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Research article

Comparative organizational network analysis considering formal power-based networks and organizational hierarchies

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ABSTRACT

Comparative organizational network analysis makes it possible to identify the similarities and differences between organizations according to the content of their networks. This research is a comparative study of organizational networks based on formal power. To accomplish this goal, networks were developed in three organizations from different sectors with workers distributed in high, middle and operational levels in the organizational hierarchy. For the study, 100% of the workers within the identified networks were included. The results indicated that, considering centrality and connectivity network indices, there were no statistically significant differences between organizations according to formal power network behavior. However, we obtained statistically significant differences in terms connectivity and centrality considering the workers' hierarchy. The representative nodes of high and middle hierarchical levels had higher indices of connectivity and centrality than the nodes representative of the operational level. This study makes it possible to identify the formal roles within networks based on legitimate power, which can serve as a basis for decision-making processes and resource allocations, for the strategic use of the networks created.

1. Introduction

The use and study of organizational networks has started to be considered an essential part of organizational culture; and the importance given to organizational leadership, workers' relationships and the establishment of social patterns can be identified and verified through organizational network analysis (Balkundi and Kilduff, 2006). Networks have also served to differentiate effective managers from successful leaders due to their use as a strategic form of decision making (Robbins and Judge, 2013). Technology has allowed the use of networks to proliferate and the recognition if their importance for the managerial actions of both formal and informal organizational leaders (Campbell and Meddings, 2006). Additionally, the use of networks in leadership processes allows us to identify the ways in which leaders guide their activities, how they can measure the effectiveness of communication and how they conduct their planning (Liu and Moskvina, 2016). Thus, one of the main uses of networks by leaders is the achievement of personal objectives and goals, and another main use is a means to help their colleagues and collaborators achieve their own objectives (Campbell and Meddings, 2006).

1.1. Leadership and formal power in organizations

Leadership and power in organizations have been concepts that have often been treated in an interconnected way (Taucean et al., 2016). On many occasions, one term has been confused with the other, but despite having similarities, there are elements that differentiate them. Power has been identified as the current or potential ability to influence other people (Campbell and Meddings, 2006; French and Raven, 2014; Lunenburg, 2012). Fernandez (1991) indicates that leadership also implies the exercise of influence over other people. This influence can be represented by personal attributes or contingent elements. In this sense, power and leadership are characterized by the levels of influence that people exercise, where leaders can have access to various types of power

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(Campbell and Meddings, 2006). For Taucean et al. (2016), the effective use of power allows the success of leaders to be determined (Lunenburg, 2012; Taucean et al., 2016).

One of the forms of power that is identified as part of formal leadership is the power given by the authority. This type of power is also known as legitimate power and refers to the ability to influence and make decisions based on their position within the organizational hierarchy (Lunenburg, 2012; Taucean et al., 2016). This form of power has been recognized as the most effective in certain organizations, especially to obtain quick responses and to improve the performance of the organization's members (Campbell and Meddings, 2006). One important aspect of legitimate power is that in organizational spaces, we can find people who have the right to influence and people who have the obligation to receive this influence (French and Raven, 2014). The same happens with leaders in general since leadership applies when there is a consensus between the person who influences and the person who agrees to be influenced (Fernandez, 1991). However, formal leaders have a type of legitimate influence that allows them to have direct access and control over an organization's resources and to make decisions with greater impact compared to what informal leaders could do (Sparrowe and Liden, 2005). For Zohar and Tenne-Gazit (2008), there are two ways in which influence manifests itself between people: communication and relationships. Both communication and relationships lead to the formation of networks (Zohar and Tenne-Gazit, 2008).

1.2. Organizational networks and leadership

Organizational networks are structures based on the existence of nodes, which in this case would be the people who work in the organization; and the existence of relationships between nodes (Balkundi and Kilduff, 2006; Liu and Moskvina, 2016). Leadership in organizations can be studied from the analysis of organizational networks through the identification of the weights of people who function as nodes in these networks (Liu and Moskvina, 2016). Networks can be classified as formal or informal depending on the relationships between nodes. Formal networks refer to the relationships between nodes based on legitimate, reward or punishment power, having a direct relationship with the hierarchy that people occupy (Marineau, 2014; Norbom, 2010; Peiró and Meliá, 2003); and informal networks are when the relationships between nodes are based on referent and expert powers (Peiró and Meliá, 2003; Ramos et al., 2019). Formal leaders can be part of informal networks when the characteristics of the activities they perform are not necessarily planned or intentionally elaborated; thus, they are not a part of their formal roles (Hoppe and Reinelt, 2010; Sparrowe and Liden, 2005).

