# Environmental impact assessment effectiveness in public-private partnerships: study on the Colombian Toll Road Program

# Environmental Impact Assessment Effectiveness in Public-Private Partnerships: Study on the Colombian Toll Road Program

Gabriel CASTELBLANCO[1], Jose GUEVARA[2], Diego ROJAS[3], Juan CORREA[4], and Koen VERHOEST[5]

## ABSTRACT

Public-private partnership (PPP) has been positioned as a relevant contracting method for developing large-scale infrastructure projects, which entail potentially high-magnitude negative impacts on the environment. The effectiveness of their Environmental Impact Assessment (EIA) is crucial to achieving sustainable development of these large-scale infrastructure projects. To unravel the drivers for the EIA effectiveness and the multiple combinations built by the complexity of these drivers, this paper analyzes 28 road PPP projects from Colombia employing a fuzzy-set qualitative comparative analysis (fsQCA) approach. This paper decodes conjectural causal links between specific conditions grouped in superordinate clusters (i.e., consultants' capability, project features, and communities' participation) and EIA effectiveness dimensions (i.e., normative, procedural, substantive, and transactive). Findings revealed that no single combination of causal conditions ensures multidimensional EIA effectiveness. This study demonstrated that EIA effectiveness relies significantly on the integration of specific features of three external stakeholders: consultants, non-preferred proponents, and communities. This study constitutes the first empirical multidimensional identification of the combination of conditions that generate EIA effectiveness in road PPPs.

**Keywords**

PPP, EIA, concessionaire, communities' involvement, consultants' capability, qualitative comparative analysis, prior consultation.

[1] Assistant Professor, Department of Management and Production Engineering, Politecnico di Torino, Turin 10129, Italy; email: gabriel.castelblanco@polito.it, *(corresponding author)*

[2] Associate Professor, Department of Civil and Environmental Engineering, Universidad de los Andes, Bogota 111711, Colombia; email: ja.guevara915@uniandes.edu.co

[3] Graduate Research Assistant, Department of Civil and Environmental Engineering, Universidad de los Andes, Bogota 111711, Colombia; email: d.rojasm@uniandes.edu.co

[4] Independent Researcher, Bogota 111711, Colombia; email: juanfelipecorreas@gmail.com

[5] Research Professor, Research Group on Politics and Public Governance, Department of Political Science, University of Antwerp, Antwerp 2000, Belgium; email: koen.verhoest@uantwerpen.be

## INTRODUCTION

Public-Private Partnership (PPP) has been positioned as a relevant contracting method for developing large-scale infrastructure projects worldwide during the last 30 years (Hodge et al. 2017; Hodge and Greve 2016). These large infrastructure projects entail significant complex implications for the socio-economic, cultural, biological, and physical-chemical components of the environment (Castelblanco et al. 2021a; Liu and Lai 2009). The magnitude of the potential environmental consequences of the construction and operation of PPP projects must be addressed with suitable mechanisms to assess and prevent such impacts (Castelblanco and Guevara 2022a; Soria-Lara et al. 2020).

Environmental Impact Assessment (EIA) is incorporated as one of the main tools to promote sustainable development in infrastructure within the project's decision-making processes since the early phases in a life-cycle perspective (Glasson et al. 2012). In PPPs, the concessionaire is usually responsible for the EIA and environmental licensing in the shaping phase (Faith-Ell and Arts 2009). This early involvement of the concessionaire in the EIA aims to incorporate innovation for preventing and addressing environmental impacts through the PPPs' life cycle.

EIA aims to identify and assess the inherent impacts of infrastructure projects relative to environmental components (Liu and Lai 2009). This instrument is useful to scope, study baseline conditions, identify prospective impacts, foresee significant impacts, and assess these impacts (Chanchitpricha and Bond 2013; Shepard 2005). EIA allows the public sector examines significant environmental impacts and decides either to approve or deny the project based on the appropriateness of the mitigation measures proposed for the foreseeable impacts (Bojórquez-Tapia et al. 2005).

Despite the pertinence of the comprehensive goals of the EIA process for the protection of the economic, social, and natural environments, there remains a huge gap between these theoretical goals and the real performance of EIA in real projects (Androulidakis and Karakassis 2006; Barker and Wood 1999; Kabir and Momtaz 2012; Khan et al. 2020; Lawrence 1997). Moreover, frequently

62 the EIA is restricted to mere documental assessments that are not controlled or monitored effectively,
63 resulting in inaccurate assessments and forecasts often derived from standardized practices limited to
64 accomplish the minimal requirement of the terms of reference for licensing (Caro-Gonzalez et al.
65 2021; Lawrence 1997; Paliwal and Srivastava 2012).

66 The effectiveness of EIA is crucial to achieving sustainable development of infrastructure,
67 especially for large-size projects such as PPPs. Researchers have recognized the relevance of EIA
68 effectiveness and increased their attention on this topic during the last decade. The outcome of this
69 focus is the assessment of EIA processes, and the development of quality control (Caro-Gonzalez et
70 al. 2021; Loomis and Dziedzic 2018). Most researchers agree that EIA effectiveness is complex and
71 multidimensional, being composed of four dimensions, namely, procedural, normative, transactive,
72 and substantive (Chanchitpricha and Bond 2013; Loomis and Dziedzic 2018).

73 Although significant efforts have been dedicated to defining EIA effectiveness theoretically,
74 research is still missing to provide decision-makers with a multidimensional assessment of EIA
75 effectiveness with empirical support. Moreover, the heterogeneous conditions that could have an
76 individual or joint incidence on EIA effectiveness have not been explored thoroughly in extant
77 literature. Prior research is limited to conceptualizing EIA effectiveness in a theoretical way, focusing
78 on literature reviews (Loomis and Dziedzic 2018), theory-development for one single dimension of
79 EIA effectiveness (Cashmore et al. 2004; Lyhne et al. 2017), or developing frameworks to measure
80 EIA effectiveness (Chanchitpricha and Bond 2013). Moreover, the scarce research that analyses the
81 EIA effectiveness through a practical approach is limited to quantifying the proportion of EIAs that
82 did not influence decisions or the projects that did not conduct EIA (Heinma and Põder 2010).
83 Although the dimensions of EIA effectiveness are defined theoretically, there remains a gap in the
84 research to understand the relationship between the conditions and the EIA effectiveness supported
85 by empirical data.

To investigate the drivers for the EIA effectiveness and the multiple combinations built by the complex interplay of these drivers, this research aims to identify the causal structures that generate causal pathways to EIA effectiveness in road PPP projects. The goal is to identify significant conditions of EIA effectiveness performance and understand the empirical relationships between them in road PPPs. Specifically, this study is focused on the following research questions: (1) What are the significant conditions that lead to a high EIA effectiveness in road PPPs? And (2) How do the combinations of conditions enhance the EIA effectiveness? This study uses Fuzzy-set Qualitative Comparative Analysis (fsQCA) methodology to build inferences supported by 28 PPP road case studies, constituting the most recent road PPP program in Colombia. This is the first study that assesses the EIA effectiveness in PPP infrastructure by focusing on a national PPP program.

## BACKGROUND

### Conceptualizing EIA Processes and EIA Effectiveness

The EIA process comprises five different processes, namely, scoping, analyzing baseline conditions, establishing potential impacts, forecasting significant impacts, and assessing these impacts (Glasson et al. 2012). The scoping process establishes all the possible impacts that the project may generate, regardless of their minor or major relevance (Caro-Gonzalez et al. 2021). Analyzing baseline conditions enables the identification of the existing environmental context as a benchmark to compare future circumstances in multiple project alternatives (Hansen and Wood 2016). Establishing potential impacts implies considering the project's time framework and specific conditions to establish potential impacts in a more detailed way than the scoping (Lyhne et al. 2017). Forecasting significant impacts includes predicting the potential effects of adverse situations by considering techniques such as experiments, pilot models, statistical models, mathematical models, case studies, and subjective judgment (Liu and Lai 2009). Finally, by assessing the impacts, the significance of the potential consequences on natural resources can be foreseen and measured (Caro-Gonzalez et al. 2021). EIA effectiveness results from establishing the right objectives for the EIA and

meeting these goals during the project implementation, by employing the appropriate means for environmental caretaking (Glasson et al. 2012). There is a consensus among most authors about the plural and multidimensional nature of EIA effectiveness (Cashmore et al. 2004; Chanchitpricha and Bond 2013; Loomis and Dziedzic 2018; Morrison-Saunders and Bailey 2009). According to the literature, three major EIA effectiveness dimensions were initially identified, namely, substantive, procedural, and transactive (Loomis and Dziedzic 2018). More recently, the fourth dimension of EIA effectiveness was introduced: normative effectiveness (Baker and McLelland 2003).

The procedural dimension analyzes the adherence to the policy and the EIA process structure (Loomis and Dziedzic 2018). Assessing procedural effectiveness is useful for gaining insights into the quality of the process and report of the EIA (Cashmore et al. 2004). However, this dimension of effectiveness neglects to analyze the contributions of the EIA to environmental decisions and planning (van Doren et al. 2013).

The substantive dimension assesses the impact of the EIA on the reduction of negative environmental impacts and the decision-making process (Chanchitpricha and Bond 2013). The analysis of this EIA effectiveness dimension is less common than others such as the procedural (Loomis and Dziedzic 2018). This EIA effectiveness dimension has been conceptualized as the extent to which EIA reaches the expected purposes and results (van Doren et al. 2013). The assessment of this EIA effectiveness dimension has been focused on multiple features such as the degree of consideration of environmental issues in the decision-making and the alterations in the environment resulting from the EIA (van Doren et al. 2013).

The transactive dimension of EIA effectiveness focuses on obtaining the outcomes with the least time and financial costs (Chanchitpricha and Bond 2013). The EIA transactive dimension has been the least analyzed among the four EIA effectiveness, and when studied it is often just in a superficial way (Loomis and Dziedzic 2018). This is a counterintuitive pattern considering the

extended criticism in this regard (Glasson et al. 2012; Runhaar et al. 2013). Furthermore, transactive ineffective EIA has a direct negative impact on project developers (Loomis and Dziedzic 2018).

Normative effectiveness refers to how well the policy meets its intended objective (Baker and McLelland 2003). For this EIA effectiveness dimension, the policy goals and achievements are traditionally related to sustainable development (Chanchitpricha and Bond 2013). However, this dimension also use to be incorporated socio-economic policy goals related to how democratic and transparent is the EIA process, which usually is controlled by the environmental agencies (Baker and McLelland 2003). Traditionally, previous studies have preferred interviews and documental analysis to characterize means of improving the normative EIA effectiveness, which reflects the necessity of considering this data source in this research (Loomis and Dziedzic 2018).

