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Dynamics of coordination-clusters in long-term rehabilitation

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Abstract

Purpose – The purpose of this paper is to introduce a novel approach to studying disaster management operations: the emergence of coordination-clusters in long-term rehabilitation projects and innovation dynamics in coordination-clusters.

Design/methodology/approach – The problem addressed is examining the coordination dynamics in long-term rehabilitation operations. A mixed methods research approach was adopted where a combination of qualitative and quantitative techniques was used for data collection and analysis to study the phenomenon of the coordination evolution in long-term rehabilitation projects.

Findings – The results indicate resilience in the behavior of involved actors from different organizations as they re-organize into coordination-clusters and collectively work to overcome the unfolding challenges of long-term rehabilitation projects in areas affected by major disaster.

Research limitations/implications – The results provide some answers to the question of how to map and analyze the phenomenon of coordination-clusters and their consequent coordination dynamics, and thereby steps to redesign the approach to execute long-term rehabilitation projects in places affected by major disasters.

Practical implications – The combination of Actor-network theory and critical incident technique with social network analysis and community detection provides an integrated network-based view of coordination dynamics in long-term recovery operations. Such perspective would broaden the empirical basis for the planning and management of complex disaster management operations.

Originality/value – The results of the research offer a new approach to study coordination dynamics in disaster management operations. The proposed method provides a tool to examine the evolution of processes involved with the recovery phase of a disaster management cycle.

Keywords Disaster relief operations, Crisis management, Development aid logistics, Collaborative innovation, Coordination-clusters, Interorganisational coordination

Paper type Research paper

Introduction

Disaster and emergency events create a social disturbance to the daily routine of communities with potential losses in lives and property damage (Dynes and Aguirre, 1979; Lindell *et al.*, 2001; Quarantelli, 2005). Entities from different backgrounds (public and private) institutions, non-profits, community-based associations and volunteers work together to save lives, limit damages and restore daily routine in the affected communities. Disaster management processes involve different organizations that carry out different tasks during disaster management cycles. Customarily, a disaster management cycle consists of four phases: mitigation, preparedness, response and recovery. Disaster management processes are the product of collaborative work carried out by different organizations to cope with the complex conditions that accompany disaster and emergency events. However, the diversity of groups involved during a disaster management cycle creates a challenging environment for interorganizational coordination. Some of those challenges may result from the operational practices of

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governmental agencies, nongovernmental organizations (NGO) and private organizations as they follow independent hierarchies and pre-set goals (Kapucu, 2005, 2009; Comfort and Kapucu, 2006; Comfort *et al.*, 2010, 2014; Weber *et al.*, 2012; Kapucu and Garayev, 2013).

The presented work in this paper examines the dynamics of networked collaboration in long-term recovery and the fluid clustering dynamics of its operations over time following the 2004 Tsunami disaster in India. The relief operations investigated are based on a case-study data set of a collaborative relief effort that involved a mix of global and local organizations operating in the region (Weber *et al.*, 2012). Very often, such a combined effort leads to an imbalance between global and local actors with regards to resources and accountability. Local actors, like local NGOs (LNGOs) in vulnerable regions, tend to be small in capacity and less powerful in technologies and in organizational capabilities (O'Brien, 2010). Despite that fact, LNGOs are more relevant than global actors (i.e. foreign aid organizations) when it comes to the local sustainability of disaster management outcomes (Bennett *et al.*, 1995). Executing operations in those settings required complex intercultural and technical collaboration between organizations (Turner, 1976; Mendonça *et al.*, 2007).

The challenging management conditions associated with the disaster management processes put pressure upon the existing structures of organizations and entities involved during initial response operations and afterwards during the recovery operations. In the initial relief process, information is preliminary, aid is time critical and competition over resources between organizations is strong. Therefore, governance structure needed to shift away from the existing hierarchical structure into ad-hoc collaboration modes. Successful parties form network-based structures to work together toward shared goals, responsibilities and unified action to produce a common outcome (Benini, 1999; Kapucu, 2005; Moynihan, 2009; Abbasi and Kapucu, 2012; Kapucu and Garayev, 2013; Weber *et al.*, 2015).

In disaster management research, the networked-coordination and emerging coordination groups were recognized by a number of researchers (Kapucu, 2005; Comfort and Kapucu, 2006; Moynihan, 2008, 2009; Abbasi and Kapucu, 2012; Butts *et al.*, 2012; Kapucu and Garayev, 2013; Boersma *et al.*, 2014). Yet, collaboration problems in network-based settings were treated with concepts that are rooted in individual behaviorist approach. This conceptual problem reveals some hidden practical problems in strategic management and planning during disaster management. Moreover, there is a lack of proper tools to study networked-coordination and characteristics of emerging coordination groups in disaster management (Weber *et al.*, 2012; Noori *et al.*, 2016a).

In this paper, we apply a combination of qualitative and quantitative methods to study the topic of interorganizational coordination dynamics of collaborative networks in disaster management operations. Noori *et al.* (2016a, b) proposed a mixed method approach to study interorganizational coordination in network-governed structures based on using coordination theory (Malone and Crowston, 1990, 1994) in combination with social network analysis (SNA) and community detection techniques in complex networks. However, the proposed method was devised to examine coordination dynamics inside emerging network structures during disaster response operations (i.e. response phase) (Noori *et al.*, 2016a, b).

The above method lacked the ability to accommodate long-term characteristic, nature of events development and type of actors involved during the recovery phase. Yet, Weber *et al.* (2014, 2015) examined evolution of collaboration in emerging networks during long-term recovery operations. The work by Weber *et al.* (2012, 2015) followed a qualitative approach where actor-network theory (ANT) and critical incident technique (CIT) were used to extract critical information about actors involved and actions taken in the recovery networks at both local and global levels. Therefore, a new method was developed whereby: ANT and CIT methods are used to extract the coordination network specifics in the recovery operations; and SNA combined with community detection algorithms were used to visualize and examine the emerging coordination structures (or coordination-clusters Noori *et al.*, 2016b) during the long-term recovery operations.

The findings showed a constant pattern of emerging coordination-clusters and innovative actions throughout the rehabilitation operation that is governed by the rising demands in response to disturbances caused by the critical incidents (CIs). Such findings help advance our understanding of the evolution of interorganizational coordination and the dynamics in organizational collaborative networks in unstable environments and complex situations.

The work presented in this paper is the first single case study (Eisenhardt, 1989; Yin, 2009) that investigates long-term disaster management in Tamil Nadu, which is India's most affected state during the 2004 Tsunami disaster (Weber *et al.*, 2012). Weber *et al.* (2015) examined three innovative and successful emerging relief networks of organizations executing rehabilitation projects after the 2004 Tsunami in the Tamil Nadu region. The organizational networks were compared from both ad-hoc to long-term collaboration perspectives (Yin, 2009; Turoff *et al.*, 2013; Weber *et al.*, 2015). The units of analysis are the emerging organizational collaborative networks involved in the rehabilitation projects. Primary and secondary data, interviews and context material were plotted and evaluated for detailed analysis of heterogeneous network-actors following grounded theory principles (Glaser and Strauss, 1967).

The findings' main implication for corporate planning concerns organizational preparedness for emerging coordination-clusters. First, the initial development of the response network in disaster management is truly based on a heterogeneous worldview. Second, however, the idea of a uniform common situational awareness is still necessary to the evolution of such collaborative networks. Third, governmental and donors agencies, have to learn to identify and support such local emerging networks and to restrict the influx of transnational NGOs without local ties in order to reduce problems of competition, contact overloads, the explosion of market prices and skilled labor fluctuation. The proposed analysis framework implication for research is that dynamic innovation networks (DINs) emerge right from the beginning and evolve dynamically based on the occurrence of CIs over the course of a disaster management cycle. In order to tackle coordination problems in unpredictable settings, a conceptual shift from traditional theories of individual behavior to more real world evidence and complex systems approaches seems overdue in disaster management research (Weber, 2016).

The following sections of the paper provide a background to the work presented, including a sample network from the case study, and details of the adopted research method. The results section shows the stepwise evolution of coordination-clusters in the collaborative network over period of years (2004-2010). New insights obtained by this clustering analysis have useful implications for the work of all practitioners of long-term relief. The final section covers a discussion of the results, the limitations and the conclusion of the work presented in the paper.

Dynamics in disaster relief networks

Disaster management processes are the product of collaborative work carried out by different organizations to cope with complex conditions that usually accompany disasters.

To understand the dynamics of disaster management operations, we need to look at the processes system as a network-governed structure, where all actors work toward shared goals, responsibilities and unified action to produce a common outcome (Kapucu, 2005; Moynihan, 2009; Abbasi and Kapucu, 2012; Kapucu and Garayev, 2013). Interorganizational networks involved in disaster management change and re-structure throughout the different stages in the long term. Global and local actors have to perceive changes in their environment and to adapt their activities accordingly. While the evolution of response operations depends on the given conditions of the disaster itself, the recovery operations of disaster management depend on the actor networks on site. In the initial days and weeks, urgent demand requires action to protect lives and rescue injured and vulnerable populations. Only in later stages only, information becomes available and used for the long-term restoration of livelihoods. Full information, again, is never possible, as the crisis environment changes constantly, no longer evolving from disaster but from reconstruction. The ways in which disaster management transitions from one phase to the next can be neither described nor defined.

Research on cooperation within organizational networks in disaster management recognizes that resources scarcity, communication and cooperation are factors hindering an effective disaster response (Balcik *et al.*, 2010; Boin and Hart, 2003; Comfort, 1990; Kapucu, 2005). However, according to the literature, studies on later stages of recovery or on the full cycle of disaster management are rare due to a focus on emergency assistance and humanitarian logistics. Thus, selective and not comprehensive disaster management strategies gain support from the academic side while applicable knowledge is needed to fulfill the requirements not only of effectiveness but also of sustainability (Weber *et al.*, 2012, 2015).

