Social Network Analysis for the Implementation of Sendai Framework for Disaster Risk Reduction in Iran

Homa Yousefi Khoshsabegheh
Tehran University of Medical Sciences
Ali Ardalan
Tehran University of Medical Sciences
Amir Hossein Takian (takiana@tums.ac.ir)
Leila Hedayatifar
New England Complex System Institute
Abbas Ostadtaghizadeh
Tehran University of Medical Sciences
Behnam Saeedi
Nogyo Shokuhin Sangyo Gijutsu Sogo Kenkyu Kiko

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Abstract

Background: Over recent years, the exposure of people and assets to disasters has been faster than reducing vulnerability in all countries. As a result, new risks have been formed and losses due to disaster are progressively increasing. Suffering from significant losses in the aftermath of disasters every year, Iran is no exception. Governmental and non-governmental stakeholders are jointly responsible for managing the risks of disasters. Hence, appropriate, collaborative and timely interactions of involved organizations will play an important role in their operation, especially during disasters.

Methods: In this study, we used the Social Network Analysis (SNA) to analyze the network of stakeholders in disaster risk management in Iran. Our review of literature, laws, and regulations of disaster risk management plus brainstorming identified a list of 85 stakeholders. We used the Delphi method among purposefully selected experts to score the relationship between the stakeholders. We then used the modularity optimization method to identify groups with greater interaction. Organizations with key-roles in the network and the ones in need of stronger relationships were identified through centrality measurements.

Results: The density of this network was 0.75, which represented that not all the stakeholders were connected. Among all organizations identified, the National Disaster Management Organization and Civil Defense Organization showed higher influences considering their responsibilities.

Conclusion: To provide a visual and tangible picture of the status and interrelationships among the stakeholders, this method identified groups with better interaction using community/cluster detection and modularity optimization methods. Understanding the current structure of the network and strengths and weaknesses of the interactions among stakeholders may help improve disaster risk management in Iran. Results of this research determine the role and importance of different organizations, their weakness, and strong points. Also, results help them to plan to strengthen their roles and solve their problems.

Background

Based on the World Disaster Risk Report, sustainable development is impossible without considering the disaster risk reduction approach (1). Ample evidence indicates that, through disaster management strategies, the risk of loss of life and assets increases faster than vulnerability reduction strategies all around the world (2). Statistics show that hazards such as earthquakes, tsunamis, tornadoes, and floods have caused annual economic losses of $250–330 billion globally. Moreover, from 1980 to 2012, 42 million years have been lost (YLL) due to disasters, over 80% of which occurred in Low and Middle-Income Countries (LMICs) (3).

Due to its geographic location, topographical properties, and high structural and non-structural vulnerabilities, Iran is prone to many hazards (4). Iran's World Risk Index was 4.87%, which ranked 112th out of 171 countries. The country was also ranked high-risk based on the Lack of Coping Capacities index (80.35%), middle based on Vulnerability, and Lack of Adaptive Capacity indexes by 47.78% and 43.81%, respectively (5).

At the Third United Nations' World Conference, the International Strategy for Disaster Risk Reduction was adopted under the Sendai Framework. Expected outcomes for the period of 2015–2030 are included the substantial reduction of disaster risks, mortality, and losses to livelihoods, health, economic physical, social, cultural, and environmental and business assets in the countries. Therefore, the need for commitment, good faith, knowledge, experience, and resources are inevitable. Despite the most emphasis on governments' role for the disaster risk reduction, the Sendai Framework endorsed the shared duty of the governments and concerned stakeholders. According to the policies and regulations of this document, non-state stakeholders, as enabler agents, play an important role in helping governments. The first step in this way is to identify stakeholders and determine their role and importance (2).

Given the complex nature of disaster risk management (DRM) and the diversity of the structure of relevant organizations, traditional methods of stakeholder analysis are less able to examine the dynamics and interaction of these links (6–10). Organizations are not important lonely in a network but their links and interactions with other stakeholders determine the importance of that organization. In these cases, methods such as the tools in network analysis approaches that examine the behavior of systems collectively would be an appropriate option (11–13). This is a matter of distinguishing and prioritizing the network analysis approaches over descriptive methods (14). Numerous studies have investigated the coordination and inter-organizational cooperation in disasters using these approaches. The flow of information among relief teams and the way of communicating in the response phase are evaluated in many studies and drawbacks are considered as lessons learned (7–9, 15–20).

While coordination at all levels is an essential action in DRM, inconsistency among stakeholders has become one of the major recognized organizational challenges, (21). Coordination prevents parallel work and loss of resources through planning, making mutual trust, combining capacity and timely use of resources in different organizations (7, 11). Analyzing the stakeholders' roles and responsibilities are considered as the first steps in establishing effective coordination and cooperation before the hazards occur (8, 21).

By identifying the internal and external coordination and communication challenges of systems, the challenges for planning and policy-making could be eliminated (10, 22). For instance, a study was conducted to investigate the communication between the members of the incident command system (ICS) in the response process of six incidents (three firefighting operations due to hazardous chemical incidents and three police operations in response to emergency calls). The results showed that different types of communication affect the response phase quality in two types of events and, the best communication model was introduced accordingly (18, 23). Another study was carried out based on reports of organizations to the Federal Emergency Management Agency (FEMA). The results showed that effective response and recovery require the optimal coordination among organizations and the trust between the governmental and non- governmental sectors at all levels as well as in the society. They emphasized that optimal preparation and response could be achieved within the framework of inter-organizational trust and coordination. (7, 16).

