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Recent Methods and Techniques in Environmental Impact Assessment

Laiba Saleem, Amina Qadri, Faiqa Amin and Humaira Perveen*

Department of Chemistry, University of Agriculture, Faisalabad-38040-Pakistan.

Abstract

Environmental impact assessment evaluates the potential environmental impacts of a project for sustainable development and to minimize the negative harms faced by the environment and society. Implementation of EIA has faced many challenges including unreliable data, consultant bias, limited public participation, stakeholder personal interests, government policies, and lack of modern techniques. However, EIA has continued to flourish and enhanced its effectiveness by adapting new methods including LCA, MCDA, SEA, and SIA, and new techniques such as GIS software, remote sensing, environmental modeling and simulation, machine learning, and big data analysis. Life cycle assessment (LCA) evaluates the impacts of a product in its entire life cycle. Multi-criterion decision analysis (MCDA) evaluates different factors and provides multiple choices and alternate ways to reduce the impacts. Decision making is improved by SEA which evaluates the proposed plan and policies. The lack of public participation is resolved by introducing SIA (Social Impact Assessment) by urging the communities to raise their concern and give their approval regarding the project. Recent technologies such as remote sensing and GIS software are valuable tools for EIA. Remote sensing allows for data collection from difficult-to-access areas, while GIS helps visualize complex environmental contexts and develop mitigation strategies. Environmental modeling simulates real-world scenarios to predict project impacts on air, water, and land. Understanding of environmental issues has improved by Big Data Analysis and Machine learning which has enabled better decision-making in EIA. The future of EIA hinges on short-term improvements like training and long-term goals like integrating EIA with economic and social evaluations. By addressing challenges and embracing advancements, EIA can become a powerful tool for sustainable development.

Keywords: Environment impact assessment, LCA integration, SEA, MCDA and SIA, remote sensing, GIS, BIG DATA Analysis

Full length review article **Corresponding Author*, e-mail: laibas097@gmial.com

1. Introduction

An Environmental Impact Assessment (EIA) is a process that evaluates the effects of large-scale projects or other actions that significantly impact the environment, including both natural and man-made elements. Participation and consultation are integral to this evaluation process. In the United States, the National Environmental Policy Act of 1969 (NEPA) led to the creation of the Environmental Impact Assessment (EIA) process. This systematic and integrative process is used to evaluate the potential effects of a proposed project before deciding whether or not to approve it. NEPA provides a detailed description of the potential environmental impacts of a proposed activity [1]. The present-day challenges of population expansion, resource depletion, climate change, and inequality have prompted organizations and individuals to consider the far-reaching effects of their current actions. As a result, stakeholders, including businesses, investors, nonprofit groups, legislators, and entrepreneurs, are proactively examining the impact of their activities. This approach enables them to anticipate and mitigate potential adverse outcomes, safeguarding their operations, financial interests, and reputations while contributing to a sustainable future [2].

Environmental impact assessment is a process that helps in identifying the potential environmental, social, and economic consequences of a proposed project. It provides alternative options and drafts to follow, which leads to better monitoring and management of resources. This, in turn, results in the betterment of society and the socio-economic state of a country. For example, Pakistan's economy is flourishing, and the country's population and urbanization are growing at an impressive rate. However, the environment in metropolitan areas has suffered due to uncontrolled growth and ineffective natural resource management, impacting the country's socio-economic framework [3].

Therefore, it's essential to focus on environmental conservation to preserve the world's natural treasures and safeguard public health. Environmental impact assessments (EIAs) can be used to systematically analyze the environmental effects of development projects, make informed decisions, and promote sustainable development. Pakistan follows the methodology for analysis in EIA from Ahmad and Wood (2002), Wood (2003), and Fuller (1999). The stages involved in EIA analysis are screening, scoping, review of EIA reports, public participation, decision-making, mitigation of impacts, and monitoring [4].

An EIA-PPA is a type of assessment that evaluates the impact of a project on the environment. It involves tracking and analyzing the effects of a project after it has been implemented. This assessment is crucial in determining the accuracy of the EIA's predictions by comparing the expected results with the actual impacts [5].Public participation is a source of communication between the stakeholders and the public. Understanding the barriers to public participation in EIA is crucial for promoting it. There are two types of barriers. Individual barriers include negative attitudes and lack of knowledge. Institutional barriers include paternalistic culture, ineffective information distribution, lack of opportunities, and shortage of time and resources [6].

EIA has brought the concept of sustainable development of projects for the stakeholders. The stakeholders are distinct groups holding different opinions about a specific project or a problem. Take an example of climate change impacts where the response of stakeholders varies. One type of stakeholder is from local government, NGOs, and other local organizations with little knowledge, less technical, and more interested in public participation. while some other companies and agencies are more professional and have already improvised the methods and techniques for integrating the impacts of climate change in their decision-making such as environmental agencies [7]. Strict measures have been implemented to improve the EIA process including enhanced screening and reporting, increased public participation, and adherence to guidelines and time constraints in developing countries such as Germany, the USA, the UK, etc. [8].