The network-based approach to investigate multiple actors' settings could bear answers to provide a structure analysis of the complex environment created by disasters. Network analysis is used from physics to information systems, from sociology to political and management theories. The rising interest in network concepts relates to the spread of new technology, social media and the personal experience of "living in a small world" (Watts and Strogatz, 1998) or "being linked" (Barabasi, 2003). ANT is one of the traditional network approaches, which was developed to analyze dynamics and change by historically retracing the emergence of macro-actors. It associates human actors with technical artifacts, according them the same significance and thus proposing theory for understanding today's socio-technical figurations (Latour, 1999; Tatnall, 2011). Network evolution and governance are all but strategic choices of single actors where the network formation translates to successful alignments of interests of a multitude of actors. ANT allows an internal analysis of networks and through a focal actor, in contrast to positivistic approaches that take an external, as from above perspective. Mapping the mobilization of local and global actors in an actor-network environment facilitates the examination of actors' involvement in disaster management (Stanforth, 2006). In global disasters the link of these "network sub-regions" is of crucial importance to realizing the orchestration of coordinating on different local and global levels during relief operations (Dorogovtsev and Mendes, 2003).

To extract relevant aspects of the organizational networks engaged in disaster management operations, ANT was used to understand the transition between the different stages of disaster management. However, the ANT limitation in providing an abstract level of the network, another tool was used to remedy such shortfall. CIT was employed to help construct an event structure analysis that provided information of crucial events in details.

In a typical global disaster management network, it is observed that heterogeneous network actors emerge with public and private funding for the implementation of envisaged rehabilitation programs. Those programs take place over a certain period of time with critical milestones regarded as obligatory points of passage. Nonetheless, the start and end dates of those projects do not necessary mean beginning and end points of network dynamics. Actors in response networks range from the donor side – private and public supra-national institutions or foreign private donors – to the beneficiaries' side at the local level, connected through different intermediary organizations and actors.

Coordination clustering in recovery stages

There are four distinct stages to a disaster management cycle: mitigation, preparedness, response and recovery (Public Safety – Government of Canada, 2011; Department of Homeland Security, 2013). The disaster management cycle comprise a set of protocols and frameworks called disaster management plans or frameworks. Those protocols facilitate interorganizational and intraorganizational communications, coordination and collaboration throughout the different stages of a disaster management cycle (Bigley and Roberts, 2001; Lindell *et al.*, 2001; Comfort and Haase, 2006; Moynihan, 2009; Richter *et al.*, 2010; Bram and Vestergren, 2011). Figure 1 is an illustration of the disaster management cycle.

The recovery stage (or post-disaster phase) in a disaster management cycle is the focus of this research. The recovery stage is the final stage of the disaster management cycle during which actions are taken to repair, rebuild and construct damaged properties and to restore a community's disrupted social routines and economic activities. Recovery activities typically center on the provision of aid for temporary housing and residential reconstruction, the restoration and reconstruction of public infrastructure and facilities, and the provision of assistance to households and businesses that experienced physical damage and other losses (Public Safety – Government of Canada, 2011; Bram and Vestergren, 2011; Department of Homeland Security, 2013).

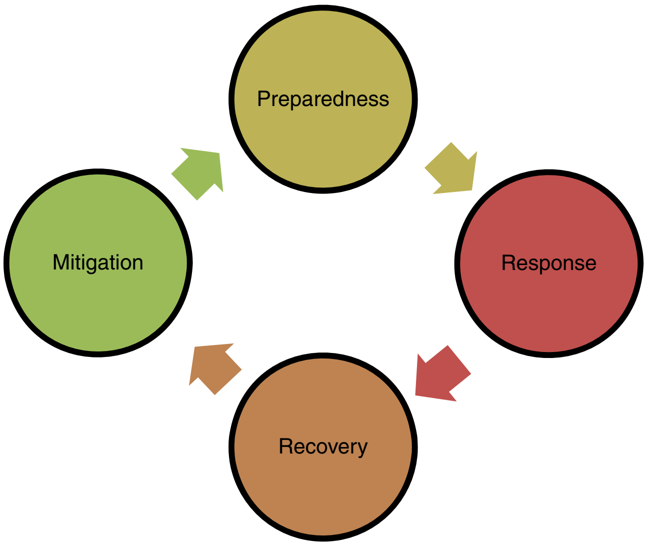


Figure 1.
The four stages of the disaster management cycle

During the recovery phase, small and large-scale organizations from different backgrounds collectively coordinate relief efforts to assist the affected population. Interorganizational coordination becomes a critical factor to the success or failure of disaster response operations at different stages (Hossain and Kuti, 2010; Kapucu *et al.*, 2010). The wide spectrum of parties involved in response operations, from macro institutions to micro individual, creates a set of complex relationships that needs to be identified and whose different contributions need to be mapped and measured (Kapucu, 2005; O'Sullivan *et al.*, 2013).

The disruptive nature of disasters forces high levels of uncurtaining, dislocation and trauma. Such conditions require a dynamic response and an adaptive organizational structure to cope with the intense changes resulting from those disruptions (Dynes and Aguirre, 1979; Kapucu, 2009; Topper and Lagadec, 2013). Therefore, during disaster management operations there are different network structures called coordination-clusters (Noori *et al.*, 2016b) would emerge at different levels of interactions inside the overall operations. What was observed from studying coordination-clusters is the adaptive behavior of coordination-clusters proves a great deal of resilience in the networks behavior during response operations.

Hence, coordination groups are recognized by several scholars in the disaster management field (Comfort and Haase, 2006; Butts *et al.*, 2012). Clustering structures form in response to the escalating series of unexpected events in a disaster and according to the availability of resources, such as personnel, equipment, supplies and funds. These structures are dynamic and change in nature (number of actors or organizations) throughout the disaster management stages (Noori *et al.*, 2016b).

To study the characteristics of coordination-clusters in relief networks, ANT and CIT were applied as a framework to identify organizations (or actors) involved, CIs, activities coordinated, and identify actions and tasks required to overcome obstacles and achieve common goals of rehabilitation projects in the areas affected during 2004 Tsunami in India (Weber *et al.*, 2012, Weber, 2016). Examples of such CIs in the recovery operations of post disaster rehabilitation projects are: lack of resources like crews, equipment, public disagreement, scarcity of funding and others.

The process of investigating the formation of coordination-clusters and the actions to overcome disruptions will contribute to a better understanding of the coordination dynamics during the long-term rehabilitation operations. Therefore, it is essential to examine existing disaster management systems to reach clear insights that can contribute to improving the reality of disaster management.

Research method and data analysis

In this paper, we focus on addressing the phenomenon of interorganizational coordination during the recovery phase of a disaster management cycle. The research method applied is an expansion of a framework that was devised to examine interorganizational coordination during the response phase (Noori *et al.*, 2016a, b). However, in this paper we modify the method to investigate coordination dynamics in rehabilitation projects. Unlike during the response phase, the occurrence of disruptive incidents during the recovery phase is less intense, with restoration operations requiring a longer time span that can last for years.

Thus far, coordination dynamics in long-term rehabilitation operations includes several variables such as the human factor, resources, ethics, authority, trust, coordination and the unexpected natural development of the disaster events themselves (Weber *et al.*, 2012). Therefore, to handle the complexity of the problem at hand, we followed a mixed methods research approach (Johnson and Onwuegbuzie, 2004; Johnson *et al.*, 2007; Creswell, 2013). Using the mixed methods research enabled us to combine qualitative and quantitative theories and methods for data collection and data analysis to study the phenomenon of interorganizational coordination in long-term rehabilitation operations in a disaster management network.

In the qualitative section, textual analysis in combination with ANT and CIT were used to extract details of actors and event involved with the rehabilitation operations in the Tamil Nadu region. The extracted data from the rehabilitation operations were cataloged and organized based on the type of the CIs, the organization (actor) and the year when the CI took place. Table AII is the full of CIs over the period from 2004 to 2010 for the sample case study. In the quantitative section, SNA and community detection algorithm were used to construct visual representation of the organizations and associated CIs and afterwards extract the coordination-clusters of organizations with common CIs. The clusters show organizations working together in tackling common CIs occurrences during the execution of rehabilitation projects.

The case-study method (Eisenhardt, 1989; Yin, 2009) was followed to investigate the long-term rehabilitation operations in Tamil Nadu, India's most affected state during the Tsunami disaster in 2004. The qualitative methods applied, ANT and CIT, were combined in a process study triangulating interview data, contextual data and newspaper clippings (Van de Ven, 2007). The utilization of CIT provided a description to the course of action followed by involved actors.

Developed as a method for investigating aviation incidents (Flanagan, 1954), CIT applies to case studies of small number of actors indicating sequential incidents of a process. Nonetheless, CIT method cannot reveal cause-effect-relations. CIs are defined as "key event (pos. or neg.) that influenced or changed plans or ongoing operations of an actor in disaster management." The weakness of the method consists in its limited reach and the bias of reconstructing reality. The bias was addressed by framing interviews systematically with questions and formal introduction. On the other hand, CIT offers considerable advantage focusing on activities for their effect in the course of a complete process instead of focusing on mere perceptions. The fact that CIT captures negative incidents makes it even sounder as a tool for disaster management research (Weber *et al.*, 2014).

Data analysis of ten in-depth interviews and secondary data are carried out in ATLAS.ti 6.2 in a mixed coding approach inspired by grounded theory starting with an inductive generation of codes and a second step of theoretical coding (Glaser and Strauss, 1967). The Atlas.ti is among the most used computer assisted qualitative data analysis software programs, recently in its ATLAS.ti 7 version (Friese, 2014). It operates textual data stored in hermeneutic units (HUs) that can contain voluminous and different data files. These files can be shared for virtual collaboration in a research project.

