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Article

UNDERSTANDING THE BARRIERS RESTRAINING EFFECTIVE OPERATION OF FLOOD EARLY WARNING SYSTEMS

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Abstract: Over the years, a variety of structural and non-structural measures have been employed by the human societies to counter the growing frequency and intensity of natural disasters. Among the various measures, Early Warning Systems (EWSs) have globally been acknowledged as one of the key non-structural measures for disaster mitigation and preparedness, especially due to their multi-faceted benefits. However, their effective operation during rapid-onset disasters like floods is often disrupted pertaining to a variety of reasons. These manifold reasons have today become critical barriers which restrain the smooth functioning of EWSs. This paper theorizes that the numerous barriers restraining the effective operation of EWSs can primarily be categorized into Knowledge, Technology and Institutional aspects. To support this argument, the study presents an overview of three selected examples of flood disasters in Cameron Highlands (Malaysia), North Kyushu (Japan) and Sri Lanka. Based on published literature, the study lists out key reasons that affected the timely functioning of Flood-EWSs in all the selected cases and explains them in relation to the three theorized categories of barriers. In view of the current limited understanding, this study provides a new perspective for understanding the barriers in EWSs and correspondingly enhancing their operation during disaster situations.

Keywords: *Flood disasters; Structural measures; Non-structural measures; Early Warning Systems; Effective operation*

1. Introduction

Natural disasters and extreme weather events have today become a global reality. In the wake of climate change, the growing frequency and intensity of both slow-onset (like droughts) and rapid-onset disasters (like severe storms) are presenting serious challenges to human societies around the world. It is important to note that flood events (rapid-onset disaster) are reported to be the most frequent and widespread of all-natural disasters (WMO, 2013; Jongman et al., 2018). Floods generally refer to the overflow of water due to a combination of meteorological and hydrological extremes that submerge the usually dry lands. Strikingly, flood events accounted for more than forty percent of all weather-related disasters between 1995 and 2015 (UNISDR, 2015). During this period, more than 3000 flood events affected around 2.3 billion people around the world (95% of them live in Asia). Jongman et al. (2018) underlined that between 1980 and 2016, the total direct damages from flood disasters exceeded $1.6 trillion and at least 225,000 people lost their lives. Although flood disasters are increasing around the world, their share in Asian countries cannot be overlooked as it continues to be the world's most disaster-prone region (Yi, 2017). Few selected Asian countries like Japan, India, Sri Lanka etc. which are customarily prone to floods, have recently experienced their worst flooding in decades. A recent report by Asian Development Bank (ADB, 2017) pointed that increasingly severe weather triggered by climate change is further putting millions of people at risk, particularly the poorest and marginalized ones, across the rapidly developing countries of southern Asia. The 1.5 °C special report on the impacts of global warming developed by Intergovernmental Panel on Climate Change (IPCC, 2018) has also predicted a significant increase of extreme rainfalls in the next few decades which is projected to further worsen the flooding situation in Asia.

Although, it is not possible to control the flood disasters entirely, the resultant damages can be minimized through a range of flood protection and management measures, which are primarily categorized into structural (hard) or non-structural (soft) measures. The 'hard' structural measures include the construction of physical structures to reduce or avoid potential impacts of flood hazards like dikes, dams and flood control reservoirs and improving drainage channel capacity. On the other hand, 'soft' non-structural measures refer to the application of knowledge, laws or policies to reduce flood risks and its impacts like watershed management, land use regulations, building codes and standards, economic instruments, flood forecast warning systems etc. (UNISDR, 2017; Acosta-Coll et al., 2018). While financial limitations constrain the implementation of large-scale structural measures for flood preparedness and management in low- and middle-income countries, non-structural measures like Early Warning systems (EWSs) have proved to be extremely efficient and cost-effective in curbing the negative impacts of flood disasters like economic losses, loss of human lives and damage to property (UNEP, 2012). EWSs serve for providing relevant and timely information about the forthcoming flood disasters to the communities at risk, which allows them to make risk-informed decisions and take necessary actions like evacuation before the disaster strikes. Numerous studies (Bouwer et al., 2014; Acosta-Coll et al., 2018) have pointed that EWSs provide multi-faceted benefits despite their minimal costs, and therefore have been successfully employed around the world in a diverse range of developed and developing countries (IOC, 2009; Linham & Nicholls, 2010).

