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Evaluating the network of stakeholders in Multi-Hazard Early Warning Systems for multiple hazards amidst biological outbreaks: Sri Lanka as a case in point

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ABSTRACT

Synergized impacts of simultaneous hazards amidst COVID-19 have called for the need for highly collaborative multi-sectoral approaches for disaster preparedness planning. In such a context, this study aims at evaluating the network of stakeholders in the National Early Warning System of Sri Lanka during preparedness planning. Social Network Analysis was used to visualise the network of stakeholders for selected hazard scenarios. Furthermore, a series of key informant interviews were conducted focusing on disaster preparedness planning during the recent multiple hazard scenarios. The findings highlight the need for a framework to guide the stakeholder coordination in preparedness planning for multiple hazards.

1. Introduction

Within the last 20 years, from 2000 to 2019, disasters took 1.23 million lives away, with an average of 60,000 per year while affecting over 4 billion people worldwide. Total economic loss due to disasters has been reported as 2.97 trillion US dollars within the said period [13]. In 2020, climate-related hazards apart had claimed 15,080 lives in 389 recorded events [12]. In parallel with those disasters, the COVID-19 pandemic has resulted in over 1.73 million deaths during the year 2020. And also, as of the 28th of November, COVID-19 has caused over 5.1 million deaths with over 260 million infected cases [64]. Though the death toll due to climate-related hazards is very low compared to mortality due to the pandemic, the occurrence of simultaneous hazards amidst a pandemic cannot be neglected. Mitigation and prevention measures taken for COVID-19 have interrupted response mechanisms for other natural and man-made hazards and vice versa [45]. Disruptions to containment measures such as social distancing can create more uncertainty in infection and fatality rates [40]. The COVID-19 pandemic itself exposed several vulnerabilities in the society and disproportionately affected specific communities such as daily wagers. Not limiting to overwhelming the health sector, devastations caused by COVID-19 have cascaded across socio-economic and political aspects as well [6,15]. These unprecedented impacts have the potency of affecting exposure, vulnerability and response elements of other hazards [44]. Therefore, decision-makers were urged to take stringent actions to mitigate the synergized impacts of multiple hazards occurring simultaneously during a pandemic.

Accordingly, creating effective Multi-Hazard Early Warning (MHEW) systems with adequate preparedness and response planning for potential risks has become a dire need due to the impacts of the COVID-19 crisis and simultaneous climate-related hazards [49]. In 2015, the Sendai Framework for Disaster Risk Reduction (SFDRR) prioritized enhancing MHEW systems as one of the initiatives to address exiting challenges in disaster management and prepare for the future, thus reducing disaster risk under the priority 04 [62]. It targets to increase the availability of and access to multi-hazard early warning systems, disaster risk information, and assessments by 2030. In the present, validating the relevance of 'Bangkok Principles for the International Conference on the Implementation of the Health Aspects of SFDRR', the unfavourable impacts of the COVID-19 and concurrent hazards call for the need for fostering advocacy and support for cross-sectoral, transboundary collaboration for all hazards, including biological hazards [57–59,61]. Strengthening institutional coordination, empowering local actors, altering emergency response and preparedness measures, extensive use of forecasting models, etc., are a few measures that have been suggested to improve the existing disaster preparedness and response planning in a MHEW environment [45,60].

Currently, in Sri Lanka, the disaster management mechanism is empowered by the Disaster Management Act No. 13 of 2005. The Disaster Management Centre (DMC) functions under the National Disaster

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Management Council to execute and coordinate disaster management activities related to twenty-one hazards mentioned in the said Act [53]. The DMC is responsible for coordinating early warning and risk assessment activities. Although a national early warning system exists, past studies have highlighted several gaps related to early warning mechanisms in the county. Both authorities and the public community are responsible for these gaps and issues [28,41]. Furthermore, recent studies show that activities such as risk communication, risk assessments, and preparedness and response planning related to biological hazards mainly depend on the public health sector [3,31]. The need for emulating multi-sectoral approaches to mitigate the impacts of biological hazards and potential cascading impacts is significantly highlighted. However, a limited number of studies have been conducted to identify the effectiveness of the stakeholder coordination in preparedness and response planning in Sri Lanka in a multiple hazards scenario that features a pandemic such as the COVID-19 outbreak.

In this context, this paper attempts to evaluate the network of stakeholders of disaster preparedness and response planning in MHEW systems for compound hazard scenarios that include biological outbreaks taking Sri Lanka as a case in point. Social Network Analysis (SNA) was used in this study to identify the network of stakeholders engaged in preparedness and response planning in the country for concurrent hazards amidst a pandemic. Furthermore, insights from experts who are involved in the disaster management activities in country were used in this paper to validate the findings of SNA with practical conditions occurred in preparing and responding to concurrent hazards amidst COVID-19.

2. Literature review

2.1. Additional burden set by COVID-19 on preparedness measures for multiple hazard scenarios

The occurrence of multiple hazards simultaneously can synergistically devastate a community. For instance, climate-related hazards such as floods, storms, and landslides that induced severe disasters during COVID-19, have posed challenges in responding to multiple hazards at the same time. When relevant authorities for disaster management in a country have to deal with several crises coinciding, response measures taken for one disaster can cause an increase in the impacts of another [60]. For instance, imposing rules on social distancing to mitigate the severe effects of COVID-19 can affect the response measures for a concurrent hazard such as tsunami, flood, etc. During the COVID-19 outbreak, coping capacities of emergency responses were reduced, although the occurrence of an additional disaster amplified the challenges [9]. During the COVID-19 outbreak, options available for safe evacuation were limited due to social distancing and restrictions on movements. Therefore, it was predicted that large evacuation measures for a concurrent hazard scenario could trigger a drastic increase in the morbidity and mortality of the pandemic [11,63,37,43].

