A study of people-centered early warning system in the face of near-field tsunami risk for Indonesian coastal cities

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Abstract

Purpose – This study aims to identify the gaps in current policy and propose a viable framework for policy improvement regarding people-centered tsunami early warning chain in Padang City. The objectives are to describe the gaps and flaws in the current policy regarding local tsunami early warning chain, to identify potential actors to be involved in the tsunami early warning chain and to assess the roles and capacity of actors, and their potential for involvement in early warning.

Design/methodology/approach – This study is an exploratory study using social network analysis (SNA) on regulations and other legal documents, and primary data sources from a focus group discussion and semi-structured interviews.

Findings – The study found that the existed regulation lacks extension nodes to relay warnings to the populations at risk, often referred to as “the last mile.” Moreover, receiving warning information from both formal and informal sources is important to mobilize people evacuation more effectively during an emergency. The study found that mosque communities and disaster preparedness leaders are the potential actors who should be involved in the local early warning chain.

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Practical implications – The research findings were presented as a recommendation to Padang City Government and have been legalized as the new tsunami early warning chain procedure in the Padang City Mayor Regulation 19/2018.

Originality/value – This research investigated local tsunami early warning dissemination in Padang City using SNA. The study demonstrates a close collaboration between researchers, practitioners and the community.

Keywords Early warning, Tsunami, Social network analysis, Community level, End-to-end warning system, Warning dissemination, Tsunami early warning chain, Community level early warning dissemination

Paper type Research paper

Introduction
The 2004 Indian Ocean Tsunami was a major disaster not only for Indonesia but also for other Indian Ocean countries, and worldwide. The catastrophe caused more than US$7bn of economic losses, 229,866 deaths and 42,883 missing casualties. These devastating impacts led to the Indonesian Government developing the Indonesian tsunami early warning system (InaTEWS), as well supporting regional early warning efforts, which became known as the Indian Ocean tsunami early warning system. The InaTEWS was established and fully operational less than four years after the disaster.

Despite these efforts, recent events suggest there are still shortcomings in the implementation of end-to-end tsunami warning systems. For instance, in 2018 Indonesia suffered two deadly non-tectonic tsunami events, the first in Palu due to a coastal landslide induced by an earthquake (Kumar et al., 2019), and the second in the Sunda Strait due to the flank collapse of Gunung Anak Krakatau (Solihuddin et al., 2019). The InaTEWS was not able to warn the at risk populations in a timely manner, in part due to the InaTEWS having been developed to detect tsunami induced by tectonic activities. Investigations in the aftermath of the events suggested numerous contributory factors, including the types of tsunami source, the high level of tsunami hazard, lack of preparedness, high vulnerability because of population density in the coastal area and a “failing” tsunami early warning system.

Early warning systems are blamed for the loss of lives due to disasters more often than they are praised for the lives saved. This is likely due to the difficulty in accounting for the number of lives saved by a successful warning, in contrast to the ease by which the number of deaths can be calculated when warning system fails to adequately reach at risk communities. These failings are often attributed to the institutional dimension, rather than the technological dimension (Garcia and Fearnley, 2012). Warning products from the upstream part of the warning system often fail to reach the population at risk due to some missing links at the local level (Spahn et al., 2014). Moreover, different dissemination methods might deform the information content. Consequently, tsunami warning systems need to be supported by an end-to-end chain of information to deliver warnings in a timely manner.

A tsunami early warning system is a complex and dynamic system, involving not only the technology but also socio-technology, multi-level stakeholders and governance. The InaTEWS data and information flow, as shown in Figure 1, is composed of two main components, i.e. upstream and downstream. These are often referred to as the structure and culture components, respectively, and involve many multi-level government actors, as well as a wide range of regional, national and local stakeholders (BMKG, 2012).

The upstream is a system, which is very much relying on technological performance for monitoring, detecting, analyzing and disseminating tsunami warnings to the interface
agency and local government. The technology capability of several national government actors, led by Indonesian Agency for meteorology, climatology and geophysics (BMKG), the BMKG is very significant in the upstream component. The downstream component is a socio-technological system for conveying tsunami warning, and includes decision-making, as well as issuing and disseminating the evacuation order and tsunami warning information to all people at risk. This downstream component depends on many factors such as local government policy/regulation on tsunami warning, supporting infrastructure for evacuation and behavior of the people in responding the warning. A previous study in Padang City exposed the wide range of responses by people when they received warning information during tsunamigenic earthquake on September 30, 2009, ranging from immediate evacuation to postponing evacuation, to refusing to evacuate because of a variety of reasons and logical frameworks of thinking (Rahayu and Nasu, 2011). A more detailed analysis from 400 responses indicated that after both receiving formal warning from government and natural warning, such as strong shaking, some followed designated evacuation routes, while others acted spontaneously, even trespassing on neighbors’ land (Rahayu, 2012). Rahayu concluded that more effective tsunami early warning can be achieved by understanding and accommodating these behaviors of the people, and using this information to plan and/or improve downstream warning chain (Rahayu, 2012).

