



Research Paper

Challenges at the early stages of the environmental licensing procedure and potential contributions from geomorphology

Cristina I. Pereira^{a,b}, Celene B. Milanes^{c,*}, Rafael Sarda^d, Benjamin Cuker^e, Camilo M. Botero^f^a Coastal Systems Research Group, Playas Corporation Ltda., Bogotá, Colombia^b Corporación para el Desarrollo Sostenible del Urabá –CORPOURABA, Barrio Manzanares, Cl. 92, No 98-39, Apartadó, Colombia^c Civil and Environmental Department, Universidad de la Costa, Barranquilla, Colombia^d Centro de Estudios Avanzados de Blanes, Consejo Superior de Investigaciones Científicas, CEAB-CSIC, Spain^e Department of Marine and Environmental Science, Hampton University, Hampton, VA 23668, USA^f University Sergio Arboleda, School of Law, Santa Marta, Colombia

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ABSTRACT

Defining impact significance is the main technical task that influences decision-making during the Environmental Licensing Procedure (ELP). The ELP begins with screening to determine potentially significant impacts of the proposed project. Scoping then follows to address any interventions deemed worthy of attention in the production of an Environmental Impact Assessment (EIA). This will include consideration of relevant landforms and geomorphological processes. However, preliminary assessments of environmental impacts often lack the scientific robustness to procure substantive and transactive effectiveness. This review presents an examination of the established practices of screening and scoping while highlighting the foremost challenges to improve the technical grounds of the ELP. The analysis of screening and scoping practices stresses the need for novel methods that ensure the sequential reasoning between their criteria while improving the preliminary evaluation of impact significance. Reducing the inherent subjectivity of discretionary judgment requires scientific methodologies that acknowledge the interaction between the natural system and human interventions, which has been addressed by geomorphological research. The knowledge consolidated in this review opens the gate to explore the compatibility between the United Nations strategy of Ecosystem Approach (EA) with the ELP through a novel geomorphological interpretation of the EIA. Therefore, this diagnosis demonstrates that screening and scoping practices would benefit from reliable methods that balance the precautionary principle with the efficient character required in the ELP.

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1. Introduction

Originally, the Environmental Impact Assessment (EIA) was conceived as a decision-making process that considered: (a) screening out minor interventions that did not require a full impact assessment, (b) scoping the assessment of the screened-in interventions, (c) selecting among development alternatives, (d) predicting impacts and (e) defining mitigation and/or compensatory measures. In practice the EIA became a tool for environmental management agencies to use the assembled information to endorse interventions (Weston, 2000; Wood and Becker, 2005; Retief et al., 2011; Morgan, 2012). Consequently, scientific literature recognized as similar concepts the technical procedure of

impact assessment (identification, quantification, and planning management) and the regulatory processes to approve or reject human interventions (Del Furia and Wallace-Jones, 2000; Chanchitpricha and Bond, 2013; Del Enríquez-de-Salamanca et al., 2016). Given this ambiguity, some scholars name 'environmental licensing' to what others call EIA system or process (Lima and Magrini, 2010; Jaskoski, 2014; Villarroja et al., 2014; Bragagnolo et al., 2017; Burgel et al., 2017; Monteiro and da Silva, 2018; Pereira et al., 2019). Therefore, the consolidation of current literature here presented focuses on the first two stages of the EIA, as part of the licensing procedure, to highlight the need for a novel theory that improves its effectiveness. This is an opportunity to introduce a geomorphological perspective in the screening and scoping stages of impact assessment.

Screening is the procedure for deciding on whether an EIA is required for a particular intervention, while Scoping identifies

* Corresponding author.

E-mail address: cmilanes1@cuc.edu.co (C.B. Milanes).

the key environmental issues needing consideration for any intervention deemed worthy for the next stages of the EIA. Both stages try to define preliminary criteria of impact significance, but the screening makes the distinction among interventions, while the scoping makes it within the impacts of a single intervention (Rocha and Fonseca, 2017; Triana and Enriquez, 2007). To determine impact significance of a proposed project typically includes both objective and subjective criteria. Scientific, social and political concerns inform development of the various metrics used to characterize the potential impacts (Weston, 2000; Pinho et al., 2010). Rapidly developing economies produce numerous projects requiring EIA consideration. Finite resources deem effective screening to assure the allocation of time and money for full scale EIA of the projects most likely to produce significant impacts. And some authors advocate limiting the scope of the EIA to the most salient issues. This allows adequate resources to address those issues, and keeps more minor concerns from obscuring the most significant threats (Chanchitpricha and Bond, 2013; Bond et al., 2018). Consider the effort and expense to do a routine EIA that requires testing of soil and ground water, developing a history of the land and its prior uses, determining the ecological and cultural value of the pre-developed land, surveying the community to identify social impacts, and more. To wit, Pope et al. (2013) call for re-focused scientific research that identifies simpler and less expensive screening and scoping processes to make the EIA more appealing to all parties. Therefore, improving scoping and screening lies within the issues of substantive and transactive effectiveness of the EIA by optimizing time, effort, and resources for significantly impacting interventions and relevant natural processes.

