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An Overview of the Environmental Impact Assessment of Mining Projects in Chile

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Abstract: In accordance with the Sustainable Development Goals of the United Nations, the Environmental Impact Assessment (EIA) is the main management tool used to identify and prevent the impact of productive activities on the environment and human health and promote compensation measures. Metallic mining is the main productive sector in Chile. In 2021, Chile was the highest global producer of copper, the second-highest producer of molybdenum, and the third-highest producer of silver. Other types of non-metallic mining, such as siliceous aggregates, iodine, and hydrocarbons, are also notable. Mining activity requires robust and flexible environmental legislation. This paper analyzes the performance of the Chilean EIA system regarding mining projects entered into the system as Environmental Impact Declarations (EIDs) for low-incident projects and Environmental Impact Studies (EISs) for high-incident projects. The 2867 mining projects submitted to the Chilean EIA system as EIDs (91.8%) and EISs (8.2%) between 1994 and 2019 were compiled. For a proper performance evaluation, a representative sample of 68 projects (61 EID and 7 EIS) was studied through a principal coordinate analysis using eleven indicators widely used in the EIA scientific literature. The results do not show significant differences between the EID and EIS projects or remarkable differences regarding the increasing restrictions introduced by the successive regulatory periods SD30, SD95, and SD40. Based on the observed weaknesses, four opportunities for improvement are proposed focused on creating a simplified sanctioning procedure, upgrading the form of delivery of the project monitoring information, early citizen participation, and incorporating the climate change variable into the projects. This paper extends the methodology introduced in previous papers to evaluate the performance of the Chilean EIA system in mining projects, seeking also to offer a feasible methodology to other countries with a similar socio-economic context or other productive sectors potentially impacted by the degradation of land and renewable natural resources.

Keywords: environmental impact assessment; mining; follow-ups; Chile

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1. Introduction

Mining is carried out on the five continents, predominantly in America, Africa, Asia, and Oceania. The USA, Canada, Mexico, Peru, Chile, South Africa, Australia, Kazakhstan, and China are the countries where the greatest variety of metallic and non-metallic minerals are produced, with Canada the global leader in potash production, Mexico the global leader in silver production, Chile the global leader in copper and iodine production, China the global leader in gold production, and Australia the global leader in iron and lithium production [1].

In 2021, Chile was the main producer of copper in the world, reaching a production of 5,508,084 tons (26.6% of the world's production). At the regional scale, the main copper-producing regions were Antofagasta (53%), Tarapacá (12.3%), Atacama (8.3%), and O'Higgins (8.2%). In addition, Chile is also the second-highest producer globally of molybdenum with 49,403 tons, with the Antofagasta (41%), Coquimbo (18.8%), O'Higgins (15.3%), and Tarapacá (9.5%) regions being the main producers, and the fourth-highest global producer of silver with 1383 tons, with the Antofagasta (66.3%), O'Higgins (8.3%), and Coquimbo (7.8%) regions being the main produces [2]. In general, metallic mining in Chile is concentrated in the northern zone from the Arica and Parinacota regions to the O'Higgins region and in the austral zone in the Aysén and Magallanes regions. These regions also produce other metals such as gold, lead, and zinc. Non-metallic mining associated with siliceous aggregates, iodine, and hydrocarbons is also notable.

Mining is an essential economic sector in Chile that requires continuous monitoring to cope with the Sustainable Development Goals (SDGs) adopted by all United Nations member states, specifically in relation to sustainability and the provision of essential natural resources to the world. Mining activity contributes directly to goal 6 "clean water and sanitation", goal 7 "clean and affordable energy", goal 13 "action clean", and goal 15 "life and land" of the 2030 agenda of the SDGs [3]. On the other hand, the main limitations of the mining sector to achieving the SDGs are related to clean water and sanitation (SDG 6), life below water (SDG 14), and life on the land (SDG 15). So, the policies aimed at promoting preventive environmental measures and monitoring systems to avoid the degradation of land and renewable natural resources are mandatory [4]. The Environmental Impact Assessment (EIA) has become a useful tool for identifying, predicting, interpreting, and preventing the impact of the productive sectors on the land and renewable natural resources, thus reducing the negative impacts of projects [5–7]. The EIA was adopted by the USA in 1970 and before long, Australia, Canada, Sweden, and New Zealand also adopted this legal instrument [6]. This was the subject of the United Nations Conference held in Rio de Janeiro in 1992 in which the member states officially recognized the EIA as the main preventive legal tool to achieve these objectives [8]. In 2012, more than 191 countries used the EIA as a decision-making tool [9]. The transference and dissemination of these global challenges to society are a less-known mission of the EIA.

In Chile, Law 19,300 of the Environmental Base Law enacted in 1994 created the National Commission of the Environment and recognized different instruments for environmental protection including investigation, environmental education, environmental impact statements, prevention and decontamination plans, and the EIA [10,11]. Between 1994 and 2022, three successive modifications of the Environmental Impact Assessment System Regulation (EIASR) were introduced. The first was Supreme Decree N°30 (SD30) in 1997, the second was Supreme Decree N°95 (SD95) in 2001, and the third was Supreme Decree N°40 (SD40) in 2012, with the latter currently being enforced [12–14]. In 2010, Law 20,417 modified the former Law 19,300. The more relevant amendments were the creation of the Ministry of the Environment, the Superintendence of the Environment, and the Environmental Assessment Service (EAS). The EAS is responsible for managing the EIA system in Chile [10,11].

