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Using Social Network Analysis to Assess Humanitarian Operations Networks in Disaster-Response Contexts

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ABSTRACT

The purpose of this research is to examine how Humanitarian Operations Networks (HON) can be evaluated in disaster response settings using Social Network Analysis (SNA). Finding out what factors significantly impact operational performance, as well as learning about the structure and operation of these networks and the degree of connectedness among players, is the main goal. The research looks at how the Indian government handles natural disasters that strike suddenly, drawing on information gathered from a poll of people who have signed up for S2ID run by MDR. Utilizing the social networks of the initial participants, a snowball sampling strategy was implemented to ensure diversified representation beyond close relationships and reach a larger audience. Using this approach, we can pinpoint the most important players, the most important channels of communication, and any obstacles that can delay or prevent the efficient use of resources. The results show that improving disaster response efficiency is possible through better network connectivity, information flow, and inter-organizational cooperation. Better decision-making, transparency, and resilience in humanitarian operations are made possible by the valuable insights into the structure and dynamics of HON provided by SNA, as demonstrated in the study. In order to enhance cooperation, improve operational performance, and increase disaster preparedness frameworks, the results provide practical suggestions for humanitarian groups, lawmakers, and disaster managers.

Keywords: *Social Network Analysis, Humanitarian Operations, Disaster Response, Resource Allocation, Network Centrality.*

I. INTRODUCTION

There are many different parties involved in humanitarian activities in disaster response, including local authorities, foreign relief organizations, NGOs, and government agencies. Minimizing the impacts of disasters on impacted populations requires effective coordination and rapid decision-making. Problems with effective communication, distribution of resources, and coordination among various parties continue to plague disaster planning and response efforts, despite rising funding for these areas. Relational structures regulate interactions and impact performance outcomes;

nevertheless, traditional assessment methodologies frequently ignore these factors in favor of focusing on individual organizations or linear operational procedures. An effective methodological framework for mapping, analyzing, and understanding the patterns of relationships among participants in humanitarian operations networks arises in this setting as Social Network Analysis (SNA). Communication styles, information exchange, and collaborative ties can all be better understood via the prism of SNA, which provides a fresh perspective on both official and informal connections.

Research and practitioners can use SNA to identify key players, essential hubs, and potential bottlenecks in disaster response by portraying humanitarian actors as nodes and their interactions as edges. To illustrate the point, actors with poor connections may not receive important operational updates, whereas nodes with high connections may operate as important information brokers. Stakeholders can optimally deploy resources, boost collaboration, and discover capacity-building opportunities by understanding these network arrangements. When it comes to operational efficiency and resilience in times of crisis, SNA is a game-changer since it allows for the evaluation of interorganizational trust, collaboration, and interdependence. Recent large-scale disasters like pandemics, earthquakes, and hurricanes have highlighted the significance of network-centric viewpoints in humanitarian operations, as these crises demand swift resource mobilization and collaboration between various agencies. Duplicated efforts, delayed help delivery, and inadequate resource utilization are common outcomes of poorly connected or fragmented networks, according to case studies. On the other hand, operational effectiveness and response times are better in well-structured networks that have balanced centralization, strong connectivity, and redundant information.

We may objectively evaluate the performance of your network and identify strategic solutions with the use of quantitative indicators provided by SNA, such as degree centrality, betweenness centrality, closeness centrality, and network density. In addition, operational planning and situational awareness are both improved by integrating SNA with GIS and simulation models, among other analytical tools. To better understand where help is needed and where there are holes in logistics or communication, it can be helpful to superimpose network topologies with geographical data on impacted areas. By modeling the network's reaction to different catastrophe scenarios, resource limitations, or actor failures, SNA can also bolster scenario-based planning. These findings have the potential to shape collaborative frameworks, standard operating procedures, and policies that enhance the ability to respond to humanitarian crises.

