et al., 2012; Failler, 2010; Costanza et al., 1998). However, monetary valuation, in addition to what has been discussed before in the cost-benefit analysis and executive order sections, is not an effective way of comparing positive and negative impacts. Especially, in the case of an irreversible change in ecosystems or near critical thresholds, monetizing such critical assets leads to a significant undermining of their values (Braat and de Groot, 2012). Thus, in order to accurately account for the impacts (both positive and negative) of CBA, ecosystem services should be considered in non-monetizing ways; although, quantifying those impacts is still required to weigh the costs and benefits. Other concerns, such as the distribution of costs and benefits of ecosystem services, both regionally and temporally, were implied as important moral and technical issues by researchers (Honrado et al., 2013; Braat and de Groot, 2012; MEA, 2005a, 2005b).

For calculating damage compensation, as mentioned from the Exxon Valdez case, ecosystem services, more than just goods, tend to be considered in recent years by courts of law. Although it seems there would be no way, except for money, to compensate for damages from such accidents, monetizing ecosystem services is inevitable, and quantifying ecosystem services with non-monetizing methods could be applicable. Regardless of the monetizing valuation method, quantifying the extent, intensity, and other aspects of impacts on ecosystem services caused by the accident constitutes the basis for calculating compensation.

Although the aforementioned advantages of linking EIA to human well-being have been discussed occasionally by researchers, analysis of ecosystem service impacts are not included in traditional EIA (Slootweg et al., 2003). Rosa and Sánchez (2015) investigated five cases and reported no consideration of ecosystem service in three of them and an incomplete consideration in the other two instances. Also, Honrado et al. (2013) found that none analyzed EIA by explicitly assessing ecosystem services. Studying Strategic Environmental Assessment (SEA), which is similar to EIA but used for policies, programs, and plans rather than projects (Hirji and Davis, 2009), shows no consideration of ecosystem service in decision-making processes (Eira, 2009).

The only method found in oil and gas industry that incorporates ecosystem services is proposed by IPIECA in ecosystem services guidance (see the guidance at Biodiversity, 2011). This guidance introduces several checklists to evaluate the impacts of development projects in this industry on ecosystem services. Although the proposed checklists tried to incorporate many concepts (such as risks and opportunities, secondary and cumulative impacts, and the industry dependencies on the environment), a lack of quantitative analysis can be mentioned as its primary shortcoming. Barker and Jones (2013) reported that ecosystem services' consideration for impact identification/evaluation, mitigation, significance, and the role of cumulative effects are not performed well within EIA processes of offshore oil and gas industries.

To quantitatively gauge ecosystem services' contribution to human well-being, one way is to consider each ecosystem service directly and then link it to relevant well-being components (see De Groot et al., 2002). This perspective constitutes the basis of most extant research and proposed methods in this field of study. Some researchers tend to modify monetizing approaches to capture the value of ecosystem services (see Seidl and Moraes, 2000). As discussed earlier,

there are some critiques and shortcomings around monetizing approaches, which need to be addressed by other methods. For example, monetizing an ecosystem service around the threshold of irreversibility can significantly underestimate its value. Meanwhile, monetizing would still be helpful and essential in some cases, such as determining damage compensation in the occurrence of an accident. On the other hand, non-monetizing approaches can resolve most of those defects by using non-monetary metrics. For instance, Vandewalle et al. (2009) suggested quantifying the status of ecosystem services by studying the status of species that contribute to ecosystem services. That approach helps further our understanding of changes in critical thresholds. However, both approaches suffer from a common problem insofar as they analyze ecosystem services directly. Measuring ecosystem services per se, like other contributors of human well-being, such as the amount of available resources, cannot accurately indicate the level of an individual's ability to use them. As discussed earlier, having great parks in a town does not necessarily mean that the whole of society can enjoy using them.

The Millennium Ecosystem Assessment (MA) clarified the interaction between human well-being and the environment (MEA, 2005a). General Kofi Annan (the UN secretary at that time) called for MA in 2000 to evaluate the impact of ecosystem changes on human life and to provide "the scientific basis for action needed to enhance the conservation and sustainable use of those systems and their contribution to human well-being" (MA website). In an MA Synthesis Report (2005a), first, ecosystem services were divided into four main categories: Provisioning (such as providing food and fresh water), Regulating (such as regulating climate and flood in a region), Cultural (such as delivering aesthetic and spiritual benefits), and Supporting (such as providing suitable conditions for nutrient cycling and soil formation). Then, MA split human well-being into several constituents (security, basic material for good life, health, good social

relations, and freedom of choice and action) and sketched the interaction between the components of ecosystem services and human well-being, as shown in Figure 1 (MEA, 2005a).

