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Information network on Twitter regarding early warning of mount Semeru eruption

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ABSTRACT

Background: Indonesia is a country that is highly susceptible to volcanic disasters. One potential measure the community can take is to utilize social media platforms to participate in disaster mitigation efforts. The hashtag #Semeru exemplifies the utilization of social media in disseminating information regarding volcanic disasters. It became a trending topic on Twitter regarding the information on the eruption of Mount Semeru at the end of 2021. **Purpose:** The primary objective of this research is to examine the operational mechanisms of the Mount Semeru eruption early warning system on Twitter. Furthermore, the objective is to determine the key actors responsible for disseminating early warning information on Twitter. **Methods:** This study employed the Social Network Analysis (SNA) method. **Results:** The findings show that the network distribution pattern of the Semeru eruption early warning system has a radial communication network pattern with indicators of low network density levels. The actors @fiersabesari, @bnonews, @asumsico, @disclose.tv, @jawafess, and @ insiderpaper have a proximity centrality value of 0 due to their lack of acquaintance. On the other hand, two actors possess a closeness centrality value: @melodiysore with a value of 0.8 and @daryonoBMKG with a value of 0.2. This study highlighted that the actors involved in disaster management and mitigation had a level of popularity that ranked outside the top 10. **Conclusions:** The information network system for the early warning of the Mount Semeru eruption on Twitter forms a network distribution with a radial communication pattern that is concentrated at one point and acts as a key actor. Eight key actors play a role in disseminating early warning messages, specifically @fiersabesari, @daryonoBMKG, @bnonews, @ asumsico, @disclose.tv, @theinsiderpaper, @melodiysore, and @jawafess (community). **Implications:** This study demonstrates the benefits of using Twitter as a timely indicator for disasters, notably the eruption of Mount Semeru. It can effectively engage the community and government in disseminating early-warning information about volcanic eruptions.

Keywords: Disaster early warning; Information network system; mount semeru eruption; social network, Twitter

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INTRODUCTION

Indonesia's abundance of volcanoes poses a significant risk for natural disasters, encompassing volcanic eruptions, seismic activities, and tsunamis. The volcanic eruption of Mount Semeru in late 2021 has garnered significant attention from the Indonesian population. The abrupt volcanic outburst resulted in a significant number of casualties. According to *the National Disaster Management Agency*, 14 fatalities were recorded (BNPB, 2021). Moreover, Midaada (2021) reported that the lack of timely notification to the public led to a significant number of casualties, as individuals were unaware of the Semeru eruption. Following this issue, different parties expressed concerns over a pre-eruption warning system during the Semeru volcanic activity (Rozie, 2021). One of them is Wigyo, the chairman of the Coalition for Environmental Protection. He emphasized the necessity of installing an early warning system in Indonesia, given the significant number of volcanoes in the country (Rozie, 2021).

Indonesia is a geographically diverse archipelago renowned for its extensive volcanic activity. It ranks third worldwide regarding the number of volcanoes behind the United States and Russia (Rizaty & Mutia, 2021). There are currently 127 active volcanoes in Indonesia (Magma, 2021). Therefore, the Indonesian government should enforce disaster mitigation measures to minimize or prevent the consequences of volcanic natural disasters that may occur in the country. One mitigation effort the government can make is to utilize social to distribute information to the public.

The use of social media in disaster response has been used by researchers, for example, in search and rescue (Wei et al., 2012), emergency assistance (Goggins & Mascaro, 2012), evacuation (Ichiguchi, 2011), tsunami early warning (Chatfield & Brajawidagda, 2012), and reducing the risk of the Mount Sinabung disaster (Lestari & Rinasti, 2020). Social media can also be utilized for epidemic intelligence (Kostkova et al., 2014). Several government agencies, including the Queensland Police Service (QPS) in Australia, the Federal Emergency Management Agency (FEMA) in the United States, and The Meteorology, Climatology, and Geophysics Agency in Indonesia, also use social media for emergency and disaster management. They utilize social media as a complementary information platform to engage with their communities (Chatfield & Brajawidagda, 2012).