An increasing number of academics have begun to see networks as a key factor in organizational and inter-organizational performance, which has led to a surge of interest in using SNA for disaster management in the last decade. Interagency cooperation, relief supply chains, and emergency

medical services networks have all been the subject of research. Nevertheless, there are still unanswered questions regarding how these networks change dynamically when stressed, how informal connections play a part, and how network structure affects operational results. In order to increase efficiency, decrease reaction times, and improve overall humanitarian impact, it is crucial to address these gaps and develop methods based on research. In conclusion, humanitarian operations networks in disaster-response contexts can be robustly and insightfully evaluated using Social Network Analysis. Supporting strategic decision-making, SNA finds patterns that impact operational effectiveness, identifies key players and potential vulnerabilities, and focuses on relationships rather than isolated organizational traits. Research on humanitarian operations that incorporates network perspectives shows potential for better coordination, more efficient use of resources, and increased resilience to complicated and frequent crises.

II. LITERATURE REVIEW

Ponce-López, Víctor & Spataru, Catalina. (2022) in this study, we offer a methodology for analyzing social media data using a variety of datasets. The approach relies on machine learning classifiers, more especially filtering binary classifiers that have been trained on datasets that record responses to earthquakes, floods, and catastrophic floods as benchmarks. Utilizing deep bidirectional neural networks, these classifiers are constructed. Datasets collected in reaction to disasters are used to train classifiers using deep bidirectional Transformer neural networks and techniques for fine-tuning using discrete handcrafted features. In order to guide the development of the multiclass classification strategy, we utilize one of the benchmark datasets that contains the most categories important to catastrophes to assess the present state of the art. Multiclass classification methods developed in this study employing support vector machines attain a precision of 0.83 and 0.79, correspondingly, compared to Bernoulli naïve Bayes (0.59), multinomial naïve Bayes (0.79), and 0.91. Binary classification algorithms in the MDRM dataset employing deep learning techniques (DistilBERT) beat BoW and TF-IDF. As an alternative, the deep learning approach used by the UnifiedCEHMET dataset achieves a precision of 0.92 for severity, which is higher than BoW's 0.70 and TF-IDF's 0.68.
Cachia, Romina & Holgado, Daniel. (2020) This essay delves into the potential applications of network analysis in humanitarian protection. Our goal is to compile existing knowledge on the function of humanitarian aid networks and to analyze their potential for use in emergency response through interventions that might promote and enhance various facets of humanitarian protection. With this body of knowledge in hand, we set out to provide academics and practitioners with a systematic framework for humanitarian protection using network analysis and visualisations in two primary domains:(1) safeguarding individuals and (2) facilitating protection at the community level. Given social network analysis's adaptability, we think it would be a good area to study for humanitarian protection.

Muniz-Rodriguez et al., (2020) Researchers in the fields of geography and computer science have proposed using social media data collected during natural disasters to direct rescue and response operations. In this comprehensive review, we look at the ways social media can help with two things :(1) getting the word out about emergency warnings and responses during and after a natural disaster, and (2) finding out what people need in terms of physical, medical, functional, and emotional support in the aftermath of a disaster. By searching three databases, we were able to compile a list of forty-four research articles. Researchers used a broad variety of spatiotemporal scales while analyzing social media data. There is a chance for public health organizations to disseminate emergency alerts through social media platforms, which are known as broadcasting tools. By encouraging users to self-report their whereabouts, social media helped pinpoint where medical aid or relief efforts were most needed, with maps serving as a popular visual representation of this data. Social media analysis demonstrated potential in retrospective analytics as a means to pinpoint persons' locations and shorten reaction times. We need more studies on how to control rumors and misinformation on social media.

Tacheva, Zhasmina & Simpson, Natalie. (2019) through a review of the literature and examples of its application in humanitarian operations analysis, this study aims to raise awareness of SNA among researchers in the field of humanitarian studies. A suggested agenda for interested researchers is motivated by a thorough study of the relevant literature. Using secondary data, we analyze two Afghan humanitarian networks to show how SNA is used and how useful it is. The second case study shows how to use Monte Carlo simulation to generate benchmark null sets for detecting network motifs using random graphs. When it comes to studying humanitarian organizations and community structures, SNA is a versatile and helpful tool for assessing patterns of collaboration. Within humanitarian clusters, there are network motifs that indicate a clear affinity between certain agencies. Using SNA in humanitarian research might be difficult; however, the authors outline the most typical problems and offer solutions. Implications for reality Researchers and practitioners alike can benefit from SNA's ability to map networks, pinpoint problem areas, and improve observational communication. By lowering the barrier to entry for SNA, we hope to contribute to a better understanding of efficient humanitarian relief systems by capturing intricate, ever-changing linkages. This is the first study to thoroughly examine SNA's use in empirical humanitarian research, and it puts out a particular research plan based on SNA. Additionally, humanitarian studies do not yet use random graphs to assess observed SNA indicators.