To best of our knowledge, there are not many stakeholder analysis based on the network analysis method, most of which have merely been focused on the response phase of DRM in Iran (16, 21). This study aimed to analyze the network of DRM stakeholders' as the first step for the implementation of the Sendai Framework in Iran. In addition to providing a visual and tangible picture of the status and interrelationships among the stakeholders, this method identified groups with better interaction using community/cluster detection and modularity optimization methods. Using centrality measurements (Degree, In-Degree, Out-Degree, Betweenness, Closeness, and Eigenvector), the organizations that play a key role in the network, as well as the organizations that need to strengthen their relationships were identified. Quantitative results were also used to interpret the interaction between the organizations and understand the blind spots of the links. Through understanding the relationships among various stakeholders in DRM, an opportunity will arise to plan for enhancing the level of stakeholders' participation with lesser roles.

Methods

There are two main organizations for DRM in Iran: the National Disaster Management Organization (NDMO) and the Civil Defense Organization (CDO). The NDMO has 14 specialized working groups with diverse members according to the title and description of their duties. Based on the members of these working groups, we developed a list of 52 organizations. Data triangulation was used to enhance the data credibility (24). A review of the literature, rules, and regulations related to DRM was then conducted and 11 organizations were added to the list. We then emailed the list to 32 experts of DRM. The experts were selected based on their experience or employment in one of the organizations involved in DRM. Following brainstorming, the list expanded to 85. The title of eight organizations was also corrected. The list remained unchanged after we received 19 response sheets. The name and the number assigned to the organizations for simplicity are presented in Table 1.

In the next step, we created a matrix of 85 actors using the Excel software. The matrix was then emailed to 32 experts. The social profile of the participants is described in Table 2. During this round of Delphi, the experts were asked to rate based on the Likert scale (0–5: 0 means the lack of interaction and 5 means the maximum connection), the extent to which organizations interacted with each other for DRM. This method is best known as the Full-rank Ordinal Measures of Relations (14).

The matrix was completed and returned by 17 people. Two reminder emails were sent to the remaining 15 experts within 10 interval days. The number of responses then increased to 22, and the network analysis was performed with 22 participants (68.75% response rate).

For data analysis, the responses were called in Python software and the corresponding networks were formed. We visualized the developed networks by Gephi software. Stakeholders played the role of nodes (circles) in our networks and the relations between them were the links. Links were weighted and directed. The weight of the links shows the average score of each link in the 22 response sheets. Due to the long list of the organization, the numerical code was used instead of its name. The non-governmental sector was also identified through bolder margin circles. Figure 1 shows a schematic view of the process of data extraction.

Density is one of the popular indices to show the ratio of the presented links to the possible links (25). A network with n nodes can maximally have $n(n-1)$ directed links or $n(n-1)/2$ undirected links. Density 1 represents a fully connected network and density 0 represents a fully sparse network with no link. Heterogeneity in the node connections and lack of some links in the network reduces the density index below 1.

Heterogeneity in the organizations' connections and weight of these connections (in range of 0 – 5) indicates the unequaled impact of organizations in the stakeholder's network. Over the years, different centrality measurements have been introduced and used to quantify effective nodes in terms of their different roles in networks. We used four centrality measurements in our analysis; Degree, Betweenness, Closeness, and Eigenvector.

Degree centrality is one of the first centrality measurements which count the number of links by each node in the network. It indicates the reputation of nodes. The higher the degree of a node means the greater its authority (23). In a directed network, in-degree and out-degree can be different for each node. In-degree counts the number of the interaction of other nodes with a node and out-degree counts the number of the interaction of a node with other nodes. In our stakeholder's network, in-degree shows the frequency that other organizations refer to an organization for planning, coordinating and their actions. In contrast, out-degree shows the frequency that an organization contributes to other organizations in the network. As links in our network are weighted, we can also calculate Weighted Degree (WD), Weighted In-Degree (WID), and Weighted Out-Degree (WOD). Betweenness determines the position of a node within a network based on its ability to establish relationships among other couples (26). Organizations with a high betweenness play the role of the interface in the network, removing them might disturb the flow of communications and information in the network. These nodes are also known as brokerage (27). Closeness centrality is another important indicator that shows the closeness of a node to other nodes in the network (28, 29). It is calculated as the inverse of the sum of the length of the shortest paths from each node to all the other nodes in the network. The nodes that are higher in this index make their connections with other network nodes more easily because they have fewer intermediaries.

Eigenvector centrality is the last index we used. It quantifies the ability of a node to get connected to nodes with a higher degree. The importance of this indicator is determined when the main node does not seem very important in terms of other centrality measurements; however, it is connected to other important nodes and is the bottleneck of communication for other nodes or clusters (30).

Heterogeneity of node's connections usually leads to the formation of clusters of nodes that mostly communicate with each other than the rest of nodes in the network (11, 31, 32). We find these clusters or communities by applying the Louvain (33) method with modularity optimization (34). In the beginning, the Louvain algorithm considers all the nodes in as single clusters. Iteratively, nodes join their neighboring clusters in the next steps to maximize modularity. Modularity is a scalar value in range −1 to 1 that quantifies the distance of detected clusters from the ones in the network with randomized links. Negative modularity refers to the situation that nodes are assigned to the wrong clusters, zero occurs when the

number of detected clusters is equal to the number of nodes, and higher positive values represent more optimal partitions (35, 36).

In order to view the visual details of the network in denser networks, we eliminated weaker links with the network reduction technique in the sequential stages (11). This was carried out to identify organizations with weaker communication and design interventions in order to ensure their cooperation. The comparison of these measures identifies the organizations with a key role in the network, plus the relationships in need of strengthening. Figure 1 summarizes the whole process of data preparation and analysis in this research.

