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Research Article

Engaging Stakeholders in Extraction Problems of the Chilean Mining Industry through a Combined Social Network Analysis-Analytic Network Process Approach

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This paper proposes a state-of-the-art methodology for the analysis of stakeholders and their role and performance related to SMEs in the mining industry in the Chilean region of Coquimbo. The relationships between the actors are studied and prioritized according to their support network position. An individual index for each actor based on their influence on solving problems is provided. The social network analysis was used to know the influence of the actors in the sector through the centrality measures. Furthermore, a methodology to measure stakeholders' influence based on the multicriteria method analytic network process approach is proposed. Both methods are used to identify the main stakeholders, study their relationships, and identify the most influential actors involved in executing strategies to boost the sector performance. The results show that the network remains cohesive thanks to certain actors, while the links between private actors must be strengthened; likewise, some public actors should assume a more proactive role in dealing with the problems of the sector.

1. Introduction

Mining is one of the most important economic activities worldwide. Globally, Chile is recognized as one of the largest producers and exporters of minerals, mainly copper. In 2019, Chile produced 5,822 thousand metric tons, equivalent to 28.4% of the world's copper production, which, at the national level, generates a high impact on the gross domestic product (GDP) of the country (9.4% in 2019) [1].

Small and medium-sized companies (SMEs) in the mining industry are significant contributors to this sector and important employment generators [2]. They depend on national development and promotion policies. As a drawback, this generates high inefficiency in productive activities. In this study, we focus on some of the problems related to these companies, given their social and economic impact and the scarce information available in this regard [3].

Mining activities are among the main polemical industries and constitute a real concern worldwide, especially in developing countries like Chile [4]. The modernization of the mineral extraction and treatment processes should be one of the sector's major concerns. However, these activities have been carried out in the same way for more than a century in Chile, where traditional exploitation and treatment practices are difficult to give up. Several other problems are also frequent, e.g., the lack of innovation in their processes and the error in estimating mineral deposits' value [5].

The problems of the sector are intensified in SME mining and are reflected in their production. Additionally, the limited allocation of resources and the absence of efficient plans and programs threaten the implementation of their projects.

The active and coordinated participation of the sector's actors in resolving the problems mentioned above is key for

decision making in the mineral extraction processes. Also known as "stakeholders," actors can positively or negatively influence the treatment of a given problem [6]. In the case of SMEs involved in Chilean mining, stakeholders usually apply their ability to act in favor. However, they can also become a threat, developing practices and activities incompatible with the sector's progress, which can turn them into allies or enemies.

As in other previous works, the first step to reach concerted solutions is to identify the related stakeholders and analyze the relationships between them [7]. A solution proposed from the joint work of stakeholders would imply considering participatory methods. They are widely used to address the difficulties of decision-making processes in different scenarios. Nonetheless, one of the challenges of participative processes is selecting proper stakeholders [8].

Within the well-known stakeholder theory, social network analysis (SNA) helps address this challenge. SNA depicts, models, and analyzes a community of agents using a network structure with some nodes and links that represent participating actors and their relationships [8].

The network view has reshaped conventional theory [9], and for that reason, network thinking has been effectively utilized in various areas at different levels. For instance, in economic geography, SNA has been considered a promising tool for empirically investigating the structures and evolution of inter-organization networks and knowledge flows within and across regions [10]. Regarding the mining industry [11], SNA has been applied to examine the strategic role of human resource management in decision-making processes and to determine how the human resources department collaborates with other departments or external organizations.

Considering the network of stakeholders involved in SMEs' problems in the mining industry in Chile, we believe that the action of one or more actors can affect the entire network. Therefore, the structure of this network may be the result of the actions of a few stakeholders. From this point of view, we consider it interesting to use the network approach to understanding the structure of this network.

Describing the existing relationships between the small and medium-sized mining industry stakeholders and their influence in the treatment of the sector's problems can help assess new solutions that support the development of this group. In this way, promoting new ways of cooperation between the different actors could correct the negative impacts caused by the influence of a few actors. The complex network method can be used to study this kind of complex structural relation among these stakeholders, in which there are different individuals with a large number of interactions [12].

The research on social networks has proved that a complex network is more suitable to the characteristics of the real network and that this complex network is composed of several subnetworks [13]. Many SNA-based methods, especially corporate-level and industry-level research, do not fully use SNA constructs to unravel the underlying complexity of the networks [14]. There are many traditional social network analysis methods but few studies from the perspective of complex networks [13].

For this reason and as a novelty of this study, the prioritization logic proposed by the analytic network process (ANP) technique [15] is used to analyze the influence of the actors and compare it with the standard centrality measures of the SNA. Thus, a new SNA-ANP approach to measure the influence among stakeholders exert is proposed. ANP is a well-known multicriteria decision method (MCDM) that models a typical decision problem in the form of a network based on the influence between the problem's elements and prioritizes them based on the influence relationships between them [16,17]. Another advantage of the application of these methodologies is their usefulness in circumstances where there is little precise information, either because it has not been obtained, processed, and disseminated by decision makers; because it is not feasible to generate the type of accurate and complete information that other techniques require; or simply because the one that exists is out of date or not relevant [18,19].

To summarize, the main objective of this study is to analyze the influence relationships between the actors and, based on these influence relationships, prioritize the stakeholders to involve them in future decision-making processes. The aim is to provide different individual indexes for each stakeholder, analyzing the concept of influence from a multirelational point of view based on a combined SNA-ANP methodology. This methodology is used to analyze stakeholders using as a case study the small and medium-sized mining industry of the Chilean region of Coquimbo. In addition, we propose how to take advantage of different actors' positions for the treatment of problems related to the extraction of the mineral.

The rest of the paper is organized as follows. Section 2 presents the context of the case. Section 3 presents the literature on SNA and ANP. Section 4 details the methods proposed and illustrates how the proposed model works through the case study. The results of the case study are discussed in Section 5. Section 6 proposes some implications of the results in the development of strategies for the sector. Finally, Section 7 concludes the study.

