IMPROVING LANDSLIDE RISK COMMUNICATION
IN THE MANDI DISTRICT

JULIAN BAUMGAERTEL, NIAMH FENNESSY, SAGAR GHAI,
Yoon Kyong Lee, Karan Mahajan, Nicole Mikolajczak

ADVISORS: DR. VARUN DUTT, DR. STEPHEN MCCAULEY,
DR. INGRID SHOCKEY
Our goal was to develop, evaluate, and improve landslide risk communication strategies in Mandi, a region affected by pervasive landslides. Policymakers, scientists and village residents were interviewed to understand how the stakeholders experience landslides. We determined the key gaps in knowledge, specifically regarding landslide causes and signs, the residents’ perceptions of risks and the hazard maps, and the current communication strategies. We developed an educational plan and an SMS-based risk communication system that can be used to send warning, alert, and educational messages.
ACKNOWLEDGEMENTS

We would like to express our gratitude for those who have helped make this project a success:

• The Indian Institute of Technology – Mandi and Worcester Polytechnic Institute for the opportunity to participate in this project.
• Dr. Varun Dutt, Dr. Stephen McCauley, and Dr. Ingrid Shockey for their guidance and support over the course of the project.
• Dr. Dericks Shukla for his valuable insight into landslides and risk communication.
• The Mandi District Assistant District Magistrate, the head of the Mandi District relief department, and the representatives from the United Nations Development Program for taking the time to participate in our interviews.
• Er. Prateek Chaturvedi from the Geo Hazard Division of the Defense Terrain Research Laboratory and his scientists for providing more information about landslides and risk communication.
• The village residents, for their hospitality, and for their participation in the interviews.
• Jacob Maalouf for performing the voice-overs in the English version of the video animation.
AUTHORSHIP PAGE

Julian Baumgaertel contributed to creating the educational pamphlet.

Niamh Fennessy contributed to conducting interviews and taking notes during the interviews, coordinating the written interviews with the scientists, as a secondary editor of the poster and portions of the website, as a secondary designer of the educational pamphlet and video animation, analyzing data, conducting the SWOT analysis, writing each section of the report, and as the primary editor of the report and booklet.

Sagar Ghai contributed to conducting and translating the interviews with the residents and policymakers, designing the technical solution, and completing the back-end programming of the technical solution.

Yoon Kyong Lee contributed to conducting interviews and taking notes during the interviews, as a secondary editor of the poster and portions of the website, designing the educational pamphlet, designing and creating the educational video animation, analyzing data, conducting the SWOT analysis, writing each section of the report, and as a secondary editor of the report.

Karan Mahajan contributed to conducting and translating the interviews with residents, and translating the educational pamphlet, animated video, and the website.

Nicole Mikolajczak contributed to conducting interviews and taking notes during the interviews, taking photographs, designing and creating the PowerPoint presentations, infographics for the interviews and final poster, designing and creating the website, designing the technical solution, completing the front-end programming of the technical solution, conducting the SWOT analysis, writing each section of the report, and as a secondary editor of the report.
# TABLE OF CONTENTS

Project Report.................................................................................................................................1
  Landslides in Mandi District...........................................................................................................1
  Landslides: Causes and Communication......................................................................................2
  Methodology: Data Collection and Prototype Development.........................................................4
  Results: Site Assessment and Interviews......................................................................................6
  Discussion......................................................................................................................................12
  Project Outcomes..........................................................................................................................14
  Works Cited....................................................................................................................................17

References.........................................................................................................................................18

Appendices......................................................................................................................................22
  Appendix A: Background ..............................................................................................................22
  Appendix B: Methodology ............................................................................................................23
  Appendix C: Results and Discussion............................................................................................31
  Appendix D: Project Outcomes.......................................................................................................48
  Appendix E: Poster .......................................................................................................................56
  Appendix F: Photos .......................................................................................................................57
Landslides are feared in mountainous regions for their unpredictable and highly destructive forces that result from downward and outward slope mass movements. The District of Mandi, located in the heart of Himachal Pradesh, northern India, is prone to frequent and pervasive landslides. Shown in Figure 1 below, this region has a diverse terrain ranging from hills to mountains, with major river systems cutting through the valleys.

Natural hazards such as monsoonal rains, harsh winters, and earthquakes make the region vulnerable to landslides, and human activities such as farming and forestry practices, animal grazing, and road construction exacerbate these natural conditions.

In order to mitigate the impact of landslides in prone areas, effective risk management and communication are necessary. Risk communication strategies generally aim to provide stakeholders with information to reduce risk, to respond to an event, and to recover afterwards. Currently, there is no universal solution for managing landslide risks; however, adaptations of early warning systems (EWS), which detect factors that indicate potential disasters and communicate the risk information to the affected parties, have been the most effective risk communication strategy. Nevertheless, EWS and other landslide risk communication strategies are controversial because their poor implementation in communities has led to numerous social, economic, and environmental issues. As a key topic at the Third United Nations World Conference on Disaster Risk Reduction in 2015, landslide risk communication initiatives were outlined to educate vulnerable communities about the causes and consequences of landslides, and to promote awareness of the warning systems and risk management in place.

Although the Himachal Pradesh government has formulated a Disaster Management Plan, an effective risk communication strategy does not currently exist. The deficient communication between stakeholders about the prevalence and hazards of landslides increases the associated risk. The goal of this project was to develop, evaluate, and improve landslide risk communication strategies in the Mandi District. In order to reach our goal, we assessed the current conditions in the district to generate a baseline assessment, collaborated with stakeholders to understand how they experience and confront landslides, and developed and evaluated a landslide education program and a technical communication solution specific to the Mandi region.
Landslides: Causes and Communication

In this chapter, we address the key elements of risk communication and the terminologies associated with landslides, and evaluate early warning systems through case studies.

Causes of Landslides

There are two main causes of landslides: natural and human causes, both which can result in landslides that damage life and property. Examples within each category of landslide causes can be found in Table 1.

<table>
<thead>
<tr>
<th>Natural Causes</th>
<th>Human Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prolonged rainfall</td>
<td>Deforestation</td>
</tr>
<tr>
<td>Earthquakes</td>
<td>Construction</td>
</tr>
<tr>
<td>Soil composition</td>
<td>Animal grazing</td>
</tr>
</tbody>
</table>

Two reports detailing the fundamentals of human-caused landslides are described in Appendix A.

Risk Assessment and Risk Communication

Risk assessment is used to identify potential hazards, including landslides, and analyze possible outcomes in the event that a disaster occurs. If the risk assessment made by the stakeholders results in an improper response to the situation, the stakeholders then become more vulnerable to the risk. Oftentimes, the stakeholders’ response is dependent on their perception of risk, which can be influenced by culture, experience, and education. Thus, it is critical to assess the stakeholder’s perception of the risk at hand before considering technical solutions (Breakwell, 2014; Patra, 2015; Devi, 2015).

