Post disaster governance, complexity and network theory: evidence from Aceh, Indonesia after the Indian Ocean Tsunami 2004

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Abstracts

This research aims to understand the inter-organizational network typology of large scale disaster intervention in developing countries and to understand complexity of post disaster intervention through the use of network theory based on empirical data from post tsunami reconstruction in Aceh, Indonesia, during 2005-2007. The findings suggest that the 'degrees of separation' (or network diameter) between any two organizations in the field is 5. There are significant amount of loops in the network which reflects typical 'small-world' realities and therefore made no significant difference with the real human networks as found in previous experiments. The findings show the landscape of humanitarian actors is not randomly distributed. Many actors were connected to each other through certain hubs, while hundreds of the actors make 'scattered' single 'principal-client' links. The paper concludes that by understanding the distribution of degree, centrality, 'degrees of separation' and visualization of the network, authorities can improve their understanding of realities of coordination from macro to micro scales.

1. Complexity of Large Scale Disasters

Large scale disasters or big catastrophes are defined as events that trigger hundreds to thousands loss of lives, affected millions of people, collapsed/damaged thousands of buildings and created huge economic losses in proportion to the scale of economy of the areas affected. They create complexity that often went beyond the comprehension of local authorities.In developing countries context, it has been observed that big catastrophes invite external organizations to come and help the survivors. An increasing involvement of hundreds to thousands of non-state and non-governmental actors after big catastrophes in the countries may create more complex realities beyond the comprehension and the capacity of the respective actors such as governments and local disaster response authority. Recent large scale disasters in Asia (e.g. Indonesia, Myanmar, Pakistan) and the Caribbean (Haiti) exemplify the fact of high involvement of international non-governmental actors and international organizations (INGOs/IOs). In addition, large scale disasters and the presence of INGOs/IOs stimulate the births of hundreds to thousands of local NGOs ((Stumpenhorst et. al., 2011, Fisher, 2010).

The author have personally observed the rise of NGOs in Indonesia where large scale crisis events took place in different provinces in Indonesia. Stumpenhorst et. al. (2011) found that following the earthquake 2010 in Haiti, the number of NGOs increased uncontrollably. Admitting that large catastrophes create complex issues is just the beginning of solving the problem. Lack of understanding of complexity landscape creates coordination problem such as over concentration and overlapping of intervention in one area but missing the other survivals in need in other areas. Post disaster intervention Aceh and Nias (Indonesia) is complex (Pandya, 2006). Recorded disaster mortality in Aceh due to the transoceanic Indian Ocean Tsunami in 2004 is about 170,000 not including the rest of 15 other countries. Post disaster interventions were exacerbated by the legacy of 30 years of 'civil war' in the region. A rather successful peace

processes that later led to more conducive situation added weight to complexity of disaster recovery.

Based on the author's direct experience as a field worker during reconstruction in Aceh, Indonesiam after the Indian Ocean Tsunami 2004 - high asymmetric of information could lead to unnecessary and unhealthy competition of aid players. This often led the situation where five INGOs and contractors compete to lobby the same local communities to offer housing aid. At worst, three INGOs/IOs could end up building houses in the same village, using different legitimacy approaches: one INGO made a deal with villagers directly, while the other two separately dealt and gained permission from district governments and reconstruction authority. This personal experience is part of the reason why the author motivates to write this paper.

The problem is neither 'anarchy situation' (where no clear or authority existed) nor that governments and reconstruction authority intentionally created the situation. It is rather that conventional methods to guide understanding of post disaster complexity proved ineffective. It took longer time to understand the macro picture of reconstruction players' behaviors. Unfortunately, at the time when reconstruction authority began to understand more details of actors, the reconstruction clock might already finish. Quality of intervention is therefore is always prone and vulnerable due to the lack of understanding of the multifaceted problems on the field.

The situation above is typical a 'tragedy of the commons' which Garret Hardin illustrates as the use of common property resources where limited natural resources is exploited by local individuals and households without bad intention to destroy local sustainability – unfortunately, in the end everybody lose (Hardin, 1968). Following the Indian Ocean Tsunami (IOT), especially in Aceh during 2005-2007, the author observed another 'tragedy of the commons' phenomenon where the commons were humanitarian and reconstruction aid. In this game, the commons are expected to be extinct when the reconstruction resources end.

The difference with Hardin's 'tragedy of the commons' is that in humanitarian aid, aid players expect aid to be stopped after a certain period of time. But the game will be repeated in new disasters hit areas where similar INGOs/IOs are likely to exercise their 'moral imperative' with already limited aid resources. Everybody should win in this game to meet the vision of rebuilding resilient (social-physical) structures that can absorb future shocks.Experienced and trained authorities and officials are often struggled to deal with post disaster complexity because they barely experienced the same scale of disasters before.

Complexity is now understood as one of the features of post disaster reconstruction situations which make coordination difficult to occur. Boin et. al. (2010:2) argued that "coordination is the Holy Grail of disaster response: the call for more and better coordination is heard during and after most disasters. How complex networks under disaster conditions can be orchestrated remains unclear at best, however". Available data suggests more than 1000 local, national and international organizations (including state and non-state actors) delivered their post disaster intervention in at least 5000 multi-sector projects in post IOT intervention in Aceh.

Recent large scale disasters also show similar trend in terms of involvement of actors. More than 500 INGOs/IOs involved in post Cyclone Nargis in Myanmar 2008 and more than 700 INGOs/IOs responded to devastating earthquakes in Haiti 2010 (Fisher, 2010).These figures (Myanmar and Haiti) do not yet include local and national organization. Humanitarian

coordination is a tool that is used to achieve organized behaviors to produce desired outcomes such as effectiveness, efficiency and accountability in disaster responses.