Volcanic eruptions have primary, secondary, and additional impacts on affected communities. Given the issue, it is necessary to develop mitigation measures to reduce its impacts. One effective way is establishing an early warning system utilizing social media platforms. (BNPB, 2021). According to Monardo (2021), the significant or immediate impacts arising from volcanic eruptions include the movement of pyroclastic flow, the creation of lahars, the deposition of volcanic ash, and the emission of hazardous volcanic gases. One significant primary impact in Indonesia was the fatality caused by pyroclastic during the eruption of Mount Merapi in 2010. In addition, lava is

one example of a secondary or indirect impact resulting from volcanic eruptions. Meanwhile, other dangers induced by volcanic eruptions, such as tsunamis and land movements, are referred to as collateral hazards (BNPB, 2021).

Early warning systems and rapid communications ensure that scientific knowledge and expertise are used to protect the public. Recently, people have been utilizing social networks such as Facebook and Twitter to create, share, exchange, and manage information (Kostkova et al., 2014). Ananda (2020) gave the example that the Meteorology, Climatology and Geophysics Agency (BMKG) and the National Disaster Management Agency (BNPB) have utilized social media as an early warning system in Indonesia. Among various social media, Twitter was selected because of its lightning-fast processing times and massive user base, thereby significantly increasing the dissemination of information to wider audiences.

Additionally, Twitter is one of the most frequently accessed platforms for searching for disaster information (Kim & Hastak, 2018). According to Kaur (2019). As the main information medium, Twitter is widely used by local people regarding disasters and emergency situations. Use this application to provide various information such as detailed geographic location, reports on affected communities, fast response emergency assistance and updated information on an area regarding the progress of recovery from various natural disasters.

The high number of internet users in Indonesia, which has reached 73.7% (APJII, 2020), has caused several agencies such as BMKG and BNPB to start relying on Twitter as the initial source of early warning information for disasters.

Social media has a fundamental influence in changing the role of communication technology into a means of human interaction and communication in Indonesia (Rosenbaum & Bouvier, 2020)to the images of women throwing their make-up into trashcans outside the Miss America pageant in New Jersey, to the pamphlets used by 1980s anti-nuclear war demonstrators to disseminate word about the next protests: technology has always played an important role in social movements. With the advent of social media, the role of technology has not only become more important but has also fundamentally changed how people communicate. This has resulted in a shift in the organization and dissemination of activist ideas and subsequent mobilization to action. This shift has been described and critiqued in a variety of ways but the framework that best captures how activism and our understanding of it has changed, and that forms the starting point of this Themed Section, is the logic of connective action (Bennett & Segerberg, 2012. The presence of social media as an early warning system for disasters makes it a convenient platform and people can access information easily and simply, because they only use hashtags or keywords (Barisione & Ceron, 2017). According to Lim (2014), one of the advantages of social media is the ability

to mobilize information and respond quickly. There are several research and literature studies related to the use of social media in disaster early warning systems, the research of Kostkova et al. (2014) the role of the social network Twitter during the 2009 swine flu pandemic. The results found that Twitter could function as an early warning system for the general public during the 2009 swine flu pandemic. Subsequent research was conducted by Palen and Hughes (2018), who surveyed media use social experience in natural disasters.

Based on the findings of previous studies, there still need to be research gaps concerning the utilization of social media in natural disaster early warning systems. Previous studies have examined the utilization of social media from the perspective of determination technology in several studies. In contrast, the pattern and dissemination of messages on social media still need to be improved in research and literature reviews.