2. The Context: SMEs in the Chilean Mining Industry

Small and medium-scale mining comprises all those privately owned mines with an extraction capacity of up to 200 tons of "ore" per day. This group's main characteristic is that the smelting and refining processes are carried out by the National Mining Enterprise ENAMI [5, 20]. ENAMI is a company for promoting and developing small and medium-sized enterprises in the mining industry of the Government of Chile, which provides them with subsidized payment treatment [5, 21].

This segment comprises a large group of small miners who adhere to the government's promotion policy, and most of them sell their products to ENAMI's purchasing powers through a tariff system [5, 21]. Unlike large-scale mining, the demands on small-scale mining in terms of reserves, implementation time, and initial investment are minimal, the capacities and infrastructure needs are moderate, and the

employment per unit of production is high. Hence, the specific production pattern makes small-scale mining an attractive option for developing countries [22]. However, several studies indicate that this sector has less equipment, difficult working conditions, and extreme sensitivity to low price cycles [2].

This study focuses on SMEs in the Coquimbo Region (with a total of 33.4% of the mines located in Chile), recognized as one of the most productive areas of the country. The Coquimbo Region contains 11.1% of the total area of exploration mining concessions and 11.5% of the country's exploitation in 2019 [1]. The interest in analyzing SMEs' situation in Coquimbo lies in the productive specialization in the mining activity of this region. This specialization has given rise to a regional development strategy based on creating mining alliances in which SMEs play a leading role.

Chile promotes some policies for the development of small and medium-scale mining through ENAMI [23, 24]. However, these policies also generate some inefficiencies, mainly in terms of incentives. By providing fixed rates and assuring the purchase of their products, small mining producers are not incentivized to reduce costs or to improve the quality of the products they deliver.

Table 1 shows the most critical problems related to the mineral extraction and sale processes faced by small and medium-sized mining companies in the Coquimbo Region [25, 26]. This research will focus on the problems of the mineral extraction process. These processes are the basis for the subsequent sale of the mineral, which must comply only with the buyer's procedures and requirements: ENAMI.

To solve this type of problem, the commitment of mining producers and the organizations that represent them, public and private, is essential. They must understand that this is a common challenge and that the only long-term solution lies in the conviction to share coordinated efforts among all actors [23]. This study intends to provide an individual index for each actor based on his or her influence on the problems and propose some recommendations about how to engage actors in addressing the problems.

3. Theoretical Background

3.1. The Importance of Stakeholder Analysis. Stakeholders can be defined as any group or individual who can affect or is affected by the achievement of an organization's purpose [6]. The stakeholder approach proposed by stakeholder management theory is strongly related to managing the relationship with those groups and individuals.

Interest in analyzing how stakeholders influence management processes, decision making, and conflict resolution has grown significantly, as can be seen in the literature [6, 27]. Therefore, stakeholder management has been adopted in many different areas such as corporate governance, social responsibility, project management [28], environmental management [29], urban development [30], or public management [31], among many others.

However, the identification of the agents, the analysis of their mutual influences and interrelations, the study of the impact or importance in decision making, and the measurement of these influences constitute a real problem that is not fully resolved in the literature. For this reason, so-called "stakeholder analysis" has become an increasingly popular area. The objective of stakeholder analysis is to generate knowledge about the relevant agents so that their behavior, intentions, relationships, and the influences or resources they can contribute to the decision-making processes can be better understood.

Although this analysis is mainly focused on defining methods for identifying and selecting key stakeholders [31–33], many tools have been proposed to improve management and stakeholder engagement. According to Bourne and Weaver [34], there are three basic approaches followed to identifying stakeholders: customer relationship management (CRM), techniques for listing and mapping stakeholders, and social network analysis (SNA).

In general, the analysis of the stakeholders' qualities helps us identify each one of them and thus to know more precisely the expectations they may have. Therefore, selecting the appropriate way of managing stakeholders is crucial. Yang [30] considers that there is no perfect method of identification and prioritization of actors. Therefore, it is convenient to combine different techniques, depending on the case study to which it is applied, that is, according to the number of stakeholders and interest groups, according to the relationships to be studied, and according to the type of information to be extracted.

3.1.1. Social Network Analysis (SNA). SNA was initiated in the early 1920s [35]. It enables relationships to be represented and described systematically and compactly [36]. SNA sees the social world in terms of interactions, rather than as an aggregation of actors who act independently, and thus focuses on patterns of relationships as the unit of analysis [37, 38] and in the implications of these relationships [9, 35, 39].

Since its institutionalization in the 1980–90s, SNA has grown significantly, both in terms of the number of publications and the number of disciplines involved using the SNA approach [40].The method has been applied in many fields, including resource utilization, social communication, disease transmission, strategic planning, science interaction, smart specialization, and project management [35, 41].

Many SNA metrics and concepts have been developed to characterize and compare network structures and positions within them [41]. When selecting each actor's centrality, it is important to keep in mind what we want to consider in the study. This is what a centrality indicates to a specific property. An actor may be visible in terms of one centrality but not another. Therefore, this actor may be more useful in one respect than another may be. A detailed description of centrality measures can be found in [35, 37, 41, 42].

3.1.2. Analytic Network Process (ANP). The analytic network process (ANP) is a theory of relative measurement of intangible features proposed by Saaty [15]. It defines the prioritization model as a network in which the relationships between decision elements represent the influence between them [43–45].

Table 1: Main problems of SME mining in Coquimbo.

Problems of production technology: mineral obtaining process	Commercialization problems: mineral sales process
Lack of professional qualifications	Lack of orientation of small and medium-sized companies in the mining industry for the sale of mineral ore
Lack of strategic business vision	Lack of knowledge in the process of buying and selling minerals
Lack of entrepreneurial capacity	The inefficiency of the state-owned company ENAMI
Technological obsolescence	Low production capacity of the state-owned company ENAMI
Financial weaknesses	Setting of high treatment charges by the state-owned company ENAMI

In a network of actors, the decision elements can be considered the actors of the network, among which it is necessary to identify those with the greatest relevance to the problem, determined by the influence they exert and receive, and what makes them the most relevant actors of the analyzed network.

Like SNA, ANP represents the influence of the elements of a decision problem in a matrix. However, an essential step of ANP is identifying the network elements and their relationships. This is a network design that forces the decision maker to conduct an in-depth analysis of the problem.

