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Community Activation for Disaster Risk Reduction Through OpenStreetMap: A Scoping Review

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Abstract – The advancement of geospatial technology has significantly altered how data is utilised for facilitating the growth of open-access data for disaster risk reduction (DRR). OpenStreetMap (OSM) is a part of Volunteered Geographic Information (VGI), built on the concept of volunteerism and heavily reliant on user contributions to spatial data. In recent years, OSM has emerged as a fundamental tool in all aspects of DRR, enabling well-informed decision-making and empowering active community contributions. This study aims to review the utilisation of OSM in DRR and proposes recommendations to enhance community resilience. The five-step scoping review method was conducted on 25 selected papers to investigate the current knowledge and uncover the potential applications of OSM within the community for DRR. The review commenced by defining the research questions, identifying pertinent literature sources, selecting relevant literature for inclusion, extracting key themes from the literature, and finally, consolidating, summarising, and reporting the results. The findings revealed that OSM's worldwide accessibility for various objectives has been instrumental in its widespread adoption and rising prominence. Nevertheless, this review emphasises that despite its rapid expansion into other fields, OSM continues to hold significant importance and widespread usage in the context of DRR. This study presented findings on community involvement in OSM and explored the opportunities for community-led DRR implementation. The paper provides insights into the application of OSM in advanced and developing countries while delving into potential future pathways. OSM places significant emphasis on community-driven, on-the-ground data collection, providing governments with a chance to enhance policy management in DRR. As the incorporation of OSM in decision-making expands, it will garner attention from diverse sectors, demonstrating the platform's effectiveness on a broader and more impactful level.

Keywords *– Disaster Risk Reduction (DRR), OpenStreetMap, Volunteered Geographic Information, Open-access Data, Disaster*

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1.0 Introduction

The integration of location-based information-sharing technologies and the rise of volunteer geographic information (VGI) have transformed community engagement within disaster management. The concept of VGI was first introduced by Michael Goodchild in 2007; this term refers to the process where individuals, regardless of their scientific background, actively contribute to creating geographic information (Arapostathis, 2020). The sources of VGI data can be categorised into two primary groups: (1) conventional, pure, structured, or purpose-driven and (2) unstructured, unintentionally driven sources. The initial category includes dedicated websites where users are encouraged to provide or create specific information following straightforward guidelines or procedures. One of the most widely known examples in this category is OpenStreetMap (OSM). Over the years, a diverse ecosystem comprising volunteer mapping communities, businesses, government entities, and humanitarian organisations has emerged. These stakeholders actively participate in and rely on the open geographic database of OSM for a wide range of applications.

The Sendai Framework for Disaster Risk Reduction (SFDRR) 2015-2030 has recognised the importance of science and technology, where it promotes innovative solutions for decision-makers in developing an implementation plan for more effective Disaster Risk Reduction (DRR). Research related to DRR relies heavily on scientific data, including multidisciplinary observations, analysis and simulation, dispersed across national and community boundaries (Li et al., 2019; Fakhruddin et al., 2022). The rise of disaster occurrences has created a growing demand and responsibility for supporting DRR strategies. This situation has prompted inquiries into utilising alternative and supplementary data sources and the involvement of additional actors and communities to support efforts and potentially assist humanitarian organisations and decision-makers in handling various tasks. OSM data has become a valuable tool for DRR. It is closely related to geospatial technology supplemented with other geospatial tools to help identify disaster-prone areas, develop early warning, and provide a safe path for emergencies and zoning disasters according to risk magnitude. The core focus of OSM centres around community engagement and interactivity, which plays a pivotal role in fostering resilience and encouraging greater public participation in disaster management. Therefore, this study will review OSM's utilisation in DRR and propose recommendations to enhance community resilience.

2.0 Background of Study

Over time, there has been a growing utilisation of community engagement and public or community participation in DRR (Kankanamge et al., 2019). Community presence in technology-mediated approaches such as social media and mobile applications is often called 'crowdsourcing' or 'participatory sensing'. By harnessing crowdsourced collective knowledge from the community, we can access supplementary information and expand diverse solutions, leading to quicker and more precise disaster responses. Experience in harnessing community wisdom has been shared through several studies in the literature where broader benefits have been consistently identified that include near-real-time data collection, cost savings, improved crisis communication, location pointers to where help is needed, collective intelligence and better situational awareness and ground truth (Ogie et al., 2019; Gao et al., 2011; Roche et al., 2013; Zook et al., 2010).

Crowdsourced platforms involving spatial data generation by the community are known as VGI. VGI, a subset of crowdsourcing, involves acquiring spatial data directly from the community without requiring specialised qualifications. This means that the data contributor can voluntarily apply their skills and knowledge to any VGI platform without any requirement. VGI has garnered increasing attention from researchers due to its potential to resolve various technical challenges, such as difficulties in detecting disaster areas and the time-consuming process of obtaining authoritative data. Timely and up-to-date information is crucial before and after a disaster strikes, and crowdsourced data can prove valuable in such scenarios. Open-access data, mainly based on crowdsourced information, empowers users to design, contribute, and update data, relying heavily on the participation of the community, especially the local residents. Local communities, particularly those in high-risk areas, possess valuable knowledge about disasters or emergencies. VGI presents an opportunity for them to leverage this knowledge effectively.

The concept of VGI is closely related to the term citizen science (CitSci), which involves the participation of volunteers in public scientific research to enhance scientific knowledge. CitSci and VGI are crucial in geospatial capacity-building and facilitating scientific advancements (Kocaman et al., 2021). In collaborative mapping, particularly in VGI, CitSci allows citizen scientists to contribute their basic knowledge to spatial data, promoting capacity-building in digital mapping and emerging technologies. VGI proves advantageous for citizen scientists by streamlining the data collection process, reducing the time and effort required to obtain

information. Moreover, it fosters a knowledge exchange between citizen scientists and mapping experts, enabling valuable knowledge transfer.