Therefore, this study aims to address two research questions. The first research question is, "How is the information network system for the Mount Semeru eruption early warning information on Twitter?". This research question helps the readers know the distribution network pattern, the density of the early warning network, and the diameter of the Mount Semeru eruption network. The second research question is, "Who is the key actor in disseminating information on the early warning of Mount Semeru eruption on Twitter?". This research question helps the readers know the degree of centralization, proximity centralization, and centralization of intermediaries for disseminating information on the Mount Semeru eruption early warning on Twitter. We have analyzed 86642 tweets related to the hashtag #Semeru, which became a trending topic on Twitter during the eruption of Mount Semeru on December 4, 2021.

RESEARCH METHOD

This study employed a Social Network Analysis (SNA) approach to visualize information networks and identify key actors in the Mount Semeru eruption early warning network on Twitter. Additionally, this study utilized Gephi software for text mining, with assistance from Twitter Streaming Importer and API (Application Programming Interface). The dataset that had been obtained was then visualized using the layout of Force Atlas2. The selection of this layout is to provide space for nodes with more networks without overlapping with other nodes (Gephi.org, 2011).

All datasets obtained were then subjected to data processing. The data processing stage is carried out with two approaches, namely filtering data and processing data. In filtering data what is done is identifying data sets in the form of text originating from tweets, likes, comments, mentioning other Twitter user accounts, or all activities carried out by users based on the keyword #Semeru.

At the data filtering stage, relevant data is categorized with the eruption of Mount Semeru, categorizing data based on contextual and non-contextual. contextual data is data that uses the

keyword #semeru and is in accordance with the eruption of Mount Semeru, while non-contextual data is data that uses the keyword #semeru, but the content is not at all related to disasters, for example buying and selling or gossip news that uses the word the same key. Non-contextual data is not used in the next stage, namely processing research data.

The dataset that we have collected and analyzed is 86642 tweets related to the hashtag #Semeru on 04 December 2021. SNA approach can map and visualize communication networks among its users (Eriyanto, 2019). According to Bakry (2020), the SNA approach can enable identifying conversations and message distribution on Twitter. therefore, the SNA approach can be applied to all social aspects available on social media. SNA studies examine two main components: actors and relationships (Borgatti et al., 2013). The network is a medium of interaction between one actor and another, thus forming social relations (Sari & Dwiyanti, 2018).

The use of graph theory in network analysis can provide an overview of message distribution and interpretation of network structure on Twitter. This theory aims to map patterns of social networks and network communications such as nodes and edges. The mapping results provide insight into the context of network relationships between one actor and another. (Chatfield & Brajawidagda, 2012). The measurement and data analysis stage using various data analysis techniques, namely the number of nodes and relationships in an actor, measuring the density level of the #semeru network structure, measuring the farthest distance between actors using the network diameter. Network diameter is the most significant distance between two pairs of dyadic nodes. then measure the role of central actors using a metric centrality approach which includes: degree centrality, intermediary centrality and closeness centrality of the volcanic eruption early warning network.

The relationships between actors in a social network can be visualized using graph theory (Borgatti et al., 2013). Graph theory is used to determine the relationship and role of actors in a network by creating communication patterns consisting of nodes and edges (Eriyanto, 2014). Meanwhile, nodes are entities of actors, such as individuals or institutions on a social network. In addition, edge refers to a connection or relationship that connects one actor to another (Bakry, 2020).

According to Valeri and Baggio (2021), many actors (nodes) are interconnected with various relations (edges). The edges of the graph can be either directed or undirected, meaning they can represent either symmetrical relationships among nodes or causal relationships among those nodes. It depends on the characteristics of the nodes. In addition, the edges of the diagram can be classified as directed if the relationship among nodes is symmetrical. In contrast, undirected edges occur when nodes have a causal relationship (Kadushin, 2012).

RESULTS AND DISCUSSION

The utilization of social media for interpersonal communication is having a substantial increase. They use many applications to engage in extensive communication, including interactions among individuals, individuals with institutions, and institutions with society. In addition, they also utilize the hashtag (#) to mark the central issue of the conversation, the main point of information, or the keyword in the topic search. Kochkina and Riccardi (2021) explained that social networking involves personal communication with institutions, agencies or companies. This activity can be done with social media applications like Facebook, Twitter, and Instagram. According to Mulyadi and Fitriana (2018), the hashtag (#) serves to identify messages in online communication activities.

