Tsunami early warning chain assessment utilizing social network analysis

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Abstract. The application of rapid and accurate disaster early warning information has served as the key to successful mitigation for natural disaster. For example, in a tsunami disaster condition, precise information from authorized stakeholders must be immediately and accurately conveyed to the people potentially affected by the disaster. However, in practice in the field, the disseminated information has been however uncertain, failing to reach the lowest level of society. For this reason, a study is required to identify the information network that existed in the community when the tsunami disaster occurred. One method in determining this information includes Social Network Analysis (SNA), referring to a study method of structural relationships among the interacting network members, involving: individuals, organizations, or institutions. In this study, a survey was conducted to 90 respondents at the disaster location. From the results, it was found that 14 actors were involved in disseminating information on the tsunami disaster in the lowest community. The result of the Social Network Analysis indicated that the value of the degree of centrality, actor of mosque information obtained the highest value of 0.231, implementing that most of the community at the lowest level received tsunami information from announcements disseminated through information from mosques. Meanwhile, the lowest value of network closeness centrality was hamlet (RT/RW), having a value of 0.876, indicating that information from the mosque was beneficial as disaster early warning information. Upon calculating the degree of centrality and closeness at the lowest level of society, information from mosques and hamlet (RT/RW) serves as the most influential actor in disseminating tsunami information in Pandeglang Regency, Banten, Indonesia.

1. Introduction
Disaster events are inevitable from human life, especially for the past few years, the incidence of disasters tends to increase [1]. To reduce the risk of damage, each country has hazard mitigation plans updated regularly [2]. One of the most threatening disasters for the Indonesian state is the tsunami disaster, due to the presence and existence of earthquakes and volcanoes in Indonesia. Lack of information related to tsunamis caused by volcanic activity will increase disaster risk for coastal areas [3]. One of the events was the Pandeglang tsunami, Indonesia, which occurred in 2018. This tsunami disaster is a silent tsunami phenomenon because the tsunami was not caused by earthquake activity; because of that, there is no warning that results in a significant enough loss, namely 32 billion Rupiahs includes ecosystems and buildings destroyed [4].

In terms of tsunami disaster mitigation, information is an essential thing in reducing the effects of the disaster. To regulate tsunami early warning information, in Indonesia, the Indonesia Early warning system program has been prepared (InaTEWS), while the scheme of the InaTES has been described in...
figure 1. Information about the tsunami must reach the community less than 5 minutes after the earthquake [5]. However, sometimes this information does not reach the public, due to problem regarding the information network [6] or issues in the government bureaucracy [7].

**Figure 1. Flowchart of tsunami early warning information dissemination**

*Source: InaTEWS Document*

When the tsunami occurred, communication between residents about information was minimal, and the information available was often inaccurate [8]. Thus, it is necessary to modify the current flow of tsunami information so the information can quickly get to the community. This study looks at the actors who play a role in the community in the tsunami incident, which will later be recommended to be included in the existing tsunami early warning information chain.

### 2. Methodology

This study utilizes an exploratory method, which uses a semi-quantitative method. Figure 2 describes the flowchart of this research. The first step is conducted to identify the network information on disseminating tsunami early warning information. There are two important questions that become the main data in this research: from whom do they get tsunami early warning information, and to whom do they disseminate tsunami warning information. These two primary data are the main input for the Social Network Analysis (SNA). Social Network Analysis is interdisciplinary methodology research that combines many disciplines such as sociology, Physics, Mathematics, Computer Science, and many more [9]. To calculate the SNA analysis, this research applies the UCINET software, an open-source program that has a general package for social network analysis. The program can be used to characterize the network and the position of the nodes within networks [10]. The outputs of this analysis include: degree centrality, network diagram, and closeness centrality that can be seen in figure 2.
Degree Centrality is showing the knot of linkage of the actor. Degree centrality in Social Network Analysis is used to show the popularity level of the person. The actors with a high degree of centrality have an essential role in disseminating information due to communicating with other actors in the network [11]. The equation that is used to measure Degree Centrality can be shown in equation 1.

\[ C_D(i) = \frac{D(i)}{N-1} \quad \text{Eq 1.} \]