Meanwhile, international organizations have prioritized the Ecosystem Approach (EA) as a comprehensive and science-based path to the conservation and management of natural resources. The EA was introduced in 1994 by the Convention on Biological Diversity-CBD as “a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way” (CBD, 2004). This strategy relies on twelve principles, the Malawi principles (CBD, 1998), and is implemented through the Ecosystem-Based Management (EBM), which may adopt multiple strategies to balance the use and conservation of biological diversity. However, the growing number of guidelines and labels for EBM practices has led to confusion in the application of the EA strategy (Borgström et al., 2015). To deal with this issue, Sarda et al. (2014) proposed a system that facilitates the EA application with a standard scheme called the Ecosystem-Based Management System (EBMS). The EA strategy can improve the use of scientific methodologies to balance environmental management between levels of biological and landscape organization and the recognition of cultural diversity as an integral component of ecosystems (CBD, 2004). However, there is no explicit or implicit reference to the Ecosystem Approach in most EIA regulatory frameworks because the later were normatively developed long before the standards that established the former (Wawrzyczek et al., 2018). Therefore, the consideration of landform processes and ecosystem services in the twelve principles of the Ecosystem Approach is worth considering for improving the EIA framework.

In this context, geomorphology can play a crucial role in the EIA (Panizza, 1996; Cendrero et al., 2001); but most recent studies overlook the potential contribution of this geoscience discipline in the early stages of screening and scoping. Therefore, this review paper aims to consolidate the current understanding of screening and scoping practices, to further discuss the dilemma between efficiency and precaution in the EIA and identify research gaps. Moreover, and based on the relevance of the precautionary principle, the role played by the geomorphology discipline and the Ecosystem Approach is discussed in the light of the condensed knowledge about the early stages of ELP (Environmental Licensing Procedure).

Accordingly, Section 3 consolidates screening and scoping state-of-the-art and stresses their limitations. Section 4 analyzes the role of geomorphology in environmental assessments and outlines its limitations on the traditional understanding of the evaluation of impacts. Section 5 discusses the challenges and opportunities brought by the Ecosystem Approach when considering its articulation with a geomorphological interpretation of the EIA to improve conventional practices of environmental licensing. Finally, the concluding remarks highlight research gaps from the demonstrated need for improving screening and scoping practices, along with the fundamental changes demanded by a geomorphological perspective of the Ecosystem Approach.

2. Methodology

This research relies on a literature review of textual documents in a thematic consultation (Hurtado, 2010), which focused on research and review articles from scientific journals within the field of Environmental Sciences. Authors followed the snowball method (Webster and Watson, 2002; Wohlin and Prikladnicki, 2013) to find literature by consulting the bibliography of key documents on ‘screening’, ‘scoping’ and ‘environmental impact assessments’. Over 20 selected documents were validated by thematic correspondence and further registered in informative units through a category matrix.

Based on a content analysis of the eleven key references (Berg, 2001), the information gathered from each document was organized, classified, and categorized. The contents registered during the literature review included the various definitions of screening and scoping, the relevance of each stage within the environmental licensing procedure, the challenges of their traditional implementations and the main methods or typologies conceptualized by the various authors. Given the volume of information gathered, two categorization matrices were filed as a literature review instrument, one for screening and another one for scoping. Tables 1 and 2 present the categorization matrix for screening and scoping methods or typologies extracted from the main references reviewed.

The inputs of such categorization matrices facilitated the description of the screening and scoping stages presented in Section 3.1. Afterwards, the relationships among documents were identified in light of the main approaches and strategies of screening and scoping practices, as depicted in the conceptual scheme of Section 3.2. Finally, Section 3.3 addresses the interpretation of screening and scoping challenges from the dilemma between the EIA principles of environmental precaution and efficiency.

3. Consolidating screening and scoping knowledge

3.1. Definitions, relevance, and challenges

Screening and scoping occur at the beginning of the Environmental Licensing Procedure (ELP) to ensure that negative effects are properly assessed and early enough to consider alternatives and adopt cost-effective mitigation measures (Durden et al., 2018). The screening stage determines the need for an EIA as a licensing requisite while correlating the extension of the environmental evaluation of the intervention with the significance of its impacts (Slootweg and Kolhoff, 2003; Pinho et al., 2010; Retief et al., 2011). Conversely, the scoping stage addresses two procedural functions of the impact assessment and environmental management. Some authors highlight the role of scoping in prioritizing *impact significance* according to the reach and depth of impacts to approximate their importance and the level of effort required in the assessment (Acerbi et al., 2014; Glasson et al.,

Table 1

Key references related to screening approaches and strategies (Category Matrix).

Key reference	Approaches			Strategies		
	Technical	Discretionary	Social	Generic	Case-by-Case	Mixed
Pinho et al. (2010)	Predetermined or objective criteria (thresholds, preestablished measures and indicative limits) By thresholds based on limits according to predefined criteria	Preliminary study or early environmental evaluation	Critical or subjective criteria (context)	Criteria registered in legislation, regulation, or official guidelines Established list	Case-by-case (complement of other method)	X
Rocha and Fonseca (2017)	Thresholds or policy delineation (by intervention character or area factors)	Discretionary judgement of a public servant, consulted experts or consideration of sensible ecological areas			Case-by-case or preliminary study	X
The World Bank (2012)		Discretionary or customized (expert judgement)		Prescriptive or standardized (lists)	Case by case	X
Retief et al. (2011)	Environmental thresholds	Preliminary study (decision support system + checklist) discretion in a case-by-case exam		Descriptive lists	Discretion in a case-by-case exam	X
Wood and Becker (2005) Acerbi et al. (2014)	Thresholds Generic list	Expert judgment Discretionary criteria	Public consultation Public consultation		Case-by-case	X

3

Table 2

Key references related to scoping approaches and strategies (Category Matrix).