GOI (n.d.) underlined that since the early development of EWSs in 1980's, they have been used for different types of hazards like technological, hydrological, meteorological etc. However, EWSs gained prominence at global level only in January 2005, after it was identified as one of the key priorities in 'Hyogo Framework for Action' (HFA) which was adopted by 168 countries during the Second World Conference on Disaster Reduction in Kobe, Japan. Thereafter, EWSs have been incorporated as an integral component of disaster risk management by local and national governments around the world.

GDPC (2017) explained that the word 'system' in EWSs refers to the interplay between an array of sub-systems (elements) aimed at facilitating disaster risk communication and quick response to protect those in need. EWSs basically comprise of four key elements namely risk knowledge, monitoring and warning, dissemination and communication, and response capability, where each part is required to function efficiently for the system to be successful. Noticeably, the technological advancements over the years have improved the flood monitoring and forecasting by helping simulate flood situations and predicting possible fluctuations through various computer programs and modelling techniques. However, several researchers (Glantz, 2003; Tompkins et al., 2005; Linham & Nicholls, 2010) have repeatedly stressed that the prediction aspects of EWSs are not useful until they are translated into simplified warning messages that the target communities can understand and unless the information provides adequate lead time for the communities to take necessary actions. Various studies have also highlighted that the inability to transmit the accurate disaster information in a timely manner to the vulnerable communities has limited the effectiveness of EWSs as a whole, and this is the key reason that the communication and dissemination of risk information are the said to be the weakest of links of EWSs (United Nations, 2006; IFRC, 2009; Molinari et al., 2013).

A considerable amount of literature has been published on understanding EWSs and improving their effectiveness. However, majority of these studies have focused on improving the efficiency of individual sub-systems rather than enhancing the overall functioning of EWSs. Unlike the current research trends, this paper tries to understand the overall functioning of EWSs during flood disasters and identify the key barriers that restrain their effective operation in disaster situations. Notably, the term 'effective operation' of EWSs throughout this paper mainly relates with the timely flow of disaster information from scientific communities to the vulnerable communities. This study argues that the plentiful barriers that limit the operation of EWSs during disaster situations can primarily be categorized into Knowledge, Institutional and Technology aspects. To validate this argument, a case study-based approach is been used wherein the key issues that restricted the functioning of EWSs in specific flood disasters are discussed. Three different case study examples from Asia namely North Kyushu (Japan), Cameron Highlands (Malaysia) and Sri Lanka are been investigated in this study. These selected examples represent typical cases of flood disasters wherein the EWSs failed to achieve their purpose of providing timely information to vulnerable communities and stimulating necessary action. Notably, this research follows an interpretative approach and is primarily based on published literature. The study highlights the variety of reasons that affected the smooth operation of EWSs in selected cases and explains them in relation to the three stated categories of barriers. Towards the end, the study derives important lessons from all the case studies and puts forward the key considerations for systematically enhancing the effectiveness of EWSs.

2. Early Warning Systems and their significance in flood disaster management

Early Warning Systems (EWSs) are defined as 'an integrated system of hazard monitoring, forecasting and prediction, disaster risk assessment, communication and preparedness activities systems and processes that enables individuals, communities, governments, businesses and others to take timely action to reduce disaster risks in advance of hazardous events' (UNISDR, 2017). The key attributes of EWSs in flood disaster management entail monitoring the dynamics of flood disasters, simulating their future scenarios, communicating and disseminating warnings and putting in place the needed mechanisms to reduce their impacts. As discussed in the previous section, EWSs include four interrelated key elements (Figure 1): (1) *Risk knowledge*: systematic collection of data and disaster risk assessments; (2) *Monitoring and Warning*: detection, analysis and forecasting of the hazards and possible consequences;

(3) *Dissemination and communication*: timely, accurate and actionable warnings and associated information on likelihood and impact; and (4) *Response capability*: preparedness at all levels to respond to the warnings received. Most importantly, each of the four components essentially need to be coordinated across different sectors at multiple levels for the EWSs to work effectively. Failure in any single component or a lack of coordination across them could possibly lead to the failure of the whole system (Kundzewicz, 2013; Molinari et al., 2013).