Article 10 of Law 19,300, which was later detailed in Article 3 of SD40, specifies the projects that must mandatorily be entered into the Chilean EIA system. Subsequently, Article 11 of Law 19,300 and Articles 5 to 10 of SD40 established the legal objects of protection in relation to human health, renewable natural resources, life systems and customs of human groups, environmental values, landscape and tourist values, and cultural heritage. Nowadays, the Chilean regulation considers two methods for entering projects into the EIA system, the *Declaración de Impacto Ambiental* (Environmental Impact Declaration, EID) and *Estudio de Impacto Ambiental* (Environmental Impact Study, EIS). Regardless of the method of entry, all the projects are evaluated by the state administration institutions for environmental competencies, with the EAS being the institution in charge of the process. An EID must demonstrate that the project will not have a significant impact on the objects of protection defined by law, whereas an EIS refers to projects that will have a significant environmental impact and must implement mitigation, compensation, or repair measures [14,15]. The two types of projects, EIDs and EISs, consider the evaluation of the effects that productive projects can have on renewable natural resources, especially on land, water, and air. The main difference between EISs and EIDs is related to citizen participation. In the case of EISs, participation is mandatory, whereas EIDs are only analyzed if requested by two citizen organizations or ten people directly affected. In this case, the legal requirements must be met for the commencement of the process. EISs also consider processing times longer than EIDs [6]. The latest regulation, Law 20,417, which was enacted in 2012, established the *Servicio de Evaluación Ambiental* (Environmental Assessment Service, EAS) as the institution in charge of managing the EIA process despite the different state institutions participating in the process. In 2017, the Presidential Advisory Commission for the evaluation of the EIA system was created to identify improvements for the EIA System [16].

In this regulatory context, the evaluation of the performance of the Chilean EIA system regarding mining projects is mandatory, even more so considering that mining is one of the main productive sectors of the country. For reliable proposals, many references in the scientific literature, which aimed to evaluate the performance of the EIA system in various countries, were consulted. The evaluation criteria used in international regulations were grouped into different categories (or levels) related to the stages "Before and During the EIA". The most relevant studies concerning EIA issues were reported by Wood [17], Annandale [18], Ahmad and Wood [19], and Khosravi [20]. These authors mostly focused their evaluation criteria on legislation, administration, and the EIA process. Previous research conducted by the authors of this paper was devoted to evaluating the performance of the Chilean EIA system in general [6], in particular, the aquaculture and sanitation sectors [15,21]. Rodríguez-Luna et al. [6] compared the state of knowledge and the scientific approach to EIA issues in Chile, Spain, Canada, and Brazil, whereas Rodríguez-Luna et al. [15,21] introduced a new category "After the EIA" and new criteria related to the follow-up, control, and sanctions for non-compliance with the project. The findings of this previous research demonstrated the importance of understanding not to disengage from what happens after a project is environmentally licensed. Other authors have used or adapted the evaluation criteria proposed by the above-mentioned authors [17–20] to assess the EIA system of the Middle East and North Africa [22], Pakistan [23], Egypt [24], Laos [25], the Gulf Cooperation Council States [26], Abu Dhabi and the United Arab Emirates [27], Bangladesh [28], and Myanmar [29], but without proposing methodological innovations for the evaluation criteria. Following this scientific literature search, the most relevant criteria reported in the scientific literature for evaluating the performance of the EIA systems were summarized and are shown in Table 1.

In recent years, an increasing number of Chileans have questioned the EIA system in terms of greater trust and credibility and a higher level of citizen participation. Despite the mission of the Presidential Advisory Commission for the evaluation of the EIA system [16] being to identify possible improvements to the EIA system, the reality is far from optimal. So, new scientific instruments to evaluate the Chilean EIA system based on feasible improvements aligned with the regulation and technical capabilities of Chile are needed, as well as credible measures adapted to the increasing social interest and citizen participation.

Based on the knowledge gained by the authors through EIA research in Chile and other countries and the above-mentioned necessary regulatory improvements, this paper analyzes the performance of the Chilean EIA system to detect the weaknesses and strengths regarding mining projects, with a special focus on measures to avoid the degradation of land and renewable natural resources. To achieve this objective, the following innovative tasks have been performed: (1) analysis of the Chilean EIA system regarding mining projects, (2) identification and evaluation of proper indicators to make reliable comparisons of a representative sample of mining projects entered as EIDs and EISs, and (3) identification of opportunities for improvement aimed at improving the performance of the Chilean EIA system for mining projects.

Table 1. The most relevant criteria reported in the scientific literature for evaluating the performance of EIA systems.

Category	Criterion	Wood [12]	Annandale [13]	Ahmad and Wood [14]	Khosravi et al. [15]	Rodríguez-Luna et al. [6]
EIA Legislation	Legal basis	•	•	•	•	•
	Provisions for appeal by the developer or public against decisions			•		•
	Legal or procedural specification of time limits			•		•
	Implications for proceeding without EIA approval				•	•
	EIA process steps in regulations				•	
	Adequacy of the law for conducting an EIA				•	
EIA Administration	Review of the EIA report	•	•	•	•	•
	Administrative support		•		•	•
	Competent authority for EIA and determination of environmental acceptability			•	•	•
	EIA centralization at the national level				•	•
	Level of coordination with other planning and pollution control bodies			•		
	Specification of sectoral authorities' responsibilities in the EIA process			•		
EIA Process	Coverage	•	•			
	Alternatives for design	•	•	•		•
	Screening	•	•	•		•
	Scoping	•	•	•		•
	Content of the EIA report	•	•	•		•
	Adoption of decisions	•	•	•	•	•
	Impact control	•	•	•	•	•
	Mitigation	•	•	•	•	•
	Consultation and participation	•		•	•	•
	System control	•	•	•	•	•
	Strategic environmental assessment	•		•		•
	Cost and benefit	•		•		
	Requirement for environmental management plans			•		
	Experience in strategic environmental assessment			•		
	Baseline information					
After EIA	Public information process and post-evaluation					•
	Supervision and punishment for non-compliance					•
	Resolution of environmental disputes					•