Results

Our findings revealed 85 organizations involved in DRM in Iran, of which 58 are governmental agencies and the rest are non-governmental actors. Figure 2 shows the network of the corporation of these organizations (circles) with each other. Our directed network has 5370 links out of a maximum of 7140 possible links (85 * 84). Therefore, the density of the network is 5370/7140 = 0.75 indicating that the network is fairly connected and most of the organizations have a reciprocal collaboration.

Figure 2 illustrates the colors of the node, which indicate to which cluster nodes belong to. Three clusters were detected in this network, with a difference in the number of organizations. Organizations within each cluster have more and stronger connections among their members than the rest of organizations in the network. We found that most of the members in each cluster belong to a class of DRM in Iran. Members of the blue cluster (39 organizations) are more involved with the theoretical basis of DRM. While members of the red cluster (30 organizations) are more involved with operational and executive affairs and the green cluster members (16 organizations) are more involved with policy affairs. Links are colored based on the color of the origin and destination nodes.

Each of the A-F panels in Figure 2 represents the role of organizations based on one of the centrality measurements. The bigger size of the node shows a larger value of measurement for a node. The first three panels (A, B and C) show the importance of the organizations based on WD, WID, and WOD centralities. WID quantifies how much other organizations refer to an organization, WOD quantifies how much an organization cooperates with other organizations, and WD is the sum of the WID and WOD. Among all agencies, the NDMO (30) from the operational and executive affairs cluster showed the largest cooperation with other organizations in the system. The CDO (45) from the theoretical agencies cluster and the Plan and Budget Organization (PBO) (71) from the policy affairs cluster had the largest operations within the system next to NDMO (30). The Ministry of Communications and Information Technology (MCIT) (76), and the non- governmental sectors including Iranian Red Crescent Society (IRCS) (16), and International Organizations (35) play a more important role in the network, compared to the other organizations. Most of these organizations are governmental and their high grades emphasize the fundamental role of government in DRM (2). In contrast, the Lifesaving and Diving Federation of Iran (54), and the Iranian Artists Forum (57) demonstrated the minimum values for these degree centralities. Organizations with higher degrees play the role of core or hub organizations in the network.

Eliminating nodes that have high betweenness could challenge the flow of communications on the network (27). Figure 2-D shows that IRCS (16) and the MCIT (76) have the most impressive role regarding the betweenness measurement. Although their WD was lower than some of the nodes, the Ministry of Interior (MoI) (3) and the Islamic Republic of Iran Broadcasting (IRIB) (20) also play a key role in interacting with other organizations and with each other in the network.

Figure 2-E shows the score of agencies regarding the Closeness centrality. This is an important measurement in DRM, as it can potentially define which organizations are close to the core organizations and which ones are far, therefore they may need to revise and renew their operational links. It shows that most organizations are reasonably near to core organizations.

The Eigenvector centrality score nodes based on their connections to high degree nodes. The significance of this measurement is determined by the fact that sometimes an organization does not seem to have good connections to other organizations, but their main connections are with core organizations. Figure 2-F shows that most organizations have strong connections to the core organizations, whereas only a few organizations are on the border of the network and do not have good connections.

After using the link removal technique and removing weaker links in successive stages, more clusters were detected. Figure 3 shows the number of removed links in each stage (detailed information is shown in the table at the right panel).

Figure 4 represents the networks with an emphasis on WD measurement during the link removal steps. Figure 4-A shows the whole network. Removing links equal to and less than one, the network follows almost the same pattern as before (Figure 4-B). The number of clusters did not change at this point, and only the number of organizations in each cluster, as well as the cluster of some organizations, changed. In the following steps, by removing the links weighing 0–2, the number of clusters changed to 4, whilst by removing the links weighing 0–3, the number of clusters increased to 5. In the last step, we removed the links with the weight of 0–4. Only the strongest links are shown in the network.

According to this figure, by removing weak links, the association of some organizations was completely interrupted. A large number of organizations had links with weights less than 2 and 3, and weaker links are mostly found in the non-governmental sector. In the next stages of deletion, the trend was changed dramatically. The NDMO (30), the CDO (45), the Center for Strategic Studies (66), the Ministry of Health and Medical Education (MoHME) (47), the Ministry of Defense and Armed Forces Logistics (1) showed an acceptable position in five stages, indicating their key role. On the other hand, the MCIT (76), the Guardian Council (28), the Various Insurance Organizations (36), the Organization for Mobilization of the Oppressed (51) and the Ministry of Co-operation, Labor and Social Welfare (48) were among the important organizations that fall sharply in the second stage (removing links 1–2). This reveals the vulnerability of the relationship between these organizations and reveals the need to strengthen their relationship.

Discussion

The successive changes in the structure of DRM in Iran over the past decades have shown the special attention of policy-makers to respond appropriately. Currently, responsibility for DRM lies primarily with two organizations: CDO and NDMO. The CDO operates under the command of the General Staff of the Armed Forces. Civil Defense is defined as a series of unarmed acts that reduce the vulnerability of manpower, buildings, facilities, equipment, and arteries to enemy hostile and destructive operations or reduce the risks of abnormal accidents. The NDMO is also affiliated with the MoI, with its corresponding organizational categories in the governorates. This organization was found with the aim of integrated management of policy, planning, coordination and coherence in the areas of implementation, research and monitoring various stages of DRM. The NDMO also organizes the affected areas using the facilities and capacities of ministries, institutions, public and governmental companies, banks, insurance corporations, and community- based organizations. There are 14 specialty and operational teams of representatives from various institutions within the organization, whose members follow their workgroup approvals in line with their tasks.

