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Social Network Analysis in disaster management

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Abstract

Paper aims: This paper aims the use of Social Network Analysis (SNA) as an assessment tool to answer the following research questions: (i) Who are the actors in Humanitarian Operations Networks (HON)?; and (ii) Which actors exert influence on HON?

Originality: This paper proposes the use of SNA in a different context, bringing new technics to the field of humanitarian logistics.

Research method: Multiple methodological tools are used such as UCINET, Cytoscape, and EXCEL® to apply SNA in the Brazilian context of sudden-onset natural disaster-response operations.

Main findings: This application validates the consistency of using SNA to assess HON, besides validating the stakeholder relationship model of the Public, Private, and People sectors in disaster-response operations.

Implications for theory and practice: Results show strong participation of the public sector in disaster-response operations in Brazil, indicating the need for greater engagement from civil society. Besides, the proposed method can be adopted in the context of any other country.

Keywords:
Humanitarian operations. Disasters. Social Network Analysis.

1. Introduction

Natural sudden-onset disasters require great agility in immediate response operations to keep the lives, health, and morale of the affected population (Eriksson, 2009). Such operations face great challenges regarding time pressure and urgency in a complex environment of great uncertainty, resource shortages and infrastructure damages (Jiang & Yuan, 2019). Hence response operations to such events require high interaction amongst stakeholders of different profiles, cultures, and interests in stressful situations (Caruson & MacManus, 2011), and thus coordinating these stakeholders becomes critical for effective outcomes (Khodarahmi, 2009; Fontainha et al., 2017).

Rigid boundary systems with a top-down approach and command and control mechanisms have proven to be ineffective for coordinating disaster-response operations (Kapucu et al., 2010). Studies highlight the need for more cooperative and collaborative approaches in coordinating humanitarian operations (Silva, 2016; Cozzolino et al., 2017). The absence of coordination, cooperation and collaboration in this context may lead to undesired decisions, which can negatively impact beneficiaries' welfare (Wankmüller & Reiner, 2020). To solve this problem, Hackman (2011) identifies enabling conditions – such as establishing clear norms of conduct and providing well-timed team coaching – that increase the likelihood that teams will be effective in any setting or type of organization, such as intelligence, defense, crisis management, and law enforcement professionals.

Humanitarian Organizations may operate in highly complex distribution networks (Leiras et al, 2021) and challenges (Costa et al., 2015; Mendonça et al., 2019). Network analysis are an effective approach to assess focusing events, which are sudden and unpredictable events with dramatic consequences (Birkland, 1997; Brasil, 2021), such as disasters and emergencies. Networks can also be used to address problems that require an adaptive and flexible approach due to inconsistent information or uncertain conditions. Moreover, networks analysis can be applied on situations in which the knowledge and resources required to solve the problem surpasses the available capacity (Provan & Lemaire, 2012). In this context, networks analysis emerges as a potential tool to be applied in disaster-response operations (Kapucu & Demiroz, 2011).

In this context, this study aims to propose the use of Social Network Analysis (SNA) as an assessment tool to answer the following research questions: (i) Who are the stakeholders in a Humanitarian Operations Network (HON)?; (ii) Which actors exert influence on a Humanitarian Operations Networks (HON)?; and (iii) How does a Humanitarian Operations Networks (HON) forms? Hence we propose the use of SNA in a different context, bringing new technics to the field of humanitarian logistics. Furthermore, we validate our mathematical model with data from a real problem setting, using several methods and softwares to endorse the results, such as UCINET and CytoScape.

This paper is structured into six sections. Section 2 presents the theoretical background used to provide grounding to the study. Section 3 presents the methodology adopted in the research. Section 4 presents the research's results and section 5 discusses them. Finally, Section 6 presents the conclusion and suggestions for future work.

2. Theoretical background

Social Network Analysis (SNA) is a quantitative technique used to assess the structural relationships and positional value of individuals or organizations within a network based on centrality measures (Freeman, 2004). It is related to the analysis of patterns and network structure (density) and nodal position within a network (centrality), allowing the identification of its bottlenecks, strengths, and weaknesses (Pavlovich, 2003). It also contributes to increasing the visibility of relationships among hidden or informal stakeholders in a network (Cross et al., 2003).

Disaster-response operations require interaction amongst stakeholders from diverse fields and sectors (Kapucu et al., 2013). Although the tasks of each stakeholder may be different, they are connected to achieve common goals, forming a network. This network requires collaboration, coordination, communication, partnerships, and interoperability (Kapucu et al., 2010). As it depends on relational interactions and data, Social Network Analysis (SNA) can be applied to assess such networks. Nevertheless, there are particular characteristics of disaster response operations that distinguish the application of Social Network Analysis (SNA) in this context. For instance, such networks present atypical structures, besides the difficulty in identifying every stakeholder involved in disaster response operations and in structuring the relationships and interactions among them.

The concept of Humanitarian Operations Networks (HON) used in this study was based on the concept developed by Thomas & Kopczak (2005, p. 2) as the process of planning, implementing, and controlling the efficient, cost-effective flow and storage of goods and materials, as well as related information, from the point of origin to the point of consumption for the purpose of alleviating the suffering of vulnerable people. The function encompasses a range of activities, including preparedness, planning, procurement, transport, warehousing, tracking and tracing, and customs clearance.

During a crisis, it is difficult to perform coordination properly due to environmental uncertainty, the involvement of innumerous stakeholders from diverse contexts and the lack of resources. If such situation turns into chaos, collaboration amongst stakeholders is unlikely to continue and their relationship can vary during the operation. Hence the application of Social Network Analysis (SNA) for understanding how the actual network has deviated from the planned one can be a valid tool to assess the performance of disaster management efforts, helping to increase the effectiveness of disaster risk management (Kapucu & Demiroz, 2011).

The uncertainty along with the constant changes during a disaster response operation leads to variations in the interaction between stakeholders and in their relationships. Therefore, the network can suffer profound changes during the response operation, with moments filled with interactions among stakeholders and other with almost none.