Key reference	Approaches			Strategies		
	Technical	Discretionary	Social	Generic	Case-by-case	Mixed
Mandelik et al. (2005) Triana and Enriquez (2007) Snell and Cowell, 2006	Sectors or localities Technocratic model (impact ID techniques: list, matrices, superposition of maps, computational models)	Expert opinion Discretionary ToR Discretion	Public participation Social model	Generic ToR Norms and standards	Case-by-case Case-by-case	 Incremental
Acerbi et al., 2014			Public consultation	Generic ToR	ToR defined case by case (authority /proponent balance) Adapted ToR from generic guidelines	
Durden et al., 2018			Stakeholders' consultation			

2012; Triana and Enriquez, 2007; The World Bank, 2012). Other authors stress the practical use of scoping in *defining the information required* for the impact assessment to avoid critical gaps in the environmental baseline (Weston, 2000; Snell and Cowell, 2006; Durden et al., 2018). Such prioritizations are often condensed in Terms of Reference (ToR), with considerations of the extension scale, level of detail, and methods to tackle the environmental assessment (Mandelik et al., 2005; Polido and Ramos, 2015; Borioni et al., 2017).

The importance of both screening and scoping rely on the optimization of available resources for managing environmental impacts, but their challenges fall upon different characters. For one thing, inefficient screening either include interventions without significant effects or exclude potentially impacting interventions from the environmental assessment, which can result in additional costs or erode the benefits of the EIA to influence an informed decision (Wood and Becker, 2005). Given the limited resources and administrative capacities in the environmental system of most countries (Kolhoff et al., 2018; Pereira et al., 2018), there is a pressing need for filtering the interventions that enter the EIA system to avoid endless periods of decision-making and inefficient management measures linked to low-quality environmental impact statements (EIS) or reports (Retief et al., 2011). Such operational character of the screening sets the stage for the main targets of regulatory reforms that seek to comply with environmental protection standards (Rajaram and Das, 2011; Rocha and Fonseca, 2017). Thus, the main challenges of traditional screening practices fall upon the issues of transparency and clear guidance because there is a pressing need for explicit criteria to filter the interventions to be controlled as well democratize the responsibility of the decision-making among the ELP parties (Joseph et al., 2015; Durden et al., 2018).

Similarly, inefficient scoping either led to unnecessary work, with the consequent increase of costs and delays, or to underesti-

mate significant effects, which reduces the usefulness of the ELP as a management tool. Excessive requirements in poorly prepared ToRs results in unnecessary information for the competence of an EIA (Snell and Cowell, 2006; Triana and Enriquez, 2007). Meanwhile, limiting the spatial reach of the assessment to the strict neighboring area of the intervention can give low scientific and conservation value to the EIS (Mandelik et al., 2005). Particularly, the tendency of including rather than excluding issues during the scoping is more an outcome of legal concerns than environmental precaution (Snell and Cowell, 2006). Such imbalance of parameters for the environmental assessment may be why Soria-Lara et al. (2020) denounces a lack of structure in the scoping stage, which represents a barrier to achieve effectiveness in the ELP. This is consistent with one of the main challenges of scoping practices pinpointed by Durden et al. (2018), which stresses a deficiency in applying expert judgment to quantify the potential effects of an intervention through the synthesis and interpretation of the environmental baseline. Also, Joseph et al. (2015) highlight the need for further research in defining specific enough decision criteria for environmental assessments, that are also flexible enough to adapt to each case.

3.2. Approaches and strategies

A lack of scientific consensus in the EIA literature has driven diverse taxonomies for screening and scoping methods, which are addressed in this review. Several authors have proposed a diversity of classification schemes for screening (Wood and Becker, 2005; Pinho et al., 2010; Retief et al., 2011; The World Bank, 2012; Rocha and Fonseca, 2017) and scoping (Mandelik et al., 2005; Acerbi et al., 2014), but common notions can still be extracted and conceptualized. In this sense, and as a novel contribution to EIA knowledge, Fig. 1 depicts the diversity of screening and scoping practices in terms of the main conceptual frameworks