EIA was introduced in Pakistan's environmental protection ordinance in 1983 and was declared mandatory in 1994. In July 1997, the ordinance was converted into the Pakistan Environmental Protection Act (PEPA). EIA proponents and consultants face several pressures that can help to enhance the quality of Environmental Impact Assessment (EIA) [9].These pressures include demands from regulatory bodies for high-quality reports, community and public pressure to ensure sustainable development, media scrutiny, pressure from senior management within companies, pressure from international funding agencies such as the World Bank, Asian Development Bank, Japan International Co-operation Agency, Canadian International Development Agency, and others, to conduct EIAs in line with their assessment standards [10].

Earlier studies conducted in Pakistan have found a significant discrepancy between theory and reality regarding Environmental Impact Assessment (EIA) reports and methodology. Despite the growing knowledge in the field, the quality of reports seems to be deteriorating. This conclusion is supported by the widespread perception in Pakistan that the EIA is merely a formality and not a national obligation. There are several reasons behind the nation's poor EIA quality including the lack of qualified specialists and transparent procedures, limited capabilities of regulatory bodies, and deficiencies in monitoring and follow-up systems [11].

The issue of climate change presents a significant obstacle to economic progress. The kind of development that takes place affects not only the amount of greenhouse gas (GHG) emissions but also how much society is exposed to the impacts of climate change. This has led to the widespread recognition that it is essential to incorporate the consideration of climate change and its effects into development policies and projects. These projects affect the natural and human systems leading to mal-adaptability.The baseline for considering climate change impacts and adaptations in EIA is given in the following table [12].The main goal of the EIA process is to achieve sustainable development. The EIA helps to decide whether a developmental project requires an assessment, whether it is necessary or not, and if any changes or maintenance of the project are needed [13]

2. Recent developments in EIA methods.

Since the United States passed the National Environmental Policy Act (NEPA), scholars, experts, and government employees have put in a lot of effort to create systems that can help in the development of environmental impact statements (EISs). Though most of this work has been carried out in the USA, EIA processes are being introduced into more and more nations, which is leading to innovative thinking and improvement in EIA methodologies worldwide. While EIA techniques are being developed globally, the United States remains the primary source of such technique [14].

3. Life cycle assessment and its integration with EIA.

Life cycle assessment is a methodology used to evaluate the environmental impact and resource utilization of a product or service throughout its life cycle. LCA encompasses all environmental impacts, human health, and resource usage. Its popularity grew in the 1990s despite criticism, and it continues to develop for the better [15]. There are four phases in the LCA study which include goal and scope, life cycle inventory, assessment of impacts, and interpretation of results [16].

4. LCA analysis for wastewater management.

Industries play a vital role in a country's economy, but they also pose a significant threat to water reservoirs by releasing toxic waste into them. Therefore, it is crucial to manage the wastewater being discharged from both industrial and domestic areas to protect the lives of people and the environment from being destroyed by it. The petroleum industry is a crucial source of energy that meets the growing demands of the world community. However, this industry also has negative aspects, such as the release of

harmful chemicals and effluents into water sources from various parts of the industrial plant [17].

Therefore, there is a need for life cycle assessment (LCA) to manage wastewater from the petroleum industry. The oil and gas industry, also known as the petroleum industry, consists of three parts: upstream, which involves development and production; mainstream, which covers processing, storage, and transportation; and downstream, which includes refining crude oil and gas, marketing, and distribution. Therefore the systematic methodology of LCA is used for the assessment of the effluents and resources used in the industry [18].

Several studies have examined the impact of increasing the boundaries of wastewater treatment systems to include the entire urban water and wastewater system. This includes the removal of freshwater, creation of drinking water, transportation of wastewater to the treatment plant, and distribution and use of drinking water. By characterizing the entire urban wastewater system, researchers can assess the environmental effects of transitioning from traditional centralized wastewater treatment plants to more decentralized systems. Studies have found that separation systems, which separate urine, feces, and grey water, offer environmental benefits over traditional centralized systems [19].

This is because they increase the potential for nutrient recycling and prevent the direct release of nutrients into the environment. When the wastewater system model is expanded to include fertilizer offset production, these benefits become even more apparent. Returning wastewater nutrients to agriculture can decrease the need for mineral fertilizer, which in turn prevents significant environmental burdens associated with the production and application of mineral fertilizer. Additionally, the overall energy demand can be greatly reduced by recovering energy through a digestion process from the organic matter of household bio-waste and toilet wastewater [20].