While landslide risk assessment involves analyzing possible outcomes of landslides, risk communication involves the dissemination of this prediction. It is important to understand the type of risk that an area experiences in order to create an effective risk communication strategy. In India, there are many agencies and non-governmental organizations (NGOs) that attempt to provide tools for better risk assessment and communication through methods such as landslide hazard zonation mapping. Early warning systems have been successfully used as a risk communication strategy to mitigate the effects of landslides in mountainous regions by providing warning information with sufficient time to reduce damage. Sättele et al. (2015) categorize three classes of EWS: alarm system, warning system, and forecasting system. These classifications are determined by the systems’ function of automation, and their characteristics are shown in Table 2.
Table 2. Characteristics of Early Warning Systems, adapted from Sättele, 2015

<table>
<thead>
<tr>
<th>Alarm System</th>
<th>Warning System</th>
<th>Forecasting System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autonomous</td>
<td>Semi-autonomous</td>
<td>Not autonomous</td>
</tr>
<tr>
<td>Detect on-going process</td>
<td>Detect precursors</td>
<td>Detect precursors</td>
</tr>
<tr>
<td>Short lead times</td>
<td>Extended lead times</td>
<td>Extended lead times</td>
</tr>
<tr>
<td>Threshold</td>
<td>Threshold + expert decision</td>
<td>Expert decision</td>
</tr>
</tbody>
</table>

It is important to establish warning criteria describing when, how, and to whom an EWS should distribute a warning. These criteria can ensure proper communication between stakeholders and fulfillment of responsibilities, so that the risk communication strategy does not become ineffective and cause further damage (Cloutier, 2015). An example of assigned responsibilities for each stakeholder is shown in Figure 2.

Figure 2. Example of responsibilities assigned to each stakeholder in an EWS

Case Studies on Early Warning Systems

We compare four case studies from Japan, China, Malaysia and Mexico that address how each country implemented an EWS for natural disasters. Each case study pertains to our site because of the similar geography, climate, and causes of landslides. These case studies are summarized in Table 3.

Table 3. Summary of the Japan (Natural Hazards Observer, 2008), China (Wen, 2005), Malaysia (Abdullah, 2013), and Mexico (Hernandez-Moreno, 2016) Case Studies

<table>
<thead>
<tr>
<th>Problem</th>
<th>EWS Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan Tectonic plates → earthquakes</td>
<td>Ground sensors + education</td>
</tr>
<tr>
<td>China High rainfall → landslides</td>
<td>Rain level</td>
</tr>
<tr>
<td>Malaysia High rainfall → landslides</td>
<td>Rain level + education</td>
</tr>
<tr>
<td>Mexico Deforestation → landslides</td>
<td>Residents + experts</td>
</tr>
</tbody>
</table>
Information from each case study was utilized to help develop an effective risk communication plan for the Mandi District. In order to create an effective risk communication strategy for landslides, it is important to consider the stakeholders’ risk assessment and the components of a communication strategy. For our site’s location, the constraints of the communication strategy include Mandi’s location in a mountainous region with rivers and intense rainfall, combined with improper road construction due to more tourism in the region, increasing the district’s susceptibility to landslides.

Methodology: Data Collection and Prototype Development

In order to develop, evaluate and improve risk communication strategies in Mandi District, we established three objectives outlined in Figure 3.

![Figure 3. Project objectives and associated strategies](image)

Our first objective assessed the current conditions in Mandi District. To determine the locations of the villages to visit for interviewing, we utilized the landslide hazard map from the National Remote Sensing Centre. This map and its corresponding key are shown in Figure 4.
In order to obtain a selection of village regions with varying levels of landslide hazard, we identified the coordinates of locations with various hazard levels using the GPS coordinates feature on the landslide hazard map. The GPS coordinates were then applied to Google Maps to determine the identity of the villages in the selected locations. The list of village regions we visited was: Katindhi region (low risk), Dudar region (moderate risk), Nela region (high risk), and Khaliar region (very high risk). The map of their locations is located in Appendix B. When traveling to the villages, we recorded any signs of recent landslide activity by taking photographs in order to gather visual data about the prevalence of landslide activity in the area. Additionally, we visited the remnants of a landslide near the IIT-Mandi Kamand Campus.

To understand the stakeholders' perceptions of landslides and risk communication, we conducted interviews with three stakeholder groups: policymakers, scientific experts, and residents. When interviewing village residents, we employed a semi-structured interview style. If the interviewee did not speak English, our IIT teammates conducted the interview in Hindi and their responses were translated into English. Through the interviews with the residents, we were able to evaluate their initial understanding of the causes of landslides and prevention measures, their perception of landslide hazard in the area, and their access to technology and preferred methods of warning. To gauge the residents’ perception of landslide severity, we performed a brief survey with a random sample of 40 people. Residents were shown three pictures with different levels of landslide severity, and were asked to specify which ones they considered landslides.

Additionally, we conducted open-ended interviews with the policymakers and written interviews with the scientific experts. In the interviews with employees from the District Commissioner’s office including the Assistant District Magistrate, and landslide experts from the Defense Terrain Research Laboratory, we investigated the current risk communication strategies in place and the potential opportunities for improvement. Interview questions can be found in Appendix B.

The information gathered from our groups of interviewees was organized in a database. We then analyzed the data through coding and created histograms to display the key findings from multiple sets of variables including village, age, and level of education. An educational program involving an animated video and informative pamphlet were created to increase landslide awareness. We also established criteria to determine which warnings and alerts are sent to whom, and when, and developed a SMS messaging communication strategy to disseminate these messages to the stakeholders in affected area.
regions. A website was created to bridge the educational and technical solutions. Additionally, we conducted a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis to assess the effectiveness of our proposed strategies.

**Results: Site Assessment and Interviews**

Below, we present the results of our site assessment and interviews corresponding to our objectives. In total, 59 people were interviewed from the village regions of Katindhi, Dudar, Nela, and Khaliar. Additionally, policymakers from the District Commissioner’s office and scientists from the Geo Hazard Mitigation Division of the Defense Terrain Research Laboratory were interviewed.

**Objective 1: Site assessment**

When travelling to the different sites for interviews, photographs of the damage caused by landslides were taken. The photos displayed varying levels of severity of landslide events that have occurred in the Mandi District. For example, we visited the remnants of a landslide that occurred near the IIT-Mandi Kamand Campus. This landslide can be seen in Figure 5a. It is larger in scale compared to others observed, such as the one shown in Figure 5b. From the site assessment, it was clear that landslides of varying severity occur in the area, but landslides such as the smaller one shown in Figure 5b are more common than the large one shown in Figure 5a.

**Objective 2: Collaboration with our Stakeholders**

Our open-ended interviews with the Assistant District Magistrate (ADM), the head of the relief department, and two representatives from the United Nations Development Program (UNDP) revealed important information regarding the current policies and strategies in place for landslide risk communication, as well as the progress that is currently being made to improve disaster risk communication in the Mandi district.