This study illustrates how the community utilizes social media, particularly Twitter, to share disaster updates. It examines the pattern of information network systems and identifies vital network actors on Twitter engaged on Twitter. More complete information can be seen in Table 1.

The system-level analysis includes information distribution patterns, network density, and network diameter. The actor level includes the calculation of network centrality, namely degree centrality, proximity centrality, and intermediary centrality (Zhang & Luo, 2017; Eriyanto, 2019). According to Carnia et al. (2021), graph theory employs frequency centrality to determine the actors' centrality. It enables the identification of Twitter accounts that possess significant influence or contribute significantly to spreading informational messages by each actor. The higher the degree of centrality value, the more popular the actor is. Soumokil et al. (2013) explained that there are two types of identification of the presence of actors in a network, namely indegree and out-degree. Indegree refers to messages received by an actor from other actors, while out-degree refers to messages sent by actors to other actors. Calculation of degree centrality value or CD (v)

Table 1 Data analysis design

Analysis Level	Unit of Analysis	Output obtained
Network System Level	Information Distribution Pattern	How to visualize network data
	Network Density	How is network density formed?
	Network Diameter	How many levels of diameter are formed
Network Actor Level	Degree Centrality	How is the popularity of the actor in the network
	Centrality of Proximity	How close are the actors
	Intermediary Centrality	Which actor has an intermediary role

Source: Research Result, 2022

uses the following formula:

$$C_D(v) = \frac{d(v)}{n-1} \dots\dots\dots\dots\dots\dots\dots\dots (1)$$

D is the number of relations (links), and n is the number of population members (nodes).

The second analysis, Closeness Centrality, is employed to identify influential actors by measuring the proximity of their relationships based on the shortest distance. The calculation of the closeness centrality value or CC (v) can be formulated as follows:

$$C_C(v) = \frac{n-1}{\sum D_{ij}} \dots\dots\dots\dots\dots\dots\dots\dots (2)$$

D is the shortest path to another actor, and n is the number of population members (nodes).

Third, Betweenness Centrality is utilized to identify the most influential actors in spreading information on Twitter. This Betweenness Centrality is determined by assessing the extent to which these actors serve as intermediaries for information exchange. The formula used to determine the betweenness centrality value, or CB (v), is as follows:

$$C_B(v) = \frac{\frac{\delta_{ij} P_k}{\delta_{ij}}}{n^2 - 3n - 2} \dots\dots\dots\dots\dots\dots (3)$$

Ꞵij Pk is the number of the shortest stages of the actor, and Ꞵij is the number of paths in the network, while n2-3n-2 is the maximum value. The value of Betweenness centrality normality is 0-1, and close to 1 is the best.

Early warning to the public about disasters is an act of providing information in language that is easily digested by the community. According to Chatfield and Brajawidagda (2012), one of the goals of an early warning system is to predict the potential for natural disasters accurately to minimize the impact that occurs by utilizing technology. The utilization of an early warning system can improve community emergency preparedness and response. It is evident that disaster forecasting is fundamental.

We can forecast the magnitude of the likelihood of a disaster, its timing, geographical area, potential consequences, and the necessity for mass evacuation. Table 2 provides a comprehensive overview of the exact details of

Table 2 Characteristics of an early warning system

Scope	Infor-mation Speed	Infor-mation Quality	References
√	√		(Pamuji et al., 2020)
√	√		(Weyrich et al., 2021)
√	√		(Palen & Hughes, 2018)
√			(Hui et al., 2012)
√	√		(Chatfield & Brajawidagda, 2012)
	√	√	(Fortier & Dokas, 2008)

Source: Research Result, 2022

the early warning system.