In the event of a disaster, one of the most important issues is the timely performance of the organizations in order to provide the best services in the coordinated space. This coordination has begun before the occurrence of hazards, and all actors in this area must establish appropriate communication with other stakeholders in accordance with their duties (8, 10, 12, 15, 17, 20, 37, 38). The stakeholders are individuals, groups, and organizations that are influenced by decisions and plans of an organization, or affect its decision-making (4). Accordingly, an analysis of the network of DRM stakeholders in Iran was conducted with 85 organizations. The appearance of the network of DRM stakeholders shows acceptable consistency with a density of 0.75. This is the strength of the network, which is necessary for planners to set up a participatory program by identifying key network entities and institutions (39). The network has three clusters that are different not only in the number of cluster members but also in the importance of the organizations within each cluster. The main node of each cluster is usually the node that has the largest number of connections to other nodes and is considered to be the core organization (30). These cores have also good connections to the nodes in other clusters.

The NDMO (30) is the main organization in the red cluster with 30 members. Other important members of this cluster include the IRCS (16), the MoHME (47), the IRIB (20), and the Universities of Medical Sciences (UMS) (14) whose dominant activity is operational. The NDMO is the main DRM organization, as well as responsive for most DRM plans in Iran. This could justify placing this organization in this cluster and with operational/executive organizations. However, considering the political position of the NDMO, it is expected to be placed in a cluster with policy-making organizations (the blue cluster in Figure 2). This could be related to the process of establishing and maintaining this organization. Approving the establishment of the NDMO by parliament in 2007 for a period of 5 years, the duration of its pilot operation was then extended by the end of 2014. The organization has continued to operate without new approval. This may put the legitimacy and power of the organization under question, undermine the role of policy-making and affect the organization's core position in the network. It seems necessary to finalize the legal structure of this organization and clarify its responsibilities and powers, more transparently. Moreover, although NDMO

(30) is categorized within the red cluster, it has very good links to the members of the two clusters representing its core role of the network.

In the blue cluster, the CDO (45) is the core organization. The members of this cluster are often major organizations such as the Ministries of Defense and Armed Forces Logistic (1), Agriculture (49), Science, Research and Technology (50), Industry, Mine and Trade (60), Petroleum (61), and Energy (62), which plays a key and effective role in DRM, especially in the phase of prevention and preparedness. Therefore, the CDO (45) has maintained its special political position. The main members of this cluster are often involved in strengthening the theoretical basis of DRM.

The third cluster has 16 members, i.e. the PBO (71), the Guardian Council (28), the General Inspection Organization (83), the MoI (3), the Municipalities and Village Administrators (40) and the City and Village Councils (41) among the most important organizations. The last two organizations are considered as subsidiaries of the MoI. In addition to important organizations in the field of politics, organizations that can be effective in financial support are also located in this cluster. The Ministry of Economic Affairs and Finance (53), Banks (7), and PBO (71) are among these organizations. The presence of these organizations, along with the policy-makers, is an ideal position for policy-making and implementation. However, there are organizations in the green cluster that are expected to be more relevant in the area of policy-making with other organizations. Therefore, it is essential that the core organizations of this cluster develop their communications in this area. The common point for the three clusters is the presence of some national organizations as the core members. This issue is considered as a good opportunity to create the necessary coordination to manage the risk of disasters in Iran, which should be used to its maximum.

To understand the role of effective organizations regarding the various roles that sectors can play in the network, we applied different centrality measurements. As mentioned earlier, the MoI (3) is the legal authority for DRM in Iran, while the NDMO (30) is a subordinate entity. In addition, the MoHME (47), the IRCS (16), and the IRIB (20) are responsible for three specialized working group Health care, the Rescue and Public Education, and the Education and Information of the NDMO (30), respectively. The main part of the DRM activities in Iran focuses on the response phase. These three organizations play the most important role in the response phase. As a result, the WOD (Figure 2-C) index compared to the WID (Figure 2-B) is higher for these organizations, which might indicate their influence and power. Nonetheless, the WID of these organizations is also desirable, which indicates the mutual importance of these organizations. In contrast, some organizations have higher WID than WOD, such as the CBOs (23), the Organization for Mobilization of the Oppressed (51), the Mobilizing the Medical Society Organization (64), and the Militia Volunteer Force (85). As these organizations are society-based and the target groups of their programs are vulnerable people, proper planning and joint programming could lead to better community-based disaster risk management. This is an opportunity to promote community resilience (2).

However, organizations including the Ministry of Education (6), private hospitals (10), Iranian Blood Transfusion Organization (55) and the International Institute of Earthquake Engineering and Seismology (11) are the ones with centrality measurements less than the average of the network. While these organizations are key members of the 14 workgroups of the NDMO, they play a significant role in the DRM

cycle, especially in prevention and preparedness. Therefore, it is the duty of their core organizations in the clusters to provide some solutions and improve their operations with the appropriate organizations in the network. For example, the Ministry of Education (6), which is considered a vital infrastructure, might have a significant impact on community resilience (2). Schools have special operational capacities and play an effective role as educational poles, which could be used as evacuation places at the time of disaster (40). At the Bangkok Summit in 2007, it was suggested that disaster risk reduction should be incorporated into educational policies, to be used to promote educational systems to transfer training to the community (41). The IRCS, as the responsibility of the Public Education working group, might plan activities in this regard, using its high betweenness capacity in cooperation with the NDMO (Figure 2-D).

The lack of coping capacities of Iran is 80.35%, which is categorized among high-risk countries. In terms of vulnerability and lack of adaptive capacities, it is classified as 47.78% and 43.81% (5), respectively, which indicates Iran's low resilience. The Organization for Mobilization of the Oppressed (51) is a governmental organization that supports vulnerable economic groups, which along with Iran's Small Industries and Industrial Parks Organization (8), they can contribute to the improvement of these indices. Using their betweenness position, the NDMO, along with the risk-transfer capacity of the Various Insurance Organizations (36) need to strengthen the Organization for Mobilization of the Oppressed (51) towards facilitating community resilience. The Organization for Mobilization of the Oppressed (51) and the Various Insurance Organizations (36) are able to prevent the aggravation of the consequences of disasters. Indeed, achieving the Built Back Better goal in the Sendai Framework is possible through the provision of operational strategies and promoting a culture of prevention and preparedness on the "response" (2).