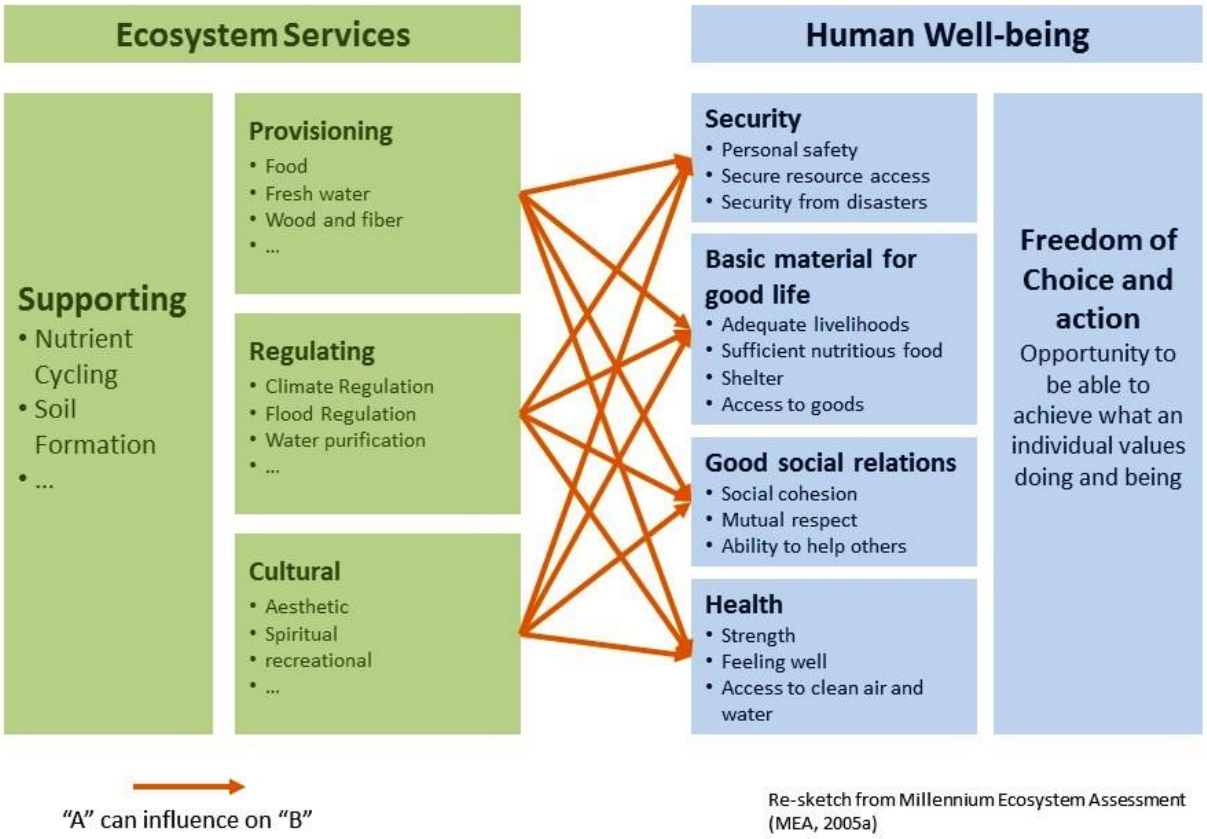

Figure 1. Interactions between components of ecosystem services and constituents of human well-being.

Freedom of choice and action was defined by MA (2005a) as "the opportunity to achieve what an individual values doing and being". This definition may look similar to the definition of "capability" at first glance; however, the MA capability approach's definitions of freedom are different (Polishchuk and Rauschmayer, 2012). As regards MA, "freedom of choice and action" is defined as the individual free will without having necessarily any reasoning. However, what capability approach defines as an opportunity to achieve (freedom) is related to specific functioning: the ones that individuals reason to value. Thus, it can be concluded that the phrase

"freedom of choice and action" includes all capabilities. Since freedom of choice and action is affected by other components of human well-being, and it is highly dependent on the level of achievement of the other components, it would be very sensitive to the changes of ecosystem services. This sensitivity is transferred to the individual capabilities as a subset of freedom of choice and action. As ecosystem services change, not only do capabilities change directly, but also other effected components of human well-being make changes in some capacities.

Polishchuk and Rauschmayer (2012) proposed using a capability approach as an alternative way of evaluating ecosystem services' impacts on human well-being. They argued that a capability approach could surmount most of the limitations related to mainstream monetization and utilitarian approaches. In their conceptual framework for capabilities, the environment and ecosystem services serve three functions related to the influence of capabilities. Ecosystem services act as a resource and material good necessary for creating a capability; provide the necessary condition for converting resources to capabilities; and indirectly cause an opportunity to enhance capabilities. For example, fresh water can be used as a resource for the capability of being well-nourished; it can provide a condition for people to put their resources into use and form the capability of having a leisurely life at a lake to be used for aquatic recreation sports; and it increases health in the society by enabling people to convert more resources into a capability as they live longer. Thus, they argue that looking at ecosystem services through the lens of a capability approach provides an ability to assess the role of ecosystem services in a multi-dimensional way rather than a utilitarian single-dimensional perspective.

As the framework developed by Polishchuk and Rauschmayer shows, capabilities can illustrate how ecosystem services and the environment contribute to human well-being. Thus, it

is beneficial to look at ecosystem services through the lens of a capability approach when it is necessary to assess environmental impacts. In addition, even more than the benefits mentioned by Polishchuk and Rauschmayer (2012), the ability to be quantified and easily communicated makes the capability approach appealing in the context of risk analysis for EIA. As Polishchuk and Rauschmayer (2012) concluded, there is a high potential in ecosystem services to capture the role of the environment in human well-being, and more research is needed to make use of the capability approach as a practical mode for assessing ecosystem services. Thus, it is important to specify relevant capabilities that are suitable for gauging probable changes in ecosystem services that are caused by human actions in a practical way for EIA use. In the next section, capability approach in risk analysis is introduced. EIA as part of risk analysis can find benefits of what has been developed using a capability approach. Then, current applications of the capability approach are mentioned. Finally, the implementation of the capability approach for assessing the environmental impacts is discussed.

A Capability Approach to Risk Analysis (CRA)

Gardoni and Murphy (2006) proposed implementing a capability approach in risk analysis to quantify the consequences of natural and man-made disasters. They discussed special features of CRA to reveal the ability of this new approach to remove some limitations and bring some benefits to current risk analysis practices. The limitations mentioned include narrowly-identifying consequences, lack of appropriate metric, implicit value judgment, and those based on preferences. More than overcoming those limitations, CRA can be adapted to quantify any kind of consequence related to different types and magnitudes of hazards within any period of time (Gardoni and Murphy, 2009). Another advantage of CRA, also mentioned by Gardoni and Murphy (2009), is its consistency with United Nation's development index and the fact that it is easily communicable, which can be helpful in public policy decision-making. Other benefits of CRA that they mention include providing more tangible criteria for acceptability and tolerability thresholds and unveiling potential inequalities in distribution of a risk in a society.

