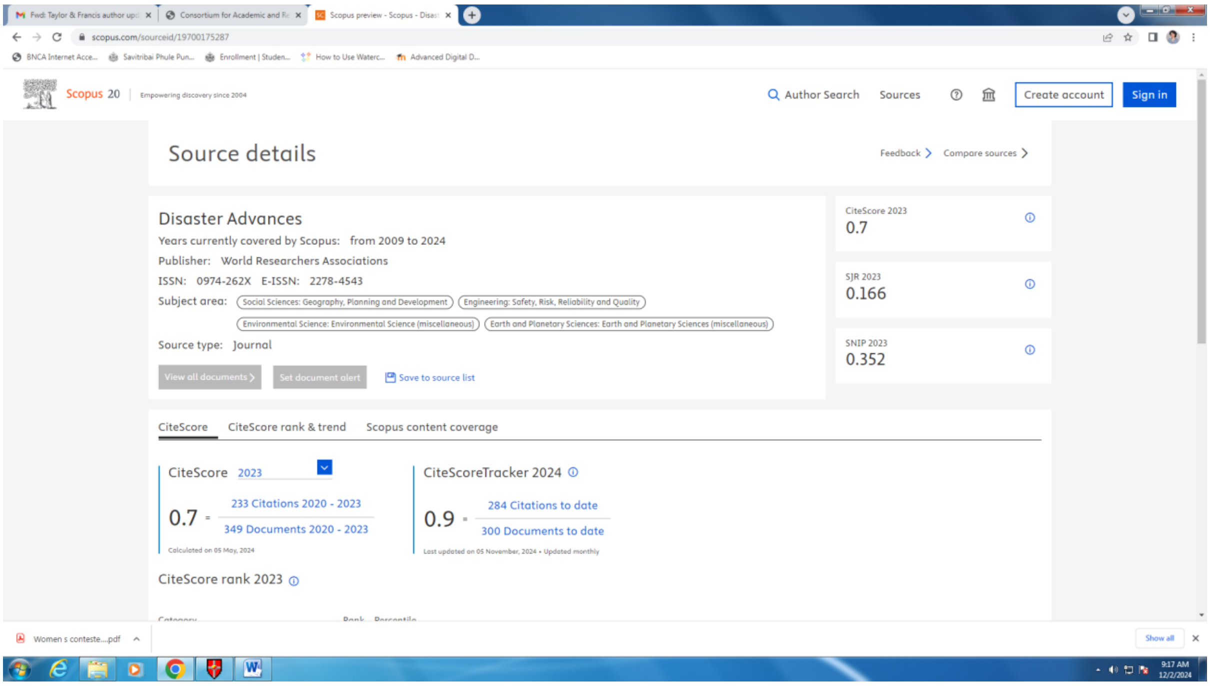

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Landslide Vulnerability of Urban slums: Case of Warje Slum, Pune, Maharashtra

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Abstract
The rapid urbanization in developing countries contributed to the severity of urban environmental hazards such as slope failure and flooding. In addition, heavy rainfall or alterations to natural environmental characteristics trigger the incidence of hazards such as landslides where local topographic conditions often exacerbate the vulnerability of the built environment. Landslide causes numerous fatalities and financial damage to millions worldwide and India is no exception.

In most of the Indian cities, the physical expansion during the past few decades has resulted in increased vulnerability, with the occupation of hill slopes subject to instability. Therefore, the impact of physical characteristics of the environment and human interventions needs to be examined in assessing urban vulnerability. This study examines the vulnerability of urban settlements to landslide risk with Warje Slum, Pune, Maharashtra as a case study. It attempts to understand better the causative factors of landslides and their impact to suggest ways for better disaster management to save life and property in the future.

Keywords: Risk, vulnerable, slums, slopes, perception.

Introduction

Urbanization and consequent increase in populations contribute to the vulnerability of cities to disasters; landslide is one of them. Sky-reaching land prices in urban areas force people to construct houses on steep hill slopes. In addition, the use of substandard quality materials and technology significantly intensifies the occurrence of urban landslides. In developing countries like India, people living in disaster-prone areas have grown by seventy to eighty million per year. Landslides are the world's third most crucial natural disaster causing human casualties and damage to property and infrastructure. Various factors resulting in landslides are causative and triggering factors whereas causative factors that create a favorable condition for landslides include slope, geology, land-cover aspect and land use.