Since the organizations with higher eigenvector centrality have more relationship with important organizations in the network; they can use their capacity to improve the communication of isolated organizations. Moreover, organizations with high closeness are also the right option. Indeed, each of these indicators might determine the difference in the potential role of the organizations. Considering this fact, the NDMO (30), Various Insurance Organizations (36), IRCS (16), MoI (3), MoHME (47) and PBO (71) are organizations with high value in all the centrality measurements. If these key organizations properly perform their tasks and outline the organizational expectations of other stakeholders, and create the necessary coordination before the hazards occur, the quality of the response phase will also improve (42).

To examine the visual details of communications among the members of the network, we deleted weaker links sequentially. Isolated organizations that are not well-matched in their group could be easily identified. In the first step, we removed the weakest links with weights less or equal to 1 (77% or 4159 links remain). Most organizations remained in the same cluster as they were (Figures 4 A and B). The network still had a solid consistency despite the deletion of these links. Some organizations from the blue cluster were relocated to the green cluster. The members of the red cluster remained the same except the NDMO (30). Depending on the nature of the tasks, the CDO (45) continues to work with strategic and military organizations, i.e. the Ministry of Defense and Armed Forces Logistics (1), the Islamic Republic of Iran Army (81) were placed in the blue cluster.

By removing links weighing less than or equal to 2 (44% or 2358 links remain), the number of clusters increased to 4 (Figure 4-C). The blue cluster is mostly unchanged. This indicates strong communication among the members of this cluster. The other two clusters, red and green, in panels A and B in Figure 4 were subsequently rearranged and divided into three clusters. The NDMO (30) is located in the red cluster with three organizations of the PBO (71), the IRIB (20) and the MoI (3). Looking at the size of the green cluster nodes shows that these organizations have a relatively smaller WD than the other three clusters. The Climatological Research Institute (44), the Agricultural Economics Association (78), the Water Resources Management Company (68), the Geological Survey and Mineral Exploration of Iran (69), the Ministry of Agriculture (49) and others are also located in this cluster. These organizations could have joint activities in almost all areas of climate change and land use. Therefore, their placement in a cluster indicates their proper relationship with one another and could bring good results in this area in the case of joint planning and the use of this opportunity. Certainly, there is a need for organizations with high betweenness or eigenvector centralities, such as the NDMO for this coordination. This provides the communication that they need to explain the clear expectations from each of these organizations. The IRIC (16), the commissions of health in parliament (77), the MoHME (47), the UMS (14), and private hospitals (10) also have joint activities in the brown cluster in executive activities. Proper coordination between these organizations could improve the provision of services, especially in the response phase. Obviously, this coordination should take place in the form of working group meetings, joint programs, and scientific and operational exercises prior to the occurrence of the incident. Describing organizational duties and expectations, monitoring and evaluation strategies are inevitable.

In the next step, the number of clusters increased to 5 by removing links of weight less than or equal to 3 (16% or 845 links remain), Figure 4-D. The network is still connected representing that all organizations have at least some strong cooperation with organizations inside the network. We rearranged the node's location to better present the clusters. Purple links between the two red and blue clusters appear to be significant compared to other clusters. Given the presence of the NDMO (30) and the CDO (45) in these two clusters, there is an appropriate relationship between the responsible organizations in DRM. The IRIB (20), the CBOs (23), the Friday Imams Policy Council (72) and the Ministry of Culture and Islamic Guidance (2) are in the mustard cluster organizations. The nature of the tasks of these organizations shows that they could take effective measures to promote public awareness. In the case of proper planning, this would allow access to the first objective of the Sendai Framework, which is understanding disaster risk (2). The striking feature of this cluster is through strong but limited links with red clusters, which are in need of an upgrade. In the purple cluster, organizations involved in climate change maintained their relationship, which shows the strength and coherence of the cluster. Nevertheless, this cluster does not have an effective relationship with yellow and mustard clusters. However, tackling climate change requires education and culture (mustard cluster) measures to prevent and deal with the consequences. The UMS (14), Jahd-e Daneshgahi (13), the MoHME (47), and the commission of health in parliaments (77) are the most important yellow cluster organizations that can play key roles in climate change. Therefore, it is necessary for the NDMO to strengthen its role in facilitating communication between these clusters.

In the last step, links with a weight of less than or equal to 4 (6% or 334 links remain) were deleted (Figure 4-E). Following this, despite the fact that the number of clusters did not change the association of eight organizations was completely interrupted by the network. The disfigured organizations included: Iran Small Industries and Industrial Parks Organization (8), the Islamic Revolution Housing Foundation (9), the Ministry of Education (6), and the Ministry of Industry, Mining and Trade (60). Despite their undeniable role in this area, they can challenge DRM if there is no plan to enhance their communication, especially for prevention. Because according to the Sendai Framework, it is necessary to communicate and cooperate closely with stakeholders, including indigenous people, volunteers, and owners of the professions, for designing and implementing policies, programs and standards (2).

