The 2018 Sulawesi earthquake and tsunami in Indonesia signaled the failure of a risk communication system, causing Indonesia to be accused of mishandling the natural disaster. Many criticisms focused on allegations that the country’s meteorology and geophysics agency canceled the tsunami alert too early and misinformed public, that the sirens weren’t operable to warn local people, the tidal buoys did not work to send the tsunami signal, consequently, causing casualties. Improving the risk communication system raises the following question: what are the criteria for designing a risk communication system for areas in the disaster-prone zone? This paper employs multi-criteria decision analysis (MCDA) as a framework that is integrated with the combination of technical and cultural risk communication to provide such an answer. As for the findings, this study includes sixteen indicators that are distributed among nine criteria of a risk communication system within two types of measurement: qualitative and quantitative. It suggests that a risk communication system shall work better on a two-way process. Stakeholders’ and decision-makers’ involvement and public participation are required to make better decisions because it leads to better awareness of risks and greater acceptance of risk management strategies that are jointly agreed upon.

Keywords: earthquake, Indonesia, multi-criteria decision analysis (MCDA), risk communication, tsunami

1. Introduction

Humans have always faced danger from climatic phenomena such as storms, droughts, and crop failures and geological events such as earthquakes and tsunamis [1]. In 2018, Indonesia experienced the 7.5 magnitude Sulawesi earthquake and the resultant tsunami which killed at least 1,994 people [2]. Indonesia was accused of mishandling this disaster [3–5]. Criticism was focused on the allegation that the country’s meteorology and geophysics agency (Indonesian BMKG) canceled the tsunami alert too soon, which led to casualties [6, 7]. At that time, sirens for alerting the public weren’t operative and the tidal buoys did not work [8–11]. The risk communication intervention by the Indonesian National Board for Disaster Management depends on one-way mass media risk communications to inform the public of the risk of imminent disaster [12]. Therefore, this raises questions on the importance placed by a government on the risk communication system to inform the public and to handle natural disasters in this area. After all, risk communication is a fundamental part of risk management strategy [13].

According to Slovic [14], an effective risk communication system may increase the awareness of the stakeholders, the public, including households, businesses, and communities, about their exposure and vulnerability to hazards and natural disasters. In addition, the system informs the stakeholders and the general public about what is needed for prevention, mitigation and emergency preparedness in case of natural hazards. Without good risk communication, the general public in disaster zones may underestimate some risks and not take sufficient precautions while overestimating others and leading to non-optimal allocation of resources [13]. In any case, governmental agencies or state officials have the basic responsibility to notify citizens about their exposure to major hazards and natural disasters. Yet, an effective risk communication system needs to be inclusive, engaging public actors at all levels of government as well as private actors such as companies, civil society organizations, NGOs and citizens.

1.1. Risk Communication System

In response to natural disasters such as earthquakes and tsunamis, many countries have invested great effort in improving their disaster risk preparedness and resilience. For instance, in the U.S., recognizing the threat of these natural disasters, in 1995 the U.S. Congress directed National Oceanic and Atmospheric Administration (NOAA) to lead a federal or state working group to formulate and advance a plan for reducing tsunami risk to the U.S. coastal communities. Following the 2004 Indian Ocean tsunami, the U.S. Congress passed the Tsunami Warning and Education Act (TWEA, P.L. 109–479, Title VIII) to strengthen the National Tsunami Hazard Mitigation Program (NTHMP)’s capabilities and “to improve tsunami preparedness of at-risk areas in the United States and its

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Identifying Criteria for Designing Risk Communication System in Palu, Sulawesi, Indonesia

Table 1. Model of risk communication [1].

<table>
<thead>
<tr>
<th></th>
<th>Technical model</th>
<th>Cultural model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of communication</td>
<td>Usually one way (experts to laypeople or target audience)</td>
<td>Collaborative (citizens, local people or communities, experts, agencies)</td>
</tr>
<tr>
<td>Source of knowledge of risk</td>
<td>Science and technology</td>
<td>Science and local, cultural knowledge and experience</td>
</tr>
<tr>
<td>Objectives</td>
<td>1. To translate and inform</td>
<td>1. To inform by recognizing the social contexts of the meaning</td>
</tr>
<tr>
<td></td>
<td>2. To change risky behavior</td>
<td>2. To change risky behavior when in the interest of the affected groups</td>
</tr>
<tr>
<td></td>
<td>3. To assure concerned groups</td>
<td>3. To involve affected groups in the judgement of acceptable and unacceptable risks</td>
</tr>
</tbody>
</table>

territories” [15, 16]. Consequently, NTHMP developed and rigorously implemented a risk communication system that integrates several components such as the Tsunami Early Warning system and education-based community engagement.