The interview with the Assistant District Magistrate (ADM) revealed that currently, there is no automatic prediction method for landslides in place at the district level. Rather, their department receives rainfall information from the Indian Meteorological Department and then the information is disseminated. A mass SMS message is sent to the functional departments that need to be informed, but this multi-step process does not reach the residents. Additionally, when a landslide occurs, people call in the disaster to a 24-hour helpline in the police department where the operator then transfers the
information regarding the disaster to the relevant party. Agencies such as the Indian Red Cross Society, and disaster management teams at the local level respond to the disaster following an established protocol that includes information regarding relief money to be allocated and responsibilities for responding to the disaster. The money is allocated according to the State Disaster Response Fund (SDRF) and the National Disaster Response Fund (NDRF) and varies according to the type of damage incurred. For example, 4.00 lakh may be paid to the family of a deceased person, if a person is killed by natural disaster, and Rs. 3,000 can be paid for the loss of a sheep, goat, or pig. The complete list of assistance available can be found on the Himachal Pradesh government website. The head of the relief department supported the information received from the ADM and also provided information about the hierarchy of communication in the case of a disaster. This hierarchy can be found in Figure 6.

According to the interview with the representatives from the United Nations Development Program (UNDP), they are currently working as a liaison between all functional departments of the state government to help facilitate the communication for disaster management. They are focusing on community-based strategies, which include community feedback and outlining the responsibilities of each person. Additionally, they are working to train village leaders on how to respond to earthquakes, and are implementing informational sessions about earthquake readiness with local students.

The written interview with the scientists in the Geo Hazard Mitigation Division of the Defense Terrain Research Laboratory provided more information regarding the scientists' perspectives on landslides and risk communication. According to the scientists, landslides are caused by prolonged rainfall, seismic zones, and anthropogenic activities and can cause effects such as traffic jams, injuries, fatalities, and economic and property losses. The scientists stress the importance of educating people about the causes and consequences of landslides by providing simulations and photos of the damage caused by landslides, as well as mitigation measures in order to advance the way people perceive landslide risk.

From our interviews with village residents, it was evident that many residents have developed a perception of landslide risk that does not correspond with the level of risk shown on the hazard map. Figure 7 shows the perception of landslide hazard risk of the interviewed residents in the Katindhi, Dudar, Nela, and Khaliar regions.
When asked why landslides occur, the highest percentage of interviewees believed that rain was a main cause, regardless of their village, age, or education level. Additionally, 37% of interviewees were unsure of what physical signs to look for in a landslide prone area that could indicate potential landslide occurrence. “ Unsure” was a more common response than any mentioned by the policymakers and scientists. Figure 8 shows additional responses, and illustrates how these responses vary between villages. The miscellaneous category encompasses the responses from both residents who were unsure, and those who did not provide an answer to the question.

*Figure 7. Residents’ perception of landslide hazard in Katindhi region (Low Risk), Dudar region (Moderate Risk), Nela region (High Risk), and Khaliar region (Very High Risk) based on interviews with the residents.*
When asked about methods to reduce the occurrence of landslides, approximately 44% of residents believed that planting trees was an appropriate method, regardless of their village, age, or education level. Another common response was building retention walls, whereas some residents did not believe that any methods would reduce the possibility of landslides. Responses regarding the types of land use which trigger landslides varied by village, as seen in Figure 9. As in Figure 8, the miscellaneous category encompasses the responses of residents who were unsure, and those who did not provide an answer to the question.
Dudar was particularly less knowledgeable about the effects of land use, with most residents answering “unsure”, or failing to answer the question at all, as depicted by the miscellaneous category. The residents were interviewed about the current policies in place to reduce this higher-risk land use, but more than 60% of the interviewees said they were unsure of the current policies in place. When asked if there was any funding available in the case of damage caused by a landslide, there was a fairly even divide between “yes” and “no”, but some residents were unsure or did not answer the question. Additionally, more than 60% of people interviewed were unsure about current strategies in place to mitigate landslides. When asked what information they would like to receive in a landslide warning, many residents responded with “location”, “severity”, and “time” regardless of village, age, or education level.

Additionally, residents were shown three ways of presenting the same information: an info-graphic (metagraphic), a pie chart (graphic), and a table (tabular) and were asked which method of presentation was the easiest to understand. Whether or not their place of residence directly impacts their response is not clear, but the responses in Dudar differ more than the other villages. These results can be seen in Figure 10.

![Figure 10. Residents’ preference of easiest method of presenting information](image)

Figure 11 shows that when asked about their access to technology, most residents responded that they have access to a television, mobile phone, and the local newspaper, which many also mention as their common sources of obtaining news.
When asked about their preferred methods of landslide warning, residents responded that text message, loudspeaker announcement, and television were their preferred methods. Although these three methods were the most commonly mentioned, there were a wide variety of responses, depicted in Figure 12.

**Figure 12. Residents’ preferred methods of landslide warning**
Residents were also asked if they would use a hazard map if one was provided for them. Fifty percent of people said they would use a hazard map, contrasting the 0% of people who mentioned the hazard maps as their preferred method of risk communication.

Discussion

Our interviews with the residents of Mandi District revealed important information regarding their perceptions of the level of hazard in their village and their general knowledge about landslides and the current policies and strategies in place, as well as their access to technology and preferred method of receiving a warning. The information obtained from these interviews was then utilized accordingly with the information obtained from the interviews with both the scientific experts and the employees in the District Commissioner’s office in order to determine the most effective risk communication strategy to implement.

Perception of Landslide Hazard

The results obtained from asking the residents about their perceived level of landslide hazard in their village indicate that residents’ perceptions consistently underestimate the level of risk shown by the Bhuvan landslide hazard map for those areas. The majority of residents interviewed in Nela believed that they were living in a low hazard zone, rather than the high hazard zone depicted by the hazard map. In Dudar, 50% of residents believed that the village is located in a low hazard zone, and 40% of residents believed that the village is located in a moderate hazard zone, corresponding with the map. In Khaliar, 90% of residents interviewed believed that the village is located in a low or medium hazard zone, whereas the hazard map categorizes the zone as very high hazard zone. Eighty percent of residents in Katindhi predicted the level of hazard in the village to be low. Although the hazard map does not include Katindhi, we hypothesize that the level of hazard in the village is low because of its location on a mountaintop, away from potential debris fall. It is also important to note that significant percentages of residents were unsure about the level of landslide hazard in the area. This nuance could be attributed to local residents actually being unaware of the level of risk in the area, or being afraid to admit that they are living in an area with a higher level of risk. There is a clear discrepancy between residents’ perception and the information presented by the hazard map, the policy tool currently used for landslide risk communication, according to the policymakers and scientists. The hazard map may be inaccurate in places, but regardless, the discrepancy between what the map presents and what the residents perceive plays a crucial role in the success of a risk communication strategy because the stakeholders’ perception of risk can determine how they will react to landslide events.