The members of the mustard cluster were active in the military field. This cluster has almost no relation to the purple cluster and is most closely related to the blue cluster. In the blue cluster, the CDO (45) remains the most important organization, while most of the mustard cluster communication is with this organization. Investigating the blue cluster links indicates there is a strong and logical connection between its organizations, which might be very effective in tackling climate change. For example, the link between the organizations of the Ministry of Agriculture (49) and the Iranian Agricultural Economics Society (78) or the relationship between the Iran Water Resources Management (68) and the Ministry of Agriculture (49) and the Climatological Research Institute (44) is fully comprehensible and is the positive point in this cluster. The high WID of the CDO (45) in this cluster is also a strong point, and reviewing the links confirms the authority of this organization among the four other clusters. The NDMO (30) has nearly similar conditions with CDO (45) in the green cluster. However, the CDO (45) receives most of its communication from the mustard cluster, while the NDMO (30) receives links from all clusters in a balanced fashion. As a result, this organization can facilitate the association of the CDO (45) with other stakeholders. Red cluster members are almost all active in the field of health and have good connections with each other. In this cluster, the PBO (71), the Ministry of Cooperatives, Labor and Social Welfare (48) and the Ministry of Economic Affairs and Finance (53) are the organizations expected to play a more effective role in DRM, especially the pre-occurrence of hazards. However, it seems they are almost isolated in the current situation. The political status of these organizations has an important role to play in this area, rendering it to become more involved in this field, for instance through trustee organizations such as the NDMO (30). Despite the change of the network, Figure 4 shows that the NDMO (30), the CDO (45), the Presidential Center for Strategic Studies (66), the MoHME (47), the Ministry of Defense and Armed Forces Logistic (1) retained their status in all five stages of removal of links. In short, it could be concluded that the strength of the DRM network in Iran is the presence of cohesion clusters, in which particular groups work with their members and in parallel cooperate with members in other groups. The group that works on a larger scale can improve the performance of DRM. Moreover, the presence of multiple core organizations spread across all clusters shows that there is not a single core organization responsible for the entire management of disasters. Nevertheless, the NDMO and CDO could theoretically play the role of main cores in the network. Multi-core network help reduce the time performance of the system when a disaster happens and let the organizations get coherent in a shorter time period. The other important fact is the key role of national organizations. The findings also showed that despite the high density in the network, there are weaknesses

in the communications of some organizations. It can be expected that tangible upgrades could be achieved if network communications of DRM stakeholders are improved.

Conclusions

Although reducing the risk of disasters has been conventionally the responsibility of governments in Iran, this, in reality, is a shared responsibility of the government and relevant stakeholders. We used different centrality measurements (degree, in-degree, out-degree, betweenness, closeness, and eigenvector centralities) to find effective organizations in the DRM network. In particular, CBOs, as enablers, play an important role in helping the government comply with national policies and laws at the local, national, regional and global levels. Governments can use social network analysis to make policy, regulation, and culture-building. Our assessment of the stakeholders in the DRM network in Iran demonstrated a good coherence. The network includes three clusters of organizations with different responsibilities (the theoretical basis of management, operational and executive affairs, and policy affairs), most of whom collaborate with their members strongly. Removing less weighted links in the network reveals that there are some more coherent clusters inside the main three clusters. In order to strengthen DRM (especially prior to the occurrence of hazards), and implement the Sendai Framework, it is necessary to define the organizational tasks and the participatory plan. Needless to say that transparent process of accountability, monitoring, evaluation, and reporting on the progress of work need to be also explained. To improve the analysis, it would be worthwhile to monitor and compare the network of organizations before and during disasters, periodically.

In addition, SNA could provide a visual and tangible picture of the status and interrelationships among the stakeholders and identify groups with better interaction using community/cluster detection and modularity optimization methods in other issues. Also, it could determine the role and importance of different organizations, their weakness, and strong points and help them to plan to strengthen their roles and solve their problems.

Abbreviations

No

Abbreviations

Stands for

1

SNA

Social Network Analysis

2

YLL

Years of Life Lost

3

LMICs

Low and Middle-Income Countries

4

DRM

disaster risk management

5

ICS

incident command system

6

FEMA

Federal Emergency Management Agency

7

NDMO

National Disaster Management Organization

8

CDO

Civil Defense Organization

9

WD

Weighted Degree

0

WID

Weighted In-Degree

11

WOD

Weighted Out-Degree

12

PBO

Plan and Budget Organization

13

MICT

Ministry of Communications and Information Technology

14

IRCS

Iranian Red Crescent Society

15

MoI

Ministry of Interior

16

IRIB

Islamic Republic of Iran Broadcasting

17

MoHME

Ministry of Health and Medical Education

18

UMS

Universities of Medical Sciences

Declarations

- Ethics approval and consent to participate

  This research has acquired the approval of Tehran University of Medical Sciences' Institutional Review Board (IRB). The IRB follows the stipulated clauses of the Helsinki Declaration. In observing ethical considerations, the participants were informed about the objectives and importance of the study. Participants were also reassured that the information obtained was for research purposes. The approval code to do the research is Ir.tums.sph.rec.1396.4315 on 22 January 2018.

- Consent for publication

  Not applicable

- Availability of data and materials

  Supplementary data is Centrality indices in the Organizations (Table 3).

- Competing interests

  We declare that none of the authors or their organizations has any conflict of interest in the publication of this paper.

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- Authors' contributions

  -Conception and design: Homa Yousefi Khoshsabegheh

  - *Acquisition of data:* Homa Yousefi Khoshsabegheh

  - *Analysis and interpretation of data:* Homa Yousefi Khoshsabegheh, Leila Hedayatifar

  - *Drafting of the manuscript:* Homa Yousefi Khoshsabegheh, Abbas Ostadtaghizadeh

  - *Critical revision of the manuscript for important intellectual content:* Ali Ardalan, Amir Hossein Takian,

  - *Statistical analysis:* Homa Yousefi Khoshsabegheh, Leila Hedayatifar

  -Administrative, technical, or material support: Homa Yousefi Khoshsabegheh, Ali Ardalan, Amir Hossein Takian, Abbas Ostadtaghizadeh, Behnam Saeedi

  - *Supervision:* Ali Ardalan, Amir Hossein Takian, Abbas Ostadtaghizadeh

  - *Other/s (specify):* Amir Hossein Takian (English proofreading)

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- Number of figures and tables

  4 Figures, 2 Tables

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Tables

Table 1: Name of the organizations and the number assigned to them.