Wikipedia, Worldmap, Google Earth Engine, Wikimapia, Wheelmap, and OpenStreetMap (OSM), which are particularly popular for disaster-related purposes, are notable examples of VGI. OSM is one of the successful VGI platforms, and it serves as a digital map database that offers open data for querying, downloading, modifying, and visualisation. OSM operates as a community-based, freely accessible, and editable map service designed as an alternative to authoritative mapping sources (Vargas-Munoz et al., 2021). To better understand OSM, its concept is comparable to Wikipedia, allowing any member of the user community to access and edit virtually using all available features. OSM finds significant utility in various applications, particularly disaster management, where it can leverage local knowledge to map catastrophic situations or hazards.

Over the last decade, OSM has played a vital role in supporting humanitarian initiatives globally and bridging crucial data deficiencies for implementing significant development frameworks like the SFDRR. The recent years has seen OSM becoming foundational in all aspect of DRR to support informed decision-making while empowering the contribution from the community. One of the approaches to enhancing the quality of society that contribute to OSM as digital mappers is through Mapathon. Mapathon is a coordinated mapping event where mappers can digitally connect and create up-to-date maps needed in disaster management (Saah et al., 2019). Besides Mapathon, there is also a Hackathon, which focuses on application development to create functioning software or hardware (Kamiriotou & Kitsios, 2022). Both Mapathon and Hackathon events are currently getting more attention from many countries as they can help map and highly detect crisis areas.

As OSM data continues to gain attention, several challenges remain in utilising this type of data. One of the primary concerns is the reliability of the data, as users may face difficulties in trusting it. Open-access data is prone to vandalism, leading to irrelevant data that can impact the results. Moreover, it has been discovered that some level of skill is necessary to work on OSM, despite no specific requirements for user registration. While anyone with internet access can freely contribute to the spatial data on the OSM platform, basic knowledge of geospatial technology remains essential and presents another challenge in its usage.

3.0 Materials and Methods

The five-step scoping review method was done to explore existing knowledge and identify opportunities revolving around the application of OSM among the community in DRR. The scoping review started with identifying the questions to be addressed; identifying the relevant literature sources; selecting literature to be included in the present review; recording key themes emerging from the literature; and collating, summarising, and reporting the results. The steps for this study are summarised in **Error! Reference source not found.**.

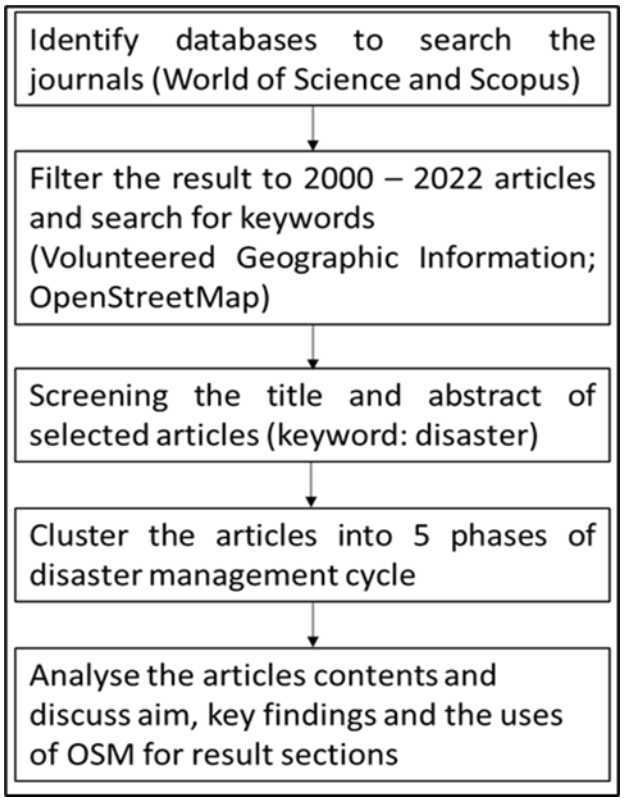

Figure 1. Methodology diagram

3.1 Identification of Questions

Building on the work by Scholz et al. (2018), this review elaborates further on the application of OSM in five phases of disaster risk reduction (disaster mitigation, disaster prevention, disaster preparedness, disaster response and disaster recovery), particularly among community-led efforts. This review aimed to build on the existing knowledge to involve larger stakeholders in disaster risk reduction.

3.2 Identification of Literature Sources

A systematic literature search using the keywords ‘OpenStreetMap’, ‘Volunteered Geographic Information’ and ‘Disaster Risk Reduction’ was done in two scientific databases, Web of Science and Scopus. The two databases are the most extensive for scientific publications on this topic. Results from the search were retrieved in the format of CSV and uploaded into Microsoft Excel for the title and abstract screening.

3.3 Selection of Literature for Review

The selection of literature was made in two phases: Screening of the Title and Abstract and Screening of the Full Text. The publication which fulfils the following criteria will be included in the review:

1. Published in English from 2000 through 2022.
2. Used Volunteered Geographic Information specifically on ‘OpenStreetMap’ as an approach.
3. Argued on the usability of OSM as an open-sourced tool for mass data gathering on disaster.
4. Explored different facets of disaster risk reduction (management, prevention, mitigation, recovery).

The review will exclude all the studies that used OSM for any event unrelated to the disaster.

3.4 Recording of Key Themes

All full-text versions of the selected article will be printed and distributed to the authors after the screening. The authors will perform a clustering process based on the type of disaster, region and the type of disaster management. The authors will discuss and agree to the list of key themes and proceed with the following review step.

3.5 Collation, Summary, and Reporting of the Results

After clustering, the important information from each article was extracted/analysed to be presented/visualised into charts/diagrams. The aim, key findings, and uses of OSM will be identified to structure the result and fulfil the objective of this review.

4.0 Results and Discussions

This review included 25 selected papers focused on the application of OSM in DRR and the importance of community contribution to OSM. The section is divided into three subsections: Overview of selected articles, analysis of community involvement in OSM, and opportunity to use OSM for community-led implementation for DRR.

4.1 Overview of Selected Papers

The analysis found that OSM has been extensively utilised for disasters and in various other fields, such as the health sector, tourism, transportation, environmental studies, and more. OSM is globally available for diverse purposes, contributing to its growth and increasing attention. However, this review has highlighted that despite OSM's rapid expansion in other domains, it remains highly relevant and widely used in DRR. After the clustering process, it was revealed that OSM plays a crucial role in disaster scenarios by offering up-to-date and detailed information about physical elements, particularly in high-risk areas. The review study demonstrated that most of the research utilised OSM data to analyse, assess, and estimate the impact of disasters, focusing on disaster-prone countries like Nepal, Italy, Haiti, and the Philippines (see Figure 2). The increasing contribution, particularly in disaster-prone regions, will bolster disaster preparedness and response efforts in affected areas. This will aid policymakers and researchers in formulating improved plans for disaster risk management, which emergency response teams can then utilise.