However, formal relationships between workers and their leaders within formal networks have been recognized as crucial for the success of organizational management processes (Sparrowe and Liden, 2005). Informal leaders who do not have formal authority experience many frustrations when seeking to implement functional activities and usually manipulate the networks where they seek to exert a more social influence (Balkundi and Kilduff, 2006). Additionally, Marineau (2014) affirms that networks made by formal power, where formal leaders are identified, have relationships and forms of management that turn out to be more precise than those of informal networks.

1.3. Roles of formal leaders in organizational network analysis

There are several roles that nodes occupy in the studies of organizational networks and that define the function that the node occupies within its network. The importance of identifying the roles of the nodes is given by determining how critical the presence of that node is within the network (Pasqualino et al., 2013). In this way, people can be identified as connectors, as bridges, and as centralizers of information, among other node classifications (Balkundi and Kilduff, 2006; Long et al., 2013; Pasqualino et al., 2013). The two roles that were identified as being related to formal leadership for the present study were the bonding and bridging roles.

Bonding refers to the connectivity that people have with other people; thus, it is related to forming their own group (Hoppe and Reinelt, 2010). This type of meter allows the identification of social elements such as trust, which can lead to indicators of group work efficiency and is determined from the density of the network connectivity. Conversely, bridging refers to the mediating role of a node that facilitates connections between groups within the network (Hoppe and Reinelt, 2010). Bridging allows us to identify a node's potential for collaboration and the use of network resources. One of the indices associated with bridging that has been little considered in the social sciences is stress centrality, which makes it possible to calculate the number of short paths between nodes (Brandes and Erlebach, 2005). This does not necessarily indicate that the communication between groups is lost when eliminating a node with a high level of stress centrality but rather that the communication path is lengthened.

Leaders who are nodes with high stress centrality are key people because they can speed up the transmission of information and, consequently, can facilitate their work as organizational managers. To guarantee effective communication in networks, it is essential that the information arrives in the fastest way possible and spreads throughout the network, but this depends on the level of connectivity of its nodes (Zohar and Tenne-Gazit, 2008). According to Jia et al. (2012), considering the short connectivity paths between nodes, which is the stress centrality index, is the better way to identify these important nodes because identifying these nodes shortens the divergence of the information that is transmitted (Ishakian et al., 2012; Scardoni and Lau, 2012).

This study aims to characterize the roles of formal leaders in organizational networks based on formal power, considering the connectivity and stress centrality indices in the networks. Formal leaders with high connectivity are those who receive the largest number of selections, so it is a popularity factor; furthermore, formal leaders with high stress centrality are those through whom information passes immediately from a greater number of nodes, which allows them to be identified as critical in decision-making processes due to the quality of information and relationships they manage.

2. Materials and methods

This research is a comparative study of the analysis of organizational networks based on informal power and the occupational hierarchies of its members.

2.1. Sample

The sample consisted of 100% of the population of workers from three companies in Ecuador belonging to the banking, cooperative and commercial sectors. The organizations were chosen for their heterogeneity according to their economic sector. This way, conclusions act as result of a comparative analysis, using contrast between organizations, as a form of multiple case study. The description of the population is found in Table 1.

2.2. Instrument

For the construction of the networks, the same question was asked to the three organizations: "Who is my boss?" It should be noted that the original questionnaire was longer and referred to different sources of power. However, it was decided to choose the question that was common in the three organizations analyzed, that was related to formal power. This allowed us to acquire information to form the network corresponding to formal power to establish the roles of the formal leaders in it. The survey applied contained the names of all the workers of each organization so that there were no errors when selecting the name of the worker according to the question, as well as their own name. The option of "no one" was included in the answers.