In general, the steps to carry out a prioritization process using ANP are

(i) Identifying the components and elements of the network and their relationships (influence matrix).

(ii) Conducting pairwise comparison and calculating relative importance weights.

(iii) Placing the resulting relative importance weights (eigenvectors) within the original influence matrix (unweighted matrix).

(iv) Weighting the unweighted matrix elements by the corresponding priorities of the clusters so that they can be column stochastic (weighted matrix).

(v) Raising the weighted matrix to limit powers until the weights converge and remain stable (superlimit matrix).

The steps and mathematical formulation of the ANP process can be found in [15, 16, 46].

In this paper, we propose the use of ANP logic to quantify the relative influence of stakeholders on the problem of mineral extraction. We conducted the analogy in which the stakeholders identified are the elements in the decision model that should be ranked to prioritize their role in solving the problems for the Chilean sector of mining.

Moreover, to maintain the binary scale of relationships, as in the SNA, no paired comparisons are made between elements. Therefore, the influence matrix is directly transformed into a stochastic column matrix (weighted matrix). This ANP approach allows us to analyze the stakeholders' interdependencies to reflect deeply on the influences of stakeholders on the others (among stakeholders).

4. The SNA-ANP Approach for Stakeholder Analysis

This study proposes the analysis of the network of the small and medium-sized mining industry of the Chilean region of Coquimbo through a methodology that combines SNA, in the stakeholder's identification and the analysis of their influences, and ANP, for the analysis of these influences and the prioritization of the most influential stakeholders in dealing with the problems of this group of companies. Therefore, we have named the proposed methodology SNA-ANP-based approach for stakeholder analysis. The purpose is to associate the actors' positions to decision-making processes and the responses to the mineral extraction problems that this group of companies faces.

The study is exploratory as it examines ANP's approach to stakeholder analysis. It is also descriptive because it combines the SNA-ANP approach to describe the network and its actors' characteristics. The following steps were used to conduct this research (Figure 1).

The combined use of the two techniques has previously been performed in the works of [47–49] for the identification of actors to link in multicriteria decision-making processes. However, as far as the authors know, both techniques have not been combined to study influences between the same elements and compare results.

4.1. Problem Formulation. The correct definition of the problem to be dealt with is the initial stage and is the basis for applying any methodology related to decision making. As mentioned in Section 2, among the possible drawbacks to be addressed in this work, we have focused on problems related to production technology. These problems were identified and classified in previous works [25, 26] through a survey answered by 340 companies belonging to the National Mining Society Database (SONAMI database of small and medium-sized companies in the Coquimbo Region) from which the main problems that are shown in Table 1 of this work were extracted.

4.2. Design: Definition of the Elements of the Stakeholder Analysis. In both techniques (SNA and ANP), the relations are as important as the actors are; therefore, the two fundamental components to identify are the list of stakeholders and the type of interaction to be studied.

4.2.1. Nodes: Identification of Stakeholders. The main interest groups related to mining exploitation in Chile are summarized in Table 2. These actors were selected among associations of small miners, medium-sized companies, or services that usually carry out functions of promotion,

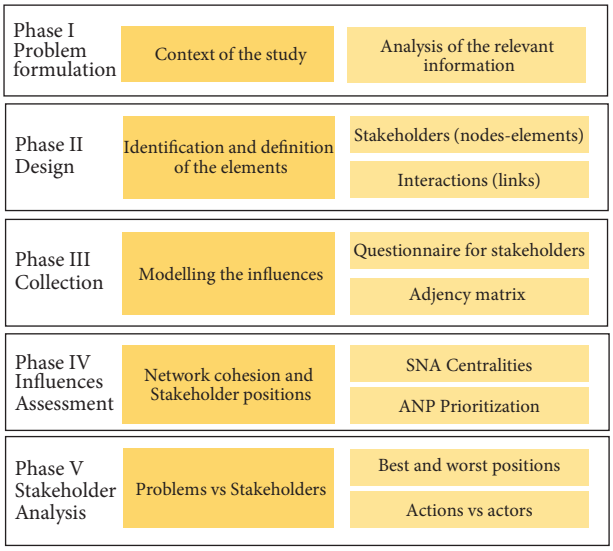

Figure 1: The SNA-ANP proposed approach.

support, technical support, and control of the sector's activities.

Since this study was carried out in the Coquimbo Region, the actors that are directly related to the mining SMEs in this region were identified. For this, a survey of the information was carried out through the Regional Government (GORE) and the Regional Ministerial Secretariat of Mining (SEREMIA). On the other hand, the Ministry of Mining was consulted to define the central government actors that have a direct relationship with SMEs in the different regions of Chile. The list of key stakeholders was compiled, including all these identified actors.

Their public or private nature determines the first characteristic of these actors. The first group corresponds to public institutions, while the second one is conformed of those that do not belong to the Government of Chile and are characterized as being private organizations and trade associations.

The actors represent the nodes in the SNA and the decision elements in the ANP.

4.2.2. Interactions: One-Mode Network. The second key elements are the links between the nodes that represent the relationship between different stakeholders. As this paper analyzes the actor's influence in the problems related to mineral extraction, the relationships (relational content) are those interactions between the actors related to the treatment of the problems.

According to Hanneman and Riddle [36] and many other studies, sharing of information and interactions can be used to establish links between two nodes in a social network. In this work, the relationships between all the actors were studied.

4.3. Collection and Modeling of Influences. A questionnaire was designed as a tool to collect data (Table 3) and sent to the 31 actors listed in Table 2. Responses were received from 17 actors out of the 31 (Table 4). The rest of the actors did not respond despite several attempts. In these cases, the methodology advises against interviewing them because their unwillingness would bias their answers and, therefore, the results. If they were key actors, they would be nominated by the rest of the participants [10].

The network was formed with the 17 actors who answered, taking into account their representativeness in decision-making problems related to mineral extraction.