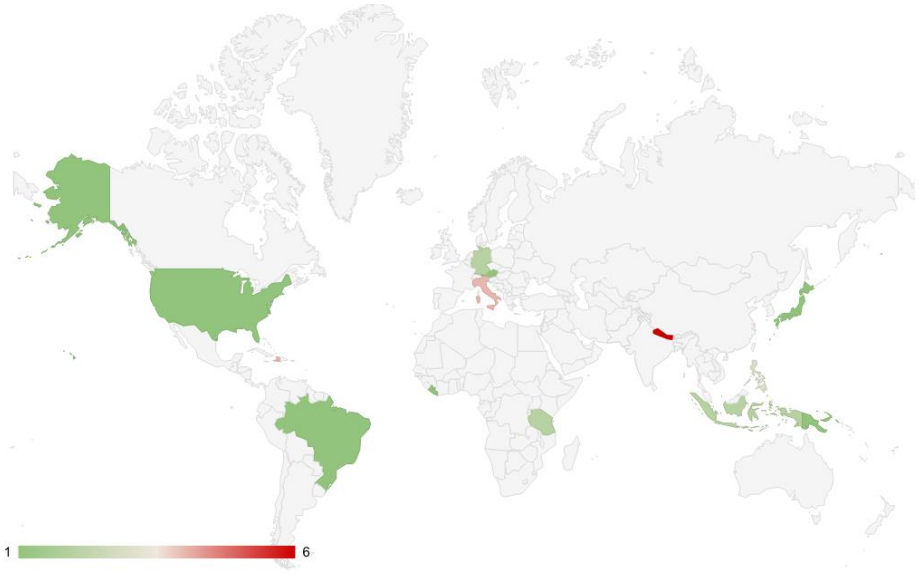

Figure 2. Distribution of study location from 25 selected papers

Figure 3 visualises the distribution of disaster types from the selected papers. The findings revealed that OSM was predominantly employed for analysing or estimating earthquake and flood risks, with both categories accounting for 33% of the total, as depicted in the figure. In addition to floods and earthquakes, other types of disasters include typhoons, landslides, tsunamis, droughts, hurricanes, volcanic eruptions, diseases, etc. The "Others" category in the figure encompasses natural hazards that were not explicitly mentioned in Paprotny et al. (2020) and a study by Scholz et al. (2018), which solely focused on exploring the potential of VGI for DRR. This figure indirectly explains the concentration of study locations around earthquake and flood-prone areas, as shown in Figure 2.

Most of the papers have highlighted the significance of OSM in DRR. It offers insights into the role of the community in open-access data, the application of OSM datasets for disaster risk analysis, and the potential of OSM in DRR. Table 1 presents the extracted information from all selected papers, categorised into subsections: 1) Analysis of Community Involvement in OSM; 2) Opportunities for Community-led Implementation in DRR and 3) Implementation of OSM in developed and developing nations. Besides focusing on the analysis of community contributions to OSM data, the table also emphasises the uses of OSM data. Most application-oriented papers utilised OSM data to develop and build applications, prototypes, and disaster models for estimating, analysing, and assessing the impact of disaster risks.

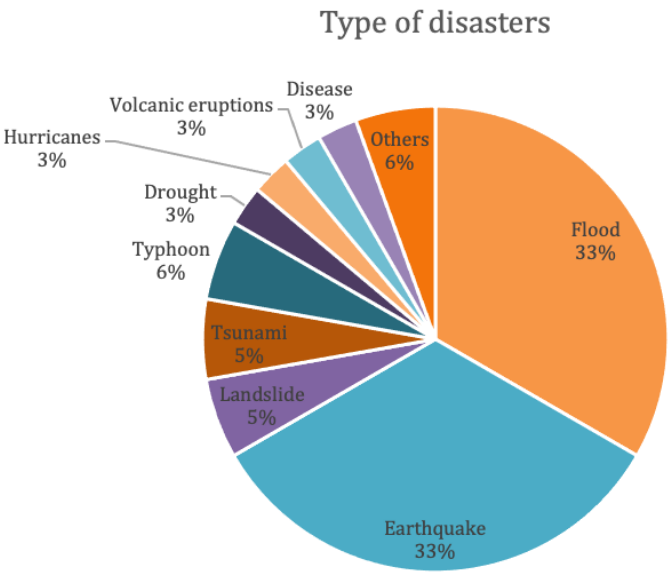

Figure 3. Division type of disasters

When discussing the growth of OSM data in disaster-related studies, it becomes evident that OSM can yield positive results in assessing disaster impacts. With accurate and easily accessible data, OSM has repeatedly demonstrated its suitability for disaster mapping and management (Giardino et al., 2012; Goldblatt et al., 2020). Several studies conducted from the selected papers have shown that OSM datasets can be effectively utilised to identify impacted areas and observe the disaster impacts through applications or disaster modelling, often visualised in risk maps. Furthermore, OSM provides reliable estimations of disaster impact, as this review has proven by comparing OSM data with other datasets. However, it is important to note that OSM for DRR still requires support from other spatial datasets. The review revealed that most studies necessitate additional data to conduct their research, as OSM primarily provides datasets on physical elements like buildings, roads, and waterway channels. In rural areas, OSM may not offer a complete set of data, which underscores the need for complementary spatial data to produce more robust results for disaster impact analysis. Combining crowdsourcing data sources with different datasets proves helpful in supporting the disaster management system (Tayra et al., 2021).