In order to determine if a difference in perception of the definition of landslides between the residents, policymakers and scientists plays a role in the gap in hazard perception, the residents’ perception of severity was gauged with an additional survey involving photos of various landslides. From the survey, 63% of respondents said that they did not consider the smallest landslide shown to be a landslide. This response could provide a reason for why residents’ perception does not align with the current hazard
maps: the probability of all sizes of landslides may be considered when creating the hazard maps, not just the large-scale landslides that residents think of. Contrastingly, when the ADM was asked about the sizes of landslides, he responded that the definition of a landslide is very subjective and that there is no specific size involved in the definition. He stated that large landslides are reported if they cause a road blockage or damage to life or property, but other than that, the majority of landslides go unreported. This lack of consistent definition adds to the gap in communication.

An effective risk communication strategy will address the existing discrepancy in a two-pronged fashion: by raising landslide awareness through an educational program, and by providing a customizable message based on location and severity of the landslide that will inform stakeholders of a landslide occurrence.

**Guiding Principles for Education**

Our findings suggest that there are gaps in understanding of knowledge of landslides and the policies in place between the residents, policymakers, and scientists. Many residents are aware of one or two causes of landslides, but are unaware of the human causes, some of the natural causes, the signs of a potential landslide, or the types of land use that can trigger landslides. The education strategy that we develop should address this gap in knowledge and aim to educate the residents in a way that promotes a community-centered approach rather than a top-down approach. Additionally, many residents mentioned that they would use a hazard map if one were provided for them in order to increase their awareness of the hazard level in locations they typically travel to, but that they would require education on how to use the map. Because the results do not show significant differences in knowledge level between villages, age groups, or education levels, for the majority of topics, one set of educational materials may be developed, instead of needing to alter the educational material to each group.

**Guiding Principles for Landslide Warning Systems**

The results regarding the residents’ access to technology demonstrate that a large majority of the 59 residents interviewed have access to a television and a mobile phone with text messaging capabilities. On the contrary, a much smaller percentage of interviewees use a radio. An effective landslide communication strategy should incorporate technology such as the television or text message because it would accommodate a large majority of residents.

It is also crucial to consider the residents’ preferred methods of receiving a landslide warning when creating a new strategy. Most residents are unaware of the hierarchy of communication, described in Figure 6, through which they should receive information, as explained by the head of the relief department. Therefore, our strategy should address the hierarchy of communication and include the village residents who are currently not involved in the communication pathway.

In order to bridge this gap, our developed landslide communication strategy must consider both the desires of the residents and what the policymakers and scientists believe is feasible. The most commonly preferred method of communication of the 59 interviewees was text message, followed by television, and then loudspeaker announcement. Although the majority of people prefer text messages, televisions, and loudspeaker announcements, each method has flaws that cannot be overlooked. Some interviewees mentioned that they
do not have access to a mobile phone, or that they are illiterate and would only be able to understand a phone call and not a text message. Other residents mentioned that they would be frightened and confused by a loudspeaker announcement. Zero percent of residents preferred a hazard map as a communication method. The previously mentioned need for more education, combined with the lack of immediate notification provided by a hazard map are the most likely reasons that a hazard map is not a preferred method of communication. Text message and television, strategies that residents already have knowledge about and which can provide immediate notification in the case of a predicted or experienced landslide, are the preferred methods instead. When deciding which strategy to implement, we considered these technological preferences and limitations to determine the optimal solution. Additionally, the results obtained from questions regarding the information residents would like to receive in a landslide message: location, time, and severity, combined with the response that a graphical method of presenting information, will be useful in creating a technical solution.

**Project Outcomes**

From the analysis of our results, two main problems with the current conditions emerged: a lack of landslide education for residents, and a gap in risk communication between policy makers, scientists, and residents, particularly regarding the dissemination of landslide warnings and alerts. To address these shortcomings, we have formulated two recommendations, supported by a SWOT analysis:

1. Develop an education plan to implement in conjunction with the United Nations Development Program (UNDP)’s Earthquake Education Program.
2. Implement a risk communication strategy utilizing mobile phones and SMS messaging to inform stakeholders of landslide occurrences.

**Recommendations for an Education Plan**

To increase the awareness of village residents about landslides, their causes, their prevention, and their mitigation, we recommend the development of an education plan, to be implemented in conjunction with the UNDP earthquake education program. Our results indicate that many village residents are unsure of the causes of landslides, and either do not believe that the possibility of landslides can be mitigated or are unsure of the ways to reduce this possibility. Additionally, many interviewees responded that they are unsure of the current communication strategies, and many residents answered that they were aware that they could receive governmental funding in the case of damage, but mentioned an inaccurate amount of assistance. This gap in knowledge needs to be addressed. Because there is currently a program being implemented by the UNDP for earthquakes, implementing a landslide education program in conjunction with the UNDP program has the potential to be successful. We recommend the creation of an informative video animation to be shown in the schools during the earthquake training sessions, and pamphlets as a take-away material for students to bring home to their families. In general, the video animation and pamphlets should address the key discrepancies and gaps in knowledge that have arisen in our interviews such as the causes and signs of landslides,
and the policies and sources of funding available. We have created a sample animation and corresponding pamphlet, which can be found in Appendix D. The video highlights rain as the leading cause of landslides and falling rocks as a key sign to look for, as well as phone numbers to contact in the case of an emergency and where viewers can learn more information about the assistance available to them. The pamphlet reiterates the same information, but also includes more specific details about the causes and signs of landslides, as well as the assistance available, with important funding information detailed in a chart. When combined with an improved technical solution, the education plan will help to improve the communication of landslide risks in the district.

**Recommendations for a Risk Communication Strategy**

To bridge the existing communication gap between policymakers, scientists, and residents, we recommend the implementation of a risk communication strategy using mobile phone SMS messaging to inform people of potential landslide occurrences, post landslide occurrences, and general information about landslides. The use of mobile phones can allow for a widespread warning with immediate notification. The text messages should be sent in Hindi, and should include information regarding the location, severity, and time of the event, as mentioned by residents in our interviews. Because text messaging is currently the strategy in place for communication at the administrative level, the foundation is in place for efficient implementation at the local level as well.

The prototype of our landslide risk SMS communication system includes a simulation of an early warning system that is based on rainfall data, and a method of sending a post-landslide alert. It uses a user-friendly program that calculates the probability of landslide occurrence in specific regions. This is a semi-autonomous system in which the program allows the user to choose to send an educational message or a warning message based on the calculated probability. The probability is compared against a threshold calculated from a study on the National Highway-58 from Rishikesh to Mana in the Garwal Himalaya (Experimental, 2015). This probability is shown to the user in a Graphical User Interface (GUI) so that the user may decide which type of message to send. The message is then sent to registered participants using Twilio Applications Program Interface (API). More information about Twilio, the GUI, an in-depth process flow of the communication system, system architecture, and code of the program can be found in Appendix D.