Table 1. Characterization of organizational workers.

	Company 1	Company 2	Company 3
Gender			
Male	68,8%	38,6%	78,4%
Female	31,2%	61,4%	21,6%
Hierarchy			
Operational-level workers	65,6%	87,0%	85,1%
Middle-level managers	27,4%	7,7%	11,2%
High-level managers	7,0%	5,3%	3,7%
Total	503 participants	246 participants	436 participants

Note. For network studies, the entire population of the organizations was considered, so the number of participants was 100% representative of their organizations.

2.3. Design

The survey was available until all collaborators completely completed it, and it was a requirement that the entire population complete the instrument. Due to the characteristics of the network and to control the filling, the instrument was not anonymous; however, it was indicated that the results would only be processed by the researchers, and it was also required that participants signed a filling consent form. Having access to the names of the participants made it possible to perform the subsequent the filling process.

2.4. Data analysis

The indices used in the networks were connectivity and stress centrality. As previously explained, the determination of nodes using both indicators makes it possible to identify the people who had the highest degree of selections and, therefore, those who exert the greatest influence within the network. Meanwhile, stress centrality allows to identify those nodes through which relevant information passes within the network, which is also relevant for leadership. The calculations were made using the Cytoscape program, which also allowed us to identify the connectivity and stress centrality indices of each of the nodes. The graphs made reflect each of the leaders of the three levels of hierarchies identified in different colors: senior managers (red), middle managers (black) and operational personnel (green).

3. Results

The results presented show the calculations related to the stress centrality and power network connectivity of three organizations and the differences calculated between them. Likewise, as part of the research, the results of these indices are shown by comparing the hierarchical levels within each organization.

3.1. Description of organizational networks based on formal power

Organizational networks based on formal power are represented in Figures 1, 2, and 3. In the case of Company 1, the network based on formal power is represented in Figure 1.

Figure 1 shows that the network is composed of three groups: a large island, where most of the collaborators are interconnected; and two smaller islands, where there is no communication with the rest of the collaborators. The black and red nodes, representing the top and middle managers of the organization, respectively, can be seen graphically as the nodes in the center of the main choices.

This Figure shows a distribution of high and middle managers towards the center of the network, which allows us to affirm that the relationships between the leaders of the higher management are closer than the relationships between people who do not occupy the same hierarchy. However, leaders from middle management are found in the main centers of groups who are formed towards the periphery of the network. This means that they continue to have an important role within