With OSM, it is also much easier for the users to identify the changes in the condition area, including buildings, roads or any infrastructure after disaster strikes. This depends on the availability of past and present data to detect the differences between the elements. OSM provides an option where users can continuously and regularly update these elements in OSM. This is important as the updated data is needed to avoid the staleness of the data irrelevant in disaster response. OSM is based on volunteerism, which is driven by self-spirits and passions, where most users are not getting paid for their mapping work at OSM. Mapping work back then was done primarily by a group of Geographic Information System (GIS) specialists. Still, with the advancement of technology, the community can now directly involve in mapping activities at OSM without needing qualifications. The importance of community contribution to OSM data will be discussed in the following subsection.

Table 1. Extracted information from 25 selected papers

No	Elements of OSM data	External Source / Additional Data	Objective of the study / Application of the data	Type of disaster	Study location	Source
Analysis of community involvement in OSM						
1	n/a	n/a	To identify the impact of new contributors on mapping disaster activities	Earthquake	Nepal	Parr (2015)
2	n/a	n/a	To analyse the local and external OSM contribution activities	Earthquake	Nepal and Italy	Ahmouda et al. (2018)
3	n/a	n/a	To evaluate the contribution in mapping disaster activities	Earthquake	Italy	Minghini et al. (2017)
4	Roads and buildings	n./a	Assess the quality of OSM data	Earthquake, Typhoon and Disease	Haiti, Philippines, Liberia and Nepal	Anderson et al. (2018)
5	Roads and buildings	n/a	To identify the potential of citizen scientists and mappers based on their contribution to OSM	Landslides and Flood	Nepal	Parajuli et al. (2020)
Application of OSM						
6	Roads	LiDAR data	Develop automated detection of road blockage	Earthquake	Haiti	Liu et al. (2013)

7	Buildings	Used Web-GIS prototype to assess disaster impact using open data	To develop a prototype to estimate the earthquake impact	Earthquake	Nepal	Olyazadeh et al. (2016)
8	Roads	Normalised differential vegetation index (NDVI), Synthetic aperture radar (SAR) datasets	Develop and update the flood map using OSM with the application of NDVI data to identify water-covered areas and SAR datasets to map the evolution of flood	Flood	Italy	de Musso et al. (2018)
9	Buildings	Authoritative data	Estimate exposure to natural hazard	Natural Disaster	Countries in Europe	Paprotny et al. (2020)
10	Roads and topography	Authoritative data	Build a reachability model for disaster response	Earthquake	Papua New Guinea	Warnier et al. (2020)
11	Buildings	SPOT Images	Estimate the conditions of the buildings	Earthquake	Japan	Kushiyama & Matsouka (2019)
12	Buildings	ResUnet-CRF was applied for building extraction, and the Edge Density Index (EDI) and	Build automated deep learning to update the condition of the buildings after a disaster	Typhoon	Philippines	Ghaffarian et al. (2019)

		Variation-HOG (V-HOG) indices were used to detect changes in the building footprint				
13	Roads	Post-GIS was used to process the data	Develop web and mobile applications to identify the radius of roads affected by disaster	Earthquakes, Tsunamis, Volcanic Eruptions, Floods, Drought, Hurricanes and Landslides	Indonesia	Ariyanto et al. (2019)
14	Roads and buildings	Synthetic Aperture Radar (SAR)	To detect changes and identify the difference in roads and buildings before and after a disaster	Earthquake and Tsunami	Indonesia	Gupta et al. (2021)
15	Waterways or channel element	Tropical Rainfall Measuring Mission (TRMM)	Develop an urban flood model	Flood	Tanzania	Gebremedhin et al. (2020)
16	Waterways and roads	Imported the data to QGIS to process and visualise the data	Mapped and assessed the drainage channel	Flood	Philippines	See et al. (2020)

17	Buildings	Survey data	To predict flood damage to the buildings	Flood	Germany	Cerri et al. (2020)
18	Roads	CORINE land cover ad LUISA land cover	To assess flood risk through comparison of object-based approach (OSM) and grid-based approach	Flood	Countries in Europe	Van Ginkel et al. (2021)
19	Buildings	Basic European Asset Map (BEAM) and authoritative datasets	Provide a comparison of OSM data and external data and estimate the flood impact	Flood	Germany	Sieg & Thieken (2022)
20	Roads	n/a	To survey the road network properties		Italy, Nepal, the United States of America and Tanzania	Valenzuela et al. (2022)
Opportunity of using OSM for Community-led Implementation for DRR						
21	n/a	n/a	To discover the potential of Volunteered Geographic Information (VGI) for disaster response effort	Earthquake	Haiti	Zook et al. (2010)
22	Linear features (roads, rivers and railways) and polygon features (buildings and natural structures)	Orthophotos, LiDAR data, authoritative data, CORINE Land Cover (CLC)	To compare different datasets for flood simulations	Flood	Austria	Dorn et al. (2014)

23	Roads and waterway network	Hourly rainfall data by Tropical Rainfall Measuring Mission (TRMM) and topographic information from digital elevation models (DEMs)	To identify the potential of open-source data, combined with multiple spatial data to develop flood simulation	Flood	Haiti	Anderson et al. (2018)
24	n/a	n/a	To explore the potential of OSM in DRR through the Missing Maps approach	n/a	n/a	Scholz et al. (2018)
25	Roads	Application of Sketch Map tool to assess the OSM data quality	OSM data was used to identify the potential of the Sketch Map tool in DRR	Flood	Brazil	Klonner et al. (2021)

4.2 Analysis of Community Involvement to OSM

OSM has established a crowdsourced map that various experts worldwide populated based on the inputs from on-the-ground sources (Guntha et al., 2020). OSM is an open-access platform that allows any user from around the world to apply their on-the-ground knowledge through mapping activities and is available for everyone. OSM can gather information on disasters because OSM allows local and external contributions, which enables the engagement of the community in contributing the data. Users usually contribute to OSM with at least a basic mapping skill. Still, they do not necessarily need to only focus on their locality area because they can also map any area as they can always refer to another source such as Google Maps. With no restrictions or limitations on mapping areas, OSM presents an opportunity to foster globally disaster-resilient communities.