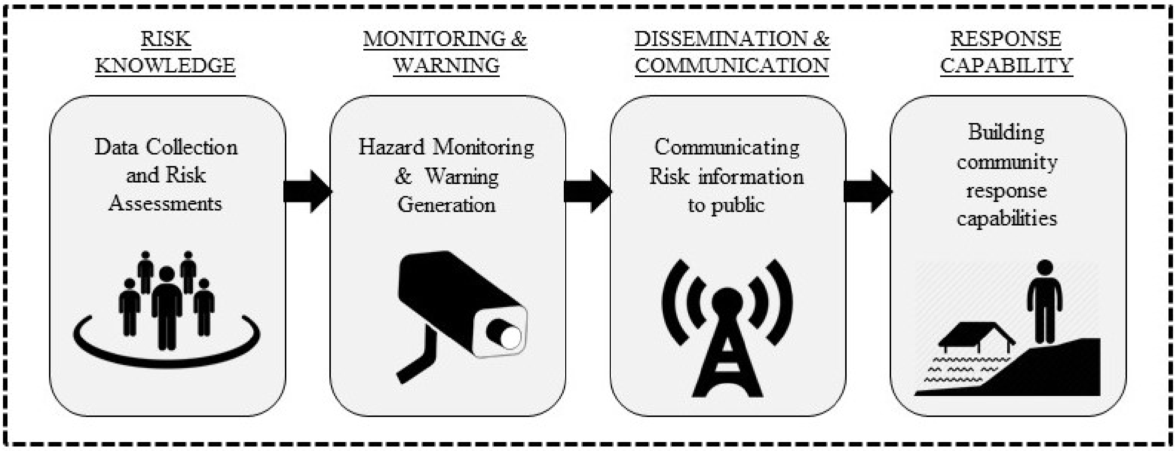

Figure 1. Four key elements (sub-systems) of EWSs (Image Source: Author)

Flood-EWSs empower the flood prone communities to proactively respond to imminent threats by providing a timely prediction of the scale or magnitude, duration and likely damages of the forthcoming flood disaster at a particular location and time (Travis, 2011). The flood forecasting is mainly based on the data collected from sensors placed at strategic locations in local water basins (rivers, lakes) or flood defences (dikes, dams, embankments). The technological advancements over the years have further enhanced the effectiveness of EWSs in providing accurate predictions from likely days to hours of flooding (Georgaka et al., 2012).

Blöschl et al. (2015) outlined that flood disasters differ based on the processes that produce them like riverine floods (triggered by heavy rainfall), coastal floods (triggered by strong winds and high tides), pluvial and ground water floods, as well as by artificial system failures (like failure of levees and dams). Some of the flooding events occur slowly allowing adequate lead time to prepare and suitably respond, while others (e.g. flash floods) can develop quickly within a short duration. Fujita & Shaw (2019) explained that the flood phenomena and the corresponding level of destruction also vary in different countries because of the different topography. The resulting impacts can also be widespread from small neighborhood or community level to entire river basins, causing mass relocation of people, property damage, infrastructure damage, outbreak of health risks etc. Undeniably, there are numerous factors ranging from types of floods, target communities, expected range and scale of flooding etc. that need to be considered for flood disaster management in different contextual settings. Correspondingly, the role and functioning of EWSs also varies depending on the social (like age groups, gender), economic (like income levels) and environmental settings (prone to dam floods, riverine floods etc.) in different areas. Learning from Jha et al. (2012) and GDPC (2017), the key functions of EWSs specifically for managing flood disasters can be explained under the umbrella of four key elements as below:

1) Risk Knowledge: Establishing baseline understanding of low-lying vulnerable areas, knowledge of areas with inappropriate drainage capacities, socio-economic characteristics of communities at risk, determined priorities set at regional level.

2) Monitoring and Warning: Constant monitoring and assessment of rainfall patterns and water levels in the surrounding water bodies like dams, lakes, rivers and sea, Constant updating of the expected criticalities to the concerned stakeholders.

3) Dissemination and Communication: Communicating the rainfall and flood-based information to all the relevant stakeholders in an easy to understand language via robust means of communication and ensuring effectual transfer of real-time information to the general public at all stages of disaster.

4) Response Capability: Enhancing the community response capabilities at different levels and ensuring operationalization of necessary risk reduction measures (evacuation, asset movement etc.) once the inundation trends are spotted and announced.

3. Barriers restraining effective operation of Flood-EWSs

EWSs are theoretically regarded as linear models aimed at communicating information from scientific agencies to target communities (Foster, 1980), however Garcia & Fearnley (2012) emphasized that in practice they are highly complex due to variations in scale, onset, frequency, hazard types and the economic, political and social contexts where they operate. As explained in the previous section, the roles and function of different elements of EWSs are theoretically well established, however their effectiveness is completely reliant on the coordinated functioning of all the actors involved in the four key elements and the failure in even a single link could render the overall system performance unsatisfactory. From risk monitoring to risk communication, there are multiple institutions and organizations like governments, meteorological organizations, hydrological departments, local communities etc. involved in different phases of information flow, which need to collaborate, coordinate and ensure information sharing at all levels. While timely communication of flood warnings to all relevant stakeholders is one part, EWSs cannot be deemed effective until they persuade community members to take adequate actions against the impending flood disasters.