Kapucu & Demiroz (2011) managed to identify these variations in the interaction among stakeholders and their relationships during disaster response operations and after conducting an in-depth study of news reports, government documents, and after-action reports. Observing such changes and stakeholders' behaviors, the

authors opted to separate the disaster into four phases: i) information sharing, ii) resource sharing, iii) evacuation, search, and rescue of victims; and iv) provision of humanitarian aid and services (assistance) to beneficiaries.

The authors observed that the first phase (information sharing) was the one with the most interactions because sudden-onset disasters require immediate responses based on information that is shared amongst network stakeholders both vertically and horizontally. Information sharing involves communication, which is one of the three primary levels of coordination (communication, collaboration, and joint strategic planning), as recognized by the International Federation of Red Cross and Red Crescent Societies (2013).

The availability of resources for each stakeholder on the network is different, and so is the process of sharing them (Haque & Uddin, 2013), reinforcing thus the importance, pointed out by Kapucu & Demiroz (2011), of understanding how stakeholders behave and interact in this phase of the disaster response. Resource sharing, supply, and requests from other stakeholders also must be considered (Kapucu & Demiroz, 2011; Guo & Kapucu, 2015).

Evacuation, search, and rescue of victims are critical processes for a disaster-response operation, since most victims are saved within the first 48 hours after the event strikes (Poteyeva et al., 2007). Therefore, these activities are assessed in this study based on evacuation requests; collaboration to evacuate; and search and rescue of victims (Guo & Kapucu, 2015).

Humanitarian assistance can play a vital role for beneficiaries (Pan American Health Organization, 1999). However, as beneficiaries' demand changes during the disaster response, the roles and activities performed by the different stakeholders also vary, implying thus in changes in interactions among them. The challenge of providing humanitarian aid to beneficiaries was assessed in this study based on requesting humanitarian assistance, shelter, food, and water supply, and providing medical care (Kapucu & Demiroz, 2011; Guo & Kapucu, 2015).

3. Research method and design

This paper proposes the use of Social Network Analysis (SNA) as an assessment tool to identify how Humanitarian Operations Networks (HON) are formed, how they behave, their degrees of connectivity, as well as identifying their critical elements. The consistency of the proposed method is then validated by an application considering the Brazilian scenario for sudden-onset natural disaster-response operations.

Brazil is a country of considerable extension, with a huge variety of geographic features, vegetation, climate, and population density. Due to this diversity, the occurrences and severity of disasters are also diverse. From 2008 to 2014, over 40% of Brazilian municipalities experienced at least one natural disaster, mainly floods or landslides (Brasil, 2015). In 2020, the Americas concentrated 7.7% of the world's natural disasters and Brazil was in 3rd place, after Mexico and the United States (Centre for Research on the Epidemiology of Disasters, 2020). This scenario justifies the choice of our object of analysis. However, it is important to highlight that the proposed method can be adopted in the context of any other country vulnerable to natural disasters.

Data was collected through a survey. Details on the development of the questionnaire are given in subsection 3.1, while section 3.2 presents the universe and research sample. Section 3.3 details how the network analysis was conducted.

3.1. The questionnaire

The questionnaire (Appendix A) was developed and answered via GoogleForms®, aiming to analyze the effectiveness of the humanitarian operations management network, in terms of gaps observed in the relationships between respondents and the cognitive assessment of their collaborative experiences. For that, it was necessary to create a list of indications to be able to identify the links between the stakeholders. Therefore, it was decided to use the research protocol proposed by Zaw & Lim (2017) where they focused on the collaborative experiences, considering the four phases proposed by Kapucu & Demiroz (2011): i) information sharing, ii) resource sharing, iii) evacuation, search and rescue of victims; and iv) provision of humanitarian aid and services (assistance) to beneficiaries.

As a result, the questionnaire was structured into five sections, composed of open and closed questions, dichotomous and non-dichotomous. The first section was composed of filter questions that guarantee that the sample is composed only by respondents who had previous experience in natural disaster-response operations. The next four section were built considering the four steps of the disaster response process proposed by Kapucu & Demiroz (2011) to identify the relationship between actors / stakeholders, especially with a focus on governance and collaboration. The second section aims to identify information sharing. This study addresses stakeholder's

ability to generate and share information with its partners and to strengthen collaboration. Therefore, questions were applied to indicate the node (stakeholder) in the middle and at the end of the process of information sharing, since they are essential for the survival of a network (Flecha, 2010). The third section aims to identify the provision of resources or resource sharing (material, financial assets, and human resources). The fourth section deals with evacuation, search, and rescue of victims. The fifth section deals with the provision of humanitarian aid and services (assistance) to beneficiaries.

3.2. The universe and sample

The snowball technique for sampling was adopted in this research. The process of creating a snowball sample is based on using the social network of the initial individuals to gain access to the collective. According to Malhotra (2011), this process should follow these steps: (1) Set up a membership program where individuals invite other members; (2) Identify groups or organizations that can provide access to some initial individuals who meet the study characteristic; (3) After getting the initial contacts, we need to ask for your participation. This part would be similar to a conventional sampling technique but intended to obtain a reduced sample size; (4) After the first interview, we ask participants to access the other guests; (5) Ensuring the diversity of contacts through the appropriate selection of initial individuals and promoting that the recommendation is not limited to close contacts only.

The population considered in the study was composed by the users registered to access the Integrated Disaster Information System (S2ID) of the Ministry of Regional Development (MDR), since it is the main government agency dedicated to the subject (Brasil, 2021). S2ID is the platform of the National System and Civil Defense with the objective of qualifying and providing transparency to the management of risks and disasters in Brazil.

In 2019, there were 10,000 active S2ID users distributed in 75% of the Brazilian municipalities. They are municipal and/or state agents in charge of protection and civil defense actions (Brasil, 2021).

Considering the population of 10,000 S2ID users, 5% reliability, a 10% error, and 50/50 split, the minimum sample size required 96 valid questionnaires (Malhotra, 2011; Pollfish, 2021). Initially, a pretest survey was conducted with 10 respondents who have had at least experience in one disaster-response operations and that could represent the official position of their organization, in order to check the readability and collected via e-mail. Afterwards, the survey links were sent via more than 2000 email and WhatsApp® messages in July and August 2019. This resulted in a sample of 100 valid respondents.