Nobel prize-winning economist Amartya Sen and philosopher Martha Nussbaum introduced the capability concept for the first time in the development economics and policy (e.g., Sen, 1989, 1999a; Nussbaum, 2001a, b). A genuine opportunity to achieve a functioning (a certain state of being or doing) that an individual reasons to value is called "capability" (Sen, 1993). For example, assume "being adequately educated" is a functioning, then the genuine opportunity to be educated is the capability of being educated (Murphy and Gardoni, 2012a). "Genuine opportunity" means that there is no extrinsic barrier to acquiring a specific functioning. Extrinsic barriers include every situation that a society can impose on an individual making him/her unable to reach what he/she values. For example, if a mentally capable person willing to study (has no intrinsic barrier) feels no extrinsic barrier, such as racial discriminating policies or

lack of infrastructure to find access to schools, it can be said that he/she has a genuine opportunity to study. Note that the result for both a person with and without a capability can be the same: a person without any mental, physical, financial, etc. obstacles may still decide not to attend school, like a person who does not go to school because of a racial discrimination barrier. Since all valuable states of being and doing can be defined as "functionings," the quality of life and well-being of humans can be gauged by the level of achievability of those functionings. Thus, the level of acquiring capabilities in a society can be a competent indicator of the level or standard of living of individuals in that society.

Although human well-being can be assessed by other aspects, such as primary goods and utilities available for an individual, the superiority of the capability approach makes it more viable for use. Thus, assessing the amount of primary goods, for instance, can be misleading since the amount itself cannot demonstrate the ability of a person to use them in a way for reaching his/her goals (Murphy and Gardoni, 2007). However, since the capability approach gauges the valuable *ends* of the process of fulfilling an ambition rather than just gauging the *means*, such as income, it can demonstrate the level of well-being more precisely (Sen, 1999b). In addition, having the same resources does not necessary translate as the opportunity to use them. Social norms, for instance, may allow one to use his/her own bicycle and do not allow the other (Murphy and Gardoni, 2012b).

To compare the capability approach with utility assessment, Murphy and Gardoni (2007) bolded the weakness of the utilitarian perspective related to what they called "adaptive preferences". They mentioned that since utilities gauge the level of individual satisfaction, and satisfaction is related to the level of individual expectations, utilities could not be a proper representative of an individual's well-being, when individuals adapt their expectations and

preferences to the current situation. Thus, although a person living in a deprived society would declare him/herself to be satisfied due to his/her adapted expectations and preferences, the capability approach, unlike the utilitarian approach, can recognize a true depravity from the lack of fundamental capabilities (Murphy and Gardoni, 2008).

Current and Proposed Applications of CRA

Due to the unique features of the capability approach, the United Nations has implemented it to measure the level of individuals' well-being around the world. This is accomplished by introducing the Human Development Index (HDI), which can gauge the level of achieved functioning in society (Gardoni and Murphy, 2009). "[T]he ability of people to lead the kind of life they have reason to value" indicates the standard of living of people from the perspective of the capability approach (Anand and Sen 2000). Three capabilities contribute to HDI: ability to have a long and healthy life, being knowledgeable, and have a decent standard of living (United Nations Development Program, 2014). The level of achievement of a capability can be gauged by using indicators, due to the fact that capabilities are not directly quantifiable (Gardoni and Murphy, 2009). For example, the UN uses life expectancy at birth, mean years of schooling, and gross national income (GNI) per capita, as indicators for aforementioned capabilities, respectively.

After proposing the implementation of the capability approach in risk analysis (CRA), various contributions of it have been discussed. CRA contribution encompasses all three components of risk analysis: risk determination, risk evaluation, and risk management. Changing the way that a risk is conceptualized and assessed is the most influential contribution of CRA in the risk determination stage, which would be crucial in the quantification process of a risk and its associated measures (Murphy and Gardoni, 2012a). The shift from prevailing approaches, such

as a utilitarian approach or primary goods to CRA, can solve the problems caused by their limitations, which were discussed earlier, in the first stage of risk analysis (risk determination).

Providing accurate and understandable metrics for assessing the information gained from the risk determination stage is a benefit of using CRA in a risk evaluation stage. Determining the threshold of acceptability (tolerability) of risks, which is one purpose of the risk evaluation stage, and also crucial for making decisions about its corresponding measures, can be justified clearly in an easy-communicable manner consistent with what the UN uses to gauge the level of development in a society (Murphy and Gardoni, 2012a; Murphy and Gardoni, 2008). This consistency can make the metric, and the measures taken based on it, meaningful when it is able to show how those evaluations and measures contribute to raising the level of development and standard of living in a society or community.

Risk determination and risk evaluation eventually constitute the underpinnings of risk management to ensure that proper policies are adopted and that decent decisions are made regarding risk and its relation to society (Murphy and Gardoni, 2012a). Hazard mitigation policies, as far as they are constrained by limited resources, need to consider all of the risks integrated and offer appropriate strategies for minimizing the societal impacts related to those risks (Murphy and Gardoni, 2007). Resource allocation in this situation requires a decision framework that is able to (1) prioritize the hazards, (2) assess different strategies to cope with them, and (3) determine the most effective strategies (Murphy and Gardoni, 2007). What CRA proposed in this stage concentrates on a way of resource allocation and mitigation strategy that protects and promotes individuals' capabilities more than others (Murphy and Gardoni, 2007). Although Murphy and Gardoni discussed this issue in the context of natural hazards, there is no

obstacle for generalizing this contribution of CRA to managing other forms of risks posed to society.

To gauge the societal impacts of a hazard, Gardoni and Murphy (2006) established a framework using the capability approach. They proposed the Hazard Impact Index (HII) for measuring the impacts of natural and man-made hazards on human life. HII uses follow two capabilities in this regard: "the capability to escape preventable morbidity" and "the capability to own property and maintain its integrity". Although those capabilities can be generally useful in some cases that affect both humans and the environment directly, such as nuclear disasters, they are not as effective in cases affecting the environment severely without threatening human life. In oil spill catastrophes, for example, measuring capability to escape from morbidity does not provide meaningful information about the impacts, since the hazard does not affect this capability of the individuals significantly. Therefore, although the framework of HII can be used, the capabilities need to be changed in order to capture the influence of environmental impacts on human well-being.