Glantz (2003) specified that EWSs are often interrupted at various nodes in the flow of warning messages from scientific agencies to target communities. Thereafter, numerous barriers interrupting the flow of disaster information have been identified in the international scientific literature (Glantz, 2003; ISDR, 2006; UNEP, 2012; Kundzewicz, 2013; Ibrahim & Kruczkiewicz, 2016), however the EWSs are still alleged to be unbalanced with respect to the development of its four key elements (Molinari et al., 2013). Garcia and Fearnley (2012) pointed that the current academic research on EWSs is mostly fragmented and is primarily based on theoretical approaches (United Nations, 2006) rather than practical applications (Zschau & Kuppers, 2003). Garcia and Fearnley (2012) further clarified that the key issue with the current scientific research is that, a discrete approach is used for the development of four key elements (sub-systems) of EWSs with limited consideration to the links between them. Various United Nation agencies have also stressed that the integrated EWSs are the most economical, efficient and successful means for disaster risk reduction (UNISDR, 2006; United Nations, 2006; IFRC, 2009). Evidently, the scientific communities are continually engaged in enhancing the efficiency of EWSs, however their efforts are alleged to be multi-directional and there is no standardised methodical approach to achieve the purpose.

In view of the identified concerns, this viewpoint theorizes that the plentiful barriers constraining the efficiency of EWSs can primarily be classified into three categories namely Knowledge, Technology and Institutional (Figure 2).

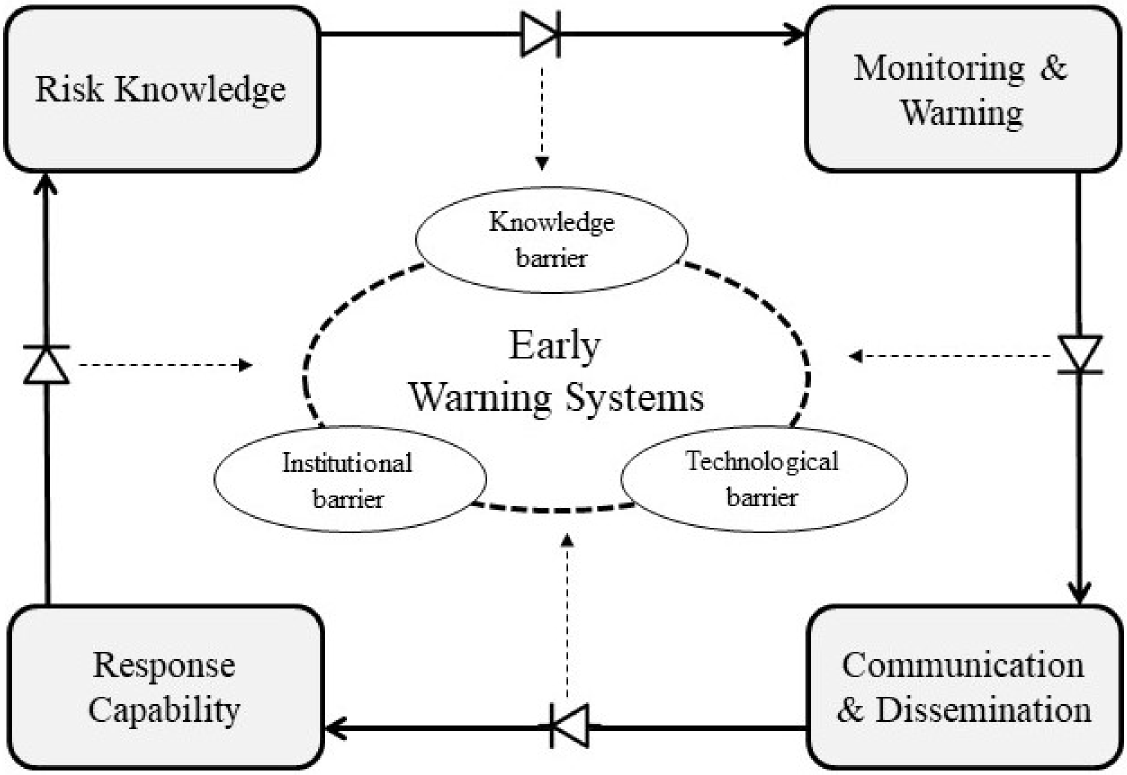

Figure 2. Different types of barriers in Flood-EWSs (Image Source: Author)

Knowledge: The knowledge aspect refers to the awareness level of scientific agencies, government bodies and target communities pertaining to forthcoming flood risks, technological features of EWSs, level of vulnerability etc.