**Drivers for EIA Effectiveness**

This subsection retrieves the most relevant concepts that shape the framework for conceptualizing key drivers for EIA effectiveness. The theoretical justification concerning these drivers are the basis for the formulation of directional expectations that will feed fsQCA analyses.

EIA entails a socio-technical system that requires the involvement of multiple stakeholders, which makes it collaborative, interpersonal, and inclusive by integrating environmental consultants, impacted communities, private firms, and the public sector (Chanthy and Grünbühel 2015; Kågström 2016; Khan et al. 2018; Lawrence 1997; Morrison-Saunders and Bailey 2009). Simultaneously, EIA requires integrating quantitative and qualitative information from the project's social, economic, and natural environment to establish accurate risk assessments (Bond et al. 2018; Faubert et al. 2010; Lawrence 1997), which are essential for identifying and assessing the relevance of risks and impacts (Castelblanco et al. 2021b, 2022a; Marcellino et al. 2022a; b).

The infrastructure literature shows no consensus regarding the required conditions for achieving EIA effectiveness (Hansen and Wood 2016; Heinma and Põder 2010; Khan et al. 2020; Zvijáková et al. 2014). Based on the literature review conducted, comprehensive composite

conditions for EIA effectiveness were gathered from three main clusters: 1) the role of environmental consultants (Androulidakis and Karakassis 2006; Kågström 2016; Kamijo and Huang 2019; Khan et al. 2018; Momtaz and Kabir 2013); 2) project features (Badr et al. 2011; Cashmore et al. 2002), and; 3) communities' participation (Bond et al. 2018; Chanthy and Grünbühel 2015; Morrison-Saunders and Bailey 2009). These clusters encompass the most relevant measures associated with accomplishing EIA effectiveness in accordance with the extant literature (Androulidakis and Karakassis 2006; Badr et al. 2011; Morrison-Saunders and Bailey 2009).

***The Role of Consultants***

The role of the environmental consultants has been recognized as a meaningful driver for EIA effectiveness in studies conducted in European countries such as Portugal, Ireland, Greece, Denmark, Belgium, Spain, Germany, and the UK (Androulidakis and Karakassis 2006; Barker and Wood 1999; Cashmore et al. 2002), as well as countries like the US (Tzoumis 2007), South Africa (Sandham and Pretorius 2008), Egypt (Badr et al. 2011), Bangladesh (Kabir and Momtaz 2012), Pakistan (Khan and Chaudhry 2021), and Cambodia (Chanthy and Grünbühel 2015). The relevance of environmental consultants is based on the common practice of the preferred proponent to hire them for carrying out entirely the EIA on its behalf, which makes EIA effectiveness depend on them to some extent (Kågström 2016; Khan et al. 2018). Consequently, these consultants are in charge of advising responsible stakeholders on key EIA procedures, practices, and policies, as well as conducting the assessment and proposals for mitigation of the potential environmental impacts of the project (Morrison-Saunders and Bailey 2009).

Multiple researchers agree on the preponderance of resources available to conduct the EIA effectively (Chanthy and Grünbühel 2015; Khan et al. 2018). The relevance of specific consultants' resources such as the number of consultants involved in the assessment has been emphasized in previous research as an essential driver for EIA effectiveness. (Kamijo and Huang 2019). Moreover, this driver has been also identified in multiple case studies in countries such as Egypt (Badr et al.

2011), Greece (Cashmore et al. 2002), and Cambodia (Chanthy and Grünbühel 2015). The implications of the number of consultants may be contradictory. On one hand, high number of consultants is desirable for providing the heterogeneous disciplines required and gathering multiple technical backgrounds that may potentiate a holistic assessment (Androulidakis and Karakassis 2006). Conversely, high number of consultants increases potential coordination pitfalls that may lead to issues such as duplication of information or even inconsistencies between sections of the EIA and also may endanger profitability for consultants (Badr et al. 2011; Kabir and Momtaz 2012).

***Project Features***

Project features play a key role as drivers for EIA effectiveness, as established in extant EIA literature (Badr et al. 2011; Barker and Wood 1999; Cashmore et al. 2002; Sandham and Pretorius 2008). Such characteristics constitute a differentiator among the cases that may impact their outcomes (Verweij 2015) and influence the magnitude and complexity of potential environmental impacts (Badr et al. 2011). Specific project features play a key role as drivers of the EIA effectiveness: project cost, number of bidders, initiation process, and location. They constitute key determinants for ground, tectonic, geological, morphological, bioclimatic, and climactic conditions, as well as for government support, cost, and interest from potential private investors (Androulidakis and Karakassis 2006).

The relevance of project cost on EIA effectiveness has been emphasized in multiple analyses in several European countries (Barker and Wood 1999) and some other countries such as Egypt (Badr et al. 2011), and South Africa (Sandham and Pretorius 2008). High capital costs in a project often result in an increase in the magnitude and complexity of the potential environmental impacts (Badr et al. 2011). This complexity is reflected in a higher amount of impacted communities, higher interrelationships among impacts, more difficulty in determining impacts accurately, and higher uncertainty in forecasting (Bond et al. 2018; Faubert et al. 2010). As a result, high potential for adverse impacts can lead concessionaires to invest increasing commitment levels and resources for developing EIA (Cashmore et al. 2002).

Bidders in project procurement processes have been identified as relevant drivers for EIA effectiveness (Badr et al. 2011). The number of bidders that take part in PPP tendering has been recognized in the extant literature as a key indicator of the strength of competition (Domingues and Sarmento 2016). Due to the comprehensive tendering requirements regarding previous specific experience of PPP bidders, a limited number of proponents often participate in tendering processes because of the effort required to select suitable partners for establishing the proposed special purpose vehicle (Aladağ and Işik 2020). The number of procurement participants is also limited in large-scale projects because of the significant investment of proponents required for tendering processes (Soecipto and Verhoest 2018). Moreover, previous researchers have identified counterintuitive implications of strong competition such as its impact on a higher probability of aggressive bids, which may result in higher budget constraints (including constraints for conducting a proper EIA) (Domingues and Sarmento 2016). In any case, due to the few market participants in the PPP market, non-preferred bidders play a significant role in the middle- and long-term in order to increase their probability of winning future tenders (Cave and Nicholls 2016). In the middle-term, non-preferred bidders exert accountability over the project based on their knowledge about EIA processes, stakeholder issues, and environmental permits when preparing the detailed proposal during the tendering stage; while in the long-term they may be able to bid more aggressively in new tenders to increase their chance to win future bids (Nijsten et al. 2010; Uttam et al. 2012).

On the other hand, the influence of the initiation process on EIA outcomes has been documented previously in developing countries. In particular, it is important to highlight EIA-related differences according to PPP initiation processes (Castelblanco et al. 2020). While for solicited proposals, the public sector identifies PPP scope and invites private firms for the tendering (Osei-kyei and Chan 2018); for unsolicited initiatives, the proposal is presented by private companies to the government with no prior request from the public sector, which usually is motivated to address slow

implementation and the scarcity of innovation in projects initiated by the public sector (Casady and Baxter 2021).

Finally, project location is a meaningful determinant of potential environmental impacts involved in PPPs (Badr et al. 2011). This project feature may be a key determinant for ground, tectonic, geological, morphological, bioclimatic, and climactic conditions (Androulidakis and Karakassis 2006). Moreover, the sensitivity of some key stakeholders regarding the location of projects may also influence potential project impacts (Aladağ and Işik 2020).

***Communities' Participation***

Communities' participation is not only a requirement within the EIA process but also has been identified by multiple researchers as a key factor for effective EIA (Chanthy and Grünbühel 2015; Morrison-Saunders and Bailey 2009). Previous research has evaluated EIA performance and identified that public participation plays a crucial role across pre- and post-submission phases in Europe (Barker and Wood 1999). This factor is even more relevant in developing countries, which traditionally have been recognized for their poor performance in this regard (Kamijo and Huang 2019).

The link between responsible stakeholders and concerned communities is fundamental to the trust-building that is required for the long-term legitimacy of EIA and project during their life cycle (Bond et al. 2018; Chanthy and Grünbühel 2015). Moreover, public involvement is a meaningful goal for EIA, which require conducting a public consultation process with communities (Sinha and Neeraj Jha 2020). A successful public consultation process also allows for unraveling meaningful inputs for building the EIA and the overall planning process (Chanthy and Grünbühel 2015). On the contrary, the lack of proper participation of key social stakeholders such as indigenous people or the local civil society restricts the consideration of their multiple perspectives and interests, resulting in the erosion of the legitimacy of the process (Korhonen-kurki et al. 2014).

**PPPs and EIA**

Legal frameworks around the world do not make distinctions between EIA conducted among PPPs, and traditional project deliveries (Glasson et al. 2012). In both cases, specialized consultants were hired to conduct the EIA required for the environmental licensing of the project (Morrison-Saunders and Bailey 2009). There is, however, a significant difference between both project deliveries regarding consultants' accountability.

Traditional procurement methods such as Design-Bid-Build (DBB) tend to neglect the accountability of consultants once the design phase has finished (Azhar et al. 2014; Ibbs et al. 2003). Therefore, the potential risks, derived from the EIA developed by the consultant or from its pitfalls, are allocated among the public sector and the contractor that wins the bidding for the construction (Faith-Ell and Arts 2009). As a result, traditional project deliveries were preferred for less complex infrastructure projects with fewer environmental risks (Hansen and Wood 2016).

To incentivize the efficiency and innovation of the private sector, PPPs tend to establish that the concessionaire should be responsible for the detailed design and the EIA in the shaping phase of the project (Jooste et al. 2011). In theoretical terms, PPPs allow the concessionaire to incorporate innovation within the design and the EIA to achieve the best trade-off possible for the construction and operation phases (Castelblanco et al. 2022b; Castelblanco and Guevara 2022b; Grimsey and Lewis 2011). However, many jurisdictions worldwide prefer to involve the concessionaire at the end or after the EIA to reduce future environmental uncertainty; limiting the room for concessionaires' innovative practices (Agarchand and Laishram 2017; Faith-Ell and Arts 2009; Noble 2002).

The involvement of concessionaires in the EIA also aggregates meaningful stakeholders who demand increasing standards. Debt providers play a significant role; they complement traditional requirements, therefore increasing requirements for the concessionaire regarding good practices (Faubert et al. 2010). This could reduce environmental risks that may increase long-term uncertainty (Faith-Ell and Arts 2009; Faubert et al. 2010). Simultaneously, impacted stakeholders, such as local communities, ethnic minorities, and users, may be incorporated through the consultation processes

conducted either by the public or the private parties (Castelblanco et al. 2022c; Reeves 2013; Rojas et al. 2020).