Kim, Jooho & Hastak, Makarand. (2018) the dissemination of emergency information to a community impacted by a disaster is a crucial function of social media platforms like Facebook and Twitter in disaster management. In the event of an emergency, it is the fourth most often used source. There have been a lot of investigations into social media data in an effort to decipher the networks and glean important information for disaster preparedness and response. After Hurricane Sandy in

2012, the worst U.S. disaster was the 2016 flood in Louisiana, which damaged over 60,000 dwellings. Members of the disaster-stricken community in Louisiana were able to access important information through social media platforms, such as maps showing where emergency shelters were located, details on medical services, and updates on the debris removal operation. Using social network analysis, this research deduces useful information from social media data collected during emergencies. During crisis responses, we investigate patterns that emerge from the aggregated Facebook interactions of internet users. It highlights the value of social media for disseminating news during times of crisis. The study found that organizations, individuals, and emergency agencies make up the three primary parts of social networks. Simply said, a social network is a group of individuals coming together. They consistently engage in information sharing, communication with the city of Baton Rouge, and upgrading of information. Connecting one community to another, emergency services and organizations sit on the social network's periphery. In order to better prepare for disasters, emergency agencies might use this study's findings to inform their social media operating tactics.

Mohammadfam, Ira et al., (2015) in this study, we will take a look at how well an emergency response team (ERT) is prepared in a refinery. Relationships based on trust and collaboration was used to study preparedness. As a quantitative method, this study made use of social network analysis. Overall, this was accomplished by making use of the SNA indicators of density, degree, reciprocity, and transitivity. Each of these metrics was computed at three different team levels: first-line, supportive, and overall. In order to get the necessary data, we used UCINET 6.0, a social network analysis application, and conducted structured interviews. This study's findings suggest that first-line teams can be highly effective in ERT, which is associated with improved SNA indicators and, as a result, easier team member readiness. Furthermore, the results showed that the supporting teams were not very cohesive. One major obstacle to ERT performance was the lack of cohesiveness in the overall network outcomes across all teams. Statistical analysis shows that trust and coordination networks are highly correlated (82%). The discovery of SNA presents a significant chance for planners and managers to identify readiness issues centered on the trust and cooperation among emergency management response teams. The results show that improvement of the current situation and optimization of reaction team readiness can only be achieved via fundamental efforts and evaluation of the program's success.

III. RESEARCH METHOD AND DESIGN

Research Approach

This study suggests that Social Network Analysis (SNA) be used as a technique for evaluation in order to determine the formation, behavior, degree of connectedness, and important characteristics of Humanitarian Operations Networks (HON). An application that considers the situation in India for

actions related to responding to sudden-onset natural disasters then verifies the strategy's compatibility. Information was gathered by means of a survey.

The Universe and Sample

This investigation utilized the snowball sampling technique. Building a snowball sample relies on tapping into the initial participants' social networks to access the collective. Here is the recommended procedure: (1) Create a membership program where participants can invite others to join; (2) Find organizations or groups that can supply a sample of people who fit the study's description. (3) We must request your involvement after obtaining the initial contacts. This part would be like a traditional sampling method, but with the goal of getting a smaller sample; (4) After the first interview, we encourage participants to reach out to the other guests; (5) Making sure there's diversity in contacts by picking the right people at the beginning and encouraging that recommendations aren't limited to close friends and family only Researchers used the Ministry of Regional Development's (MDR) Integrated Disaster Information System (S2ID) users as their demographic of interest since it is the primary government agency devoted to the topic. For India's risk and catastrophe management to be qualified and transparent, the National System and Civil Defense have created the platform known as S2ID.