Coordination is difficult because aid bureaucrats often use irrelevant metrics and tools to understand the complex situations.This paper hypothesizes that understanding complexity through the use of network theory can help improve the performance of post disaster interventions especially in the context of large scale natural hazards. This paper uses the case of Indian Ocean Tsunami 2004 in Aceh to demonstrate the potential use of network theory to unpack complexity of aid agencies and organizations in post disaster situations.

How can organizations maximize the use of aid if the complexity landscape is not well understood. This paper asks 'what is the typical network of humanitarian industry complexity landscape of large scale disasters looks like?' and 'what does it means for managing complexity of post disaster governance?'

The next section discusses why network theory can be used to understand the details of complexity of organization to organization coordination. Section 3 discusses the concept of polycentric governance and its connection with network theory. Section 4 describes the research method. Section 5 provides the findings which will be discussed in Section 6. Closing remarks are provided in Section 7.

2. Network theory and Big Catastrophes

Magsino (2009) reported recent initiatives in USA to explore how network analysis could be applied during all phases of the disaster cycles. Intergovernmental and interorganizational interaction in disaster context is complex (Kapucu et. al., 2010). Large scale disasters can hypothetically trigger new formation of actors' networks such as global-local humanitarian actors. In developing countries context, post disaster governance is arguably more complex due to lack of human resources and high information asymmetry (due to dysfunctional and lack of communication infrastructure following a catastrophe; and lack of transparency and information sharing). This invites external actors to come and transact their humanitarian imperatives.

Comfort, Ko and Zagorecki (2004) promotes the usefulness of network theory in the context of disaster coordination and response systems. Butts et. al. (2007) provided good examples of actors' communication networks in the World Trade Center Disaster. Kapucu (2006) demonstrates an early use of network theory in understanding multiorganizational communication and coordination in disaster context at smaller scale. Informed by their network analysis from the US context, Kapucu et. al. (2010) found that effective post disaster intervention come from bottom up and local organizations are usually fast and more responsive to disasters. Varda et. al. (2009) noted the use of social network methods in disaster studies based on Post-Katrina context by assessing the network of the socially isolated groups. Katrina disaster in 2005 also triggered new opportunities for the US based scientists to explore the use of network theory in understanding post disaster interventions.

Creating a centralistic incident command system and structures for post disaster intervention is a serious challenge, especially when higher level authority barely understood the landscape of complexity. Even though there may be options to suggest a more decentralized intervention systems such as humanitarian cluster systems that recently promoted in global humanitarian response systems (See Table 1), such efforts may miss some other emerging (uncontrolled)

clusters that may not be fit according to the 'traditional' sense of sectors and humanitarian cluster system.

Unfortunately, there is barely paper uses network theory for disaster research outside US and Europe context. In addition, the use of the approach in the US context is limited to a much smaller scale of nodes (organizational actors) being involved in Katrina. This paper not only pioneers itself to understand post disaster governance setting from developing countries, by focusing on Indian Ocean Tsunami 2004 in Aceh and Nias, Indonesia where "a big-bang" formation of post disaster networks took place during 2005-2007, but it also provides evidence concerning network typology of large organizational networks following large scale disaster.

3. Polycentric disaster governance and complex networks

Disaster risk governance framework recognizes the polycentric nature of disaster risk and emergency management where there are many overlapping arenas (or centers) of authority and responsibility for disaster risk reduction and post disaster intervention. In this paper, polycentric governance refers to the nature of decision making in humanitarian emergencies as functioning across many centers and domains and across scales and levels (Lassa, 2011; 2012). The evidence of polycentric governance also appears in the context of emergency management today, especially under the concept of humanitarian cluster approache (See Table 1), as currently promoted by international actors. In the sense of network theory, the 'many centers' emerges as 'hubs' and sub networks of inter-organizational actors.

Experienced field workers and specialists of international humanitarian emergencies may have predicted that the convenors of humanitarian clusters (Table 1) are the ones that are most likely to have high connections in regards to post disaster organizations' network. The cluster convenors are most likely to be part of 'the centers' or 'hubs' while some other local organizations may hypothetically be the actors in the 'periphery'. For instance, the International Federation of the Red Cross (IFRC) is likely to be a hub in the network because it is mandated to be the lead or convenor of emergency shelter cluster. Likewise, UNDP is likely to be important because it is mandated to lead early recovery clusters

Table 1. Humanitarian emergency cluster and cluster convenors

Name of cluster	Convenor or cluster leader (Humanitarian Cluster Evaluation)	Convenor or cluster leader (Case of Haiti)
Water, Sanitation and Hygiene (WASH)	United Nations International Children's Emergency Fund (UNICEF)	UNICEF
Education	UNICEF and Save the Children Alliance	UNICEF and Save the Children Alliance
Agriculture	Food and Agriculture Organization (FAO)	FAO
Health	WHO (World Health Organization)	WHO
Emergency Shelter	UNHCR (for conflict) and IFRC	UNHCR and IFRC

	(for natural hazards)	
Early Recovery	UNDP (United Nations Development Programme)	UNDP
Camp coordination and management	UNHCR and IOM (international organisation for migration)	IOM
Logistics	WFP (World Food Programme)	WFP

Source: Adapted from Stumpenhorst et. al., 2011 and Stoddard et. al., 2007

Humanitarian cluster approach is basically a means for coordinating clustered responsibilities of actors during humanitarian relief emergency response such as agriculture, health and emergency shelter clusters (Stumpenhorst et. al., 2011). Each organization can sign up for more than one cluster membership. Big organization may sign up for more than 5 clusters membership. However, most actors do not comply with the cluster approach. The lead of each cluster is listed in Table 1.Network governance (or networked governance) model challenges the old assumption of structural analysis in social science (including economics and engineering), that disaster management outcomes simply arise from the sum of efforts from agents, namely, individuals and organizations (Lassa, 2011; 2012).