Capturing the Environmental Impact on Human Well-Being Using CRA

In order to gauge human well-being that is potentially influenced by environmental impacts using the capability approach, it is necessary to first define the relevant capabilities and their proper indicators. Relevant capability can be affected by probable environmental impacts of the case, and thus, it is able to show how human well-being is linked to the affected environment. As discussed earlier, ecosystem services can show this link clearly, and thus, they can help find the relevant capabilities of the highest importance. The most important capabilities are the ones related to the ecosystem services affected by the impacts. To select proper capabilities from the affected ones, three rules need to be satisfied. First, selected capabilities should be the most

important ones related to the issue (Sen, 1993). For instance, although a tornado can decrease the capability of individuals to study by destroying the schools in a town, changes in this capability can be neglected in comparison with the impacts on the capability of persons to being sheltered. The second rule is called "parsimony," which means that the least possible number of capabilities should be used to gauge the issue (Gardoni and Murphy, 2009). Gardoni and Murphy (2009) mentioned the third rule as "orthogonality," which means that each capability should provide unique information that the others cannot indicate.

To gauge the environmental impacts of a hazard on a society, using the following capabilities are proposed by this paper: (1) capability to enjoy recreational, spiritual, relieving, and similar activities related to the environment, and (2) capability to be adequately-nourished. In order to show the difference between the level of importance of religious, spiritual, and, in general, sacred matters and other issues, it is highly recommended to split the first capability into two, whenever a sacred environment is involved. Although capability to enjoy recreational activities and capability to enjoy spiritual activities seem to be very similar and potentially combined, the nuances inherent in the nature of each makes it impossible for them to be evaluated in the same category.

Those two capabilities are among the most important benefits that humans rely on the environment for achievement; they can embrace most aspects of ecosystem services, influencing human life, and they have no overlap that may cause redundancy in the process of EIA. In the following section, these claims (three criteria of capability selection) are discussed to show the appropriateness of using them in assessing the environmental impacts of human well-being.

Importance, Parsimony, and Orthogonality

The importance of the selected capabilities will be discussed from the perspective of EIA. As mentioned, ecosystem services show the interaction between the environment and human well-being. Therefore, the capabilities should be selected in a way that the most important ecosystem services are included.

1. **Capability to enjoy recreational, spiritual, relieving and similar activities related to the environment.** This capability is related to cultural ecosystem services. The importance of these kinds of services is mostly due to the fact that such ecosystem services are unique and irreplaceable. Importing similar services from other places may regulate degradation of other local ecosystem services; however, cultural services cannot be substituted (Plieninger et al., 2013). As an example, food that local farms provide can be replaced by food produced by non-local farms, yet a national forest that some generations have the experience of enjoying and feeling an attachment to, cannot be replaced by any other land. Although preserving such attachment feelings is similar to Nussbaum's fifth central capability (emotions), the capability proposed here considers more than emotions. By using the word "*enjoy*", we try to protect every form of cultural interaction between humans and the environment, whether emotional, physical, or spiritual. Since the environment may serve various functions in different cultural services, *enjoy* would be the most suitable verb to encompass all of the forms. For example, a person may attach emotionally to a historical place, may use a lake for a physical activity like swimming, or may worship in a unique holy place. All kinds of enjoyment of the cultural services of the environment are embraced by this capability.

The distinction between spiritual and other cultural services provided by the environment compelled us to separate the spiritual elements from this capability. Instead, this paper suggests an independent capability for sacred activities; although, they are both categorized as cultural ecosystem services. The environment related to spiritual and sacred activities are among the most sensitive places in a community. Complaints raised about the development projects near such places, and the conservative reaction to any changes related to them, demonstrate that society adopts a strict approach for preserving this capability. Such changes, in addition to decreasing the relevant capability, are considered as desecrating or profaning, which makes the situation worse. For example, artificial snowmaking for a ski resort in the San Francisco Peaks has raised legal debates concerning violation of the Religious Freedom Restoration Act (RFRA) of 1993 (Dunstan, 2012). Dunstan (2012) contended that not only was the expansion of the resort in the sacred mountains objected, but also that using treated wastewater for snowmaking was desecration. Thus, sacred environments need special attention in evaluating the environmental impacts of human actions.

In those areas involving sacred places, the evaluation of the impacts on the sacred aspects of this capability has to be done separately from other aspects. This means that it should be considered as two distinct capabilities with their own indicators. The results should be presented as two different indices separately and without any kind of summation. Combination of these two capabilities may induce compromise in losing one of them. As the ski resort example shows, increasing the capability of enjoying recreational activity caused a decrease in the capability of enjoying spiritual

activities in this case. Combining the two capabilities may hide the importance of decreasing the spiritual enjoyment if the recreational index becomes higher than the spiritual index.

2. **Capability to be adequately nourished.** One of Nussbaum's central capabilities is being adequately nourished, which is included in the bodily health category. This capability is highly related to the environment and dependent on both provisioning and regulating ecosystem services. Most of the provisioning services are related to food and water that humans need to consume. And, provisioning services related to foods are supported by most of the regulating services, such as climate regulation, soil formation, and water purification. The importance of preserving those services is largely discussed in the literature and in detail. For example, climate regulation, water purification, and watershed protection are among the most important ecosystem services that wetlands provide (Brander and Schuyt, 2010). These unique services are necessary for agriculture and food production. Moreover, Brander and Schuyt (2010) mentioned that wetlands not only provide food and fresh water, but they also play an important role in food webs by regulating ecological processes. Such services are so important and unique that they should be secured and preserved for future generations (Brander and Schuyt, 2010).

   This capability is not limited to food and water; unique plants used as a medicine are also included. Medicinal herbs are categorized among those irreplaceable services of the environment that need to be preserved and can be considered in this capability. The importance of preserving medicinal herbs is clarified by evaluating their contribution to people's life. Matthews et al. (1999) implied that medicinal herbs,

more than broadly used in original form, play a crucial role in producing new medicines. Such importance entails securing the ability of a community to access these unique resources.