India has 12.6% of its total land as landslide prone. Research indicated that India had the highest casualities, nearly 56,000 casualties from 4,800 landslides around the world between 2004 and 2016. The country accounts for 20% of landslide deaths witnessing the fastest rise in human-triggered fatal landslides. It is found that maximum construction-triggered landslide events occurred in India, accounting for 28% followed by China, about 9%, Pakistan at 6% and the Philippines, Nepal and Malaysia, 5% each. The densely populated residential construction on hill slopes renders landslide risk management more complex. Besides lack of legislation, marginalization of low-income housing with inefficient policy measures, poor soil-use management, socio-economic crisis and lack of technical support contribute to people's susceptibility.[2]

Landslides are geomorphological processes associated with the topography's dynamic development, particularly in tropical and temperate environments. The prediction of landslides is a complex phenomenon making it difficult to protect such areas from catastrophic consequences due to landslide occurrence.[12] In urban areas, the lack of urban planning and infrastructure has led the most underprivileged population to occupy risky and unsuitable construction areas with low real estate land value.[3]

Landslides in Urban Slums: In urban areas, human activities such as housing and infrastructural construction on hill slopes and deforestation accelerate the occurrence of landslides.[1] In developing countries like India, intensive urbanization, inadequate land use and high land values compel the most impoverished population to occupy areas with vulnerable geologic and topographic characteristics. This aspect results in slum development on the hill slopes, a common phenomenon in Indian cities.[14] Recurring landslides constantly threaten the poor and socially marginalized populations living on small hillocks.

The densely populated, unplanned, haphazard, structurally deficient construction accompanied by poor infrastructure results in soil erosion, enhance the risks of landslides, particularly in the rainy season.[18] The hill slope is generally comprised of silty clay with a poor shear strength compared to sand and clay/shale. Consequently, such areas are susceptible to slope failure and mass wasting as the gravitational force acting on the slope exceeds its resisting force.

In the rainy season, soil's susceptibility to landslides increases due to excessive rainfall that saturates the soil, increasing soil mass. In such an event, material movement occurs because of slope instability depending on the slope. The slope instabilities result from geological, morphological and human-induced changes in the physical environment. In the rainy season, due to rainwater absorption, the mineral present in the water dissolves the soil and becomes heavy, losing its compaction. This process is aggravated in the case of high-intensity rains because soil minerals dissolve very quickly, turning the soil into a heavy mass of mud. Besides, deforestation increases the risk of landslides due to the absence of vegetation that holds the soil, protecting it from erosion and stabilizing the hill slopes.[13]

Risk Perception and Vulnerability: Risk represents the likelihood of an event occurring and its likely consequences governing how people live in safer and more sustainable communities. It is a belief created through the interaction between various social aspects and people about what is dangerous and what processes and factors are likely to harm them.[21] Disaster mitigation behavior of endangered people depends on risk perception that includes perception about the severity, occurrence probability, usefulness of mitigation efforts and ability to implement the suggestion.[15] Perception 'is the establishment, proof of identity and analysis of sensory information imperative to signify and recognize the environment.[19]

Risk perception refers to the qualitative evaluation of the possibility of an unwanted event, the degree of its effects and one's managing abilities.[23] Disaster risk perception and knowledge affect mitigation and adaptation behavior and disaster preparedness. People's social vulnerability depends on socioeconomic conditions and their experience of disasters that affect their response to an emergency.[8] Vulnerability depends on physical exposure to hazards and people's socioeconomic conditions generated over a long period. Vulnerability comprises resilience and strength of livelihood, baseline status, self-protection measures, social protection and governance.[6]

Risk Management and Risk Preparedness: Risk management efficiency depends on how people perceive the risks.[16] Local governments and communities prepare disaster risk management plans, having planned interventions formulated with the identification of risks, vulnerabilities and capacities against local hazards. Such plans are based on historical data of hazards at a given location addressing current hazards and vulnerabilities.

However, they often overlook future vulnerabilities and risks.[17] Risk is impending for responsiveness of uninvited, disparate effects on human life, wellbeing, assets, or the environment setting. People often prefer to live in a risky location as the availability of other facilities and benefits overshadows the risk perception.

Generally, people perceive the risk but do not accept the responsibility to mitigate others, complaining lack of resources and help offered by others and government bodies. Perception of disaster risk is more in the people belonging to lower income groups and they are generally more concerned with occurrence of natural disasters[9]. This aspect is due to fewer resources to cope with an adverse situation. Many of them cannot afford disaster preparedness measures and continue to live under disaster threats.[11]

Factors Affecting the Response of People to a Disaster: People's response to an emergency situation depends on their perception and inappropriate perception leads to failure of efforts taken for their personal, public and environmental protection[21]. Risk perception significantly influences an individual's motivation to prepare for disaster. However, research demonstrated that the interrelationship between risk perception and social response is often weak. This weak relationship is referred to as "the risk perception paradox" for three reasons. In the first case, a person understands the risk, but they prefer to accept it considering the benefits that are more than the negative impacts. In the second case, people perceive the risk but avoid taking action and pass on the responsibility to respond to others. Finally, a person understands the potential risk but refuses to respond in light of their perceived lack of resources to face the emergency.[23]