Table 2 demonstrates that early warning systems feature three fundamental characteristics, specifically, scope (Chatfield & Brajawidagda, 2012; Hui et al., 2012); Palen & Hughes, 2018; Pamuji et al., 2020; Weyrich et al., 2021; speed of information (Chatfield & Brajawidagda, 2012; Fortier & Dokas, 2008); Palen & Hughes, 2018; Pamuji et al., 2020; Weyrich et al., 2021) and information quality (Fortier & Dokas, 2008). Social media's flexible and dynamic characteristics provide broad-scale reach to the entire community. This characteristic is defined as the ability to reach audiences in remote areas connected via the internet. The utilization of social media, which reaches 73.7%, according to the esteemed APJII (2020), enables the rapid and fair distribution of social media messages amongst all actively engaged users. Finally, information quality refers to the accuracy, completeness, and clarity of user-generated information to the intended audience.

Mount Semeru Eruption Early Warning Information Network System Level: Network system analysis was employed to answer three research questions about information regarding the early warning system for the Mount Semeru eruption: network distribution patterns, network density, and network diameter. A network can be conceptualized as a dynamic space wherein nodes actively partake in intricate exchanges, forging connections based on shared interests and knowledge facilitated by the hashtag #Semeru. The use of hashtags on Twitter functions as a means to articulate points of view in the context of modern digital society, where individuals are connected to each other through integrated networks without any mediation from network intermediaries (Baritone & Ceron, 2017). In addition, the Social Network Analysis application has been used to distribute messages and analyze information about the pandemic (Hung et al., 2020), analyze the network structure of social movements (Bakry & Kusmayadi, 2021), carbon emissions (Sun et al., 2020), tourism (Pratama, 2018; Valeri & Baggio, 2021), online games (Soumokil et al., 2013), and early warning system (Chatfield & Brajawidagda, 2012).

Cohesive networks occur because someone has the same interests and interests in social media so that individuals tend to take collective action in interaction and communication on social media. the formation of this collective action will produce collective sentiment in certain situations and contexts. This is due to the characteristics of social media which are open and allow for two-way interaction. (Kitazawa & Hale, 2021). Networks can be identified and analyzed by examining congruity in message distribution patterns, network information density, and network diameter. This research yields a network distribution pattern that manifests as a radial communication pattern, as depicted in Figure 1. The radial pattern of communication has the characteristic of being concentrated at one point, which acts as a key actor in the network. The radial distribution pattern of personal

Source: Analysis Results, 2022

Figure 1 Visualization of the Mount Semeru Eruption Early Warning Network

network information exhibits notable attributes regarding its reception of effective and efficient messages (Bakry & Merdekawati, 2021). The reason behind such an occurrence lies in the inherent ability of each network member to interact in interpersonal exchanges (within an open network framework), hence allowing the transmission and reception of messages without the mediation of other actors.

Source: Twitter, 2022

Figure 2 BNPB Indonesia's Twitter related to the distribution of hot clouds of Mount Semeru

Based on the network visualization above, the distribution pattern of network information is primarily focused on a few key actors (nodes) highlighted in red, encompassing @fiersabesari, @bnonews, @asumsico, and @disclosetv. The pattern of information distribution is formed when Twitter users try to find various information about the eruption of Mount Semeru. They connect with other users so that interaction can be established among actors.

Possible interactions that can be created include mentioning other actors, be they individuals or organizations, quoting and replying to the tweets of individuals or institutions to share said content across their respective networks, and giving likes or comments on other actors' tweets.

In Figure 2, the Indonesian BNPB actor made a Tweet regarding the information on the movement of the volcano-pyroclastic flow of

Table 3 Metrics of the Mount Semeru

Metrics	Information
Number of Nodes	34259
Number of Edges	86642
Average Degree	2.529
Network Diameter	16
Network Density	0.001
Strong Bond	34122
Weak Bond	688

Source: Research Results, 2022

Mount Semeru, which other users responded to by commenting, retweeting, and liking tweets. This activity indirectly demonstrates that Twitter users attempt to establish connections in the same network. According to Carrington (2011), the characteristics of social networks are a collection of entities that interact and are connected in the same pattern and network structure.