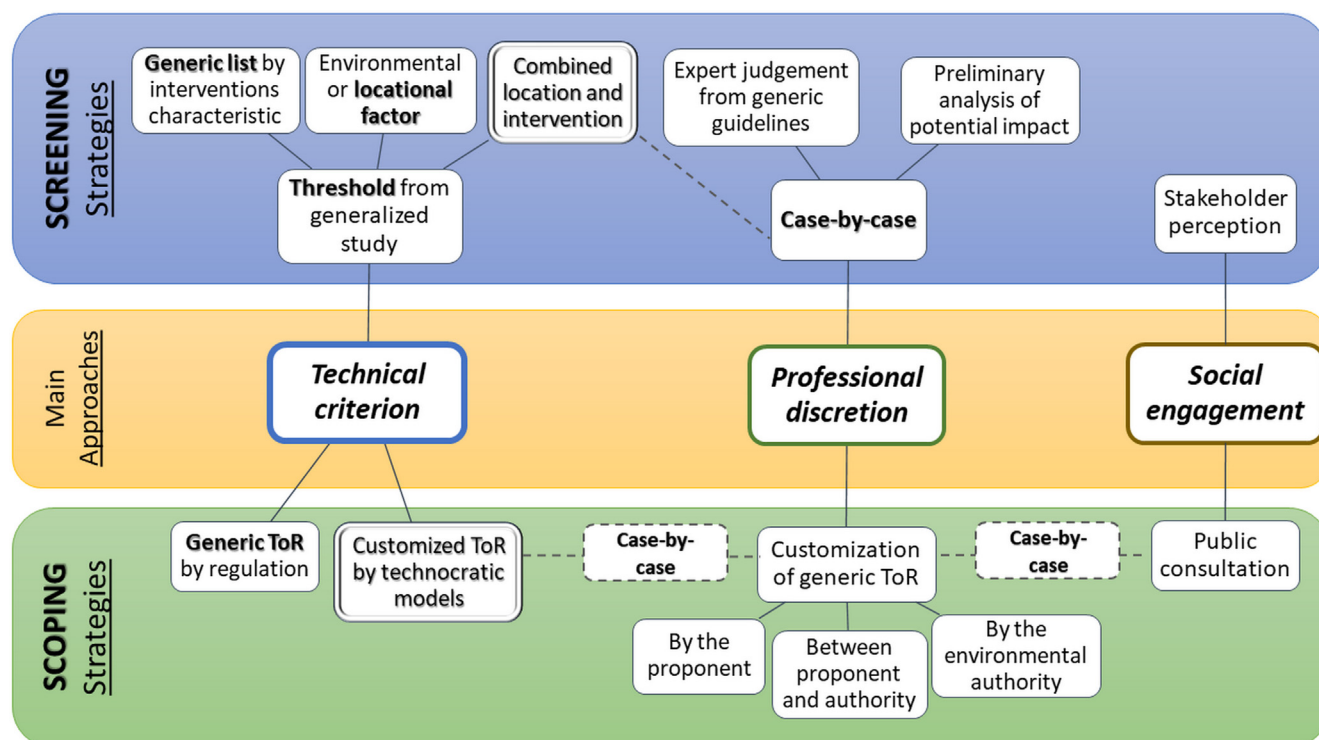


Fig. 1. Synthesis of main approaches and strategies for screening and scoping. Based on: Snell and Cowell (2006), Pinho et al. (2010), Retief et al. (2011), The World Bank (2012), Acerbi et al. (2014), Rocha and Fonseca (2017). ToR stands for Terms of Reference.

(approaches) and the means of achieving the purpose of the stage (strategies). The three main approaches range in their reliance on objective and subjective criteria for discriminating impact significance.

Technical criterion represents the objective end of the spectrum, where predetermined measures and guidelines are set as indicative limits often registered in the legislation or regulations (Snell and Cowell, 2006; Pinho et al., 2010; Rocha and Fonseca, 2017). The *professional discretion* implies a value judgment from the public servants, consulted experts or technical staff of the environmental authority during an early evaluation of the intervention's impacts (Weston, 2000; Mandelik et al., 2005; Wood and Becker, 2005; Acerbi et al., 2014; Rocha and Fonseca, 2017). *Social engagement* refers to the insertion of arguments and information from stakeholders and the general public into the discussion over the significance of the impacts to be screened or scoped (Weston, 2000; Slootweg and Kolhoff, 2003; Snell and Cowell, 2006; Acerbi et al., 2014; Durden et al., 2018). Consequently, the diverse screening and scoping practices can be framed into one or a mixture of technical, discretionary, and social approaches, but the actual strategy within each approach and EIA stage is rather varied.

The variations of screening strategies using thresholds often relies on the outcome of a generalized study across an industry or area (Fig. 1). As such, a generic or standardized list of inclusive or exclusive interventions are based on the characteristics of the industry, such as production volume or size of the land required (Rajaram and Das, 2011; Retief et al., 2011; The World Bank, 2012; Rocha and Fonseca, 2017). Thresholds set by locational factors center on environmental limitations, often linked to sensitive areas or carrying capacity considerations that rest on policy delineations or regulations (Retief et al., 2011; Pereira et al., 2018). Despite having a prescriptive or standardized character, Rocha and Fonseca (2017) have defined locational and geographical factors as part of the technical reference in the case-by-case screening strategy where potential interventions are individually assessed. A novel strategy in this regard would imply the integration of locational factors and intervention typologies in a generalized study able to offer sound and clear technical criteria for straightforward case-by-case analysis. Furthermore, the approach of professional discretion is almost exclusive to the case-by-base strategy, where the environmental authority performs an individual analysis of potential environmental impacts (Pereira et al., 2018) or the expert judgment of specialists is combined with a generic list or standardized guidelines (Wood and Becker, 2005; Pinho et al., 2010). Finally, screening strategies involving social engagement are less popular than in the scoping stage, however, the societal context of a human intervention tends to trigger a full EIA even if their impacts are less likely to be significant (Pinho et al., 2010). Furthermore, public consultation is considered a way to increase transparency in the screening process (Wood and Becker, 2005). Therefore, stakeholder's perception is a compelling critical and subjective screening criterion.