The basic unit of a HU is a primary document (PD). Within a PD, the software allows the coding of text or visual data in many different ways (automatic coding, in-vivo coding and many more). Codes, quotes and memos are basic elements of data analysis. ATLAS.ti 7.0 provides, in addition, analytical operations as frequency counts, cross-tabulations, a complex query-tool and network-view functionality. Voluminous data can be interpreted in systematic and collaborative ways, which improves results and the validity of results of a qualitative research study.

ATLAS.ti was used in a study on DINs and foresight in global relief operations to explore primary (interviews of NGO directors, donors and government agents) and secondary data (annual reports, contracts, newspaper clippings) on relief after

Tsunami 2004 (Weber *et al.*, 2015). Table I represents an example of CIs coding in both ANT and SNA networks. The full list of the coding is included in Table AI.

The time frame of the data samples starts from 2004 when the Tsunami disaster took place until 2010 when the rehabilitation operations were halted. The results from the textual analysis are organized in a table that represents CIs associated with every actor involved in the network during rehabilitation programs of the disaster recovery phase. After constructing individual ANT networks for each year, SNA was applied to map the actors and associated CIs involved in the rehabilitation operations over seven years (from 2004 to 2010). Figure 2 is a sample of CI mapping per actor network only for the year 2005.

The results of using ANT, CIT and SNA methods provided a static perspective for the interactions among network members and processes executed based on the network members' behavior. In order to examine the dynamics of processes evolution inside the networks, it was crucial to include the time factor and order of social interactions in order to examine patterns of evolution of social behaviors in a network (Berger-Wolf and Saia, 2006; Chu *et al.*, 2013; Wolbers *et al.*, 2013; Weber *et al.*, 2014; Noori *et al.*, 2016b). Incorporating the time factor is considered a critical element that enables a close observation of the patterns of coordination in the emerging innovation networks (Weber *et al.*, 2014, 2015). The series of network graphs over the duration of the rehabilitation projects produced a dynamic perspective of collaboration evolution inside the actor networks.

Afterwards the community detection algorithm, Louvain algorithm (Blondel *et al.*, 2008), was applied to examine the emerging coordination- clusters in the network graphs of the snapshots of the operations. There are several algorithms that are based on a different principle to divide a network and detect clusters such as number of nodes or number of links or average number of nodes/links per cluster (Fortunato, 2010; Leskovec *et al.*, 2010). Those methods require initial values to the size of clusters, which was not suitable for the purposes in this paper because it is fundamental to have the ability to detect emerging structure without having a biased initial value. Therefore, the employed method was based on the cluster or partition modularity values. The modularity is a scalar value between −1 and 1 that measures the density of links inside a cluster or partition as compared to the links between communities (Fortunato and Barthelemy, 2007; Blondel *et al.*, 2008; Fortunato, 2010). Community detection methods are used to detect or partition static network or single snapshots. Therefore, some algorithms can produce inconsistent data if they were used for evolving networks. Yet, Aynaud and Guillaume (2010) pointed out the suitability of the Louvain method for detecting communities in evolving networks (Aynaud and Guillaume, 2010). In addition, the Louvain method is well known for the high quality of its partitions and its speed (Leskovec *et al.*, 2010; Waltman and van Eck, 2013). Figure 3 illustrates an example of the CI-based coordination-cluster in a network snapshot of the actor network of the sample case study.

Critical incident ANT code	Critical incident SNA Code
CI lack of resources	CI-1
CI cooperation need assessment	CI-2
CI lack of information	CI-3
CI innovative action	CI-4
CI distribution	CI-5
CI new partner	CI-5

Table I.
Code key for the critical incidents (CI)

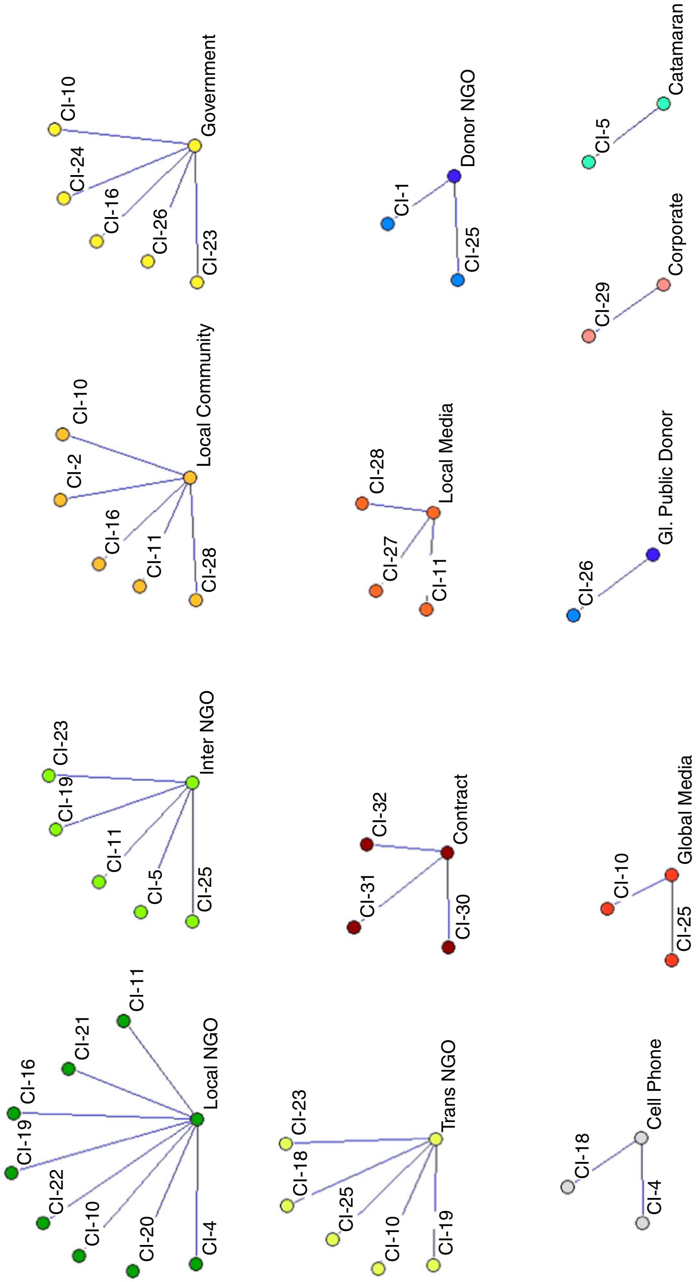


Figure 2.
SNA of CIs mapping of key actors involved in long-term rehabilitation operations, 2005

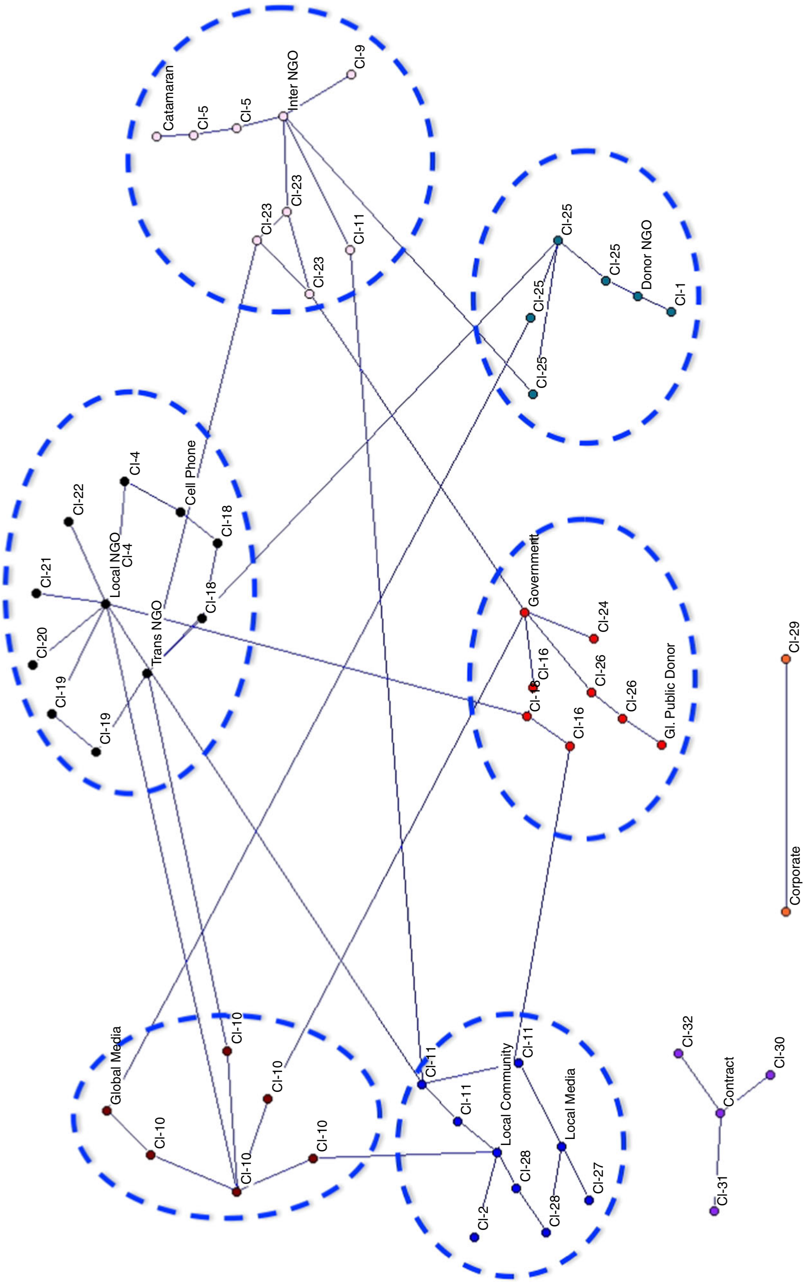


Figure 3.
Coordination-clusters in rehabilitation operations in the emerging Enayam network, 2005

Furthermore, some network analysis metrics such degree of centrality, closeness and cliques are used to measure organizational network characteristics. Degree of centrality provides information about the organization's (or unit's) position within the network whether it occupies a central or a more peripheral position in the network based on the number of network ties maintained with other members. The degree of centrality is based on the number of links maintained by an organization with other members in the network (Jackson, 2008a, b; Rodriguez *et al.*, 2010). Table II shows values of the degree of centrality are listed for the 2005 Enayam network. Figure 4 shows the coordination-clusters from Figure 3 in addition to the degree of centrality values included for nodes inside those cluster.