This recommended communication strategy involves participant registration. In order to provide a platform for registration, we recommend the creation of a website. The website can also include access to the educational material and emergency contact information, and a method of communicating concerns and feedback about the communication strategy and educational material. Our prototype includes both English and Hindi pages of the website. When registering for the service, the receiver of the message will provide their telephone number and their location of residency, which are necessary for the landslide risk SMS communication system to send messages to the appropriate audience. The registration website is easy to access for those who use the Internet, but is uneasy for those without Internet access. An additional recommendation when implementing this strategy is for villages to hold registration sessions, in which a computer is accessible, or information can be manually collected, and residents may register for the
SMS service. To expand the benefits of the registration sessions, the educational animation may be shown, and educational pamphlets may be distributed.

**Conclusion**

Landslides are common in the mountainous Mandi District due to prolonged rainfall, seismic activity, and construction. Our study revealed two main findings: there is a lack of landslide education in the district, and there is deficient communication between the policymakers, scientists, and residents. A gap between residents’ knowledge and the scientists’ information exists, and oftentimes, the residents underestimate the level of landslide risk in their areas when compared to the hazard maps in place. Additionally, the residents are not currently included in the hierarchy of communication when disasters occur.

Based on interviews with the three stakeholder groups, we recommend the implementation of an educational program to increase landslide education and hazard awareness among residents. We also recommend the implementation of a landslide risk SMS communication system to inform residents of potential landslide occurrences or after a landslide has occurred, and provide them with additional information.

To increase the scope of the recommendations, suggestions include conducting further research with residents to determine if the level of landslide hazard in the area they live affects their knowledge of landslides or perception of risk. If their place of residence is a determining factor in knowledge level, the educational materials could be altered accordingly.

We also recommend the implementation of a sensor-based system to acquire rainfall and soil data from regions to more accurately predict landslides, and to investigate alternate methods of registering for the SMS service in addition to the website. Our prototypes are easily adaptable initial steps to create an effective risk communication strategy in the Mandi District.
Works Cited


Breakwell, G. M. (2014). The psychology of risk. Published by Cambridge University Press


REFERENCES


Breakwell, G. M. (2014). The psychology of risk. Published by Cambridge University Press.


### APPENDICES

#### Appendix A: Background

*Table 1. Kullu District, India Report (Gardner, 2002) and Amprav, India Report (Rautela, 2005) about Human Causes of Landslides and the Consequences and Suggestions Learned from Each Report*

<table>
<thead>
<tr>
<th>Reports</th>
<th>Human Cause</th>
<th>Consequences and Suggestions</th>
</tr>
</thead>
</table>
| Kullu District, India Report     | ![Hypothesis: deforestation and animal grazing](image)  
|                                 | ![Conclusion: infrastructure of roads on the sides of mountains](image)      | ![Due to poor planning and ignorance of the fragile landscape, there has been an increase in landslides.](image) |
| Amprav, India Report             | ![Hypothesis: British effective risk management strategy, reduced major landslides](image)  
|                                 | ![Conclusion: Over time, lack of awareness caused villagers to misuse the land increasing their risk of landslides](image)  | **Effective landslide risk communication:**  
|                                 |                                                                           | ![Continuous public and political awareness and communication of threat](image)  
|                                 |                                                                           | ![Plan of action](image)  
|                                 |                                                                           | ![Enforcement of regulations](image)  
|                                 |                                                                           | ![Documentation of Risk](image)  |
Appendix B: Methodology
Map of Village Regions Visited:

Figure 1. Map depicting the locations of the IIT-Mandi Kamand campus (black circle), and the four villages where interviews were conducted: Katindhi, Dudar, Nela, and Khaliar (circles color-coded to match accordingly with their level of risk depicted on the hazard map).

Interview Questions for Experts:

Section I. Background Information
1. Male/Female
2. How old are you?
3. What village are you associated with?
4. How far do you live from the village?
5. What is the highest level of education you have completed? (School, Trade, Qualification, Undergraduate, Postgraduate (Master’s/Ph.D))
   a. If interviewing scientist: what area of study do you specialize in?
6. What is your occupation?
   a. If interviewing official: what position do you hold?
   b. Both: What are your daily work tasks?
   c. Both: In what ways does your occupation relate to landslides?
7. How many landslides have you experienced during your lifetime?
Section II. Questions for Officials about Technology Used and Policies in Place

1. What kind of policies are in place to address landslide events?
2. What kinds of policies are in place to prevent improper land use in hazardous areas?
3. Can you describe the structure of communication in place including who to contact when a landslide occurs, who is responsible for sending out early warning signals, and who is in charge of managing distress of clearing the area when a landslide occurs?
4. Do you think people are responding to the risk communication system in place? Why or why not?
5. How are people typically warned about natural disasters such as earthquakes or floods?
   a. What has been effective about these risk communication strategies?
6. What sort of media or technology do people in villages typically respond to when implementing a new policy?
7. When there is a change in leadership, how can you assure that the new official will continue previous policies?

Section III. Questions for Scientists about Technology

1. In what ways do you think technology and education can advance the ways people perceive landslide risks?
2. What types of technology are available in this region to assess when landslides might occur such as sensors or RADAR, or LIDAR, etc.?
3. Is all the information about landslide data gathered available to the public, and where would they find this information?

Section IV. Questions about Preparedness

1. How prepared do you believe that the residents are to handle a severe landslide event?
2. What information is necessary for residents to feel prepared for a landslide event?
a. If the landslide is severe enough for people to evacuate, is the necessary information the same or is it different? Please describe.

3. Is there any type of financial assistance available for residents in the case of a landslide?

4. In case of a landslide, what means of transportation are available to residents wishing to evacuate the area?

Section IV. Questions about Improving the System

1. What types of characteristics do you believe make an effective risk communication strategy?

2. If we were to design a way for the residents to respond to warnings, do you have any ideas or suggestions?

3. Do you perceive any problems with the current strategies in place?

Interview Questions for the Village Residents:

Section I. Background Information

1. Male/Female?

2. How many people do you have in your family?

3. How old are you?

4. What is the highest level of education you have completed? (Field of expertise)

5. What is your occupation?

6. What village are you associated with?

Section II. Questions about Perception of Landslides

1. What is your perception of landslides? Do you think they are risky or not risky?
   a. How many times have you seen landslides in the past?
   b. What was your experience like?