In Indonesia, the risk communication system is regulated by Keputusan Keputusan Kebijakan Menteri Komunikasi dan Informasi No.20/P/M.KOMINFO/8/2006 (Communications and Information Ministerial Decree) on Tsunami Early Warning System, which states that “the media is obliged to broadcast information on a potential disaster as a STOP PRESS item within the shortest possible time and without delay after receiving the information from the [Indonesian BMKG]” [17, 18]. In addition, this regulation states that the media has a critical role to perform as the mechanism for disseminating earthquake and tsunami information to the public. STOP PRESS is included in the communication protocol in the Indonesian adaptation of people-centered Early Warning System (EWS) [19, 20]. People-centered EWS considers the needs of the public by identifying target populations, especially the ones that are vulnerable and interacting with the public to determine their needs and capacities [21]. However, what happened in Sulawesi showed that the Indonesian integration of people-centered risk communication system failed to deliver the full element of this EWS intervention. People-centered was operated without considering the major technical risk of communicating without sufficiently considering the cultural model of risk communication that may work in Sulawesi’s local context.

1.2. Technical and Cultural Model of Risk Communication

According to Cox and Pezullo [1], the technical model of risk communication is defined as the rendition of technical data containing environmental or human health risks for public understanding with the goal of educating a target audience. The primary goal of the technical model of risk communication is to share quantitative risk assessments with the public at large with three objectives, namely, to inform, to change behavior, and to assure the public. On the other hand, the cultural model of risk communication involves the affected public in assessing risk and designing risk communication campaigns and fosters democratic dialogue in the public sphere about risk (Table 1).

1.3. Objective

Palu, Sulawesi is a developing community. Different ethnic groups from other Indonesian regions, such as the Aceh region that experienced a tsunami in 2014, live in this region. Therefore, several languages are spoken in the region [22]. Policy- and decision-makers need to consider the best criteria to apply in designing a risk communication system to improve disaster risk preparedness and resilience for communities who live in this region. Undeniably, risk communication is an important part of risk management for disaster reduction and preparedness. However, there are no criteria of assessment to serve as a guide in building a risk communication system in Palu, Sulawesi, an area populated by diverse communities that see natural disasters in their diverse ways based on their cultural and religious beliefs. Therefore, following multi-criteria decision analysis (MCDA) steps, this paper makes an effort to inform the decision-makers at Indonesian National Board for Disaster Management (Indonesian: Badan Nasional Penanggulangan Bencana – BNPB) regarding the criteria that they may consider for designing the risk communication system for Palu, Sulawesi, Indonesia. Therefore, this paper identifies and lists the criteria and their indicators and also formulates a set of equation to calculate the overall performance of the criteria.

2. Materials and Methods

2.1. Study Area and Context: Sulawesi and Indonesian National Board for Disaster Management

Study area: Palu, Sulawesi, Indonesia. Palu is the capital of the Central Sulawesi province and is situated on a long, narrow bay at the mouth of the Palu River. It is 1,030 miles northeast of Jakarta. Because of its posi-
tion between mountain ridges, the climate is dry. Demographically, according to the Central Agency on Statistics of Indonesia (BPS-Badan Pusat Statistik), Palu has a population of around 342,754 spread within six local ethnic groups (Kaili, Kulawi, Pamona, Banggai, Bugis, Tionghoa) with Islam as the dominant religious belief, followed by Christianity, Hinduism, and Buddhism [23]. With regard to natural disasters, before the 2018 Sulawesi earthquake and tsunami event, in 2005, Palu was rattled by an earthquake of magnitude 6.2 [24]. Sulawesi island is in one of the earthquake-prone zones and sits astride fault lines [25]. Therefore, it is very likely that a tsunami may strike Palu again in the future. Thus, much must be done to reduce future losses from similar events.