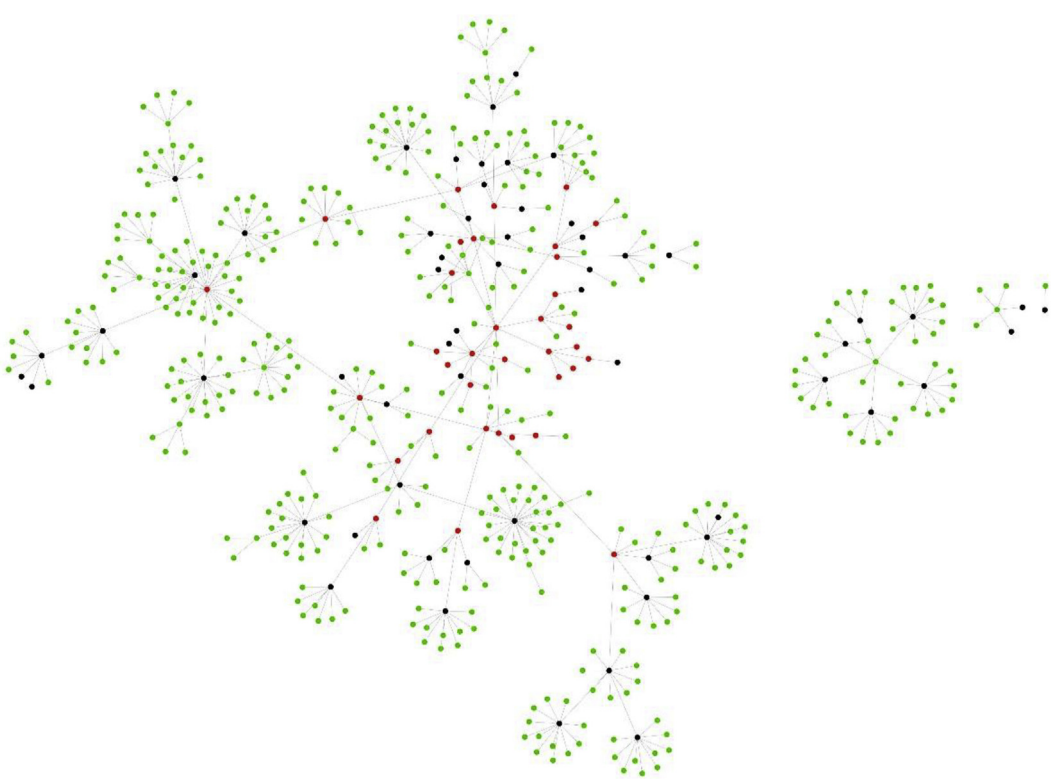

Figure 1. Organizational network of Company 1, based on legitimate power. Note. The people who are high-level managers are in red, the middle-level managers are in black and the operational-level workers are in green.

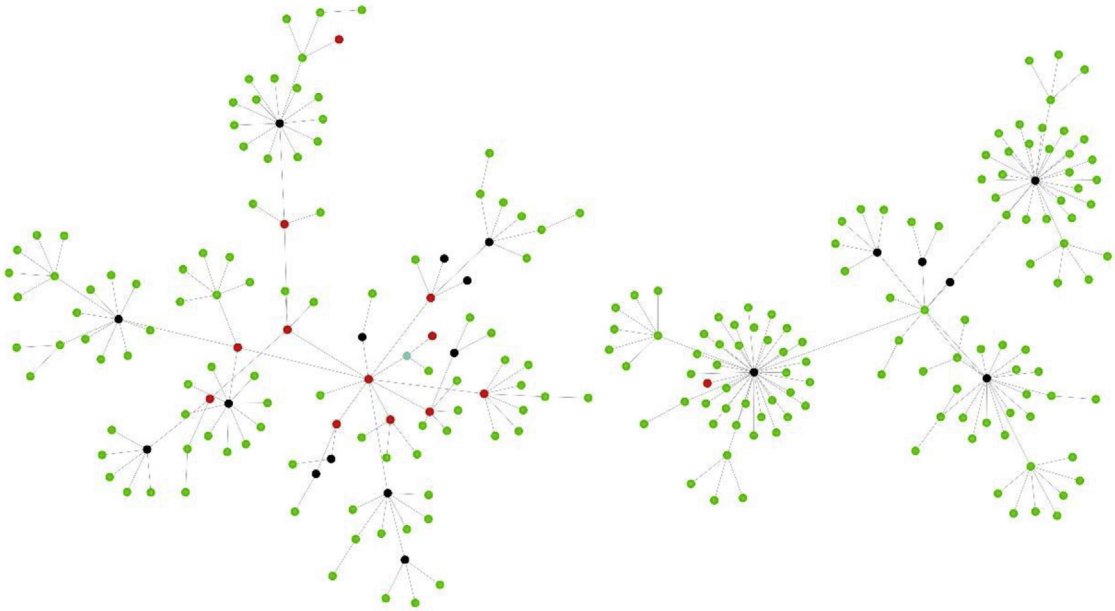

Figure 2. Organizational Network of Company 2, based on legitimate power. Note. In red are the people who are part of high-level managers, in black are the middle-level managers and in green the operational-level workers.

the network, but they are more connected with the nodes that represent people with less hierarchy. The network graph of Company 2 is presented in Figure 2.

The distribution of the network in Figure 2 shows that there are two large groups that do not connect with each other; however, workers are distributed in these two groups in almost the same proportion. The black and red nodes can also be visualized in the election centers and as connectors between the groups.

In Figure 2 we can find something like Figure 1. In this organization, the nodes that correspond to high-level leaders are close and interconnected with each other, while the nodes of the middle management are found more towards the periphery of the network and have more connections with people who do not have higher hierarchies within the organization. Finally, the network related to Company 3 is graphed in Figure 3.