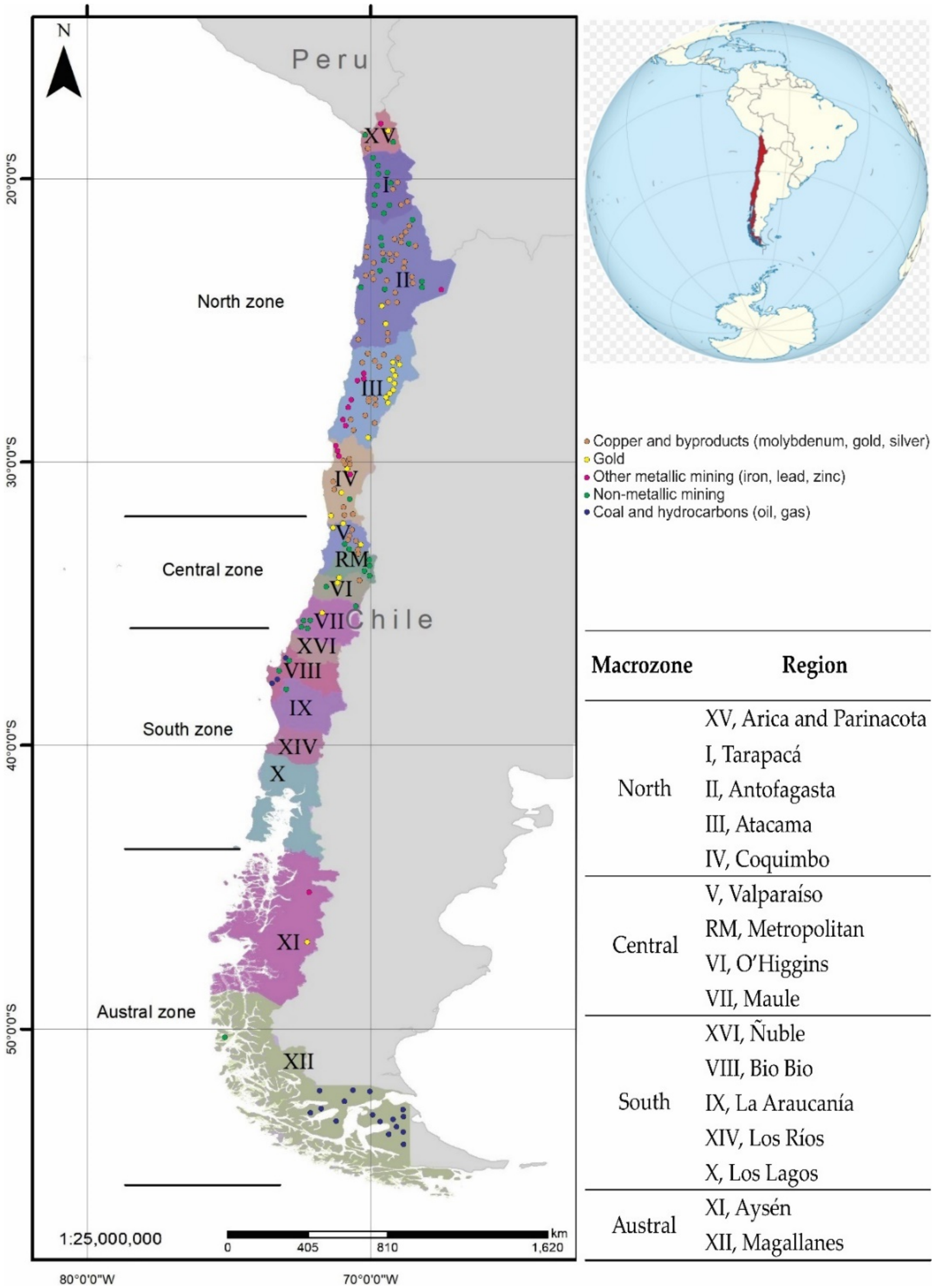
2. Materials and Methods

2.1. Study Area

Chile is located in South America, has an elongated surface of 4270 km^2 between latitudes 18° S and 55° S, and has a population of 17.5 million inhabitants, of which 12.6% are indigenous [30]. The elongated geography and varied geology of the country determine a variety of climates from hyper-arid in the north to polar in the south, with diverse metallic and non-metallic mining resources. Figure 1 shows the main mining districts in each of the four macrozones and sixteen regions of the country.

2.2. Data Source

Information concerning the mining projects submitted to the Chilean EIA system as EIDs and EISs between 1994 and 2019 was obtained from the website of the Environmental Assessment Service (https://www.sea.gob.cl (accessed on 16 January 2022)). Only 2867 mining projects cataloged as "type i" were considered (Table 2). The "type i" projects refer to those with mandatory entry into the EIA process according to Law 19,300. The gathered mining projects were classified according to their status as approved, rejected, unadmitted, abandoned, withdrawn, not rated, in evaluation, license expired, and waiver of license [21,31,32].



Macrozone	Region
North	XV, Arica and Parinacota
	I, Tarapacá
	II, Antofagasta
	III, Atacama
	IV, Coquimbo
Central	V, Valparaíso
	RM, Metropolitan
	VI, O'Higgins
	VII, Maule
South	XVI, Ñuble
	VIII, Bio Bio
	IX, La Araucanía
	XIV, Los Ríos
	X, Los Lagos
Austral	XI, Aysén
	XII, Magallanes

Figure 1. The main mining districts in each of the four macrozones and sixteen regions of continental Chile. Mining information was obtained from the official website of the Ministry of Mining of Chile (https://www.cochilco.cl/SIAC/Paginas/Mapa-Minero-de-Chile.aspx) (accessed on 17 November 2022).

Table 2. Projects submitted to the Chilean EIA system as EIDs and EISs in the period 1994–2019 by region. Crude information was obtained from the official website of the EAS (https://www.sea.gob.cl (accessed on 16 January 2022)).

Macrozone	Region	Submitted Projects		
		EIS	EID	Total
North Zone	XV, Arica and Parinacota	4	23	27
	I, Tarapacá	18	105	123
	II, Antofagasta	61	412	473
	III, Atacama	53	402	455
	IV, Coquimbo	24	240	264
Central Zone	V, Valparaíso	13	132	145
	RM, Metropolitan	22	184	206
	VI, O'Higgins	4	81	85
	VII, Maule	0	58	58
South Zone	XVI, Ñuble	0	72	72
	VIII, Bio Bio	3	144	147
	IX, La Araucanía	1	56	57
	XIV, Los Ríos	0	55	55
	X, Los Lagos	0	57	57
Austral Zone	XI, Aysén	2	61	63
	XII, Magallanes	8	524	532
Inter-regional		23	25	48
Total		236	2631	2867

2.3. Selection of Projects

The first evaluation consisted of examining the "type i" projects related to mining activities. Table 3 summarizes the regulations of Law 19,300 and Supreme Decree N°40 concerning these projects.