5. Multi-criteria decision analysis (MCDA) for EIAand its framework.

Multi-criteria decision analysis is a tool works to prioritize decision-making based on multiple criteria. MCDA offers many opportunities to improve the environmental impact assessment process. It provides an organized framework to assess the impact of various alternatives and incorporates subjective opinions shared by stakeholders on criteria with accurate data on the possibilities. This approach can enhance the decision-making process and ensure that all aspects are thoroughly considered [21].MCDA involves three steps in EIA consisting of observing the impact on the environment, evaluating their significance, and considering alternative solutions for better results. It builds the framework for alternative criteria by taking information from the experts, agency workers, and residents while considering the stakeholders' opinions on the matter as well [22].

6. Strategic environmental assessment (SEA) and its linkages with EIA.

SEA is the systematic evaluation of alternatives to established or current PPPs within the framework of a more comprehensive vision, set of objectives, or aims to determin e the possible results of numerous techniques to choose the finest alternation for the desired results [23]. The EIA approach does not properly consider the collective impacts of different projects. EIA is only limited to developing ideas for developmental projects related to environmental sites or areas. EIA seems to overlook small harmful activities, if merged, they can be very dangerous. It is slow in directing the decisions which can be irreversible. EIA often has to face problems of shortage of time and finances. It faces difficulty in assessing the indirect impacts and Better alternatives having lesser environmental impact may be eradicated at the decision-making phase by the stakeholders [24].

It will help in screening out hostile projects towards the environment before taking irreparable actions and decisions. It will help in releasing pressure faced during EIA analysis due to finances and shortage of time by improving policy, programming, and plans. SEA will notify a range of alternatives with detailed information on the key trade-off for the main objective of a given project at the crucial stage of decision-making so that the owners don't make a rash decision towards the environment. The government forces the use of SEA not as a substitute for EIA but as a pre-assessment before initiating EIA which evaluates the impacts of the alternative chosen by the SEA [25].

7. Incorporation of SIA into EIA

Socio-economic impact assessment (SIA) was developed in the 1970s and 1980s to assess the impacts caused by major resource development projects such as hydrothermal power plants, coal power plants, and oil and gas development projects in the US and China. The National Environmental Policy Act of 1969 in the US caused many publications of many authors including works of Wolf (1974), Lang and Armor (1981), Finsterbusch (1980,1985), and Carley and Bustelo (19840) leading to a discussion on the role and nature of SIA [26].

8. Social Impact Assessment, aims and its types.

The study of social impact assessment involves anticipating and managing the social effects of development. Social impact assessment is a branch of environmental impact assessment. It proposes knowledge on how the developmental project affects the lifestyles and routines of people and communities daily. It provides a platform for the people and the affected community to raise their concerns. SIAs are the developmental plans of people impacts [27]. SIA (Social Impact Assessment) involves key stakeholders to maximize social benefits, minimize negative social impacts, and ensure that projects are tailored to the target populations.

It is a democratic process that ensures ownership, transparency, and equity through public participation. SIA makes projects more socially sound and inclusive by involving the community, considering the social impact of the project, and ensuring that the project benefits all members of the community [28].The following are the main aims which are the role of SIA during the EIA process. The identification of social impact from development projects and the systems, procedures, and methods used to mitigate the social impacts. There are many types of social impacts occurring due to the development projects that are related to human lifestyle and communities [29].

9. Steps in SIA

The Social Impact Assessment (SIA) is a crucial process that involves several activities aimed at evaluating the impact of a planned intervention on the environment and the people involved. SIA actively participates in the environmental design, identifies the interested and affected parties, collects baseline data, predicts impacts, recommends mitigation measures, and assists in devising monitoring and management programs. It also provides expert advice on site selection, resolution processes, and coping strategies for dealing with residual or non-mitigate impacts. Additionally, SIA contributes to community skill development and advises on appropriate institutional and coordination arrangements for all parties [30].

10. Public Participation and Citizen Science in EIA

Public participation is crucial at different stages of EIA like scoping, decision making, review, etc. EIA depends on the nature of the project and legislation and varies from country to country. On the type of environment the EIA is considered for and how many communities are affected by the project. Public participation can occur during any step of the process of assessment and can be considered during the result evaluation. In many underdeveloped countries, public participation is not much of a concern because of a lack of knowledge, government policies, and the corrupt environment of agencies [31].

At the screening stage, public participation benefits a lot in the development projects like hydrothermal, mining, power generation, and metal industry by reforming the earlier environmental report. At the scoping stage, the involvement of owners and the shareholders of the given project is made so that they would know about issues and give their opinions to solve them. Public participation educates people about the project and its impacts on their society, health, and lifestyle and enables them to speak their minds [32]. It ensures that early assessment of problems arising from different alternatives before proceeding further in the process. At the draft-making, public participation involves meetings held between stakeholders and the public for better communication and exchange of information to relieve their concerns. They may give their written suggestion and impacts they may face due to the project. All these involvement ensure the efficient execution of EIA analysis [33].