Calculating the margin of error requires plugging in a few variables into a formula. These include your sample size and the population standard deviation. The latter variable requires a calculation of its own.

The standard deviation is a measure of the spread of scores in a data set that pertains to a specific population. A low standard deviation entails that most of the scores are closer to the average one, while a higher standard deviation shows that the scores are more dispersed. In short, this metric is also used for the purposes of data reliability.

The sample size also was defined by criteria of accessibility, experience, and knowledge about the object of study. The snowball technique keeps returning the answers to the questionnaire within the disaster segment, since the indication is based on the performance in the area.

3.3. Network analysis

Data was tabulated using Excel spreadsheet and then analyzed using UCINET® and Cytoscape software's. UCINET® provides statistics that allow network analysis and Cytoscape was originally designed for biological research, but now it is a general platform for complex network analysis and visualization. The UCINET ® program contains several network analytic routines (e.g., centrality measures, dyadic cohesion measures, positional analysis algorithms, clique), and general statistical and multivariate analysis tools, such as multidimensional scaling, correspondence analysis, factor analysis, cluster analysis, and multiple regression (Borgatti et al., 2007).

Centrality measures are indicators of the amount of collaboration and cooperation, connectivity, and communication that are objectives of creating network structures. Therefore, four types of centrality measures were used in this study: degree, closeness, betweenness, and eigenvector. Each of them analyzes the position and power of network actors from a different perspective (Wasserman & Faust, 1994).

4. Results

This section presents the results obtained through the application of Social Network Analysis (SNA) in the context of the Brazilian scenario for sudden-onset natural disaster-response operations.

It is important to highlight that, in the data collection process, we asked for the respondents to indicate the stakeholders with who they had direct relationships in natural disaster-response operations. The questions were in a system of "who indicates who", creating thus a directed connection. As a result, we identified 523 stakeholders involved in natural disaster-response operations in Brazil.

Due to the large number of actors involved in disasters detected in the field research, we identified the need to group these stakeholders. Therefore, we used the Public-Private-People relationship (3PR) model proposed by Fontainha et al. (2017) for disaster-response operations as a basis to validate the stakeholders in Humanitarian Operations Networks (HON) identified through Social Network Analysis (SNA). In systematic literature review conducted by Fontainha et al. (2017), 41 stakeholder models were identified in 28 papers. The stakeholder nomenclature and definitions considered in these existing stakeholder models were assessed by the authors to identify the main stakeholders of DHO (Government, Military, Legislative and regulatory, Direct supplier, Private sector, Media, International aid network, Donor, Local aid network, and Beneficiary), which were categorized into three groups (public, private and people). Such stakeholders and their relationships were visually represented in the 3PR model.

The 3PR model can be applied to assess the relationships between different stakeholders for a particular event, requiring adaptations according to the specificities of each case (Fontainha et al., 2017). Consequently, networks identified to the Brazilian scenario of sudden-onset natural disaster-response operations may not present all ten stakeholders. Moreover, not every stakeholder may interact with each other. We must reinforce that a network only presents the stakeholders that are connected, since a network only exists if such connections occur. Therefore, we opted not to visually represent on the networks stakeholders who are not connected with each other. First, in the analysis of measures of centrality, only the most connected actors appear and the second is that they would not fit in the figures presented.

Subsections 4.1 to 4.4 present the natural disaster networks for sharing and seeking: (i) information; (ii) resources; (iii) collaboration for evacuation, search and rescue of victims; and (iv) humanitarian aid. For each network, the following centralities are analyzed:

- Betweenness: the betweenness centrality of a node v is given by the expression/Formula 1:

$$g(v) = \sum_{s \neq v \neq t} \frac{\sigma_{st}(v)}{\sigma_{st}}$$

(1)

Where σ_{st} is the total number of shortest paths from node s to node t and $\sigma_{st}(v)$ is the number of those paths that pass-through v.

- Centrality degree: In-degree is the sum of nodes that arrive at a certain node and the out-degree is the sum of nodes that leave a certain node; and

- Closeness: it measures the ability to reach a node within the network. Thus, the closer to 1 is the proximity centrality; the more easily the node is reached (Chelmis & Prasanna, 2011). Closeness is given by the expression/ Formula 2, where d(y,x)} is the distance between vertices x and y.

$$C(x) = \frac{1}{\sum_{y} d(y,x)}$$

(2)

4.1. Information

Figure 1 presents two different networks. Figure 1A shows the relationship among the stakeholders when searching for information in a disaster response, while Figure 1B presents such relationship when stakeholders are sharing or providing information. Besides, such figures highlight the betweenness and closeness of each network.