Finally, the analysis of an organizational network facilitated a better understanding to the structure and the formation of interorganizational relationships between the nodes (organizations) and formations of their links (Zaheer *et al.*, 2010). Using network analysis can help examine the impact of network ties on organizational performance, examine links that are most or least beneficial to the network members, locate which nodes are most influential in the network, and finally determine which changes in the organization or unit position can influence the network.

Case study: Tamil Nadu 2004-2010

Since the 1980s the small NGO DAN[1] works in coastal villages to support economic and social development, supported by foreign donors and the Indian Government with a focus on women micro saving groups. When the 2004 Tsunami washed away villages, livelihoods and saving groups within hours, the disaster shattered the socio-economic fabric of the coastal region for years.

Alerted by villagers' cell phones, the director and DAN staff got involved from the first day: bringing the injured to nearby hospitals, removing debris and distributing water, food, clothes and blankets. Already within first days, contacts were made with global NGO partners, again by cell phone. During months and years of disaster management in a particular colony in Tamil Nadu, the arisen actor-network provided fishing equipment to 250 fisher families, organized medical and psychological care, provided counseling and training on counseling, initiated night-schools for the children. The networked relief turned out to be not only efficient but also highly innovative. In terms of gender empowerment, it started saving groups for men and training in electronics and boat engine repair for women. Against initial resistance from global non-profit partners it went into co-venturing operations with a private for-profit partner to build a technical workshop. Inventing "distribution cards" solved distribution and duplication problems. For medical care, an emergency tent to avoid overcrowded hospitals was created locally, and later, as a local need for psychological counseling became apparent, special trauma trainings were invented. Night-school education for children started, many of the students being semi-orphaned. The network even succeeded in getting the activity adopted by the government, once foreign support ended in the late 2000s.

It was the first time DAN was part of a disaster management network. As an organization it was neither prepared for catastrophes nor for rehabilitation. Its strategy was protective and entrepreneurial from the beginning, and reluctant toward media and contacts outside the trusted network. The DIN still faced typical problems and failures, especially in distribution, poor quality of delivered catamarans, accounting problems with global donors and high fluctuation of skilled labor. As Tsunami 2004 broke all records in terms of global media coverage, foreign

Node no.	Degree of centrality	Code
1	8	Local NGO
2	5	CI-10
3	2	CI-17
4	1	CI-18
5	1	CI-19
6	2	CI-4
7	3	CI-15
8	1	CI-20
9	4	CI-11
10	5	TransNGO
11	2	CI-17
12	2	CI-10
13	3	CI-21
14	2	CI-6
15	4	CI-23
16	5	InterNGO
17	2	CI-5
18	1	CI-9
19	2	CI-21
20	2	CI-11
21	2	CI-23
22	5	Government
23	2	CI-24
24	2	CI-10
25	1	CI-22
26	2	CI-15
27	2	CI-21
28	3	Local Media
29	1	CI-25
30	2	CI-26
31	2	CI-11
32	2	Global Media
33	2	CI-10
34	2	CI-23
35	1	Gl. Public Donor
36	2	CI-24
37	2	Donor NGO
38	2	CI-23
39	1	CI-1
40	5	Local Community
41	2	CI-15
42	2	CI-10
43	2	CI-26
44	2	CI-11
45	1	CI-2
46	1	Corporate
47	1	CI-29
48	3	Contract
49	1	CI-12
50	1	CI-27
51	1	CI-13
52	2	Cell Phone
53	2	CI-6
54	2	CI-4
55	1	Catamaran
56	2	CI-5

Table II. Degree of centrality for the 2005 Enayam network

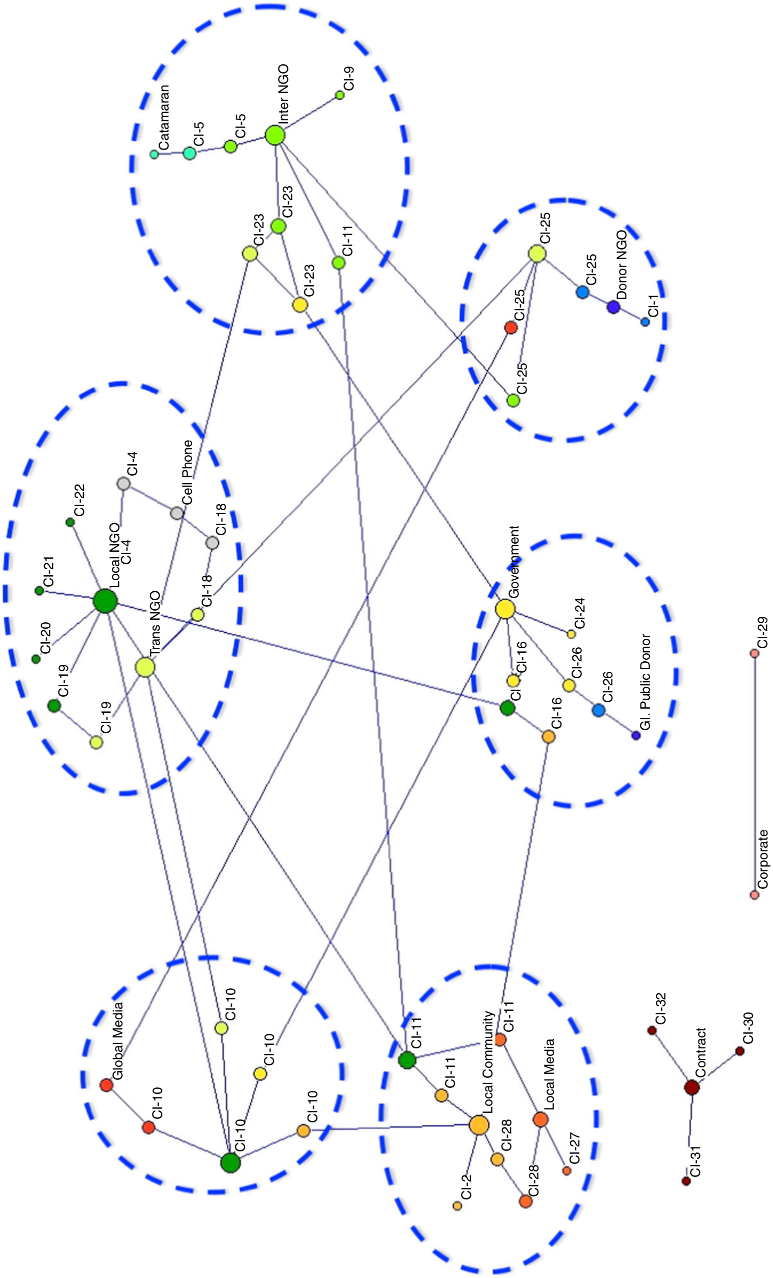


Figure 4.
Degree of centrality for coordination-clusters in rehabilitation operations in the emerging Enayam network, 2005

donations climbed to record levels. Therefore, the global partner NGO could find immediately support from a European donor NGO that itself grew from 8 to 350 members within days. The early fixing of rehabilitation contracts in January 2005 established a relief actor-network only a few weeks after the disaster. This support enabled flexible and entrepreneurial activities of local actors such as the unusual inclusion of for-profit partners and the risk-taking decision of backing a women start-up in a technical field on which fishers' lives depend on the sea. None of the activities would have been possible in this spurt without the use of cell phones. In the remote region of poorest and destroyed infrastructure, all important contacts, from villagers to LNGO staff, from local to global level, from the implementation of distribution cards to the initial call to a company for engine repairs, all contacts were made possible by the only recently pervasive Indian cell phones.

Table III shows an exemplary section of the CI-chart (Miles and Huberman, 2002), information extracted from the case of Enayam and Helen presents actors involved (column) and CIs occurred (rows) for each year. The full matrix of actors and CIs for a time frame (2004-2010) of disaster management is provided in Table AII.

Results

The collected data were analyzed using Pajek software (version 4.04, http://mrvar.fdv.uni-lj.si/pajek/). The emerging network of actors and CIs was reconstructed per year while Louvain community detection was applied to extract coordination-clusters. Figure 5 shows several clusters within the actor-network that emerged based on different CI occurrences and frequencies, e.g. CI-lack of information (CI-3), CI-cooperation needs assessment (CI-2) or CI-starting relief actions (CI-12).