Researchers tend to believe in the aggregation of variables and sums of actors. Applied network theory advocates the fact that agents and institutions exist and co-exist more in the form of networks. Furthermore, it not simply a network approach versus aggregation but 'what kinds of network' we are actually dealing with? This argument is based on the emerging form of governance as networks of individuals and organizations/institutions (see Jones et al., 1997, Stoker, 2006, and Crawford, 2006).

In the study of governments, Goldsmith and Eggers (2004) noted growing spaces where governments purposefully network with other networks of providers (of public goods) to enhance the delivery of public goods to meet their policy goals. The defined networks could involve third-party government, that is, private firms and NGOs, or joined-up government in the form of multiple and multilevel government agencies.

4. Research Methods

Network theory is invented from Graph Theory, a mathematical branch. The theory suggests that it is not the sums of parts that matters but the connection of parts that matter most (Barabási, 2003). Growing up as a civil engineer, the author agrees with the idea that the sum of physical materials of a still standing structure equals the sum of physical materials of the structure when it collapsed in earthquakes and it equals the sum of wastes of physical materials from the same structure. What matter most is the connection between parts or elements of the engineering structures that give a building a real function of resilience to earthquakes shocks.

Castells (1996) defines a network as a set of interlinked nodes or a node is the point at which a link intersects itself . A node can be an organization or an individual in a particular situation. Social network is social structure made of agents that are coded as nodes that are tied with other agents (nodes or a.k.a. vertices) (Scott, 2002). Quantitative sociologists turn graph theory into social network analysis (SNA) to analyze ties among people, groups of people, organizations,

and countries. Together, these ties form networks. Hence, SNA detects and interprets patterns of social ties among actors (Nooy, Mrvar and Batagelj, 2005:5).

Social network theorists argue that network analysis presents a better explanation of social behavior because it assumes a society is by no means merely a sum of individuals – instead society actually comprises of networks of individuals, organizations, and institutions.The network is also known as a graph. A graph is a set of nodes and a set of lines between pairs of nodes. A graph represents the structure of a network; all it needs for this is a set of nodes (or vertices/points) and a set of lines (links) where each line connects two vertices. As elementary school children understand it, a line connects two dots or endpoints or vertices (nodes).

A node is the smallest unit in a network and can represent either an agent (e.g., an organization, an adult female/male, a biological cell, an object). Furthermore, a node/vertex can be identified by a number or a label. A line connects two nodes in a network, which can represent any relational quality.

Loops are important to be noted because they represents organizations or actors that may not be linked with others but themselves. This could be generous private agencies that come and distribute whatever forms of aid on their behalf. In the network structure, they must appear as standalone actors.

The diameter of network [Equation 1], the average path length of the networks [Equation 2] and loops will be measured. Let l (i , j) denote the shortest distance between node i and j. The distance is measured by the number of links for one node to connect to other node. The diameter of a network is the largest distance between any two nodes in the network. The average path length is the average distance between any two nodes in the network – a measure of efficiency of transmitting information or ideas. The later variable is bounded but can be much shorter than by the former variable.

$$\text{ND (Network diameter)} = \text{Max l}\,(i,j) \qquad [1]$$

$$\text{APL (Average path lenght)} = (\textstyle\sum_{i \geq j} \text{l}\,(i,j))/\ (\text{n(n-1)/2}) \qquad [2]$$

Two types of centrality analysis are used namely, *degree centrality* and *betweenness centrality*. Centrality analysis refers to positions of individual vertices (or nodes) within a network. Degree centrality is the easiest to measure as it is the number of ties (or links) connected to a given node or "the number of nodes that the focal node is connected to" (Opsahl, Agneessens, and Skvoretz, 2010). Equation [3] is the mathematical explanation of degree centrality:

$$\text{CD (Si)} = \textstyle\sum_{\text{j}}^{\text{N}} \text{Sij/ N} \qquad [3]$$

Here, i is the focal vertex (node), j represents all ties (or links), and N is the total number of nodes in the given network.

To determine the leader(s) in a network of inter-organization (to represent the lead institution/ organization or individual leader of a unit of community or set of organisations), one can identify the highest value of *betweenness centrality*. Arbesman and Christakis (2010:6) rewrite the equation as follows:

$$\text{CB (Si)} = \sum_{j}^{N} (\frac{\text{Pi(kj)}}{\text{P(kj)}})/(\text{N}-1)\text{N}-2)/2 \quad [4]$$

Pi(kj) is the number of distance or the shortest path) between k and j that i lies on and P(kj) is the total number of geodesics between k and j.

Nooy, Mrvar, and Batagelj (2005) argue that the more a node is a go-between, the more central its position in the network. It means that the more a node possesses dense relational ties between other nodes (agents/actors and or organisations) the more important the node is to the flow of any aid resource in the post disaster reconstruction network. The *betweenness centrality* has a value between 0 and 1. The higher the value, the higher the centrality of the node in the network, which is an indication of leadership or a hub function.

Post disaster interventions network involves 'donor-partner' relationship. Therefore, two additional measures will be introduced: the first is the indegree - measured by the number of links (arcs) a node receives. Indegree is therefore the first level partners or 'implementing partners'. The second is the outdegree, measured by the number of links (arcs) it sends (e.g. the number of organizations a donor transfers grants). In this context, it is the donor or the direct source of the first level partners. Therefore, these two measures must recognize the direction of links. In the case where organizations use their own resources to distribute aid (without intermediaries), it is called self-sponsorship and therefore, it is considered self-transaction which will be seen as solitaire nodes (unconnected to the rest of the actors) or loops. However, they are all treated as part of the network because they were willing to report their activities to the existing reconstruction authority.