Natural and other hazards did not stop occurring because of the unprecedented COVID-19 pandemic. A multiple hazards situation such as natural hazards during a pandemic can synergize socio-economic vulnerabilities in a country Devakumar et al. [18,39]. The twin impacts of compound hazard events can adversely affect communities that are already marginalized and severely affected [8,60]. For instance, travel restrictions and quarantine rules have resulted in an inadequate supply of food and relief items to victims of natural hazards in India and Bangladesh [54,60]. The compound impacts of the pandemics combined with concurrent disasters can further affect the health system of a country that is already overwhelmed by the pandemic. Hariri-Ardebili [27] illustrates that the loss of functionality of a hospital turns out to be rapid during parallel hazardous events in which natural hazards and pandemics co-occur. During the COVID-19 pandemic, withstanding the dual impacts of concurrent disasters became a significant challenge to the healthcare system win several countries such as Croatia, Fiji, Japan, etc. [2,10,65]. Such synergized impacts of multiple disasters occurring simultaneously have made evident the dire need for a proactive multi hazard approaches in disaster risk reduction.

2.2. Strategies to address impacts of simultaneous hazards amidst a pandemic

The impacts of concurrent hazards during the COVID-19 pandemic and its cascading effects have demonstrated that hazard by hazard disaster risk reduction must be altered to a multi-hazard approach, including high-level disaster preparedness. Developing ways to isolate, measure and manage or prevent systemic risk with a sound understanding of cascading risks has become a challenge currently [58]. In this regard, governments have a major responsibility to make complex and highly compromised decisions incorporating the need for mitigating impacts of multiple hazards and cascading effects [23]. International and national policies need to be altered to address contingency plans aiming to improve prevention, preparedness, mitigation, response and rehabilitation to multiple concurrent hazards [7]. In this regard, risk governance, disaster management capacities, multi sectoral coordination, community engagement, early warning systems, etc. are vested with a major responsibility [49].

Out of these possible strategies, emulating a multi-sectoral coordination is paramount in reducing the disaster risk of concurrent hazards and cascading impacts of pandemics. The coordination of multi stakeholders is important in enhancing the preparedness and response planning against possible multi-hazards contexts, such as a tsunami amidst the pandemic [57–59]. Countries should ensure the effectiveness coordination between both government departments and non-government organizations in disaster preparedness and planning [26,60]. Bangkok Principles for implementation of health aspects of the Sendai Framework emphasizes the necessity of integrating health into planning process at national and local levels [61]. The collaboration between health officials and disaster management authorities is considered significant. The unfavourable cascading impacts of the COVID-19 pandemic validated the need for following these principles [57–59]. According to recent studies local actors have a major role to play in preparedness and response planning for compound hazard events at the initial stages [60]. In multi sectoral approaches, collaboration with relief services, community-based organizations, and private sector organizations considered significant specially in relation to addressing potential cascading impacts. Likewise, multi sectoral coordination stands paramount in preparedness and response planning for multi hazard events [35].

In responding to multiple hazard events amidst a pandemic like COVID-19, it is paramount to be proactive and take necessary actions to prepare and reduce vulnerabilities in the community [60]. Within multi sectoral approaches, the effective coordination among stakeholders directly affects being proactive in preparedness and response planning [48]. The issues associated with availability and flow of information in a communication network of stakeholders affect the effectiveness of strategies in disaster management [33]. Due to the lack of coordination among stakeholders, a communication gap has been created within existing disaster preparedness and response planning mechanisms in a multi hazard environment [32]. These issues call for need for evaluating the behaviour of stakeholders in multi sectoral communication to optimize the stakeholder coordination in relation to disaster preparedness and planning.

2.3. Hazards occurred in Sri Lanka during COVID-19

Being a tropical country located closer to the Bay of Bengal, Sri Lanka receives rainfall from multiple origins, namely, monsoonal, convectional and depressional rain [17]. During COVID-19, Sri Lanka experienced heavy showers mainly due to monsoon seasons and depressions in the southeast Bay of Bengal. For instance, the country received over 200 mm rainfalls within 24 h in May 2020. In Kegalle District, which was the most severely affected, nearly 2000 victims and 400 damaged houses were reported during these heavy showers. High winds and landslides were the main reasons for damaged houses and victims [24,25]. Sri Lanka received heavy showers during the period from 2nd to 5th of December due to the Northeast monsoon and activation of depression in the southeast Bay of Bengal. During these heavy rainfalls, the northern province of Sri Lanka is worst affected [29]. During Cyclone Burevi, DM officials took anticipatory actions, and thousands of people were evacuated to safety centres in the Northern and Eastern provinces [25].

In 2021, the Southwestern region in Sri Lanka received more than 300 mm rainfall within 24 h due to the activation of Southwest monsoon winds. The National Disaster Management Centre (DMC) has reported with a month starting from the 2nd of May 2021, 84 divisions in 10 districts were affected during heavy showers. A total of 245,212 victims were reported within the said period, with 14 deaths. Furthermore, two persons were missing due to floods and cutting failures at the time of reporting [21]. Recently in late October 2021, a total of 62,247 people across 17 districts have been affected due to heavy showers followed by floods and landslides. Within a period of 2 weeks, 20 deaths were reported from districts; Kurunegala (6), Badulla (4), Kegalle (4), Puttalam (3), Matale (1), Galle (1), and Mullativu (1) [16]. Since the Southwest monsoonal showers in 2021 were received during the third wave of COVID-19 in the country, the preparedness and response capacities of the country's DM mechanism for multiple hazard scenarios were intensively tested.