From Figure 1A, it is possible to identify the stakeholders that have the most intermediary power (betweenness) in Information Searching (A), which are: Local Aid Network (0.1905), Government (0.1786), and International Aid Network (0.0833). There is a great interaction between these stakeholders, contributing to the formation of two large hubs in the network (stakeholders highly connected to several others, which contribute to reduce the distance between groups and individuals of the network, as defined by Wasserman & Faust, 1994). These
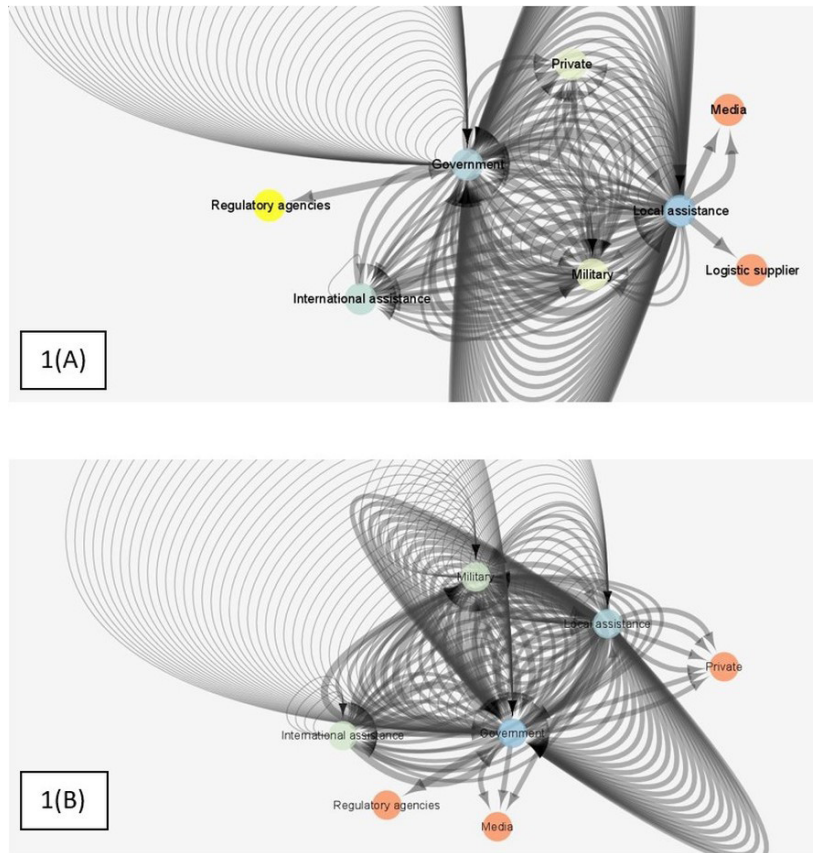
Figure 1. (A) Information Searching and (B) Information Sharing and Provision - Betweenness and closeness. Primary source, 2019. *People (local aid network, donor, international aid network), Public (military, government, legislative and regulatory) and Private sectors (media, enterprises/companies, direct supplier), and the beneficiary. The color of nodes is proportional to their betweenness. It's heat scale, rainbow colors. The closer to red the lower the centrality and it increases towards blue. (blue to red, blue=high, red=low)*

stakeholders have a strong ability to produce and share information. It can also be observed a greater movement of stakeholders that are more easily reachable (closeness). The most central stakeholders are the Local Aid Network (0.875), Government (0.7778), International Aid Network (0.7), Private Sector (0.5385), and Military (0.5). The Regulatory Agency, the Direct Supplier, and the Media presented zero degree of closeness. From assessing the centrality degree, we can also observe that there is a lack of balance between in-degree and out-degree, which means that stakeholders are not active in the information searching network except the Government (in-degree = 112 and out-degree = 70) and the Military (in-degree = 30 and out-degree = 22).

In the network for Information-Sharing and Provision (Figure 1B), it is observed that the stakeholders with greatest closeness centrality are Government (1.0), Local Aid Network (0.875), International Aid Network (0.636), and the Military (0.636). From the Private Sector, the Regulatory Agency and the Media had zero degrees of closeness. The betweenness is highly for the government (0.143) and the Local Aid Network (0.071). The International Aid Network, the Military, Regulatory Agencies, and the Media had zero intermediation. Moreover, the assessment of the centrality degree shows that, in this network, the Government (in-degree = 103 and out-degree = 77) and the Military (in-degree = 39 and out-degree = 24) are also the stakeholders that have the most balance.

4.2. Humanitarian aid

Humanitarian aid is based on four activities: requesting humanitarian assistance, shelter, food, and water supply, and providing medical care (Kapucu & Demiroz, 2011; Guo & Kapucu, 2015).

Figure 2 shows the networks for Searching (A) and Providing (B) Humanitarian Aid. In the Search network (Figure 2A), there is an intense movement for these services and supplies, and the nodes with the highest proximity centrality are the Military (1.0) and the International Aid Network (1.0). The government has a 0.8 degree of closeness, the Local Aid Network a 0.66 degree and the Private Sector did not score, i.e., had any relevance in this action. From assessing the centrality degree, we can verify that this network has only one active hub (the Government) with the desirable balance between in-degree and out-degree (in-degree = 35 and out-degree = 29).

As for the network for Providing Humanitarian Aid (Figure 2B), it is fragile in connections and interactions without the main actor (hub). The guardian nodes of the network (betweenness centrality) are the International Aid Network (0.333) and the government (0.25). On the other hand, the Military, the Direct Suppliers, and the Local Aid Network had zero intermediation degree. This network has few stakeholders, and the nodes with proximity centrality are International Aid Network (1.0), the Government (0.6), and the Military (0.444). Other stakeholders, such as Direct Suppliers and Local Aid Network, in terms of proximity, have a zero degree. Moreover, when assessing the centrality degree, we verified a lack of balance between in-degree and out-degree. It reflects that this network is disaggregated, sparse, and with few connections among stakeholders, which have a non-significant performance.
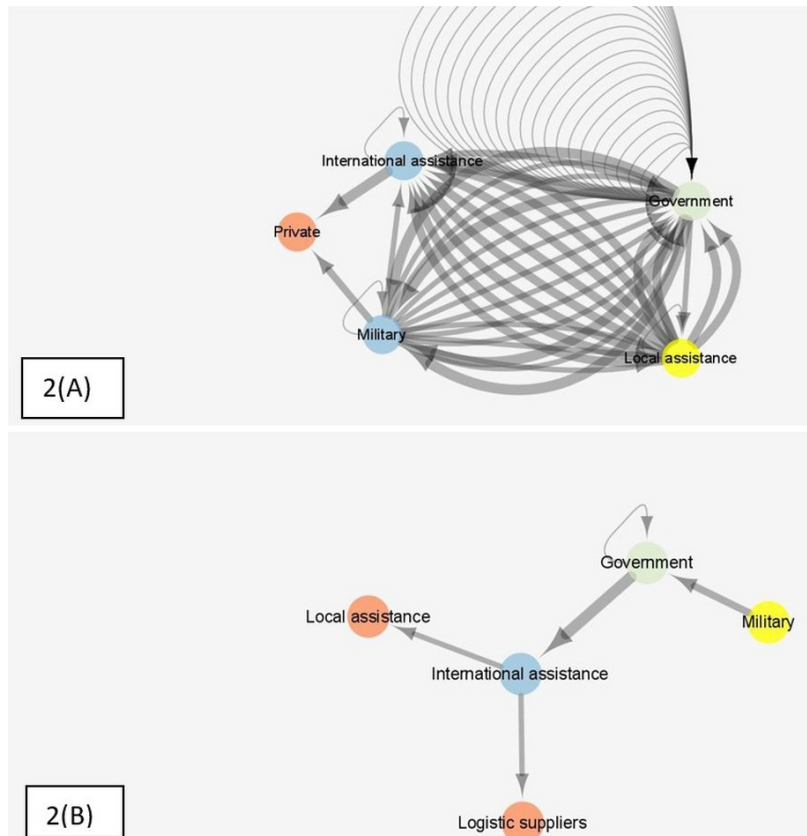

Figure 2. (A) Searching Humanitarian Aid and (B) Providing Humanitarian Aid - Betweenness and closeness. *The color of nodes is proportional to their betweenness. (blue to red, blue=high, red=low). Primary source, 2019.