Figure 3 shows three groups: one has the largest number of collaborators interconnected, and the other two groups are smaller and are not

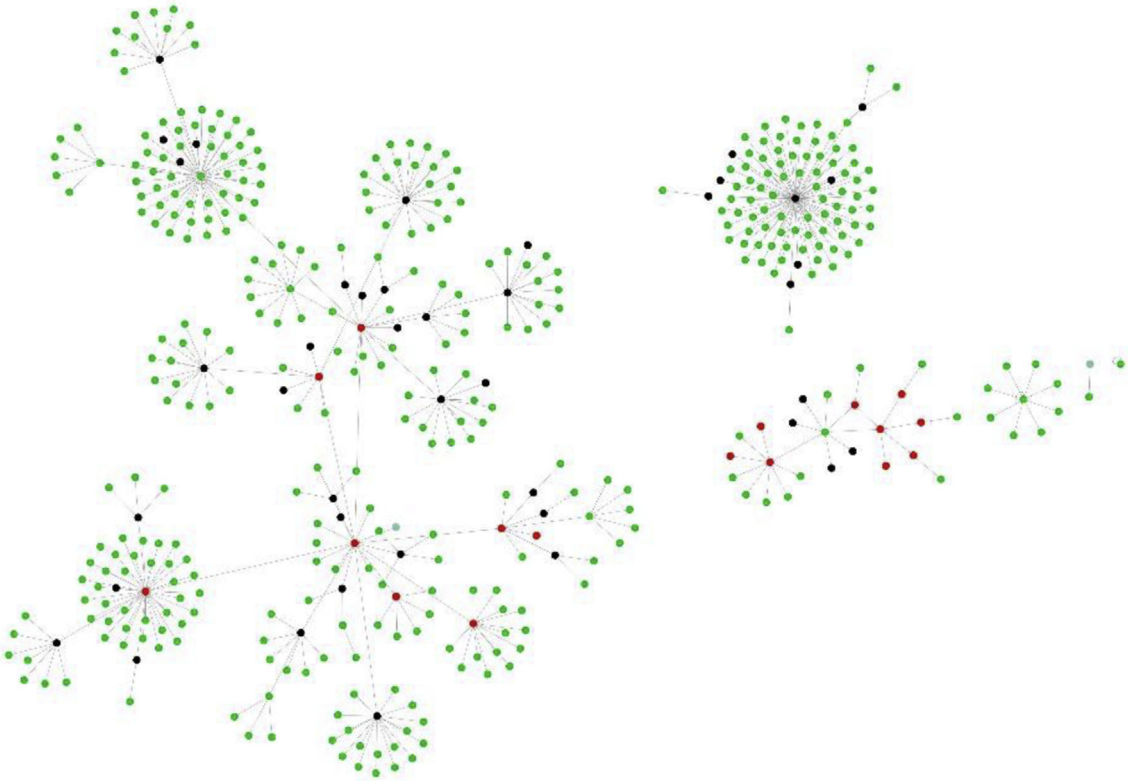

Figure 3. Organizational Network of Company 3, based on legitimate power. Note. In red are the people who are part of high-level managers, in black are the middle-level managers and in green the operational-level workers.

Table 2. Organizational differences considering connectivity and stress in the formal power network.

	Company 1	Company 2	Company 3	Sig.
Connectivity	0,044	0,048	0,031	0,454
Connectivity (Standard Deviation)	0,018	0,032	0,014	0,184
Stress	0,021	0,027	0,023	0,323
Stress (Standard Deviation)	0,007	0,018	0,008	0,090

Note: The difference mean comparison results were obtained using the Kruskal-Wallis test.

connected to each other or to the largest group. The red and black nodes appeared as central in most elections, except for a few groups where the key people are not necessarily from the highest hierarchies. Unlike the previous Figures, in Figure 3 people with higher hierarchy are more dispersed within the network and we can affirm that the relationships they have with those nodes that represent people without formal hierarchical roles are similar to the relationships that they have with them the people of middle management.

3.2. Differences between organizations considering the centrality and connectivity indices

Table 2 shows the results obtained from the calculations, where the general differences between indices can be identified.