Table 3. Types of mining projects that must be entered into the EIA system.

Letter	Description
i.1	Mining development projects whose ore extraction capacity exceeds 5000 tons per month.
i.2	Surveys, understanding them as a set of endeavors and actions to be developed after mining exploration that is conducive to minimizing geological uncertainties and are associated with concentrations of mineral substances from a mining development project, which are necessary for characterization and to establish the mining plans on which the exploitation schedule of a deposit is based; 40 or more platforms and their respective perforations are considered in the case of the Arica, Parinacota, and Coquimbo regions, and 20 or more platforms and their respective perforations are considered in the case of the Valparaíso and Magallanes regions.
i.3	Disposal waste and sterile projects where massive mining waste is disposed of resulting from the extraction or benefits, such as sterile, low-grade ores and ore tailings treated by leaching, tailings, slag, and other equivalents, resulting from one or more mining development projects that by themselves or as a whole have the capacity for extraction considered in the previous letter i.1.
i.4	Oil and gas mining development projects and those actions or endeavors whose purpose is the exploitation of deposits including the activities carried out after drilling the first well exploration and the installation of plant processors.
i.5	Projects or extraction activities of aggregates or clay of industrial dimensions.
i.6	Peat extraction industrial features. It is understood that with peat, a mixture of vegetation remains in different degrees of decomposition present in peat bogs, which differs from the vegetation found on their surfaces, including, but not limited to, moss sphagnum, and with which they functionally connect.

A probabilistic sampling method was used to define the proper size of the project sample. Specifically, a proportional stratified sampling method for a finite population [33–35] was implemented in order to determine the sample size, with a 90% confidence level and

10% error [36,37]. The sample size was determined using approved projects. The used expression was

$$\eta = \frac{N\, Z^2 P\, Q}{e^2\,(N-1) + Z^2\, P\, Q} \quad (1)$$

where η = the sample size, e = the sample absolute error, N = the population size, P = the percentage of individuals with characteristics or conditions, Q = the percentage of individuals without characteristics or conditions, and Z = the imposed confidence level.

2.4. Selection of Indicators

For proper identification of the indicators, a systematic review of the scientific EIA literature was carried out, including the world-renowned experiences reported by Wood [17], Annandale [18], Ahmad and Wood [19], Khosravi et al. [20], as well as the recent experiences gained in Chile by Rodríguez-Luna et al. [6,15,21]. These latter authors proposed a set of criteria to compare the EIA system in Chile with those in other countries that share similarities [6]. The comparisons were further extended to evaluate the performance of the Chilean EIA system regarding aquaculture and sanitation projects [15,21]. After this selection, eleven evaluation criteria, which mostly focused on the process and post-EIA period, were chosen. Table 4 includes the selection criteria, which used an ordinal scale for indicators A, B, J, and K, and a nominal scale (yes or no) for indicators C, D, E, F, G, H, and I [38,39]. The information concerning the project indicators was obtained from the official website of the Environmental Assessment Service (http://www.sea.gob.cl (accessed 16 January 2022)) and the National Environmental Enforcement Information System (https://snifa.sma.gob.cl (accessed on 16 January 2022)).

Table 4. Selected indicators to compare the mining projects.

Indicator	Description	Options	Score	Reference
A	Processing time (working days)	≥361 271–360 181–270 91–180 1–90	1 2 3 4 5	[15,21]
B	Description and justification of the area of influence	No information. Information not justified. General information only. Moderately justified information. Detailed and justified information.	1 2 3 4 5	[15,21]
C	Methodology to identify and evaluate environmental impacts	Yes No	2 1	[15,16,21]
D	Use of international regulations	Yes No	2 1	[15,16,21]
E	Existence of mitigation, compensation, or repair measures	Yes No	2 1	[15,19,21]
F	Identification of contingency and emergency measures	Yes No	2 1	[15,19,21]
G	Consultation and participation	Yes No	2 1	[6,17,19,20]
H	Appeal after project approval or rejection	Yes No	2 1	[15,19]
I	Public information after the environmental license is obtained	Yes No	2 1	[15,16]
J	Post-auditing	No information about supervised or unsupervised projects. Project without non-compliance. Breach of environmental license or sector permit.	1 2 3	[15,16]
K	Punishment for non-compliance	No information. Project without infraction. No classified or minor infraction. Serious infraction. Very serious infraction.	1 2 3 4 5	[15,16]

2.5. Data Analysis

For the performance of the matrix of the indicators in mining projects, a standardization of the data by the total was performed and a similarity matrix using Kendall's rank correlation was calculated. A hierarchical cluster analysis by group average was performed and a Simprof test with 1000 permutations to identify similar groups with a 5% significance was implemented [40]. Subsequently, a principal coordinate analysis (PCoA) was conducted to identify the patterns and relationships among the projects, indicators, and normative stages as a prerequisite to finding the similarities between the objects and the explanatory variables. This operation reduced the dimensionality and enabled the projection of the similarity values among the samples and the relevant relationship among a set of objects was preserved. The following step was a comparison of groups of projects in the regulatory periods SD30, SD95, and SD40. Numerical analysis and plotting were conducted using the Primer 7 v7.0.13 program from PRIMER-e engineering research [41].