Data Collection Tool

A combination of open-ended and closed questions, as well as non-dichotomous and dichotomous options, was present in each of the five sections of the survey. To ensure that we were gathering data from individuals with relevant experience in disaster response, we asked filter questions in the first portion of the survey. The four steps of a catastrophe response provided the basis for the subsequent four sections, in order to determine the interdependencies among the many parties involved, with an emphasis on cooperation and leadership. Finding out who shares what data is the goal of the second part. The capacity of stakeholders to create and disseminate information to their partners, as well as to fortify their cooperation, is the focus of this research. So, during the outset, midpoint, and final stages of information transmission, queries were utilized to identify the node (stakeholder), guaranteeing the network's longevity. Thirdly, we'll talk about resources—material, financial, and human, which seeks to establish resource provision or sharing. Rescue operations, including victim evacuation and search, are covered in Section 4. Humanitarian aid and assistance provision to recipients is addressed in Section 5.

Network Analysis

We used Excel to tabulate the data, and then we ran the numbers via UCINET® and Cytoscape for analysis. Statistical tools for network research are available through UCINET®, and Cytoscape provides a global platform for advanced network analysis and visualization. When first created,

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Cytoscape served the needs of the biological research community. Among the many networks analytic routines included in the UCINET® program are algorithms for positional analysis, clique, and dyadic cohesion, clustering, and multiple regressions.

IV. RESULTS AND DISCUSSION

Results from SNA applied to the Indian scenario for operations responding to sudden-onset natural disasters are presented in this section.

In particular, as part of our data collection process, we asked respondents to identify the stakeholders with whom they had direct communication throughout disaster response operations. There was a directed relationship because the questions were structured in a "who indicates who" format. We were able to narrow the field down to 304 key players in India's disaster response activities.

We discovered the necessity to categorize these stakeholders due to the vast number of actors participating in catastrophes that were detected in the field investigation. HON stakeholders were identified by SNA. To validate these stakeholders, we used the 3PR model that has been developed for disaster-response operations. To evaluate the interdependencies of various event stakeholders, one can use the 3PR model, with certain tweaks made for each unique situation. As a result, not all 10 stakeholders may be represented in networks that are associated with the Indian situation of responding to sudden-onset natural disasters. On top of that, not all stakeholders will engage in conversation with one another. Because a network cannot exist apart from the existence of connected stakeholders, it is essential that we stress that a network can only display such stakeholders. Consequently, we decided against using visual representations of stakeholders on the networks that are not related to one another. For starters, they wouldn't fit in the given statistics, and secondly, only the most linked actors are considered in the analysis of centrality metrics.

Participants include members of the public (military, government, legislative and regulatory bodies), members of the private (media, enterprises/companies, direct supplier), and members of the local and international aid networks, as well as the recipient. The degree to which nodes are between other nodes determines their hue. Colors of the rainbow, heat scale. As one draws nearer to the text, the centrality decreases and the color blue grows. Stakeholders have a strong capacity to generate and disseminate information (blue to red, where blue is high and red indicates poor). A larger number of stakeholders who are more approachable are also moving closer. Local Aid Network (0.875), Government (0.7778), International Aid Network (0.7), Private Sector (0.5385), and Military (0.5) are the most important stakeholders. There was absolutely no intimacy between the agency in charge of regulation, the direct supplier, and the media. In addition, the imbalance between in-degree and out-degree is evident from the centrality degree assessment; this indicates that no stakeholders, with the exception of the government, are actively participating in the information searching network.

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Among the stakeholders in the Information-Sharing and Provision network (Figure 2), the government, the local aid network, the international aid network, and the military are the most closely related (1.0, 0.875, 0.636, and 0.636, respectively). The media, the regulatory agency, and the private sector were all completely distant from one another. The Local Aid Network has a betweenness of 0.071 and the government has a betweenness of 0.143. The media, regulatory bodies, the military, and the international aid network all played no middleman role.