4.3. Resources

The networks for Searching and Providing Resources (material, financial assets, and human resources) are presented in Figure 3, highlighting their guardian nodes (centrality through intermediation).

Betweenness centrality behaves differently when it comes to resources. In the Resource Searching network (Figure 3A), the most active stakeholders are the Military (0.107), the Government (0.095), and the Local Aid Network (0.083), which stood out in the intermediation of the search for resources. However, stakeholders such
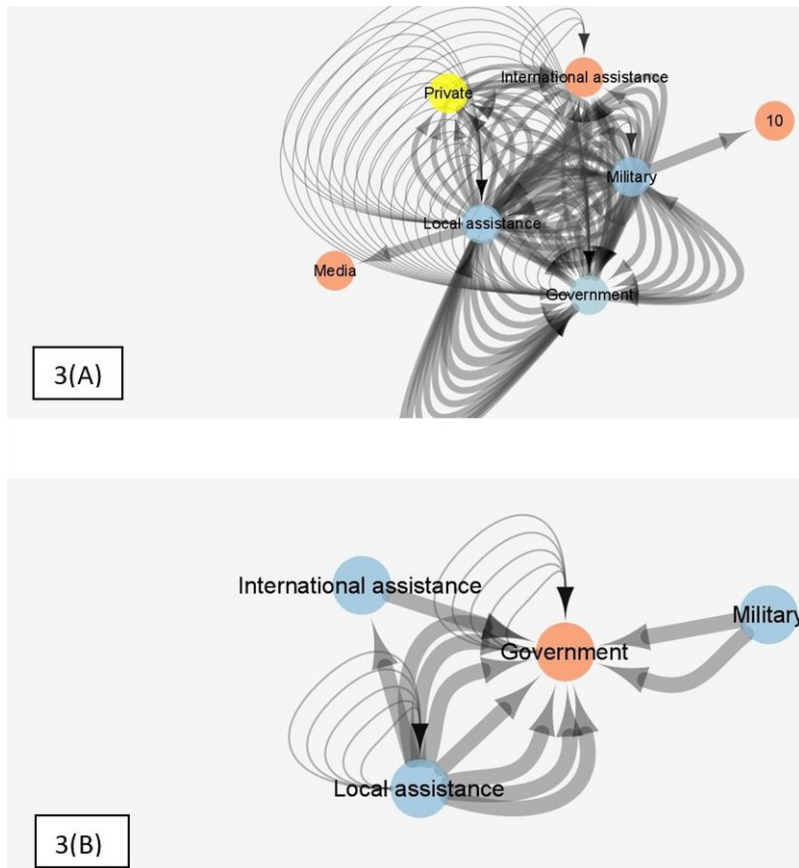
Figure 3. (A) Searching Resources and (B) Providing Resources - Betweenness and closeness. *The color of nodes is proportional to their betweenness. (blue to red, blue=high, red=low). Primary source, 2019.

as the International Aid Network, the Private Sector, the Government, the Beneficiary, and the Media, despite appearing in the network, did not obtain a degree of intermediation. Besides, the stakeholders with the most closeness are the Local Aid Network and the Military (0.777), the Government (0.7), and the Private Sector (0.583), and thus are more easily reached. Moreover, when the analysis of centrality degree showed that, for this network, only the government presented the right balance between in-Degree (58) and out-Degree (33).

On the other hand, the network for Providing Resources (Figure 3B) is reduced, disconnected, and dispersed, with no intermediary stakeholder, even though the Government, the Military, the Local Aid Network, and the International Aid Network do appear in Figure 3. The International Aid Network, the Beneficiary, and the Media, although appearing, had zero proximity. The stakeholders with the highest centrality of proximity are the Military, the Local Aid Network, and the International Aid Network, while the government, despite appearing in this network, had no relevant degree of proximity (0.0). Besides, when assessing the centrality degree, we could verify that no stakeholder stands out in terms of "in-degree" and "out-degree", indicating that the stakeholders that participate in the network, but they are not necessarily connected to the others. Furthermore, for the first time in this research, the stakeholder Beneficiary was cited by respondents and appeared in a network.

4.4. Evacuation, search and rescue of victims

Figure 4 shows the networks related to Searching (A) and Providing (B) Collaboration in the Evacuation, Search, and Rescue of Victims, highlighting the guardian nodes of the network (centrality through intermediation).