11. Advanced techniques for EIA (Geographic Information System (GIS) and Spatial Analysis in EIA)

A geographic information system (GIS) is software designed to collect, organize, evaluate, handle, and display any physical, biological, environmental, ecological, or geological data. GIS collects different types of data from maps, and satellites and puts them together at a single platform. It helps in visualizing the complex environmental context by combining data on land, maps, and environmental biodiversity. Environmental practitioners can evaluate the correlations between various factors in a geographic setting by using spatial analysis, which is made possible by GIS [34], [35].

It may be used, for instance, to pinpoint susceptible places, forecast the dispersal of contaminants, or assess how deforestation affects nearby ecosystems. This kind of study is essential for spotting possible hazards and creating workable mitigation strategies. For both immediate and long-term evaluations, it is essential to continuously monitor the environmental conditions. Data from field surveys, satellites, and sensors may be included in GIS [36].

This integration offers the latest information that is essential for evaluating the environmental effects of projects. For example, it may be used to monitor changes in land, wildlife movement patterns, and air and water quality. GIS helps in the early assessment of risks such as floods, storms, and earthquakes which is beneficial information in the EIA. By comparing different models, predictions can be made beforehand to prevent the ultimate destruction from upcoming natural disasters [37].

12. Remote Sensing Applications in EIA.

To evaluate the impacts of projects thoroughly, there is a use of data collected from sensors including satellites, drones, radar, and earth images. Remote sensing offers many advantages such as the ability to detect permanent patterns, control the play speed on the digital data, and provide automatic data analysis without personal mistakes [38]. It also enables highlighting or enhancing the image quality, capturing images at different spatial angles efficiently, and obtaining images of areas that are impossible to capture with traditional methods. Remote sensing provides high resolution, effectiveness, precision, and accuracy, making it a perfect tool for obtaining baseline information for environmental impact assessment projects, as well as monitoring the environment even after the completion of the analysis [39].