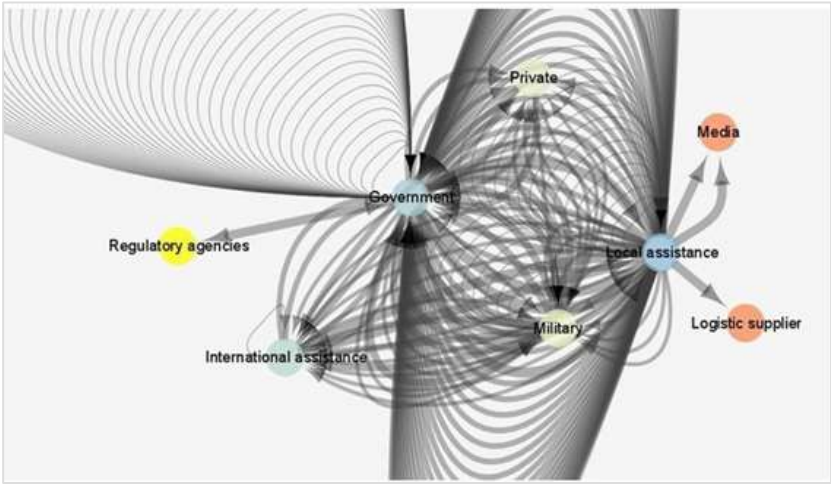

Figure 1: Information Searching Betweenness and Closeness

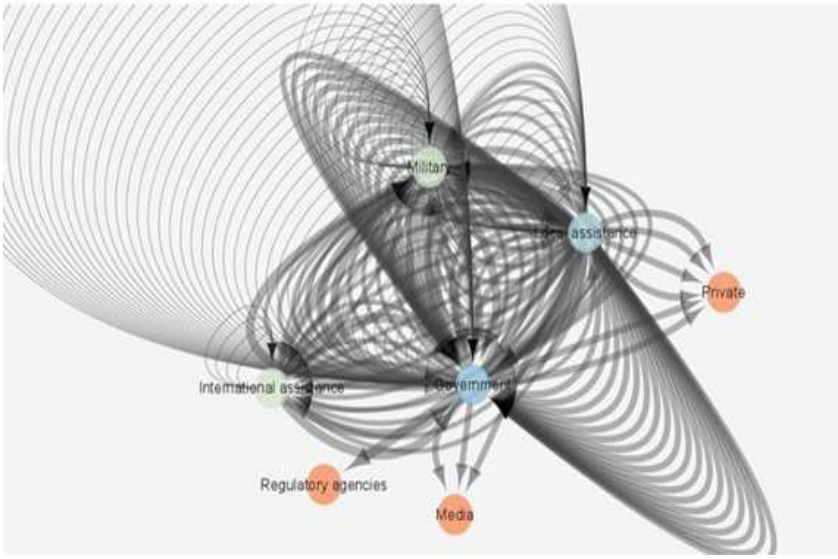

Figure 2: Information Sharing and Provision - Betweenness and Closeness

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Humanitarian Aid

In order to provide humanitarian relief, one must first seek it, then provide a safe place to stay, food, and water, and last, provide medical treatment.