Figure 5 shows the formation of five clusters that represent the CIs occurred during the initial stages of rehabilitation projects in December 2004. In the network graph we can see that the LNGO is emerging as a focal actor in the network as it is linked directly to clusters 1, 2 and 3 and indirectly via common CIs to cluster 4. The LNGO plays a

Actors	2004 Disaster	2005
Local NGO	CI lack of resources CI cooperation need assessment CI lack of information CI innovative action CI distribution	CI NGO Influx CI competition CI doubling self-help groups CI cooperation CI innovative action CI fear of sea CI money overload CI contact overload pressure
Transnational NGO	CI new partner CI cooperation need assessment	CI competition CI NGO Influx CI opposition to government CI new partner CI punctdirdis
Intermediary NGO	CI new partner CI decision making CI cooperation need assessment	CI distribution CI lack of coordination CI opposition to government CI contact overload pressure CI LessLearn Workshop

Table III. Sample of actors and CIs of the response network of Enayam case

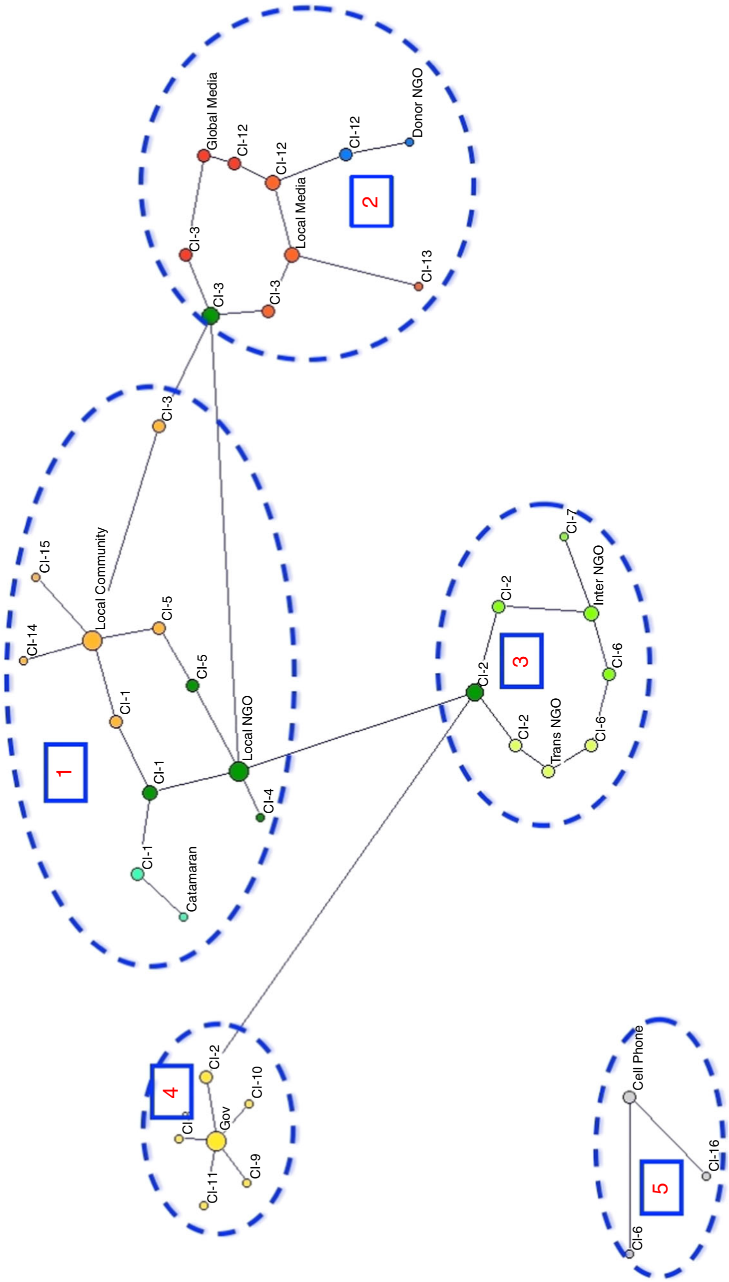


Figure 5.
Coordination-clusters in rehabilitation operations network for year 2004 for Enayam network

crucial role in the rehabilitation project as it collaborated with the local community, foreign donors and the Indian Government when Tsunami 2004 hit the coast.

By looking closely at the dynamics inside cluster 1 in Figure 5, we can learn that LNGO linked to CIs related to a lack of information and a need to assess all procedures in executing the project and expense funds. To overcome such uncertainty, ad-hoc collaboration started within the local community to develop workshops and with the local media to raise awareness of ways to help replace lost fishing boats and catamarans. In contrast, the occurrence of CI-12 for the donor NGO's reflected the need for publicity within the local community and a requirement to increase visibility at the global aspect as it was related to local media and global media actors in cluster 2. In Figure 5, the LNGO can be seen as connected to cluster 2, which involves both local media and global media with the help of donor organizations. The same pattern of association of emerging coordination-clusters with actions taken to overcome common obstacles (i.e. CIs) is recognized in subsequent networks for the other years from 2005 to 2010. Figure A1, includes the complete series of network graphs over the project duration.

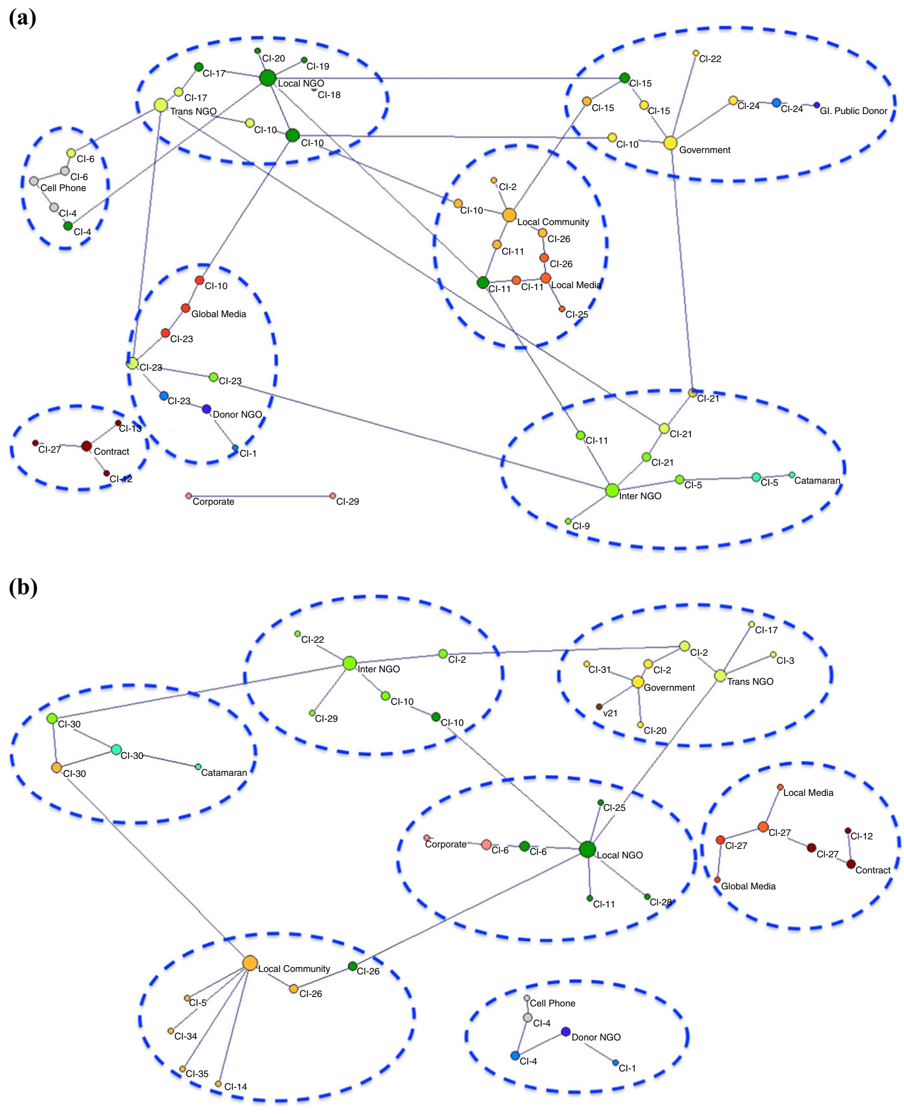
The different clusters form and change based on similarities of CIs between them. In the graphs listed in Figure A1, the evolution of the actor-network shows a pattern of dispersion into different functional clusters, new actors' engagement and redistribution of actors and CIs' within the coordination-clusters. The cluster increase highlights segmentation in the network, which is making it more difficult to achieve an integrated coordination during the recovery operations. In fact, it indicates that integration across the clusters is increasingly difficult to achieve when sequential goals and CIs related to them are targeted by heterogeneous actors. In later years, the stepwise realization of different goals leads to a decrease of CIs and activities (2008 onwards). However, at each stage of the rehabilitation process, the network masters challenges and finds sustainable solutions for relief and reconstruction.

Besides the clustering dynamic itself, another measure of collaborative management develops the changing centrality of nodes in networked response operations while they move across the clusters. As the actor network evolves, the size and position of nodes (CIs or actors) changes depending on the CIs shared by the actors and its frequency. We computed centrality values to examine the evolution of dominant CIs in the coordination-clusters.

In Figure 6, we can see changes in the nodes' centrality values as they switch clusters, which reflect the change in activities carried out by involved actors. Most clusters contain at least one influential node that played a crucial role in the execution of the rehabilitation operations – such as CI-26 (CI-skilled labor fluctuation) or a prominent actor (local community, catamaran, etc.). It becomes apparent that a centrality value is high for a node in one year but not in the next, e.g., CI-10 (CI NGO-influx) and CI-11 (CI-contact overload) in 2004, and CI-23 (CI LessLearnedWorkshop) in 2005.

Discussion and conclusion

The analysis shows that network coordination clustering is a crucial dynamic of long-term recovery processes of global disaster management. Clusters emerge in response to the occurrence of certain events (CIs) throughout the sustained recovery period. It is important to notice that, as a result of this dynamic, the cluster formation does not necessarily move along the lines of a formal project plan or set dates of a program's start and finish. It has a more adaptive nature, which is based on emerging inter-dependencies between the organizational actors and the contingencies



Notes: (a) Centrality values for Eyanam 2005; (b) centrality values for 2006

Figure 6.
Influential CIs for actor network of Enayam and Helen Colony case

of the disaster management. For instance, in 2004, LNGO had to compete with similar NGO's for funding. But in 2005, it already started from a protected frame (CI 24, CI-contract) and could create innovative solutions for "building back better" as new training programs. Local and global media remained rather connected to donor NGOs. In later years, medical care (CI-medicare) and boat repair (CI-30) became an issue; therefore, LNGO and other organizations improvised mobile clinics and barefoot counselors for primary health (CI-medicare) and replaced misfit catamarans. Such actions become visible in the 2007, 2008 and 2009 network graphs in Figure A1.