## RESEARCH METHODOLOGY

### Reasons for Adopting fsQCA

This study adopts fsQCA due to multiple reasons. First and foremost, this study presented theoretical reasons for assuming that the conditions identified produce a combined effect on the EIA effectiveness (Schneider and Wagemann 2010). Secondly, the cases analyzed (e.g., 28 PPP projects) constitute a medium-size dataset, which is a sample too large for in-depth case studies and too small for regression analysis (Callens et al. 2021). Third, this approach allows the investigation of conjunctural causation through a systematic comparative analysis across small individual cases sample (e.g., 10-30) to maintain complexity (Rihoux and Lobe 2012). A small sample of individual cases is suitable for this study because of the reduced number of these PPPs in Colombia and the magnitude of each initiative (i.e., the average cost of 400 million dollars each) (World Bank 2016). Fourth, qualitative comparative analysis (QCA) is useful to identify complex relationships between a set of causal conditions and EIA outcomes (Befani and Sager 2006). Therefore, this approach identifies multiple configurations (i.e., combinations) of conditions resulting in equifinality (i.e., the same outcome) (Dai et al. 2021). This combinatorial effect of potential causal conditions is relevant for this study to analyze the complexity of relationships between causal conditions that produce a specific EIA effectiveness outcome. Fifth, the case design aimed to gather common background features (e.g., one single PPP program in a ten-year period with common normative background), which are relevant for the sampling procedure in QCA design (Rihoux and Lobe 2012). Sixth, fsQCA was chosen because it reduced the likelihood of contradictory configurations where the same combination of conditions resulted in different outcomes in comparison with crisp-set QCA (Rihoux and Lobe 2012).

FsQCA was preferred over mvQCA because this study required to establish clear differences between members and non-members for each condition and outcome (Schneider and Wagemann 2007; Vink and Vliet 2009). This is something difficult to do through mvQCA due to ambiguity-related concerns (Pappas and Woodside 2021; Schneider and Wagemann 2007). Additionally, prior research has emphasized the inconveniences in terms of using mvQCA with ordinal notions derived from underlying interval-scale level data (Vink and Vliet 2009). This means that it is not suitable to adopt categories in mvQCA in cases where it is necessary to ordinate ranges (e.g, the highest value in category 1, a lower value in category 2, and the lowest value in category 3) (Schneider and Wagemann 2007). Considering that this study relies on multiple conditions associated with ordinal notions (e.g., project cost, number of bidders), the adoption of fsQCA is justified.

**Theoretical Basis of Qualitative Comparative Analysis**

QCA integrates qualitative and quantitative approaches to decode complex relationships of causality among outcomes and configurations (Delhi and Mahalingam 2020). Moreover, QCA integrates the variable-oriented (i.e., quantitative) and case-oriented (i.e., qualitative) approaches (Verweij 2015). From the quantitative point of view, QCA analyzes an adequate number of cases as required to produce generalizations from an analytic-formalized approach by using Boolean algebra to reduce cases into conditions, which allows for replication (Ragin 2008). From the qualitative perspective, QCA considers individual cases as complex entities by considering causality from the different combinations of conditions that may generate the same outcome (Rihoux and Lobe 2012).

QCA has features of case study analysis and statistical analysis to analyze diverse conjectural causations (Ragin 2008). QCA also reveals the most recurrent set of causal conditions that results in a specific outcome (Verweij 2015). The use of QCA has grown during the last decade because it enables in-depth analysis and, simultaneously, generalization to build theory when the complex interplay between outcomes and conditions is not fully acknowledged (Shrestha et al. 2021).

Crisp-set QCA was the original method developed in the late 1980s, which considered Boolean values (i.e., 0 or 1) for the conditions and outcomes (Rihoux and Lobe 2012). The binary configuration allows assigning 0 when there is no membership and 1 when there is membership (Shrestha et al. 2021). Crisp-set QCA aims to simplify complicated and long expressions into the least complex solution (i.e., parsimonious) (Rihoux and Lobe 2012). Consequently, when different Boolean expressions cause the same outcome but differ in just one causal condition, the algorithm considers the causal condition that differentiates both expressions as irrelevant and removes it to build a more parsimonious combined expression (Shrestha et al. 2021).

The Boolean configuration of crisp-set QCA may lead to contradictory configurations and loss of information, which affected the analysis (Dai et al. 2021). To reduce the loss of information and inconsistent configurations of crisp-set QCA, two alternative QCA techniques were introduced, namely, multivalue and fuzzy-set QCA (Rihoux and Lobe 2012). Multivalue QCA considers values greater or equal to crisp-set values to characterize relevant subgroups and consider more information (Dai et al. 2021). The fuzzy-set (fsQCA) uses continuous values between 0 and 1 to capture different membership levels among the causal conditions (Ragin 2008).

Among the alternative QCA techniques, fsQCA has become especially preferred for studies focused on PPPs in both developed and developing countries because of the application of partial membership in the potential conditions (Dai et al. 2021; Gross 2010; Ragin 2008). FsQCA analyzes and contrasts cases in a more granular way by establishing these partial memberships on the potential conditions when it is not possible to obtain large data sets (Delhi and Mahalingam 2020).

**Applied Methodological Procedure**

To understand the drivers for the EIA effectiveness and the multiple combinations built by the complex interplay of these drivers in road PPPs, this study adopted a condition-oriented perspective focused on the conceptual understanding of types of cases, cross-case comparisons, and reliability and robustness of QCA solutions (Thomann et al. 2022). A five-stage fsQCA methodology

was conducted to this end, as is shown in Fig. 1. The subsequent subsections detail the theoretical basis of fsQCA, the reasons for adopting fsQCA, and the five methodological stages conducted.

**Fig. 1.** Methodology stages

## Case Selection

The selection of the road PPP program in Colombia for the analysis was based on three main reasons: First, Colombia is one of the seventeenth megadiverse countries in the world ranking among the first five positions in the diversity of mammals, birds, reptiles, plant species richness, freshwater fish, amphibians, and butterflies (Rodríguez-Zapata and Ruiz-Agudelo 2021). As a result, these cases are representative of large infrastructure projects such as road PPPs in representative megadiverse countries in the five continents (e.g., Australia, Brazil, China, India, Indonesia, Mexico, South Africa, the US) that entail more complex baseline environmental factors, which implies higher prospective impacts to be identified, foreseen, and assessed in the EIA. Additionally, the scope and regulation for conducting the EIA are well-established in the legal framework through multiple laws and decrees that include specific terms of reference and specific requirements (Caro-Gonzalez et al. 2021). This mature framework allows for representativeness among legislations in multiple countries. Finally, in this country, the EIS and EIA are open access public documents that are provided by the environmental licensing authority (Caro-Gonzalez et al. 2021). The availability of reliable public information allows for transparent data for the analysis.

Data was collected from multiple Colombian road PPPs who had completed the environment license process. The cases were chosen purposively in this study, with consideration that fsQCA is significantly more case-sensitive in comparison to single-case studies or statistical analysis based on large samples (Cho et al. 2021). In selecting these cases, the greatest variety of causal factors and outcomes for decoding the relationships among them was taken into account. Road PPP projects that have completed the procurement phase were included as candidate cases for gathering empirical evidence for this study. A total of 59 road PPP projects were preselected.

Cases for the study were selected via a screening process based on the following criteria: (1) projects that have completed the environmental licensing process excluding two projects with 57 road PPPs remaining. (2) the projects all had significant magnitude and complexity, therefore projects below 120 million USD were removed, excluding 23 projects, with 34 remaining. (3) PPPs that were not procured under a project finance scheme were removed, excluding 5 PPPs. As a result of this screening process, 29 initiated PPP roads fell within the criteria and were selected, which constitutes a small sample of individual cases to maintain complexity as suggested by Rihoux and Lobe (2012). These cases exhibited variability among the causal factors to analyze complex causality under a QCA approach (Delhi and Mahalingam 2020). The cases analyzed are presented in Table 1.

**Table 1.** Road PPP cases selected

**Data Collection**

A comprehensive content analysis of scientific literature on EIA and PPP was conducted. The analysis included the following keywords: "EIA", "environmental impact assessment", "effectiveness", "public-private partnership", "PPP", "P3", "PFI", "private finance initiative", "concession", "BOT", "build operate transfer", "toll road". The search for manuscripts was limited to those included in the Web of Science search engine during the last 25 years. The initial search gathered 417 manuscripts. Refinement of the search excluded 69 conference papers and thesis dissertations, and 348 remained. After this procedure, unrelated categories were removed (e.g., *Infectious Diseases, Political Science, Automation Control Systems*) excluding 124 articles. The result was the retrieval of 224 articles from 92 journals for further analysis. The list of the articles analyzed is presented in Appendix S1.

On completion of the content analysis, a detailed case study was conducted for each road PPP case by triangulating data sources: concession agreements/contractual documents, legal information, and documents regarding the EIA/environmental license process. Furthermore, enhancement of the data collection was achieved by conducting in-depth semi-structured interviews based on open-ended

questions with multiple respondents, including representatives from consultant companies, environmental agencies, public sector institutions, concessionaires, and academics. A semi-structured approach is useful to allow informants to further elaborate on answers and provide supporting evidence (Yin 2003). Interviews lasted between 60 and 110 min and were recorded to avoid any loss of information. A detailed case study of each road PPP was developed and validated with key respondents, which is presented in Appendix S2 because of its length (more than 3,000 words).

**Definition of the Causal Conditions and Outcomes**

To define the causal conditions and outcomes, the content analysis conducted simultaneously with the case study identified the potential conditions and outcomes. Moreover, a coding process was employed to analyze information from multiple sources in a structured way (Bazeley and Jackson 2013). This process resulted in the identification of potential conditions and outcomes to be considered for EIA effectiveness, as discussed in the Findings section. The definition of the conditions and outcomes was based on the in-depth knowledge of the variables and cases. Additionally, there was a limitation on the maximum number of conditions based on the number of cases for reducing the probability of generating low consistency and contradictions (Marx and Dusa 2011), which is a criterion consequent with previous research within the QCA methodological approach (Moschouli et al. 2018; Soecipto and Verhoest 2018). Consequently, this research adopted six conditions for the 28 cases analyzed.