Currently, in Sri Lanka, the Disaster Management Centre is legally mandate to execute the national-level disaster preparedness activities ensuring its last-mile dissemination in collaboration with relevant technical agencies and committees for hazards identified in the Disaster Management Act of the country [4]. Although Sri Lanka has a devised disaster preparedness and planning mechanism for multi-hazard contexts, recent studies have stressed severe gaps in the system. Poor coordination among government departments, lack of human resources, poor stakeholder communication, lack of clarity and accuracy, bottlenecks in communication skills are a few of the existing gaps in the current disaster management mechanism [36,41,47]. Recent studies, that have focused on mitigation of COVID-19 and concurrent hazards in the country, have stressed the need for multi sectoral coordination in disaster management approaches [4]. Recently carried out study has explored the communication networks of stakeholders during emergency preparedness phase for different hazard events. The results emphasize the complexity of operating procedures in several hazard events [51]. However, there is no effort taken towards evaluating the behaviour of stakeholders in communication networks during compound events. This can be highlighted as a research need since recent studies on early warning mechanisms for pandemics as well stressed the need for the collaboration between public health sector and disaster management authorities [52].

3. Methodology

In order to address the research question, which was mentioned earlier in the introduction, this study has aimed to evaluate the behaviour of communication network of stakeholders during preparedness and response planning phases for multi hazard contexts amidst biological hazards. In this regard, Sri Lanka was taken as a case study since Sri Lanka is exposed to a variety of hazards. Accordingly, this study consists of three steps as detailed below.

3.1. Selection of multiple hazard scenarios

This study attempts to identify and analyze communication networks of stakeholders for possible multiple hazard scenarios in Sri Lanka amidst a biological outbreak according to the existing national preparedness and emergency operations. Cyclones, floods, droughts, landslides, vector-borne diseases and coastal erosion are considered the most frequent hazards that affect Sri Lanka [56]. Though tsunami is not a frequent hazard, its potential damage is considerably high. Sri Lanka has its highest risk index among all types of disasters for tsunamis (8.9 out of 10) [5]. Cyclones, floods, and landslides are hydrometeorological hazards that occur simultaneously in the country. Most of the time, Sri Lanka experiences localized and seasonal floods and landslides [1]. Therefore, considering the frequency and impacts of hazards occurring in the country, the following scenarios shown in Table 1 were selected for the study.

Table 1
Identification of possible multiple hazards scenarios.

Scenario No.	Biological Hazards	Landslides	Floods	Cyclones	Droughts	Tsunamis
I	√	√	√	√	-	-
II	√	√	√	√	-	√
III	√	-	-	-		√
IV	√	-	-	-	√	

3.2. Identification of stakeholders and their interrelationships

In order to identify the stakeholders in preparedness and response planning for selected multiple hazards scenarios in Sri Lanka, recently published disaster management action plans and Emergency Operation Procedures (EOPs) were referred. Out of these plans, National Emergency Operation Plan (NEOP) [2015] is a national operation plan published by the Disaster Management Centre [DMC], Sri Lanka, under the guidance of the National Disaster Management Council (NDMC). NEOP defines stakeholders to be involved in carrying out emergency operations in the event of hazards that are listed in the National Disaster Management Act No. 13 of 2005 [19]. Table 2 denotes the key stakeholders for carrying out emergency preparedness and response planning before the occurrence of selected six hazards individually.

Although the NEOP covers all the hazards listed in the National Disaster Management Act individually, it does not provide operation procedures for compound/multi hazard events. Therefore, in identifying stakeholders for four multi hazard scenarios, the combination of all the stakeholders who

Table 2
Classification of stakeholders.

Type of hazard	Stakeholders
Epidemics	Disaster Management Centre (DMC), Ministry of Health (MOH), Hospitals (HP), Divisional/ District Secretary (DDS), District Disaster Management Coordination Unit (DDMCU), General Public (GP), Public Media Institutions (PMI), SL Airport, and Aviation Services Pvt. Ltd. (SLAAS), Public Health Inspector (PHI), Air Ports (AP), Ministry of Mass Media Information (MMMI), Ministry of Local Government and Provincial Councils (MLGPC), Local Authorities (LA), Grama Niladhari Divisions (GND), SL Army (SLA), SL Police(SLP)
Landslides	Disaster Management Centre (DMC), General public (GP), Hospitals (HP), SL Army (SLA), Public media institutions (PMI), Ministry of Mass Media & Information (MMMI), Ministry of Health (MOH), Ministry of Education (MOE), Schools (SCH), Divisional Secretary/District secretary (DDS), Road Development Authority (RDA), District Disaster Management Coordination Unit (DDMCU), Sri Lanka Transportation Board (SLTB), National Building Research Organization (NBRO), Local authorities (LA), Department of Meteorology (DOM), Grama Niladari (GN), SL Police (SLP), Ministry of Provincial Council and Local Government (MPCLG), Provincial RDA (PRDA), SL Navy (SLN)
Floods	DMC, Mahaweli Authority Sri Lanka (MASL), Department of Irrigation (DOI), Ministry of Agriculture (MOA), GP, MMMI, DDS, SLA, SLP, DPL, GN, PMI, DDMCU, CEB, DOM, SLP
Droughts	SLP, DDMCU, SLA, GP, DMC, DOM, Ministry of Agriculture (MOA), Mahaweli Authority SL (MASL), Department of Irrigation (DOI), Ceylon Electricity Board (CEB), SLA, MMMI, PMI, District Police (DP), MPCLG, GN
Tsunami	DMC, DOM, DDMCU, GP, SLP, Geological Survey & Mines Bureau (GSMB), IOTWC (Indian Ocean Tsunami Warning Centre), NARA (National Aquatic Reservation Authority), SLA, SLN, MOE, SCH, RDA, HP, PMI, SL Airport and Aviation Services Ltd. (SLAAS), SL Ports Authority (SLPA), PRDA, JMA, PTWC (Pacific Tsunami Warning Centre), MOH, Coast Conservation Department(CCD), SLTB, Meteorology Climatology and Geophysical Agency (BMKJ), Indian National Centre for Information Services (INCOIS),Joint Australian Tsunami Warning Centre r, Regional Integrated Multi-Hazard Early Warning Systems (RIMES), California Integrated Seismic Network (CISN), Coast Police Stations (CPS), LA, Minister, Deputy Minister(DM), Secretary(SEC), Non-Governmental Organization (NGO), International NGO (INGO), Fishing community(FC), Department of Fisheries (DOF), Office of the Chief Defence Staff(OCDS), National Disaster Relief Services Centre (NDRSC)