Since 2011 and along with Australia and India, the InaTEWS has been a designated Tsunami service provider for 24 countries in the Indian Ocean region. The system has also been tested by several real events, as it was established in 2008, with a high rate of success and able to issue tsunami warning less than 4 min after the earthquake (Triyono, 2012). However, studies have also revealed some flaws and limitations in the regulations
governing the system, as well as its implementation. For example, in terms of reaching the
population at risk, besides national mass media and remotely controlled tsunami sirens,
InaTEWS has only the authority to relay the warning messages to the emergency
operations centers (EOCs) at the city and regency level (BMKG, 2012). The task of extending
the chain of warning to the population at risk is mandated to the local governments, as also
regulated in Indonesian Law no. 24/2007 regarding disaster management.

This makes it necessary for cities and regencies with areas exposed to tsunami hazard to
be ready with the local level procedure regarding how to disseminate the warnings at times
of tsunami emergency. However, the agencies in charge often lack the capacity to develop an
end-to-end warning system, as it requires efforts in terms of funding, time and successful
multi-stakeholder partnerships (Thomalla et al., 2009).

For example, although Padang City is recognized as one of the leading Indonesian cities
for disaster risk management, as of 2017, there were still found to be some missing links in
their tsunami warning chain. Their regulation regarding the tsunami early warning chain
(Padang Mayor Regulation no.14/2008) had not been updated since 2010, and thus, has not
considered the InaTEWS service guidelines that were established in 2012. Also, the
regulation only focused on the city level decision-making procedure and had not specified
the other “interface actors,” besides the Padang City EOC, and city television (TV) and radio
channels. Interface actors are the persons or organizations that are responsible for
disseminating the warning message to the public at the community level. These actors are
essential in an end-to-end early warning system, especially in the case of near-field tsunami
events.

Other studies have concluded that a people-centered approach is the best approach for an
effective early warning system (Garcia and Fearnley, 2012). This requires the “last mile”
population to “own” the system. This sense of ownership should be not only achieved
through the involvement of the civil society in the whole process (i.e. community-based) but
also by acknowledging their roles in the policies and help to build their capacity through
economic aids and trainings (Spahn et al., 2014).

The topic of social capital is often associated with a community-based or people-centered
early warning system. Indeed, the community-based approach in all disaster phases puts an
emphasis on local partnership, leadership and voluntary involvement. Therefore, to initiate
people-centered early warning systems, it is necessary to identify the potential actors in the
community with the capacity as these interface actors. Identifying potential interface actors
in the community does not guarantee effective end-to-end warning dissemination, but
cognition of their involvement is vital at times of emergency (Comfort, 2007). This suggests
a people-centered approach needs to be incorporated into tsunami early warning policies.

Objectives
To address this gap, this study aims to identify gaps in the current policy and propose a
viable framework for policy improvement regarding people-centered tsunami early warning
chain. It will achieve this through a detailed study of tsunami early warning in Padang City
and address several objectives:

- to describe the gaps and flaws in the current policy regarding local tsunami early
  warning chain;
- to identify potential actors in the community to be involved in the tsunami early
  warning chain; and
- to assess the roles and capacity of these actors and their potential for involvement in
  the tsunami early warning chain.
Literature review

Sumatera, Java and Bali are Indonesian major islands, which lie very close to the active subduction zone parallel to the west coast of Sumatera from Aceh to Lampung, and south from Java, Bali and Nusa Tenggara coasts. As a consequence, the regions located along these shorelines are highly exposed to the threat of near-field tsunamis. According to the tsunami hazard assessment by the Indonesian national earthquake center (PUSGEN) in 2017, there is a potential of M 8.7 to M 9 tsunamigenic earthquake along this subduction zone. In addition to that, the major cities in these regions have a high population concentration in the coastal area, leading to a high social-economical vulnerability against the tsunami hazards. The Indian Ocean tsunami in 2004, Pangandaran tsunami in 2007 and Mentawai tsunami in 2011 were some of the devastating tsunamis generated from the fault.

In the wake of the 2004 Indian Ocean tsunami, InaTEWS was developed through the collaboration of 17 national level institutions in Indonesia (BMKG, 2012). In the early warning model proposed by UN-ISDR, a people-centered early warning system should consist of four elements as follows: risk knowledge, monitoring and warning service, dissemination and communication and response capability (Basher, 2006). The risk knowledge and response capability elements should be implemented in the communities at risk. In the InaTEWS, the warning service is focusing on two of these four elements: the monitoring and warning service, otherwise called the upstream part, and the dissemination and communication element or the downstream part.

The upstream part of InaTEWS is mainly technological, relying on hardware detection devices and decision support systems, whose operation is handled by the BMKG. Meanwhile, the downstream part is the responsibility of the national disaster management agency, interface agencies and local government. As a result, the responsibility for passing on the warning information to the “last-mile” population is mandated to the local government at the city or regency level. This part, in particular, requires a partnership of multi-institutional stakeholders to disseminate warning information in a timely manner, including when there is a very limited lead time. To achieve this, the warning chain needs to be exercised frequently and established in some form of regulations. It is also necessary to evaluate the system to ensure successful warning dissemination and response when a tsunami does occur.

Attention also needs to be paid to the response capability element, such as evacuation. Studies on evacuation behavior have been published for over 50 years. Earlier studies tended to focus on evacuation behavior as individual actions. More recently, as early warnings have been implemented for many hazard types, evacuation has been viewed as collective actions, as evacuees are motivated by actions taken by others, and external information such as warnings (Mawson, 2005).