Moreover, selected capabilities should be at the least possible number (parsimony). The two capabilities proposed earlier can cover almost all crucial aspects of ecosystem services, and there is no need to select other capability, unless for special cases. The first capability mentioned above can capture changes in cultural ecosystem services, and the second capability can capture changes in provisioning and regulating ecosystem services. Since any change in supporting ecosystem services will affect the associated cultural, provisioning, or supporting ecosystem services, evaluating the capabilities related to those three ecosystem services can serve as a representation of the changes in supporting ecosystem services as well. Thus, the aforementioned two capabilities would be adequate for EIA in general cases.

The proposed capabilities are also orthogonal, which means that capturing the impacts on one of them cannot necessarily indicate the impacts of the other. As an example, assume a temple in a wood with various kinds of vegetation, including one type of medicinal herb. Constructing a road in vicinity of the temple can affect the ability of using it due to the high pitch noise caused by the traffic passing on the road, but it may have no significant influence on the vegetation and the medicinal herb. On the other hand, digging some wells in the region to use groundwater can drop the groundwater surface, and it may cause some vegetation, including that medicinal herb, to become dry. However, having some wells in the region may not affect the practice in the temple.

By using proper indicators for each proposed capability, the impacts of a hazard on the environment can be quantified. Following Gardoni and Murphy (2009) procedure to obtain HII,

the result for each capability is a dimensionless quantity called a "*capability index*." Then, HII is constructed by aggregating capability indices, whether applying different or equal weight to each of them. Gardoni and Murphy (2009) insisted that capability indices should be combined with equal weights, since the value of each one is "incommensurable" or "irreducible" to the others. They discussed that the indicators might change in order to quantify the impacts in various time-spans after the occurrence of a hazard (emergency, short-, and long-term periods). Tracking indicators in a specific subpopulation, such as a specific race or gender, can depict how the risk would be distributed in a society (Gardoni and Murphy, 2009). This feature of CRA can be very helpful for evaluating the effectiveness of the associated decisions and measures for reducing inequality in society by trying to distribute risk evenly.

The Role of CRA in EIA

Prevailing use of EIA caused criticism due to its weak theoretical underpinnings. "[T]he administrative framework for EIA emerged from a political imperative, not a scientific background, and practice commenced prior to the development of adequate scientific capacity" (Lee et al., 1995). Lawrence (1997) mentioned explicitly that EIA has been defined and developed poorly in theory. In fact, he described EIA as a combination of several disciplines, such as planning theories, social sciences, economics, and biology with less effectiveness than the summation of them all. By using scientific knowledge and expertise in various disciplines, EIA, as an applied science, tends to identify the probable impacts (positive and/or negative) of a proposed action on the human environment (Chang et al, 2013). Responding to this issue, various methods and frameworks have been developed and modified; however, integrating those methods of impact assessment remains a challenge for practitioners (Morgan, 2012).

Its initiator, the law, has not specified any target or standard for EIA. This caused EIA to be ineffective in some ways. Although EIA is expected to ensure that environmental impacts (including physical, life, and social ones) are considered in developments' decisions (Glasson et al., 2012; Wathern, 1988), "[it] becomes a framework for negotiation and compromise" (Cashmore, 2004). Lack of environmental standards and targets in this environmental management tool, as Benson (2003) argues, creates an opportunity for such negotiations. EIA would be acceptable as far as it can convince political parties, rather than meet scientific, robust criteria. In this regard, implementing the capability approach, because of its quantifying nature, can help decision-makers to identify several targets for protecting the environment. The level of acquiring capabilities or HII can define dangerous, tolerable, required, expected, and favorable

thresholds. The target of protecting or even improving the environment can be set more concretely based on this concept.

Maintaining a net environmental deterioration of zero, proposed by Jay et al. (2007), as a target is not sufficient. Nevertheless, it is favorable to mitigating the negative impacts. Being at zero does not indicate a distribution of costs and benefits in the society and over time. As discussed earlier, geographical, temporal, racial and other forms of discrimination in distributing costs and benefits should be analyzed in order to acquire a profound understanding of the issue. Although Sadler (1999) proposed the implementation of a natural capital approach in EIA, the approach was not developed to investigate distribution. The approach found application in Germany and was used for identifying a suitable location for environmental enhancement as a compensation of negative impacts elsewhere (Wende et al., 2005). Cotton et al. (2014) identified cost-benefit distribution as the required part of future frameworks. Since each proposed action may hinder some environmental services that a group of people may have interest in (R. L. Lawrence et al., 1997; Walker, 2009), EIA has to ensure as long as possible that no one loses his interest for the sake of others' benefit. Cotton et al. (2014) discussed the distribution cost and benefit geographically; however, other forms of distribution can be the subjects of this issue. For example, temporally studying the distribution indicates future generations' status in terms of experiencing costs or benefits. In this regard, the capability approach can assess the capabilities for a particular group of people, such as race, gender, age, among others, to show their experience in each case. If associated indicators use data collected from a specific group of people, the final capability indices would be related to the studied sub-population. Thus, the distribution of costs and benefits of the proposed action can be evaluated in a variety of ways and from various perspectives.

The proposed action also needs to be evaluated with respect to other actions. Such evaluation is referred to as Cumulative Effects Assessment (CEA). CEA has not been developed adequately, since the influence of various actions can be even more complex than the impacts of one action, and conducting CEA is more complicated than EIA for a single action (Morgan, 2012). However, because of the fact that updating capabilities for several actions is very practicable, implementing the capability approach would be helpful in this issue as well. Using the same capabilities for various projects and actions, and tracking the changes in those capabilities, can demonstrate how those projects and actions are related to each other in terms of their impacts on the environment and human well-being.