Node Number	Node Name	Node Number	Node Name
1	Ministry of Defense and Armed Forces Logistic	44	Climatological Research Institute
2	Ministry of Culture and Islamic Guidance	45	Civil Defense Organization of Iran (CDO)
3	Ministry of Interior (MoI), Provincial government, Governorate, Regional government	46	Law Enforcement Force of the Islamic Republic of Iran
4	Iranian Meteorological Society	47	Ministry of Health and Medical Education (MoHME)
5	National Fire and Safety Service of Iran	48	Ministry of Cooperatives Labor and Social Welfare
6	Ministry of Education	49	Ministry of Agriculture
7	Banks	50	Ministry of Science, Research and Technology
8	Iran Small Industries and Industrial Parks Organization	51	The Organization for Mobilization of the Oppressed
9	Islamic Revolution Housing Foundation	52	Iran Civil Aviation Organization
10	Private Hospitals	53	Ministry of Economic Affairs and Finance
11	International Institute of Earthquake Engineering and Seismology	54	Life Saving and Diving Federation
12	Road Maintenance and Transportation Organization	55	Iranian Blood Transfusion Organization
13	Jahd-e Dneshghi	56	Real Estate Registration Organization of Iran
14	Universities of Medical Sciences (UMS)	57	Iranian Artists Forum
15	Research Centers	58	National Organization for Civil Registration
16	Iranian Red Crescent Society and Related Subsets (IRCS)	59	Ministry of Roads and Urban Development
17	State Welfare Organization of Iran	60	Ministry of Industry, Mine and Trade
18	Social Security Organization	61	Ministry of Petroleum
19	Islamic Development Organization of Iran	62	Ministry of Energy
20	Islamic Republic of Iran Broadcasting (IRIB)	63	Statistical Center of Iran
21	Department of Environment	64	Mobilizing the Medical Society Organization
22	Atomic Energy Organization of Iran	65	Telecommunication Company of Iran
23	Community Based Organizations (CBOs)	66	Presidential Center for Strategic Studies
24	Ports and Maritime Organization	67	Ministry of Foreign Affairs
25	khatam-al Anbiya Construction Headquarters	68	Iran Water Resources Management
26	The Center for Urban and Architectural Studies and Research	69	Geological Survey and Mineral Exploration
27	Pasteur Institute or Iran	70	National Cartographic Center
28	The Guardian Council	71	Plan and Budget Organization (PBO)
29	National Iranian Oil Refining and Distribution Company	72	Friday Imams Policy Council
30	National Disaster Management Organization (NDMO)	73	Technology and Innovation Cooperation Center
31	Forests, Range and Watershed Management Organization	74	Iranian Legal Medicine Organization
32	Nursing Organization	75	Psychology and Counseling Organization
33	Iran Medical Council	76	Ministry of Communication and Information Technology (MCIT)
34	Engineering Organization	77	The commission for health in the parliament
35	International Organizations	78	Iranian Agricultural Economics Society
36	Various Insurance Organizations	79	General Directorate of Endowments and Charity Affairs
37	Mountaineering Federation	80	Iran Airports and Air Navigation Company
38	Iran Meteorological Organization	81	Islamic Republic of Iran Army
39	Islamic Revolutionary Guard Corps	82	The Islamic Republic of Iran Railways
40	Iran Municipalities and Village Administrators	83	General Inspection Organization

41	City and Village Councils of Iran	84	Judicial System
42	Imam Khomeini Relief Foundation	85	Militia Volunteer Force
43	Out of Health System Research Centers		

Table 2: Characters of experts participated in the Delphi process.

Characteristic	No (%)	Characteristic	No (%)	Characteristic	No (%)
Sex		**Education**		**Job Place**	
Male	16 (72.7)	Bachelor Master	3 (13.6)	Governmental	17 (77.3)
Female	6 (27.3)	Doctorate and upper	7 (31.8)	Non-governmental	5 (22.7)
			12 (54.6)		
Age		**Job History (Years)**		**Kind of Reviewed Organization**	
30-35	6 (27.3)	50-10	5 (22.7)	Governmental	58 (68.2)
36-50	8 (36.4)	11-15	9 (40.9)	Non-governmental	27 (31.8)
50 and more	8 (36.4)	More than 15	8 (36.4)		

Figures

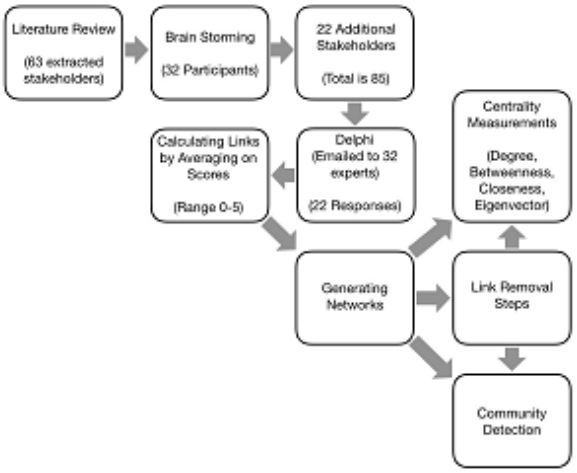


Figure 1

A schematic view of the process of data preparation and network analysis.