3. Results and Discussion

3.1. The Mining Projects in the Chilean EIA System

A total of 2867 mining projects were submitted to the Chilean EIA system as EIDs (91.8%) and EISs (8.2%) between 1994 and 2019 (Table 2). Mining projects represented around 11% of the total projects from different productive sectors submitted to the EIA in this period [6]. Table 5 shows the selected samples (number of mining projects) entered as EIDs and EISs by region after the methodology described in Sections 2.3 and 2.4 was applied. The Antofagasta (473 projects), Atacama (455 projects), and Coquimbo (264 projects) northern regions accounted for 41.5% of the submitted projects, and the Magallanes region (532 projects) in the austral zone accounted for 18.6%. The remaining 40% comprised projects submitted in other regions of the country (Figure 1; Table 5). Regarding the statuses of the projects entered as EIDs and EISs by region (Figure 2), 63.3% were approved, 2.9% were rejected, 15.3% were unadmitted, 3.2% were not rated, 0.3% were abandoned, 14.1% were desisted, and 0.7% had expired licenses. The figures obtained for approved, not admitted, and desisted projects were similar to those found in previous research devoted to evaluating the performance of the EIA system regarding sanitation projects [15]. Rejected mining projects (2.9%) were 0.3- and 0.7-fold higher than data obtained in previous research devoted to evaluating aquaculture (9.4%) and sanitation (4.2%) projects, respectively [15,21].

Table 5. Selected EIS and EID mining projects for statistical analysis by region.

Macrozone	Region	Type of Project	
		EIS	EID
North Zone	XV, Arica and Parinacota		
	I, Tarapacá	1	3
	II, Antofagasta	1	11
	III, Atacama	1	10
	IV, Coquimbo	1	4
Central Zone	V, Valparaíso	1	3
	RM, Metropolitan	1	2
	VI, O'Higgins		2
	VII, Maule		1
South Zone	XVI, Ñuble		1
	VIII, Bio Bio		2
	IX, La Araucanía		1
	XIV, Los Ríos		1
	X, Los Lagos		2
Austral Zone	XI, Aysén		1
	XII, Magallanes		16
Interregional		1	
Total		7	61

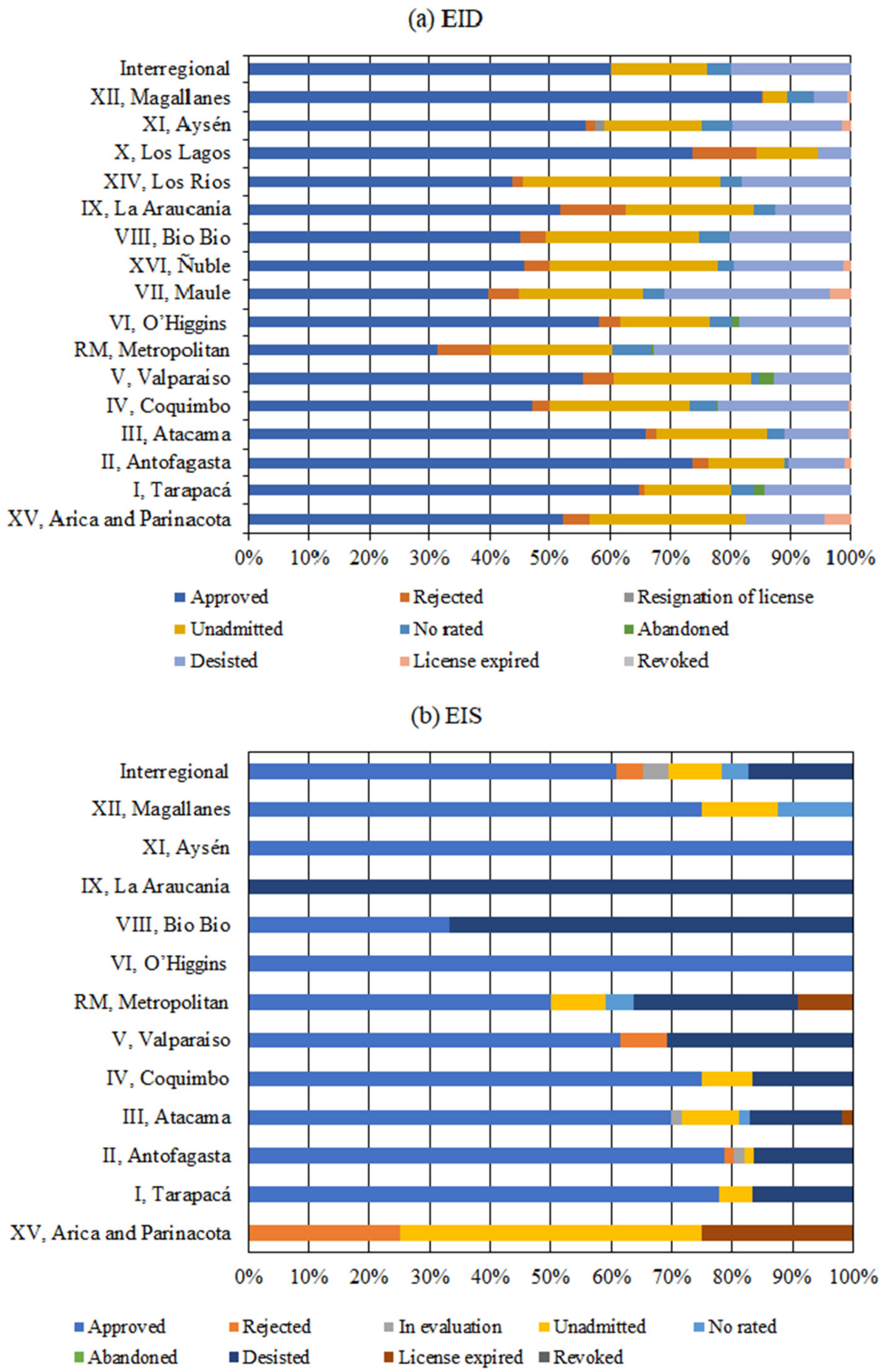


Figure 2. Statuses of the mining projects entered as EIDs (**a**) and EISs (**b**) into the Chilean EIA system between January 1994 and December 2019. This information can be downloaded from the official website of the Environmental Assessment Service (www.sea.gob.cl) (accessed on 1 august 2022).