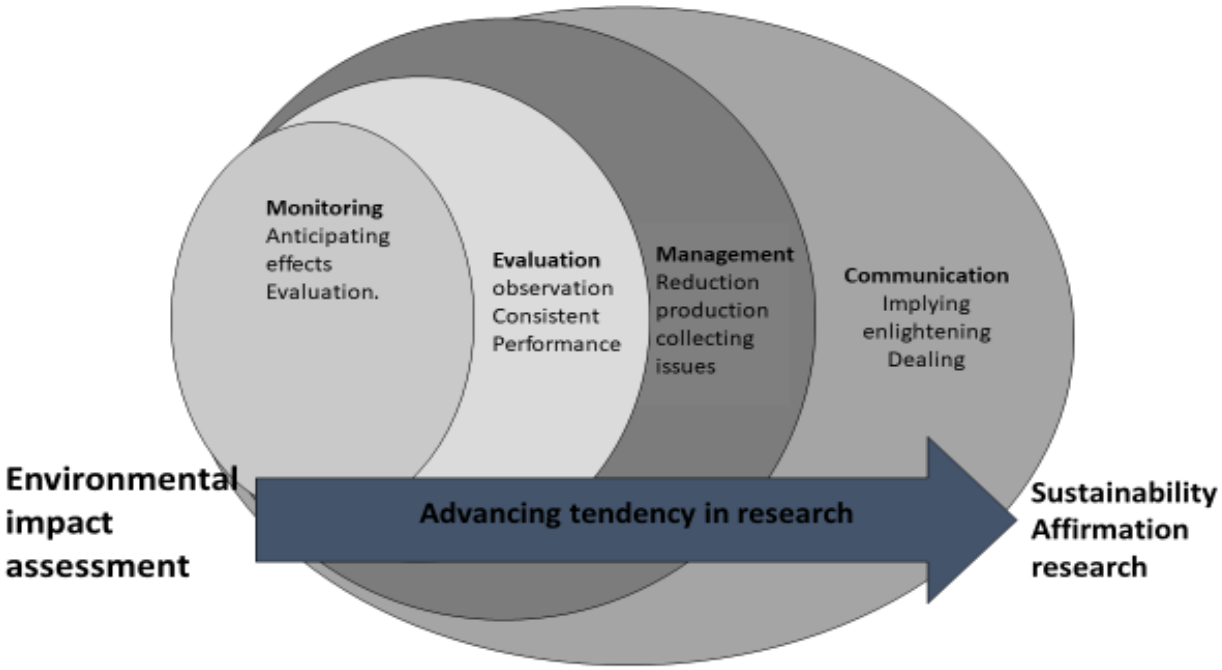

Figure 1. Evolution of EIA

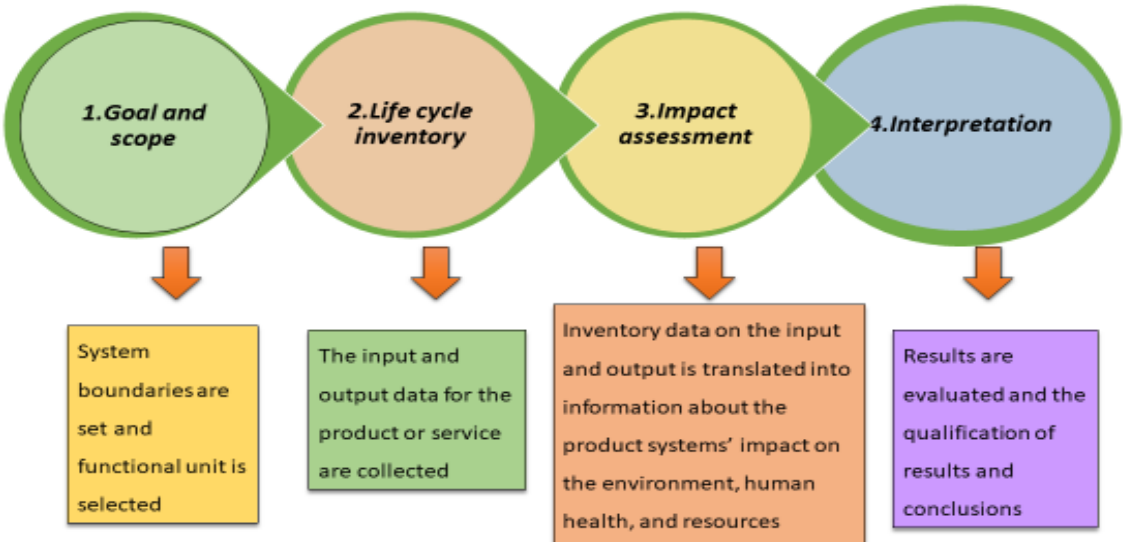

Figure 2. Phases of LCA

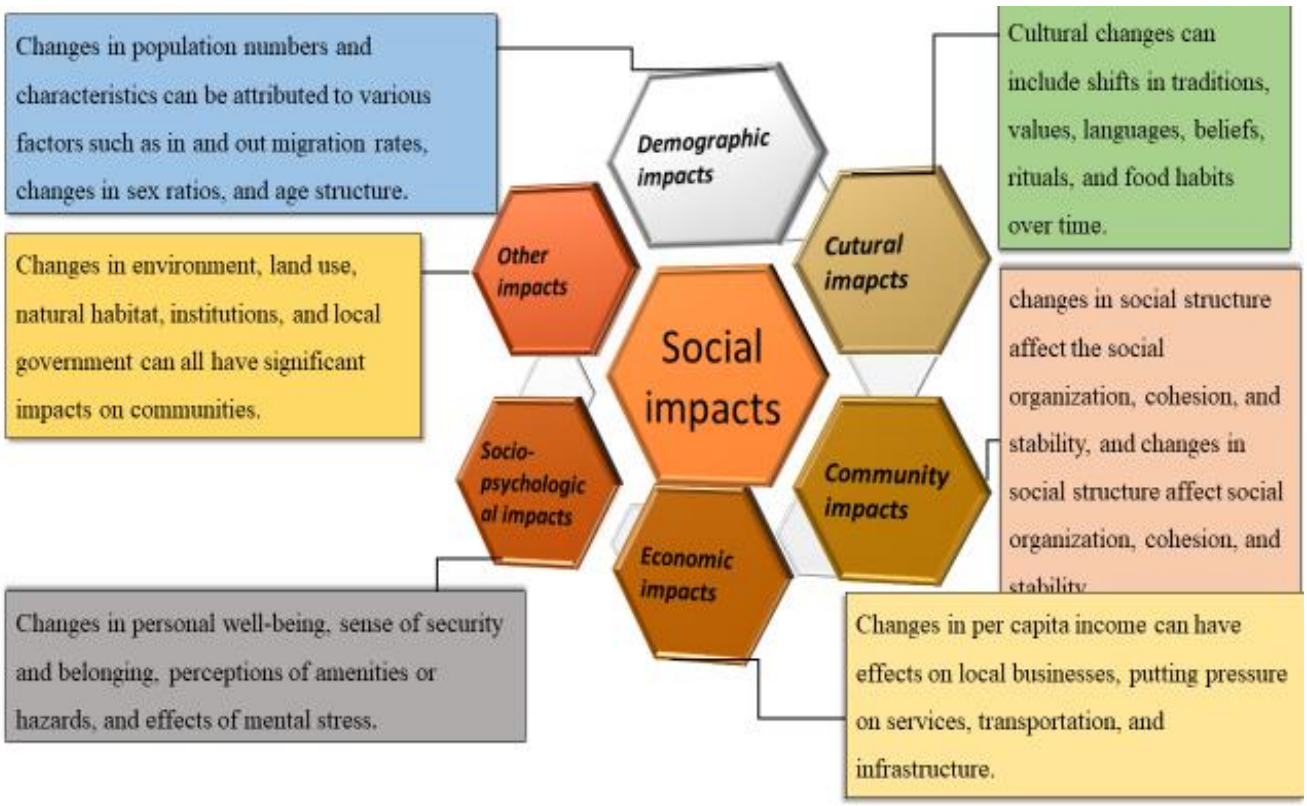

Figure 3. Types of Social Impacts