Visually, a self-sponsorship organization appears as one unconnected node.This paper also evaluates the K-core of the network. A k-core classifies relatively dense sub-networks to find cohesive subgroups. "A k-core is a maximal sub-network in which each vertex (node) has at least degree k within the subnetwork." K-core is used to identify clusters of nodes that are tightly connected because each node has a "particular minimum degree within the cluster" (Nooy et. al., 2005; Opsahl et. al., 2010). A 3-core means all nodes that are connected by degree subsequently three more to other nodes within the core.

Data Source. The data used in this analysis is derived from April 2007 updated by Aceh-Nias Rehabilitation and Reconstruction Agency (BRR). This is the only latest version accessible to the author. The author often contributed to the BRR project updates using online system which is no longer exist. The updates is often distributed to international agencies and INGOs. Even though it is not the final version (as BRR mandates ended in the end of 2009), however, there is enough information to analyze the network properties. The spread sheet consists of "financial updates" – which contains different project financing updates from more than 800 different actors (donors-direct partner). The updates contains 1300 project financing updates breakdown into 5000 different project outputs.

This research coded the 1300 numbers of financial updates because it has much better quality. It will not affect the quality of analysis because an organization A can have more than two transactions (and more project outputs) supported by organization B in more than one different sector. Due to time limitation, the analysis focuses on the donor-partner data. Therefore,

regardless how many projects and the size of the contracts of the projects were made between any two nodes (principal-client or donor-partner) it will be treated as one single link.

This approach does not discount data quality in terms of the formal links between the organizations. After data cleaning, the dataset has a total of 797 organizations. 797 organizations mean 797 nodes.

Softwares. The overall analysis of the network of post disaster governance network in Aceh, the author will use Pajek's algorithm - detail explanation can be seen in Nooy et. al. (2005) . Gephi's algorithm is used as an alternative visualization for good qualitative interpretation.

5. Results: Visualization of Post Disaster Actor Network

5.1. Network diameter and degree distribution

Based on both Gephi's network analysis and Pajek's network algorithm, the diameter of the network is 5 with n = 797 nodes and total links 977. The average path length is 1.715 (based on Gephi). The number of loops is 28, meaning that there are 28 nodes that link to no other organization but only to themselves. These loops are visible in the Figure 1A.

Ten categories (partitions) were made namely: Aceh-Nias Reconstruction and Rehabilitation Agency (BRR Aceh-Nias), Indonesia government institutions at national level; Local government organizations, Bilateral aid from independent countries are coded, Multilateral aid organizations such as United Nations including World Bank, International NGOs, Local-national NGOs, private firms, Universities and Others (none of the above). There were 472 INGOs in Aceh and Nias during 2005-2007 (Table 2), delivered their post disaster reconstruction aid (from housing to agricultural to health and other sectors). There were 147 NGOs included. There were 25 multilateral organizations (such as United Nations agencies such as UNDP, WFP) including the World Bank and European Commission. There were 36 bilateral donors were involved in this analysis (such as Australian Government, US Government, French and German government and so on). Aceh-Nias Rehabilitation and Reconstruction Agency is grouped alone as BRR (Table 2). BRR is a 'multi-sectors' agency as it involved and governed all the reconstruction sectors.

Table 2. Sums of degree, out-degree, in-degree and total sums of actors

Groups	Degree	In-degree	Out-degree	No of orgs	Degree (%)	Out-degree (%)	In-degree (%)	# Orgs. (%)
Other organizations	0.014	0.010	0.019	19	1.2%	0.8%	1.5%	2.4%
University	0.015	0.005	0.025	10	1.2%	0.4%	2.0%	1.3%
Privatefirms	0.043	0.067	0.019	51	3.5%	5.4%	1.5%	6.4%
Local-national NGOs	0.180	0.029	0.332	147	14.7%	2.3%	27.0%	18.4%
International NGOs	0.695	0.720	0.670	472	56.5%	58.5%	54.4%	59.2%
Multilateral orgs	0.133	0.185	0.082	25	10.8%	15.0%	6.6%	3.1%

Bilateral orgs	0.101	0.200	0.001	36	8.2%	16.2%	0.1%	4.5%
Local governments	0.024	0.009	0.039	28	1.9%	0.7%	3.2%	3.5%
National govt agencies	0.012	-	0.024	8	1.0%	0.0%	1.9%	1.0%
BRR	0.011	0.004	0.018	1	0.9%	0.3%	1.4%	0.1%
Total	1.23	1.23	1.23	797	100%	100%	100%	100%

Source: Author. Data from BRR April 2007. The calculation uses Pajek mode 1 (directed).

Table 3 shows the 'power law' phenomenon as seen in Figure 3 (degree distribution and betweenness centrality distribution). Figure 3 shows that 1.62% of nodes (17 organizations) are linked to more than 15 nodes. The highest connected node is UNDP (degree centrality). UNDP also possess the highest betweenness centrality. Bilateral donors such as USAID (United States Assistance for International Development), Japan Government and Canadian Government were shown up in the degree distribution. They apparently divided their funds to some organizations ranging from local to international organizations. However, in regards to betweeness centrality, they seem to enjoy less influence. One of the main reason why nodes such as UNDP could enjoy such a high connection because they play as intermediary roles between donors, governments and civil society.