Regarding the projects entered as EISs, the Aysén (100%), O′Higgins (100%), Antofagasta (78.7%), and Tarapacá (77.8%) regions represented the highest percentages of project approval, although the percentages in the Aysén and O′Higgins regions corresponded to a much smaller sample than in the Antofagasta and Tarapacá regions. On the other hand, the Arica and Parinacota regions did not present approved projects and registered high percentages of projects rejected (25%) and not admitted (50%). The Magallanes region registered the highest percentage (12.5%) of projects not rated.

In relation to the projects entered as EIDs, the highest percentages of approved projects were found in the Magallanes (85.3%), Antofagasta (73.8%), and Los Lagos (73.7%) regions. The La Araucanía (10.7%) and Los Lagos (10.5%) regions recorded the highest percentages of rejected projects. The Los Ríos, Ñuble, Arica and Parinacota, and Bio Bio regions recorded percentages of unadmitted projects over 25%. The Aysén region registered the only expiration of an environmental license out of all the projects analyzed.

When the EIS and IED projects were compared, the percentage of projects approved was 60.2% for EIS and 55.8% for EID projects. These figures diverge from those obtained for the evaluation of the EIA system in aquaculture and sanitation projects [15,21], where EIDs recorded higher approval percentages than EISs. In this same sense, the percentages of rejected projects were slightly higher for EIDs (4.0%) than EISs (3.0%). These figures are nevertheless similar to those found by Rodríguez et al. [15] in sanitation projects. In addition, the high percentage of projects not admitted as EIDs (19.3%) was noticeable since it implies that there was no compliance with the technical and/or minimum legal requirements to admit the projects. In the case of EISs, this percentage was significantly lower (8.1%). Finally, the high percentage of projects that were desisted was quite similar for both EISs (23.6%) and EIDs (16.3%) during the evaluation of the EIA system in sanitation [15] and aquaculture [21] projects. In summary, more mining projects entered as EISs were approved than EIDs in relative terms. This shows divergent behavior regarding the previous evaluations of the EIA system in aquaculture and sanitation projects.

3.2. Statistical Analysis of Indicators of the Projects

After the overall analysis performed in Section 3.1, a representative sample of 68 mining projects was obtained (61 EIDs and 7 EISs). PCoA was conducted to identify the patterns and similarities among the projects. This analysis used (i) indicators A to K described in Table 4 after extracting indicators C and G because they did not provide statistical variability; and (ii) the progressive restrictions that the successive regulatory periods SD30, SD95, and SD40 imposed on the 61 selected projects entered as EIDs and EISs. The seven projects entered as EISs were removed from this analysis due to the reduced statistical representativeness of this sample. Figure 3 shows the first factorial plane, PCO1 and PCO2, which represents 105.3% of the sample's total variance. The first factorial plane identified five groups. Group 1 included the largest number of projects, which corresponded mostly to the third regulatory period SD40, with some projects from the first (SD30) and second (SD95) regulatory periods. The results showed a distribution of the projects belonging to the first and second regulatory periods in the other four groups, i.e., there were no significant differences concerning the regulatory periods. These findings are contrary to those observed during the PCoA conducted for aquaculture [21] and sanitation [15] projects, where clear differences concerning the regulatory periods were observed.

The following analysis was the first multidimensional scaling (MDS) factorial plane to show the similarities in the multivariate dispersion of the projects entered as EIDs and EISs. Figure 4 shows three groups without significant differences between the projects entered as EIDs and EISs during the first (SD30), second (SD95), and third (SD40) regulatory periods. These results are quite different from those obtained during the analysis of aquaculture [21] and sanitation [15] projects, where significant differences between projects entered as EIDs and EISs using the same indicators were found.

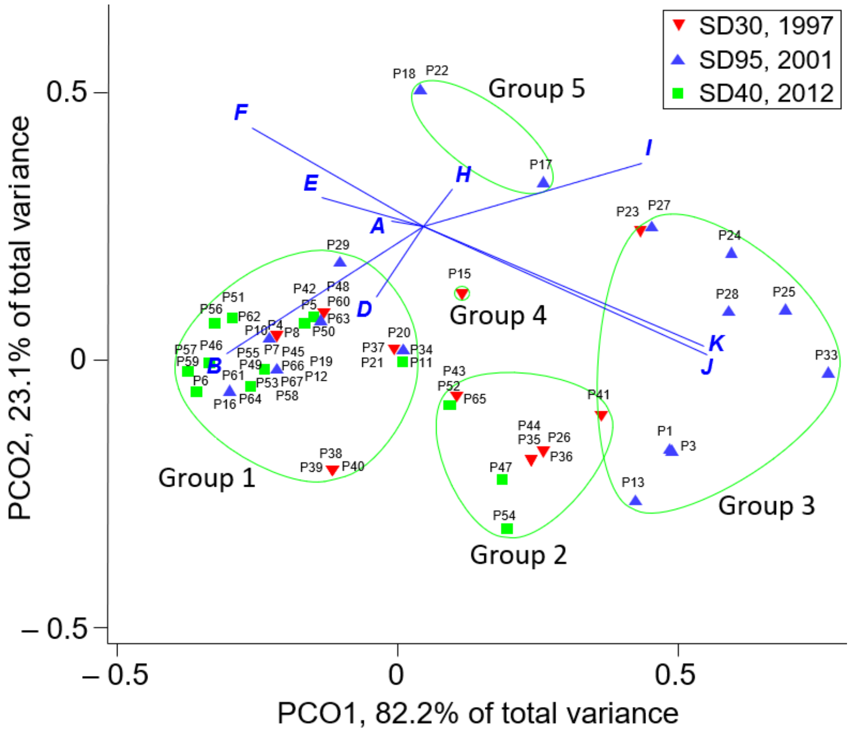


Figure 3. Principal coordinate (PCO) analysis showing the first factorial plane, PCO1 and PCO2, of 61 projects entered as EIDs. The descriptions of indicators A to K are in Table 4. The projects entered as EISs were excluded from this analysis.