Many terms have been used to describe OSM users; some might use OSM contributors, digital mappers, digital volunteers and citizen scientists, but all terms essentially refer to the same group and can be generalised as 'OSM users'. OSM users are based on communities, some are local, and some are non-local. Still, community involvement in OSM can be one of the good indicators for capacity building towards disaster resilience. As these articles focus on the application of OSM to disaster, the assessment of the selected journals reveals an increased number of contributions to OSM, mainly after disasters occur. This indicates that OSM users demonstrate significant effort in mapping disaster activities and express high interest and enthusiasm in disaster response efforts. OSM allows anyone, with or without spatial background, to register as OSM users. So, in general, OSM users can be divided into two categories, the experienced users, including a group of mapping experts and the new users, which usually refers to OSM users with less or no spatial background. Still, both categories play an important role in contributing data to OSM. Through this assessment, it was also revealed that experienced users mostly drove the number of contributions. In contrast, new users usually provide a small contribution to the data due to their lack of experience and practice which caused them not to be able to contribute to the mapping activities significantly. Experienced users were also focusing more on improving the quantity and quality of data, which is crucial as the data were then usually used in the field by the rescue and response team.

The concept of OSM is to emphasise local knowledge. Still, it allows users worldwide, local or international, to contribute to OSM data freely. This means that any users can add or edit the OSM data without being physically present at the locations. This is what is usually called

remote mappers. International contributors are just as important as local contributors because some countries might not have a group of mapping experts. This is when international contributors can contribute their skills and knowledge in mapping disaster activities in the risk area. The selected study locations mainly focus on disaster-prone regions in developing countries such as the Philippines, Nepal and Indonesia. It is revealed that most of these countries have received international contributions. Developing countries have received and need more international assistance than developed countries which may already have their group of mapping experts. Developed countries usually have better access to technology, like internet access and broader opportunities to improve their mapping skills through training programs provided in their country. Besides, it was also revealed that international contributors are still actively mapping the affected area even after the disaster event than local contributors. This shows that OSM is an effective platform because it allows the engagement of local mappers and international mappers, allowing them to share their skills and knowledge.

The OSM data are now widely used for many purposes, so the quality and accuracy must be maintained. In the context of disaster, OSM data have usually been used to monitor and provide crucial information in areas of risk which is essential for disaster preparedness and response. But the main disadvantages of OSM are lack of knowledge about how the data was captured (El-Ashmawy, 2016). This means that where or how the data were obtained is always questionable. Local mappers mostly added the local data, but the concept of OSM that allows users from everywhere to contribute to the data freely will probably cause an accuracy problem because outsiders or general users may have limited knowledge of the mapping area. Hence, many approaches have been conducted to assess the quality of OSM data, such as comparing the OSM data with the authoritative data or using an automated approach to evaluate the quality of OSM datasets. Comparison of the OSM data with authoritative datasets usually requires extra effort and time. However, accessing the quality of OSM data through automated approaches is much easier, and less work is needed. The automated approach gives promising results while enhancing OSM quality without referencing other proprietary datasets (Kaur & Singh, 2019). This means that the automated approach should become another alternative as different datasets are not needed, and this would save some time and effort. The method of assessing the quality of OSM data should need to be intensified so that the quality can be maintained. Then it can be further used for disaster preparedness and response.

The increasing number of participations in mapping disaster activities using OSM indicate the community's interest in using open-access data to integrate their knowledge. This could enhance the disaster preparedness and response effort. Traditionally, the researcher must go through many processes to seek spatial data. Still, now, OSM provides a readily prepared dataset, making it easier for anyone to conduct research activities. Training should be provided to encourage greater participation in OSM, especially for local users, to enhance their understanding and strengthen their mapping skills through the platform. OSM is renowned for its ability to integrate the knowledge of local mappers, who possess extensive experience and information about their areas. This fosters active engagement of the local community in enhancing disaster management at the grassroots level. As a result, emergency teams can deliver more efficient services during disasters.

4.3 Opportunity of Using OSM for Community-led Implementation of DRR

OSM holds a rich potential for building community resilience as OSM is a free editable map which allows anyone with mapping gadgets and internet access to contribute the data. Besides, OSM has been foundational to DRR as it has been used in many aspects to support decision-making, especially in disaster preparedness, response, and recovery. OSM emphasise local knowledge of disaster events through mapping activities. The local community, especially those at risk, can now integrate their experience and expertise into OSM so that the data can be further used for disaster risk management. OSM is very functional when the data is complete and provide detailed information on all elements because it will be easier to conduct any assessment or estimation of disasters without having to undergo a lot of external process like getting the authoritative datasets which may require a lot of procedures. OSM aims at building and maintaining a free editable map database of the world collaboratively so that people and end-users are not forced to buy geodata traditionally and subsequently be subjected to restrictive copyright and license commitments (Arsanjani et al., 2015). It has become more accessible for anyone to use the data provided by OSM, which would also increase the participation of OSM users.

The OSM users have different mapping experiences, which is attractive as we can observe the various mapping skills and techniques in OSM. But the biggest concern is the data quality, so it is necessary to develop the standards to maintain the data quality. The OSM mapping training should be conducted more often, not only to enhance the skills of open mappers but also to promote the application of open-access databases in nurturing the local knowledge to assess any aspects of

disasters. Building community resilience is important to strengthen their ability to adapt to future challenges and allow them to support decision-making policy that minimises the impact of disaster. Everyone is responsible for keeping updated and aware of disasters because disasters can sometimes happen unpredictably. OSM is one of the promising approaches that allow community engagement in mapping disaster activities because the availability of open-access data would be a huge opportunity to enhance and support any disaster preparedness, response, and recovery efforts.

OSM relies on the number of volunteers since it is based on an entirely voluntary process. The more volunteers work on it, the faster its development process runs, but one thing that might become a challenge is that the amount of contribution is inconsistent in all countries (Latif et al., 2018). Some areas have a high amount of data, while others still lack data. The concept of volunteerism in OSM means that the total contributions depend on the user's motivation to provide input consistently. Increasing participation in OSM requires significant efforts and is undoubtedly challenging. Learning the mapping process itself can be time-consuming, and teaching newcomers about the importance of community involvement might pose difficulties (Schott et al., 2021). Consequently, strategic approaches are essential to ensure the community becomes interested and committed to contributing to OSM.

OSM has been recognised as having significant potential in DRR, allowing the community to actively participate in providing data that can aid authorities in better disaster management, both during and after disasters. Technological advancement makes the sharing process much easier, encouraging open communities to gather relevant information for open mapping. OSM is strong because it is an ecosystem, a collection of tools and approaches designed to support a central database and map (Westrope et al., 2014). Disaster can be destructive, and the growth of OSM will benefit much for disaster preparedness and disaster response.