With respect to the trade associations, of the nine existing ones, the six that participated in the study were included in the network since they are representative in terms of their production size, number of workers, and sales distance from their deposit to ENAMI, while the remaining three are much smaller and not very representative. On the other hand, the eight mining companies existing in the Coquimbo Region, classified as medium-sized mining enterprises, were considered not relevant for this study. These companies sell the final product of their process in a different way than trade associations, and therefore their sales relationship with ENAMI is different. That is, trade associations sell their product extracted from their deposit directly to ENAMI, while the companies, once their product has been exploited, process it in their own plants, obtaining a product and by-product as benefits. Considering these eight companies, with different relationships in the extraction and sales problems with the main promoter of the sector in the Chilean Government´s mining industry (ENAMI), would have altered the relationships of the key network players and their connections with the rest of the network.

Regarding safety entities, in the initial list, we had ACHS (Chilean Association of Security), CCHC (Chilean Chamber of Construction), and IST (Worker Safety Institute). All of them are private non-profit entities, whose missions are very similar and which provide full coverage for work accidents and develop risk prevention programs in Chile. Therefore, CHCH was considered as representative of the three occupational health and safety entities.

Table 2: List of actors.

No	Acronym	Description	Type	Main activity
1	ENAMI	National Mining Enterprise	Public	Promoting, processing, trading
2	SONAMI	National Mining Society	Private/ business	Promotion and advisory services
3	SERNAGEOMÍN	National Geology and Mining Service	Public	Promotion
4	CORFO	Production Development Corporation	Public	Promotion
5	SERCOTEC	Technical Cooperation Service	Public	Promotion
6	SEREMÍA	Regional Ministerial Secretariat of Mining	Public	Technical support
7	GORE	Regional Government	Public	Promotion
8	SENCE	National Training and Employment Service	Public	Training-technical support
9	DDT	Labor Department	Public	Control
10	IST	Work Safety Institute	Private/ business	Training and prevention
11	ACHS	Chilean Security Association	Private/ business	Prevention
12	CCHC	Chilean Chamber of Construction	Private/ business	Promotion
13	ULS	University of La Serena	Public	Training and technical support
14	EB	Banking Entities	Private/ business	Control
15	AGM La Higuera	La Higuera Mining Association	Private/ business	Small-scale mining: grouping and representing miners
16	AGM Andacollo	Andacollo Mining Association	Private/ business	
17	AGM Punitaqui	Punitaqui Mining Association	Private/ business	
18	AGM Ovalle	Ovalle Mining Association	Private/ business	
19	AGM El Huacho	El Huacho Mining Association	Private/ business	
20	AGM Combarbalá	Combarbalá Mining Association	Private/ business	
21	AGM Salamanca	Salamanca Mining Association	Private/ business	
22	AGM Illapel	Illapel Mining Association	Private/ business	
23	AGM La Serena	La Serena Mining Association	Private/ business	
24	CMSG	San Geronimo Mining Company	Private/ business	Medium mining: exploration, extraction, production, and processing: mine + plant
25	CMPN	Palo Negro Mining Company	Private/ business	
26	CMLL	Los Linderos Mining Company	Private/ business	
27	CMDP	Punitaqui Mining Company	Private/ business	
28	CMAC	Minera Andacollo Copper Company	Private/ business	
29	CMLP	Los Pingos Mining Company	Private/ business	
30	CMNE	Nueva Esperanza Mining Company	Private/ business	
31	CMLC	La Cocinera Mining Company	Private/ business	

Table 3: Example of the questionnaire for stakeholders.

Which of the actors do you contact in order to address issues related to mineral extraction problems? Please tick.
Actor:
National Mining Enterprise (ENAMI)
National Mining Society (SONAMI)
National Geology and Mining Service (SERNAGEOMÍN)
...
Others

Regarding the participation of the Banking Entity (EB), this was considered unnecessary, since the financing of small mining and trade associations through financial entities is almost nil because the mining sector does not provide benefits for financial entities.

Table 3 shows an example of the questionnaire that was given to the final list of stakeholders.

The adjacency matrix is built based on the actors' responses about the relationships between them to improve the problems related to the mineral extraction process. An actor (A) pointing to another actor (B) indicates that actor B supports actor A. Therefore, this matrix reflects the influence of the elements located in rows on the elements located in columns. A binary measurement scale has been used in which "1" (green) indicates that influence exists between the actors and "0" (red) indicates that there is no influence at all. Once the nodes and lines are identified, a 1-mode adjacency matrix was generated (Table 4).

4.4. Stakeholder Influence Assessment

4.4.1. Analysis through SNA Approach. Three structural or cohesion measures (network density, network centrality, and average path length) and four types of centrality measures (degree, closeness, betweenness, and eigenvector) were used. We have chosen UCINET [50] as the software to carry out the visualization and SNA analysis. The results are presented in Section 5.

4.4.2. Analysis through ANP Approach. Using ANP logic, the prioritization of the actors was obtained according to their influence in solving the mineral extraction process's problems.

According to ANP terms, the adjacency matrix obtained (Table 4) corresponds to the influence matrix representing the influences relationships. Since the calculation of relative importance weights has been avoided, to maintain the same binary scale used in SNA analysis, the influence matrix is transformed into a stochastic column matrix to obtain the weighted matrix (Table 5). Finally, the weighted supermatrix is raised until the weights converge and remain stable to obtain the superlimit matrix. These calculations have been developed using Superdecisions® software [15, 51]. The ANP results are shown in the last column of Table 6.

5. Results and Discussion

5.1. Structural Analysis of the Whole Network. Based on the adjacency matrix, a 1-mode network of stakeholders was generated. In the network, the identified stakeholders are mapped into nodes linked with arrows (Figure 2). The nodes' shape represents the stakeholder's nature, while the nodes' color represents their main activity.

A brief scan of Figure 2 shows that the network is built on several central actors that establish multiple relationships (A1, A2, A6, ...). Likewise, some peripheral nodes can only communicate through each other, for example, A5, A8, and A9. There is only one isolated node (A10). Therefore, this is a sociocentric type network connected by actors positioned in the center.

Considering only the governmental actors (Figure 3(a)), all of them maintain multiple connections with each other. On the other hand, isolating the non-governmental actors in a subnet (Figure 3(b)), the number of connections diminishes. In the last case, there are two disconnected actors (A10 and A16), while the rest are only held together by actor A2. This subnet also shows a complete disconnection among the associations.