2. Can you describe why landslides occur?

3. What education have you received about landslides?
   a. What did you learn?
b. Where did you learn it?

4. Where do landslides typically occur in this area?

5. Would you evacuate your village if a landslide was predicted to occur, or after a landslide occurred? Why?

Section III. Questions about Hazard Awareness

1. What dangers do you associate with a landslide?

2. Would you live in an area if you knew it was a high-hazard zone area for landslides? Why?

3. Can you predict what type of landslide hazard zoned area are you located in: low, medium, or high hazard?

Section IV. Questions about Preparedness and Prevention

1. What would you do if you noticed that a landslide was about to occur?
   a. What signs do you look for while in a landslide prone area?

2. What could you do to reduce the possibility of a landslide occurring?

3. If you use land, what sort of things may trigger a landslide?
   a. Do you know of any policies in place to prevent this type of usage of land?

4. Do you have any source of financial assistance if a landslide affects your property?

Section V. Questions about Risk Communication and Warnings

1. What are your preferred methods of getting warnings about landslide?

2. Do you perceive any problems with the current strategies in place?

Section VI. Questions about Potential Solutions

1. What types of technology do you have access to?
   1. What type of phone do you have, if any? (Smartphone or normal phone? If smartphone, specify which type.)
   2. What kinds of technology do you use at home? (Ex: TV, Radio, Computer, Telephone, Newspaper)
3. What form of media do you currently get news from? (newspaper, television, radio, internet, phone, smartphone, other)

2. If a landslide alert were to be sent through text message, would you be more likely to see that versus any other form of notification?

3. If you were warned about a landslide, what information would you want to know? (location, severity, time of event, etc.)

Questions about Presenting Information:

1. Which is easier to understand? (Show attached images).
<table>
<thead>
<tr>
<th><strong>Water</strong></th>
<th>70%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Protein</strong></td>
<td>20%</td>
</tr>
<tr>
<td><strong>Fat</strong></td>
<td>7%</td>
</tr>
<tr>
<td><strong>Carbs &amp; Minerals</strong></td>
<td>3%</td>
</tr>
</tbody>
</table>

2. What information does each example tell you?

**Questions about Hazard Maps:**

1. Have you ever used a hazard map?
2. Do you know how/where to access the currently existing hazard maps?
3. What information does this map tell you?
4. What does the colors on the map represent?
5. Would you notice if a map this was posted in your village or town?

Questions about Public Announcement Systems:
1. If hazard maps were used to communicate landslide risk, where should they be put?
2. How would you feel if a landslide warning announcement was made over speakers or through your television?
3. Would you trust a loud siren or flashing lights to indicate a landslide warning?
4. Would you trust a computer system to warn you about landslide events?

Questions about Apps for Smartphones:
1. What type of apps do you currently use on your phone? (Whatsapp, Viber, Facebook, Messenger, climate apps, others)
a. Do you receive notifications from these apps?
b. Why do you use these apps? *(Obtaining information, entertainment, communication, etc)*
Appendix C: Results and Discussion

Why do landslides occur?

Figure 1. Residents’ responses when asked about the causes of landslides, analyzed by village.

Why do landslides occur?

Figure 2. Residents’ responses when asked about the causes of landslides, analyzed by age group.
Figure 3. Residents’ responses when asked about the causes of landslides, analyzed by education level.

Figure 4. Residents’ responses when asked about the signs of potential landslides to look for in landslide prone areas, analyzed by village.
Figure 5. Residents’ responses when asked about the signs of potential landslides to look for in landslide prone areas, analyzed by age group.

Figure 6. Residents’ responses when asked about the signs of potential landslides to look for in landslide prone areas, analyzed by education level.
Figure 7. Residents’ responses when asked about methods to reduce the possibility of landslide occurrences, analyzed by village.

Figure 8. Residents’ responses when asked about methods to reduce the possibility of landslide occurrences, analyzed by age group.
Figure 9. Residents’ responses when asked about methods to reduce the possibility of landslide occurrences, analyzed by education level.

Figure 10. Residents’ responses when asked about what kinds of land use can trigger landslides, analyzed by village.
Figure 11. Residents’ responses when asked what kinds of land use can trigger landslides, analyzed by age group.

Figure 12. Residents’ responses when asked what kinds of land use can trigger landslides, analyzed by education level.
Figure 13. Residents’ responses when asked if there are any policies in place to reduce improper land use that may cause landslides, analyzed by village.

Figure 14. Residents’ responses when asked if there are any policies in place to reduce improper land use that may cause landslides, analyzed by age group.
Figure 15. Residents’ responses when asked if there are policies in place to reduce improper land use that may cause landslides, analyzed by education level.

Figure 16. Residents’ responses when asked if there is a source of funding available in the case of damage caused by landslides, analyzed by village.
Figure 17. Residents’ responses when asked if there is a source of funding available in the case of damage caused by landslides, analyzed by age group.

Figure 18. Residents’ responses when asked if there is a source of funding available in the case of damage caused by landslides, analyzed by education level.
Figure 19. Residents’ responses when asked if they were aware of any landslide mitigation strategies, analyzed by village.

Figure 20. Residents’ responses when asked if they were aware of any landslide mitigation strategies, analyzed by age group.
Figure 21. Residents’ responses when asked if they were aware of any landslide mitigation strategies, analyzed by education level.

Figure 22. Residents’ responses when asked what information they would like to receive as part of a landslide warning, analyzed by village.
Figure 23. Residents’ responses when asked what information they would like to receive as part of a landslide warning, analyzed by age group.

Figure 24. Residents’ responses when asked what information they would like to receive as part of a landslide warning, analyzed by education level.
Figure 25. Residents’ responses when asked about the easiest way of presenting information, analyzed by village.

Figure 26. Residents’ responses when asked about the easiest way of presenting information, analyzed by age group.
Figure 27. Residents’ responses when asked about the easiest way of presenting information, analyzed by education level.

Figure 28. Residents’ responses when asked if they would use a hazard map, analyzed by village.
Figure 29. Residents’ response when asked if they would use a hazard map, analyzed by age group.

Figure 30. Residents’ response when asked if they would use a hazard map, analyzed by education level.
SWOT Analysis

**Video Animation**

**Strengths:**
- Fun and engaging
- Caters to a wide variety of viewers (age groups, literacy)
- Easy to use with proper technology

**Weaknesses:**
- Lacks detailed information
- Specialized medium (relying on access to internet)

**Opportunities:**
- When combined with pamphlet, more success
- Easily incorporate into educational programs at schools
- If successful, can be easily translated to different languages

**Threats:**
- Lack of animation websites and money so a better video could replace this one

*Figure 31. SWOT analysis for the educational video animation*

**Pamphlet**

**Strengths:**
- Informative with contact information
- Visually appealing
- English and Hindi versions available
- Can stand alone if necessary

**Weaknesses:**
- Does not accommodate to illiterate people
- Does not appeal to children as much

**Opportunities:**
- If successful, easily translatable
- When combined with video, more success
- Easily incorporated into educational programs
- Could be distributed by various methods