are engaged in individual hazards within a particular multi hazard scenario was considered. For instance, in identifying stakeholders for Scenario III, all the stakeholders categorized under biological hazards and tsunamis were combined together. If there is a stakeholder who is categorized under both hazards, that stakeholder was counted only for one time within the compound hazard scenario.

The next step of the desk study was to establish the links between the identified stakeholders. The NEOP provides necessary directives for agencies who are engaged in disaster management activities for a particular hazard, on coordinating with other stakeholder institutions during immediate preparedness and response planning. Accordingly, if the NEOP indicates that one agency should get information from and coordinate with another agency, a relationship, which is also known as a link, was established between these two particular agencies. In each of its directives, the NEOP indicates the two-way communication among stakeholders through already established communication networks. Considering these conditions links between actors in the networks were considered undirected and unweighted.

3.3. Application of Social Network Analysis and visualizing the network of stakeholders

Modelling the communication network of stakeholders is important for identifying the behaviour of stakeholders within the network. Out of existing approaches used in network visualization, Social Network Analysis was selected for this study. This analysis technique, which was named by John Barned, can be used as a technique to map and measure formal and informal relationships within a network of actors [34,50]. SNA has several advantages: identifying units that play central roles, discerning information breakdowns, bottlenecks, and structural holes, and leveraging peer support over the other approaches used in visualizing network behaviour [50]. The communication behaviour in a network of several actors can be analyzed using the SNA technique [38]. Though history shows that SNA was tightly related to sociology, psychology, mathematics, anthropology, and network science, at present, it is at the intersection of multiple sectors [42]. Recently, SNA can be observed as a frequently used tool in disaster-related studies to analyze relationships between varied stakeholders who are implementing DM mechanisms [46,55].

Communication networks are represented visually in SNA as a network of nodes connecting to one another. In a social network, centrality can be defined as a parameter that denotes the most important, central, or influential nodes [14]. To show the behaviour of a communication network, various centrality parameters are employed. As indicated in Table 3, this study selected four centrality parameters to analyze the network of stakeholders involved in the integration of biological hazard preparedness into the country's Disaster Risk Reduction (DRR) planning.

Table 3
Summary of centrality parameter interpretation (adapted from [34]).

Centrality parameter	Description	Justification
Degree centrality	The number of a network actor's direct contacts	This parameter is useful in evaluating the ability of an actor to contact others in the network directly.
Closeness centrality	Indicates how closely a member is connected to all other members in the network	This parameter helps to identify the actors who take a central position in the network and can communicate with the help of a few intermediaries
Betweenness centrality	Evaluate actors who mediate more connections in the network (network controllers)	This parameter indicates the degree of control a member has over the information flow based on his position in the network
Eigenvector centrality	Measures the node influence in a network	This parameter helps to identify most influential nodes in the communication network

Since these centrality parameters are utilized to measure the interconnectedness of nodes in a network, the most significant and powerful authorities in the network of stakeholders involved in biological hazards preparedness and response planning can be identified based on the values obtained for each parameter. Furthermore, the centrality parameter values indicate which actors in a network of stakeholders have the most power to regulate the flow of information. To model the network of stakeholders involved in pandemic emergency planning and response operations, it is necessary to map how stakeholders are connected to one another. Accordingly, the links between stakeholders were identified with reference to emergency operation procedures and disaster management plans scrutinized as part of the desk study.

3.4. Key informant interviews

A series of in-depth key informant interviews were conducted to investigate the challenges faced by stakeholders of the existing early warning system in the country during recent climatic related hazards amidst the third wave of COVID-19 pandemic in Sri Lanka. Fourteen (14) key informants were selected, using purposive sampling technique. In selecting key informants, existing national early warning system was followed since it covers the organizations/institutes that are supposed to be engaged in disaster risk management process according to the national disaster management plan. Accordingly, experts were selected from organizations/institutions that represents the national early warning system as shown in Fig. 1. These interviews were conducted using a structured questionnaire regarding the following aspects: impacts of COVID-19 on existing early warning systems for other hazards, changes in the early warning mechanisms during the pandemic, stakeholder coordination during COVID-19, and suggestions to improve the existing EW system for future multiple hazard scenarios.

4. Findings and discussion

Figs. 2–5 depict communication networks of stakeholders immediately before the event of multiple hazards scenarios I, II, III and IV, respectively. In these visualised models, stakeholders are represented by nodes which are ranked based on the Degree centrality value being represented by the varying node sizes. The relationships between stakeholders are represented by edges/links.

Furthermore, using the centrality parameters described in Table 3, stakeholders were ranked in order to identify the significance and roles of stakeholders in the communication networks related to selected potential multiple hazards scenarios. The top three stakeholders under each centrality parameter were shown in Table 4 for the four hazard scenarios.