4.4 OSM in Malaysia

In a country like Malaysia, which is categorised as a developing nation with low risk and vulnerability to natural hazards, it has been observed that there is less demand for open-data technology, mainly due to low disaster awareness among the community. Communities residing in low-risk areas typically show little concern for disaster issues, which explains the slow-paced development of OSM in Malaysia. Based on rough observation, the low-risk community tends to use authoritative data as it is believed the data is more accurate and reliable. In contrast, open data

is usually used as additional or supporting data. It has become a challenge to encourage community participation in OSM as this will be significantly influenced by cultures and socioeconomic factors (Husen et al., 2018). However, many approaches have already been conducted to enhance community involvement in OSM data, such as the Mapathon program and basic training on OSM, to build the capacity of open data in Malaysia.

4.5 Future Direction

Community involvement in mapping work has become increasingly relevant in today's technologically advanced world. With the availability of crowdsourcing data, people are becoming less dependent on authoritative sources for information. One significant aspect of crowdsourcing data in DRR is that volunteer crowdsourcing can quickly make disaster-related details accessible in the cloud shortly after a disaster (Kankanamge et al., 2019). For instance, during a disaster, having sufficient and up-to-date data in platforms like OSM enables disaster responders to identify accessible routes for rescue operations within a short period. This underscores the importance of capacity-building training for communities to understand how their contributions can significantly impact, especially in disaster response. Mapathons, as discussed previously, serve as one example of a capacity-building activity to enhance community participation, starting with smaller areas and gradually expanding to larger scales. Increased community participation will lead to the rapid growth of OSM, contributing to data consistency.

OSM offers the opportunity to harness citizens' knowledge in addressing problems that governments may be unable to solve alone or find too costly to manage (Budhathoki & Haythornthwaite, 2012). Disasters can cause significant changes in the affected area's landscape, necessitating frequent data updates for rapid rescue responses. Local community-provided data can assist emergency responders in taking necessary actions to mitigate the impact of disaster risk and promptly identify affected areas. Additionally, datasets available in OSM can aid governments in formulating policies for improved decision-making in DRR. OSM emphasises the importance of on-the-ground data collected by the community, presenting an opportunity for governments to strengthen policy management in DRR. As the usage of OSM in policymaking grows, it will attract interest from different sectors, showcasing the platform's usefulness on a larger scale. It is recommended that further research be conducted to understand better the genuine challenges and obstacles hindering the broader application of OSM. Additionally, there is ample potential in OSM

that remains unexplored, warranting more investigations into its applications in disaster contexts. Leveraging OSM, it is believed that resilient communities can be developed, empowering them to become stronger and better prepared to confront future challenges.

5.0 Conclusions

The increasing threats of disasters underscore the importance of a strategic approach in DRR. Technological advancements now facilitate easier analysis and assessment of disaster impacts, with data readily accessible. Open-access data is a notable technological advancement with significant potential and numerous advantages, making data readily available and accessible for various purposes. Apart from saving time and effort, it streamlines user work processes. This study highlights that OSM could be one of the best ways to utilise mapping technology in DRR. OSM has many other potentials, but its effectiveness heavily relies on user contributions. With limited participation, OSM will provide less data, reducing its functionality for analysing, assessing, or estimating various aspects of disasters. Hence, community involvement becomes essential to ensure the data remains updated and available, particularly in disaster-prone areas.

It was discovered that the mapping activities were rapidly active when the disaster happened in disaster-prone areas. This also can generally conclude that most OSM users showed great interest in mapping disaster activities and received tremendous support from local or international users, which could be a good indicator for a disaster-resilient community. It also allows knowledge transfer among users worldwide with diverse backgrounds to work together in mapping disaster activities. But, the primary concern of open data is on the accuracy of data, so future work is required to improve data quality to provide more robust information.

Based on this study, the gap in local community engagement on open data is considered high, especially in least-developing countries where the OSM data is either less-updated or unavailable. This can be due to several reasons, such as a lack of technical skills or low technological infrastructure in the country. Still, these gaps can be reduced by conducting more training or programs related to OSM. The application of OSM should be explored, not limited to disaster only, and this can be done through the Community Awareness Program, where the community itself should understand the importance of their collective action can bring many potentials for data development in their locality. However, in understanding gaps in OSM implementation, further studies are suggested to acknowledge the real challenges and issues of low

application of OSM. Besides, OSM has a lot of other potential that still needs to discover, so it is also suggested to conduct more work on identifying the uses of OSM data in the context of disaster. With OSM, it is believed that a resilient community to disaster could be developed, making the community stronger and well-prepared to face future challenges.

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References

2017 Global Platform for Disaster Risk Reduction: Proceedings. Available online: https://www.undrr.org/quick/11646 (accessed on 23 December 2022).

Ahmouda, A., Hochmair, H. H., Cvetojevic, S., 2018. "Analysing the effect of earthquakes on OpenStreetMap contribution patterns and tweeting activities." *Geo-Spat. Inf. Sci.*, *21*, 195-212.

Anderson, J., Soden, R., Keegan, B., Palen, L., Anderson, K. M., 2018. "The crowd is the territory: Assessing quality in peer-produced spatial data during disasters." *Int. J. Hum-Comput. Interact.*, *34*, 295-310.

Arapostathis, S.G., 2020. "Fundamentals of Volunteered Geographic Information in Disaster Management Related to Floods." In Huang, G. (Ed.).Flood Impact Mitigation and Resilience Enhancement. IntechOpen. doi: 10.5772/intechopen.87806

Ariyanto, R., Syaifudin, Y. W., Puspitasari, D., Suprihatin, A. Y., Ananta, A., Setiawan, A., Rohadi, E. A., 2019. "Web and Mobile GIS for Identifying Areas within the Radius Affected by Natural Disasters Based on OpenStreetMap Data." *Int. J. Online Biomed. Eng.*, *15*, 80-95.