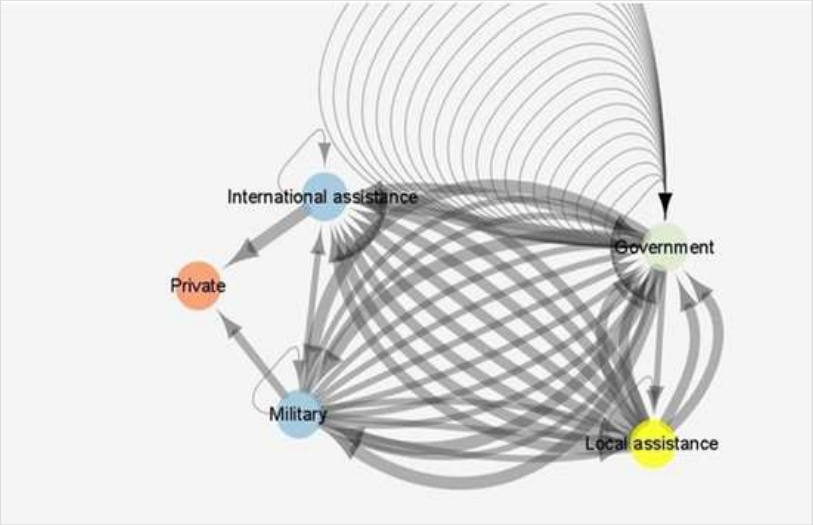

Figure 3: Searching Humanitarian Aid Betweenness and Closeness

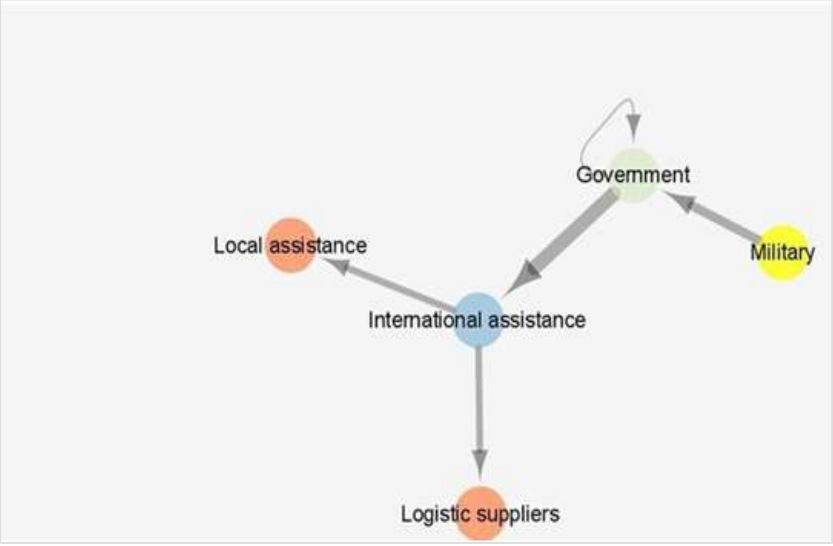

Figure 4: Betweenness and Closeness Centrality in Providing Humanitarian Aid Networks

The degree to which nodes are between other nodes determines their hue. The color blue indicates high and red low.

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Resources

Figure 3 shows the networks for Material, Financial, and Human Resource Search and Provision, with an emphasis on the nodes that serve as guardians of these networks (centrality through intermediation).

The behavior of betweenness centrality changes when resources are involved. Figure 5 demonstrates that the government (0.095), the military (0.107), and the local aid network (0.083) were the most active nodes in the Resource Searching network. These nodes were crucial in mediating the search for resources. Despite participating in the network, parties from the private sector, the government, the beneficiaries, and the media were unable to attain any degree of mediation. Furthermore, the most accessible stakeholders are the private sector (0.583), the government (0.7), the local aid network (0.777), and the military (0.777), because they are nearby.

But the Network for Providing Resources (Figure6), the Government, Military, Local Aid, and International Aid networks are all included in Figure 3. The international assistance network, the beneficiary, and the media were all present, but they were a long way apart. While the government was included in this network, its degree of proximity was 0.0, which is considered insignificant. In contrast, the military, the local assistance network, and the international help network had the highest centrality of proximity. Furthermore, when assessing the centrality degree, we verified that no stakeholder stands out in terms of "in-degree" and "out-degree." It appears that the individuals or groups participating in the network are not always in close proximity to one another, yet they do participate anyway. The stakeholder Beneficiary also made an appearance in a network and was cited by respondents for the first time in this research.