1) Technology: The technology aspect entails the monitoring and forecasting techniques and the warning communication systems. It mainly relates to accuracy and efficiency in flood forecasting and information dissemination to the communities at risk.

2) Institutional: The Institutional aspect ensures the overall flow of timely information from scientific agencies to the target communities and stimulating necessary actions for flood management. Both the aspects of Knowledge and Technology essentially depend on Institutional aspect.

While previous studies have attempted to determine the key barriers in EWSs under the umbrella of different sub-systems, this study underlines that these wide-ranging barriers primarily fall within these three stated categories. Table 1 below explains some of the well-known issues in different elements of EWSs with reference to the three aspects of Knowledge, Technology and Institutional. It can be observed that the factors of Knowledge, Technology and Institutions are interlinked and collectively drive the operations of various sub-systems of EWSs. While the current subsystem-based approach to overcome the barriers in EWSs is been contested, this study suggests that the diverse barriers in EWSs could also be addressed by focussing on the Knowledge, Technology and Institutional aspects.

Table 1. *Classifying selected key issues in different elements of EWSs under the umbrella of Knowledge, Technology and Institutional aspects (Source-Author)*

S.No.	Name of elements	Knowledge	Technology	Institutional
1	Risk Knowledge	Varied risk interpretation	Sampling errors	Top-down approach
2	Monitoring and Warning	Data complexities	Inaccurate forecasting	Stringent regulations
3	Dissemination and Communication	Language of communication	Poor communication technology	Unclear organizational arrangement
4	Response capability	Lack of education & awareness	Information storage & accessibility	Poor continency planning

4. Case Study Examples

This section presents an overview of three different case study examples of flood disasters from three different countries in Asia namely Malaysia, Japan and Sri Lanka. It is important to note that all three countries are highly prone to floods and EWSs play an important role in flood preparedness and management. This study mainly seeks to understand the key barriers that interrupted the effective operation of EWSs in respective cases without making any comparison between them. The readers should bear in mind that this study is mainly based on the interpretations drawn from the published literature, and due to practical constraints, it does not provide a comprehensive review of selected case studies. For all three cases, the study methodically explains details of the concerned flood disaster, its causes, resultant damages and characteristics of EWSs during the flood disasters. Based on these details, the study analyses the factors that restrained the effective operation of EWSs in selected cases.

4.1. Flash Flood Disaster in Cameron Highlands, Malaysia (October 2013)

4.1.1. Details of flood disaster, Cause and Resultant damages

Cameron Highlands is a district in Pahang, Malaysia. On 23rd October 2013, Sungai Bertam (the main river flowing through Cameron Highlands) overflowed after the excess release of water from the Sultan Abu Bakar Dam causing flash floods in Cameron Highlands. The floods caused heavy property damage as 80 houses were swept away and 3 people lost their lives (The Malaysian Insider, 2013; Khalid et al., 2015).

4.1.2. Operation of EWSs during the flood disaster

Flood risk communication provided by Sultan Abu Bakar Dam is based on a siren system which alerts the local community whenever the dam authorities wanted to release water. Notably, the same siren system had been exercised for the past 20 years and there was no difference between the siren signals for normal water release and the emergency signal for a flash flood. On the day of flood disaster, the siren system had been operating continually since 9 pm (siren signal for normal water release). At 12 midnight on the same day, the dam authorities switched on emergency signal for flash flood following the release of more water than usual. However, the local communities could not differentiate between the normal and emergency siren signals and this restrained their response capability to the forthcoming flood disaster (Khalid et al., 2015).

4.1.3. Key issues identified in operation of EWSs

1) The siren systems used by the dam authorities for communicating risk information to the vulnerable communities were reported to be confusing as there was no clear distinction between normal and emergency warning. The normal warning was usually issued following the release of dam water and the emergency warning corresponded with the overflow of water from the dam. Resultantly, the flood victims could not recognize the scale and magnitude of forthcoming flood disaster although the flood-EWSs were in operation.