Audience and institution scope: BNPB is the board of Indonesian for natural disaster affairs. BNPB was established in 2008 in order to replace Badan Koordinasi Nasional Penanggulangan Bencana or Bakornas PB (National Disaster Management Coordinating Board). BNPB’s chairman is appointed directly by the President of Indonesia and reports directly to the President. BNPB is charged with directing the disaster management effort, providing guidance on disaster prevention, emergency response, rehabilitation, and reconstruction in a fair and equitable manner; assigning the standards for the implementation of disaster and risk management in accordance with the laws and regulations; informing the public, and managing donations [26]. The annual budget of this board is approximately $100 million [27]. BNPB works closely with BMKG, local NGOs, and intergovernmental organizations such as the International Federation of Red Cross and Red Crescent Societies (IFRC), UNESCO, WHO, etc. Therefore, this paper is addressed specifically to BNPB.

2.2. Methods

This study combines two methods: qualitative textual analysis (desk review of documents) and MCDA. Textual analysis was conducted to collect and assess documents [28] related to risk communication program and system from institutions that have worked closely with BNPB, namely, WHO, NOAA-NTHMP, IFRC, UN Inter-Agency Secretariat of the International Strategy for Disaster Reduction (UN-ISDR) and BNPB itself. These international institutions have been stakeholders and donors for other humanitarian projects as well.

From the textual analysis assessment, I selected MCDA as the framework for identifying and recognizing the relevant criteria and indicators for risk communication intervention of tsunami early warning. As a framework, MCDA helps decision-makers to identify/recognize the relevant criteria in the specific context [29]. In addition, MCDA opens an opportunity to create ranking “by quantifying, scoring and weighting a range of quantitative and qualitative criteria” [30]. As a general framework, MCDA provides support in complex decision-making situations with multiple and often conflicting objectives of the stakeholders’ groups and/or decision-makers, which they value variously [31]. The MCDA application emphasizes multi-stakeholder processes to structure problems and to facilitate dialogue on the relative merits of alternative courses of action [32, 33].

According to Saarikoski et al. [34] and Brondum et al. [35], the following are usually the phases of a participatory MCDA process: (1) identifying the problem (the decision context of the problem and the objectives and concerns of key stakeholders or partners), (2) structuring the problem (developing and determining criteria for evaluating the alternatives), (3) estimating alternatives performance (or ranks) regarding each criterion using a form of an impact matrix, (4) eliciting the values of stakeholders and/or decision-makers (e.g., ranking the criteria based on priority or assigning numerical weights to show the relative importance of each criterion); (5) employing a mathematical model to synthesize the results to evaluate trade-offs and the overall performance of alternatives either to explain different perspectives and/or to find new solutions or to propose a solution to the decision-making problem; and lastly; (6) conducting a sensitivity analysis of the model to user-inputted weights.

3. MCDA as a Framework

3.1. Problem Definition

The 2018 Sulawesi earthquake and tsunami event in Indonesia, which caused a considerable loss of life, indicated the failure of the risk communication part of the EWS intervention. Based on the area and specific context of this study, there is no evidence of any criteria that may guide the assessment of risks in designing communication system for Palu, Sulawesi, Indonesia. Therefore, I seek to identify the criteria that will guide the designing of the elements of EWS.

3.2. Identification of Options

All four uses of risk communication system, which include all the key risk communication system uses in the study area that is Palu, were defined as MCDA options, namely (i) risk knowledge, (ii) monitoring and warning service, (iii) response capability, (iv) dissemination.

3.3. Defining Criteria of Risk Communication System

In order to identify criteria and values for indicators to measure the above-mentioned four options of use for a risk communication system, I subtracted risk communication documents pertaining risk communication development from WHO, IFRC, ISDR, NOAA, and BNPB. Nine criteria were identified and supported by 16 indicators (Table 2).

3.4. Definitions of Criteria

Criterion 1: Communication channel: online-based (social media). Social media could be a platform for people to share common discourses that may have an impact on building resilient communities [36]. Social media
Table 2. Criteria and indicators used to assess the design capacity to deliver risk communication system in Palu, Sulawesi, Indonesia as assessed through MCDA.