There are many variables concerning the decision-making to protect oneself from an impending hazard. Miletli and Peek (2000) defined the processes that evacuees go through after receiving a warning as a sequence of hear, perceive and response. In their study, they also note that the content, style and channel of warnings, as well as characteristics of the receiver, are the important factors that determine the response outcomes. Depending on the people’s characteristics, evacuees might have varying responses to different sources of the warnings they received. Several factors such as risk awareness, personal trust to the government and mass media, involvement in the community and social networks can influence their preferred warning information source. These preferences can have a great influence on the evacuation decisions, and thus, people-centered early warning systems should consider disseminating the warning messages through various channels (Lindell and Perry, 2012).
A study by Taubenböck et al. (2009) found that about 30 per cent of their samples who received tsunami warnings during the 2007 Padang earthquake were informed through informal sources. The study highlighted the need to involve empowered neighborhood leaders for informal warning dissemination to cope with the critical time of the tsunami lead time in the case of near-field tsunamis. Besides, the involvement of local stakeholders can be very beneficial, as it was found to increase local resilience and aid for faster social recovery (Kapucu, 2015).

Sorensen stated that the key issue in establishing an effective early warning system is to join the detection sub-system with the dissemination and response sub-system (Sorensen, 2000). In the case of the downstream tsunami early warning system in a local community, challenges can be found in reaching the neighborhood leaders and mobilizing evacuations in a timely manner. Moreover, an additional challenge may also be found in integrating the bottom-up approach of local community involvement with the top-down nature of the upstream part of the early warning system, such as the InaTEWS (Thomalla et al., 2009).

In her seminal paper, Comfort asserts that a common operating picture among actors in an emergency response is a salient component for successful crisis management (Comfort, 2007). Thus, in the case of downstream tsunami early warning system, an integrated scheme for the warning chain should be established as a formal plan and simulated through training. Meanwhile, according to Krackhardt, influence is achieved when formal power is in line with informal power, such as when cognitive accuracy is implemented (Krackhardt, 1990). Consequently, in developing a community-based tsunami early warning system, neighborhood leaders, who have the means and capacity as interface actors in the early warning chain, should be recognized in the formal plans. Moreover, having a recognized operating plan will be crucial to ensure smooth coordination between emergent voluntary actors in the community and formal agencies (Whittaker et al., 2015).

On the other hand, an end-to-end warning chain should be the goal of a people-centered early warning system. An end-to-end early warning system emphasizes the connectedness of actors to make sure the warning messages reach the last-mile population in a timely manner (Spahn et al., 2014). This requires a sufficient communication capability and a clear operating procedure regarding the warning chain to be implemented by all the actors involved. Hence, it is important to visualize the network as a whole in the process of planning the downstream early warning system.

Methodology
This study is an exploratory study, which uses semi-quantitative methods. The study involves several data collection and analysis methods. To understand the subject in an in-depth manner, primary and secondary data were collected in several layers (in the provincial, city and district scale) as illustrated in Figure 2.

Data collection
This study uses mainly three different methods to collect data. Firstly, secondary data was collected through document reviews on existing regulations and legal plans regarding the tsunami early warning system in Padang City. The documents include:

- Padang Mayor Regulation 14/2010 regarding Padang City tsunami early warning chain;
- Padang City tsunami contingency plan; and
- National tsunami early warning system standard operating procedure (SOP).
The primary data was collected in two methods. A focus group discussion (FGD) about the downstream tsunami early warning system in Padang City was conducted on February 22, 2016. In parallel, a field survey through semi-structured interview was conducted in the Koto Tangah District in Padang City as the cross-validation for the FGD data.

The Padang tsunami contingency plan mentions a number of organizations in regard to tsunami emergency. However, according to the contingency plan, the majority of these organizations are responsible only in the emergency services of their respective sectors, while only a few are involved in the early warning chain. In practice, it was found that multiple organizations have taken some roles in the early warning system although they were not stated in the regulation. For the exploratory purpose of the research, the organizations identified from this regulation were invited to attend the FGD, which was conducted on February 22, 2016. The aim of this FGD was to develop the social networks of tsunami early warning chain and identify actors within the community who could potentially be incorporated for policy improvement. Delegates from 20 different organizations attended the FGD.

In parallel with the FGD, a survey was conducted to cross-validate the findings regarding local interface actors. The survey was conducted on February 20-27, 2016 in Koto Tangah District, Padang City. In total, 71 community respondents were surveyed using semi-structured interviews. These were used to understand their expectations and past experiences of receiving tsunami early warning messages. The objective of this survey was to create a complete view of the tsunami early warning chain from the community perspective. Table I presents a summary of the respondents’ characteristics.

Among the respondents are 36 community leaders. This group was identified as potential interface actors during the FGD. Despite the limited number of respondents, purposive and simple clustered sampling was used to increase the reliability of the data. The distribution of different community roles they represent and the sub-district of the respondents are shown in Table II.