- \( C_D \) = Degree Centrality
- \( i \) = Actor
- \( D(i) \) = the set of all individuals adjacent to the members
- \( N \) = sum the actor on the social network

Closeness Centrality measure by a geodesic distance that connects from each actor in the social network. Closeness Centrality is used to consider the time needed by the actor to access the information from another actor or the total amount of steps that connect one actor to another actor in the network. The equation that uses to measure Closeness Centrality can show in equation 2. The closeness centrality focuses on measuring the distance between an actor and another in the network [11]. The lower value in closeness centrality means the closer the actors can interact with other actors.

\[ C_c(i) = \frac{n - 1}{\sum_{j=1}^{n} d(i,j)} \quad \text{Eq 2.} \]

- \( D(i,j) \) = distance each actor I to j
- \( n \) = The number of actor that in the network
- \( \Sigma \) = Sum of nearest distance from actor \((i)\)
One of the important things in these methods is to select who or what of the actor that have an impact on the early warning information dissemination. From the literature review, there are 14 actors that chose can be seen in table 1.

| No | Actor                                                                 | Sources                                                                 |
|----|----------------------------------------------------------------------|------------------------------------------------------------------------|
| 1  | Meteorology, Climatology and Geophysics Agency (BMKG)                | InaTEWS (2010)                                                         |
| 2  | Indonesian National Army (TNI)                                       | InaTEWS (2010)                                                         |
| 3  | National Police                                                     | InaTEWS (2010)                                                         |
| 4  | Regional Disaster Management Agency (BPBD)                          | BNPB Towards Tsunami Resilient Indonesia (2012)                        |
| 5  | TV Station                                                          | Warning in the face of tsunami risk, Harkunti Pertiwi Rahayu (2019)    |
| 6  | Pandeglang District Government                                      | InaTEWS (2010)                                                         |
| 7  | Labuan sub-district Government                                      | InaTEWS (2010)                                                         |
| 8  | Community members                                                  | InaTEWS (2010)                                                         |
| 9  | Disaster Preparedness Group (Kelompok Siaga Bencana)                | Warning in the face of tsunami risk, Harkunti Pertiwi Rahayu (2019)    |
| 10 | Tsunami Siren                                                        | Warning in the face of tsunami risk, Harkunti Pertiwi Rahayu (2019)    |
| 11 | Mosque                                                              | Warning in the face of tsunami risk, Harkunti Pertiwi Rahayu (2019)    |
| 12 | Village Government                                                  | Warning in the face of tsunami risk, Harkunti Pertiwi Rahayu (2019)    |
| 13 | RT (Rukun Tetangga) / hamlet                                       | Communication Network Analysis (Eriyanto, 2014)                         |
| 14 | RW (Rukun Warga) / hamlet                                          | Communication Network Analysis (Eriyanto, 2014)                         |

3. Result and Discussion

3.1. Early Warning Information Network from InaTews Document
The information early warning tsunami disaster network is based on the InaTews Document. The implementation of the Tsunami Early Warning System is shown in figure 3. In the InaTews Document, the six government organizations involve with the tsunami early warning system in Indonesia, including: BMKG, Military, National Police, Ministry of Communication and Information Technology, Ministry of Home Affairs, BNPB, and Local Government. From the figure 3, it is obvious that The BMKG serves as the source of the tsunami early warning system. Ministry of Communication and Information Technology has a task to spread the information to the community members by the electronic media such as Television, Radio, or Telecommunication Provider.
Figure 3. Information network diagram of tsunami early warning system from the InaTews document

From figure 3, it is apparent that the information that comes to the community have to go through several layers. The minimum layers that the information of tsunami early warning is two layers, which is from BMKG to The Minister of Communication and Information and go through the community. The minister of communication and information has the task to deliver the information to the media such as television and radio, the radio and TV provide it to the community. Information from television and radio often does not reach the community because the community does not have access to the radio and tv. This information network creates a big problem in terms of the dissemination of tsunami early warning information[6]. There is not an institution that has a task to spread the information at the community level.