Furthermore, the network dynamics in the rehabilitation operations exhibited similar characteristics to the dynamics in disaster response operations in Noori *et al.* (2016b). One characteristic is the actors' to increase connectivity to switch between the clusters over the time and changing the shape of the networks (Boersma *et al.*, 2014). Switching is a term introduced by Castells (1996), which conceptualizes "the ability to connect and ensure the cooperation of different networks by sharing common goals and combining resources" (Castells, 2009, p. 45). The switching capability and alteration between different sub-networks enhanced the capacity of the collaborative network. However, the factors controlling such switching events need further exploration.

In the examples of actor networks, one observed a consistent pattern of emerging coordination-clusters based on tasks required at a certain point of time during the execution of long-term rehabilitation programs within the disaster recovery stage. This pattern is similar to the one observed in the network dynamics during disaster response operations (Noori *et al.*, 2016b). Despite the diversified background of actors involved, the results showed resilience in the behavior of actor networks as they self-organize into task-oriented clusters. The clusters' formation comes in response to the emerging critical events that created a flexible framework to accommodate constant changes in the environment and in resource availability. The occurrence of CIs in the example networks did not hinder the progress of rehabilitation programs. To the contrary, it forced the involved actors to seek alternative actions and collaborate to achieve success in their mission to help deliver aid and rebuild the local community.

In conclusion, despite the difficulties imposed by various conditions of the post-disaster stage that can paralyze the execution of well-planned recovery programs, actors involved were capable to reconfigure themselves to create new ties with other members including new ones to response to critical events. The adaptive behavior of coordination-clusters proves a great deal of resilience in the networks behavior compared to the classical response systems. The question of how to map and analyze the emergence of clusters and their consequent coordination dynamics, and thereby how to help create flexible disaster management plans, remains open to future research.

Note

1. Pseudonym.

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Further reading

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(The Appendix follows overleaf.)

Appendix 1

Critical incident code	Critical incident SNA code
CI lack of resources	CI-1
CI cooperation need assessment	CI-2
CI lack of information	CI-3
CI innovative action	CI-4
CI distribution	CI-5
CI new partner	CI-5
CI decision making	CI-7
CI different goals in reconstruction	CI-8
CI lack of coordination	CI-9
CI NGO-Influx	CI-10
CI contact overload	CI-11
CI starting relief action	CI-12
CI visibility	CI-13
CI lack of management capacity	CI-14
CI fear of sea	CI-15
CI solution	CI-16
CI competition	CI-17
CI doubling self-help groups	CI-18
CI cooperation	CI-19
CI money overload	CI-20
CI opposition to government	CI-21
CI punctdirdis	CI-22
CI LessLearn Workshop	CI-23
CI contract	CI-24
CI local people disaccord	CI-25
CI skilled labor fluctuation	CI-26
CI ending relief action	CI-27
CI money spoiling self-reliance	CI-28
CI donor travel	CI-29
CI boat repair	CI-30
CI time pressure housing delay	CI-31
CI starting workshop	CI-32
CI duplication	CI-33
CI rising market prices	CI-34
CI urgent	CI-35
CI accounting	CI-36
CI gender	CI-37
CI report	CI-38
CI medicare	CI-39

Table AI.
Full coding list of critical incidents (CIs) with SNA codes

Appendix 2

Table AII. Full list of actors and critical incidents for Enayam and Helen colony case study

Actors	2004 Disaster	2005	2006	2007	2008	2009	2010
Local NGO	CI lack of resources CI cooperation need assessment CI lack of information CI innovative action CI distribution	CI NGO Influx CI competition CI doubling self-help groups CI cooperation CI innovative action CI fear of sea CI money overload CI contact overload pressure 3	CI new partner CI money spoiling self-reliance CI NGO Influx CI skilled labor fluctuation CI local people disaccord CI contact overload pressure	CI starting workshop CI boat repair CI contact overload CI-money spoiling self-reliance CI duplication CI medicare CI punctdirdis	CI lack of resources CI lack of information CI boat repair CI new partner CI distribution CI innovative action CI medicare	CI distribution CI skilled labor fluctuation CI punct dirdis	CI cooperation need assessment CI opposition to government
Transnational NGO	CI new partner CI cooperation need assessment	CI competition CI NGO Influx CI opposition to government CI new partner CI punctdirdis	CI lack of information CI competition CI cooperation need assessment	CI starting workshop CI boat repair CI money overload CI skilled labor fluctuation CI medicare	CI lack of information CI punctdirdis CI duplication	CI money overload	CI lack of information CI decision making
Intermediary NGO	CI new partner CI decision making CI cooperation need assessment	CI distribution CI lack of coordination CI opposition to government CI contact overload pressure CI LessLearn Workshop	CI punctdirdis CI donor travel CI cooperation need assessment CI boat repair CI NGO Influx	CI starting workshop CI donor travel CI punctdirdis	CI donor travel CI boat repair CI punctdirdis CI doubling self-help groups	CI report	CI report

(*continued*)

Table AII.

Actors	2004 Disaster	2005	2006	2007	2008	2009	2010
Government	CI different goals in reconstruction CI cooperation need assessment CI lack of coordination CI NGO-Influx CI contact overload	CI contract (Disaster Act; Coastal Regul Act) CI NGO Influx CI punctual diridis CI fear of sea CI opposition to government	CI cooperation need assessment CI money overload CI time pressure housing delay	CI time pressure housing delay CI money overload CI local people disaccord CI distribution	CI time pressure housing delay CI local people disaccord CI gender CI rising market prices	CI rising market prices CI NGO influx	
Local media	CI starting relief action CI lack of information CI visibility	CI local people disaccord CI skilled labor fluctuation CI contact overload pressure	CI ending relief action	CI boat repair	CI duplication		
Global media	CI starting relief action CI lack of information	CI NGO influx CI Lessons Learned Workshop	CI ending relief action	CI boat repair	CI duplication		
Gl. public donor		CI contract		CI ending relief action	CI accounting	CI report	
Donor NGO	CI starting relief action	CI LessLearn Workshop CI lack of resources	CI lack of resources CI innovative action	CI lack of resources CI boat repair CI new actor	CI innovative action CI end of relief action	CI donor travel	CI report

(*continued*)

Actors	2004 Disaster	2005	2006	2007	2008	2009	2010
Local community	CI lack of resources CI lack of information CI lack of management capacity CI fear of sea CI distribution	CI fear of sea CI NGO Influx CI skilled labor fluctuation CI contact overload pressure CI cooperation need assessment	CI distribution CI rising market prices CI urgent CI skilled labor fluctuation CI boat repair CI lack of management capacity	CI Starting workshop CI distribution CI competition CI fear of sea CI rising market prices CI medicare	CI rising market prices CI Skilled labor fluctuation CI solution CI boat repair CI local people disaccord	CI donor travel CI medicare	CI medicare
Local private actor		CI decision making	CI new partner	CI starting workshop			
Contract		CI starting relief action CI ending relief action CI visibility\y	CI starting relief action CI ending relief action	CI time pressure housing delay CI medicare CI ending relief action	CI solution		
Cell phone	CI solution CI new partner	CI new partner CI innovative action	CI innovative action	CI innovative action	CI new partner	CI local people disaccord	CI lack of resources
Catamaran	CI lack of resources	CI distribution	CI boat repair	CI distribution	CI boat repair	CI duplication	CI duplication

Table AII.

Appendix 3

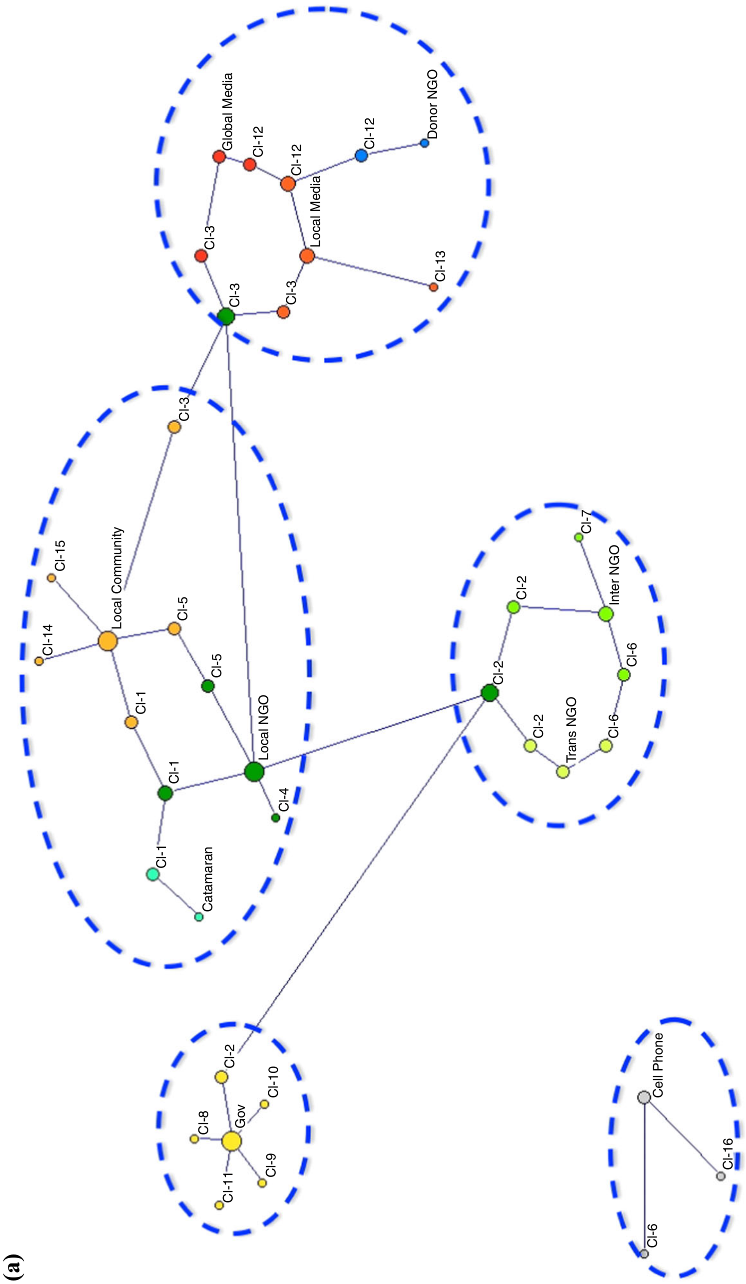

Figure A1.
Full list of graphs of networks representing actors and critical incidents for Enayam and Helen colony case study