Although four different hazard scenarios were considered for the analysis of communication networks, the results of these scenarios showed a similar pattern in regard to centrality parameters of the stakeholders included in networks as shown in Table 4. Therefore, it was decided to present the identified patterns in an aggregated format to support the policy level of preparedness and response planning. Since the insights of the field data collection agree with the findings of the SNA, which was based on documented and published operating procedures, results of both steps were combined together to present a holistic picture on how the conditions in plans and policies are reflected in the practical conditions. Accordingly, based on findings of stakeholder analysis and key informant interviews, four major areas which need immediate attention of authorities were identified as follows:

4.1. High complexity associated with stakeholder coordination and governance

Developed communication models make it evident that communication networks of stakeholders for multiple hazards scenarios at the emergency preparedness and response levels are complex. Past studies have also highlighted the high complexity of emergency operation procedures during specific hazards in the country [41,51]. Due to the increased complexity in emergency procedures and communication networks, several functions of

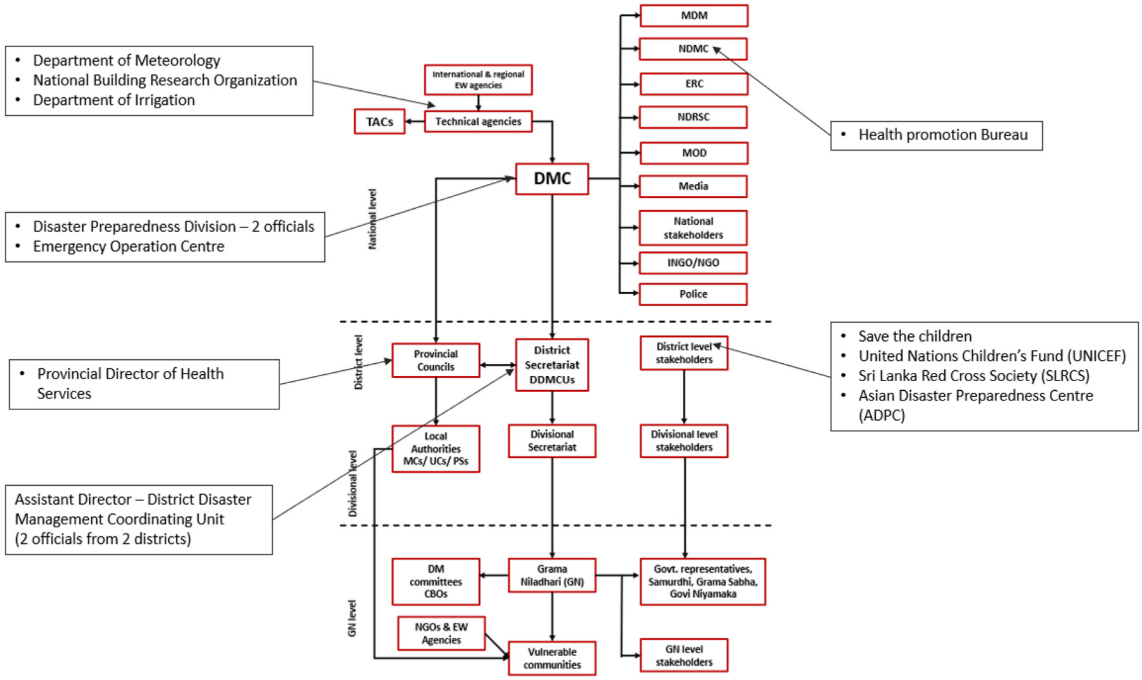

Fig. 1. Selection of key informants for interviews.

stakeholders can overlap, creating commotions. Furthermore, it can lead to power struggles between authorities as well. This is alsoan already existing issue in the MHEW system of the country. For instance, during the COVID-19 pandemic, haphazard structures were established despite the presence of already formed agencies for coordinating and implementing disaster management mechanisms [3–5]. Key informants have highlighted that the presence of these haphazard structures and ad-hoc task forces have often created power struggles at the regional level during the Southwest Monsoon 2021. Therefore, there is a higher possibility in the future as well to experience power struggles between authorities due to the complexity of operating procedures.

The National Disaster Management Act in Sri Lanka stipulates that DMC is the legally mandated agency to execute and coordinate the disaster management mechanism in Sri Lanka [20]. The findings of the analysis of communication network fall inline with this. Accordingly, the results of SNA results depict that Disaster Management Centre becomes the stakeholder with the highest ability to contact the others in the communication network directly in most of the scenarios. It is clear that DMC is vested with the

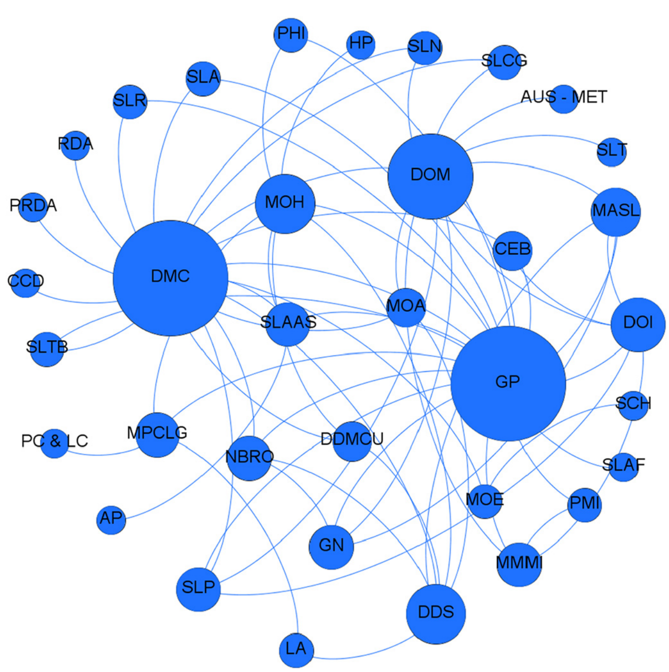

Fig. 2. Communication network diagram of stakeholders pertaining to hazard scenario I.

