Network Analysis of Search and Rescue (SAR) and Relief Operations in Bangladesh's Recent Floods

Md. Asaduzzman (0424052106), Rahul Drabit (0424052106), Md. Saidur Rahman
Department of Computer Science & Engineering
Bangladesh University of Engineering & Technology
Email: aznarabin@gmail.com, rahuldrabit@gmail.com, saidurrahman@cse.buet.ac.bd

***Abstract*— Floods are among the most devastating natural disasters, disrupting lives, infrastructure, and critical services. Effective Search and Rescue (SAR) and relief operations depend on efficient coordination between multiple agencies, NGOs, and volunteers. This study applies network science principles to analyze the structural efficiency of SAR and relief networks during Bangladesh's August 21, 2024 floods. Using data collected from As-Sunnah Foundation's emergency and rehabilitation teams, we construct and evaluate the response network using key metrics such as degree centrality, clustering coefficient, characteristic path length, and network density. Our findings indicate that a well-connected, small-world network structure enhances operational efficiency, improving resource allocation and communication speed. By comparing our findings with prior humanitarian response networks, this study provides insights for optimizing future disaster response frameworks to enhance resilience and effectiveness.**

Keywords—Aid Networks, Emergency, Rehabilitation Team,

I. Introduction

Floods pose a recurring threat to Bangladesh, leading to significant humanitarian crises. The effectiveness of Search and Rescue (SAR) and relief operations is crucial in minimizing casualties and ensuring rapid assistance to affected populations. Given the complexity of emergency response efforts, understanding the underlying network structure of coordination among various organizations is essential for improving operational efficiency.

Traditional disaster response frameworks often rely on predefined hierarchical structures, which may become ineffective in large-scale, rapidly evolving crises. Recent advancements in network science suggest that highly connected, small-world networks can facilitate faster communication, improved resource distribution, and better coordination among response teams [1].

In this study, we analyze the SAR and relief operations network formed during the August 21, 2024 floods in Bangladesh. We use graph-theoretic analysis to examine how different organizations—such as NGOs, government agencies, and local responders—interacted to manage the crisis. By comparing key network metrics with prior disaster response studies [2], we aim to provide insights into optimizing future emergency coordination efforts.

The primary contributions of this study are:

1. Constructing a network model of SAR and relief operations during the August 2024 floods.
2. Analyzing key network properties (centrality, clustering, path length, density) to evaluate efficiency.
3. Comparing with past disaster response networks to identify structural strengths and weaknesses.
4. Providing recommendations for improving future flood response strategies.

By leveraging network analysis, this study aims to support policy makers, NGOs, and emergency responders in designing more efficient and resilient disaster response networks for future crises.

II. Literature Review

A. *Proactive Humanitarian Aid Networks and Small-World Effect*

A relevant study by Das et al. [1] explores how proactive humanitarian aid networks can be structured using guided topology and small-world effects to improve response efficiency. Their work focuses on the 2007 Sidr disaster in Bangladesh, where the humanitarian network consisted of **111 nodes** and **169 edges**, forming a small-world network with high clustering and short path lengths. The study highlights:

- Small-world networks facilitate faster information dissemination and better connectivity among responders.
- Guided topology ensures that key actors (hubs) play a strategic role in maintaining network efficiency.
- The network's clustering coefficient **(0.193)** and average path length **(4.152)** indicate a balance between local collaboration and global reach.

These findings suggest that disaster response networks should be proactively structured to enhance resilience and adaptability, particularly in resource-limited environments like Bangladesh.

B. Link Formation in Emergency Response Networks

Another critical study by Abbasi et al. [2] investigates the evolution of emergency response networks through link formation dynamics. Their research examines how connections among responders evolve over time based on two key principles:

1. Cumulative Advantage Process (Rich-Get-Richer Phenomenon) – Highly connected nodes (actors) tend to gain more links over time, reinforcing their role as key coordinators.
2. Structural Position & Brokerage Role – Participants occupying brokerage positions (connecting different groups) are more likely to attract new links, improving overall network efficiency.

Their study, which analyzes real-world emergency responses, concludes that:

- Well-connected hubs accelerate coordination by acting as information centers.
- Adaptive networks (those that evolve dynamically) perform better than rigid hierarchical structures.
- Emergency managers should identify and strengthen key actors to improve response effectiveness.

C. Relevance to Our Study

These prior works provide valuable insights into how SAR and relief networks should be structured:

- The small-world effect improves efficiency, ensuring faster rescue operations in time-sensitive disasters like floods.
- Strategic hubs and broker nodes play a crucial role in coordinating SAR operations.
- The evolution of response networks should be monitored to enhance adaptability in future crises.