Next, the cases were systematically analyzed by employing NVivo 12. First, the semi-structured interviews were analyzed through the lens of the potential conditions and outcomes established. Second, concession agreements and contractual documents were reviewed comprehensively to retrieve project features such as project size, project cost, number of bidders, initiation process, and location. Third, a systematic review was conducted of legal information to identify the relevant EIA legislation applicable to each project and judgments concerning the claims issued by the communities against the EIA in each project, which allows for retrieving features

433 regarding the EIA's normative effectiveness and communities' involvement. Fourth, documents were
434 gathered regarding the EIA and environmental license process of each project to assess communities'
435 participation, consultants' capability, and the outcomes.

436 **Calibration of Causal Conditions and Outcomes**

437 A calibration scheme to score each of the causal conditions and outcomes objectively was
438 conducted, following the coding process recommended for conducting QCA to avoid inconsistent
439 and subjective scoring (Rihoux and Lobe 2012). The calibration scheme aims to establish the rubric
440 to assess to what degree each case belongs to each of the potential conditions and outcomes (Ruhlandt
441 et al. 2020b). Partial levels of membership were developed for each causal condition and outcome.
442 These membership build the calibration, keeping a strong link between empirical analysis and
443 theoretical data-driven by the cases, theory, and informed judgment (Rihoux and Lobe 2012). Table
444 2 shows an example of the calibration scheme for one specific potential causal condition (i.e., prior
445 consultation), which is a factor in the communities' participation. The full calibration scheme is
446 presented in Appendix S3. To calibrate each factor to guarantee the correctness and accuracy of the
447 classifications and the outcomes' reliability under multiple scoring calibrations, multiple sensitivity
448 analyses were conducted. The membership scores guarantee objectivity, consistency, reliability, and
449 replicability to prove the strength of the factors for each case.

450 **Table 2.** Example of calibration scheme for Communities' Involvement

451 **Data Analysis**

452 ***Screening Process: Comparison of Theoretical Concepts with Empirical Data***

453 This study adopted an inductive analysis in order to choose the final conditions for analysis
454 (Iyer and Banerjee 2019). Firstly, a consensus was gained based on the comprehensive literature
455 review about the clusters of potential conditions. Next, the most relevant features of these clusters
456 were listed and measured based on supporting theory and associated indicators. Third, for analyzing
457 the empirical information, the data from the cases (i.e., EIA/environmental license documents, semi-

structured interviews, and lawsuits/courts' judgments related to the EIA) were triangulated. Fourth, a content analysis of case-related documentation was done through the lens of the features identified in previous stages. Lastly, the most critical features identified in the cases were selected according to their recurrence in the literature giving priority to characteristics able to aggregate some others in one, resulting in the six most critical conditions selected; which is the maximum number possible considering the limitation on the number of factors that can be analyzed in QCA according to the sample of cases (i.e., 28 PPPs) (Marx and Dusa 2011). As a result of this configuration, the probability of producing results on random data is 6%, which is below the threshold suggested by Marx and Dusa (2011).

***Truth Table***

On the completion of the calibration scheme, each project was systematically scored to build the truth table where the columns display the conditions and outcomes, while the rows show the configuration of conditions and outcomes for each case (Table 5). All the outcomes and conditions in the truth table were scored for all the cases according to the calibration scheme established. To validate the scoring process of the cases in the truth table, the authors performed two distinct roles, namely, analysts and supervisors. Therefore, the first, third, and fourth authors played the role of analysts to score the cases independently. In case of disagreement on any specific score, the analysts discussed the discrepancies. If any discrepancy remained after the discussion, the supervisor (i.e., second author) led further discussions with the analysts until reaching a consensus.

***Causal Necessity***

A causal necessity analysis was conducted following the data collection and the calibration process, using fsQCA software (version 3.0) (Ragin et al. 2017). This analysis is useful to assess the extent to which a subset of the causal condition generates a specific outcome (Ragin 2008). A condition is therefore considered necessary if all the occurrences of the outcome demonstrate the presence of this condition (Ruhlandt et al. 2020a). The consistency value represents the rate of occurrence of the

causal condition for the outcome (Dai et al. 2021). Consequently, the relationship between a condition and a specific outcome will be stronger as the consistency is higher (Homayouni et al. 2021). A condition is assumed as necessary if its consistency value is higher than 0.9 (Cho et al. 2021).

### *Causal Sufficiency*

Following the assessment of the causal necessity, an analysis of the causal sufficiency of multiple configurations of conditions was conducted, which generates a specific outcome. To do so, the truth table was analyzed to establish the combinations of causal conditions that generate an outcome (Rihoux and Lobe 2012). Overall, causal sufficiency aims to calculate to what extent a specific causal condition is representative of a specific outcome subset (Ragin 2008). Overall, a causal condition could be assumed as sufficient if its coverage value is higher than 0.8 (Ragin 2008).

## VALIDATION

This study aimed to achieve reliability and replicability of the data collection and analysis by involving diverse practitioners, to giving specific roles to the authors during the data analysis. The authors' objective was to validate the potential conditions based on a complement between internal and external perspectives.

Internal validation was reached by conducting a structured grouping strategy for establishing the potential conditions and the categories of each of them. Each author played specific roles: three analysts (the first, the third, and the fourth authors), and two supervisors (i.e., the second and the last authors) because of their higher experience. The three analysts separately reviewed the concession agreements, contractual documents, legal information, EIAs, and environmental licenses in line with the potential conditions established. Each of the authors checked every single condition and then scored for each case. If there was a disagreement in any country among the analysts, all the analysts debated their discrepancies. If there were two rounds of debate without consensus, the discrepancies were discussed with both supervisors until achieving consensus.

External validation was achieved through conducting the Delphi methodology. This process was employed in the study because it is useful for the identification and validation of the potential conditions (Ruhlandt et al. 2020a). It enables the seeking of both individual and consensus opinions from multiple experts physically separated but, at the same time, keeping experts' anonymity (Hanna and Noble 2015).

To refine and validate the factors identified in the content analysis of literature, a Delphi process was conducted with a panel of experts. Firstly, the potential experts were identified based on their experience and knowledge in the EIA applied in PPPs. The criteria for selecting candidates for the Delphi process was to have more than 5 years of significant work experience focused on PPPs and EIA (or a closely related environmental subject area). Secondly, once the potential candidates were identified, the final selection of the panel was conducted. From 19 potential candidates, 10 experts conducted three consecutive rounds of the Delphi process. Next, to reduce bias, the questionnaire included various methods such as the contrast effect and the collective unconscious, recommended in similar studies (Ruhlandt et al. 2020a). If the experts considered some additional factors to be missing during the first round, they were invited to supplement the preliminary potential causal conditions and outcomes. Finally, the Delphi process analytical included scoring each potential causal condition and outcome derived from the content analysis on a Likert scale where 5 represents extremely important, which is consistent with previous approaches (Delhi and Mahalingam 2020). An iterative process was conducted to reach consensus, therefore, if the ratings of participants diverge from the group's average, further interviews were conducted to elucidate the explanation of the divergence, as recommended by similar studies (Ruhlandt et al. 2020a). As a result, an agreement was reached after three rounds of discussion and feedback and more than 30 hours of interviews.

Overall, this study incorporated multiple good practices recommended for increasing replicability and validity. Consequently, this study presented a detailed justification for the selection criteria for the cases chosen (Thomann et al. 2022). The number of conditions was limited according

to the number of cases for reducing the probability of generating low consistency and contradictions (Marx and Dusa 2011). The manuscript and supplementary materials incorporate the threshold values, truth table, coverage, and consistency measures (Jordan et al. 2011; Thomann et al. 2022). Additionally, the threshold values for fsQCA, the calibration of the conditions and outcomes (Jordan et al. 2011). The analysis of necessary and sufficient conditions was developed in different steps, starting with the analysis of necessary conditions (Thomann et al. 2022).

## FINDINGS

### Screening Process of Conditions

As a result of the literature reviewed, ten factors were identified along the three clusters established as follows. Firstly, the clusters of the factors, namely, environmental consultants' capacity (Androulidakis and Karakassis 2006; Kågström 2016; Kamijo and Huang 2019; Khan et al. 2018; Momtaz and Kabir 2013), project features (Badr et al. 2011; Cashmore et al. 2002), and communities' participation (Chanthy and Grünbühel 2015; Morrison-Saunders and Bailey 2009) were identified. Secondly, the most relevant features (i.e., ten) of these clusters were listed and the maximum number allowed for the analysis (i.e., six) were selected according to their recurrence in the literature giving priority to features able to aggregate some others in one. For example, *project cost* (PC) was built based on a normalized indicator of cost (million USD per km) to aggregate cost (USD) and size (km) nominal indicators in road infrastructure. As a result of the screening process, the six most critical factors were selected as shown in the next subsection.

### Operationalization and Calibration of Conditions and Outcomes

The operationalization of the causal conditions within the clusters identified was conducted based on the comprehensive literature review and the analysis of the cases. The membership calibration in this study is based on empirical and theoretical studies as recommended by QCA researchers (Rihoux and Ragin 2009). The calibration scores for the conditions and outcomes are presented in Table S3 in the Supplementary Material.

557 ***Conditions***

558 The six conditions for EIA effectiveness were operationalized through the three main clusters
559 identified in the literature review: project features, consultants' capability, and communities'
560 participation (Table 3) (Agarchand and Laishram 2017; Sedlin et al. 2020; Sinha and Neeraj Jha
561 2020).

562 **Table 3.** Conditions identified for the Study

563 The project features cluster is composed of four conditions, namely *project cost*, *number of*
564 *bidders*, *initiation process*, and *location* of the project.

565 (1) *Project cost* (PC) is represented in this study by the normalized cost condition (i.e., cost
566 per km). This indicator was preferred over traditional measures associated with project size such as
567 total cost or road width and length because, apart from such aspects, normalized cost also allows for
568 identifying difficulties linked to terrain-related characteristics (e.g., local geotechnical conditions and
569 incidence of complex infrastructures such as tunnels and bridges), which has been positively
570 correlated with the likelihood of future cost overruns (Kumar 2021). Additionally, this is in line with
571 prior research on transportation megaprojects adopting cost per unit distance as a suitable proxy for
572 conducting cost-related analysis (Priemus et al. 2008).

573 This condition was directly calibrated based on the review of the 28 PPP projects under study,
574 with maximum and minimum costs of 27 and 1 million USD per km, respectively. The $50^{th}$ percentile
575 was established as the cross-over point (i.e., 4 million USD per km); and the $20^{th}$ (i.e., 2 million USD
576 per km) and $80^{th}$ (i.e., 6 million USD per km) percentiles were assumed as the full non-membership
577 and full membership thresholds, respectively.