**Threats:**
- Governmental issued pamphlet could have more success

*Figure 32. SWOT analysis for the educational pamphlet*
Figure 33. SWOT analysis for the semi-autonomous SMS System

Strengths:
- Someone has responsibility (person vs. computer)
- Website provides more communication and feedback abilities

Weaknesses:
- Need personnel → human error
- Relies on internet
- Need account

Opportunities:
- Easily implemented by others because it is pre-made
- Governmental communication with residents

Threats:
- Better website could exist with more resources
- Better system for calculation (more technological, advanced, and accurate)
- Lack of money allows for competitor success
Appendix D: Project Outcomes

EDUCATIONAL PLAN

Pamphlet (English):

Governmental Aid: Financial Assistance
For damages of property due to landslides, funding will be provided accordingly by the State Disaster Response Fund (SDFR) and the National Disaster Response Fund (NDRF):

<table>
<thead>
<tr>
<th>Incidence</th>
<th>Amount</th>
<th>Additional Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal houses (domestic)</td>
<td>5,000 (max)</td>
<td></td>
</tr>
<tr>
<td>Vehicles</td>
<td>1,000 (max)</td>
<td></td>
</tr>
<tr>
<td>Home damaged</td>
<td>15,000 (max)</td>
<td></td>
</tr>
<tr>
<td>Business, shop, store</td>
<td>5,000 (max)</td>
<td></td>
</tr>
<tr>
<td>Non-governmental organizations</td>
<td>10,000 (max)</td>
<td></td>
</tr>
<tr>
<td>Governmental</td>
<td>50,000 (max)</td>
<td></td>
</tr>
</tbody>
</table>

Hazard Maps of Himachal Pradesh

Landslide Education

References
What is a Landslide?

Landslides are downward and outward slope mass movements. They can vary from small and undamaging to large with unpredictable and highly destructive forces.

What are the causes of landslides?

<table>
<thead>
<tr>
<th>Natural causes</th>
<th>Man made causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Premonitory rainfall</td>
<td>Construction</td>
</tr>
<tr>
<td>Earthquakes</td>
<td>Mining</td>
</tr>
<tr>
<td>Soil composition</td>
<td>Deforestation</td>
</tr>
</tbody>
</table>

MYTH: Landslides are not caused by an act of God.

Response to landslides:

If you or someone is hurt, call #108 for ambulance response. Call #1077 to report the occurrence of a landslide. Inform other people you know about the event.

About us
Julian Baumpaertel,
Haunch Fennersley,
Sagar Ghei,
Sarah Toon Kyong Lee,
Karpan Mahajan,
Nicole Noladowsak

Pamphlet (Hindi):

सरकारी सहायता

वित्तीय सहायता

भूस्खलन की कारण संपत्तिको नुकसान को घन राज.आपदा परस्करिति को छोटा, और राष्ट्रीय आपदा परस्करिति को छोटा पूर्वानु दिया जाएगा।

|| पदार्थ || वर्ग || अनुप्रेरककीय वाक्यावर्ती ||
|---|---|---|
| 1 | पृथ्वी पृष्ठभूमि में सूचना || 500 सौ कोड़े || पृथ्वी पृष्ठभूमि में सूचना ||
| 2 | पृथ्वी पृष्ठभूमि || 300 सौ कोड़े || पृथ्वी पृष्ठभूमि में सूचना ||
| 3 | पृथ्वी पृष्ठभूमि || 200 सौ कोड़े || पृथ्वी पृष्ठभूमि में सूचना ||

भूस्खलन शिक्षा
Video Link (English):
https://www.youtube.com/watch?v=hW70g3IBG7M
Video Link (Hindi):
https://www.youtube.com/watch?v=_bJ06zOVgS4

TECHNICAL SOLUTION
Website:
The website can be accessed through the following link: landsliderc.weebly.com. The website content is both in Hindi and English and can be found using the same link. There are four tabs for the website: Home, About Us, SMS Registration, Landslide Education, and Contact. The following are brief descriptions of each page.

- **Home**: Welcomes the guest to the website. It provides a short introduction of our problem statement and short descriptions of the website pages.
- **About Us**: This page describes the project in depth and includes photographs of interviews and site assessments, description of project goal and objectives, and a description of the project problem.
- **SMS Registration**: The page sends the guest to a survey made through Google Forms. This form is used to register people to receive text messages about when a landslide is about to occur, when a landslide has occurred, and educational material on
landslides. Details about the Landslide Risk SMS Communication System are detailed below.

- **Landslide Education**: This page contains an embedded link to the educational video, an electronic copy of the pamphlet, and extra information about the causes of landslides, policies in place, and other helpful information.
- **Contact**: This page provides details about who to contact for help when a landslide occurs. In addition, it provides a place for residents to communicate directly to government officials about landslide events, landslide education, or criticism on the SMS system.

**Prototype: Semi-Autonomous Landslide Risk SMS Communication System**
Below is the process flow of the communication system. The code developed for the following information can be found at [https://github.com/sagarghai/istp/tree/master/landslides](https://github.com/sagarghai/istp/tree/master/landslides). The following simulates an early warning system only based on rainfall data from Terhi District in conjunction with our SMS communication system.

1. Google forms is used to enter participant information. This survey can be accessed through the develop website: https://landslidsrc.weebly.com. 
   - Phone number
   - Region of Residency
   - This information will be in Google Sheets: using python code called gspread which extracts the data from Google Sheets and places in and excel file

2. Rainfall data is acquired from a weather website called Accuweather. A regression formula calculates the temporal probability.
   - Scrappy is a python module which hits a url, and downloads the entire html. This is converted to a Java Script Object Notation (JSON) object which belongs to class “response”, which is a text format. JSON can be queried using Xpath, which can uniquely identify elements in an html response. We use Xpath to get precipitation amount of the last day and use it as one of the variables in the calculation of temporal probability. Using the previous rainfall data of Tehri District from 1955 to 2000, the variables for the 3rd day and 30th day are filled for the regression formula found from the Bhuvan study(Experimental 2015).

3. Once the temporal probability is calculated, we move on to calculate the spatial probability.
   - This is done by the gspread python library which takes the information row by row from the spreadsheet. This information is entered by the participant which includes their telephone number and their area of residency. This information is taken into nested array format for example `[[telephone number, location],[telephone number, location]]`. The is_susceptible method
checks if the phone number is in the susceptible area or not. If it is true, then the message will be sent to this area, otherwise the phone number will not be sent a message.

4. This information is then presented in the form of a Graphical User Interface (GUI) of the program. The GUI was developed using the python package “Tkinter”. This flow between each window within the program can be seen in the figures below.

**Figure 3.** Main menu window allowing user to choose to send a post-landslide message or a pre-landslide message through “Alert Message” button or “Check Daily Risk” button.