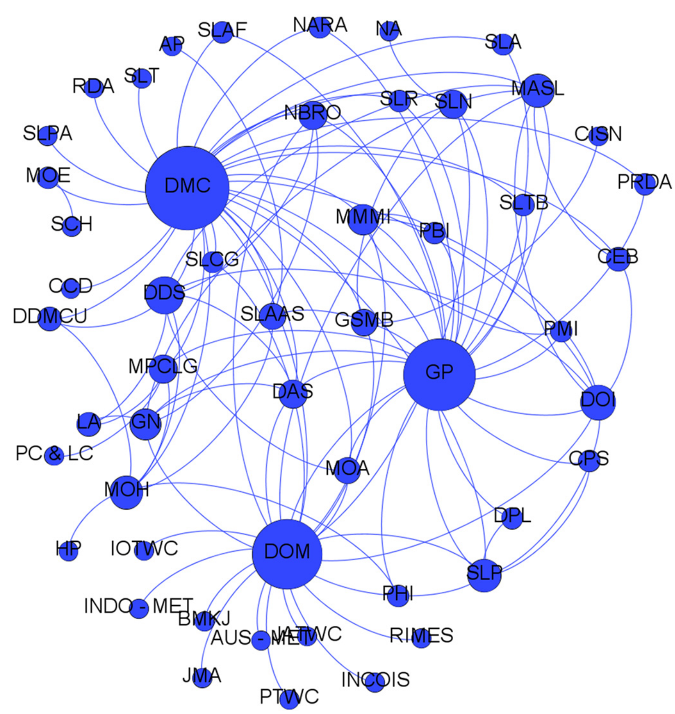

Fig. 3. Communication network diagram of stakeholders pertaining to hazard scenario II.

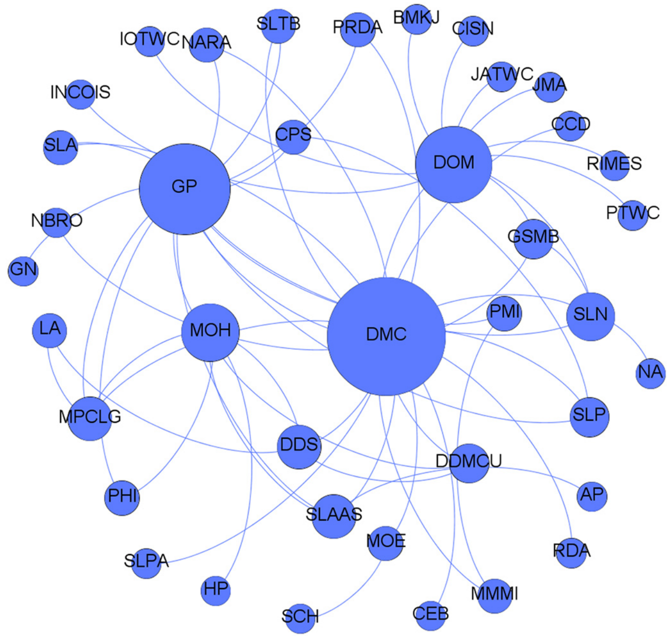

Fig. 4. Communication network diagram of stakeholders pertaining to hazard scenario III.

central role in coordinating and implementing emergency response mechanisms immediately before a multiple hazard scenario in the country. However, the findings of the key informant interviews highlight several issues regarding the power vested with the DMC. For instance, hap hazard structures established during COVID-19 have affected the functionality of DMC. Furthermore, it is revealed that government decisions made during the recent compound hazard events lack enough consistency. Although the DMC is the legally mandated agency for coordinating and executing DM activities, DMC had a less involvement during COVID-19. Moreover, issues were reported in regard to absence of legal enforcements at the village level in executing DM activities. Therefore there is a need for emulating a sound legal basis to function effectively during multi hazard events since responding to multiple hazards simultaneously specially during a pandemic needs rapid stringent decisions.

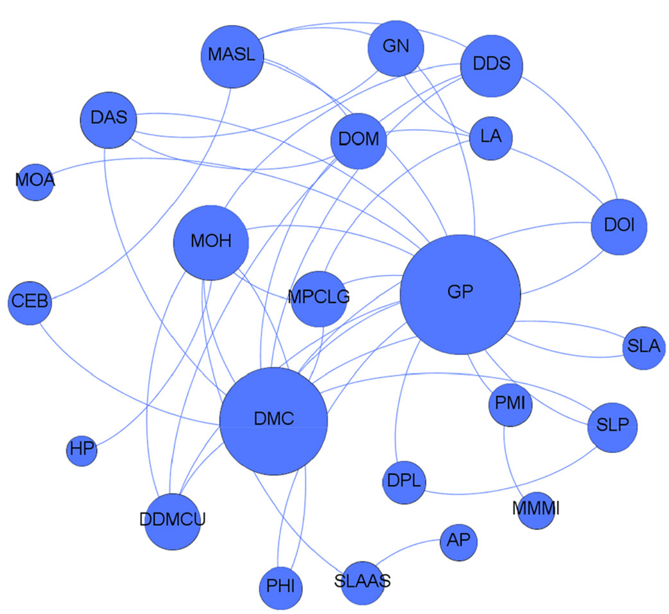

Fig. 5. Communication network diagram of stakeholders pertaining to hazard scenario IV.