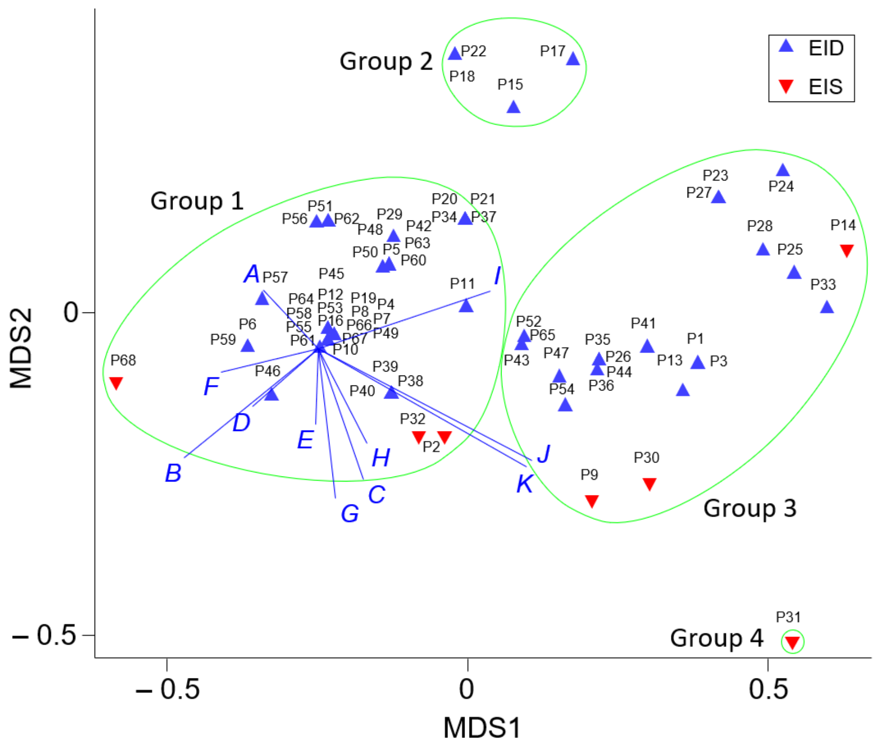


Figure 4. First multidimensional scaling (MDS) factorial plane showing the similarities in the multivariate dispersion of the projects entered as EIDs and EISs. The green circles show the estimated groupings of projects using hierarchical cluster analysis with a Simprof test [40].

In accordance with the information shown in Table 4, the analysis of the indicators A to K is described below.

Processing Time (indicator A). For EIDs, 64% of the projects completed the process in 90 working days or less and 31% were processed in the 91–180-day range. For EISs, 71.4% of the projects completed the process in 180 days or less. For both the EIS and EID projects, no significant differences in relation to the regulatory periods SD40, SD30, and SD95 were observed.

Description and justification of the area of influence (indicator B). For EIDs, 26% of the projects detailed and justified information about the area of influence, 10% included a moderate justification, 24.5% included general information, and 39.3% did not justify or provided information. For EISs, 28.6% of the projects detailed and justified information about the area of influence, 57.1% included general information, and 14.3% did not provide any information. Regarding the evolution of the indicator over time, a better performance in the third regulatory period SD40 was observed. The formerly analyzed aquaculture and sanitation projects [15,21] showed this same behavior.

Methodology to identify and evaluate environmental impacts (indicator C). All the projects entered as EIDs did not use specific methodologies since the Chilean regulation does not impose that requirement. On the contrary, all the projects entered as EISs considered methodologies. The significance matrix was one of the most used methodologies, which was also reported in the analysis of sanitation projects [15].

Use of reference international regulations (indicator D). Only 7.4% of the projects (both EIDs and EISs) used international standards, the main components being noise in fauna and vibrations. No significant differences between EISs and EIDs regarding the use of reference standards during the three regulatory periods were observed. This is because the use of this kind of regulation was directly related to the risk of affecting certain sensitive environmental components and not the way in which the project was entered into the EIA system.

Existence of mitigation, compensation, or repair measures (indicator E). For EIDs, 93.4% of the projects did not consider these measures. All the projects entered as EIDs did not consider the mitigation or repair measures since they are only mandatory for EISs. On the other hand, all the sampled EIS projects considered the mitigation measures, whereas only some projects considered the compensation and repair measures.

Identification of contingency and emergency measures (indicator F). The percentage of projects that considered the contingency and emergency measures was 44.4% in the first regulatory period DS30, 63.4% in the second period SD95, and 100% in the third period SD40. As observed, this indicator improved over time through the incorporation of specific requirements in successive regulations. The same results for EIDs and EISs were obtained.

Consultation and participation (indicator G). All the projects entered as EISs included citizen participation regardless of the regulatory period. In contrast, none of the projects entered as EISs included citizen participation. The justification for this is that Article 94 of the Environmental Impact Assessment System Regulation does not allow open citizen participation in mining projects [14]. This is a debatable issue since the rulings of the environmental courts and the Supreme Court indicated that the environmental load configuration of mining projects entered as EIDs is for the benefit of society and to avoid negative environmental externalities. Another debatable issue is that the Chilean regulation does not require early citizen participation, thus evidencing a clear weakness of the Chilean EIA system compared to the more consolidated EIA systems in other countries [6].

Appeal after project approval or rejection (indicator H). Different percentages of projects entered as EISs (42.9%) and EIDs (3.3%) were subjected to administrative appeals after obtaining their environmental licenses. Appeals were lodged by project owners or citizens who participated in the EIA process. The Chilean EIA process considers appeal opportunities after obtaining or rejecting the environmental license. This is a strength of the Chilean system compared to the EIA systems in other countries since the involved parties can appeal to higher institutions such as Environmental Courts when there are unresolved issues in the administrative claims [6].