Figure 4. Steps in Social Impact Assessment

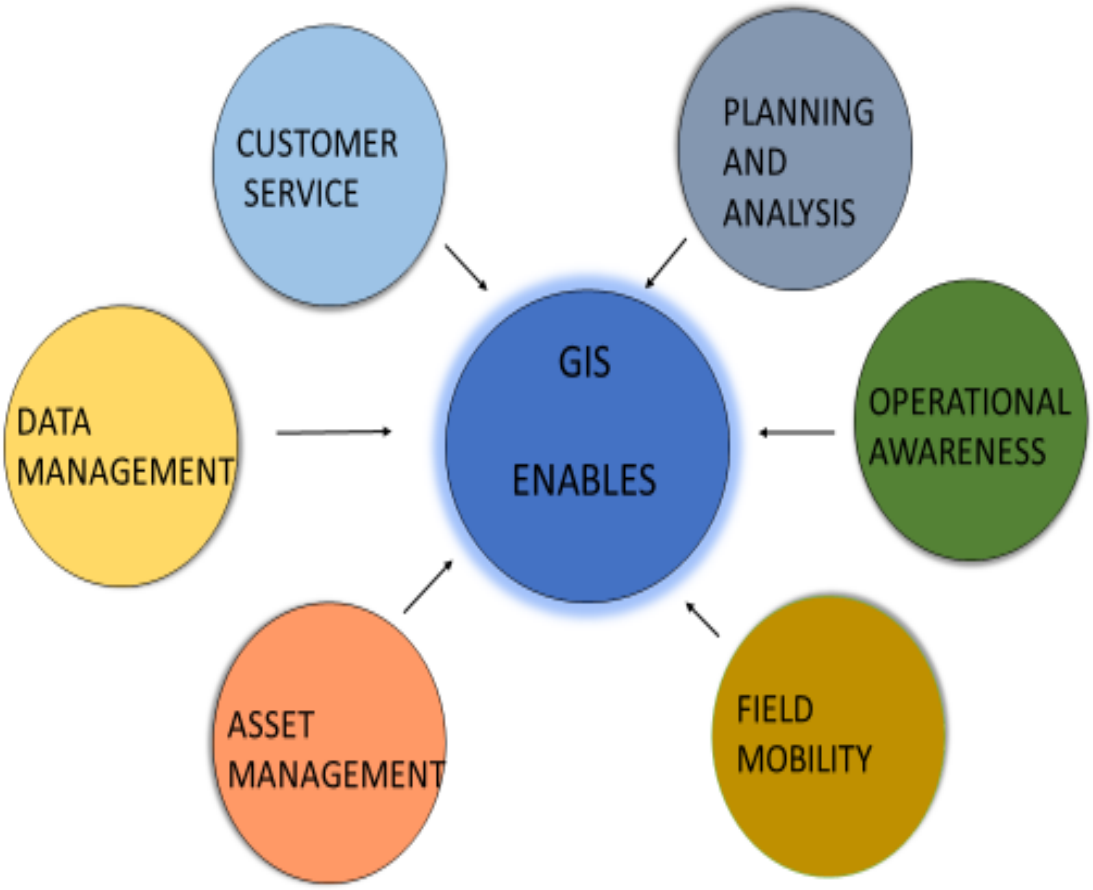

Figure 5. GIS Services

Table 1: The evolution of EIA and adaptation throughout the countries [40]

Part A:

	EIA procedure	Baseline For Climate Change
Planning stage	**project need and justification** **strategic environmental assessment**	**Analysis of climate change**: Should we consider climate change risks and vulnerability for this project, given its scope (e.g. design life and investment level)? If the project is sensitive to climate change, what would be the broader implications?
Conceptualization stage	**Project identification** **EIAScoping:** Observes what needs to be evaluated.	**observing climate change risk and adaptation options assessment:** What are the climate variables and project elements that require assessment? Who will be responsible for conducting the assessment?
Comprehensive evaluation stage	**Conducting EIA:** • Baseline environmental characteristics • Potential impacts • Management measures **Formal public consultation** • Determination: • Submission • Review • Conditions	**Conducting the climate change risk and adaptation option assessment** Which climate variables and project elements should be assessed? Have climate risks and adaptation options been properly identified and evaluated? Is there potential for maladaptation?
Execution of plan stage	**Implementation/ monitoring:** • Construction • operation • Maintenance	**Implementing climate change adaptation measures**: Climate change adaptation measures can be implemented through CMP, OMP, and EMP. Key performance indicators can monitor climate change and climate-proofing.

Part B:

	Stage 1 **Purpose**	**Stage 2** **Direction**	**Stage 3** **Execution**
Advanced economies	Canada	Australia	Australia
	Spain	Canada	Canada
	European Union	Netherland	
Underdeveloped countries	Bangladesh	Grenada	
		Kiribati	
	Dominica	Trinidad and Tobago Caribbean Community	
	Kiribati		
	Saint Lucia Samoa		
	Solomon Islands		
	Caribbean Community		
Global organizations	Asian Development Bank		
	Inter-American Development Bank		
	World Bank		

Table 2: Comparison of LCA and EIA

	LCA	***EIA***
Objective	To assess a process or service's environmental performance and suggest areas for prospective life cycle adjustments.	to evaluate the advantages and disadvantages of a proposed project.
Type of tool	analytical	Procedural
Main use	To enhance a product, service, and process Exchanging information on the environmental effects of a product Extended strategic planning	To meet judicial needs To suggest the need for alternatives to the project
Time	Retrospective and prospective	Prospective
Spatial focus	Normally, not site-specific, but some life cycle assessment methods are site-specific	Site-dependent
Types of impact considered	Overall potential environmental impacts	All effects of the planned projects on the local environment
Strengths	Complete assessment of effects based on cradle-to-grave approach LCA serves as a validation for the system boundaries used in the evaluation of the environmental impacts	Assesses both types of impacts. Considers the socio-economic impact of a proposal and combined impacts of all times.
Weaknesses	Does not address the economic and social aspects Due to the varying production processes across countries, it is important not to compromise the credibility of LCI data while maintaining its confidentiality.	Boundaries are limited to a planned proposal Regional and global impacts are not easily addressed and assessment does not use a special environmental impact assessment method [41].

Table 3: Methods of GIS used in EIA.

OVERLAY METHOD	CHECKLIST METHOD	MATRIX METHOD	NETWORK METHOD
Overlaying the information of the targeted area for achieving goals	Recording the environmental parts, properties, and operations categorically.	Associating particular schemes to definite effects.	Making a network of possible effects of a project including primary and secondary impacts [42].

Table 4: AIR QUALITY INDEX

Air quality index values	Levels of health concerns	Colors
0 to 50	Good	Green
51 to 100	Medium	Yellow
101 to 150	Unhealthy for sensitive groups	Orange
151 to 200	Unhealthy	Red
201 to 300	Very unhealthy	Purple
301 to 500	Catastrophic	Maroon

13. Environmental Modeling and Simulation in EIA.

Modeling is the process of using mathematical equations to simulate situations from life to anticipate or foresee their subsequent actions. It uses software to implement real-life scenarios of the impacts of alternates. It assists in understanding environmental elements like air, water or land and how they are affected by many projects and predicting their future actions. By using mathematical equations, different situations are anticipated and evaluated for their outcomes. There is a range of models that are categorized from simple to complex and can be modified depending on the type of project under assessment. For example, air quality index model [43].

14. AIR QUALITY INDEX(AQI)

The air quality index is used by environmental control agencies to tell the people of origin the quality of air at the current and how much it will be affected in the future. It has different names in different countries. The United States Environmental Protection Agency (AQI), is divided into six fragments. If the AQI value is higher than 300 then it is harmful to the people and the environment and its value lower than 50 is considered ideal for living [44].

15. Machine Learning and Big Data Analysis in EIA.

To comprehensively understand the underlying causes of the growing issue of air pollution and to develop effective policies to address it, it is important to consider both linear and non-linear factors. While linear factors can be analyzed using traditional methods, non-linear factors require more advanced tools such as machine learning and big data analysis to accurately capture their influence on air pollution. It enhances the efficiency in predicting air pollution. It provides instantaneous and quick responses in indicating air pollution so that it becomes easier to deal with the effects beforehand [45].