Table 3 displays the prominent metrics of the Mount Semeru eruption early warning network. The network contains a total number of 34259 nodes and 86642 edges. The network demonstrates a low density of 0.001, implying that not all actors (nodes) are connected. The network density value ranges from 0 to 1, with 0 representing no network density and 1 representing perfect density (Eriyanto, 2014). In addition, the network density value of 0.001 indicates that interconnection among network members is rare. Hansen et al. (2011) argue that density represents the interconnectedness of individuals in a network. This density varies from low density (loosely connected groups of individuals) to high density (highly connected users). The extent to which the network is densely interconnected affects its information flow rate. The results of research by Zubcsek et al. (2014) show that the intensity of communication between individuals in the information community is more significant than in other network areas. In addition, studies on the role of social network structure in information diffusion in Digg and Twitter have found that the speed at which information is spread through the network depends on its density (Isa & Himelboim, 2018). Furthermore, the mean value of 2,529 degrees is still lower than the expected average from social networks, which is 3 (Chatfield & Brajawidagda, 2012).

The network diameter represents the maximum distance between two nodes. In this case, the value of 16 indicates that the information needs to traverse an additional 16 nodes before reaching its destination. This implies that the information will reach there. In contrast, the average path length of 4,749 can be considered normal. This metric represents the average value of the shortest paths between every pair of interconnected nodes within a given network. There number of weakly connected components is 688, while the number of strongly connected components is 34122. In a directed network, weak connection components are the number of relations between actors whose information flows in one direction (asymmetric). In contrast, the number of solid nodes connected to components is the number of relations in which the information flow is

two-way (symmetric). According to Kadushin (2012), an asymmetric or one-way relationship is a relationship that occurs between actors who have a role and those who do not have a role. Some actors provide information, and some actors receive information. At the same time, symmetrical or two-way relationships are relationships that communicate and interact with each other, and both actors have the same role.

Actor Level Network Early Warning of Mount Semeru Eruption: The network actor level analysis is used to answer the following three questions related to degree centrality, intermediate centrality, and proximity centrality among actors in the information network for the early warning of the eruption of Mount Semeru. This analysis aims to determine the key actors involved in distributing early warning information regarding the eruption of Mount Semeru. Based on the dataset, eight key actors (0.799) were identified from each different group (modularity class). The identified actors include individuals and institutions, such as @fiersabesari (individual), @bnonews, @asumsico, @disclose.tv, @melodiysore, @jawafess, @theinsiderpaper, and @daryonoBMKG. The role of each actor can be seen in the Table 4.

Table 4 indicates the key figures in the information network responsible for early warning of the Mount Semeru volcanic eruption. Three primary analyses were carried out to determine the role of actors, including degree centrality analysis (DC), proximity centrality analysis (CC), and intermediate centrality analysis (BC). First, the degree of centrality analysis is used to determine the number of

Table 4 Key actors of the Mount Semeru eruption early warning network

No	Actors	Profiles	DC	CC	BC	Number of Followers	Proportion
1	@fiersabesari	Author	7584	0.0	0	9910470	0.079
2	@bnonews	Media	3126	0.0	0	206614	1.512
3	@asumsico	Media	2894	0.0	0	280767	1.030
4	@disclose.tv	Media	2527	0.0	0	735162	0.343
5	@melodiysore	Fan of BTS	2085	0.8	3126 (0.001)	4790	43.52
6	@jawafess	Community	1930	0.0	0	723933	0.266
7	@theinsiderpaper	Media	1789	0.0	0	104352	1.714
8	@daryonoBMKG	Coordinator of BMKG	1735	0.2	88572 (0.008)	27763	6.249

Explanation: DC (Degree Centrality); CC (Closeness Centrality); BC (Betweenness Centrality); Proportion (comparison of DC to Number of Followers)

Source: Research Results, 2022

connected connections among actors or the popularity of actors in social networks.