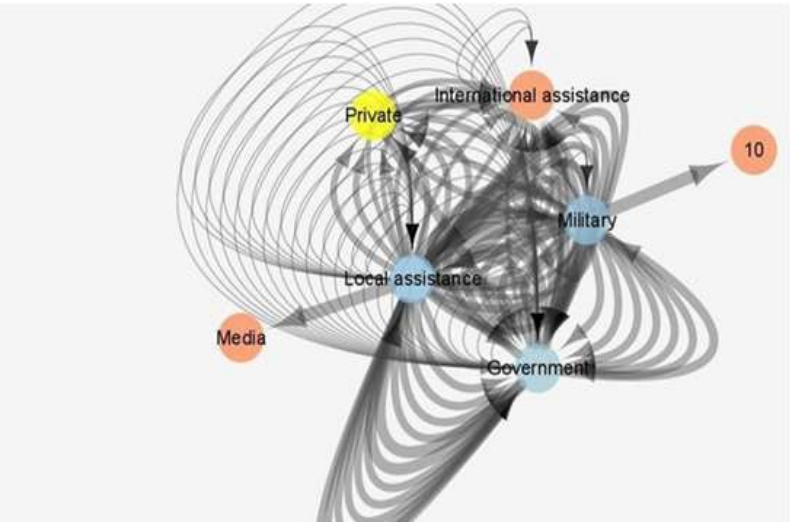

Figure 5: Searching Resources Betweenness and Closeness

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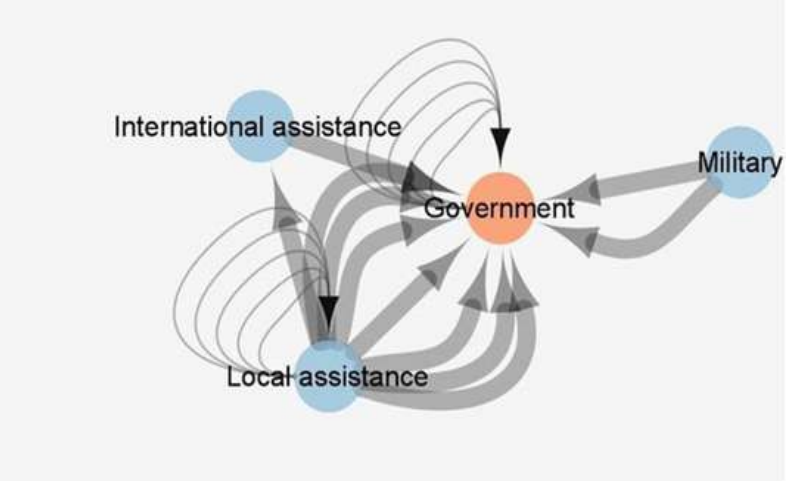

Figure 6: Providing Resources - Betweenness and Closeness

Evacuation, Search and Rescue of Victims

Protective nodes, representing centrality through intermediation, are highlighted in Figures 7 and 8, which illustrate networks related to collaboration in evacuation, search, and rescue operations. Figure 7 indicates that, within the network for collaboration in evacuation, search, and rescue of victims, the following stakeholders demonstrated notable betweenness centrality: the International Aid Network (0.016), the Private Sector (0.041), the Military (0.066), the Local Aid Network (0.233), and the Government (0.191).