578 (2) *Number of bidders* (BID) is employed as an indicator to examine the intensity of
579 competition and, consequently, the potential accountability exerted by non-preferred bidders
580 (Domingues and Sarmento 2016). On one hand, the presence of one single bidder can be interpreted
581 as if the PPP project did not significantly incentivize private firms to participate in the procurement

process, as potential proponents might have perceived the project too risky or incompatible with their interests (Aladağ and Işik 2020; Badr et al. 2011). This may diminish accountability levels across multiple project phases because of the absence of non-preferred proponents (Cave and Nicholls 2016).

Conversely, the existence of a significant number of proponents investing money and efforts in the bidding process can be expected if the risks-benefits ratio of the PPP is favorably perceived by multiple private partners (Badr et al. 2011). This is a positive sign in terms of improving accountability levels, as non-preferred proponents' knowledge about the project (e.g., stakeholder management issues, EIA process, and environmental permits) can influence the way the concessionaire is controlled throughout the project's lifecycle (Nijsten et al. 2010).

Direct calibration was used for establishing the membership of this condition by considering the case study data. The cross-over point was set at the average number of bidders, between 2 and 3 proponents per project. The full non-membership was established as one single bidder (i.e., $20^{th}$ percentile), which is also the minimum number of bidders found in previous studies (Domingues and Sarmento 2016; Guevara et al. 2020). In line with that, the full membership threshold was set at the $80^{th}$ percentile (i.e., more than 3 bidders), which is higher than the mean of bidders found in 32 international PPP projects analyzed among 13 countries (Domingues and Sarmento 2016).

(3) The *initiation process* (INI) reflects either if the project was originated by the public sector (solicited proposal) or by the private sector (unsolicited proposal). Consequently, the set was defined through two anchor points: full membership (1- solicited proposal), and full non-membership (0 – unsolicited proposals).

(4) *Location* (LOC) is referred to the geographical position of the PPP project in the country. The location of a road project determines several implications due to geotechnical factors, weather-related conditions, forest cover concerns, and even key determinants of the traffic such as the regional economic and demographic aspects (Androulidakis and Karakassis 2006).

607 The calibration for this condition was established by considering that the Andes Mountains
608 in Colombia are split into three branches (i.e., Western, Central, and Eastern) (Cosoy 2015). Based
609 on that, non-membership was established for regions related to the Central and Western branches
610 (Mid- and South-West regions) which are the most stable geotechnically (Cediel and Shaw 2019).
611 Additionally, these regions are the rainiest and exhibit the highest forest cover across the territories
612 encompassing the Amazon and Darien rainforests (Anaya et al. 2020). Furthermore, these territories
613 have established relevant historical economic ties with Colombian Pacific coast ports (Cosoy 2015).
614 Conversely, membership was established for regions related to the Eastern mountain range
615 (Mid-East and North regions), which are the least geotechnically-stable (Cediel and Shaw 2019) and
616 rainy (e.g., Atlantic region) areas; including territories with the lowest forest cover (e.g., La Guajira
617 desert) (Anaya et al. 2020). Moreover, these zones have constituted preponderant historical economic
618 ties with the Colombian Atlantic Coast and Venezuela (Cosoy 2015).
619 (5) The consultant's capability is focused on the resources of specialized environmental
620 consultant companies that are subcontracted by the concessionaires to conduct the EIA and obtain the
621 environmental license for the EIA approval, which is required to start the construction works. As
622 shown in Table 3, the consultants' capability relies on *staff resources* condition (STF), which assesses
623 the interdisciplinary team of specialists deployed to undertake the EIA. A statistical analysis of the
624 data was performed to identify three anchor points that define the set:
625 • Full membership: At least 60 expert positions (i.e., $95^{th}$ percentile)
626 • Cross-over point: 40 expert positions (i.e., average)
627 • Full non-membership: Less than 20 expert positions (i.e., $5^{th}$ percentile)
628 (6) The third cluster is *communities' participation* and relies on communities' involvement,
629 which assesses the significance of the participation of the inhabitants within the influence area of the
630 project in the EIA development. Previous research has demonstrated that the lawsuits entail a
631 transparent indicator of public participation success (Sedlin et al. 2020). Moreover, the absence of

lawsuits against the EIA process indicates a successful community involvement, and a significant absence of communities' involvement is reflected in multiple lawsuits led by these communities in which the court's judgments are in the plaintiff's favor.

This condition was scored and calibrated by adopting the existence of court judgments in response to lawsuits brought by communities against the EIA process at the cross-over point. The absence of lawsuits was set as threshold for full membership, which is something that has been recognized in the extant literature as a reliable indicator of successful communities' participation (Sedlin et al. 2020). Patrial membership was characterized as the presence of court judgments against the plaintiff's claim in all the cases. In line with that, the existence of court judgments in the plaintiff's favor was assumed as partial non-membership for one single verdict and as a full non-membership for two or more decisions.

***EIA Effectiveness Dimensions as Outcomes***

The relevant outcomes established for the analysis were based on the multidimensional definition of EIA effectiveness, namely, procedural, substantive, transactive, and normative (Fig. 2).

**Fig. 2.** Causal Conditions and Outcomes

Normative effectiveness analyzes the extent to which the policy meets its intended goal (Baker and McLelland 2003). Procedural effectiveness examines the adherence of the EIA to the policy and its process structure (Loomis and Dziedzic 2018). Substantive effectiveness focuses on the effects of the EIA on the reduction of negative environmental impacts (Lyhne et al. 2017). The transactive dimension considers the effectiveness of the cost and time required to conduct the EIA (Chanchitpricha and Bond 2013). The anchor points defining each outcome are presented in Table 4 and the full calibration scores are presented in Table S3 in the Supplemental Material.

**Table 4.** Anchor points for Outcomes

**Truth Table**

Among the 29 PPP projects studied, 28 (97%) were analyzed as the authors gathered enough data. Each of the 28 cases was coded according to the calibration scheme established previously. Table 5 shows the truth table presenting the fuzzy membership scores for the conditions and outcome indicators. For each of the four outcome indicators (normative, procedural, substantive, and transactive EIA effectiveness) fsQCA was conducted separately to establish the combination of conditions that led to their success. The truth table reveals that no cases were missing data, which demonstrates the completeness of the data gathered.

**Table 5.** Truth Table of fsQCA for 28 road PPP cases

**Analysis of Causal Necessity for EIA Effectiveness**

For this study, necessary conditions are considered if their consistency is higher than 0.9 (Ragin 2008). Based on such a consistency threshold, there are no necessary conditions for producing high effective EIA outcomes, as presented in Table 6. Overall, none of the consultants' capability, project features, or communities' participation includes necessary conditions for a high EIA effectiveness in an isolated way.

**Table 6.** Necessary Conditions with the Highest Consistency Scores

**Analysis of Sufficient Configurations for EIA Effectiveness**

Unlike the analysis of causal necessity, the analysis of sufficient configurations aims to expose the set of conditions configurations that are sufficient to lead to a high EIA effectiveness in each of the dimensions. The most representative parsimonious configurations of conditions for generating each of the EIA effectiveness dimensions were analyzed considering consistency values greater than 0.9 (Jordan et al. 2011). These configurations may include the absence of one or more conditions (denoted by ~) for producing EIA effectiveness. Table 7 shows the summary of sufficient combinations that led to each of the EIA effectiveness dimensions along with the number of cases.

**Table 7.** Parsimonious Solutions for EIA Effectiveness

***EIA Effectiveness Dimension 1: Normative***

The analysis resulted in three combinations of conditions leading to EIA normative effectiveness (Fig. 3). Figure 3 presents boxes to establish the presence/absence of a specific condition in sufficient combinations according to the QCA. The boxes are connected by arrows to indicate each of the combinations of conditions sufficient to produce each of the EIA effectiveness dimensions analyzed. To facilitate the interpretation of the graph, gray boxes highlight the presence of the conditions and white boxes the absence (denoted by ~) of them.

**Fig. 3.** Combinations for EIA Normative Effectiveness

While two out of the three combinations that lead to a high EIA normative effectiveness are observed on relatively low-cost projects (~project cost) and do not depend on consultants' capability, the last combination included settings from the consultants' capability (staff resources) and project features (location).

The first and second combinations that are sufficient to lead to a high normative EIA effectiveness demonstrate that relatively low-cost projects characterized by less significant affectations on the environment (e.g., non-significant tunnels) did not require the involvement of the consultants' capabilities cluster. In this regard, the second combination relies exclusively on the project features' cluster demonstrating that relatively low-cost projects may achieve a high EIA normative effectiveness independently of the communities' participation and consultants' capability according to their specific context (i.e., location). Conversely, the first combination leading to a high normative EIA effectiveness demonstrated requiring communities' involvement to reach a significant achievement of the EIA policy's intended objectives in relatively low-cost projects.

The last combination for a high normative EIA effectiveness revealed that according to the project location, specific features from the consultants become increasingly relevant by incorporating experienced consultants with significant professional backgrounds (staff resources) to achieve the EIA policy's intended objectives.

705 The Santana-Mocoa-Neiva (Table 5 – Case ID 28) project is an example of multiple
706 combinations for high normative EIA effectiveness. This is a relatively low-cost project (2 million
707 USD/km) due to its comparatively fewer representativeness of tunnels and bridges per km located in
708 the southwest region of the country. This PPP achieved a significant involvement of the communities
709 through detailed incorporation of their concerns diminishing social opposition against the
710 environmental licensing resulting in high normative effectiveness.

711 ***EIA Effectiveness Dimension 2: Procedural***

712 The EIA procedural effectiveness was analyzed, as presented in Figure 4. The analysis
713 resulted in one single combination sufficient for producing high EIA procedural effectiveness relying
714 only on consultants' capability and project features rather than communities' participation. In this
715 combination, projects driven by multiple consultants with significant professional backgrounds (staff
716 resources) located in the mid-east regions of the country, demonstrated being increasingly prone to
717 result in highly procedural EIA effectiveness.

718 The Pamplona-Cucuta project (Case ID 19) provides an example of a high effectiveness
719 procedural EIA because of the significant staff resources devoted by the consultant. Moreover, the
720 concessionaire chose one of the most experienced environmental consultant companies in EIA in
721 PPPs the country involved in four out of the 28 road PPP projects in the country, which incorporated
722 more than 50 experts from multiple backgrounds to develop the EIA resulting in a high procedural
723 EIA effectiveness.