**Analysis methods**

Social network analysis (SNA) has often been used in studies examining communication and cooperation between people and organizations during emergency responses, humanitarian aid interventions, and recovery after disaster events (Kapucu and Demiroz, 2017; Bisri et al., 2016; Kim and Hastak, 2018). This study offers a different usage of SNA by focusing on the downstream early warning chain, which presents a different set of interests to be emphasized in the study.

SNA can be used in different ways during quantitative, qualitative or mixed methods studies. A quantitative SNA may help researchers understand the form of networks through various metrics such as network size, density, etc., or of certain actors through their degree of centrality and betweenness. A qualitative SNA approach may help better understand the
<table>
<thead>
<tr>
<th>Variables</th>
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<th>(%)</th>
</tr>
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<td></td>
</tr>
<tr>
<td>&gt; 18</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>19-30</td>
<td>21</td>
<td>29</td>
</tr>
<tr>
<td>31-40</td>
<td>13</td>
<td>18</td>
</tr>
<tr>
<td>41-50</td>
<td>14</td>
<td>19</td>
</tr>
<tr>
<td>51-60</td>
<td>12</td>
<td>16</td>
</tr>
<tr>
<td>&gt; 60</td>
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<td>7</td>
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<td>41</td>
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<tr>
<td>500-2,000</td>
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<td>8</td>
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<tr>
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<td>19</td>
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<td>Civil worker</td>
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<tr>
<td>Teacher</td>
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<td>8</td>
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<tr>
<td>Private employee</td>
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<td>5</td>
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<tr>
<td>Self-employed</td>
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<td>12</td>
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<tr>
<td>Common labor</td>
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<td>5</td>
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<tr>
<td>Housewife</td>
<td>9</td>
<td>12</td>
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<tr>
<td>Retired</td>
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<td>4</td>
</tr>
<tr>
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<td>4</td>
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<td>11</td>
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<tr>
<td><strong>Education level</strong></td>
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<tr>
<td>Senior high school</td>
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<tr>
<td>Diploma</td>
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<tr>
<td>Bachelor</td>
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<td>Masters/doctoral</td>
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<td>5</td>
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<tr>
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### Table I.
Respondents’ characteristics

### Table II.
Sub-district and community roles of respondents

<table>
<thead>
<tr>
<th>Sub-district</th>
<th>Freq</th>
<th>(%)</th>
<th>Community roles</th>
<th>Freq</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parupuk Tabing</td>
<td>15</td>
<td>21</td>
<td>Disaster group</td>
<td>14</td>
<td>20</td>
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<tr>
<td>Lubuk Buaya</td>
<td>21</td>
<td>30</td>
<td>School</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Batang Kabung Ganting</td>
<td>11</td>
<td>15</td>
<td>Mosque community</td>
<td>13</td>
<td>18</td>
</tr>
<tr>
<td>Pasie Nan Tigo</td>
<td>9</td>
<td>13</td>
<td>Sub-district office</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Padang Sarai</td>
<td>8</td>
<td>11</td>
<td>Community member</td>
<td>35</td>
<td>50</td>
</tr>
<tr>
<td>Bungo Pasang</td>
<td>7</td>
<td>10</td>
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</table>
context of relationships and can also yield better overviews for smaller networks. To answer our research objectives, SNA will be used qualitatively in this study. There are three points of interest to be emphasized:

1. Gaps and flaws of the existing early warning chain according to the comparison of networks;
2. Identified mid-actors based on different networks; and
3. Evaluation of how these mid-actors can better strengthen and fasten the information flow in a tsunami early warning chain.

A social network graph can be created by analyzing the pattern of communication between nodes (could be an actor or organization) in an intended system. This study puts emphasis on understanding the gaps and differences between tsunami early warning networks based on three types of collected data, as shown in Table III.

This study is a semi-quantitative study mainly using SNA as a network visualization tool and descriptive network interpretation analysis. To conduct the SNA, the software UCINET 6 was used. The results were then interpreted and analyzed descriptively using additional information from the literature, document review, FGD and survey.

**Results**

*Network 1 (original network): documented in plans and regulations*

Network 1 (original network) is based on the Padang City Mayor Regulation 14/2010 regarding the implementation of the Tsunami early warning system. In the document, seven

<table>
<thead>
<tr>
<th>Network type</th>
<th>Data input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network 1: original network based on legal documents</td>
<td>Document review on existing plans regarding tsunami early warning system: National TEWS SOP Mayor regulation Tsunami contingency plan</td>
<td>Network matrix Identified list of actors to be invited for the FGD</td>
</tr>
<tr>
<td>Network 2: government model developed based on FGD</td>
<td>The FGD among key stakeholder at city level conducted in February 2016 involved representative from 20 identified organizations (governmental, NGO and private) from the provincial and city level</td>
<td>All stakeholders approved a network regarding the city level TEWS Identified local-level stakeholders who are potentially able to be involved in the people-centered tsunami early warning chain in Padang City</td>
</tr>
<tr>
<td>Network 3: community model developed based on the result of field study</td>
<td>Semi-structured interview with 73 respondents from the community. The respondents were selected based on their sub-district and roles in the community</td>
<td>Current state of the downstream tsunami early warning system practice in the community level Identification of roles and capacity of the actors identified in the previous FGD Proposed framework for people-centered tsunami early warning system</td>
</tr>
<tr>
<td>Network 4: the complete network developed based on the integration of government model and community model</td>
<td>Integration of Network 2 (government model) and Network 3 (community model)</td>
<td></td>
</tr>
</tbody>
</table>

**Table III.** Different types of network
organizations were identified to be included in the tsunami early warning chain for Padang City. Figure 3 presents a list of organization and their responsibilities. A network matrix was then created based on the regulation to produce a social network graph, as shown in Network 1 (original network) in Figure 4.