5.2. Degree, In-degree and out-degree Analysis

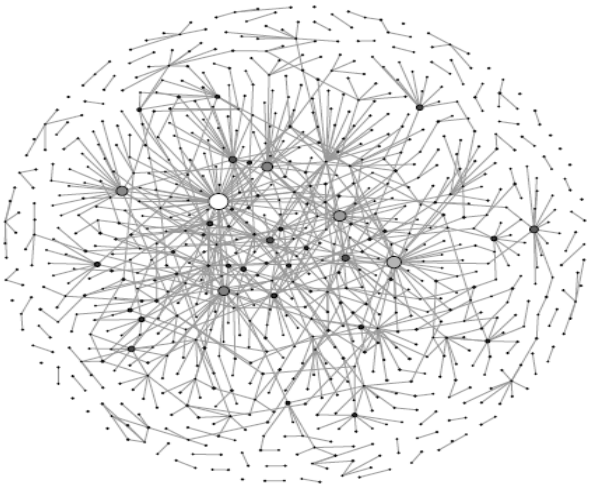
Multilateral organizations consisted only 3.1% (25 organizations) but they enjoy higher percentage in out-degree (15%). Bilateral donors comprises of 4.5% (36 countries – as registered in the April 2007 database), however, their 'out-degree' is 16.2%. BRR as the reconstruction authority is only 1 out of 797 (or 0.1%) but its indegree is 1.4% (which is quite high and shows its level of importance as the highest reconstruction authority). Overall, in terms of relational ties, INGOs have the higher percentage of degree distribution (56.5), slightly lower than their total number (59.2% or 172 organizations). Local NGOs ranked the second.This analysis demonstrates some interesting results. Bilateral organizations tend to play roles as donors. They tend to have high outdegree but very low indegree (Table 2). This confirms the reality that donors are the ones that gives grants and not receiving grants. The reason why donors' indegree is not zero is due to the existence of intermediary donors (or grant making organizations that receive money from other organizations). Local NGOs most often played roles as recipients of funds – proved by low outdegree but high indegree. Both multilateral organizations (such as United Nations) tend to play roles as both a grantor and a grantee. International NGOs tend to play the same roles as multilateral organizations as they are grantees as well as grantors. Some private firms (such as commercial banks) play roles as grantors during the Indian Ocean Tsunami 2004 and some local firms become project implementers. While BRR played roles as both a grantee in order to be the grantor.

Figure 1. Visualised Networks of Organisational Post Disasters Intervention 2005-2007Source: Author – (directed network – Gephi's Fruchterman Reingold layout). Figure 1A visualizes all-degree network (based on the number of links each nodes possesses. Figure A1 shows the centrality of actors (or 'leadership' of each node within the network. Figure 1C is K-Core, which means all nodes that are connected by degree (or links) subsequently three more to other nodes

within the core. Figure 1D demonstrates all the nodes that posses more than (or equals to) 10 links.

Figure 1. Visualised Networks of Organisational Post Disasters Intervention 2005-2007 in Aceh, Indonesia.

1A. All-degree network



1B. *Betweeness* centrality network

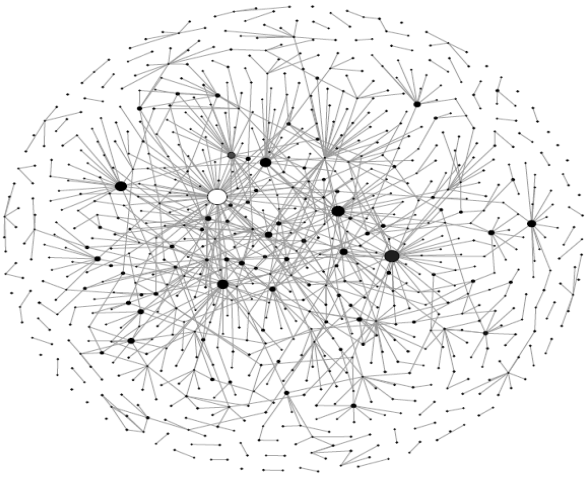


Figure 1C. K-Core (3-core)

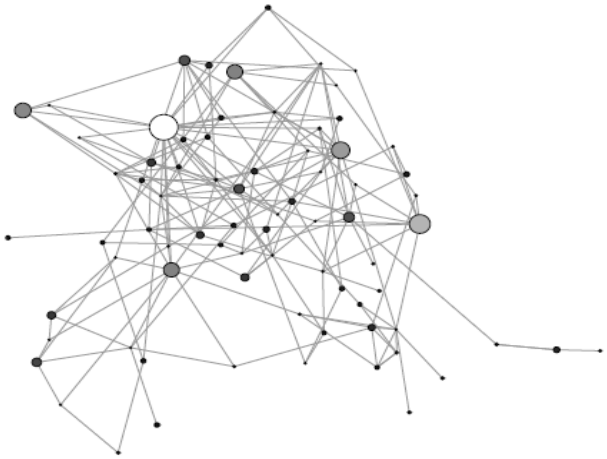
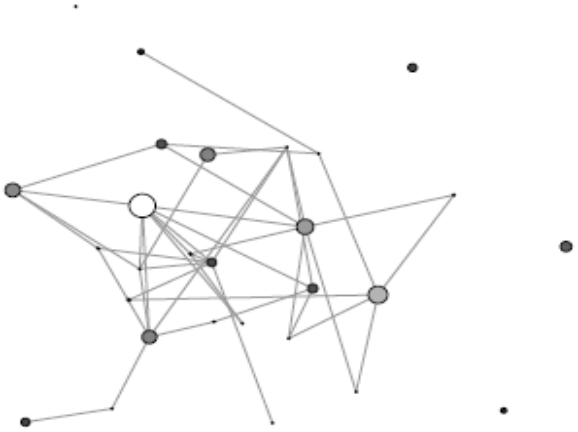