724 **Fig. 4.** Combinations for EIA Procedural Effectiveness

725 Interestingly, this combination demonstrated neglecting communities' participation but
726 including specific consultants' configurations (staff resources). Consequently, the adherence of the
727 EIA to the theoretical-methodological formulations is driven by the knowledge, experience, and
728 capabilities of the consultants and the implementation of the assessment on the site according to the
729 environmental conditions rather than the communities' participation.

730 ***EIA Effectiveness Dimension 3: Substantive***

731 The analysis of the conditions sufficient for high substantive effectiveness resulted in two
732 combinations (Fig. 5). Overall, both combinations demonstrated that communities' involvement is a
733 common sufficient condition for a high substantive EIA effectiveness. In effect, a sustained long-
734 term reduction of negative environmental impacts in large-size projects requires proactive public
735 accountability developed by the communities inhabiting local territories.

736 **Fig. 5.** Combinations for EIA Substantive Effectiveness

737 In this regard, the first combination demonstrated that the complementary accountability
738 developed in the life cycle from a high number of non-preferred bidders and communities entails
739 sufficient conditions for a highly effective substantive EIA. Interestingly, the consultants' capability
740 proved not to be significant in achieving a high EIA substantive effectiveness for this combination.
741 This counterintuitive finding proves that achieving the reduction of negative environmental impacts
742 properly relies more significantly on the performance of the concessionaire to conduct the measures
743 established in the EIA rather than the consultants' capacity.

744 The second combination sufficient to lead to a high substantive EIA effectiveness relies on
745 the three clusters of conditions: the consultant's capability, project features', and communities'
746 participation. Projects initiated entirely by the public sector (i.e., solicited proposals) with
747 concessionaire's environmental advisors that assigned fewer staff resources for the EIA (~staff
748 resources) aiming to facilitate collaboration and coordination within the consultant's team and a
749 significant communities involvement resulted in high substantive EIA effectiveness. The Discussion
750 section will provide the main reasons why fewer staff resources within the concessionaire's
751 environmental advisors may be beneficial for the EIA effectiveness.

752 The Villavicencio Yopal highway (Case ID 12) is an illustration of both combinations. This
753 is a project initiated by the public sector (solicited proposal) that simultaneously gathered a significant
754 number of bidders (six proponents), a few consultant's crew (less than 20 members with key

backgrounds), and achieved a significant communities involvement during the environmental licensing process by incorporating their main concerns within the environmental impact assessment, resulting in a high substantive EIA effectiveness.

***EIA Effectiveness Dimension 4: Transactive***

The analysis of the conditions sufficient for high transactive effectiveness resulted in five combinations of conditions that lead to a high EIA transactive effectiveness (Fig. 6). Interestingly, four out of the five combinations demonstrated that the duration of the environmental licensing process relies on reduced members within the concessionaire's environmental advisor team with specific professional backgrounds, which will be further explained in the Discussion section.

**Fig. 6.** Combinations for EIA Transactive Effectiveness

The first combination relies on relatively low-cost projects under specific contextual conditions (~location) led by a consultant team composed of a small number of specific roles. The second and third combinations for producing high transactive effectiveness have requiring high communities' involvement in common. Consequently, the accountability role of communities is a significant driver for the transactive effectiveness of the EIA and the duration of the environmental licensing process. There are two alternative pathways to reach transactive effectiveness when coexisting a few consultant's staff resources and a high communities' involvement depending on specific project features either under specific contextual conditions (location) or relatively low-cost projects. Alternatively, a highly competitive tendering process (number of bidders) results in higher accountability from the non-preferred bidders, which incentivizes optimizing the efforts within a reduced staff team to achieve a high effective EIA from a transactive perspective.

The last combination relies exclusively on project features. This demonstrates that if the project resulted from a highly competitive tendering process with three or more shortlisted tenders (number of bidders) and specific contextual factors (location), the consultants' capability and communities' participation are not required to achieve a highly effective EIA from a transactive point

of view. Transversal del Sisga project (Case ID 10) provides a meaningful example of this combination resulting in a high EIA transactive effectiveness. This is the most competitive tendering process (i.e., seven bidders) among the sample analyzed located in the mid-east region in Colombia (Boyaca), resulting in a high transactive EIA effectiveness.

## DISCUSSION

After closer examination, findings revealed common patterns about how megaprojects can achieve elevated levels of EIA effectiveness. These common patterns derived from the QCA findings may help decision-makers to improve their understanding of the drivers that lead to significant EIA effectiveness.

### *Pattern 1: One Recipe Does Not Fit All EIA Effectiveness Dimensions*

Before diving into the analysis of each EIA effectiveness dimension, particular attention should be devoted to the necessity analysis. The QCA distinguished sufficiently the necessary conditions leading to EIA effectiveness. This analysis demonstrated there are neither sufficient nor necessary single conditions for the four EIA effectiveness dimensions investigated, which means that neither the absence nor the presence of any of the conditions is necessary for multidimensional EIA effectiveness.

Results also revealed that there is no unique combination for producing high effectiveness in all dimensions of EIA and there are 11 combinations sufficient for producing unidimensional EIA effectiveness. This finding highlights the relevance of analyzing the four EIA effectiveness dimensions rather than unidimensional EIA effectiveness, which remains the most traditional perspective employed for assessing EIA in real projects (Khan et al. 2020). Consequently, findings decode the configurational essence of EIA effectiveness against the standardized approach aiming for one size fits all.

Previous literature has emphasized the role of organizational and institutional factors affecting heterogeneously at the program level. In this regard, Jooste et al. (2011) demonstrated how

805 diverse institutional and organizational factors result in the heterogeneous implementation of PPP
806 programs among regions with similar contexts. This paper complements this perspective at the project
807 level by demonstrating that even projects within the same institutional and organizational framework
808 results in heterogeneous pathways leading to a high EIA effectiveness according to specific local
809 conditions.

810 ***Pattern 2: Concessionaire's Advisors are Required for EIA Effectiveness***

811 This study demonstrated that environmental consultants play a meaningful role in all the EIA
812 effectiveness dimensions. Moreover, the role of consultants in EIA effectiveness is twofold among
813 the EIA effectiveness dimensions, as shown in Fig. 7.

814 **Fig. 7.** Co-existing Combinations for Multidimensional EIA Effectiveness based on Consultants'
815 Configurations
816

817 For EIA's normative and procedural effectiveness, a high consultant's staff resources
818 neglected the impacts exerted by other external stakeholders (i.e., non-preferred proponents and
819 communities' involvement) and only relies on its complementation with specific contextual
820 conditions (a specific location). Conversely, for EIA substantive and transactive effectiveness, a low
821 consultant's staff resources constitute the cornerstone for multiple combinations aiming for high
822 outputs but it is required to be complemented by additional external stakeholders: either a high
823 communities' involvement or a high number of bidders. The latter pattern was reflected on North
824 Connection Road (Case ID 17); which is a solicited proposal whose concessionaire chose a
825 consultancy company not involved in any simultaneous PPP project that established specific roles
826 within a reduced number of staff members. This project is a relatively low-cost solicited proposal (3.3
827 million USD per km) located in the mid-west region (Antioquia region). Overall, procedural
828 effectiveness is driven by the consultant's knowledge, experience, and an optimum allocation of
829 specific capabilities rather than an excessive number of personnel within the consultant's team that

may lead to coordination issues and the requirement of increasing managerial efforts for the control and monitoring of the activities for the EIA development.

This pattern complements previous literature focused exclusively on the relationship between consultants and the public sector (Morrison-Saunders and Bailey 2009). Each of the EIA effectiveness dimensions requires specific configurations for the consultant's capability conditions: either meaningful staff resources (for a high normative and procedural EIA effectiveness) or reduced staff resources (for a high substantive and transactive EIA effectiveness).

***Pattern 3: Project Features is a Cornerstone for Multidimensional EIA Effectiveness***

An in-depth analysis of cases revealed that multidimensional EIA effectiveness is suitable based on specific project features. This pattern was evidenced especially in Autopista al Mar 2 (Case ID 13) where the simultaneous integration of combinations driven by project features led to a high normative, substantive, and transactive EIA effectiveness, as shown in Fig. 8. The specific project features that led to a high multidimensional EIA effectiveness are related to project context (a relatively low-cost project located in the mid-west region) and specific decisions of the public (a solicited proposal with a high number of bidders) and private partners (efforts devoted on communities' involvement and selection of the consultant company for the EIA).

**Fig. 8.** Co-existing Combinations for Multidimensional EIA Effectiveness based on Project Features

Previous literature has emphasized the role of project context for risk allocation (Nguyen et al. 2018); however, this study complements this perspective by demonstrating the role of project context for EIA. Consequently, specific local circumstances to the project may be favorable to limit uncertainty regarding potential environmental impacts (i.e., relatively low-cost projects located in specific regions), contributing to multidimensional EIA effectiveness.

Sufficient conditions for multidimensional EIA effectiveness demonstrated that a significant number of non-preferred proponents was a meaningful condition for high outcomes within the project features. A high number of non-preferred proponents (highly competitive tender) demonstrated playing a meaningful role in the accountability as a sufficient condition within the combinations for two out of the four outcomes in this study. The substantive and transactive EIA effectiveness demonstrated combinations that relied on achieving a significant number of bidders, as shown in Fig. 8. As the number of bidders increases, the accountability for the successful bidder rises with respect to issues concerning project environmental performance.

An example of this pattern is the Third Lane Bogota-Girardot project (Case ID 26). This project is a relatively low-cost initiative (less than 4 million USD per km) located in the mid-west region near the capital of the country and resulted from a highly competitive tendering process in which three bidding groups were involved. The two non-preferred groups played a meaningful role in the short- and middle-term, in respect to significantly increasing the accountability of the project by triggering prominent levels of attention from public sector agencies. In this regard, although the number of prequalified bidders has previously been analyzed for achieving more competitive PPPs (De Clerck and Demeulemeester 2016); there remains a gap in the role of non-preferred proponents during the PPP life-cycle. Consequently, this study highlights the importance of identifying the accountability role of these players in terms of improving environmental outcomes.

The significance of the number of bidders highlights that the public sector also plays a significant role in the EIA effectiveness according to the project attractiveness (reflected by the number of bidders). Relevant competence during the bidding process constitutes a cornerstone for multidimensional EIA effectiveness, as it strengthens project accountability.