Table 4
Top-ranked stakeholders for centrality parameters.

Hazard Scenario	Degree Centrality	Closeness Centrality	Betweenness Centrality	Eigen Vector Centrality
I	DMC	GP	DMC	GP
	GP	DMC	GP	DMC
	DOM	DOM	DOM	DOM
II	DMC	DMC	DMC	DMC
	GP	GP	DOM	GP
	DOM	DOM	GP	DOM
III	DMC	DMC	DMC	DMC
	GP	GP	DOM	GP
	DOM	DOM	GP	SLN
IV	DMC	GP	DMC	DMC
	GP	DMC	GP	GP
	MOH	MOH	MOH	DDMCU

Within these communication networks, a direct link can be identified between the DMC and general public. This link is maintained through the Emergency Operation Centre (EOC), which functions under the purview of DMC [20]. EOC utilizes this direct connection to receive ground-level risk information via local officials and the 24-h call centre and disseminate risk information and early warnings to the general public. However, at the local level there have been several issues, in relation to maintaining this link, due to absence of legally mandated officers, frequent technical failures, and changes in attitude of people. Even though this communication link is maintained through door-to-door information sharing methods as well, it was also hindered by the presence of COVID-19. Therefore, suggestions have been made to use methods such as megaphones, early warning towers, etc. to maintain a strong link with the community.

4.2. Accuracy of hazard forecasting and warnings and lack of public trust in technical agencies

According to the results of SNA, the Closeness and Betweenness centrality values of technical agencies such as the Department of Meteorology are considerably high although they have not been ranked as the first. It depicts that these agencies have a higher control over the flow of information within the communication network and can make a high impact on information which is circulated within the network. Within these communication networks, technical agencies mainly influence the flow of information which is related to risk knowledge and hazard forecasting. In most cases, the preparedness and response planning depends on the accuracy, timeliness, and reliability of these shared risk information. Given that the involvement of technical agencies influences preparedness and response planning mechanisms of a large number of stakeholders according to SNA results, the effectiveness of information shared by technical agencies have a great significant in the effectivness of planning process.

However, at the moment, there are several issues in existing early warning mechanisms in Sri Lanka, that have been brought to light by previous studies. Accordingly even before COVID-19, there have been issues such as lack of public trust due to low accuracy, lack of clarity and false predictions, and lack of use of technological platforms [30,31,41]. Insights from key informant interviews reveal that during the third wave of COVID-19 in Sri Lanka, technical agencies have faced several challenges that reduce the effectiveness of information shared by them. For instance, technical agencies experienced a reduction in their measurements which can ultimately affect the accuracy of forecasting. Lack of human resources and limited access to measuring stations were the main reasons for this reduction. According to key informants, technical agencies hava faced these conditions mainly due to the absence of contingency plans and lack of technological equipment.

Furthermore, inadequate human resources can increase the amount of work that has to be handled by one employee. According to key informants, because of the increased load of duties and work pressure, employees had issues in attending to important notices on impending disasters timely.

This issue can pose severe disruptions when early warnings and evacuation orders have to be issued quickly for immediate response activities such as tsunami evacuations. Moreover, key informants have highlighted that travel restrictions and work from home strategies also posed challenges to the hazard detection, monitoring, and forecasting mechanism in the country. Because, in some cases, still Sri Lankan authorities use hazard monitoring systems that do not have remote access. Furthermore, although these technical agencies are equipped with automated monitoring systems, there are several issues such as high maintenance cost, fragile under Sri Lankan climatic conditions, and restricted public access to information. In addition to that, key informants have mentioned that existing systems are not user friendly, and two systems cannot be combined together for the easiness of use. Therefore, it was highlighted that more developments are required in weather forecasting systems in Sri Lanka in order to manage concurrent hazards, especially amidst a pandemic. In this regard precision of forecasting should be improved through temporal and spatial warnings to increase the lead time. Moreover, technology should be more employed in modelling and predicting hazard events after forecasting.

4.3. Lack of engagement of public health officials in preparedness planning for multiple hazard events

The results of the analysis further highlight the comperatively less engagement of the Ministry of Health in the country in preparedness planning and emergency response mechanisms for multiple hazards scenarios during a biological outbreak. According to recent studies, preparedness planning pertaining to biological hazards in Sri Lanka is a public health sector-led process. Furthermore, the Ministry of Health has a higher ability to control information and contact stakeholders in the event of a biological outbreak [3–5,30,31,52]. However, the engagement of the Ministry of Health has shown some deficiency in the response mechanism for multiple hazards scenarios, and it needs to be further strengthened by inculcating a multi-sectoral approach. COVID-19 became an eye-opener for authorities, and its impacts during concurrent hazards stressed the need for strong coordination between disaster management authorities and the public health sector in the country. Due to this need, during the COVID-19 pandemic in Sri Lanka, the Disaster Preparedness and Response Division of Ministry of Health, Sri Lanka, in collaboration with DMC, prepared and disseminated guidelines for search and rescue missions and shelter management for the southwest monsoon period [22].

Key informants from the regional level mentioned that public health officials were earlier engaged in disaster management during the relief services. For instance, the service of public health inspectors was acquired mainly for matters related to the quality of food distributed for victims. However, during the third wave of COVID-19 in Sri Lanka, public health officials were actively engaged in preparedness planning and risk communication activities. Because managing infected victims during the evacuation, search and rescue, and emergency shelter management processes became the major challenges for DM officials. According to key informants, although the active participation of public health officials was present at the planning level, several issues arose since the number of health officers at the ground level was inadequate for the execution of response activities for other disasters amidst COVID-19. Especially during the southwest monsoon 2021 in Sri Lanka, it was proven that the occurrence of multiple hazards simultaneously could overwhelm the public health sector of a country devastatingly. Therefore, there is a need to enhance theadequate engagement of the health sector in the country, in preparedness and response mechanisms for multi-hazard contexts.