2) The disaster management mechanism in Malaysia is based on Standard Operating Procedures determined by the National Security Council (NSC) Directive No.20 and Fixed Operating Regulations (Chan, 2012; Khalid & Shafiai, 2015). The directive outlines the roles and responsibilities of the all concerned agencies involved in handling disasters at different levels in Malaysia. Khalid et al. (2015) highlighted that in case of flash flood disaster in Cameron Highlands, the dam authorities failed to follow exactly all conditions of the Fixed Operating Regulations as the local communities were not sufficiently informed about the possibility of facing flash floods.

4.2. Regional flood disaster in North Kyushu, Japan (July, 2017)

4.2.1. Details of flood disaster, Cause and Resultant damages

Kyushu is the southwestern most of Japan's four main islands and North Kyushu is one of its subregions. On 5th and 6th July 2017, North Kyushu experienced torrential rains followed by floods and landslides. Many areas within North Kyushu experienced heavy rainfall that surpassed the normal monthly rainfall of July in just two days, breaking all previous records. The cities of Asakura, Fukuoka, Hita and Oita recorded new 24-hour rainfall high as the heavy rain broke previous records. This record rainfall caused huge loss of lives (37 deaths) and serious property damage (Japan Meteorological Agency, 2017a; Cabinet Office, 2017).

4.2.2. Operation of EWSs during the flood disaster

Japan Meteorological Agency (JMA) disseminates flood related warnings and information to vulnerable communities via various channels like media organizations, cellular carriers, television, radio etc. through various routes such as prefectures, police and fire departments. The warnings are currently standardized into three levels namely Caution, Warning and Emergency Warning) (Japan Meteorological Agency, 2013; Fujita & Shaw, 2019). The issuance of different levels of warning corresponds with set standards of rainfall like emergency warning (highest level) is issued when the intensity of observed rainfall is once in every few decades.

Table 2 below shows the volume of recorded rainfall in Asakura city in Fukuoka Prefecture at different time intervals on 5th July 2017. As seen in table 2, the rainfall record of 1 hour (129.5 mm at 15:38) and 3 hour record (261.0 mm at 15:40) surpassed in a very short duration and both hit the highest in history, but JMA issued Emergency Warning for this prefecture at 17:51 i.e. 131 minutes later. Reports suggest that the interval between baselines of 'Warning' (issued at 13:14 & 14:03) and 'Emergency Warning' (17:51) was so big that severe loss happened before the Emergency Warning was issued.

Table 2. Timeline of rainfall records and Emergency Warning in Asakura on 5th July, 2017 (Source: Japan Meteorological Agency, 2017a)

Time	Rainfall record at Asakura, Fukuoka Prefecture
15:38	Rainfall record of maximum in 1 hour : 129.5 mm
15:40	Rainfall record of maximum in 3 hour : 261.0 mm
17:51	JMA issued Emergency Warning in parts of Fukuoka Pre.

4.2.3. Key issues identified in operation of EWSs

1) The study finds that although the EWSs are well established in Japan, the prediction standards associated with specific amount of rainfall and time slabs restrain the effectiveness of dissemination and communication. The time slabs of 1-hour, 3-hour, 24-hour and 72-hour potentially limit the risk assessment and communication to fixed time limits and severe losses could occur before the rainfall intensity reaches a specific time slab as happened in case of Asakura.

2) During the Minister Press Conference on July 20th 2017, JMA clarified that the standard procedures were followed for releasing warnings during the North Kyushu floods and the agency systematically chose the timing for issuing the warning because at the early stage of the records becoming radical it had not been a wide scope issue yet (Japan Meteorological Agency, 2017b). Based on this justification of JMA, it could be inferred that the regulatory standards used for communicating early warnings in Japan do not allow for immediate actions even if the disaster situation is worsening.

4.3. Regional flood disaster Sri Lanka (May 2017)

4.3.1. Details of flood disaster, Cause and Resultant damages

Sri Lanka is an island country in South Asia prone to recurrent flooding. During May 2017, the country experienced severe flooding and landslides which were caused by a heavy southwest monsoon (starting from 18th-19th May). The flooding got worsened after the onset of the precursor system to Cyclone Mora. A total of 15 districts around the country were affected by the floods which killed at least 212 people, affected more than 683,831 people and caused severe losses of property according to the Disaster Management Centre (DMC). Few of the worst hit areas like Matara District, Ratnapura District, Kalutara District and Galle District received about 300 mm – 500 mm of heavy rain in a 24-hour period by 25th May (IOM, 2017; PDNA, 2017).