It can be observed that the stakeholders that stood out in terms of betweenness centrality in the network for Searching for Collaboration in Evacuation, Search, and Rescue of Victims (Figure 4A) were: Local Aid Network (0.233), Government (0.191), Military (0.066), Private Sector (0.041) and the International Aid Network (0.016).
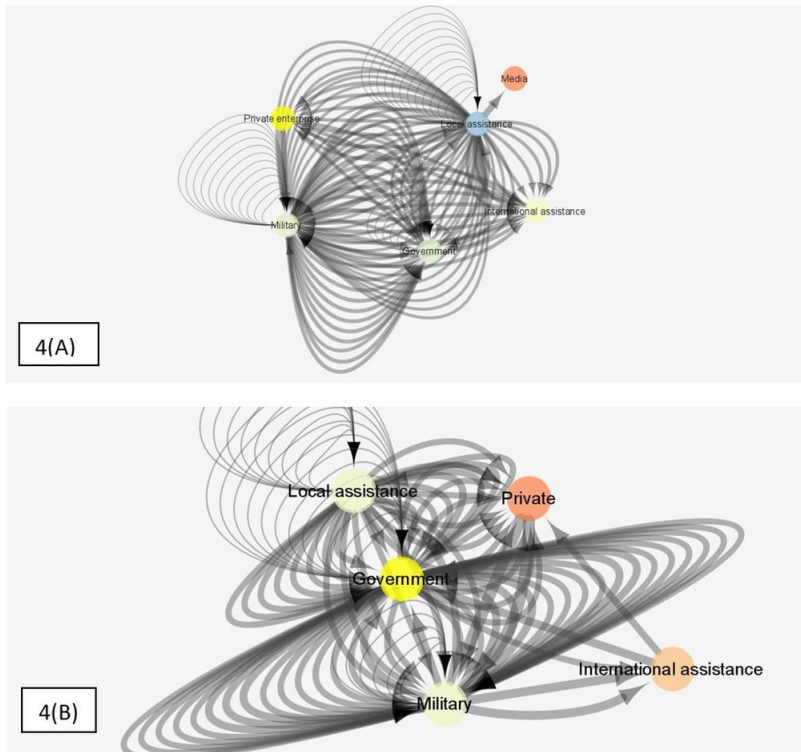
Figure 4. (A) Searching and (B) Providing Collaboration in Evacuation, Search and Rescue of Victims – Betweenness and Closeness. *The color of nodes is proportional to their betweenness. (blue to red, blue=high, red=low). Primary source, 2019.

The Media, despite appearing in the network did not have a relevant factor of intermediation. Concerning Closeness centrality, the Local Aid Network (1.0), the government (0.714), the Military (0.714), the Private Sector (0.625), and the International Aid Network (0.555) are the most easily reachable stakeholders. The media had no significant performance (0.0). Besides, centrality degree assessment shows that the government is the only stakeholder that has balance between In-Degree (44) and Out-Degree (43).

The network for providing evacuation, search, and rescue of victims has two major hubs (Figure 4B), with the Military (0.291) and the Government (0.194) as the most collaborative stakeholders. The Military stands out due to its performance in this type of event, with experience in more than 50 United Nations (UN) peacekeeping actions (Ministério das Relações Exteriores, 2019). The government (represented by the Civil Defense) stands out in the network with many connections incoming and few leaving this node due to its role of acting with a set of preventive, relief and reconstructive actions aimed at avoiding or minimizing natural disasters and technological incidents, preserving population morale, and restoring social normality (Brasil, 2012). Regarding the betweenness centrality, the Private Sector (0.041), the Local Aid Network (0.027), and the International Aid Network (0.027) appear as the least active stakeholders. The stakeholders that are most easy to reach (highest closeness) are the Government (1.0), the Local Aid Network (0.8), and the Military (0.8). The International Aid Network (0.666) and the Private Sector (0.571) are further apart in terms of reach. Moreover, from the assessment of the centrality degree, we could verify that there is a lack of balance between in-degree and out-degree, indicating that the stakeholders of this network are not active except for the government (In-Degree of 38 and Out-Degree of 43).

5. Discussion

Respondents indicated that information-sharing (81%) and information-searching (68%) are the most important activities performed in disaster-response operations, corroborating the importance of this step and the fact that information is what feeds the network (Flecha, 2010).

The degree centrality for the Search for Information and Provide and Share information networks shows a lack of balance between in-degree and out-degree. The Search for Information (Government, In-Degree =

112; Military, In-Degree = 30) (Government, Out-Degree = 97; Out-Degree = Military, 70) and Provide and Share information (Government, In-Degree = 103; Military, In-Degree = 39) (Government, Out-Degree = 77; Military, Out-Degree = 24), which means that actors are not active in the information search network except the government and the military. In the Provide and Share information network, the two actors that have the most balance are also the same as the Search for Information Network i.e. Government and the Military.

It is important to highlight the role of the Government (Civil Defense and National Center for Monitoring and Alerts of Natural Disasters - CEMADEN), the Military and the Local Aid Network (Red Cross and United Firefighters Without Borders - BUSF) in the dissemination of information in this type of event in Brazil.

The degree centrality for the network for Search for Humanitarian Aid, the government is the main actor (In-degree = 35; Out Degree = 29) and the network for Provide and Share Humanitarian Aid none of the actors proved to be relevant.

Providing and sharing resources (human and material resources) was mentioned by 60% of respondents and featured a smaller network, with few stakeholders with low interaction with each other. On the other hand, searching for resources (material and financial assets) is intense by the Local Aid Network (Red Cross), the Military (Military Fire Brigade), and the Government (Civil Defense). Only the government presented the right balance between in-Degree (58) and out-Degree (33). On the other hand, in the network for Provide Resources, no stakeholder stands out in terms of "in-degree" and "out-degree", indicating that the stakeholders that participate in the network, but they are not necessarily connected to the others. For the first time in this research, the stakeholder Beneficiary was cited by respondents and appeared in a network.

When comparing the resulting networks in terms of the stakeholder groups from the 3PR model, we can identify that, in the Public group, the Military is the stakeholder with the strongest presence and performance. They are responsible for keeping the safety, but they can also perform activities such as transportation and logistics, construction and repair, command/control/communication, and medical care in such operations when required by the government (Pettit & Beresford, 2005). The military generally have rapid mobilization and logistics capabilities associated with coordinating the flow of large quantities of supplies and personnel (Balcik et al., 2010). Military missions in humanitarian operations usually cover five types of activities: providing humanitarian assistance, protecting humanitarian assistance, assisting refugees and displaced persons, complying with a peace agreement, and restoring order (Byman et al., 2000).