Table 7 shows the main cohesion measures. The social network density is 0.228, indicating that the network is sparse and poorly connected. Such a value is low since the total number of nodes is 17, which indicates that the social network is not very large and it should not be challenging to connect many actors. The number of existing relationships in this network is weak; hence, it is necessary to improve further exchanges and relationships in the sector. This is reflected especially in the group of associations and in some entities that should be recognized as more central actors, such as A5 and A10, given their supporting role.

The social centralization of the network indicates a significant difference among some stakeholders' degree centrality. This is reflected in the network graph in the central position of some actors versus the disconnection of others.

The average degree of each stakeholder is 3.6. This finding indicates that one specific stakeholder can, on average, support more than three stakeholders. Given the size of the network, the average path length is relatively small, with a value of 2. It means that the network connections are efficient, indicating that one actor could easily be exchanged for another. This value facilitates the rapid transfer of information or resources, reducing the loss of information or resources in the process. This is especially important for the small business community that is hard hit by resource constraints.

In general, the results of the cohesion measures show that the relationships between stakeholders are not very close despite the size of the network. However, since the network is small and compact, it is not difficult to improve the connection between the most remote actors.

5.2. Power Quantification Analysis of Chilean Small Miners' Network. Some of the conclusions that emerged from the structure analysis of the whole network carried out in the previous section are reinforced and complemented by the analysis of individual indicators. Table 6 shows the measures calculated for each of the actors in the small mining industry in Chile.

Table 4: Adjacency matrix.

		A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17
A1	ENAMI	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0
A2	SONAMI	1	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0
A3	SERNAGEOMÍN	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
A4	CORFO	1	0	1	0	1	1	1	0	0	0	1	0	0	0	0	0	0
A5	SERCOTEC	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0
A6	SEREMÍA	1	1	1	1	1	0	1	0	0	0	1	0	0	0	0	0	0
A7	GORE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A8	SENCE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A9	DDT	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
A10	CCHC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A11	ULS	1	0	1	1	0	1	1	1	1	0	0	1	1	1	1	1	1
A12	AGM La Higuera	1	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
A13	AGM Andacollo	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A14	AGM Punitaqui	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
A15	AGM Ovalle	1	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0
A16	AGM Combarbalá	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A17	AGM Salamanca	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0

Table 5: Weighted supermatrix.

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17
A1.ENAMI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2.SONAMI	0	0	0.125	0	0	0.100	0	0	0	0	0.333	0	0	0	0	0	0
A3.SERNAGEOMÍN	0.083	0	0.125	0.200	0	0.100	0.167	0	0	0	0	0	0	0	0	0	0
A4.CORFO	0.083	0.143	0	0	0	0.100	0	0	0	0	0	0	0	0	0	0	0
A5.SERCOTEC	0.083	0	0.125	0	0.500	0.100	0.167	0	0	0	0.333	0	0	0	0	0	0
A6.SEREMÍA	0	0	0	0.200	0	0.100	0	0.500	0	0	0	0	0	0	0	0	0
A7.GORE	0.083	0.143	0.125	0.200	0.500	0	0.167	0	0	0	0.333	0	0	0	0	0	0
A8.SENCE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A9.DDT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A10.CCHC	0.083	0	0.125	0	0	0	0.167	0	0	0	0	0	0	0	0	0	0
A11.ULS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A12.AGM La Higuera	0.083	0	0.125	0.200	0	0.100	0.167	0.500	1.00	0	0	1.00	1.00	1.00	1.00	1.00	1.00
A13.AGM Andacollo	0.083	0.143	0	0.200	0	0.100	0	0	0	0	0	0	0	0	0	0	0
A14.AGM Punitaqui	0.083	0.143	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A15.AGM Ovalle	0.083	0.143	0	0	0	0.100	0	0	0	0	0	0	0	0	0	0	0
A16.AGM Combarbalá	0.083	0.143	0.125	0	0	0.100	0.167	0	0	0	0	0	0	0	0	0	0
A17.AGM Salamanca	0.083	0	0.125	0	0	0	0	0	0	0	0	0	0	0	0	0	0

In Table 6, red circles are used to mark low values for each indicator, amber circles are used for average values, and green circles are used for the most central actors. These measures assess different types of actor relationships and provide insights into how the stakeholders are connected within the mining sector.

There is a significant difference between the most important positions of the OutDegree and InDegree centralities. This is to be expected given the meaning of the relationship studied. Regarding OutDegree, A11ULS has the highest value [13], indicating that 13 out of the 17 stakeholders look for help from this actor to deal with the sector's problems; therefore, it is the most consulted actor. This is consistent given the role of technical support and the typology of problems related to mining production. A11ULS role is critical, especially for small miners' associations, since they only draw on it to solve the problems of the sector. Two hypotheses can be developed to explain this situation. First, the associations do not consider contacting more actors due to lack of knowledge, and second, other actors have not dealt with them in previous experiences. A7GORE, A8SENCE, and A10CCHC are actors that do not provide support to the network.

Regarding InDegre, the values of A1ENAMI [12] and A6SEREMÍA [10] are relatively high, indicating that both institutions are ones that contact more actors to deal with extraction problems. The results of both centralities give us a first idea about the strategy to be implemented considering the contact power of the triad A1, A6, and A11. In general, Associations have the lowest values, which is an evident weakness of the network, as these actors are the ones that require the most support.

Considering OutCloseness, A11ULS remains the closest actor to the rest, along with A6SEREMÍA, A4CORFO, and

Table 6: The SNA-ANP measures.