As seen in Table 2, there are no statistically significant differences between organizations considering general values related to the connectivity and stress indices. There were also no differences in relation to the standard deviations for each of the evaluated indices. This allows us to affirm that the organization is not a key attribute that defines the analysis of the formal power network. This is a positive result. Since there are no differences between organizations, we can conclude that the behavior of people within the network will respond to their hierarchy, regardless of the organization in which they belong.

3.3. Differences between hierarchical levels considering the centrality and connectivity indices

The centrality and connectivity indices were also measured considering the different hierarchies in the three organizations analyzed. The results are shown in Table 3.

Considering the mean differences between the connectivity and centrality values in the three hierarchical levels evaluated, we can affirm that there are statistically significant differences between people according to the hierarchy they occupy in the three organizations. In two out of three organizations, there are no differences between middle managers and senior managers according to the centrality and connectivity indices, which indicates that the level that people have at this hierarchy does not have a significant impact on their position within the network. However, both levels represent a formal power compared to the operational hierarchy, which are employees who are not in charge of other employees and who, therefore, do not have formal leadership roles within the organization.

Correlation analyses between the connectivity and centrality were performed for each hierarchy evaluated. These results are given in Table 4.

The results show that the levels of centrality and connectivity in each of the hierarchies analyzed present statistically significant and positive correlations. That is, the higher the connectivity is, the higher the centrality. In this sense, the formal leaders of organizations are people who have a greater influence due to the number of selections they receive, which confirms their leadership position. These people, due to the results obtained in the correlations, are also leaders considering their role within the network, related to access to information, which increases the power that the person has within their network.

4. Discussion

Our results show the relationships that exist between the sources of formal power and the level of the occupational hierarchy of the people, considering connectivity and centrality indices, which are higher in workers in higher hierarchical levels. Our results also show that the behavior of formal power networks between organizations does not present statistically significant differences. These results are discussed below. However, Fernandez (1991) acquired different results since he obtained consistency in the formation of leaders using organizational networking in only two out of three organizations studied. For this author, the network behavior indicators did not prove to be homogeneous in different organizations when explaining the development of formal leaders.

4.1. Organizational networks based on formal power do not present differences considering their connectivity and centrality indices in the organizations studied

The studies where organizational networks are compared are called network comparative studies, and their objective is to identify the similarities and differences between the networks found (Cherifi et al., 2016; King et al., 2009; Wong et al., 2015). However, previous research comparing organizations has presented different inconsistencies when organizational networks have been compared, probably due to the nature of the networks. In the study conducted by Brass (1984), the results obtained showed differences in the values related to centrality in the networks. Merrill et al. (2008) also found discrepancies in the results from a study of health organizations aimed at comparing organizational networks according to indicators of density, complexity and centrality, among others; and concluded that organizations by their context are unique in relation to the behavior of their networks. This has allowed several authors to argue the importance of the use of networks as a form of intelligence in organizations (Daňa et al., 2020), but there are still not enough studies using comparative analysis of organizational networks.

Table 3. Hierarchical differences considering connectivity and stress in the formal power network.

	Company 1	Sig	Company 2	Sig	Company 3	Sig
Connectivity						
Operational-level workers - Middle-level managers	-109,228	0,000	-85,521	0,000	-162,578	0,000
Operational-level workers - High-level managers	-199,276	0,000	-87,052	0,000	-180,197	0,000
Middle-level managers - High-level managers	-90,048	0,000	-1,530	0,944	-17,619	0,561
Stress						
Operational-level workers - Middle-level managers	-103,448	0,000	-86,928	0,000	-163,085	0,000
Operational-level workers - High-level managers	-199,921	0,000	-83,228	0,000	-183,013	0,000
Middle-level managers - High-level managers	-96,473	0,000	3,700	0,864	-19,928	0,501

Note: The difference mean comparison results were obtained using the Kruskal-Wallis test.

Table 4. Relationship between centrality and connectivity for each hierarchical level.

		Connectivity
Operational-level workers	Stress	,960**
Middle-level managers	Stress	,945**
High-level managers	Stress	,932**

Note: Spearman's correlation coefficient was used for correlation. ** indicates $p < 0.01$.