Also, in the Public group, the government, whether local, regional, or national, is the stakeholder with highest responsibility regarding the provision of humanitarian aid in disaster-response operations, as it can provide most of the necessary resources or it also requests/allows aid from other international organizations and even other governments (Fritz Institute, 2012). This stakeholder has the political capacity to coordinate diverse actors, inducing them to collaborate. Besides, it is responsible for asset governance in such operations (Buergelt & Paton, 2014; Lei et al., 2015). The Regulatory Agencies were mentioned by the respondents (National Water Agency - ANA and the Brazilian Cooperation Agency - ABC), but no relevance was shown in the resulting networks. This may be due to the fact that in Brazil these agencies have the objective of overseeing, regulating, and inspecting the provision of public services practiced by the private sector, in addition to controlling the quality of the service provided (Brasil, 2019).

Regarding the Private Sector, results show that, despite of the importance of Logistics Operators and Direct Suppliers for improving the speed and efficiency of humanitarian supply chains (Cozzolino, 2012), these stakeholders had little involvement in disaster-response operations in Brazil. Nonetheless, media did play an important role as it contributes for raising funds and donations, besides communicating relevant information (Fritz Institute, 2012).

In the People group, results show that stakeholders from the International Aid Network (international human rights and aid organizations) play a major role in disaster-response operations in Brazil. Due to their geographical reach, such institutions can articulate with other decision-makers. In this research, there was a strong involvement from international and national NGOs, the United Nations, Red Cross/ Red Crescent, as well as other smaller NGOs. Nonetheless, there is low involvement from private donors and Local Aid Networks (universities, local NGOs, community organizations), despite of their importance in disaster-response operations.

Intense interaction amongst stakeholders can be observed, especially in networks regarding information-sharing; those offering and seeking collaboration in the evacuation, search, and rescue of victims; those requesting resources and humanitarian aid. Nonetheless, in the networks for providing humanitarian aid; sharing resources; and information-seeking, there is a lack of connection, and weak interaction amongst stakeholders.

It was also observed the existence of hubs in the resulting networks. These stakeholders may not be formal leaders, but they do have the knowledge required to get the job done. It is important though avoiding a high dependence on such stakeholders by concentrating and controlling the flow of information (Cross & Prusak,

2002). The main hubs are the Government (Civil Defense) and the Local Aid Network (Red Cross) for information-sharing; Local Aid Network (Red Cross) and the Military as hubs for providing collaboration for evacuation, search, and rescue of victims. The network for resources' provision was fragile and disconnected without any highlight.

The centrality degree of the network for Search for Collaboration in the Evacuation, Search and Rescue of Victims indicates only the government with a balance between In-Degree (44) and Out-Degree (43). On the other hand, the network for Provide Collaboration in the Evacuation, Search for Missing Persons and Rescue of the Victims, presents a lack of balance between in-degree and out-degree, indicating that the stakeholders of this network are not active except for the government between In-Degree (38) and Out-Degree (46).

Moreover, in the resulting networks, the stakeholder with greater proximity never appears with a high degree of connectivity or intermediation. This may indicate that proximity is not a relevant factor for the proper functioning of such networks. Besides, there is a strong correlation between the centrality of intermediation and degree. In almost all networks, stakeholders who mediate the most are the most connected. High density and centrality imply greater interdependence between network nodes and their relationships. This can easily be verified in weak networks such as humanitarian aid and services, in which connectivity is low, resulting in low intermediation as well. Another noteworthy point is that the unbalance of centrality degree (in Degree x out Degree) has little effect on this correlation. Even highly unbalanced stakeholders with high total connectivity produce good intermediation. Therefore, it is inferred that the value of degree centrality in Degree or out Degree is more important in this type of network than the balance between them.

6. Conclusion (Additional data available at Mendeley.com Repository)

This paper proposes the use of Social Network Analysis (SNA) as an assessment tool to answer the following research questions: (i) Who are the stakeholders in Humanitarian Operations Networks (HON)?; (ii) Which stakeholders exert influence on Humanitarian Operations Networks (HON)?; and (iii) How do Humanitarian Operations Networks (HON)s form? Thus, we apply Social Network Analysis (SNA) in the Brazilian context of sudden-onset natural disaster-response operations to assess the consistency of the method in this type of assessment.

Fontainha et al. (2017) have previously mapped, through a systematic literature review, the stakeholders in disaster-response operations, categorizing them into three groups, proposing the 3PR model. We validated through Social Network Analysis (SNA) the 3PR model of stakeholder relationship of the Public, Private, and People sectors in disaster-response operations, identifying who are the actors in Humanitarian Operations Networks (HON) in Brazil (research question #1). The three groups proposed by Fontainha et al. (2017) were identified in most of the networks that resulted from this study. Results show strong participation of the public sector (65%) in disaster-response operations in Brazil. This may indicate the need for greater engagement from civil society in this type of operation in the country. It can also be a consequence of a culture of state dependence by civil society on this type of operation in Brazil.

The use of Social Network Analysis (SNA) as an assessment tool to identify Humanitarian Operations Networks (HON) stakeholders proved to be effective as it was possible to determine the existing networks in disaster-response operations in Brazil. Besides, assessing centrality measures for these networks allowed us to understand which are the stakeholders that exert influence on Humanitarian Operations Networks (HON) (research question #2). Betweenness centrality, reveals if a stakeholder provides communication linkage between two other actors on that wise that its nonexistence might cause a serious communication breakdown for those two actors or subgroups. It shows which stakeholders influence the flow of the network, and thus a high betweenness count could indicate that this stakeholder holds authority over disparate clusters in a network. Stakeholders with high betweenness centrality in a network serve as a "bridge" between different groups and are called guardian nodes. We adopted the thickness of the links between nodes as a representation of the degree of intermediation, that is, thicker arches have a higher centrality of intermediation than those that are thinner. Thus, it is possible to visually identify the nodes that support the strongest links in the network. The Government, the Military, and Local Aid Network were identified as the stakeholders that most exert influence on Humanitarian Operations Networks (HON) in Brazilian sudden-onset natural disaster-response operations.

Degree and closeness centralities are measures that can be assessed in order to help us understand how do Humanitarian Operations Networks (HON)s form and behave (research question #3). Closeness centrality is useful for analyzing the flow of communication, on the premise that the shorter the paths between an actor and other actors, the quicker the communication will be. Degree centrality shows the most connected/popular actors who can quickly connect with a wider network. It indicates the active stakeholders in the network by analyzing the

balance between the in-degree and out-degree indicators. The government was the most connected stakeholder for every network. The military also played an important role for information-sharing.