This analysis seeks to determine the popularity based on the number of relationships formed with other actors in the network (Borgatti et al., 2013; Eriyanto, 2014). With a remarkable total of 7584 relationships, actor @fiersabesari has many interpersonal relationships with other actors. @fiersabesari is a versatile artist who engages in various creative pursuits, such as writing novels, composing music, and advocating for social issues. This situation is evident because he has many followers— 9 million users in total. However, the high number of followers owned by @fiersabesari is not visible in the context of this study. Only about 0.079% of his followers shared early warning messages for the eruption of Mount Semeru.

The second to fourth actors are media actors who utilize Twitter as a platform for sharing the latest news quickly and widely. The popularity of the second (@bnonews), the third (@ asumsico), and the fourth (@disclose.tv) with each number of relationships, respectively, are 3126, 2894 and 2527. The fifth (@melodiysore) is a BTS fandom account. This account has a popularity of 2085 number of relationships. The sixth (@jawafess) is a community actor with a popularity level 1930 with many relationships. The seventh (@theinsiderpaper) is a media actor with a popularity of 1789 and many relationships. The eighth (@daryonoBMKG) is the coordinator of earthquake and tsunami mitigation from the BMKG with a popularity of 1735 relations.

Based on the results of the network popularity analysis, actors such as @bnpb_ indonesia, @infobmkg, @infomitigasi, and others still need to achieve the top ten ranking in popularity despite their presumed significance in the areas of disaster relief and prevention. Two types of relationships exist among degrees of centrality in the network, namely in-degree and out-degree relations. The in-degree relationship is a relationship that seeks to contact actors through mentions, quotes, likes, and retweets of early warning messages for the Mount Semeru eruption. In contrast, out-degree relationships are messages that are mentioned to other actors.

The second analysis emphasizes the significance of proximity. This analysis provides insight into the degree of proximity among actors, as measured by closeness centrality, which ranges from 0 to 1. A value of 0 indicates no closeness among actors in the network, while a value of 1 means perfect closeness. Actors @fiersabesari, @bnonews, @asumsico, @disclose.tv, @jawafess, and @insiderpaper have a close centrality value of 0. This value can be interpreted as these actors not knowing each other closely because of the asymmetrical direction of the relationship.

However, two actors have a closeness centrality value, namely actor @melodiysore, who has a high closeness close to 1, which is 0.8. Another actor is @daryonoBMKG, which has a value of 0.2. This closeness value exists because actor @melodiysore is one of the BTS fandoms who interact symmetrically with each other on Twitter. In contrast, actor @

daryonoBMKG is the coordinator of earthquake and tsunami mitigation from the BMKG, who actively provides disaster information.

The third analysis addresses the centrality of intermediaries. This analysis offers valuable insights into the role of actors as intermediaries in transmitting self-warning messages within the network (Borgatti et al., 2013; Eriyanto, 2014). The presence of these actors is crucial for establishing solid connections and independencies among various actors and components within the network. The absence of this actor will result in a fragmented network. The higher the value of the centrality of the intermediary, the more critical the actor's role in the network. Based on Table 3, two actors have intermediate centrality values, namely @melodiysore and @daryonoBMKG, with values of 3126 and 88572, respectively. This value means that the accounts @melodiysore and @daryonoBMKG were traversed 3126 and 88572 times the early warning messages for the eruption of Mount Semeru. Actors @ melodiysore and @daryonoBMKG have an average intermediate centrality value of 0.001 and 0.008, respectively. Meanwhile, the other six actors, @fiersabesari, @bnonews, @ asumsico, @disclose.tv, @jawafess, and @ insiderpaper, have a value of 0 intermediate centrality, meaning that these actors do not have a role as message intermediaries in the early warning of the eruption of Mount Semeru.