In Figure 4, as in all the other networks, the BMKG serves as the tsunami warning information provider. Meanwhile, in this Network 1 type, the Padang City EOC (EOC – Pusdalops Kota) is the only organization that receives the information in Padang City. Then, under city jurisdiction, the EOC must report to the City Mayor regarding the information received. The Mayor will make decision for an evacuation order, based upon the level of

<table>
<thead>
<tr>
<th>Actor / Organization</th>
<th>Role and Responsibility</th>
<th>Node symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indonesian Agency for Meteorology, Climatology and Geophysics (BMKG Pusat)</td>
<td>Provide tsunami warning information to Padang City Emergency Operations Centre (EOC)</td>
<td></td>
</tr>
</tbody>
</table>
| Padang City Emergency Operations Centre/EOC (Pusdalops Kota Padang) and Disaster Management Agency (BPBD/PK Kota Padang) | - Receive warning information from Indonesian Agency for Meteorology, Climatology and Geophysics (BMKG Pusat)  
- Propose suggestion for further actions to Padang City Mayor  
- Relay warning information to the population at risk directly or through interface actors | |
| Padang City Mayor (Walikota Padang) | Make decision regarding actions to be taken following the tsunami warning | |
| Padang City Communication and Information Agency (Diskominfo - Kota Padang) | Relay information from Padang City EOC to local television and radio channels | |
| Local Television and Radio Channels (TVRI and Classy FM) | Relay information from Padang City EOC (Pusdalops Kota) and Communication and Information Agency (Diskominfo) to the population at risk through live broadcast | |
| Indonesian Amateur Radio Union (RAPI) | Relay information from Padang City EOC (Pusdalops Kota) and Communication and Information Agency (Diskominfo) to the population at risk through live broadcast | |
| Citizen Band Radio (RAPI) | Relay information from Padang City EOC (Pusdalops Kota) and Communication and Information Agency (Diskominfo) to the population at risk through live broadcast | |
| Disaster Preparedness Community Group (Kelompok Siaga Bencana - KSB) | Relay information from Padang City EOC to last-mile population in their respective communities | |
| Padang City Vice-Mayor (Walik Wali Kota Padang) | Lead the preparation for emergency response based on tsunami early warning from Padang City EOC | |
| Padang City Secretary (Sekretaris Daerah) | Assist the preparation for emergency response based on tsunami early warning from Padang City EOC | |

**Figure 3.** Roles and responsibilities of actors as regulated in Padang City Mayor Regulation 14/2010

**Figure 4.** Network 1 (original network) based on City Mayor Regulation 14/2010
tsunami warning information. This identifies the very critical role of Padang City EOC as a disruption in the communication line between the national agency for meteorology, climatology and geophysics (BMKG) as the national service provider (NSP) and the Padang City EOC, which might result in a delay or even failure in the evacuation order and emergency response.

In the local regulation, i.e. City Mayor Regulation 14/2010, it was specified that the role of Mayor of Padang City includes making a decision regarding further actions, i.e. evacuation order and incident command system, to be taken after receiving the warning. This means that Padang City EOC will not carry out dissemination of the tsunami warning and evacuation order before receiving the instruction from the Padang City Mayor. This tie, presented as red lines on Figure 4, clearly depicts the redundant line of decision-making and communication between the Padang EOC and the Padang Mayor after receipt of the warning from the NSP, and before it is disseminated to the community. This procedure may not be feasible and practical, as the tsunami might happen at any time, and would require the Padang City Mayor to be available at any time. For example, there are many situations when the Mayor has duties out of the city or abroad, which could undermine or delay the tsunami warning dissemination process under this regulation.

Network 2 (government model): as identified by actors in focus group discussion

The first FGD was conducted on February 26, 2016. It was attended by 20 organizations from Padang City and West Sumatra Province. During the FGD, the main discussion topic was how the tsunami early warning dissemination should be conducted in the city and at the community level. The discussion resulted in a consensus emerging on the ideal tsunami early warning dissemination chain for Padang City, and involving related organizations from the city and at the community level. Based on the agreed chain, a social network graph, namely, Network 2 (government model) as presented in Figure 5, was created.

The communication of tsunami early warning in the network, as identified during the FGD, has two main purposes. The first, which is in line with this paper’s main focus, is to inform the last-mile community about the coming tsunami and order an evacuation. On the other hand, some of the organizations identified in the network indicated the main purpose is as an incident command system during post-disaster emergency response. Similarly, this function was actually found in Network 1 (original network) as the responsibility of Padang City Vice-Mayor and Secretary. These organizations are community health centers (Puskesmas and Pustu), Police (Kapoldes), public works agency (Dinas PU), development planning agency (Bappeda), social agency (Dinas Sosial) and several others.