Conclusion

This paper proposes two capabilities for the assessment of environmental impacts on human well-being with a capability approach to risk analysis. Assessing the environmental impacts of human actions has been conducted using various methods and approaches. However, the consequences of the environmental impacts on human life have not been addressed adequately. In this paper, the requirements of related laws and regulations under the title of EIA were discussed. NEPA, as the main statue protecting the human environment and its requirements, were studied. CEQ and EPA as the two main agencies established after the enactment of NEPA and their roles in EIA were explained. How EO 13563 was involved in EIA by enforcing CBA in every regulatory action of federal agencies, including CEQ and EPA, was introduced. How other entities, such as insurance companies and construction firms may be involved in EIA, was described by studying decision procedures in court cases related to accidents damaging to the environment. In the second part, EIA methodologies were investigated and found that they suffer from a poor connection to human well-being. Recent endeavors to link the environment and human life in the form of ecosystem services were explained, and the shortcomings of ecosystem services' approaches were discussed. In the third part, the capability approach was proposed to compliment current EIA methods by considering human well-being as it is relevant to the environment. Two capabilities were proposed to evaluate the role of the environment in human well-being: (1) capability to enjoy recreational, spiritual, relieving, and so forth activities related to the environment, and (2) capability to be adequately-nourished. In the last part, how capability approaches can contribute to EIA and increase its effectiveness was explained.

References

1. Anand, S., & Sen, A. (2000). The income component of the human development index. Journal of human development, 1(1), 83-106.
2. Anjaneyulu, Y., & Manickam, V. (2011). Environmental impact assessment methodologies (2nd ed.). Hyderabad: BS Publications.
3. Baker J, Sheate W, Phillips P, Eales R. Ecosystem services in environmental assessment – Help or Hindrance? Environ Impact Assess Rev 2013;40:3–13.
4. Barker, A., & Jones, C. (2013). A critique of the performance of EIA within the offshore oil and gas sector. *Environmental Impact Assessment Review*, *43*, 31-39.
5. Bartlett, R. V., & Kurian, P. A. (1999). The theory of environmental impact assessment: implicit models of policy making. Policy & Politics, 27(4), 415-433. Retrieved July 3, 2015, from http://dx.doi.org/10.1332/030557399782218371
6. Benson, J. F. (2003). What is the alternative? Impact assessment tools and sustainable planning. Impact Assessment and Project Appraisal, 21(4), 261-280. Retrieved June 20, 2015, from http://www.tandfonline.com/doi/abs/10.3152/147154603781766185#.VIfmmNLF-So
7. Braat, L.C.,Brink,P.ten, (Eds.), 2008.The Cost of Policy Inaction: the Case of not Meeting the 2010 Biodiversity Target. Report to the European Commission Under Contract: ENV.G.1./ETU/2007/0044,Wageningen,Brussels,Alterra Report1718/ /http://ec.europa.eu/environment/nature/biodiversity/economics/index_en.htmS.
8. Braat, L. C., de Groot, R. (2012). The ecosystem services agenda: bridging the worlds of natural science and economics, conservation and development, and public and private policy. *Ecosystem Services*, *1*(1), 4-15.

9. Brander, L. and Schuyt K. (2010). The economic value of the world's wetlands. TEEB case. Retrieved June 20, 2015, from http://doc.teebweb.org/wp-content/uploads/2013/01/The-economic-value-of-the-worlds-wetlands.pdf
10. Caldwell, L. K., Bartlett, R. V., Parker D. E., & Keys, D. L., 1982. A study of ways to improve the scientific content and methodology of environmental impact analysis. Advanced Studies in Science, Technology and Public Affairs. School of Public and Environmental Affairs, Indiana University, Bloomington.
11. Cashmore, M. (2004). The role of science in environmental impact assessment: process and procedure versus purpose in the development of theory. Environmental Impact Assessment Review, 24(4), 403-426. Retrieved July 3, 2015, from http://www.sciencedirect.com/science/article/pii/S0195925503002075
12. Chang, T., Nielsen, E., Auberle, W., & Solop, F. I. (2013). A quantitative method to analyze the quality of EIA information in wind energy development and avian/bat assessments. Environmental Impact Assessment Review, 38, 142-150. Retrieved July 7, 2015, from http://www.sciencedirect.com/science/article/pii/S0195925512000741
13. Costanza, R., d'Arge, R., Groot, R. D., Farber, S., Grasso, M., Hannon, B., ... & Belt, M. V. D. (1998). The value of the world's ecosystem services and natural capital.
14. Cotton, M., Rattle, I., & Van Alstine, J. (2014). Shale gas policy in the United Kingdom: An argumentative discourse analysis. Energy Policy, 73, 427-438. Retrieved June 17, 2015, from http://www.sciencedirect.com/science/article/pii/S0301421514003309
15. De Groot, R., Brander, L., van der Ploeg, S., Costanza, R., Bernard, F., Braat, L., ... & van Beukering, P. (2012). Global estimates of the value of ecosystems and their services in

monetary units. *Ecosystem Services*, *1*(1), 50-61. Retrieved June 17, 2015, from http://dx.doi.org/10.1016/j.ecoser.2012.07.005

16. De Groot, R. S., Wilson, M. A., & Boumans, R. M. (2002). A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological economics*, *41*(3), 393-408. Retrieved June 22, 2015, from http://www.sciencedirect.com/science/article/pii/S0921800902000897
17. Dunstan, A. (2012). What was Damaged?: Taking Sacred Ecology into Account in Environmental Impact Assessment. *Indigenous Policy Journal*, *22*(4). Retrieved June 27, 2015, from http://www.academia.edu/2964710/What_was_Damaged_Taking_Sacred_Ecology_into_Account_in_Environmental_Impact_Assessment
18. Eleventh Recovery Act NEPA Report. (2011). Retrieved June 27, 2015, from https://ceq.doe.gov/nepa/attachments/nov2011/CEQ_ARRA_NEPA_Report_Nov_2011.pdf
19. EPA website retrieved March 16, 2015, from http://www2.epa.gov/aboutepa/guardian-origins-epa
20. Eira C. Orientações de política sobre Biodiversidade relevantes para a Avaliação Ambiental Estratégica. Dissertação de Mestrado, Instituto Superior Técnico, Lisboa; 2009.
21. Executive Order 13563 (2011). Retrieved June 17, 2015, from http://www.gpo.gov/fdsys/pkg/FR-2011-01-21/pdf/2011-1385.pdf
22. Failler, P. (2010) *Estimates of monetary values of ecosystem service.* In: Kumar, P., ed. The eonomics of eosystems and bodiversity: eological and eonomic fundations :. Earthscan, London, pp. 367-401.