Figure 1D. ≥ 10-degree nodes



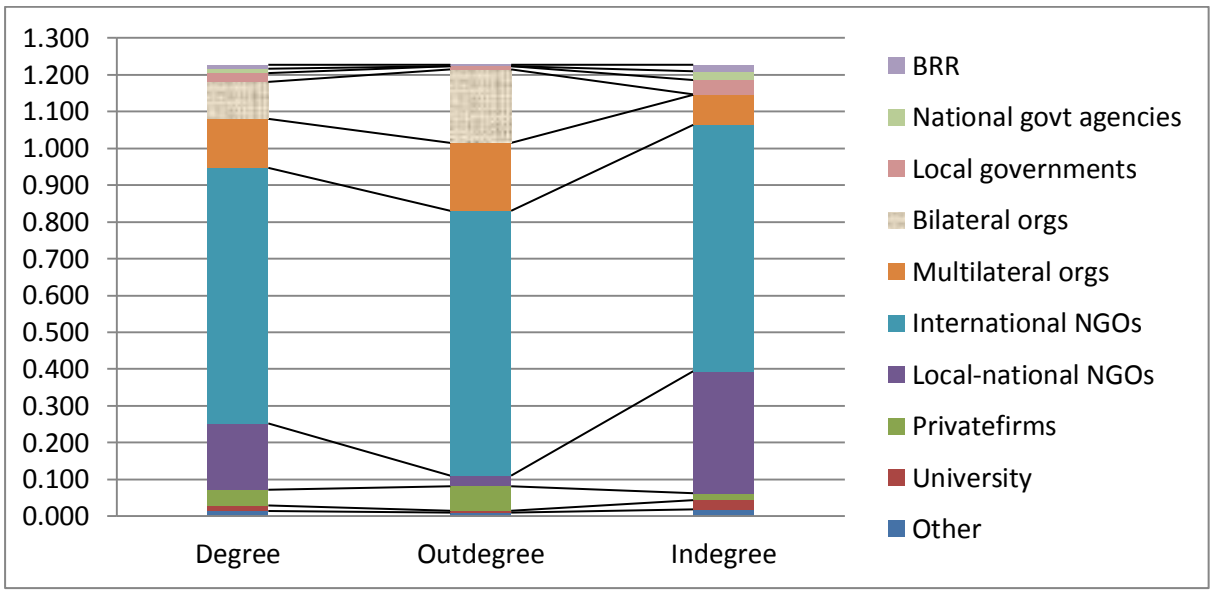
Source: Author – (directed network - Gephi's Fruchterman Reingold layout).

Table 3. Properties of Shrinked networks

Shrinked networks	No of nodes	% of nodes	No of links	% of links
2-core	249	31.05	478	48.93
3-core	76	9.48	186	19.04

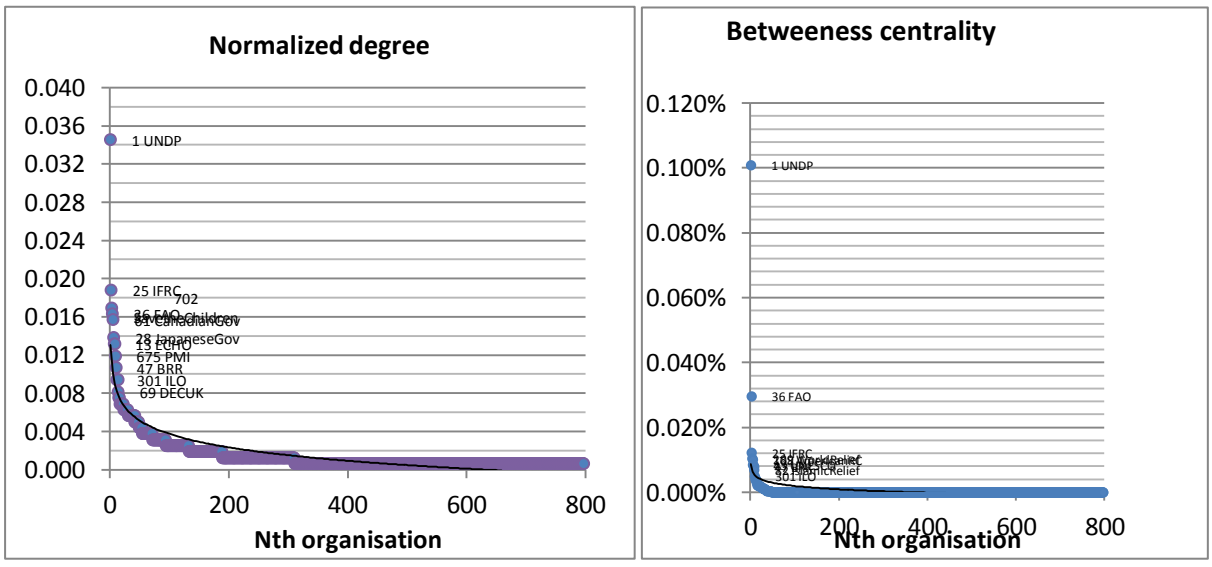
≥ 5-degree nodes	92	11.47	160	16.38
≥ 10-degree nodes	29	3.62	42	4.03
≥ 15-degree nodes	13	1.62	17	1.74

Figure 2. Degree and degree distribution analysis



Source: Author.