The second FGD meeting was conducted three months later at the district level, i.e. Padang Barat District. This second FGD focused on identifying other potential stakeholders from mid-actors as an interface from the city level to the community. The roles of new mid-actors, i.e. three NGOs actors and two civil society organizations (CSOs) or community leaders, were identified and played an important role in the public dissemination of warning messages. These are Red Cross (PMI), tsunami preparedness community (Komunitas Siaga Tsunami/Kogami), mercy corps, disaster preparedness school (Sekolah Siaga Bencana/SSB) and mosque community (Komunitas Masjid). The existence of these new mid-actors will be further explored and discussed in Network 3 (community model).

Based on these two FGD meetings, both at the city and district level, Network 2 (government model) was developed. In comparison to the previous Network 1 (original network), Network 2 (government model) has more redundancy in the warning dissemination and involves more agencies at the city level. Moreover, critical ties such as between Padang City EOC, BMKG and the Mayor of Padang, has been replaced by more
robust backup communication ties. For example, in Network 2 (government model), the Regional Office of the BMKG (for West Sumatera), who is responsible for West Sumatera region, has established several communication lines, such as with the Padang City Mayor, several other agencies in Padang City (for emergency response function) and several NGOs and community leaders (for tsunami early warning dissemination).

Network 3 (community model): toward a people-centered early warning system
According to the finding of Network 2 (government model), four mid-actors (community leaders) were the consideration of the sampling method in the community survey. For the development of the later network, i.e. Network 3 (community model), an emphasis was put to investigate the potential roles of four types of these mid-actors (community leaders) as local interface actors, i.e. sub-district office (Kelurahan), schools (Sekolah Siaga Bencana), mosque communities and disaster preparedness groups (KSB).

The network matrix was created based on a network census through an in-depth survey using semi-structured interview in Koto Tangah District, Padang City. Respondents were asked how they received or will receive evacuation orders in the case of tsunami. Additionally, local interface actors were asked if they would communicate with other actors or relay the information to the community members. The network census resulted in Network 3 (community model) as shown in Figure 6.

According to the survey in Koto Tangah District, it was found that various communication devices are involved in the dissemination of tsunami warnings to the last-
mile community, i.e. a community that does not have access to the tsunami warning information or an evacuation order because of its location or physical ability. There are four main warning channels of tsunami warnings identified for the last-mile community. These are tsunami sirens activated by Padang City EOC (32 per cent), access to mainstream media such as TV and radio channels (45 per cent), through other telecommunication devices with their links or acquaintances in the civil institutions (17 per cent). Thus, this leaves the rest to rely on warnings from local mid-actors or community leaders (29 per cent).

Discussion
Padang City is a coastal city with the highest risk of near-field tsunami in Indonesia. A tsunami hazard model shows a high probability of the occurrence of Mentawai Megathrust Tsunami to hit Padang City (Griffin et al., 2017). Since the 2004 Indian Ocean tsunami, disaster risk reduction interventions have been in place in Padang. It is also one of the pioneer cities for disaster risk reduction in Indonesia. Thus, the awareness and preparedness of the city toward tsunami might be expected as better than other coastal cities and regencies in Indonesia. Despite this expectation, the study indicates there are several aspects that require improvement in the downstream warning chain of tsunami early warning in Padang City.
Under the Indonesian disaster management law, i.e. UURI no 24/2007, and the compliance with the autonomous of government system in Indonesia to local government level, the responsibility to protect the people from disaster is at the local government level. This means that the City Mayor (or regent for regencies) has the highest responsibility to evacuate all the people at risk and leave no one behind. Upon receiving a warning from national agency for meteorological, climatology and geophysics (BMKG), and as described in the grand scenario of InaTEWS, issuing an evacuation order is the responsibility of the mayor (BMKG, 2012).

As discussed at the analysis of Network 1 (original network), there were too many critical ties in the Padang City tsunami early warning chain. These include the full reliance on the Padang City EOC to receive early warning information from the NSP and the decision-making role of Padang City Mayor. Although, further in the study, it was found that there is backup support from the Regional Office of BMKG West Sumatra region for the Padang City EOC. This reflects the need to revise and update the regulation with the advanced real-field condition. Moreover, the existing regulation regarding tsunami early warning chain in Padang was established in 2010, which was two years before the new guidelines of InaTEWS. This regulation was in the form of a mayor decree and has not yet been institutionalized in the local law. These indicate a need for Padang City to renew or improve its regulation regarding the downstream tsunami early warning system.

Padang City’s communication and information agency (Diskominfo) is the only institution whose involvement in the tsunami early warning chain has been specified in the regulation but was found to have no significant role in the practice. In the regulation, the agency has the responsibility to relay information to mainstream media such as TV and radio channels. Instead, in practice, these channels are already established through informal ties with Padang City EOC, while the role of Padang City communication and information agency is only to make sure that the channels broadcast the information.

As a coastal city with the highest risk of a near-field tsunami, losses of minutes or seconds during the lead time for evacuation in Padang City could mean risking the loss of lives due to failed evacuation. These risks should be anticipated by simplifying the bureaucracy related to procedure in tsunami warning dissemination, as well as by increasing redundancy in communication lines to strengthen the tsunami warning chain. As shown in Network 1 (original network), the decision-making responsibility of Mayor of Padang might slow down or undermine the tsunami early warning and evacuation order dissemination.