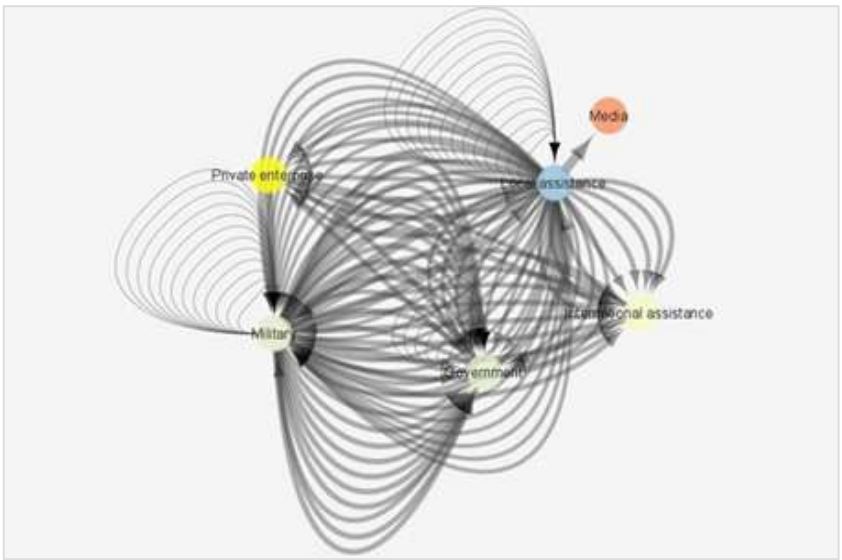

Figure 7: Searching Betweenness and Closeness

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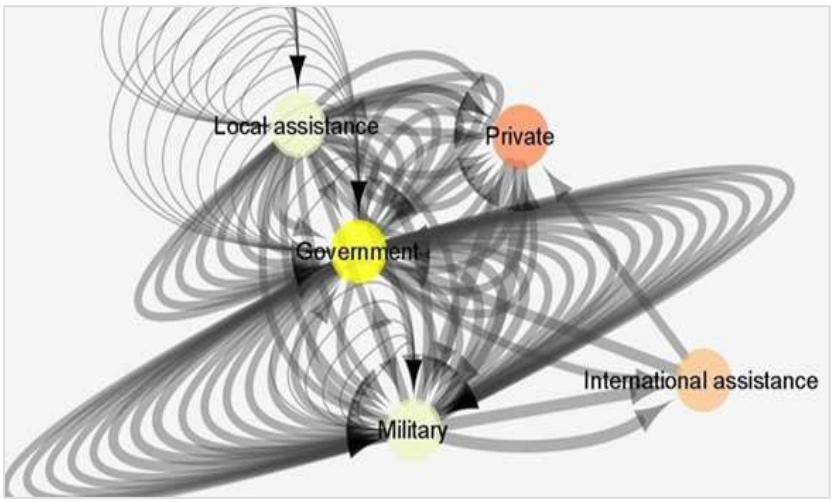

Figure 8: Betweenness and Closeness Centrality in Providing Collaboration for Evacuation, Search, and Rescue of Victims

Even though they were part of the network, the media lacked an important intermediary component. The most accessible players, in terms of Closeness centrality, are the following: 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) exhibited high levels of centrality. In contrast, the Media demonstrated no significant performance, with a value of 0.0.

The military (0.291) and the government (0.194) are the most collaborative partners in the network that provides victims with evacuation, search, and rescue services (Figure 8). Because of how well the military does in events like this, it stands out. Since the government (represented by the Civil Defense) is responsible for a suite of measures meant to mitigate the effects of technological and natural catastrophes, boost public morale, and return society to normal, this node in the network receives a disproportionate number of connections while sending out relatively few. The Private Sector, the Local Aid Network, and the International Aid Network appear to be the least active stakeholders in terms of betweenness centrality, with scores of 0.041, 0.027, and 0.027, respectively. Regarding closeness centrality, the Local Aid Network (0.800) emerges as the next closest stakeholder, followed by the Military, and ultimately the Government, which holds the highest proximity score of 1.0. In terms of reach, the Private Sector (0.571) and the International Aid Network (0.666) are positioned at a greater distance from the central nodes.

V. CONCLUSION

When it comes to disaster response and humanitarian operations, social network analysis provides a new way of looking at things. Systematic network analysis (SNA) is a powerful tool for improving operational efficiency by identifying key nodes, communication channels, and structural trends in

complex networks. The ability to quickly disseminate information, maximize resource allocation, and improve collaborative decision-making is greatly enhanced when players are well-connected and strategically positioned. On the other hand, when actors are isolated or poorly integrated, it might hinder prompt reaction. In order to improve disaster response efficacy and coordination, stakeholders can use SNA to find bottlenecks, evaluate network resilience, and execute targeted interventions. By combining SNA with other analytical tools like GIS and simulation modeling, planners can gain a more complete picture of humanitarian networks, which improves their ability to foresee problems, streamline operations, and create solid backup plans. The results of network analysis are useful for building frameworks for inter-organizational collaboration, training programs, and improving operational performance in the short term. In the end, using SNA in disaster-response networks improves the efficiency and effectiveness of humanitarian operations, making sure that help gets to the people who need it the fastest. In order to construct humanitarian networks that can withstand and adapt to increasingly complicate global calamities, it is crucial to continue researching and implementing SNA.

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