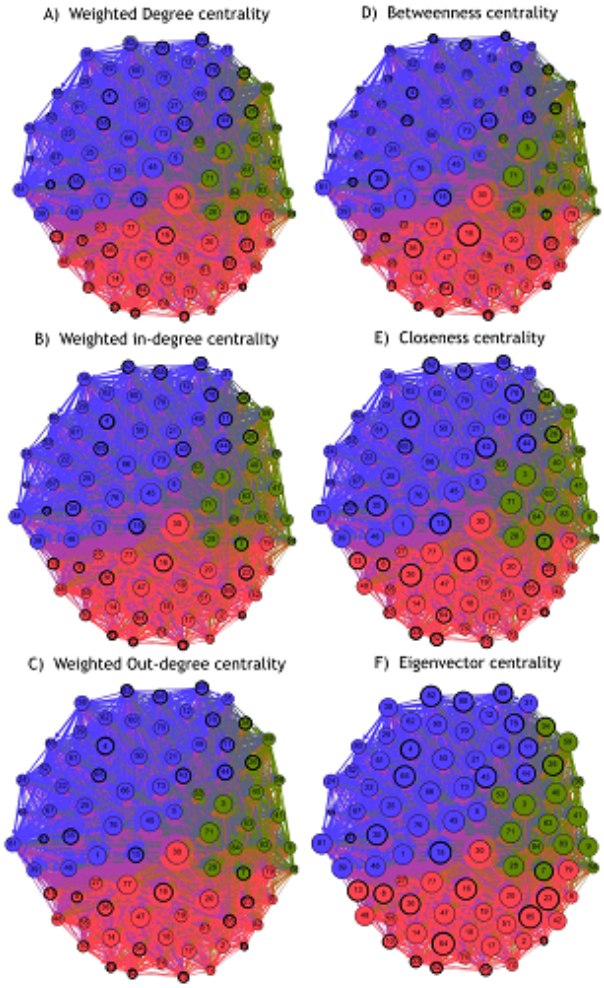


Figure 2

Overview of network centrality indicators of Iran' s disaster risk management (85 organizations and 5370 links). Three clusters have been identified through the modularity optimization methods that are shown with different colors. Each panel represents the importance of organizations regarding a centrality measurement (the title of the panels). Non-governmental stakeholders are also featured with the bolder margin nodes.

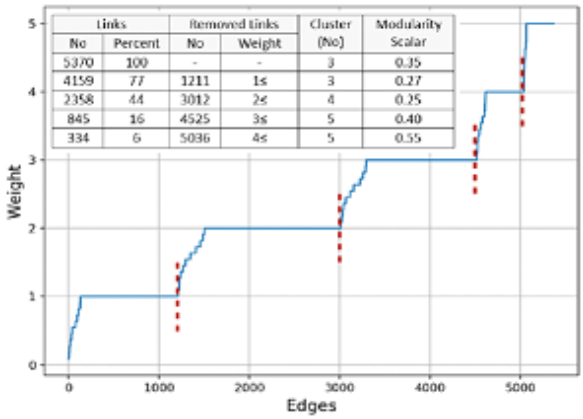
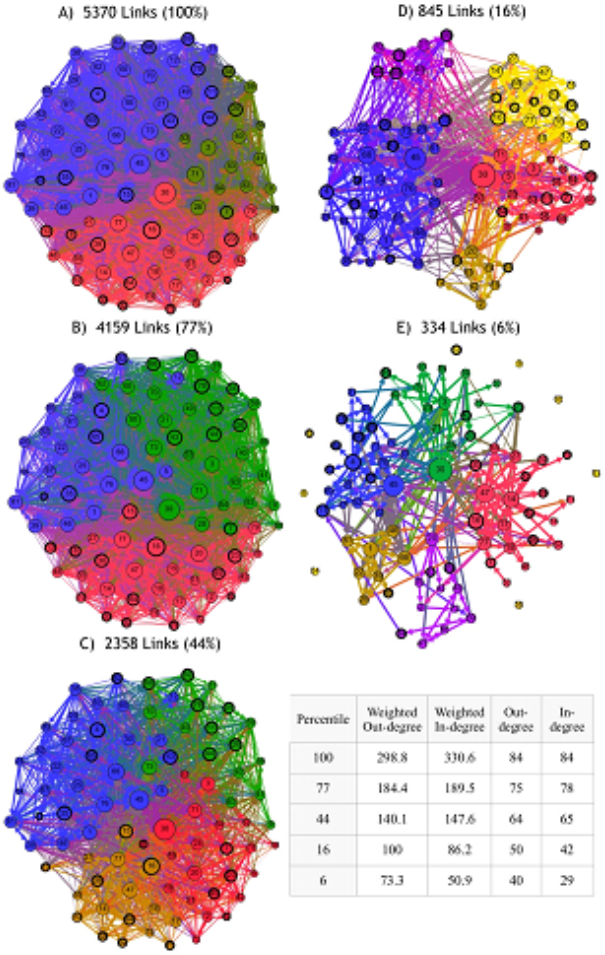


Figure 3

Number of edges that had weights less than or equal to the weights shown on y-axes. Red dashed lines represent the threshold of link removal in each stage. The inside table shows the total number of links, their percentage, number of removed links and number of detected clusters.



Percentile	Weighted Out-degree	Weighted In-degree	Out-degree	In-degree
100	298.8	330.6	84	84
77	184.4	189.5	75	78
44	140.1	147.6	64	65
16	100	86.2	50	42
6	73.3	50.9	40	29

Figure 4

Network view of Weighted Degree Centrality after Network graph reduction. Title of the panels represents the number and parentage of present links in the network after removing weak links. The right bottom table displays the centrality indicators in each of the stages of deletion.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Supplementary.docx