These results suggest the early warning chain at the city level should be simplified. This could be done by mandating the pre-defined decision-making role to disseminate the warning and evacuation orders to the Padang City EOC so the dissemination process could be carried on almost as soon as they receive the warning information if found necessary. In practice, the decision-making role of the Padang City Mayor has also been bypassed in most cases. It is, therefore, feasible to mandate the decision-making role to the EOC. Supporting this need, the guidelines of InaTEWS have provided pre-defined action to be taken by the Indonesian city EOC related to the level of potential tsunami, i.e. major warning, warning and advisory, as shown in Figure 7.

The Mayor of Padang has a very critical and important role of issuing an evacuation order for mobilizing evacuation during a tsunami emergency by exercising his or her authority. According to several respondents, they had been convinced to evacuate from a potential tsunami during the 2007 and 2009 Sumatera earthquake after receiving a tsunami evacuation order conveyed by the incumbent Padang City Mayor through the radio of the Republic of Indonesia, the local radio channel (Personal Communications, 2016).
Although Padang City EOC is the first and only gateway organization stated in the regulation as receiving warning information at the city level, in practice, the Regional Office of BMKG located in Padang Panjang could take for heads-up for a potential tsunami or have a backup role as the focal point in case the Padang City EOC faces some communication difficulties. According to our findings from the FGD meetings, the Regional Office of BMKG has established several communication ties with the Padang EOC, the Mayor of Padang and sectoral agencies (SKPDs) in Padang city through a WhatsApp messenger group. Furthermore, several other NGOs and local community leaders were also identified to disseminate warnings to the public, covering some of the last-mile population.

Finally, a survey was conducted in the Koto Tangah District in Padang City to improve the tsunami warning system for Padang City by cross-validating the findings from the FGD, i.e. Network 2 (government model), and findings from the results of the study, i.e. Network 3 (community model). Completed questionnaires were collected from 71 respondents, from which 36 are mid-actors and 35 are community members. The geo-location of those 71 respondents can be seen in Figure 8.

Among the 36 mid-actors, there were community leaders (mid-actors) grouped into four categories as follows: sub-district of (Kelurahan), disaster resilience schools (Sekolah Siaga Bencana), community mosques (Masjid) and disaster preparedness community groups (KSB). Meanwhile, from the 35 community respondents, it was found in Network 2 (government model) that about 10 respondents (29 per cent of sample populations) could not receive tsunami warnings from any existing communication devices, including sirens. This means that Network 3 (community model) as also shown in Figure 9(a) has a capacity on disseminating the tsunami warning system of 71 per cent, i.e. only 71 per cent of the samples receive tsunami warning messages. Meanwhile, the remaining 29 per cent of the people are categorized as the last mile, i.e. people who do not have access to tsunami information through existing device communication in Padang City, i.e. siren, which is operated by Padang City EOC.
The community leaders (mid-actors) identified above have their own capacity and network of communication. The community mosques (Masjid) have a mosque network and can use the mosque speaker for alerting the surrounding community. Meanwhile, the disaster preparedness community groups have used a wide variety of communication networks,
such as radio communication (HT), WhatsApp messenger group, SMS and even through
direct communications. These people are the people in the community who have the first
access to warning information from the City EOC. The disaster resilient schools use SMS
and telephone to disseminate the tsunami warning information to the parents and students.
Finally, the sub-district office uses HT, WhatsApp messenger group, SMS and the internet.
Based on Network 2 (government model) and Network 3 (community model), a combined
model was created as shown in Figure 10.

Based on our findings from the survey, the potential actors to be involved in the early
warning chain as interface actors have different characteristics. There is a varying level of
willingness to participate in the tsunami early warning chain, as well as their capacity to
reach tsunami early warning information and understand the warning information. This
should be a consideration for further studies and planning for community-based early
warning systems.

Several of the community leaders interviewed in the Koto Tangah Districts were
already taking voluntary roles as the interface actors in the tsunami early warning chain.

Figure 10. Network 4 (complete network)

Note: Based on the Integration of Government Model and Community Model
For example, they have sacrificed some funding from their own income to buy handy-talking devices to receive warning messages directly from the Padang City EOC (semi-structured interview in Koto Tangah District, 2016). Moreover, some of the disaster preparedness group (*KSB*) members had been voluntarily attending in city-level discussions and trainings regarding tsunami early warning system and represent the last-mile population.

According to the field survey findings, there are several flaws with the sirens installed in the city. One of the major problems is that only a minority of people understand the meaning of each sound pattern made by the sirens. As such, information such as Warning-1 (first warning message), Warning-2 (updated warning information), Warning-3 (tsunami has made a landing) and Warning-4 (warning cancellation) might not be fully conveyed to the last-mile community. Moreover, several community members conveyed their lack of trust in these sirens as these devices tend to be “unmanned” and “technologically-dependent” (Personal Communication, 2016). In contrast, people might put more trust in their community mosques, including during a tsunami emergency. As described by Mulyasari and Shaw (2012), *Masjid* is one form of CSOs with relatively strong leadership by influential people from the community.