<table>
<thead>
<tr>
<th>Criterion (risk communication intervention)</th>
<th>Indicator</th>
<th>Type of measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication channel: online based (social media)</td>
<td>• Total reach to online communities</td>
<td>Quantitative-analytics &amp; qualitative</td>
</tr>
<tr>
<td></td>
<td>• Online communities’ engagement</td>
<td>text-based responses</td>
</tr>
<tr>
<td>Communication channel: electronic based-mass media (text/SMS, radio, TV)</td>
<td>• Mass media reach and engagement</td>
<td>Quantitative and qualitative</td>
</tr>
<tr>
<td></td>
<td>• Total news coverage</td>
<td></td>
</tr>
<tr>
<td>Communication channel: education and outreach community-based programs</td>
<td>• Number of participants involved</td>
<td>Quantitative and qualitative</td>
</tr>
<tr>
<td></td>
<td>• Partnerships contribution</td>
<td></td>
</tr>
<tr>
<td>Evacuation planning and transportation procedure</td>
<td>• Public perception</td>
<td>Quantitative and qualitative</td>
</tr>
<tr>
<td></td>
<td>• Public intention</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Public awareness</td>
<td></td>
</tr>
<tr>
<td>Communicating uncertainty</td>
<td>• Risk probability</td>
<td>Quantitative</td>
</tr>
<tr>
<td>Message construction</td>
<td>• Relevance of language and rhetoric</td>
<td>Qualitative</td>
</tr>
<tr>
<td>Local economic analysis</td>
<td>• Per capita income (PCI)/average income</td>
<td>Quantitative</td>
</tr>
<tr>
<td>Cultural and religious beliefs</td>
<td>• Local religious perceptions of disasters</td>
<td>Qualitative</td>
</tr>
<tr>
<td>Funding-financing feasibility of the intervention</td>
<td>• Unit cost</td>
<td>Quantitative</td>
</tr>
<tr>
<td></td>
<td>• Budget impact</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Financing party</td>
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</tbody>
</table>

has commonly been used before, during, and after disasters and can also be used as a means of public education. Though it is known that social media is a powerful tool, it would be useful to explore how it can be most effectively utilized as an instrument in educating people to recognize early warning signs [21]. NOAA recognizes social media as a tool for best practices for communicating risk. The value of social media can be measured through analytics tool to calculate the total reach and engagement of online communities. Social media can facilitate one way and two-way communication, which provides the opportunity to deliver technical and cultural risk communication.

Criterion 2: Communication channel: electronic mass media (text/SMS, radio, TV, newspaper). Mass media can reach the entire population, including seasonal populations and those at remote locations. Therefore, mass media has been used to disseminate warnings [17, 18, 37]. The extent of its reach, engagement and news coverage are considered as the indicator. Mass media is categorized as one-way communication that can easily and widely disseminate technical risk communication information. However, its reach in rural areas is limited.

Criterion 3: Communication channel: education and outreach community-based programs. Education and outreach programs such as community meetings and school visits can perform two-way communication, build relationships and gain community trust at the local level [38]. In addition, this communication channel can involve local communities in decision-making to ensure interventions are collaborative, contextually appropriate and that communication is community-owned [39]. This criterion can be measured through participant involvement and partnership contribution in fostering discussion and awareness of disaster and risk. Community meetings as a communication channel offer immense opportunity for supporting the cultural risk communication model.

Criterion 4: Evacuation planning and transportation response. This integrates the transportation components into the evacuation plan. This includes travel/behavior analysis and forecasting, evacuation traffic control and enforcement, and the use of mass transit and other means for the movement of low-mobility individuals [21]. In addition, evacuation planning and simulations are important for increasing critical awareness, evacuation perception, and intentions [40].

Criterion 5: Communicating uncertainty. Communication by authorities to the public should address and include explicit information about uncertainties associated with the risks, events, and interventions and indicate what is known and what is not known at any given time [39]. Risk probability can be categorized as unknown risk, low risk or high risk [41], while risk impact can be classified as negligible, minor, moderate, major, and severe [38].