4.4. Negligence of non-government organizations and private sector

The emulation of a multi-sectoral approach has a significant impact on the smooth functioning of disaster preparedness and response mechanisms, especially in addressing cascading impacts and systemic risks during a pandemic. However, emergency response mechanisms immediately before the events of multiple hazards have neglected coordination with non-government and private sector organizations and relief services, according to the results. This issue can lead to limitations in meeting the humanitarian needs of victims. Reflections on rearranging the communication network in the planning stage, including the private sector, donors, and non-governmental organizations, stand significant in this regard. According to key informants, non-government organizations do not have the authority to join the preparedness and response activities unless there is an invitation from the government. Therefore, it is the responsibility of government DM officials to request the support of non-government agencies since they are equipped with the required resources as well. For instance, the possibility of using networks of NGOs for early warning dissemination and risk communication to last-mile was emphasized during key informant interviews. At the moment, agencies such as Sri Lanka Red Cross have a network of officials from the national to divisional level through the district level.

Furthermore, the findings of key informant interviews highlight that the existing early warning system of the country can be supported using resources which are already owned by NGOs. For instance, the International Organization of Migration (IOM) has a separate system called displacement tracking matrix to investigate impacts of victims and basic needs. Moreover, NGOs focus more on the special needs of vulnerable communities in disaster management activities. According to recent studies, DM activities in the country lack attention towards the special needs of vulnerable and marginalized populations [30,41]. In this regard, DM officials can get the support of NGOs who are mandated for addressing the needs of vulnerable communities. Furthermore, the effective coordination with local authorities and provision of adequate support to them is another key strategy in strengthening multi-hazard response mechanisms. According to the results, local authorities play a key role within the communication network for selected hazard scenarios. However, their engagement must be further strengthened with human resources, funding and political support.

5. Conclusion

This study evaluates the network of stakeholders in preparedness and response planning for simultaneous hazards amidst biological hazards taking Sri Lanka as a case in point. With the frequent occurrence of unpredictable and extreme climate-related hazards, the paramount importance of being proactive in planning for compound hazard events was greatly highlighted. Risk governance, emergency response and preparedness measures, institutional collaboration, community engagement in disaster preparedness planning and response, and the wellbeing of vulnerable communities were greatly affected during the COVID-19 pandemic. The containment measures for the pandemic have disrupted the response mechanisms for other hazards and vice versa. In addressing these challenges, improvements such as a sound legal basis, strong institutional coordination among stakeholders, emulation of a multi-sectoral approach including the health sector, empowering local authorities, strengthening hazard forecasting and predictions are needed. Out of these improvements, this study has particularly aimed at the behaviour of stakeholders in multi-institutional communication networks.

In this regard this study has utilized the Social Network Analysis method to analyze the network of stakeholders in Sri Lanka for four selected multiple hazards scenarios. Furthermore, a set of key informant interviews was conducted to investigate the challenges faced by disaster preparedness and response activities during COVID-19 in the country. According to the results obtained under centrality parameters, DMC acts as the key centralized stakeholder. It demonstrates the importance of DMC as the most controlled actor. However, in some practical conditions, DMC lacks power in legally mandating village level officials and coordinating with hap hazard structures. Furthermore, the involvement of the health sector in communication networks for preparedness and response planning during multiple hazards amidst a biological outbreak has been observed low compared to other technical agencies. However, the country has a separate and well established communication network for biological hazard preparedness under the public health sector. Therefore, this network should be integrated with the existing disaster management communication network to improve the multi institutional coordination.

Moreover, in a context where technical agencies lack the preparedness for biological hazards, thus having reduced accuracy and timeliness in hazard prediction and forecasting in practical conditions, the modelled network diagrams depict that, technical agencies such as the Department of Meteorology have a major influence on communication networks of stakeholders. Therefore, it emphasizes the need for increasing biological hazard preparedness of technical agencies to maintain their accuracy and timeliness during concurrent hazards amidst the pandemic. Furthermore, the negligence of non-government organizations and donor agencies in preparedness and response planning procedures was reflected in ground level practices. Accordingly, the absence of adequate legal provisions for the involvement of these agencies stands as a barrier for receiving required resources for the disaster management mechanism in the country. Last but not least, although local actors have a significant involvement in communication networks for preparedness and response planning according to emergency operation procedures, in practical conditions they do not have sufficient resources to optimize their involvement. Furthermore, there are several legal and political issues that affect the involvement of local actors and need immediate solutions.

Accordingly, the findings of this paper lead to future lines of inquiry in preparedness and response planning in the country for compound hazard events that concur biological outbreaks. Accordingly, the study emphasizes need for strengthening the legal power vested with national disaster management coordinating unit to legally enforce its functions until the village level and eliminate the effects of hap hazard and political structures across all administrative levels. Furthermore, technical agencies should be capable of handling the impacts of biological hazards without any impact on the accuracy and timeliness of their information. In this regard, it is paramount to develop and test contingency plans for health emergencies in collaboration with the health sector. Furthermore, since the country has an established communication network for the public health sector, this study urges the integration of public health communication network into the disaster management sector of the country. This will allow the stakeholders to prepare in advance and respond to multi hazard events effectively. Moreover, it is important to strengthen the local actors with enough legal provisions, resources, and technical skills. Lastly, the study calls for eliminating the legal barriers for non-government organizations and private sector to join the preparedness and response planning process with the resources that they are equipped with. However, limitations in implementing the above recommended measures such as integration of public health sector network with disaster management sector still need to be explored thoroughly.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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