4.3.2. Operation of EWSs during the flood disaster

Disaster Management Centre (DMC) in Sri Lanka is the main government agency responsible for coordinating early warnings and disaster preparedness. Various technical agencies in Sri Lanka monitor different hazards and provide early warning messages to DMC which ensures its proper dissemination to the vulnerable communities through various means like the Police and military communication systems, radios, early warning towers, media and the telephone etc. (Lanka Jalani, 2015). In the case of 2017 floods, DMC reportedly did not broadcast any early warnings or alerts until the storm arrived near communities at risk. The main reason behind was the lack of information sharing from concerned technical agencies namely the Irrigation Department (flood information) and the National Building Research Organization (NBRO) (landslides related information) (PDNA, 2017). After the disaster spread-out, all the three agencies namely DMC, NBRO and the Irrigation Department began sending out mass text messages about the disaster to vulnerable communities in an informal manner. Further, the Meteorological Department, which is responsible for weather forecasting, projected for a normal amount of monsoon rain about 150 mm on 25th May. However, the rainfall predictions proved incorrect as more than three times the prediction of rain (approximately 550 mm) fell in some areas between 9 pm on 25th May and 5 am on 26th May (Perera, 2017).

4.3.3. Key issues identified in operation of EWSs

1) Based on the above information, it is evident that the hierarchical institutional arrangements in Sri Lanka constrained the flow of disaster information. Although DMC is responsible for coordinating early warnings, it is completely dependent on other technical agencies for disaster-related information.

2) The poor weather forecast by the Meteorological Department indicate serious shortcomings in monitoring and forecasting technologies in Sri Lanka.

5. Discussion

The three selected case study examples represent different contexts of flooding in three different countries wherein the level of hazards, the technological capabilities, the institutional arrangements etc. are completely different. Table 3 summarizes the key issues and identified barriers in all selected cases. Noticeably, the failure of EWSs operations in the three selected cases occurred due to a variety of reasons, however the study demonstrates that they all fall within the three stated categories of Knowledge, Technology and Institutional (Table 3). It is also important to note that there were different weak links in all the cases that restrained the overall operation of EWSs. For the case of Cameron Highlands (Malaysia), the flood prediction and forecasting were accurate however the dissemination and communication of risk was not appropriate. In the case of North Kyushu (Japan), the risk communication and dissemination through set levels of warning was done, however the stringent procedures restricted the timely communication. Lastly, in the case of Sri Lanka, the dissemination and communication element of EWSs proved ineffective primarily because of the technology and institutional barriers.

Table 3. Key issues and barriers identified in EWSs of three selected cases (Source: Author)

Case Study Area	Key issues in EWSs *(type of barrier)*	Weak element of EWSs	Identified Barriers
Cameron Islands, Malaysia	1. The siren system was confusing *(Knowledge)* 2. The local communities were not aware *(Knowledge & Institutional)*	1. Dissemination & communication 2. Risk Knowledge	Knowledge & Institutional
North Kyushu, Japan	1. The warnings were issued based on rainfall intensity in standard time-slabs *(Knowledge)* 2. Emergency Warning was delayed due to the standard procedures *(Institutional)*	1. Monitoring & Warning 2. Dissemination & communication	Knowledge & Institutional
Sri Lanka	1. The flow of disaster information was interrupted *(Knowledge & Institutional)* 2. The weather forecasting technology was poor *(Technology)*	1. Dissemination & communication 2. Monitoring & Warning	Knowledge, Institutional & Technology

** The weak elements of EWSs shown in the table correspond to the four key elements of EWSs (Section 2). The types of barriers correspond with the three broad categories of barriers established in the Section 3.*

Referring to the diverse barriers to Flood-EWSs observed from the three examples, the study suggests that there are lessons to be learned from every flood disaster and it is important to use them in preparing for the future events. The importance of timely warnings and public recognizability of warnings is one of the key lessons from all the cases. Further, the regulatory prediction standards for EWSs need to be constantly upgraded in consideration with the changing climatic conditions and the characteristics of local communities. It is also important to establish a clear distinction between different types of flood warnings such that the target communities can correctly recognize the forthcoming situation and suitably respond to it. Additionally, this study lists out key factors to be considered for overcoming the barriers in three identified categories of Knowledge, Technology and Institutional aspect:

1. Knowledge barriers

Referring to the selected case study examples, the poor risk knowledge, the varied risk interpretations, the lack of awareness and trust in local communities are some of the key barriers in Knowledge aspect. The study suggests that these implicit knowledge issues need more recognition in the institutional arrangements of EWSs such as the community perception and the language used for information dissemination. Cvetković, V. M. (2019) also demonstrated that disaster risk is differently perceived by various members of the community depending on the factors like age, income level etc. The warning messages should therefore be announced in a non-technical language in consideration with the local jargon, to ensure its healthy reception by different user communities. It is also important to ensure that the local communities are aware of the technologies employed for risk communication to stimulate necessary actions during disaster situations. Further, the local communities should be made continually informed about the type, source, probability of flooding and the exposed assets to enhance their trust on EWSs.

2. Technology barriers

The poor and inaccurate weather forecasting (as in case of Sri Lanka), over-reliance on technology (as in case of Malaysia), multiple means of communication used for disaster risk communication are some of the key technology barriers in EWSs. While the element of uncertainty binds the wide-ranging controls of EWSs at every stage, its efficiency is highly dependent on the accurate predictions and adequate lead time. Correspondingly, there is need for continuous testing of forecasting parameters to address the uncertainties that could possibly restrict the operation of EWSs (as happened in case of Sri Lanka). Further, the regular physical testing of equipment along with conducting drill exercises is a prerequisite to ensure disaster preparedness.

3. Institutional barriers

The Institutional aspect is found to be the most critical component that lays the foundation for all the elements of EWSs from Risk knowledge to Response capability. The unclear organizational arrangement, top-down approach, poor contingency planning etc. in Sri Lanka case, stringent regulations in North Kyushu case and poor response capability in Cameron Highlands are some of the examples of Institutional barriers. The study suggests that the overall flow of disaster information from scientific agencies to communities at risks characteristically depends on the institutional arrangements. In the absence of proper institutional structures, the desired purpose of EWSs could never be achieved. There is need to ensure effective and robust communication networks at all levels. Likewise, the accountability and responsibility of all stakeholders should be outlined. Lastly, the agencies concerned with EWSs should regularly engage in scenario making and should uphold emergency preparedness plans for different situations.

Finally, the study suggests that although technology advancements may facilitate for accurate and timely predictions of flood disasters, the institutional and knowledge aspects need to be improved for ensuring smooth flow and appropriate reception of information by local communities. To achieve that, there is genuine need for methodically linking the aspects of technology, institutions and knowledge in consideration with the target communities as any kind of weak links shall directly restrain the effectiveness of the EWSs which might lead to devastating outcomes.

6. Conclusion

With changing climate, more severe and frequent flooding events are expected around the world. While the levels of vulnerability differ around the world, the people in low income countries are much more prone to negative flood impacts than those living in high-income countries (Jongman et al., 2015). Further, the high-income countries are better placed in responding to flood disasters through both structural and non-structural measures, however the developing countries with limited resources are highly constrained and non-structural measures like EWSs shall play an increasingly critical role in flood preparedness. The comprehensive understanding of Flood-EWSs and their major shortcomings is therefore very important to improve their functioning. While the contemporary research emphasizes on exploring further the interrelationships between sub-systems of EWSs, there is need for renewed attention towards overcoming the barriers that are constantly restraining the combined operations of different sub-systems in critical situations. Based on the three selected case study examples from three different countries in Asia, the study highlighted that the Flood-EWSs are prone to common inadequacies in the stated categories of 'Knowledge', 'Institutional' and 'Technology'. While significant progress has been made in improving flood forecasting and monitoring technology, the timely flow of information from scientific agencies to target communities is often interrupted due to various reasons that mainly fall within the Knowledge and Institutional aspects. While improved monitoring and forecasting technology is essential to continually monitor the changing risk scenario, it is equally important to ensure that the institutional structures and risk knowledge are developed to enhance effectiveness of EWSs.

This viewpoint stresses on the 'shift in thinking' from isolated subsystem-based approach to a more holistic approach, which addresses the community characteristics and institutional arrangements for smoother flow of information between scientific agencies and vulnerable communities. Through this review, it was explained that there is strong need to explore further the interrelationships between individual sub-systems of EWSs because they are multifaceted and cannot be modelled in a linear manner. Further research on understanding location specific features, technology and institutional concerns can help make effective use of evolving technologies in different contexts. The future scope of this research entails establishing contextual understanding in different regions and streamlining the risk communication methods which could cater to the varied communities in different parts of the world.

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