Figure 3. Comparison of degree and betweenness centrality distribution



Source: Author's

5.3. Betweenness centrality

It is important to note that OCHA as the coordinating agency under the United Nations which is part of the key core. However OCHA, the mandated organizations responsible for major humanitarian coordination and reconstruction coordination and information management is not included as 'leader' as measured by betweenness centrality. One of the reason is that this exercise is based on BRR database on reconstruction "who does what supported by whom". The reason for BRR become part of the top 10 leaders in the selected network is due to its roles as donor in the reconstruction process.

Based on a heuristic or an educated guess, one may not be surprised with the FAO and IFRC being on top of the together with the UNDP on top. The question is whether this measure of financial transaction is the best way to understand coordination? The answer is it is not the only way to measure coordination as along as there is other data available to suggest more detail analysis. However, in Social Network Analysis, there is already established knowledge concerning the strength of small ties that may be shadowed by the mighty connection of some nodes which may be missed by non-SNA expert (The concept of 'strength of small ties' is already common and can be found in the Nooy et. al., 2005).

What is also interesting is the fact that the betweenness centrality which measures the 'true' leaders on the ground brought some unfamiliar names to the humanitarian network in Indonesia (especially before the Indian Ocean Tsunami 2004) – such as –Tearfund UK, World Relief, American Red Cross, Mercy Malaysia and so on. The result is rather counter intuitive but indeed important for the key government and pre-existing national network to recognize the emerging important actors on the field for better humanitarian coordination.

6. Discussions

6.1. Insights for Network and Social Network Theory

It is quite surprising that the diameter of humanitarian organizations is 5. Take any two organization which one is any local NGO and the other is any international NGO, the finding suggests that either the first or the later will need on average 5 intermediaries to get connected and do humanitarian transaction.

This suggests that humanitarian actors' network typology in the context of large catastrophic disasters in the developing world like Aceh (Indonesia) reflects real world individual networks as shown by former works of such as Milgram (Travers and Milgram 1969). In retrospect, Milgram conducted an experiment where he targeted the two persons in Boston by sending 160 letters from Wichita (Kansas) and Omaha (Nebraska). His objective is to know how many links or 'intermediate persons' for any two persons. Based on an experiment in the US, Milgram (1967) found that the distance between any two people is connected by 5.2 'intermediate persons' or 'degrees of separation'.

From different setting, Dodds, Muhamad and Watts experimented with 60,000 e-mail users attempted to reach one of 18 target persons in 13 countries by forwarding messages to acquaintances of which involved 24,163 e-mail chains, when only 1.59 reach the targets. Their network is a 'small-world network' which concludes that "social searches can reach their targets in a median of five to seven steps, depending on the separation of source and target, although

small variations in chain lengths and participation rates generate large differences in target reachability" (Dodds, Muhamad and Watts, 2003).

The measure of network diameter is important because it shows the maximum distance between any two disaster response organizations. The implication of the network diameter in times of emergency intervention is more serious than Milgram's ordinary social network. It is about life and death decision where organizations should get connected to achieve their common goals in saving lives and rebuilding livelihoods of the survivors. This means that if authoritative agencies such as reconstruction authority (BRR) and United Nations Office for Coordination of Humanitarian Affairs (OCHA) were willing to ensure level of quality control of a thousand organizations, they can simply send emails all of them. However, how could they get the address or email of those organizations?

It may seem obvious that by reaching through the humanitarian clusters, they could reach the other organizations that were partners of the cluster members. The thing is how the non-cluster actors can be connected? Reaching out all the actors is obviously a heavy task. One can argue that the authorities can simply use other forms of media. However, the realities on the ground were not that simple.

The author argues that the flow of technical knowledge that ensures qualities of implementation often flow according to the flow of resources (finance and goods). Implementing partners and aid distributors to communities may only comply with their funders. The intention to avoid overlaps of aid cannot be fully controlled along the almost 1000km of affected coastal communities (from Nias Islands, to South of Aceh to the West of Aceh to the Far East of Aceh).

This research shows that the degree distribution follows power law due to 'preferential attachment' phenomenon (Barabási and Albert, 1999) where some most highly connected nodes are those who are the dominant lead of humanitarian clusters. More important than this, the cluster lead often play intermediary roles that connects NGOs, governments, donors and private sectors. The birth of new NGOs after disasters is likely to be connected to certain highly connected nodes.

The implication of this finding is that for other large scale disasters in developing world such as Haiti, Myanmar and Pakistan, the network's structure is more likely to be the same. This begs for more investigation and research. What is unique about this research is the fact that it is not an experimental research. It is the real population based on the records concerning from that were involved in the field. Even though it does not fully reflect the final number of humanitarian and reconstruction organizations in Aceh during 2005-2007, however, the recorded list is estimated to be more than two-third of the total number of actors.

In addition, all the actors were more or less used to operate or to be based in a certain period of time at different levels responding to the needs of humanitarian works in Aceh during 2005-2007.The question remains whether all the links between the nodes can only be explained by financial transaction? The answer is off course not necessarily. Emails communications can be one of the options. However, getting all the email records from the actors is also a serious challenge.

The most important steps in network analysis is clearly defining what are the nodes and the links represented. In this exercise, the links are the financial transactions. The nodes are the

organizations. Therefore, for future exercise, one can investigate more complex dimension where the nodes can be any organization and any individual and the links can either be more broad (financial transactions, knowledge and innovation sharing and standards) or more specific relations such as informal gatherings of individuals.

6.2. Insights of network theory for disasters studies

The findings have significant implications for disaster management communities. Field coordination of humanitarian emergency actors is a complex and difficult tasks. The author did not expect to find that network typology of humanitarian and post disaster reconstruction actor is similar to the real world social networks (Travers and Milgram1969; Dodds et. al. 2003). Despite critics concerning Milgram's25 incomplete chain of letters to the targeted subject, their incomplete chain of letters reflects the real world difficulties of doing 'coordination' and problems of policy coordination in the real chaotic disaster situations.