This technique fuses varying data from different platforms like satellites and sensors and gives a complete data analysis. Machine learning has the ability to modify its models according to changing environmental conditions like air conditions. It is capable of pointing out complicated patterns and trends. Its methods and models are used to analyze the risk and optimize the strategic approach towards the most efficient way and benefits at the decision-making step and policymakers. They can be updated with modern technologies and are user-friendly [46].

16. Strengths and Limitations of LCA in EIA.

One of Life Cycle Assessment's primary advantages is its complete approach to life cycle management and environmental concerns. This makes it possible to evaluate the environmental effects of product systems, which consist of hundreds of processes and account for hundreds of material uses and outputs that occur at multiple points and in various locations. Still, the precision is also a drawback that is it makes generalize and simplifications in the product system and environmental impact analysis that hinder LCA from determining the true environmental consequences. Taking into account the ambiguity associated with mapping the consumption of resources and emissions, simulating their effects, and aggregating estimated impacts over time [47].

It makes a statement that LCA computes potential effects. Another strength of LCA is its more flexible approach. The "best estimate" concept that LCA refers to an additional benefit in the framework of equivalent evaluations. This usually indicates that the same degree of care is used throughout the impact, allowing for objective comparisons and analysis of evaluations. The fact that LCA models are based on average process performance and do not support the evaluation of risks of unusual but extremely significant occurrences like marine oil spills or incidents at workplaces is a restriction associated with abiding by the "best estimate" premise [48].

Because of this, nuclear power, for instance, seems very ecologically favorable in life cycle assessments (LCAs) since the slight chance of a catastrophic accident, such as those that occurred in Fukushima, Japan, or Chornobyl, Ukraine, is disregarded. One other drawback to be aware of is that life cycle assessment (LCA) can identify which product system is better for the environment, but it cannot determine whether better is "good enough." Therefore, it is incorrect to draw the judgment that a product is ecologically sustainable based just on an LCA demonstrating that the product is less harmful to the environment than other products [49].

17. Enhancing the effectiveness of SEA in EIA processes.

SEA effectiveness is enhanced by implementing the guidelines given by the experts which include strengthening the environmental agencies to get government support to incorporate SEA into the system and enhance its effectiveness, encouraging the communication between the agencies that are involved in environmental policy-making, increasing the knowledge of the agency workers and analysts, making efforts for the selection of SEA in analysis and anticipating the better outcome, improving debates among authorities, creating new procedures and techniques and always looking for new ways [50].

18. Integration of SIA and EIA: overcoming obstacles.

There are many obstacles in SIA that vary because performing SIA is not an easy task since it is based on social components which continue to vary from time to time. Every person included in the project has their own interests. If these interests are not fulfilled then the plan is delayed or creates hurdles for the smooth operation of SIA. They can be state employees, environment agency workers, shareholders, and the direct benefactors of the project. This limits the potential of local residents to lead their troubles and are shut down by the authoritative stakeholders since they hold the power [51].

It makes the implementation of SIA more difficult. SIA needs a large sum of funds and investment but the funds are embezzled, threatening the interests. Authorities don't do justice in performing SIA. The utilization of legal mediators for the communities, the establishment of social resources, and the substitution of straightforward language for obscure terms are a few ways of reducing the knowledge gap among developers and communities [26].

19. Future directions and recommendations.

The following methods can be utilized to immediately enhance EIA practice. Enhanced case experience and updates on laws and processes can lead to better training on EIA issues, particularly as part of a capacity-building strategy or professional development. EIA processes can be improved in the short term by enhancing procedural checks and monitoring, emphasizing areas of weakness, and using monitoring and other tools to expand and adapt to developing countries' needs [52].

EIA could be sharpened as mechanisms to ensure sustainability, coordination of these processes in the initial phase with economic and social evaluation and finally with EMS tools; development of action frameworks for environmental sustainability, against which the consistency of development proposals can be tested; development of the environment, economic and social sustainability frameworks, based on which the integrated or total cost impact of development proposals can be assessed; and their application in new fields, especially areas with a global and cross-sectoral impact such as trade, financial investment and technology transfer [53].

20. Conclusions

Environmental Impact Assessment (EIA) has undergone significant advancements that offer promising tools to ensure a more comprehensive and impactful process. These tools can be categorized into key areas: Technological Advancements, Social Impact Assessment (SIA) Integration, Strategic Environmental Assessment (SEA), remote sensing, GIS software, Machine learning, and BIG-DATA analysis.However, some challenges such as unreliable data and limited stakeholder engagement still persist. To ensure the effectiveness of EIA in the future, several measures need to be taken, including the standardization and harmonization of EIA frameworks worldwide, capacity building for EIA practitioners, open access to EIA reports, and flexible project design and mitigation strategies. Overall, EIA is crucial for sustainable development. By embracing these advancements and addressing the challenges, EIA can help protect the environment for future generations.

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