Building on these findings, our study applies network analysis to the **August 2024 Bangladesh floods**, investigating how SAR and relief networks functioned in real-time. By analyzing key network properties (clustering, centralization, path length, and density), we aim to provide actionable recommendations for improving disaster response strategies in Bangladesh and beyond.

III. METHODOLOGY

A. Data Collection

To analyze the Search and Rescue (SAR) and relief network formed during the August 2024 Bangladesh floods, we conducted a field visit to As-Sunnah Foundation, a key organization involved in flood relief operations. The data collection process involved:

- **Field Visit & Organizational Understanding:** We visited the As-Sunnah Foundation to understand their rescue and rehabilitation workflows.
- **Interaction with Key Personnel:** We spoke with the main manager overseeing SAR operations to gain insights into their coordination strategies.
- **Clarifying Requirements:** We explained our research objectives and specified the required data format for network analysis.
- **Data Acquisition:** Structured data was received via Google Sheets, detailing the interactions, communication, and coordination among response teams.

B. Tools & Software Used

To analyze the network structure, we used the following tools:

- **Gephi & Cytoscape:** For network visualization and structural analysis.
- **Python (NetworkX Library):** For computing graph metrics, such as degree centrality, clustering coefficient, characteristic path length, and density.
- **GitHub Repository:** The full dataset and analysis code are available in our repository: https://github.com/Rahuldrabit/NetworkinAIDTeam

C. Network Construction & Analysis

The collected data was processed and converted into a graph representation, where:

- Nodes represent individuals or teams involved in SAR and relief operations.
- Edges represent communication and coordination links between teams.
- The network was analyzed based on key structural properties, including:
    - **Degree Centrality:** Identifying key actors (hubs) in the response network.
    - **Clustering Coefficient:** Measuring local connectivity and teamwork efficiency.
    - **Characteristic Path Length & Diameter:** Evaluating communication speed and network reachability.

- **Network Density & Centralization:** Understanding the overall structure and resilience.

D. Comparative Analysis

To assess network efficiency, we compared our findings with prior humanitarian aid networks, including the 2007 Sidr response network and other emergency networks discussed in the literature [1].

IV. Results & Findings

A. Summary of Network Properties

The Search and Rescue (SAR) and relief operations network during the August 2024 Bangladesh floods was analyzed using graph-theoretic metrics, revealing the following structural characteristics:

TABLE 1 SUMMARY OF NETWORK PROPERTIES

Metric	Value	Interpretation
Number of Nodes	18	Total responding teams/actors.
Number of Edges	81	Strong connectivity among participants.
Avg. Neighbors	7.222	High local connectivity per node.
Network Diameter	3	Shortest longest path; fast communication.
Network Radius	2	Efficient reachability from central nodes.
Characteristic Path Length	1.641	Shorter than many disaster networks, indicating rapid information flow.
Clustering Coefficient	0.600	High local cooperation and teamwork.
Network Density	0.425	Strong interaction levels among actors.
Network Heterogeneity	0.401	Moderate variation in node connectivity.
Network Centralization	0.250	A balanced distribution of influence.
Connected Components	1	Fully connected, ensuring information accessibility.