The use of Aceh's reconstruction updates provides more realistic views of the organizational coordination. It is also noted that the emergent of hubs in humanitarian network namely humanitarian clusters are proven to be central nodes. Therefore, governing post disasters interventions can be better guided by understanding this phenomenon. United Nations agencies and local authority can improve coordination effectiveness through the existing humanitarian clusters. What is lacking is that some hubs are not included in the (traditional) humanitarian clusters. Therefore, the vision of coordination should move beyond the existing cluster system.

Ramalingam et. al. (2008) highlight that cross-organizational networks have played pivotal roles post disaster interventions in recent past decades. Stroddard et al. (2007) conventionaly view post disaster network as an aggregation of individuals - as they highlighted the Inter-Agency Network for Education in Emergencies that represents over 2,000 individual members s INNE produced Minimum Standards for Education. Interestingly, they also noted refugee protection in Somalia where tens of national partners work as a network to provide protection and human security in post disaster settings. These networks need to be understood from the network theory lenses in order to understand the detail properties of humanitarian field networks.

When disaster emergency occurs at the scale of, or bigger than Indian Ocean Tsunami 2004, "an ad-hoc" big-bang formation of humanitarian emergency networks are formed. The networks often grow and then faded away or burst. Furthermore, they may be transformed into new network structures.

Key government agencies were often not able comprehend the complexity and their novelty grows as thousands of events (interventions projects) occur during the emergency and reconstruction phases. The emergency network may later transform into a new network as reconstruction and recovery begin. Large scale disasters in developing countries triggered more than hundred donors countries, hundreds of International NGOs that also serves as donors, create new formation of local NGOs in Aceh and Sri Lanka, Cyclone Nargis in Myanmar, and devastating earthquake in Haiti and floods in Pakistan 2010 led to recruitment of thousands reconstruction worker from hundreds of NGOs.

This analysis can be done as events (or transactions) occur on the ground. It may create opportunities for the respective authority to play smart coordination roles through several informed decentralized systems. Organizations like Office for Coordination of Humanitarian

Affairs (OCHA) have been often played roles in the first week of disasters in developing worlds like Indonesia. Their approach to document "who is doing what where and when" can be rapidly analyzed regularly on the field. However, this requires human resources which is often not locally available. Nevertheless, as long as there is accurate information concerning "who is doing what where and when" and as long as there is qualified staff at headquarters, the analysis can be done and networks can be monitored regularly.

In addition, if this can be done, the formation of a network and the burst of the network can be adequately monitored before, during and after humanitarian mission.There is confirmed evidence of post disaster intervention after Indian Ocean Tsunami 2004 emerged as a governance network. Involvement of actors and stakeholders (from local to the global level) was ranged from local NGOs, national and local governments, international financial institutions, and United Nations and universities, private firms, bilateral aid and so on.

It is found that government is not the only central actor as there are many central actors evidenced by the centrality analysis (degree and betweenness – See Figure 1-3). This confirms both the theory and the hypothesis that post disaster governance emerge as polycentric networks as there are many centers of authority that devise responsibility for post disaster intervention.The exercise can go beyond the grantors-grantees relationship as presented in this paper.

Real exercise on the ground should be possible and network theory can help coordinating agencies such as disaster risk management agencies (local and national) and international humanitarian coordinating agencies such as Office for Coordination of Humanitarian Affairs (OCHA) and other humanitarian clusters' leaders to map the landscape the complexity of post disaster interventions in order to inform their action concerning providing more effective and efficient intervention.

Based on the experience from Aceh, the author also suggests that the concept humanitarian cluster approaches can be strengthen using the social network analysis. This can certainly help both national and international intervention system to be more effective and efficient.The emergent of hubs highlights the strength of disaster governance framework because the hubs are in fact 'multiple centers' where command and resources are flowed through to the fields. This is called 'poly-centric' features of emergency and reconstruction management. It promotes the notion that there are many overlapping centers of authority and responsibility for disaster risk reduction and post disaster intervention (Lassa 2011).

7. Closing remarks

It can be concluded that the structure of post disaster system is highly decentralized. Therefore, any efforts to guarantee quality of interventions must understand the nature of the network. This phenomenon is called 'networked governance' of post disaster interventions.

Large scale disasters risks bring their own typology of actor's networks. However, the network is not randomly formed. Interestingly, the network diameter reflects the real world network. This seems to be counter intuitive as people may be thinking that level of ties or connection between any two humanitarian actors in a disaster specific affected geography can be less than real world individual networks.

It is clear that without understanding the landscape of complexity, government authority may not be able to create 'organized behavior' among nearly thousands reconstruction players to guaranty

quality in emergency intervention and reconstruction.There are limitations in this research. Despite clear operational benefit of this approach, future works should provide more empirical evidence from recent large scale disasters beyond financial transaction. This analysis is limited to 'principal-client' networks among donors and implementers, regardless the localities where they work.

More exploration on the different use of social network analytical tools for disaster studies is suggested. Cases from Haiti can also be presented in the next future (work in progress). The application of the theory is arguable wide and can be applied in wider context of disaster research. This includes more valuable measurements such as the density of network that can be measured over different periods of time (rather than treated the network as a single period).Post disaster governance is therefore not entirely unique. It is rather a micro-cosmos of the real world networks. However, more comprehensive studies concerning type and scale of disasters and their typical networks may guide United Nations and governments' authority to perform better in the future post disaster interventions.

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