Arsanjani, J. J., Zipf, A., Mooney, P., Helbich, M., 2015. "An introduction to OpenStreetMap in geographic information science: Experiences, research, and applications." In *OpenStreetMap in GIScience*; Arsanjani, J. J.; Zipf, A.; Mooney, P.; Helbich, M., Eds.; Springer: Basel, Switzerland, 2015; pp. 1-15, ISBN 978-3-319-14280-7.

Bertolotto, M., McArdle, G., Schoen-Phelan, B., 2020. “Volunteered and crowdsourced geographic information: the OpenStreetMap project.” *J. Spat. Inf. Sci.*, *20,* 65-70.

Bozza, A., Durand, A., Confortola, G., Soncini, A., Allenbach, B., Bocchiola, D. , 2016. “Potential of remote sensing and open street data for flood mapping in poorly gauged areas: a case study in Gonaives, Haiti.” *Appl. Geomatics*, *8*, 117-131.

Budhathoki, N. R., Haythornthwaite, C., 2012. “Motivation for open collaboration: Crowd and Community Models and the Case of OpenStreetMap.” *American Behav. Sci.*, *57*, 548-575.

Cerri, M., Steinhhausen, M., Kreibich, H., Schröter, K., 2020. “Are new open building data useful for flood vulnerability modelling?” *Nat. Hazards Earth Syst. Sci.*, *21*, 1-29.

de Musso, N. M., Capolongo, D., Refice, A., Lovergine, F. P., D’Addabbo, A., Pennetta, L., 2018. “Spatial evolution of the December 2013 Metaponto plain (Basilicata, Italy) flood event using multi-source and high-resolution remotely sensed data.” *J. Maps*, *14*, 219-229.

Dorn, H., Vetter, M., Höfle, B., 2014. “GIS-based roughness derivation for flood simulations: A comparison of orthophotos, LiDAR and crowdsourced geodata.” *Remote Sens.*, *6*, 1739-1759.

El- Ashmawy, K., 2016. “Testing the positional accuracy of OpenStreetMap data for mapping application.” *Geod. Cartogr.*, *42*, 25-30.

Fakhruddin, B., Kirsch-Wood, J., Niyogi, D., Guoqing, L., Murray, V., Frolova, N., 2022. “Harnessing risk-informed data for disaster and climate resilience.” *Prog. Disaster Sci. 16*, 100254.

Gao, H., Wang, X., Barbier, G., Liu, H., 2011. “Promoting coordination for disaster relief - From crowdsourcing to coordination.” In *Social Computing, Behavioral-Cultural Modeling and Prediction*, Salerno, J., Yang, S.J., Nau, D., Chai, SK, Eds: Lect. Notes Earth Sci., Springer, Berlin, Heidelberg; *6589*, 197-204.

Gebremedhin, E. T., Basco-Carrera, L., Jonoski, A., Iliffe, M., Winsemius, H., 2020. “Crowdsourcing and interactive modelling for urban flood management.” *J. Flood Risk Manag.*, *13*, 1-15.

Ghaffarian, S., Kerle, N., Pasolli, E., Arsanjani, J. J., 2019. “Post-Disaster building database updating using automated deep learning: An integration of pre-disaster OpenStreetMap and multi-temporal satellite data.” *Remote Sens.*, *11*, 2427.

Giardino, M., Perotti, L., Lanfranco, M., Perrone, G., 2012. “GIS and geomatics for disaster management and emergency relief: A proactive response to natural hazards.” *Appl. Geomat.*, *4*, 33-46

Goldblatt, R., Jones, N., Mannix, J., 2020. “Assessing OpenStreetMap completeness for management of natural disaster by means of remote sensing: A case study of three small island states (Haiti, Dominica and St. Lucia).” *Remote Sens.*, *12*, 118.

Goodchild, M. F., 2007. “Citizen as sensors: The world of volunteered geography.” *GeoJournal*, *69*, 211-221.

Guntha, R., Rao, S. N., Shivdas, A., 2020. “Lessons learned from deploying crowdsourced technology for disaster relief during Kerala floods.” *Procedia Comput. Sci.*, *171*, 2410-2419.

Gupta, A., Watson, S., Yin, H., 2021. “Deep learning-based aerial image segmentation with open data for disaster impact assessment.” *Neurocomputing*, *439*, 22-33.

Herfort, B., Lautenbach, S., Porto de Albuquerque, J., Anderson, J., Zipf, A. 2021. The evolution of humanitarian mapping within the OpenStreetMap community. *Sci Rep 11, 3037*. https://doi.org/10.1038/s41598-021-82404-z

Husen, S. N. R. M., Idris, N. H., Ishak, M. H. I., 2018. “The quality of OpenStreetMap in Malaysia: A preliminary assessment.” In Proceedings of International Conference on Geomatics and Geospatial Technology (GGT 2018), Kuala Lumpur, Malaysia, 3-5 September 2018.

Jonietz, D., Antonio, V., Linda, S., Zipf, A., 2017. “Highlighting current trends in volunteered geographic information.” *Int. J. Geo-Inf.*, *6*, 202.

Kamariotou, M. & Kitsios, F., 2022. “Hackathons for Driving Service Innovation Strategies: The Evolution of a Digital Platform-Based Ecosystem.” *Journal of Open Innovation: Technology, Market and Complexity, 8(3)*. https://doi.org/10.3390/joitmc8030111

Kankanamge, N., Yigitcanlar, T., Goonetilleke, A., Kamruzzaman, M. D., 2019.” Can volunteer crowdsourcing reduce disaster risk? A systematic review of the literature.” *Int. J. Disaster Risk Reduct.*, *35*, 101097.

Kaur, J., Singh, J., (2019). “An automated approach for quality assessment of OpenStreetMap Data.” In Proceedings of the 2018 International Conference on Computing, Power and Communication Technologies (GUCON), Greater Noida, India, 28-29 September 2018; IEEE: Greater Noida, India, 2019; pp. 707-712.

Klonner, C., Hartmann, M., Dischl, R., Djami, L., Anderson, L., Raifer, M., Lima-Silva, F., Degrossi, L. C., Zipf, A., de Alburquerque, J. P., 2021. "The Sketch Map Tool facilitates the assessment of OpenStreetMap data for participatory mapping." *Int. J. Geo-Inf.*, *10*, 130.