The lower part of Fig. 1 depicts the scoping strategies, in which the common product is the definition of Terms of Reference (ToR) or a document with indications for conducting an impact assessment and report it on the EIS. Mandelik et al. (2005) differentiate scoping mechanisms according to how the relevant issues are determined (expert opinion or public participation) and who is the lead (authority or proponent). The scoping practices derived from technical criterion and professional discretion may fit into the methods supported by expert opinion, being the difference in the standardized versus customized case-by-case strategies. Within the former, generic ToRs are defined by the environmental regulation or authority, while customized ToRs by technocratic models relying on the use of impact identification techniques, such as matrices, computational models, or superposition of maps (Snell

and Cowell, 2006; Acerbi et al., 2014). Scoping practices based on professional discretion imply the adaptation of generic ToRs with a discriminated level of participation from the environmental authority and the proponents or their consultants (Mandelik et al., 2005; Acerbi et al., 2014). Regarding the social engagement, public consultation is considered the most appropriate scoping practice because it ensures the inclusion of most concerning matters for stakeholders in the impact assessment (Weston, 2000; Slootweg and Kolhoff, 2003; Mandelik et al., 2005; Acerbi et al., 2014; Borioni et al., 2017). The customization of ToRs, either by scientific techniques, professional discretion or social engagement, inherently refer to the case-by-case strategy because the guidelines for assessing impacts and designing management measures are adjusted to the kind of intervention. However, this approach is incomplete without consideration of the particularities of the location. All in all, the strategies for screening and scoping may be categorized as generic or case-by-case. Often both are used simultaneously.

In practice, each government can apply a varied combination of screening and scoping strategies. For instance, the centralized and narrowed focus on the intervention's site of the EIA in Brazil compromises its effectiveness because the process disregards the region's ecosystem (Glasson and Salvador, 2000; Turra et al., 2017). Colombia uses a generic screening strategy with a prescriptive list set by arbitrary thresholds of project features, while it applies a discretionary approach in the scoping stage in which public servants customize generic ToRs (Toro et al., 2010; Pereira et al., 2018). Similarly, EU members combine generic lists with professional discretion in standardized cases for the screening while the scoping is handled case by case between the proponent and the authority (Pinho et al., 2010; Lonsdale et al., 2017; Soria-Lara et al., 2020). Another dissimilar combination is the Cuban system, where both screening and scoping are conducted with a case-by-case strategy that relies on the consultation of public administrations (Pereira et al., 2018). In these examples, as in many other contextually diverse regulatory frameworks, there is no logical connection between the fundamentals for these two stages, as opposed to what Durden et al. (2018) suggest when stating that the scoping should be based on the screening outcomes. Therefore, an improvement in the ELP practices would require sequential reasoning that aligns the concerns raised during screening with the parameters addressed in scoping a full EIA.

3.3. Efficiency or precaution: limitations of conventional approaches and strategies of screening and scoping practices

An over-simplification of the substantive and transactive effectiveness referred to in the introduction can relate to the challenge stated by Snell and Cowell (2006) about balancing precaution and efficiency in decision-making during the EIA. The precautionary principle states that environmental damages should be avoided even in absence of hard evidence. This harmonizes with the EIA's goal measured by the substantive effectiveness, about supporting decision-making in environmental protection (Snell and Cowell, 2006; Chanchitpricha and Bond, 2013). Similarly, the efficient character that must reflect the decision-making in the EIA harmonizes with achieving EIA's goals with the minimum time and resources, as assessed by the transactive effectiveness (Snell and Cowell, 2006; Bond et al., 2018). In this context, the approaches and strategies categorized in the previous section for the screening and scoping stages can be further conceptualized.

The diagram in Fig. 2 associates the inversely proportional relationship between the precautionary and efficiency principles within the main approaches and strategies for screening and scoping. For instance, the social engagement approach poses the highest position in precaution, but the lowest degree of efficiency.

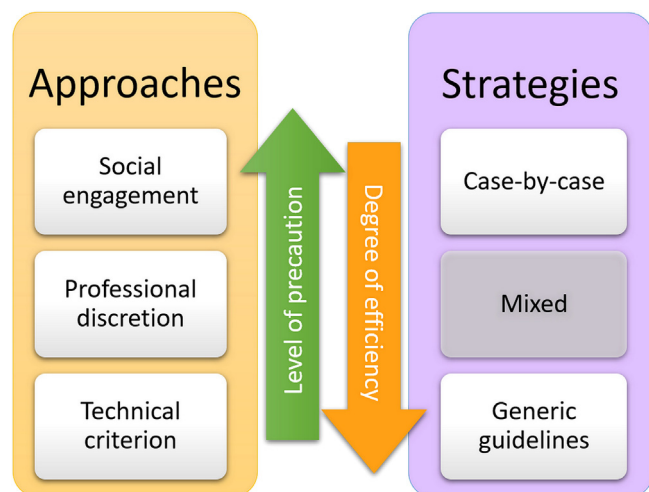


Fig. 2. Relationship between main approaches and strategies for screening and scoping with the principles of precaution and efficiency in EIA systems.

Social models provide a better interpretation of the precautionary principle of the EIA because significant impacts identified from public consultation compensates for the proponent bias and address the most concerning matters for stakeholders (Snell and Cowell, 2006; Acerbi et al., 2014). Also, consulting stakeholders and promoting the value of the information they provide yields a preliminary social license for the interventions that helps to reduce conflicts (Durden et al., 2018). However, social scoping does not solve the barriers in information, resources, and efficacy associated with the wide participation of the community, not to mention the political stain of the private interests that may permeate the common interest (Weston, 2000; Snell and Cowell, 2006). While the **social engagement** approach reduces conflicts and potential impacts, it comes with a high cost of time and resources. It is also inherently subjective and prone to being skewed by the loudest voices.