Gunawibawa and Oktiani (2020) argue that Twitter can distribute digital messages for society's humanitarian, environmental, and political issues. Not only that, Twitter can serve as an alternative space for public discussion and online seminars, wherein the online discussion room provides an opportunity for heterogeneous people with different social, cultural, educational, and even political backgrounds to discuss with each other, share ideas, and convey social criticisms without any limitations of space and time. Hence, anyone can connect to online discussions anywhere without any social barriers.

According to Wu & Cui (2018), unexpected natural disasters will leave their traces on social media, meaning that people tend to share everything on social media so that they can explain patterns and distribution of information through social networks. The use of social media by people affected by disasters has increased sharply in recent years.

Social media provides an alternative way of communicating with affected communities about the situation that is happening to them, thereby enabling public institutions or disaster organizations to carry out relief efforts for affected communities (Weyrich et al., 2021). Additionally, conversations and all activities on Twitter can be identified and classified based on specific issues by utilizing certain hashtags.

According to Mulyadi and Fitriana (2018), hashtags function as keywords representing messages in virtual communication networks. Hashtags facilitate the distribution of information and news by enhancing accessibility for all users. The effectiveness of using hashtags can also be seen in this study, which used

the hashtag #Semeru to share early warning messages regarding the eruption of Mount Semeru. Furthermore, message distribution can be assessed through various factors, such as distribution pattern, the network's diameter, the density of the network, and the identification of critical actors involved in the early warning message. Based on the characteristics of early warning, aspects of the reach and speed of information can be seen in this analysis. In contrast, the quality of information needs to be identified due to low network density.

One of the effective disaster management measures for emergencies in distributing information to affected communities is to utilize social media, such as Twitter (Kim & Hastak, 2018). Twitter can improve the effectiveness of national institutions in responding to natural and humanitarian disasters by quickly sharing information. Besides, since affected communities need to minimize post-disaster losses, such as loss of life and infrastructure deterioration, affected communities can utilize Twitter to share information about their situation and environment and what they need so the relevant parties can respond quickly.

Twitter was selected as a communication platform for affected communities and external parties because of its open nature, allowing access to all updated news without establishing relationships or friendships with other accounts (Stowe et al., 2016). At the same time, due to its open nature, unfortunately. People can quickly spread false information to other users on this platform (Jamaludin & Setiawan, 2022). Therefore, there needs to be a collaboration between the government and academics to provide education and literacy to the public so that they can take a more critical attitude towards the distribution of information on Twitter to prevent the spread of fake news on Twitter. The statement above is in line with Vimalajeewa et al. (2019), who found that social networking research as early detection has an impact on three entities: individuals, emergency agencies, and organizations.

CONCLUSION

Based on the results of data analysis, it can be concluded that the Mount Semeru eruption early warning information network system on Twitter forms a network distribution with effective communication patterns to reach all network members. Besides, due to the open characteristics of this network with low density and short coverage distance, the distribution of key actors can be readily accepted without any obstacles or intermediary actors in the network. Furthermore, the main actors in this research findings represent several entities, namely individuals, climate-related institutions and the press.

Using the social network model as an early warning system for volcanic eruptions in Indonesia might be relatively new. However, many developed countries use most network analysis models to provide warnings and disaster mitigation regarding disease outbreaks, tsunamis, and climate-related matters. Therefore, this social network model can be utilized by

the government and institutions related to disasters to carry out mitigation efforts, which are expected to minimize the impact of damage resulting from natural disasters.

Moreover, the general public can utilize social media and play a significant role as key network actors by distributing important information related to emergencies to a broader audience. Finally, for researchers in the media and technology field, it is hoped that this research can provide ideas for building a better early warning system by utilizing information related to network structure and distribution patterns, sentiment, language features and suggestions for what the community should do if an emergency occurs.

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