Kocaman, S., Saran, S., Durmaz, M., Kumar, S., 2021. "Editorial on the citizen science and geospatial capacity building." *Int. J. Geo-Inf.*, *10*, 741.

Kushiyama, Y., Matsuoka, M., 2019. "Time series GIS map dataset of demolished buildings in Mashiki Town after the 2016 Kumamoto, Japan Earthquake." *Remote Sens.*, *11*, 2190.

Latif, S., Islam, K. M. R., Khan, M. I., Ahmed, S. I., 2011. "OpenStreetMap for the disaster management in Bangladesh." In Proceeding of the 2011 IEEE Conference on Open System, Langkawi, Malaysia, 25-28 September 2011; IEEE: Langkawi, Malaysia, 2011; pp. 429-433.

Li, G., Zhao, J., Murray, V., Song, C., Zhang, L, 2019. "Gap analysis on open data interconnectivity for disaster risk research." *Geospatial Inf. Sci.*, *22*, 45-58.

Liu, W., Dong, P., Liu, S., Liu, J., 2013. "A rich Internet application for automated detection of road blockage in post-disaster scenarios." In Proceedings of the 8th International Symposium of the Digital Earth (ISDE8), Kuching, Malaysia, 26-29 August 2013.

Minghini, M., Sarretta, A., Lupia, F., Napolitano, M., Palmas, A., Delucchi, L., 2017. "Collaborative mapping response to disasters through OpenStreetMap: The case of the 2016 Italian earthquake." *Geoing. Ambient. e Mineraria*, *54*, 21-26.

Muhamad, N., Arshad, S. H. M., Pereira, J. J., 2021. "Exposure elements in disaster databases and availability for local scale application: Case study of Kuala Lumpur, Malaysia." *Front. Earth Sci., 9*, 616246.

Ogie, R. I., Clarke, R. J., Forehead, H., Perez, P., 2019. "Crowdsourced social media data for disaster management: Lessons from the PetaJakarta.org project." *Comput. Environ. Urban Syst.* , *73,* 108-117.

Olyazadeh, R., Aye, Z. C., Jaboyedoff, M., Derron, M., 2016. "Prototype of an open-source web-GIS platform for rapid disaster impact assessment." *Spat. Inf. Res.*, *24*, 203-210.

Paprotny, D., Kreibich, H., Morales-Nápoles, O., Terefenko, P., Schröter, K., 2020. "Estimating exposure of residential assets to natural hazards in Europe using open data." *Nat. Hazards Earth Syst. Sci.*, *20*, 323-343.

Parajuli, B. P., Khadka, P., Baskota, P., Shakya, P., Liu, W., Pudasaini, U., Roniksh, B. C., Paul, J. D., Buytaert, W., Vij, S., 2020. "An open data and citizen science approach to building

resilience to natural hazards in a data-scarce remote mountainous part of Nepal." *Sustainability*, *12*, 9448.

Parr, D. A., 2015. "Crisis mapping and the Nepal earthquake: The impact of new contributors." *J. Cartogr. Geogr. Inf.*, *65*, 151-155.

Roche, S., Propeck-Zimmermann, E., Merisckay, B., 2013. "GeoWeb and crisis management: issues and perspectives of volunteered geographic information." *Geojournal*, *78*, 21-40.

Saah, D., Johnson, G., Ashmall, B., Tondapu, G., Tenneson, K., Patterson, M., Poortinga, A., Markert, K., Quyen, N.H., Aung, K.S., Schlichting, L., Matin, M., Uddin, K., Aryal, R.R., Dilger, J., Ellenburg, W.L., Flores-Anderson, A.I., Wiel, D., Lindquist, E., Goldstein, J., Clinton, N. & Chishtie, F., 2019. "Collect Earth: An online tool for systematic reference data collection in land cover and use applications*." Environmental Modelling & Software 118, 166-171*

Scholz, S., Knight, P., Eckle, M., Marx, S., Zipf, A., 2018. "Volunteered geographic information for disaster risk reduction-The Missing Maps approach and its potential within the Red Cross and Red Crescent Movement." *Remote Sens.*, *10*, 1239.

Schott, M., Grinberger, A. Y., Lautenbach, S., Zipf, A., 2021. "The impact of community happenings in OpenStreetMap – Establishing a framework for online community member activity analyses." *Int. J. Geo-Inf.*, *10*, 164.

See, L. S., Calo, L., Bannon, B., Opdyke, A., 2020. "An open data approach to mapping urban drainage infrastructure in developing communities." *Water*, *12*, 1880.

Sieg, T., Thieken, A. H., 2022. "Improving flood impact estimations." *Environ. Res. Lett.*, *17*, 064007.

Tavra, M., Racetin, J., Peroš, J., 2021. "The role of crowdsourcing and social media in crisis mapping: A case study of a wildfire reaching Croatian City of Split." *Geoenvironmental Disasters*, *8*, 10.

Valenzuela, J. F. B., Legara, E. F. T., Monterola, C. P., 2022. "Typology, network features and damage response in worldwide urban road systems." *PLOS ONE*, *17*, 1-22.

van Ginkel, K. C. H., Dottori, F., Alfieri, L., Feyen, L., Koks, E. E., 2021. "Flood risk assessment of the European road network." *Nat. Hazards Earth Syst. Sci.*, *21*, 1011-1027.

Vargas-Munoz, J. E., Srivastava, S., Tuia, D., Falcão, A. X., 2021. “OpenStreetMap: Challenges and opportunities in machine learning and remote sensing.” *IEEE Geosci. Remote Sens. Mag.*, *9*, 184-199.

Warnier, M., Alkema, V., Comes, T., de Walle, B. V., 2020. “Humanitarian access, interrupted: dynamic near real-time network analytics and mapping for reaching communities in disaster-affected countries.” *OR Spectr.*, *42*, 815-834.

Westrope, C., Banick, R., Levine, M., 2014. “Groundtruthing OpenStreetMap building damage assessment.” *Procedia Eng.*, *78*, 29-39.

Zook, M., Graham, M., Shelton, T., Gorman, S., 2010. “Volunteered geographic information and crowdsourcing disaster relief: A case study of the Haitian earthquake.” *World Medical & Health Policy*, *2*, 7-33.