(*continued*)

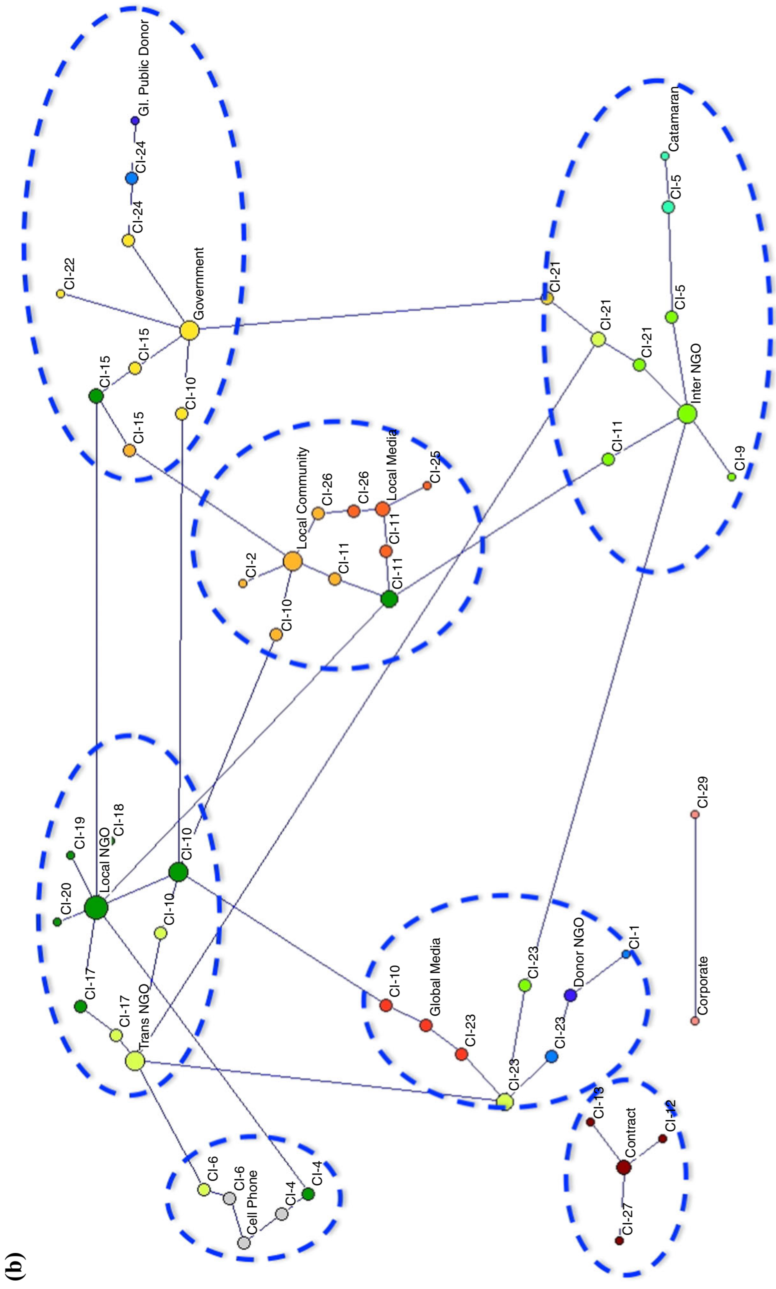

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Figure A1.

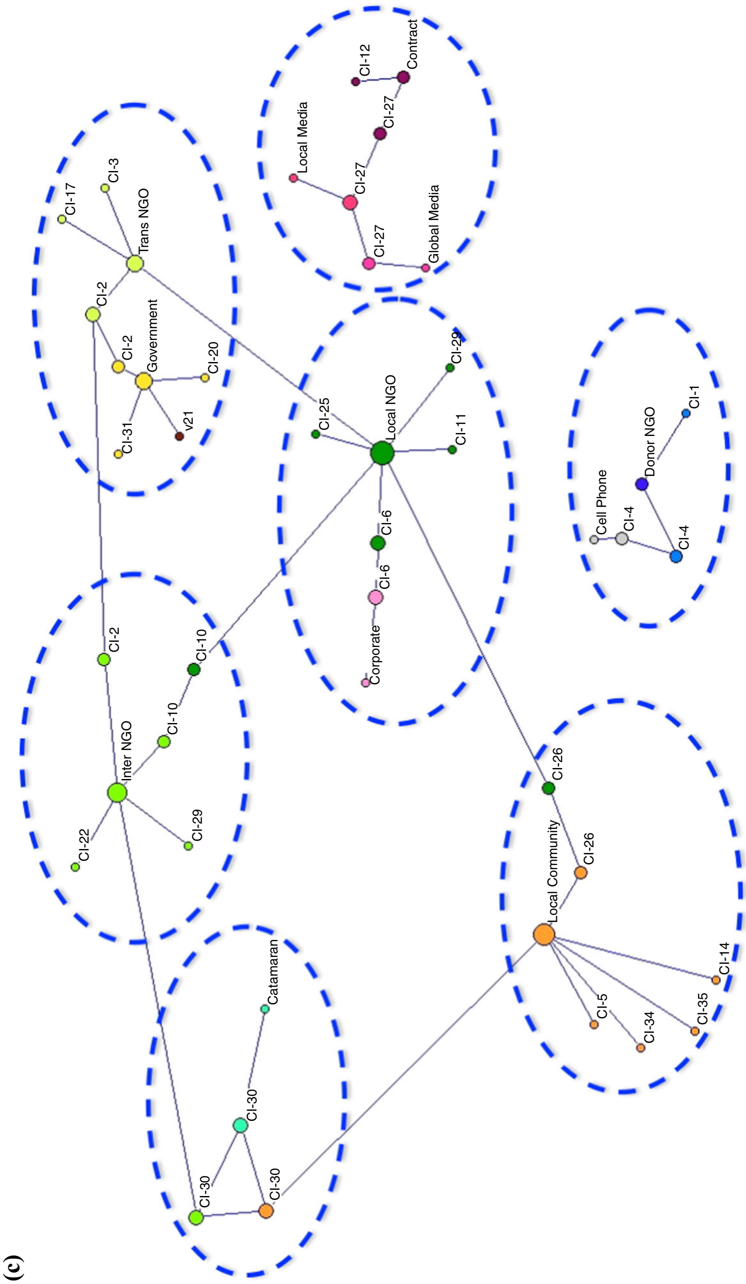

Figure A1. (*continued*)

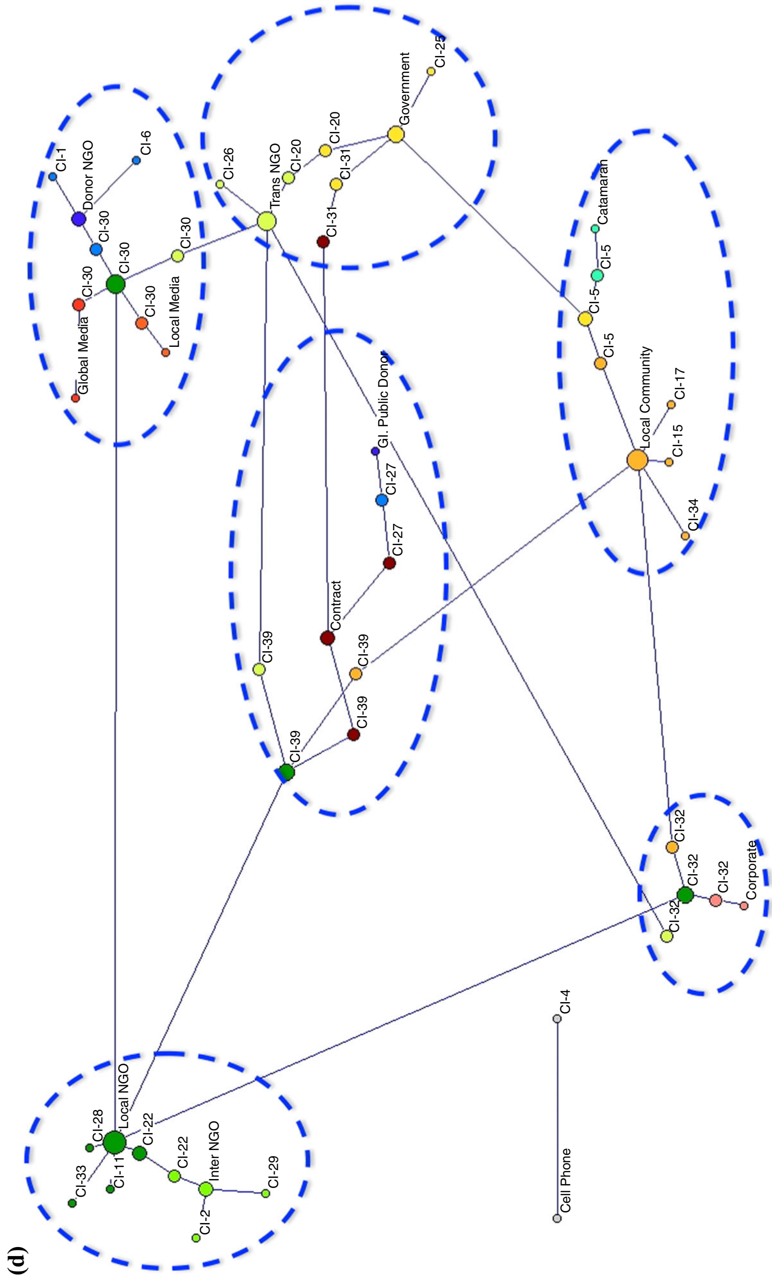

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Figure A1.