Our results suggest that there are similar behaviors in organizations when the measurements cover the same concept and type of the network, at least in terms of networks related to legitimate power. More research is needed in this regard to verify whether our results are related to the context in which they were obtained.

4.2. Formal power networks present significant differences considering the hierarchies within each organization

According to Peiró and Meliá (2003), the existence of formal power may or may not be related to the hierarchical positions that people occupy in their organizational contexts. For authors such as Marineau (2014) and Patterson et al. (2018), the legitimate power of a formal leader is related to how legitimate this leader is perceived, not because of their hierarchical position itself. However, the results obtained in the present investigation indicate that networks based on formal power have key nodes that coincide with the hierarchical position of the people in their organization. Studies such as that of Aalbers and Ipskamp (2012), Ramos et al. (2019) and Taucean et al. (2016) confirm this. Sutanto et al. (2011) indicated that informal leaders appear more frequently in networks that reflect relationships that are also informal.

For Aalbers and Ipskamp (2012), the higher the hierarchical level that a person occupies is, the more legitimate their participation within the organization, and this gives legitimacy to the ideas and information that come from this person; therefore, it is not strange that they become references in their networks of formal power. The participation of high hierarchies in networks allows the allocation of resources and accesses that strengthen their participation in networks (Aalbers and Ipskamp, 2012; Katz, 2018). At the same time, it allows us to better direct the activity of the network toward the fulfillment of organizational objectives and facilitates innovation processes.

Despite the risk indicated in studies by Lunenburg (2012), where people whose predominant power is formal can misuse it and, consequently, can use coercive power modes combined with legitimate power, in the case of the organizations studied, the high levels of connectivity and centrality found indicate that people, according to their hierarchy, are referred to as important nodes within the organizational network. These results contrast with what was shown by Sutanto et al. (2011) since their research started from the premise that centrality indicators are associated with informal roles within an organization. The present research shows that, in the context studied, legitimate power is used in a more strategic way, based on the functions given by the hierarchy, and is based more on the notion that a leader is capable of influence through legitimate power (Lunenburg, 2012).

5. Conclusion

Our results are from a comparative study of organizational networks considering legitimate or formal power and the organizational hierarchies distributed in high managers, middle managers, and operational workers. These results show that even though the graphs that represent the networks have different visual behaviors, we can identify similarities in relation to the positions of the representative nodes of high and medium hierarchies with these being the ones that receive the most selections by the rest of the nodes. When the levels of centrality and connectivity between the three organizations were compared, there were no statistically significant differences. However, considering the hierarchies of the workers, we did find differences between high-level managers, middle-level managers and operational workers. Two of the three organizations did not present significant differences in the centrality and connectivity indices between high- and middle-level managers.

The main conclusions derived from our research affirm that organizations, even if they are from different sectors, maintain the same relationships between their nodes, considering their connectivity and centrality indices in networks based on formal power. However, people have differences in relation to centrality and connectivity according to their hierarchy within the organization, allowing us to conclude that formal networks are related to formal leadership and that their use allows them to make strategic decisions in accordance with the organizational objective and influences the allocation of resources for the development of the different activities.

5.1. Limitations

The study could benefit from a larger sample of organizations to extend the conclusions from the context studied and into cross-cultural studies. It is also recommended that more networks, especially informal networks, be used to compare the results obtained, especially considering the role of informal leaders.

5.2. Further implications of the study

This study highlights the need to conduct more comparative studies considering organizational networks to determine patterns in a context and to be able to develop theories that allow one to explain the behavior of the relationships between nodes in a network. The analysis of organizational networks based on both formal and informal power is one of the key elements for the decision-making processes of management at different hierarchical levels. The results allow us to understand the relationships that are established and the roles that leaders can occupy according to their hierarchy.

Declarations

Author contribution statement

Valentina Ramos: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data.

Pablo Pazmiño: Conceived and designed the experiments; Performed the experiments.

Antonio Franco-Crespo: Contributed reagents, materials, analysis tools or data.

Carlos Ramos-Galarza: Contributed reagents, materials, analysis tools or data.

Eduardo Tejera: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data.

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Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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