Actor	OutDeg	Indeg	OutClose	InClose	OutEigen	InEigen	Between	ANP
A1.ENAMI	3	12	31	26	0.47	1.00	50.98	0.107
A2.SONAMI	5	7	37	31	0.49	0.56	9.17	0.056
A3.SERNAGEOMÍN	3	8	39	30	0.37	0.91	6.64	0.033
A4.CORFO	6	5	28	35	0.64	0.58	13.72	0.137
A5.SERCOTEC	3	2	38	39	0.30	0.35	3.13	0.043
A6.SEREMÍA	7	10	27	28	0.73	0.99	47.03	0.157
A7.GORE	0	6	64	31	0.00	0.66	0.00	0.000
A8.SENCE	0	2	64	43	0.00	0.20	0.00	0.000
A9.DDT	3	1	40	46	0.19	0.13	0.00	0.013
A10.CCHC	0	0	64	64	0.00	0.00	0.00	0.000
A11.ULS	13	3	21	35	1.00	0.57	94.62	0.261
A12.AGM La Higuera	4	1	37	46	0.52	0.13	0.14	0.060
A13.AGM Andacollo	2	1	40	46	0.21	0.13	0.14	0.017
A14.AGM Punitaqui	3	1	38	46	0.37	0.13	0.14	0.033
A15. AGM Ovalle	5	1	36	46	0.46	0.13	0.14	0.037
A16.AGM Combarbalá	2	1	42	46	0.19	0.13	0.00	0.013
A17.AGM Salamanca	3	1	38	46	0.37	0.13	0.14	0.033

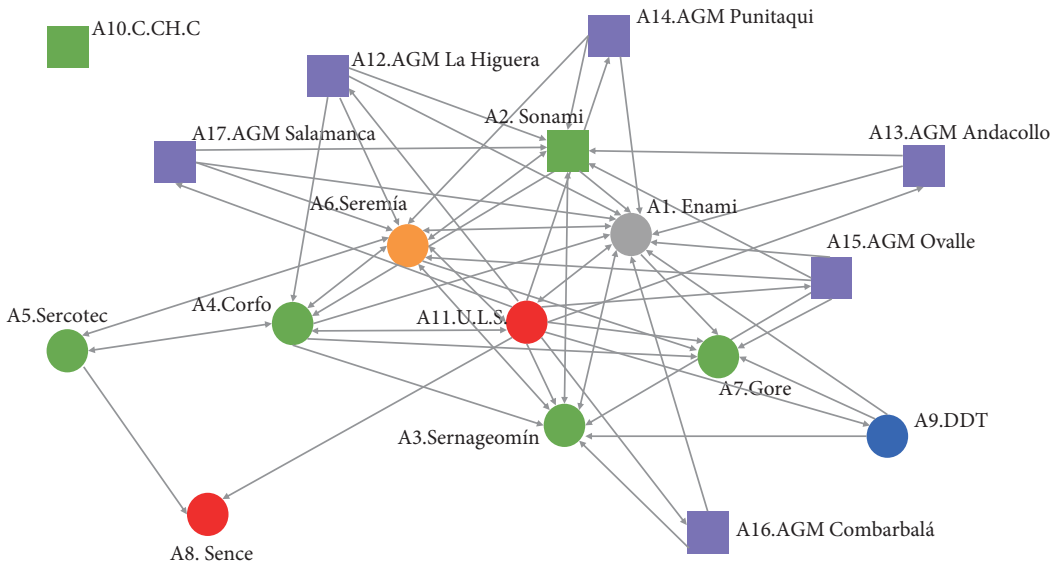

Figure 2: The social network of actors linked to the problem of the mineral extraction process of small mining companies in the Coquimbo Region, Chile (UCINET®) (circles: public actors; squares: private organizations or associations; grey: ENAMI; green: promoting; red: training; blue: control, orange: technical support; purple: association.

A1ENAMI. This suggests that A4CORFO could be an ally for the triad of actors mentioned above. Moreover, given its aim of promoting production, this actor's role must be better used and strengthened. The analysis of InCloseness shows a larger group of actors with the best results. However, given the nature of the network, associations should be able to arrive quickly and get close to the rest of the actors who support them.

OutEigen considers the privileged position of nearby nodes. This centrality shows some different results among the associations, which could be used when designing or applying strategies that seek to impact small miners directly. Especially, A12AGM_La_Higuera and A15AGM_Ovalle, which have the highest values, should make less effort to disseminate or deliver information or resources than the rest of the associations. Regarding the InEigen, A3SERNAGEOMIN seems to play a role in searching for resources for the sector.

As expected, for betweenness, A11ULS has the highest value, indicating that it has the highest potential to connect