Public information after the environmental license is obtained (indicator I). A large percentage of the projects entered as EISs (87.5%) and EIDs (60.7%) provided public information after obtaining their environmental licenses. In general, the available information was related to the monitoring of environmental components and the achieved inspections. This is a weakness of the Chilean EIA system because it evidences the problems with finding the information, despite the EIA process being available on the EAS website and having a high standard of transparency. However, the follow-up information is available on the EAS and the Superintendence of the Environment (SE) websites, although this latter institution notes a lot of problems with finding the information because the supervision and follow-up of the evaluated environmental projects are not incorporated into a single platform. This problem introduces additional complexities for citizens when trying to follow up on the projects and their components [6,15].

Post-auditing (indicator J). For EIDs, 13.1% of the projects recorded non-compliance in relation to their environmental licenses, 18% were projects without non-compliance, and 68.9% did not record supervision information or were not supervised. For EISs, 57.1% of the projects had problems with their environmental licenses, 28.6% were projects without compliance, and 14.3% did not register information. The high percentage of EID projects without information or supervision is worrying. In fact, a high percentage of the projects were related to the extraction of aggregates from small quarries and were not large mining operations. Previous research on the aquaculture sector reported the prioritization by the SE for resolving projects of large operations to the detriment of medium or small-sized ones [15].

Punishment for non-compliance (indicator K). For EIDs, 19.1% of the projects had minor, serious, or very serious infractions; 19.1% did not record infractions; and 68.9% had no information. The lack of information about this high percentage of projects is quite worrying. So, the question arises of whether the projects were operating in compliance with the regulation or whether they were permanently abandoned. If so, the SE should initiate processes to cancel the environmental licenses.

A final reflection on the analysis of the indicators is the heterogeneous behavior of the mining projects. They did not depend on the regulatory period or the method of entry into the system as EIDs or EISs, as deduced from the better performance of some indicators that were evaluated in the theoretically more permissive first regulatory period. This behavior is different from that observed during the analysis of aquaculture and sanitation projects [15,21]. The rationale for this seems to be associated with the greater development of the very important mining sector, which should require higher environmental protection standards.

3.3. Opportunities for Improvement Regarding Mining Projects

In general, citizens demand a higher level of participation during the EIA process and more access to certain information associated with the environmental monitoring of the projects. This is necessary for the coexistence of sustainable development and business in the different territories. In this sense, the identified weaknesses were related to the follow-ups of the projects, the public information provided after obtaining the environmental licenses, the lack of early participation, and the almost null adaptation to the new climate change regulation. Four opportunities for the improvement of the Chilean EIA system regarding mining projects are proposed below.

The first improvement refers to the creation of a simplified sanctioning procedure for small- and medium-sized projects. In general, the priority for auditing is for large projects to the detriment of medium- and small-sized projects, which are typically displaced instruments and most times are audited as a result of citizen complaints and not as SE initiatives. This deficiency of the Chilean EIA system was also reported in aquaculture projects [21].

The second improvement is to propitiate the connection between the EAS and SE websites. Currently, the tracking of projects is quite difficult because these institutions use different encodings for the same projects. This improvement is directly related to the unresolved challenge of improving the communication of the monitoring results [42].

The third improvement is to promote mandatory early participation in projects since citizen participation is an opportunity for early dialogue aimed at reducing the asymmetry of knowledge among consultants, owners, environmental authorities, and citizens [6,15,21].

Finally, the fourth improvement is the incorporation of the climate change variable in the EIA process, especially for those projects that can potentially affect renewable natural resources. Chile has recently published the national law on climate change so the creation of a mechanism to incorporate the climate change variable in the design of the projects is crucial [43].

4. Conclusions

Chile is a world leader in mineral production. The consequence of this is that the Chilean EIA system conducts many environmental studies of mining projects every year. This is the reason the Chilean EIA system is crucial to environmental protection, including the possibility of regulating beyond emissions and environmental quality standards in order to avoid the degradation of land and renewable natural resources.

The Chilean EIA system uses two methods to evaluate projects. The EIS is a more complex method than the EID. For the period 1994–2019, a total of 2867 mining projects were submitted to the EIA, 91.8% as EIDs and 8.2% as EISs. The northern regions accounted for 41.5% of the projects. Regarding the statuses of the projects, 63.3% were approved, 2.9% were rejected, 15.3% were not admitted, 3.2% were not rated, 0.3% were abandoned, 14.1% were withdrawn, and 0.7% had expired licenses.

The PCoA did not show significant differences between EID and EIS projects regarding the above-mentioned statuses. For EIDs, the PCoA showed five heterogeneous groups. Group 1 included a larger number of projects, which corresponded mostly to the third regulatory period SD40, with some projects from the first (SD30) and second (SD95) regulatory periods. Groups 2 to 5 included projects belonging to the first (SD30) and second (SD95) regulatory periods. On the other hand, the conducted MDS did not show significant differences between EIDs and EISs for the first (SD30), second (SD95), and third (SD40) regulatory periods. The main identified weaknesses of the Chilean EIA system were consultation and participation, the public information provided after the obtention of environmental licenses, post-auditing, and punishment for non-compliance. Four opportunities for improvement have been proposed: the creation of simplified penalty procedures for small- and medium-sized projects, improvements to the information provided after obtaining environmental licenses, mandatory early participation in projects, and the incorporation of the climate change variable into the EIA process.

In short, the Chilean EIA system should not be just considered a necessary administrative process only but should also include the "After EIA" category for proper follow-ups. In this sense, the information provided by mining projects and the monitoring of the projects are essential. This major productive sector must undoubtedly be a pioneer in regulatory compliance and contribute to improving the environmental performance of the country. This study presents a reproducible and verifiable scientific methodology to evaluate the performance and level of development of EIA systems. The methodology is applicable to diverse productive sectors and is also feasible for use in countries with basic technological and data management capabilities.

The main limitation of using this methodology in other countries is not methodological per se but is related to the existence or not of regulatory frameworks. Rodríguez-Luna et al. [6] applied this methodology to analyze the EIA systems of Chile, Spain, Canada, and Brazil, demonstrating that this methodology can be applied to compare different regulatory systems.

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