***Pattern 4: A High Communities Involvement is one of the Triggers for EIA Effectiveness***

A high community's involvement was found among the combinations for most of the EIA effectiveness dimensions as a meaningful component. This pattern demonstrated constituting a

879 common trigger for multidimensional EIA effectiveness achieved in specific project cases such as
880 Puerta de Hierro – Cruz del Vizo (case ID 18). Fig. 9 shows the simultaneous conditions allowing
881 multidimensional effectiveness where a high communities' involvement was employed in a relatively
882 low-cost solicited proposal, with a highly competitive tendering process, developed by a team
883 composed comparatively of a few members (23 members), in the least rainy and with lowest forest
884 cover regions (e.g., Atlantic region).

885
886 **Fig. 9.** Co-existing Combinations for Multidimensional EIA Effectiveness based on Communities'
887 Involvement
888
889 High levels of community involvement seem to be relevant for the success of three out of the
890 four analyzed EIA effectiveness outcomes. The communities' role tends to be paired with few
891 consultants' staff resources or a significant number of non-preferred proponents. Consequently, for
892 multidimensional EIA effectiveness, high levels of communities' involvement tend to complement
893 successfully either scarcity of consultants' staff resources or a significant number of non-preferred
894 bidders. In line with that, communities' involvement proved to be useful for improving transactive
895 effectiveness in conjunction with consultants with limited staff resources either in relatively low-cost
896 projects or for specific project contexts (location). It also shows to be important to complement the
897 accountability role played by a significant number of non-preferred proponents in high-competitive
898 tenders for achieving substantive effectiveness. Overall, significant communities' involvement
899 incorporates key EIA considerations that only can be properly known by the historic inhabitants of
900 the area. Although previous research has identified the relevance of communities' involvement in
901 improving PPP outcomes (Castelblanco et al. 2022d; c); further research is required for continuing
902 proper exploration of the complementary role of communities respecting non-preferred proponents
903 and consultants in PPP projects.
904 The prominent role of communities' involvement complements previous studies focused on
905 the relevance of specific interest groups among heterogeneous arrangements of local communities for

906 public participation aiming for effective EIAs. In this regard, previous research concluded that local
907 business companies are relevant for successful consultation processes and effective EIA in road
908 projects (Dagiliute and Juozapaitiene 2018). Previous literature has also focused on the role of ethnic
909 minorities in the development of megaprojects and their legitimacy (Horta 2012). Accordingly, this
910 study complements this traditional understanding of the role of communities' involvement by
911 demonstrating it is determinant not only for the legitimacy of megaprojects but also for their
912 environmental performance in the short- and long term.

913 **CONCLUSIONS**

914 By embracing a QCA approach, this study uses fsQCA to identify the combinations of
915 conditions that generate causal pathways to EIA effectiveness across 28 toll road PPPs. Although
916 QCA has not been widely used to analyze EIA effectiveness in PPPs, this study chose this approach
917 to combine the strengths of qualitative and quantitative methods.

918 Findings revealed that there are neither sufficient nor necessary single conditions for the four
919 EIA effectiveness dimensions inquired. Moreover, because there is not a single combination for
920 producing multidimensional high effectiveness; the analysis shows that examining each of the four
921 dimensions is required to decode the configurational essence of EIA effectiveness. Consequently, this
922 investigation explores the multiple conditions shaping environmental success, emphasizing that there
923 is not a one size fits all recipe for EIA effectiveness in road PPP projects.

924 This study contributes to the EIA body of knowledge by exposing the influence exerted over
925 the multidimensional EIA effectiveness by three external stakeholders: environmental consultants,
926 non-preferred proponents, and communities. A limited number of personnel within the environmental
927 consultants require to be complemented by either a high number of non-preferred proponents or a
928 high communities involvement for EIA normative and procedural effectiveness. Non-preferred
929 bidders demonstrated playing a meaningful role in the life-cycle accountability to achieve the
930 intended project's environmental outcomes. Communities' involvement showed complementing

931 successfully either a significant number of non-preferred bidders or scarcity of consultants' staff
932 resources by incorporating key considerations for the EIA that only can be properly known by the
933 historic inhabitants of the area.

934 Overall, this research provides a basis for academics and practitioners to explore sets of
935 drivers that trigger EIA effectiveness in road PPP projects. Concessionaire's decision-makers can use
936 this study to establish suitable strategies for multidimensional EIA effectiveness according to specific
937 project features. According to the initial setting of the project, the concessionaire may be benefited
938 from this study by purposely choosing the environmental consultant and establishing the effort
939 required for communities' involvement in order to obtain high EIA effectiveness. Each of the causal
940 pathways exposed in this study should be further analyzed in future research to facilitate their
941 implementation in the development of EIA in PPPs. Debt providers can benefit from this study by
942 incorporating meaningful insights useful to assess and mitigate environmental risk, which is a
943 significant element within the risk profile assessment for the financial closure of PPP projects. To
944 reduce environmental risks, debt providers could establish specific requirements according to the
945 project and concessionaires' features, to emphasize the specific characteristics of the environmental
946 consultant and the effort devoted to communities' involvement to reduce further impacts derived from
947 the environment and external stakeholders.

948 **LIMITATIONS AND FUTURE RESEARCH**

949 This research is limited in multiple ways. First, the 28 toll road PPPs are ongoing projects
950 and some of these projects had not finished the construction phase. Future research can focus on
951 samples of PPPs that have completed the construction and operation phases, especially when
952 considering the substantive effectiveness that benefits from a long-term rather than a middle-term
953 perspective. Second, this study focused on a single national PPP program in a developing country
954 with a single legal framework shaping the communities' participation, the EIA requirements, and the
955 environmental licensing process. Further research may benefit from a comparative analysis

incorporating cases from different legal frameworks, incorporating developed and developing countries. Third, this analysis was limited to user-pay PPPs. Further research could incorporate shadow tolls and availability payment PPPs to explore the incidence of the payment scheme in the EIA effectiveness. Fourth, the sample chosen in this study was restricted to toll road PPP projects. Future research could comparatively analyze multiple nonroad PPP infrastructures.

Last but not least, this study adopted an outcome-centered approach, which required restricting the number of potential conditions analyzed in order to ensure results' empirical relevance. Moreover, this limitation on the potential conditions analyzed implies that the authors must make multiple decisions in the bottom-up approach for selecting the final variables and their corresponding calibration and operationalization (i.e., defining the variables' indicators and transforming them into fuzzy sets). To contrast the observed cases with theoretical concepts, further research may adopt a theory-oriented approach that would allow for the inclusion of an increasing number of conditions and the integration of the four EIA effectiveness dimensions into one single outcome. Although this research provides a rigorous operationalization of the variables and outcomes for the first time, the indicators and calibration presented in this study should be considered as a first attempt to operationalize the concepts defined. There are research opportunities for further conceptualization of the indicators of the conditions. The *project cost*, for instance, might not be measured in a normalized way (cost per km).

## DATA AVAILABILITY STATEMENT

Some or all data, models, or codes that support the findings of this study are available from the corresponding author upon reasonable request.

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## Figure Captions

**Fig. 1.** Methodology stages

**Fig. 2.** Causal Conditions and Outcomes

**Fig. 3.** Combinations for EIA Normative Effectiveness

**Fig. 4.** Combinations for EIA Procedural Effectiveness

**Fig. 5.** Combinations for EIA Substantive Effectiveness

**Fig. 6.** Combinations for EIA Transactive Effectiveness

**Fig. 7.** Co-existing Combinations for Multidimensional EIA Effectiveness based on Consultants' Configurations

**Fig. 8.** Co-existing Combinations for Multidimensional EIA Effectiveness based on Project Features

**Fig. 9.** Co-existing Combinations for Multidimensional EIA Effectiveness based on Communities' Involvement

**Table 1.** Road PPP cases selected

| ID | Project | Initial investment (US millions) | Length (km) | Financial closure | Contract period |
|---|---|---|---|---|---|
| 1 | Cartagena-Barranquilla | 522 | 147 | 2016 | 25 |
| 2 | Connection Pacifico 1 Highway | 1,232 | 46 | 2014 | 25 |
| 3 | Northern Bogota Access Road Expansion | 300 | 62 | 2019 | 25 |
| 4 | Connection Pacifico 2 Highway | 312 | 98 | 2014 | 25 |
| 5 | Magdalena 2 Highway | 1,370 | 114 | 2014 | 25 |
| 6 | Connection Pacifico 3 Highway | 646 | 146 | 2014 | 25 |
| 7 | Perimetral Oriental de Cundinamarca | 536 | 153 | 2014 | 25 |
| 8 | Mulalo-Loboguerrero Highway | 638 | 84 | 2016 | 29 |
| 9 | Girardot-Honda-Puerto Salgar Highway | 559 | 190 | 2016 | 25 |
| 10 | Transversal del Sisga | 282 | 137 | 2018 | 25 |
| 11 | Autopista al Mar 1 | 713 | 176 | 2019 | 30 |
| 12 | Villavicencio-Yopal Highway | 1,069 | 261 | 2015 | 23 |
| 13 | Autopista al Mar 2 | 936 | 246 | 2019 | 25 |
| 14 | Bucaramanga-Barrancabermeja-Yondo Highway | 683 | 152 | 2018 | 29 |
| 15 | Popayan-Santander de Quilichao Highway | 620 | 76 | 2016 | 25 |
| 16 | Rumichaca-Pasto Highway | 788 | 80 | 2016 | 25 |
| 17 | North Connection | 491 | 146 | 2014 | 25 |
| 18 | Puerta de Hierro-Palmar Varela and Cruz del Vizo | 208 | 203 | 2019 | 25 |
| 19 | Pamplona-Cucuta | 520 | 63 | 2020 | 25 |
| 20 | Bucaramanga-Pamplona | 203 | 133 | 2016 | 25 |
| 21 | Girardot-Espinal-Neiva Toll Road | 290 | 193 | 2015 | 25 |
| 22 | Antioquia-Bolivar Highway | 604 | 491 | 2015 | 34 |
| 23 | Chirajara-Villavicencio Highway | 2,064 | 86 | 2015 | 30 |
| 24 | Girardot-Ibague-Cajamarca Highway | 745 | 225 | 2015 | 28 |
| 25 | Malla Vial del Meta | 482 | 354 | 2015 | 30 |
| 26 | Third Lane Bogota Girardot | 557 | 145 | 2016 | 30 |
| 27 | NUS Roads | 369 | 157 | 2017 | 30 |
| 28 | Santana-Mocoa-Neiva Highway | 1,080 | 447 | 2016 | 25 |
| 29 | Cambao-Manizales | 485 | 256 | 2015 | 34 |