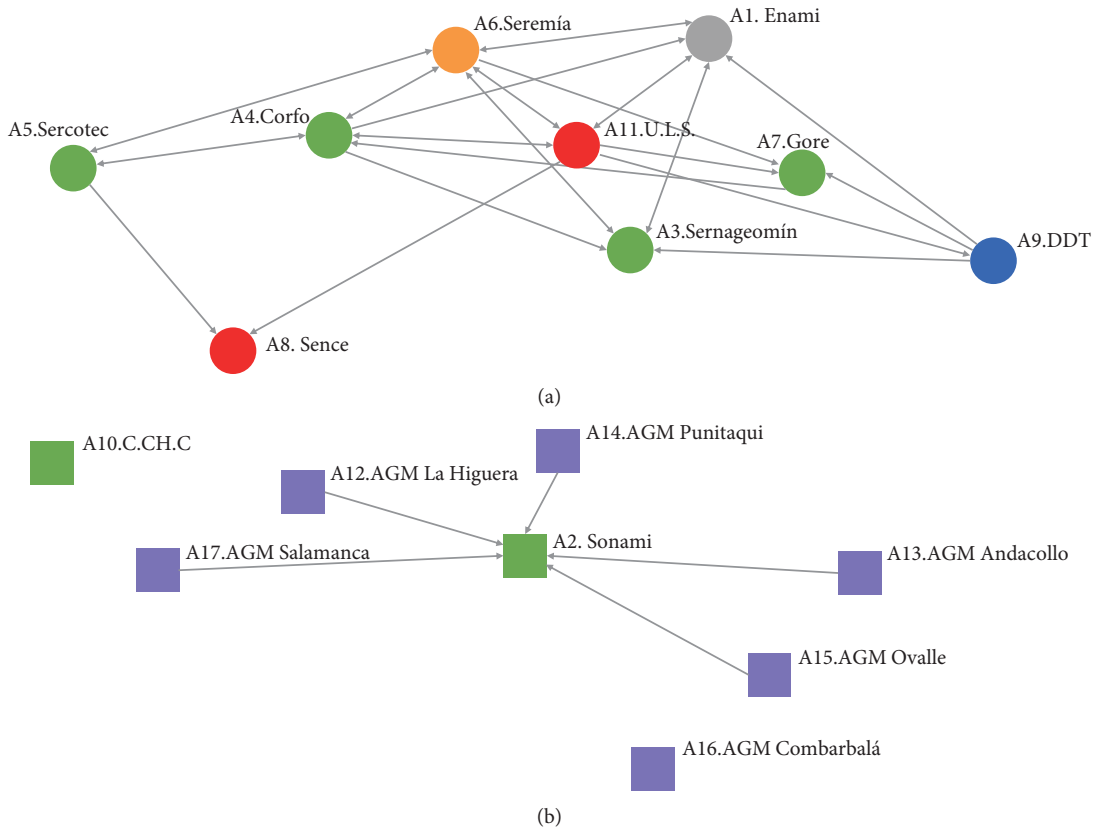

Figure 3: Subnets according to the nature of the actors. (a) Public actors. (b) Non-public actors: private organizations or associations.

Table 7: Cohesion measures.

Measure	Value
Density	0.228
Deg-centralization	0.663
Out-central	0.621
In-central	0.555
Avg-degree	3.647
Avg-distance	2.076

and control other stakeholders in the network. Stakeholders with higher values of betweenness centrality can act as brokers since they lie on many different paths in the public network and the non-public network. Consequently, they connect many different pairs of actors. Other organizations can also have power as intermediate institutions, such as A1ENAMI and A6SEREMÍA, which can help build up more connections for supporting exchanges, especially to connect the most distant actors. Moreover, these public institutions have adequate drivers and capacities to promote this sector.

Besides, it is not recommended that the network depends so much on a single actor. Actors with the highest betweenness (high and differentiated) have the power to break the link among various actors in the network, weakening the group, and thus must be treated with caution [52]. Centrality analysis also uncovers the betweenness centrality of several actors such as A7, A8, A9, and A10 and all the associations located on the edges of the network, indicating the presence of structural holes. This lack is more evident among non-public actors. They cannot frequently interact with other organizations to discuss mineral extraction problems.

Finally, we analyze the result of the proposed analysis using ANP logic. The result presents the prioritization of the actors that participate in the small companies' mineral extraction process of the mining industry of the region of Coquimbo of Chile. It establishes the dimension of an actor's influence on the problem. This facilitates the comparison between the positions of an actor with respect to others and highlights the differences between the most central and most peripheral actors.

The result reinforces that the A11ULS is the most influential actor. Its priority in this problem is 26%. This value is high, but it is also quite far from the rest. Hence, it is necessary to take actions so that the actors, especially small miners, seek more support in other types of organizations. Moreover, other actors, such as A2SONAMI, could take more relative importance, taking advantage of its proximity to the rest of the actors.

The second group comprises A6SEREMÍA, A4CORFO, and A1ENAMI, with values of 15.7%, 13.7%, and 10.7%. These three public institutions are called upon to lead the process of modernization of the sector that allows small miners to overcome extraction problems. All strategies should be led by them and aimed at those disadvantaged actors of the network, such as small miners' associations, which are the least influential as regards the problem.

The rest of the actors have zero or very low influence values. In this group, we find all the miners' associations

Table 8: Groups of stakeholders

Group	Actors	Actions to be promoted
Group I	A11.ULS	Key actor to lead the actions to be performed
Group II	A6.SEREMÍA A4.CORFO A1.ENAMI	To take a more active role
Group III	**A2.SONAMI** A5.SERCOTEC A3.SERNAGEOMÍN	To improve their connections
Group IV	A9.DDT A7.GORE A8.SENCE A10.CCHC	To increase their presence
Group V	**A12.AGM La Higuera** **A15.AGM Ovalle** A14.AGM Punitaqui A17.AGM Salamanca A13.AGM Andacollo A16.AGM Combarbalá	They are the neediest in the network. Urgent actions are required.

(A12–A17) and A2SONAMI, A3SERNAGEOMIN, A5SERCOTEC, A7GORE, A8SENCE, A9DDT, and A10CCHC. This suggests that 13 out of the 17 stakeholders do not offer any kind of support to the rest of the network. Therefore, the group addresses the same actors (A1ENAMI, A4CORFO, A6SEREMÍA, and A11ULS) regardless of the type of problem, for example, whether it is a problem related to technological obsolescence or financial weaknesses.

An advantage of using ANP logic is that it allows us to complement and summarize the situation depicted from the SNA centralities. The joint analysis using the SNA-ANP approach also allows the classifying of the actors according to the weaknesses and strengths derived from their position in the network. Each measure reveals the location and importance of actors from several different viewpoints. However, to summarize the previous results, following the proposal of Ahmadi et al. [8], we propose a classification of the actors in four groups according to their actions to promote the mining sector (Table 8).

Public actors, especially A11ULS, can easily control the network. The actors in the associations' group (Group V) have less influence because they cannot support other actors and seek support only in A11ULS. For this reason, the intervention of more central actors (Group I and Group II) to establish more support connections is imperative and urgent. Greater availability is required to help these types of actors. The associations A12AGM_La_Higuera and A15AGM_Ovalle may be the most important allies since they are the ones that hold the best position in this group.

Therefore, it is crucial to prepare more policies to encourage non-public stakeholders to ask for more support and involve more public actors supporting small businesses (Group III). A2SONAMI can serve as an intermediate to connect both groups since it is the non-public actor with better linkages among these groups.

Finally, the actors must demand a more significant presence from the actors of Group IV since their role of promoting, training, technical support, and control does not have any influence on the network.

6. Implications of the Results in Handling the Extraction Problems

Two types of actions can be proposed to strengthen the sector. The first aimed at stimulating relations between actors to improve the role and presence of certain actors in the network [42]. The second aimed at solving the problems found by taking advantage of the actors' current position [9, 35]. The objective is to detect opportunities for improvement in management and to support decision-making processes related to the mineral extraction process in the region of Coquimbo in Chile from the perspective of the actors and their positions.