23. Fourcade, M. (2011). Cents and Sensibility: Economic Valuation and the Nature of "Nature" 1. American Journal of Sociology, 116(6), 1721-77. Retrieved July 3, 2015, from http://www.jstor.org/discover/10.1086/659640?uid=3739656&uid=2&uid=4&uid=3739256&sid=21105201683863
24. Gardoni, P., & Murphy, C. (2006). Risk Analysis and Society: A Capabilities-Based Account of the Consequences of Natural or Man-Made Disasters (PSAM-0426). In Proceedings of the Eighth International Conference on Probabilistic Safety Assessment & Management (PSAM). ASME Press. Retrieved June 27, 2015, from http://ebooks.asmedigitalcollection.asme.org/content.aspx?bookid=260&sectionid=38776319
25. Gardoni, P., & Murphy, C. (2009). Capabilities-based approach to measuring the societal impacts of natural and man-made hazards in risk analysis. Natural hazards review, 10(2), 29-37.
26. Glasson J, Therivel R, Chadwick A. (2012). Introduction to environmental impact assessment. 4th ed. New York : Routledge.
27. Hanna, K. S. (2009). Environmental impact assessment: practice and participation. Oxford University Press, USA.
28. Hirji R, Davis R. Strategic environmental assessment: improving water resources governance and decision making. Water sector board discussion paper series, 12; 2009.
29. Honrado, J. P., Vieira, C., Soares, C., Monteiro, M. B., Marcos, B., Pereira, H. M., & Partidário, M. R. (2013). Can we infer about ecosystem services from EIA and SEA practice? A framework for analysis and examples from Portugal. *Environmental Impact Assessment Review, 40*, 14-24.

30. Ismail, Z., Kong, K. K., Othman, S. Z., Law, K. H., Khoo, S. Y., Ong, Z. C., & Shirazi, S. M. (2014). Evaluating accidents in the offshore drilling of petroleum: Regional picture and reducing impact. Measurement, 51, 18-33. Retrieved June 17, 2015, from http://www.sciencedirect.com/science/article/pii/S0263224114000414
31. Jay, S., Jones, C., Slinn, P., & Wood, C. (2007). Environmental impact assessment: Retrospect and prospect. Environmental impact assessment review, 27(4), 287-300. Retrieved June 17, 2015, from http://www.sciencedirect.com/science/article/pii/S0195925506001338
32. Karjalainen TP, Marttunen M, Sarkki S, Rytkonen AM. Integrating ecosystem services into environmental impact assessment: An analytic-deliberative approach. Environ Impact Assess Rev 2013;40:54–64.
33. Landsberg F, Ozment S, Sticker M, Henninger N, Treweek J, Venn O, et al. Ecosystem services review for impact assessment: Introduction and guide to scoping. Washington, DC: World Resources Institute; 2011.
34. Lawrence, D. P. (1997). The need for EIA theory-building. Environmental Impact Assessment Review, 17(2), 79-107.
35. Lawrence, R. L., Daniels, S. E., & Stankey, G. H. (1997). Procedural justice and public involvement in natural resource decision making. Retrieved June 20, 2015, from http://www.tandfonline.com/doi/abs/10.1080/08941929709381054#.Va9w4aRViko
36. Lee, B., Haworth, L., & Brunk, C. (1995). Values and science in impact assessment. Environments, 23(1), 93-100.
37. Liu, S., Costanza, R., Farber, S., & Troy, A. (2010). Valuing ecosystem services. Annals of the New York Academy of Sciences, 1185(1), 54-78. Retrieved June 27, 2015, from

http://onlinelibrary.wiley.com/doi/10.1111/j.1749-6632.2009.05167.x/abstract?deniedAccessCustomisedMessage=&userIsAuthenticated=false

38. Marples, D. R. (1988). The social impact of the Chernobyl disaster. New York, NY: St Martin's Press.
39. Matthews, H. B., Lucier, G. W., & Fisher, K. D. (1999). Medicinal herbs in the United States: research needs. *Environmental health perspectives*, *107*(10), 773.
40. MA. 2005a. Ecosystems and human well-being. Washington, DC: Island Press.
41. MA. 2005b. Ecosystems and human well-being: our human planet: summary for decision-makers. Island Pr.
42. Mendelssohn, I. A., Andersen, G. L., Baltz, D. M., Caffey, R. H., Carman, K. R., Fleeger, J. W., ... & Rozas, L. P. (2012). Oil impacts on coastal wetlands: implications for the Mississippi River Delta ecosystem after the Deepwater Horizon oil spill. BioScience, 62(6), 562-574.
43. Morgan, R. K. (2012). Environmental impact assessment: the state of the art. Impact Assessment and Project Appraisal, 30(1), 5-14.
44. Morris, P., & Therivel, R. (Eds.). (2009). Methods of environmental impact assessment (3rd ed.). Taylor & Francis.
45. Murphy, C., & Gardoni, P. (2007). Determining public policy and resource allocation priorities for mitigating natural hazards: A capabilities-based approach. Science and Engineering Ethics, 13(4), 489-504.
46. Murphy, C., and Gardoni, P. (2006). "The role of society in engineering risk analysis: A capabilities-based approach." Risk Anal., 26(4), 1073–1083.

47. Murphy, C., & Gardoni, P. (2008). The acceptability and the tolerability of societal risks: A capabilities-based approach. Science and *Engineering Ethics,14*(1), 77-92.