Criterion 6: Message construction. Warning alerts and messages should be customized to the specific needs of those at risk (e.g., for diverse cultural, social, gender, linguistic, and educational backgrounds). It should be geographically-specific to ensure that warnings are targeted to those at risk only [37]. The relevance of the language of the message and the extent of understanding of
the value of the message can be determined via qualitative techniques of measurement.

Criterion 7: Local economic analysis. The economic analysis strategies should be applied to local options for risk reduction. This will educate stakeholders on the relative costs and benefits of various options [21]. The indicator for this criterion is per capita income (PCI) or average income of the local people in Palu.

Criterion 8: Cultural and religious beliefs. The interpretation of the disaster and attentiveness to religious perceptions of the event are key to understanding the processes of religious and cultural beliefs in the time of disaster [42]. For instance, people in Sulawesi area made sense of the tsunami, its causes, and impact based on different religious interpretations [43]. Local religious perception of the tsunami disaster is the indicator of this criterion.

Criterion 9: Funding-financing feasibility. Emergency risk communication requires a defined and sustained budget which should be a part of core budgeting for emergency preparedness and response [39]. This criterion examines the unit cost of the system to consider how it fits with the annual budget of the agency, the impact of the budget and the financing parties.

3.5. Criteria Weighting and Derivation of Overall Preference Scores

Criteria weighting. I gathered and identified a list of criteria that the decision-makers at Indonesian National Board for Disaster Management may consider when making their choices while designing the risk communication system:

- Communication channel: online based (social media),
- Communication channel: electronic based-mass media (text/SMS, radio, TV),
- Communication channel: education and outreach community-based programs,
- Evacuation planning and transportation procedure,
- Communicating uncertainty,
- Message construction,
- Local economic analysis,
- Cultural and religious beliefs, and
- Funding-financing feasibility.

These criteria are based on extensive literature reviews and text-based analysis of risk communication programs run by WHO, IFRC, NOAA, ISDR, and BNPB and as assessed through MCDA. Moreover, in order to build a value hierarchy which seeks to organize goals and corresponding criteria in a way that facilitates scoring and weighting, these criteria are added to four risk communication system uses: risk knowledge, monitoring, response capability, and dissemination [17, 19, 21, 37, 44]. Criterion scores were obtained on a 6-point scale of likelihood performance [35] ranging from definitely (6), very probably (5), probably (4), possibly (3), probably not (2) and definitely not (1).

Integration of overall performance scores. Quantitative and qualitative criteria were scored on a homogeneous 100-point scale. A score of 0 represented the least level of performance encountered, and 100 the best [35, 45, 46]. Endpoints were established based on the criteria assessment. A linear value function translated the 100-point performance scale of each criterion (j) into an MCDA criterion score (0–100). For each option (i), each criterion score (Si,j) was multiplied by the criterion’s weight (Wij).

The risk communication system uses options overall preference/performance score (Fi) was derived by summing these outcomes for all the criteria (m) under each element of EWS (Eq. (1)).

$$ F_i = W_1S_{i1} + W_2S_{i2} + \cdots + W_nS_{in} \ldots \ldots \ldots (1) $$

4. Discussions and Conclusion

Risk communication is presumed to work better as a two-way process. The involvement of stakeholders and decision-makers and the participation of the public are necessary for arriving at suitable decisions as it leads to better awareness of risks and greater acceptance of risk management strategies that are jointly agreed upon [47].

The scope of this study is to identify the criteria for a risk communication intervention that can address the technical and cultural model of risk communication to support the critical elements of EWS. A major limitation of the present study is that it has not completed all steps of the MCDA process due to lack of available public data. Therefore, the overall performance score could not be obtained. The next step is to fully address the MCDA framework and invite stakeholders and policy-makers as experts from Indonesian National Board for Disaster Management, IFRC (through Palang Merah Indonesia – Indonesian Red Cross), WHO, ISDR, NOAA as well as Indonesian Meteorology, Climatology, and Geophysical Agency to participate, weigh and discuss the criteria to obtain an overall score for the risk communication system.

However, the present study has presented a solution to the problem of identifying the criteria to apply to risk communication interventions by identifying nine criteria with sixteen indicators. By combining technical and cultural risk communication through MCDA, the list of criteria offers an opportunity to improve the risk communication system.

Acknowledgements

Many thanks to Dr. Matthew Druckenmillner for his valuable feedback and support.

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