3.2. Early Warning Information Network from the result of Social Network Analysis

From figure 4, it is apparent that the mosque gives much information about the tsunami in the lowest level of community. Many arrows that come out from mosque actor to the community. For BMKG, although it is the source of information of tsunami, not many people get direct information of tsunami from BMKG. One more fact is that no community members that get tsunami information from the tsunami siren. The case of the tsunami in Labuan district was not caused by the activity of earthquake, and it was caused by the landslide of mount Krakatau Child, that causing the big wave in the sea that have a big impact in Banten, which that the maximum of inundation distance from the coastline is about 350 m [12]. Besides the mosque, there are some actors that have an important role in disseminating the information of tsunami early warning, which is The head of Rukun Warga (RW) and the head of Rukun Tetangga (RT). One of the interesting facts in figure 4 is that nobody gets information about tsunami early warning sirens. This happened because the tsunami does not happen because of earthquake activity, so the siren not ringing.
3.3. Early Warning Information Network from Community Interviews

The network diagram was created by interview 90 community members in Labuan sub-districts, Pandeglang Districts. Interviewers were asked from whom did they get the information of the tsunami early warning and then to whom they continue the information of the tsunami early warning. The network diagram from the results of an interview can be seen in table 2.

Table 2. Result of the degree centrality and closeness centrality

| Actors                                                                 | Degree Centrality | Closeness Centrality |
|-----------------------------------------------------------------------|-------------------|----------------------|
| Meteorology, Climatology and Geophysics Agency (BMKG)                 | 0.077             | 0.675                |
| Indonesian National Army (TNI)                                        | 0.019             | 0.839                |
| National Police                                                       | 0.067             | 0.886                |
| Regional Disaster Management Agency (BPBD)                            | 0.125             | 0.923                |
| TV Station                                                            | 0.163             | 0.951                |
| Pandeglang District Government                                        | 0.067             | 0.862                |
| Labuan Sub-District Government                                        | 0.106             | 0.923                |
| Community Members                                                     | 0.125             | 0.776                |
| Disaster Preparedness Group (Kelompok Siaga Bencana)                  | 0.125             | 0.945                |
| Tsunami Sire                                                          | 0.019             | 0.156                |
| Mosque                                                                | 0.231             | 0.981                |
| Teluk Village Government                                              | 0.163             | 0.963                |
| RT (Rukun Tetangga)/ hamlet                                           | 0.096             | 0.876                |
| RW (Rukun Warga)/ hamlet                                              | 0.048             | 0.876                |
The calculation of degree centrality in table 2 shows that the actors who have the highest degree centrality value are mosques that have a value of 0.231 and television that have a value of 0.163. From this result, that mosque and television become the most popular actor in the social network. From the Closeness Centrality, it is apparent that in the level of people, there are two actors that the lowest value which is Rukun Tetangga (RT) and Rukun Warga (RW) that have the same value which is 0.876, it can be interpreted that RT and RW have the closeness distance to the people that can be call or contacted be the people.

From these results, there are important actors that, according to this research, can be included in the information dissemination scheme on InaTEWS. The actors are the mosque, RT and RW. In Figure 5, you can see the existing schematic, which was redrawn from the InaTWES document, While in Figure 6 is a modified scheme that has been added by several influential actors in the dissemination of information in the field.

4. Discussion
Based on the result and the interpretation of the data, one of the problems in tsunami early warning systems relates with the information network [6]. Several actors must be included in the diagram of tsunami early warning information. One of the actors in the community who is given the most
information or provides information about tsunami early warning is a mosque. Mosques can be used as a source of information for an early warning system for tsunamis and prepare the community capacity in disaster preparedness [7]. Besides that, the government must be increase public awareness [13] by involving the Rukun Tetangga (RT) or Rukun Warga (RW) organization to spread the information of tsunami early warning to the community. By involving the community leaders such as RW and RT, can be an advantage in the early warning tsunami dissemination [14].

From the research on the dissemination of tsunami early warning information which was analysed using the social network analysis (SNA) method, it is concluded that local element actors in the community such as mosques, RT, and RW have an essential role in disseminating tsunami early warning information in the community. Hence, this research proposed to include the local element actor in the InaTEWS schema.

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