Meanwhile, closeness centrality is an indicator based on the sum of the shortest paths between the stakeholder and every other node. Therefore, it not only indicates how a network was formed but it can also be used to identify stakeholders that are best placed to influence the entire network most quickly. Results indicate a high correlation between closeness and other centrality measures for HONs in disaster-response operations in Brazil, indicating that proximity is not a relevant factor for the proper functioning of such networks. Moreover, the information-sharing network showed greater interaction amongst stakeholders, corroborating the statement that information is crucial for sustaining a network.

It is also important to highlight that the 3PR model is theoretical, while Social Network Analysis (SNA) models are empirical. SNA does not intend to segment stakeholders, but it focuses on identifying them and their connections, complementing thus the study of Fontainha et al. (2017). SNA models for disaster-response operations in Brazil present random and open relationships, with actions focused mainly on the Government and the Military. It would be more effective if other stakeholders also played more relevant roles in the network, so further research is suggested to focus on how to improve this network, how to increase the intermediation of other stakeholders, and on how to strengthen the weak networks such as humanitarian aids and resources.

Conceptually both the 3PR model and the SNA focus on the beneficiary's needs. The 3PR model represents this feature through the beneficiary's relationship with every actor. However, with the adoption of SNA, the beneficiary did not stand out as a network node, since it is a relationship network that aims to offer relief for the beneficiary. The 3PR model seems to adapt to the multifocal network model, in which every stakeholder is interconnected with each other, considering the beneficiary as the central stakeholder. Meanwhile, SNA networks seem to fit better the fuzzy model, in which stakeholders relate with each other without a formal structure.

The main limitation of this research is that the networks presented were identified for the Brazilian scenario. Nonetheless, the proposed method can be adopted in the context of any other country, helping to identify the stakeholders of HON, on understanding the formation of these networks and on identifying which are the determining factors in this process. Besides, data found in this research, like the extensive information search network, can be used to assist in the planning stages of disaster management, showing how important these steps are.

This study contributes to the disaster management literature, and the results show strong participation of the public sector in disaster-response operations in Brazil, especially from the Government, the Military, and Local Aid Networks, indicating the need for greater engagement from civil society. Therefore, public policies and advertising campaigns should be developed in order to stimulate the increase in the participation of the civil society and from private organizations and NGOs. The development of conjoint exercises is also a helpful tool to contribute to the engagement from all different stakeholders. Besides, the proposed method can be adopted in the context of any other country.

Acknowledgements

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Appendix A. Questionnaire.

Survey items used to identify collaborative relationships.

Source: Adapted from Zaw & Lim (2017).

1 – Filter questions

1)   **Where do you live? (City, state, and country)**

2)   **Have you ever been involved in any disaster in your life (floods, landslides, drought, refugees, or any other humanitarian action)?**

2 – Information Sharing

When a disaster occurs, your organization/institution:

3)   **Produce and share information to respond?** 1 ( ) yes 2 ( ) no

3a)   If yes, list at least 3 organizations/institutions?

3b)   who has indicated these institutions/organizations?

4)   **Search for information to respond?** 1 ( ) yes 2 ( ) no

4a)   If yes, list at least 3 organizations/institutions?

4b)   who has indicated these institutions/organizations?

3 – Provide and Share Resources (material, financial assets and/or human resources)

When a disaster occurs, your organization/institution:

5)   Produce and share Resources? 1 ( ) Yes 2 ( ) No

5a)   What kind of resource your organization/institution produce or share?

1 ( ) material resources 2 ( ) financial assets

3( ) human resources 4 ( ) another kind of assets (please, list):

5b)   If yes, list at least 3 organizations/institutions?

5c)   who has indicated these institutions/organizations?

6)   Search for resources? 1 ( ) yes 2 ( ) no

6a)   What kind of resources your organization/institution search for?

1 ( ) material resources 2 ( ) financial assets

3 ( ) human resources 4 ( ) another kind of assets (please, list):

6b)   List at least 3 organizations/institutions?

6c)   who has indicated these institutions/organizations?

4 - Evacuation, Search and Rescue of Victims

When a disaster occurs, your organization/institution:

7)   Requests collaboration in the Evacuation of victims, search for missing persons and rescue of victims? 1 ( ) Yes 2 ( ) No

7a)   What kind of collaboration is required for:

1 ( ) Evacuation of victims 2 ( ) Search for missing persons

3 ( ) rescue of victims 4 ( ) Other resources (please, list):

7b)   List at least 3 organizations/institutions?

7c)   who has indicated these institutions/organizations?

8) **Provide evacuation, search and rescue of victims? 1 ( ) Yes 2 ( ) No**

8a)   What kind of collaboration does your organization/institution offer?

1 ( ) Evacuation of victims 2 ( ) Search for missing persons

3 ( ) rescue of victims 4 ( ) Other resources (please, list):

8b)   List at least 3 organizations/institutions?

8c)   who has indicated these institutions/organizations?

5 – Humanitarian services and/or supplies to victims

When a disaster occurs, your organization/institution:

9)   Request humanitarian services to victims? 1 ( ) Yes 2 ( ) No

9a)   If yes, list, below what kind of humanitarian services does your organization/institution request?

1 ( ) victims' shelter2 ( ) medical services

3 ( ) other kind of humanitarian services (describe)

9b)   Do you request directly or through another institution/organization?

1 ( ) directly 2 ( ) through another institution/organization

9c)   List at least 3 organizations/institutions?

9d)   Who has indicated these institutions/organizations?

10)   Provide humanitarian supplies to victims? 1 ( ) Yes 2 ( ) No

10a) What kind of humanitarian supplies do your organization/institution provide?

1 ( ) Food 2 ( ) Water 3 ( ) medicines 4 ( ) another kind of supplies

10b) If yes, provide directly to victims or through another institution/organization?

1 ( ) directly 2 ( ) through another institution/organization

10c) List at least 3 organizations/institutions?

10d) Who has indicated these institutions/organizations?