**Figure 4.** Window for “Alert Message”.

This appears after the “Alert Message” button was pressed in the main menu. This window allows the user to choose the severity, time, and place of the landslide having occurred. This information will come from a resident calling about a landslide event occurring. When “Send Alert” button is pressed, another window will appear indicating that the alert message was sent.

**Figure 5.** Window for “Check Risk”. 
If the “Check Daily Risk” button is pressed in the main window, then this window will appear. It provides a chart indicating the places, the susceptibility of landslide for that region, the calculated probability of the landslide occurring, and the type of message that should be sent depending on the calculated probability.

![Image of a window indicating the places, susceptibility, probability, and type of message.](image)

*Figure 6. Window to affirm that “Advisory, Watch and Warning” messages were sent.*

This window appears after the “Send Advisory, Watch, or Warning” button is pressed. This window ensures that the messages were sent to the appropriate regions.

![Image of educational message windows.](image)

*Figure 7. Window for “Educational Message” and affirmation that message was sent.*

The “Educational Message” window allows the user to choose which educational topic to send to certain regions. The message sent were pre-made based on information gathered from interviews when assessing residents’ level of understanding and awareness of landslides. The “Educational Sent” window affirms that the educational message was sent to the specified region.

5. Twilio API is used to the end the messages.
   - The API has a method called *create_message* through which the messages can be processed. It takes three arguments: message to, message from, and the message itself. The phone numbers are retrieved from the google spreadsheet as mentioned before. Then the message is sent to the specific participants.

**Twilio**

There are different ways to send a text message for free, one of which is called Long Code. Twilio is a version of long code SMS which allows the user to manage multiple virtual numbers through its website service. The typical cost is about $1 per month. Twilio provides API and SDK to developers in a variety of coding languages such as Python. The SMS is limited to 160 characters long and can be either a Mobile Terminate (MT) message (Yuan, 2011).
In our program, we use the Twilio API in Python to disseminate messages. Due to the character limitation, the messages sent are held within that limitation as well. Although there are other forms of SMS messaging, this was the most applicable to our recommendation.

**Adopted Methodology for Calculating Probabilities**

The temporal probability of our program is calculated based on the following logistic regression seen in Equation 1. This formula was derived for the area along the National Highway-58 (NH-58) from Rishikesh to Mana in the Garlwal Himalaya. With a similar area and rainfall history, this formula was applied to the Mandi District. According to the formula, the probability of slope failure is dependent on the daily (DR), 3-day cumulative (3DCR), and 30-day antecedent rainfall (30DAR) (Experimental, 2015).

\[
z = -3.817 + DR \times 0.077 + 3DCR \times 0.058 + 30DAR \times 0.009
\]  
(Eqn. 1)

\[
f(z) = \frac{1}{1+e^{-z}}, \quad z \in (-\infty, 0 \to 1)
\]

According to Anbalagan et al., the spatial probability can be provided as seen in Table 1. This table provides a Total Estimated Hazard (THED) based on the Landslide Hazard Map sectioning.

**Table 1. Total Estimated Hazard (THED)**

<table>
<thead>
<tr>
<th>Hazard Zone</th>
<th>Range of corrected TEHD</th>
<th>Description of zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>$THED &lt; 3.5$</td>
<td>Very low hazard (VLH) zone</td>
</tr>
<tr>
<td>II</td>
<td>$3.5 \leq THED &lt; 5.0$</td>
<td>Low hazard (LH) zone</td>
</tr>
<tr>
<td>III</td>
<td>$5.0 \leq THED \leq 6.5$</td>
<td>Moderate hazard (MH) zone</td>
</tr>
<tr>
<td>IV</td>
<td>$6.5 &lt; TEHD \leq 8.0$</td>
<td>High Hazard (HH) zone</td>
</tr>
<tr>
<td>V</td>
<td>$THED &gt; 8.0$</td>
<td>Very high hazard (VHH) zone</td>
</tr>
</tbody>
</table>

From this table, the spatial probability can be calculated by dividing the THED by the corrected Landslide Hazard Evaluation Factor (LHEF) which considers individual and net effect of landslide causal factors also used for Landslide Hazard Zonation (LHZ) mapping (Anbalagan, 2008). Thus, total probability calculation of slope failure is shown in Equation 2.
total probability = temporal * spatial,

(Eqn. 2)
where spatial
\[ THED = \frac{LHEF}{THED} = \frac{11.0}{11.0} \]

The total probability is then compared to the triggering probability, which ranges from 0.75 to 0.85. An early warning can then be sent based on the triggering probability and the landslide susceptibility as suggested by the Bhuvan study (Experimental, 2015). The combinations of warning dissemination and susceptibility can be seen in Table 2.

Table 2. Combinations of Susceptibility and Triggering Probability to Send Warnings

<table>
<thead>
<tr>
<th>Landslide Susceptibility</th>
<th>Triggering Probability (0.75 to 0.85)</th>
<th>Triggering Probability (&gt; 0.85)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severe</td>
<td>Warn</td>
<td>Warn</td>
</tr>
<tr>
<td>Very High</td>
<td>Watch</td>
<td>Warn</td>
</tr>
<tr>
<td>High</td>
<td>Watch</td>
<td>Watch</td>
</tr>
<tr>
<td>Moderate</td>
<td>Advisory</td>
<td>Advisory</td>
</tr>
</tbody>
</table>

Table 3. Types of Messages According to Susceptibility and Triggering Probability

<table>
<thead>
<tr>
<th>Type of Message</th>
<th>When its sent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advisory</td>
<td>Moderate Landslide Susceptibility and Moderate to High (&gt;0.75) Trigger Probability <em>(Low to moderate probability of landslides)</em></td>
</tr>
<tr>
<td>Watch</td>
<td>Very High Landslide and Moderate (0.75-0.85) Trigger Probability OR High Landslide Susceptibility and Moderate to High (&gt;0.75) Trigger Probability <em>(Moderate to High probability of landslides)</em></td>
</tr>
<tr>
<td>Warn</td>
<td>Very High Landslide Susceptibility and High (&gt;0.85) Trigger Probability OR Severe Landslide Susceptibility and Moderate to High (&gt;0.75) Trigger Probability <em>(High to Very High probability of landslides)</em></td>
</tr>
</tbody>
</table>
Appendix E: Poster
Appendix F: Photos

Figure 1. Interview with the head of the Mandi District relief department (Office worker, 2016)

Figure 2. Interview with a shopowner in Dudar (Lee, 2016)
Figure 3. Remnants of a landslide near the IIT-Mandi Kamand Campus (Shockey, 2016)

Figure 4. Interview in Mandi (Mikołajczak, 2016)
Figure 5. Interview in Mandi (Mikolajczak, 2016)

Figure 6. Interview in Mandi (Mikolajczak, 2016)
Figure 7. Interview in Mandi (Mikolajczak, 2016)

Figure 8. Interview in Mandi (Mikolajczak, 2016)
Figure 9. Interview in Nela (Nela resident, 2016)