1298 **Table 2.** Example of calibration scheme for Communities' Involvement

| Value | Short description |
|---|---|
| 1.00 | **'Complete'** – The EIA development achieved full involvement and collaboration with a significant proportion of external stakeholders reaching an overall agreement |
| 0.70 | **'Limited'** – The EIA development achieved limited involvement and collaboration with external stakeholders without reaching an overall agreement, resulting in one lawsuit against the EIA process led by the communities |
| 0.30 | **'Scarce'** – The EIA development achieved scarce involvement and collaboration with external stakeholders with disagreements, resulting in two lawsuits against the EIA process led by the communities |
| 0.00 | **'Absent'** – The EIA development achieved neither involvement nor collaboration with external stakeholders with relevant disagreement, resulting in several lawsuits (more than two) against the EIA process led by the communities |

1299

1300 **Table 3.** Conditions identified for the Study

| Clusters | Conditions | (ID) | Indicative Reference |
|---|---|---|---|
| Project Features | Project Cost | (PC) | (Badr et al. 2011; Barker and Wood 1999; Bond et al. 2018; Cashmore et al. 2002; Faubert et al. 2010) |
| | Number of Bidders | (BID) | (Ayres and Cramton 1996; Cave and Nicholls 2016; Domingues and Sarmento 2016; Nijsten et al. 2010; Uttam et al. 2012) |
| | Initiation Process | (INI) | (Casady and Baxter 2021; Castelblanco et al. 2020; Osei-kyei and Chan 2018) |
| | Location | (LOC) | (Aladağ and Işik 2020; Androulidakis and Karakassis 2006; Badr et al. 2011) |
| Consultants' Capability | Staff Resources | (STF) | (Androulidakis and Karakassis 2006; Chanthy and Grünbühel 2015; Kabir and Momtaz 2012; Kamijo and Huang 2019) |
| Communities' Participation | Communities' Involvement | (INV) | (Barker and Wood 1999; Korhonen-kurki et al. 2014; Morrison-Saunders and Bailey 2009; Sinha and Neeraj Jha 2020) |

1301

1302 **Table 4.** Anchor points for Outcomes

| Outcome | Anchor Points |
|---|---|
| Normative EIA Effectiveness | **'Full membership'** – No temporary suspension on the environmental licensing process due to non-compliance with requirements |
| | **'Full non-membership'** – Temporary suspension(s) on the environmental licensing process due to non-compliance with requirements |
| Procedural EIA Effectiveness | **'Full membership'** – Complete adherence to the EIA with procedural formulations and range of conditions used in the assessment |
| | **'Cross-over point'** – Both the formulation and their conditions were altered to some extent |
| | **'Full non-membership'** – Some conditions were completely neglected in the formulations |
| Substantive EIA Effectiveness | **'Full membership'** – No unforeseen impact was found by the environmental control entities |
| | **'Cross-over point'** –Unforeseen impact(s) was(were) found during the project life-cycle by environmental control entities |
| | **'Full non-membership'** –The project works were suspended temporarily by the environmental control entities due to the issues of preventing, reducing, and mitigating negative environmental impacts |
| Transactive EIA Effectiveness | **'Full membership'** – The EIA achieved its intended outcomes within the stipulated time without license modifications required by the environmental entity |
| | **'Cross-over point'** – The EIA was either conducted beyond the stipulated time or the environmental entity required multiple environmental license modifications during project development |
| | **'Full non-membership'** – The environmental license process was suspended temporarily because of EIA deficiencies in achieving its intended outcomes within the stipulated time |

1303

**Table 5.** Truth Table of fsQCA for 28 road PPP cases

| | Potentially Relevant EIA Conditions | | | | | | Outcome Indicators | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Consultants' Capability | Project Features | | | | Communities' Participation | EIA Effectiveness | | | |
| ID | STF | PC | BID | INI | LOC | INV | PE | SE | TE | NE |
| 1 | 0 | 0.3 | 0.7 | 1 | 0.7 | 0.3 | 1 | 0 | 1 | 0.7 |
| 2 | 0 | 1 | 0.3 | 1 | 0 | 1 | 0.3 | 0.7 | 1 | 0.7 |
| 3 | 0.7 | 0.7 | 0.3 | 0 | 1 | 0.7 | 1 | 0 | 0 | 1 |
| 4 | 0 | 0.3 | 0 | 1 | 0 | 0.7 | 0.7 | 0.7 | 0.3 | 0.3 |
| 5 | 0 | 1 | 0.3 | 1 | 0 | 0.7 | 0 | 0.7 | 0 | 0.7 |
| 6 | 0 | 0.7 | 0.3 | 1 | 0 | 0.7 | 1 | 0.7 | 1 | 0.3 |
| 7 | 0 | 0.3 | 1 | 1 | 1 | 0 | 0 | 0.7 | 0 | 1 |
| 8 | 0 | 1 | 0.7 | 1 | 0.3 | 0.3 | 0.3 | 0 | 0.7 | 0 |
| 9 | 0.7 | 0.3 | 0.3 | 1 | 0 | 0.7 | 0.7 | 0 | 0.3 | 1 |
| 10 | 0 | 0.3 | 1 | 1 | 1 | 0.3 | 0.7 | 0.7 | 0.7 | 1 |
| 11 | 1 | 0.7 | 0.7 | 1 | 0 | 1 | 0.3 | 0.7 | 1 | 0.7 |
| 12 | 0 | 0.7 | 1 | 1 | 1 | 0.7 | 0.7 | 0 | 0.7 | 0.7 |
| 13 | 0.7 | 0.3 | 0.7 | 1 | 0 | 0.7 | 0.7 | 0 | 1 | 0.7 |
| 14 | 0.7 | 0.7 | 0.7 | 1 | 1 | 1 | 0.3 | 0.3 | 0.3 | 1 |
| 15 | 0 | 1 | 0 | 1 | 0.3 | 0.7 | 1 | 0.7 | 1 | 0 |
| 16 | 1 | 1 | 1 | 1 | 0.3 | 0.7 | 0.7 | 1 | 1 | 1 |
| 17 | 0 | 0.3 | 0.3 | 1 | 0 | 0.7 | 0 | 0.3 | 0.7 | 0.7 |
| 18 | 0 | 0 | 1 | 1 | 0.7 | 1 | 1 | 0.3 | 1 | 1 |
| 19 | 0 | 1 | 0.3 | 1 | 0.7 | 1 | 1 | 0.7 | 0.7 | 0.3 |
| 20 | 0 | 0 | 0.3 | 1 | 1 | 0.3 | 0.3 | 0 | 0.3 | 0.3 |
| 21 | 0 | 0 | 0 | 0 | 0.3 | 0.7 | 0.7 | 0 | 1 | 1 |
| 22 | 0 | 0 | 0 | 0 | 0.7 | 0 | 0.7 | 0.7 | 0.3 | 0.3 |
| 23 | 0.3 | 1 | 0 | 0 | 1 | 0.3 | 0 | 0.7 | 0 | 0.3 |
| 24 | 0 | 0.3 | 0 | 0 | 0 | 0.7 | 0.7 | 0.7 | 0.3 | 0.7 |
| 25 | 0.7 | 0 | 0 | 0 | 1 | 0.7 | 0.7 | 0.3 | 0.7 | 1 |
| 26 | 0 | 0.3 | 0.7 | 0 | 0 | 0.7 | 1 | 0 | 1 | 1 |
| 27 | 0 | 0.3 | 0 | 0 | 0 | 0.7 | 1 | 0.3 | 0.7 | 0.7 |
| 28 | 0 | 0.3 | 0.3 | 1 | 0.3 | 0.7 | 0.7 | 0 | 1 | 1 |

**Note:** STF: Staff Resources; PC: Project Cost; BID: Number of Bidders; INI: Initiation Process; LOC: Location; INV: Communities' Involvement; PE: Procedural Effectiveness; SE: Substantive Effectiveness; TE: Transactive Effectiveness; NE: Normative Effectiveness.

**Table 6.** Necessary Conditions with the Highest Consistency Scores

| Condition | Consistency | Coverage | Outcome | Consistency | Coverage |
|---|---|---|---|---|---|
| ~STF | 0.83 | 0.71 | NE | 0.825581 | 0.706468 |
| INV | 0.81 | 0.79 | NE | 0.808139 | 0.785311 |
| PC | 0.79 | 0.56 | PE | 0.785714 | 0.557971 |
| INI | 0.80 | 0.39 | PE | 0.795918 | 0.390000 |
| INI | 0.78 | 0.67 | SE | 0.783626 | 0.670000 |
| INV | 0.80 | 0.77 | SE | 0.795322 | 0.768361 |
| ~STF | 0.81 | 0.77 | TE | 0.806283 | 0.766169 |
| INV | 0.76 | 0.82 | TE | 0.764398 | 0.824859 |

(~) Indicates the absence of a condition

**Note:** STF: Staff Resources; CPX: Project Cost; INI: Initiation Process; INV: Communities' Involvement; NE: Normative Effectiveness; PE: Procedural Effectiveness; SE: Substantive Effectiveness; TE: Transactive Effectiveness.

**Table 7.** Parsimonious Solutions for EIA Effectiveness

| Consultants' Capability | Project Features | | | | Communities' Participation | Effectiveness Dimension | Number of Cases | Consistency | Coverage |
|---|---|---|---|---|---|---|---|---|---|
| STF | PC | BID | INI | LOC | INV | | | | |
| | 0 | | | 0 | | NE | 9 | 0.910256 | 0.412791 |
| | 0 | | | | 1 | NE | 11 | 0.932692 | 0.563953 |
| 1 | | | | 1 | | NE | 1 | 0.903226 | 0.162791 |
| 1 | | | | 1 | | PE | 1 | 0.906452 | 0.255102 |
| | | 1 | | | 1 | SE | 7 | 0.907727 | 0.461988 |
| 0 | | | 1 | | 1 | SE | 9 | 0.908889 | 0.467836 |
| 0 | | | | 1 | 1 | TE | 5 | 0.903226 | 0.293194 |
| 0 | | 1 | | | | TE | 8 | 0.938775 | 0.481675 |
| | | 1 | | 1 | | TE | 6 | 0.913043 | 0.329843 |
| 0 | 0 | | | 0 | | TE | 8 | 1 | 0.387435 |
| 0 | 0 | | | | 1 | TE | 10 | 1 | 0.507853 |

[1] Indicates the presence of the condition and [0] indicates the absence of the condition

**Note:** STF: Staff Resources; PC: Project Cost; BID: Number of Bidders; INI: Initiation Process; LOC: Location; INV: Communities' Involvement; NE: Normative Effectiveness; PE: Procedural Effectiveness; SE: Substantive Effectiveness; TE: Transactive Effectiveness.