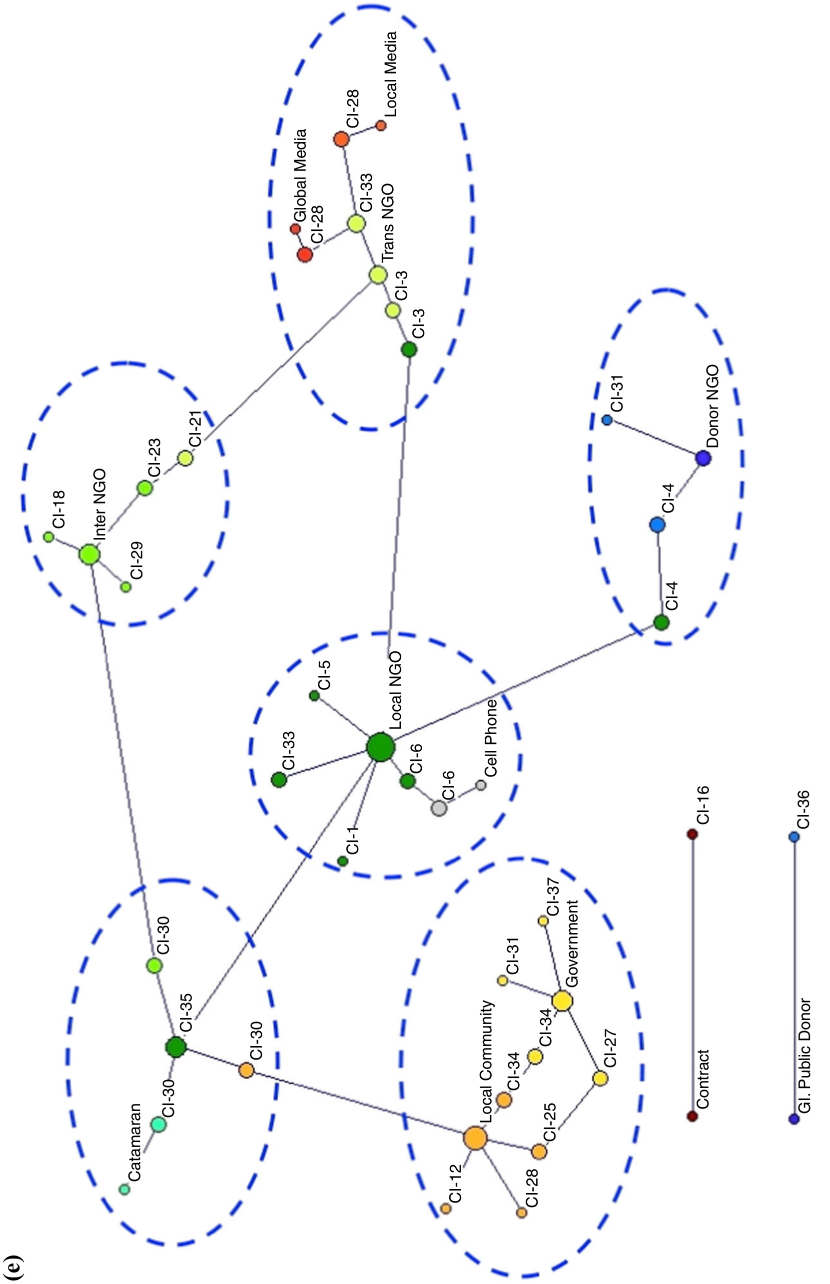
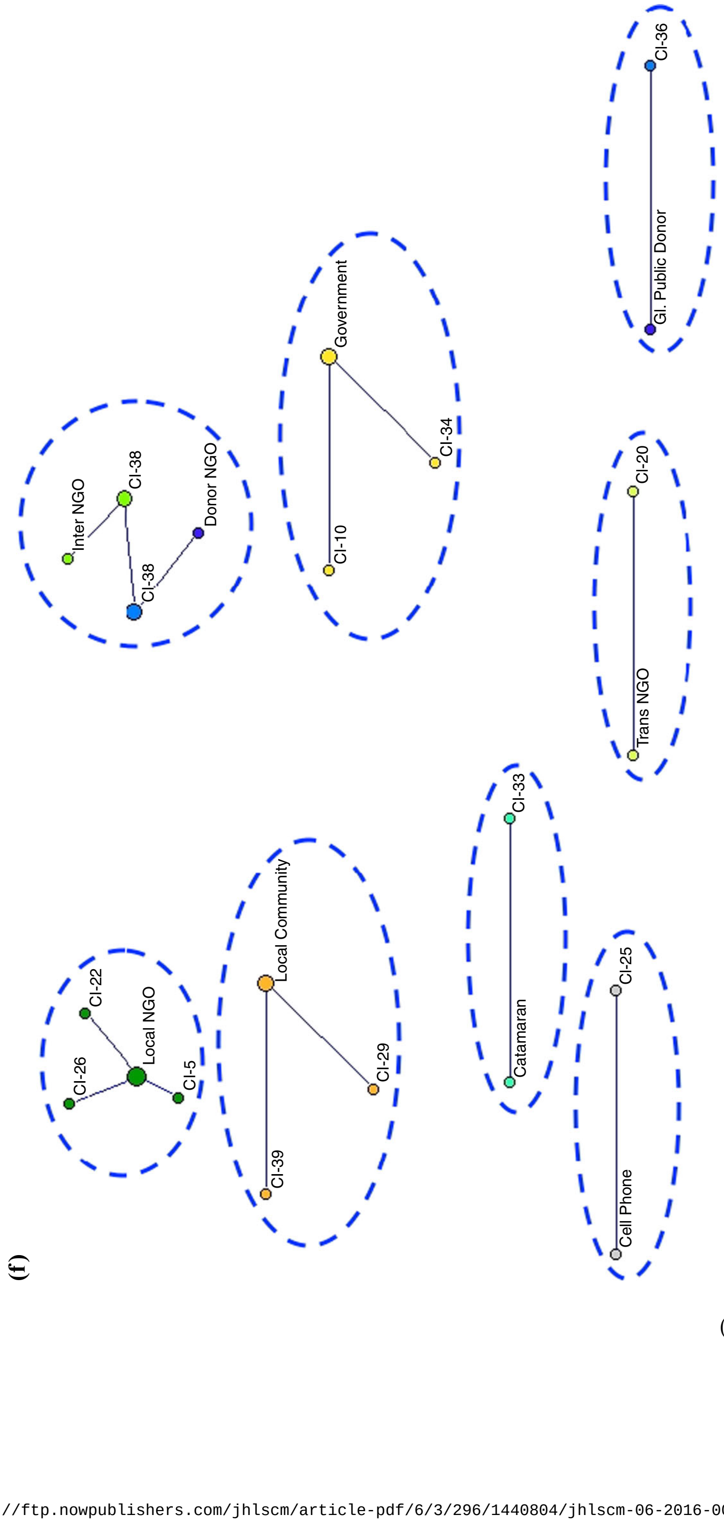
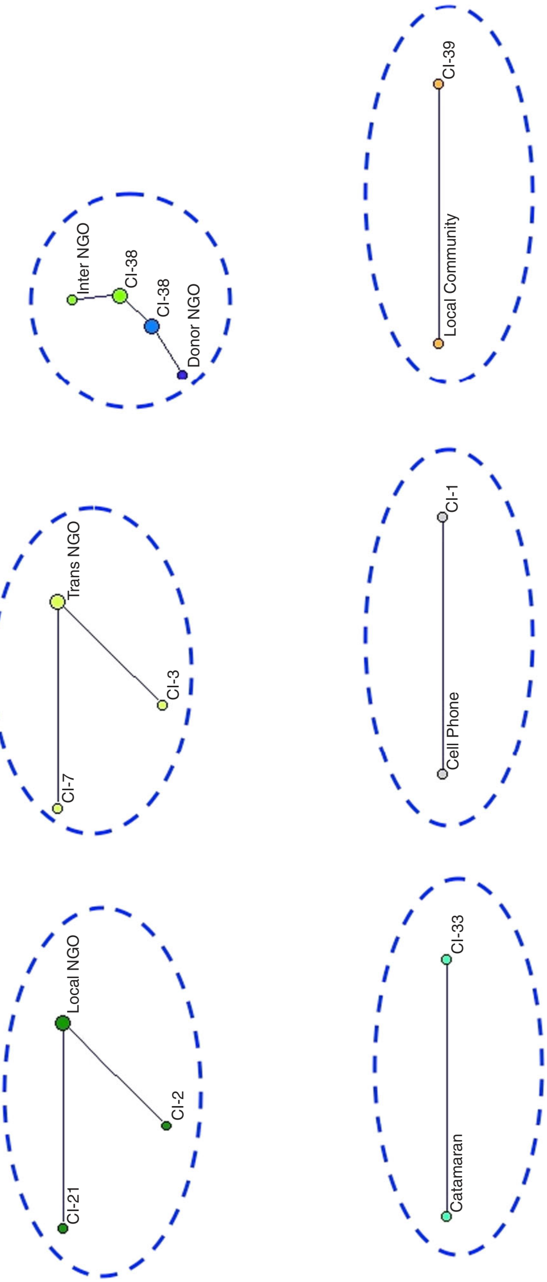


Figure A1. (*continued*)



(*continued*) **Figure A1.**

(g)



Notes: (a) 2004; (b) 2005; (c) 2006; (d) 2007; (e) 2008; (f) 2009; (g) 2010

Figure A1.