48. Murphy, C., & Gardoni, P. (2012a). The capability approach in risk analysis.*Handbook of Risk Theory*, 979-997.

49. Murphy, C., & Gardoni, P. (2012b). Design, risk and capabilities. *The Capability Approach, Technology and Design*, 173-188.

50. National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling. 2011. Deep Water: The Gulf Oil Disaster and the Future of Offshore Drilling. Government Printing Office. Retrieved June 17, 2015, from http://www.gpo.gov/fdsys/pkg/GPO-OILCOMMISSION/pdf/GPO-OILCOMMISSION.pdf

51. Noble, B. F. (2006). Introduction to environmental impact assessment: a guide to principles and practice. Oxford University Press, USA.

52. Nussbaum, M. (2000, 2001a). Women and human development: The capabilities approach. New York: Cambridge University Press.

53. Nussbaum, M. (2001b). Adaptive preferences and women's options. Economics and Philosophy, 17, 67–88.

54. Nussbaum, M. (2006). Frontiers of justice: Disability, nationality, species membership. Cambridge, MA: Belknap Press of Harvard University Press.

55. Percival, R. V., Schroeder, C. H., Miller, A. S., Leape, J. P. (2009). Environmental regulation: law, science, and policy (6th ed.). Austin, TX : Wolters Kluwer Law & Business.

56. Petts, J. (1999). Introduction to environmental impact assessment in practice: fulfilled potential or wasted opportunity?, Petts J., Handbook of environmental impact assessment vol. 2, Oxford: Blackwell; 33-59.

57. Plieninger, T., Dijks, S., Oteros-Rozas, E., & Bieling, C. (2013). Assessing, mapping, and quantifying cultural ecosystem services at community level.*Land Use Policy, 33,* 118-129.

58. Polishchuk, Y., & Rauschmayer, F. (2012). Beyond "benefits"? Looking at ecosystem services through the capability approach. *Ecological Economics,81,* 103-111.

59. Rawls J., *A Theory of Justice*, Belknap, United States, 1971.

60. Rosa, J. C. S., & Sánchez, L. E. (2015). Is the ecosystem service concept improving impact assessment? Evidence from recent international practice. *Environmental Impact Assessment Review, 50,* 134-142.

61. Rowell, A. (2012). Partial Valuation in Cost-Benefit Analysis. Retrieved July 3, 2015, from http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2062987

62. Sadler, B. (1999). A framework for environmental sustainability assessment and assurance. Handbook of environmental impact assessment, 1, 12-32.

63. Seidl, A. F., & Moraes, A. S. (2000). Global valuation of ecosystem services: application to the Pantanal da Nhecolandia, Brazil. Ecological economics,33(1), 1-6.

64. Sen, A. (1993). "Capability and well-being." Quality of life, M. Nussbaum and A. Sen, eds., Oxford University Press, Oxford, U.K., 30–53.

65. Sen, A. (1999b). Commodities and capabilities. New York: Oxford University Press.

66. Sen, A. (1989). Development as capability expansion. *Journal of Development Planning, 19,* 41–58.

67. Sen, A. (1999a). Development as Freedom. New York: Anchor Books.

68. Slootweg R, Rajvanshi A,Mathur VB, Kolhoff A. Biodiversity in environmental assessment: Enhancing ecosystem services for human well-being. Cambridge: Cambridge University Press; 2010.

69. Slootweg R, Vanclay F, van Schooten M, 2003. Integrating environmental and social impact assessment. In: Becker HA, Vanclay F, editors. The international handbook of social impact assessment: Conceptual and Methodological advances. Cheltenham: Edward Elgar; p. 56–73.
70. TEEB Foundations, 2010. In: Kumar, P. (Ed.), TEEB-The Economics of Ecosystems and Biodiversity (TEEB): Ecological and Economic Foundations. Earthscan, London.
71. Tehran municipality website: http://en.tehran.ir/default.aspx?tabid=77&ArticleId=1592
72. United Nations Development Program, 2014. "Human development report." Retrieved July 5, 2015, from http://hdr.undp.org/en/content/human-development-index-hdi
73. United States Department of Labor website retrieved June 20, 2015, from http://www.msha.gov/PerformanceCoal/UBBInternalReview/UBBInternalReview.asp
74. Vandewalle, M.; Sykes, M.T.; Harrison, P.A.; Luck, G.W.; Berry, P.; Bugter, R.; Dawson, T.P.; Feld, C.K.; Harrington, R.; Haslett, J.R.; Hering, D.; Jones, K.B.; Jongman, R.; Lavorel,S.; Martins da Silva, P.; Moora, M.; Paterson, J.; Rounsevell, M.D.A.; Sandin, L.; Settele, J.; Sousa, J.P. & M. Zobel 2009. Review paper on concepts of dynamic ecosystems and their services. Retrieved April 7, 2015, from http://www.rubicode.net/rubicode/RUBICODE_Review_on_Ecosystem_Services.pdf
75. Walker, G. (2009). Beyond distribution and proximity: exploring the multiple spatialities of environmental justice. Antipode, 41(4), 614-636. Retrieved July 7, 2015, from http://onlinelibrary.wiley.com/doi/10.1111/j.1467-8330.2009.00691.x/abstract
76. Wathern, P. (2013). An introductory guide to EIA, Wathern P, Environmental impact assessment—theory and practice, London: Routledge, 3-30.
77. Wende, W., Herberg, A., & Herzberg, A. (2005). Mitigation banking and compensation pools: improving the effectiveness of impact mitigation regulation in project planning

procedures. Impact Assessment and Project Appraisal, 23(2), 101-111. Retrieved July 13, 2015, from http://www.tandfonline.com/doi/abs/10.3152/147154605781765652

78. MEA website retrieved June 17, 2015, from www.millenniumassessment.org/en/About.html#1
79. Whitehouse website retrieved June 20, 2015, from www.whitehouse.gov/administration/eop/ceq/about