The **professional discretion** approach strikes a balance between precaution and efficiency due to its reliance on human values and its inherent link to the case-by-case strategy of significantly low efficiency. The preliminary assessment of impact significance in a discretionary approach uses value judgments and subjectivity from the public servants in charge, which rest upon the intuition, education and previous experience of a limited number of individuals (Weston, 2000; Wood and Becker, 2005; Triana and Enriquez, 2007). Such background diversity in the technical staff is more likely to introduce uncertainties because similar interventions tend to receive unequal treatment, while the authorities may be enticed to illegally influence the decision-making (Acerbi et al., 2014). As an advantage, the discretionary judgment gives certain flexibility to the licensing authorities in how and when to use technical arguments, along with the possibility to reflect the environmental circumstances and social values within the consideration of impact significance (Wood and Becker, 2005). Such precaution in the significance of potential impacts is implicit in the case-by-case strategy, where the relationship of a specific intervention with its recipient environment is addressed in a preliminary environmental evaluation (Wood and Becker, 2005; Rocha and Fonseca, 2017). Case-by-case analysis can address ecological issues that emphasize the intrinsic value of nature. But this is an expensive and complex strategy burdened with subjectivity and extensive effort put into individual preliminary assessments (Mandelik et al., 2005; Rocha and Fonseca, 2017). Optimizing the professional discretion (case-by-case) approach requires the inser-

tion of reliable methods to reduce the inherent subjectivity of discretionary judgment and improve the systematic evaluation of potentially significant impacts at the early stages of EIA.

Finally, the **technical criterion** approach poses the lowest level of precaution and the highest degree of efficiency. This is mostly attributed to the widespread use of intervention-centered criteria as a generic strategy that treats interventions alike despite their natural context. Thresholds and generic guidelines are the most used strategies because they are easy to use and understand for proponents and authority staff, which gives homogeneity, consistency and transparency to the EIA process (Retief et al., 2011; Joseph et al., 2015; Rocha and Fonseca, 2017). The downside of relying primarily on an inventory of established and generalized metrics is the inherent arbitrary and possibly decontextualized nature of such indexing since it often underestimates the relevance of locality in the significance of impacts. This minimizes the precautionary character of the technical criterion approach (Wood and Becker, 2005; Retief et al., 2011; Rocha and Fonseca, 2017). The rigidity of generic lists limits the ability to distinguish and rank the significance of various impacts. This may lead to different interpretations or abuses on a wide range of interventions undergoing an unnecessary EIA (Retief et al., 2011; Acerbi et al., 2014). Similarly, generic ToRs are the less precautionary strategy because they disregard the relative importance of environmental variables on the particular intervention, which leads to treating as equal interventions that are different (Acerbi et al., 2014). Furthermore, different thresholds within neighboring jurisdictions can result in very different EIA requirements for similar interventions on a comparable location. This creates serious political implications that undermines the public confidence in the usefulness and transparency of EIA processes (Weston, 2011; Rocha and Fonseca, 2017). Why does one town get to build an aquaculture pond and a similar nearby one find its permit denied? Therefore, improving the environmental precaution in the approach of technical criteria would require developing novel methods that rely on the scientific understanding of the natural system and its interaction with the human intervention.

Technical criteria properly integrating both intervention and locational parameters are scarce, or poorly efficient when restricted to complement the discretionary judgment in a case-by-case strategy. According to Weston (2000), conventional screening and scoping practices describe an anthropocentric rather than an ecocentric approach, because impact significance is defined as to what is considered environmentally important from a political sense. Developing an ecocentric view dictates using an Ecosystem Approach of the CBD (2004) in screening and scoping practices. In fact, Slootweg and Kolhoff (2003) state that functions of the natural system are determined by the type of ecosystem or kind of environment. As an alternative, carrying capacity analysis may approximate the interaction between locational factors of the natural setting (Ecosystem Approach) with disturbing human intervention (Rocha and Fonseca, 2017). However, such preliminary assessments concentrate on extremely local scales and there is not a clear methodology to address it at an overall scale, so environmental authorities may implement it as a management instrument (Rajaram and Das, 2011). In this context, the need for a sound and state-of-the-art methodology for furnishing a technical criterion that is sensitive to locational factors and anthropic disturbances at a medium-large scale is established. Such a methodological approach can be applied as a preliminary study across the kinds of environments in a jurisdiction to balance both precaution and efficiency in the management of environmental impacts. The role of geomorphology in the EIA facilitates the implementation of the Ecosystem Approach since the locational particularities of a human development closely link to features of the landscape.

4. The role of geomorphology in environmental assessments

Application of geomorphology helps assess the significance of potential impacts at the ecosystem scale. Geomorphology studies the features of the Earth's surface and the sculpting processes that create and shape the landscape. It enables the understanding of topography, land cover and terrain relief, all essential to the functioning of ecosystems (Scheffers et al., 2015; Lopatin and Zhirov, 2017). This interpretation also conceives the interaction of the classical geomorphic elements, such as sedimentology or morpho-dynamics, with biogenic and human components (Pereira, 2019). In this sense, emerging sub-disciplines, such as ecogeomorphology and biogeomorphology, highlight the bidirectional influence of biologic and geomorphic processes in environmental flows (Meitzen et al., 2013). Similarly, the novel term 'anthropogenic geomorphology' has risen from the interest of scholars to study man-made landscapes and the human influence over the Earth's surface (Wu et al., 2012; Li et al., 2017). Also, Geoethics is an emerging frontier discipline -between ethics and geosciences- that looks at the values of how humans relate to the Geosphere (Di Capua and Peppoloni, 2019). Regarding geomorphological susceptibility, several anthropocentric approaches have analyzed issues such as coastal erosion (Fitton et al., 2016; Arabameri et al., 2020), climate change (Goodhue et al., 2012; Billa and Walker, 2019), and landslide assessments (Achour and Pourghasemi, 2020; Al-Najjar and Pradhan, 2021; Balogun et al., 2021). Therefore, the transdisciplinary analysis of geomorphological elements would highly improve the understanding of an ecosystems' structure and function from the early stages of the EIA along with its efficiency as a management tool.