University of La Serena (ULS) is the actor with the most significant influence on the problem of the mineral obtaining process of the SMEs of the mining industry of the region of Coquimbo. This is because this public institution is committed to this region and is aiming at transferring and disseminating knowledge, techniques, and technologies related to mining topics. The Regional Ministerial Secretary of Mining (SEREMÍA) is a relevant public institution since its central role is to execute regional policies, plans, and projects. In a nutshell, these two actors could provide support to companies, helping them increase their strategic vision of the business and improve their entrepreneurial capacity.

In the third and fourth positions appear the Corporation for the Promotion of Production (CORFO) and the National Mining Enterprise (ENAMI). ENAMI is an institution for the promotion of small and medium-sized mining. CORFO is a world-class agency intended to project Chile towards the new knowledge economy of the 21st century. Both institutions play a crucial role in supporting companies' professionals and providing technological training.

Table 9: SNA-ANP analysis vs. key characteristics.

Key characteristics	Measure	Best positions	To be strengthened in
Contacted by other stakeholders Greater support capacity [7,41]	OutDeg	A11.ULS A6.SEREMÍA	A10.CCHC A4.CORFO A2.SONAMI A1.ENAMI A8. SENCE A7.GORE
Contact more actors Request support Greater access to support [7,41]	InDeg	A1.ENAMI A6.SEREMÍA A3.SERNAGEOMÍN A2.SONAMI	A15.AGM Ovalle A12.AGM La Higuer A14.AGM Punitaqui A17.AGM Salamanca A13.AGM Andacollo A16.AGM Combarbalá
Closer to support the rest of the network [37]	OutClose	A11.ULS A6.SEREMÍA A4.CORFO A1.ENAMI	A2.SONAMI A3.SERNAGEOMÍN A5.SERCOTEC A7.GORE A8.SENCE A9.DDT A10.C.CH.C
Get help faster [35]	InClose	A1.ENAMI A6.SEREMÍA A3.SERNAGEOMÍN A2.SONAMI A7.GORE	A15.AGM Ovalle A12.AGM La Higuera A14.AGM Punitaqui A17.AGM Salamanca A13.AGM Andacollo A16.AGM Combarbalá
Reduced delivery effort [29,54]	OutEigen	A11.ULS A6.SEREMÍA	A7.GORE A8.SENCE A10.CCHC A9.DDT A5.SERCOTEC A3.SERNAGEOMÍN
Less effort to seek/demand support or help [29,54]	InEigen	A1.ENAMI A6.SEREMÍA A3.SERNAGEOMÍN	A15.AGM Ovalle A12.AGM La Higuera A14.AGM Punitaqui A17.AGM Salamanca A13.AGM Andacollo A16.AGM Combarbalá A2.SONAMI
Gatekeepers Close structural holes [41,50]	Between	A11.ULS A1.ENAMI A6.SEREMÍA	A4.CORFO A2.SONAMI A3.SERNAGEOMÍN A7.GORE
Influence [15]	ANP	A11.ULS A6.SEREMÍA A4.CORFO	A1.ENAMI A2.SONAMI A3.SERNAGEOMÍN A5.SERCOTEC A7.GORE A8. SENCE A9.DDT A10.CCHC

The active, adequate, constructive, and organized participation of the actors can contribute to better managing the human, technical, and financial resources required for improvements in the mineral extraction process, favoring the access and exchange of crucial information [53], as well as the generation and adoption of commitments by the actors to contribute to management programs and reduce conflicts.

Therefore, we have related SNA-ANP measures to key characteristics of the actors. This makes it easier to identify those actors with specific characteristics required for particular improvement actions. Table 9 shows the best-positioned actors for each measure and those that should be promoted, either because they should offer or because they should ask for more support from the network.

Table 10: Mineral obtaining process problems vs. key stakeholders.

Mineral obtaining process	Required characteristics	Key actors
Professional qualifications and technology obsolescence	Providing technical advice quickly and avoiding the loss of resources.	A1.ENAMI A4.CORFO
Lack of strategic business vision and lack of entrepreneurial capacity	Providing connections between actors and influence	A6.SEREMÍA A11.ULS
Financial weaknesses	Resources and availability	A6.SEREMÍA A11.ULS

Finally, Table 10 shows the relationship between the production technology problems and the stakeholders that could support the decision making and solutions according to their position in the network and their main activity.

7. Conclusions

The application of the methodology proposed in this paper facilitates participatory decision making in the problem of the mineral extraction process. This methodology prioritizes the most influential actors and develops a novel stakeholder analysis model that recommends the participation of the most relevant stakeholders to evaluate opportunities for improvement in the management of mineral extraction processes. In this sense, this methodological approach can be a complementary method in order to go deeper into the relationship between the complexity of real social networks and the decision-making processes of these relevant actors [8].

The active participation of the most relevant actors in these processes contributes to better managing human, technical, and financial resources, relating these actors to specific improvement actions to be applied in the sector. This relationship allows establishing a connection between the sector's production technology problems and the stakeholders, who should make the decisions related to each type of problem, according to their main activity and their position in the network.

The results of the SNA centralities assign a value to the actors' influence on the problem and establish the importance of an actor concerning others, highlighting the differences between the most central and the most peripheral actors.

On the other hand, an advantage of using ANP logic is that it allows complementing the analysis of SNA centralities. The joint analysis, using the SNA-ANP approach, classifies the actors according to the weaknesses and strengths derived from their position in the network. This new approach could be applied in other complex networks with complex structural relations among stakeholders, e.g., at corporate or industrial level, since these levels have not received much attention in network research [14].

According to the results obtained, it can be concluded that government agencies are competent and of great importance for the SMEs of the mining industry of the region of Coquimbo in Chile. It is necessary to re-evaluate the role of the ENAMI, since, as the only purchasing power of minerals of the State of Chile, it results in SMEs of the mining industry of the Coquimbo Region having greater difficulties in complying with the requirements demanded by the state entity, especially with the extraction of the mineral.

Finally, as one of the main limitations of this study, we can mention the low participation of medium-sized companies. However, the information collected with the participating actors allowed us to understand the role of the actors who did not participate [54].

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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