Furthermore, the SNA method has also been useful in identifying communication ties among these community members. Our study found that community members have also established communication ties among themselves. Specifically, communication ties are identified between the disaster preparedness group (*KSB*) members with the sub-district officers and community mosques. In other words, the community leaders do not only take the role of relaying information received from city level institutions, such as Padang City EOC but also share the information among themselves. This finding indicates that there are some partnerships already established among these leaders, which could be institutionalized.

To present recommendations to assist Padang City Government in the improvement of the existing tsunami early warning chain SOP, this study proposes a simplified framework representing the common practice of people-centered tsunami early warning chain. This is presented in Figure 11. In the proposed framework, the actors in the downstream tsunami early warning chain are structured into four layers. The first consists of information...
provider institutions at the national, provincial and city levels. Then, information is disseminated by the Padang City EOC to the community members, both directly through sirens or indirectly through other organizations in the city and community level. In the framework, mid-actors, consisting of four groups of community leaders, have important roles in connecting the communication chain between city level institutions with the local community members, including the last-mile population.

The results presented in this paper have been communicated to the Padang City Mayor and senior officials in several related institutions in Padang City (Rahayu et al., 2018) via a series of public engagement meetings. These include a workshop on improving the downstream tsunami early warning SOP in Padang City on September 1, 2016, and a tabletop exercise for improved SOP in Padang City conducted September 2, 2016. These events were in conjunction with the 2016 Indian Ocean wave exercise (IOWave16) conducted on September 7 and 8, 2016 throughout 24 Indian Ocean member countries.

To get a better understanding and better engagement, as the first FGD conducted in Padang City on February 22, 2016, the research team have been working closely with several actors from the Padang City Government and community leaders in developing the people-centered early warning procedure by empowering the critical nodes as identified in this study. Finally, the procedure has been successfully tested and exercised, i.e. end-to-end tsunami exercise, during the IOWave16. This end-to-end tsunami exercise was not only able to test the performance of all stakeholders identified in Network 4 (complete network) of people-centered early warning system but also to involve about 1,300 community movement to evacuate to shelter as acknowledged and reported by ICG/IOTWMS IOWAVE16 task team in the IOWAVE16 exercise report (Intergovernmental Oceanographic Commission, 2017).

Finally, after a series of public engagement events and testing during IOWAVE16, the improved SOP referred to as the people-centered tsunami early warning system for Padang City has been institutionalized as an academic paper in improving the Padang City Mayor Regulation 19/2018 regarding tsunami early warning system.

**Conclusion**

This study was able to work on the possible improvements of the tsunami early warning system (downstream) for Padang City, using an in-depth and holistic network model. Exhaustive data assessed through a series of FGD meetings with actors from city level and district level, then combined with data obtained from semi-structured interviews in the field were used to improve the downstream tsunami early warning chain (original network). The result of this study was a three-tier of network model, i.e. proposed network, enhanced network and complete network (people-centered early warning system).

Four interface actors (mid-actors) in the community, namely, sub-district offices (Kelurahan), schools (Sekolah Siaga Bencana), community mosques (Masjid) and disaster preparedness community groups (KSB) were identified, which have different potential roles for their involvement in the downstream tsunami early warning chain, as well as different level of willingness of participation and capacity to receive and disseminate the tsunami warnings to the public. To synchronize these differences, capacity building is necessary for these actors through training and provision of better communication devices to participate in the tsunami early warning chain.

The involvement and empowerment of community leaders have several advantages beyond the warning dissemination process. From the field semi-structured interviews with the community leaders and community members, the values, which are important in people-centered early warning systems are identified among them, such as volunteerism, leadership
and trust. These values are highly advantageous and may strengthen the people-centered early warning system among the communities.

Moreover, the capacity of local police and the army (who are legally appointed as interface agencies in the InaTEWS), which might be hampered or overwhelmed by the amount of work during an emergency state, could make use of the assisting hands from local community leaders. This further justifies the need to involve community leaders and focus on community-based tsunami early warning and preparedness. Furthermore, with a solid partnership with the local government and the empowerment of these community leaders, these links of cooperation could also be used not only for tsunami early warning chain in a near-field tsunami but also adapted for other types of sudden onset hazards.

To conclude, this study was able to contribute to improving the downstream early warning systems by developing recommendations in improving the people-centered tsunami early warning chain model for Indonesia. Moreover, several findings, which are the strong points of this study are:

- removal of a single gateway agency or zero-redundancy in downstream warning chain;
- a critical shift in the role of mayor in the near-field tsunami warning system;
- identification of a backup function of Regional Office of BMKG to provide early information for heads up in the downstream warning chain; and
- finally, the identification of key interface actors (called mid-actors) in the community who have capacities to receive and relay warnings to the last mile community.

This study offers an insight into the current gaps and challenges in the downstream tsunami warning system in Padang City. The results presented will contribute not only to improve the tsunami early warning chain of Padang City but also as guidelines for other coastal cities and regencies. The findings can also be adopted as part of the existing tsunami early warning system, completing its end-to-end channel, by investigating its reliability and its compliance with the state of the art of InaTEWS. The process development of the three-tier network model can be replicated to other coastal cities and regencies in Indonesia, as well as to other regions, which is exposed to near-field tsunami and having similar government systems, i.e. autonomous at local government level.

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