In line with [Downs and Booth \(2011\)](#), environmental management issues can be geomorphologically addressed from three central fronts: (a) Conservation of natural settings; (b) Natural hazard definition; and (c) Sustainable exploitation of natural resources. Most literature on applied geomorphology refers to case studies rather than scientific discussions of geomorphological approaches and techniques to support environmental management ([Downs and Booth, 2011](#)). Nevertheless, environmental management tools, such as land-use planning and the EIA itself, requires the instrumental role of geomorphology in describing and measuring the anthropogenic impact on landforms' features ([Panizza, 1996](#); [The World Bank, 2012](#)). Consequently, the clear link between geomorphology and EIA calls for a deeper examination of the environmental management from the Earth Sciences perspective.

Surprisingly, the main scientific contributions of geomorphology to the EIA dates back over twenty years, when [Cavallin et al. \(1994\)](#) and [Cendrero et al. \(2001\)](#) discriminated landforms from geomorphological processes to integrate them in the EIA. In this traditional view, the environment is represented by three elements: landforms, processes, and raw materials. The solid-line diagram in [Fig. 3](#) depicts the relationship of these three geomorphological elements with anthropogenic interventions through two notions: risk and environmental impact. The former describes the role of processes as the geomorphological hazards that may damage the human development, while the latter is linked to the shortage and transformation of raw materials and landforms during the installation and operation of the human development. Consistent with this reasoning, characterization landforms will help to ascertain the anthropogenic impact as economic loss of raw materials or landscape damage, while geomorphological processes represent a potential damage to the human activity in terms of geological hazards.

Nonetheless, this traditional model ignores the link between the geomorphological elements themselves, as depicted by the dashed arrows and outlines in Fig. 3. According to Panizza

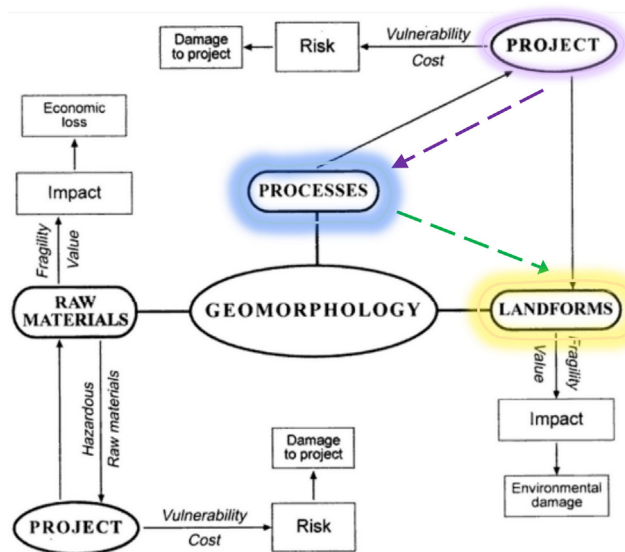


Fig. 3. Relationship between human interventions (project) and geomorphological features in the EIA context (modified from [Cendrero et al., 2001](#)).

(1996), the geomorphological processes not only have an active role as a hazard to human developments but also as the originators and shapers of the natural landforms. Therefore, the bi-directional relationship between geomorphological features and human activity indicates that processes have both passive and active roles (Pereira, 2019). Also, the geomorphological processes are central to anticipate the human impact because any perturbation to such, translates into disrupting the evolution of the corresponding landforms and their constituent raw materials. Interpretation of the geomorphological processes is then critical to the screening and scoping stages because natural processes can modulate anthropogenic impacts on both intervention and locational parameters (Slootweg and Kolhoff, 2003). In sum, the dynamic character of natural processes represents the central role played by geomorphology in the preliminary assessment of impact significance during the early stages of the EIA.

Overall, geomorphological processes have always posed a challenge in the attempt to assess and control environmental impacts. For one thing, geomorphological processes present engineering challenges to the infrastructure and operation of human interventions but also frame the character of the environmental impact (Cavallin et al., 1994). Rivas et al. (1997) neglected the geomorphological processes in their proposed set of EIA indicators, because the limited knowledge of these dynamic elements precludes precise predictions of their evolution when artificial changes are introduced. Despite over two decades since this revelation, the level of precision required in basic sciences is still limited regarding the prediction of most geomorphological processes, not to mention the extremely local nature (case-by-case) of such predictions (Pereira et al., 2018). Consequently, there is a need for involving processes and landforms as technical criteria for screening and scoping, where the knowledge limitations are addressed to the precision level expected by the applied science of environmental management.