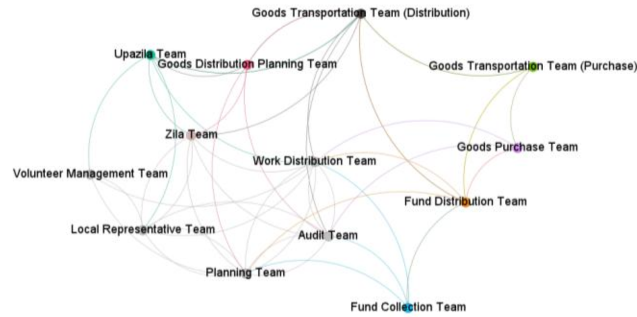

Figure 1: Network Representation of Emergency Team

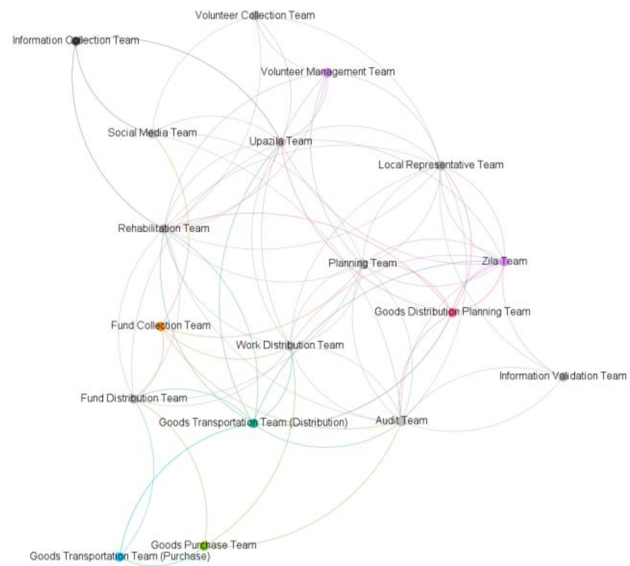

Figure 2: Network Representation of Rehabilitation Team

B. Comparison with Sidr 2007 Network

To contextualize our findings, we compare them with the 2007 Sidr humanitarian aid network [1], which had 111 nodes and 169 edges. Key differences include:

- **Higher clustering coefficien**t (0.600 vs. 0.193 in Sidr 2007) → Stronger teamwork and coordination.
- **Lower characteristic path length** (1.641 vs. 4.152 in Sidr 2007) → Faster information dissemination.
- **Higher network density** (0.425 vs. 0.028 in Sidr 2007) → More frequent interactions among participants.
- **Smaller network size compared to Sidr 2007**, but more optimized for rapid response.

C. Key Observations & Implications

1. Efficient Communication & Coordination: The low path length and high clustering suggest that SAR teams were well-

connected, enabling fast decision-making during the flood response.

2. Balanced Network Structure: The moderate centralization (0.250) ensures that no single entity dominates, reducing bottlenecks in coordination.

3. Enhanced Teamwork & Resilience: The high clustering coefficient (0.600) indicates strong local collaboration, critical for managing resources and executing rescue operations efficiently.

4. Improved Over Previous Networks: Compared to Sidr 2007, this network demonstrates stronger connectivity and faster response times, showcasing an improved network design for disaster relief.

D. *Summary of Findings*

- The August 2024 SAR and relief network exhibits small-world properties, improving efficiency, resilience, and adaptability.
- Shorter path lengths and high clustering enable rapid coordination, essential in time-sensitive disaster response.
- This study highlights the need for strategically structured response networks to optimize disaster relief operations in future crises.

V. Discussion & Implications

A. *Network Efficiency in SAR & Relief Operations*

Our analysis of the August 2024 Bangladesh flood response network demonstrates the benefits of a highly connected, small-world structure in disaster management. The **low characteristic path length (1.641)** and **high clustering coefficient (0.600)** indicate that rescue teams were able to communicate and coordinate rapidly, ensuring efficient resource allocation.

B. *Strategic Importance of Network Design*

Compared to previous humanitarian networks like Sidr 2007, our findings highlight the significance of proactive network design in disaster response:
✓ High clustering fosters strong local collaboration.
✓ Balanced centralization prevents over-reliance on a few key actors.
✓ Shorter path lengths accelerate decision-making and response times.

C. *Practical Implications for Disaster Response*

Policy & Planning: Disaster management agencies can use these insights to optimize SAR networks, ensuring resilient and scalable coordination frameworks.
Real-time Monitoring: Using network analysis tools, agencies can track evolving SAR networks during crises, making data-driven decisions.
Technology Integration: The use of Gephi, Cytoscape, and Python-based analytics can support automated network evaluation, enabling better preparedness for future disasters.

VI. Conclusion & Future Work

A. *Limitations & Future Directions*

Despite these insights, certain limitations remain:

- The study focused on static network analysis, while real-time dynamic changes were not captured.
- The dataset was limited to *As-Sunnah Foundation*, and broader participation from government and NGOs could provide a more comprehensive view.

B. *Future research should explore*

Dynamic Evolution of Disaster Response Networks – Tracking how networks evolve in real time using temporal network analysis.
Multi-Agency Coordination – Expanding the study to include government agencies, military, and international NGOs.
AI & Predictive Modeling – Using machine learning and predictive analytics to model disaster response networks in advance.

By integrating these improvements, future humanitarian aid operations can become more efficient, scalable, and resilient to large-scale disasters.

VII. References

[1] S. S. M. S. R. Sujoy Das, "Generating Proactive Humanitarian Aid Networks with Guided Topology and Small-World Effect," in *2017 IEEE Region 10 Humanitarian Technology Conference (R10-HTC)*, Dhaka, Bangladesh, 2017.

[2] A. Abbasi, " Link Formation Pattern during Emergency Response Network Dynamics," *Bepress* , pp. 1-11, 2014.