5. Contributions and challenges from the ecosystem approach

The EIA should have a high concern for any actual or potential use of habitats and/or their associated values, from the baseline definition to the mitigation options. The final aim of the EA is to

ensure that human interventions with potential impacts are considered and managed effectively, which is not far from the main goal of the EIA of identifying, evaluating, and mitigating the consequences of human actions on the environment (IAIA and IEA, 1999; CBD, 2004). Ahmad (1993), was one of the first to link the EIA with the EA, analyzing the impact of human activities on the Himalayan biogeophysical, socioeconomic, and cultural environments. Most recently, Wawrzyczek et al. (2018) examine the contribution of the twelve EA principles in identifying alternatives to better assess impacts in EIA frameworks. Furthermore, EA facilitates the inclusion of ecosystem services into EIA frameworks to ensure their value is part of the decision-making process (Comello et al., 2012; Karjalainen et al., 2013). The use of environmental functional units for analyzing anthropogenic impacts can improve screening and scoping practices if they reflect the spatial and temporal linkages through the characterization of natural processes. Besides this potential application in understanding the environmental baseline during early assessments of impact significance, the EA may facilitate the analysis of alternatives, identifying measures for impact mitigation and the consultation process for public participation. Therefore, incorporating the EA principles in the EIA can provide a more holistic and integrated view for controlling environmental impacts through licensing instruments.

Several of the EA principles are consistent with the geomorphological notions of impact assessment explained in Section 3. For one thing, the fifth principle refers to the EA attempt to preserve the ecosystem structure and functioning (CBD, 2004). This aligns with the need to better understand the geomorphological processes, to ascertain the impact significance for environmental management purposes because impacts features are better correlated to natural processes than to project design (Cavallin et al., 1994; Pereira et al., 2018). Furthermore, the eighth principle states that ecosystem management objectives should be set for the long term to accommodate the varying temporal scales and lag-effects of ecosystem processes (CBD, 2004). This process-oriented notion is consistent with the character of geomorphological elements because the dynamic essence of natural processes can be appraised by the multitemporal observation of static scenes of an environment and the connections to neighboring landscapes (Pereira et al., 2019). Lastly, the ninth principle establishes that the management must be done within the limits of ecosystem functioning and recognizes that change is inevitable (CBD, 2004). This circles back to the fifth and sixth principles about preserving ecosystem functioning, but it also embraces the dynamic notion of the geomorphological process. Particularly, processes altered by either natural or anthropic agents poses challenges to the management of environmental impacts (Cendrero et al., 2001; Pereira et al., 2018). Therefore, the decisive role of geomorphological processes in the EIA presented in this review can bring the Environmental Licensing Procedure to agreement with the Ecosystem Approach.

Despite its adoption by the CBD, the EA is yet to be diffused and internalized in the territorial management actions for more effective administration of landscapes (Andrade et al., 2011). In many western regions, EA/EBM applications are currently reinforced by policy tools, such as the Maritime Spatial Planning Directive (2014/89/EU) in Europe that requires the consideration of an ecosystem-based approach in new development projects in the marine environment. However, in practice, the main challenge of the EA application falls upon the conventional sectorized management models, where the environment is fragmented by jurisdictions instead of the ecosystem structure and functionality (Sarda et al., 2014). In a similar note, the ELP has been criticized for circling economic sectors rather than kinds of environments, not to mention the fragmentation of the natural setting into static components rather than dynamic processes for the baseline definition (Mandelik et al., 2005; Snell and Cowell, 2006; Pereira et al., 2018,

2019). Therefore, the geomorphological interpretation of the EIA presented in this work provides a plausible alternative that incorporates the EA/EBM into the environmental licensing procedure.

6. Concluding remarks

Despite the great advances in EIA theory in recent decades, its evolution continues. The main limitations and challenges of screening and scoping were discussed in this article, as a motivation to further analyze these early stages of the environmental licensing, and some concluding remarks emerge from this scientific exercise. Initially, screening and scoping stages could be grouped into three approaches: technical criterion, professional discretion, and social engagement. Those approaches differ, among other aspects, in subjectivity, optimal use of time and resources, and the balance of environmental precaution and efficiency.

Several research gaps emerge from this scientific discussion. First, there is an urgent need for an instrumental technique that ensures the sequential reasoning between screening interventions and scoping of impact assessment. Second, we need reliable methods to balance precaution and efficiency in a systematic preliminary assessment of impact significance. This is true for both screening and scoping purposes. Also, such methods must rely on the scientific understanding (or expert knowledge) of the natural system to improve the environmental precaution in the early stages of the licensing procedure. Naturally, this implies the development of a solid and vanguard methodology to set technical criteria for screening and scoping strategies, that are systematic and sensible to locational factors and anthropic disturbances.

Within this context, new developments such as the EA strategy and its EBM application combine with rising geomorphological interpretations to offer a new state-of-the-art for screening and scoping practices. Understanding geomorphological processes is key to anticipating the human impact on a site, since they produce and shape natural landforms. Perturbations to such processes disturbs the evolution of the essential landforms that characterize a site. The EA strategy demands consideration of such processes to ensure the protection of ecosystem structure and function. This means incorporating geomorphology and EA considerations into the steps of screening and scoping, as well as those that follow. This contribution encourages EIA promoters to seek for the articulation of the EA Malawi principles in screening and scoping practices, where a comprehensive and science-based path can lead to the conservation and management of natural resources.

Additional research gaps or challenges emerge from this need for an effective articulation of the Ecosystem Approach in the Environmental Licensing Procedure. First, scientific developments need to focus on a mechanism to involve processes and landforms into the technical criteria for screening and scoping, where knowledge limitations are addressed to the precision level expected by the applied science of environmental management. And last, the ELP requires the rearrangement of its early operation around kinds of environments, instead of economic sectors, prioritizing the natural processes that condition an ecosystem's structure and functioning. This review lays the foundation to strengthen the ELP with an innovate conceptual and methodological approach that includes and anticipates the geomorphological susceptibility of site locations to the effect of human interventions.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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