Previous experience of exposure to disaster shapes people's risk perception.[25] Besides, thrusts in experts and authorities also modify their response and preparedness for an emergency. People's perceived threat, disaster severity and fear govern their motivation to take action for self-protection.[7] On the other hand, excessive dependency and trust in government bodies result in a pessimist approach and people do not take action on disaster occurrence or any preparatory measures. Often infrequent occurrences and minor losses influence the perceived risk of an adverse event.[24] In dealing with uncertain risks, people's acceptability of a hazard and decision making process is based on directives and information provided by government bodies, experts. In such a case, less trust on authorities results in lower level of risk perception.[4]

Protection motivation theory postulates that people's decision to respond protectively or non-protectively depends on two cognitive processes: threat appraisal and coping appraisal.[5] Risk appraisal, also called risk perception, comprises a disaster's perceived probability and perceived consequences.[22] A coping appraisal is an act to reduce or avert the possible threat that depends on response efficacy (perceived effectiveness of an action), self-efficacy (the perceived ability to implement the action) and response cost (perceived cost likely to be incurred in implementation).[10]

Landslides in Indian Urban Areas: Landslides have been observed frequently in Indian cities in the last two decades. In Mumbai, in the financial capital of India, 1.5 lakh families live on the hill slopes and 300 lives have been lost to landslides in the last 20 years. The third major disaster in the city was the landslide at Lal Bahadur Shastri Nagar slums in Saki Naka andheri East, in 2005, killing 11 people including four children. In July 2021, 10 people were killed in an illegal slum at the height of 500 feet on a hill at LBS Marg, Vikhroli (West), due to a landslide following heavy rainfall. The constant heavy rain recently triggered a landslide in the

Tony Peddar Road area of Mumbai, resulting in a wide crack in the footpath.

The Malin village in Ambegaon, Pune, Maharashtra, in 2014, experienced a massive landslide, burying about 40 houses, reportedly killing 151 people. The heavy rainfall receiving 108 mm of rain in a day that continued throughout the following day caused the landslide. Large-scale deforestation was the primary undelaying anthropogenic reason that resulted in landslides exhibiting the sheer negligence of geological aspects in the developmental process. The village people opted for a shift of agricultural practices from rice and finger millet, for which the steep hill slopes were leveled, rendering the hills unstable. One of the possible reasons was the large-scale construction of the Dimbhe Dam in the vicinity.

The Study Context- Pune, Maharashtra: Pune is one of the large cities in Western Maharashtra where the metropolitan area has a population of 5 million, which makes it the seventh largest metro area by population in India. The total number of slums in Pune city is 151,278, with a population of 690,545 residents, making around 22.10% of the total population of Pune city (Census, 2011). The city is experiencing the indiscriminate cutting of hills and deforestation for building construction, developing residential/housing areas, clay and sand mining and developing a road network. Industrial development and mass migration resulted in an unprecedented increase in land and property prices. The unaffordability to purchase a residential facility in prime areas forces people from the low and low-medium economic class to occupy the hill slopes, top or foot of hills. Such residential structures are built without following the prescribed development control rules and regulations.

In many places, the hills are cut with steep slopes ranging from 45-80 degrees that cannot bear the heavyweight imposed by the construction activities making the area susceptible to a landslide. The landslide-prone slum community in Warje slum consists of several small clusters of settlements or slums on a hillock in Warje, Pune. Oral history has revealed that this settlement was uninhabited, the hillock on which several communities from Pune, gradually built a settlement. Later, other groups that migrated to the city from different states joined and drew in relatives and caste groups from their rural locality, consolidating their position within the community.

Material and Methods

A detailed exploratory field investigation was conducted at Warje slum Pune and data were collected through two methods: naturalistic observation and semi-structured interviews. A total of 158 residents participated in the survey. It is followed by assessing the physical vulnerability of building stock where a section of the slum was selected comprising of 526 houses in the area under study. The data were analyzed by SPSS 21 (Statistical Package for Social Sciences) and construct validity was checked by the factor analysis method. In addition, the suitability of data for factor analysis was tested through the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) and Bartlett's test of sphericity (Bartlett's test) by using SPSS.

The vulnerability of the built stock was evaluated to predict likely damages caused by landslides. The elements of buildings such as construction material, age, structure type, number of floors and number of occupants, were used to assess the vulnerability. About 526 residential units were surveyed for six factors.

Results and Discussion

A total of 158 residents participated in the study and the socio-demographic characteristics of them are presented in table 1.

Table 1
Sample Composition

Gender	Male	92	58.2
	Female	66	41.8
Economic status	20000-30000	38	24.7
	30000-50000	83	53.9
	more than 50000	33	21.4

Table 2
House Type and Disaster Experience.

Variable	Groups	Frequency	Percent
House Type	Mud	4	2.6
	Patra	30	19.5
	Brick and Patra	77	50.0
	Pacca single story	40	26.0
	Pacca double story	3	1.9
Disaster experience	No	84	54.5
	Some	68	44.2
	Very much	2	1.3

Fifty-eight percent (92) were male and 42.6 percent (66) were female. The family income of 25 percent (38) was 20000-30000, 54 percent (83) respondents earned Rs, 20,000 – 50000, while it is more than 50,000 per month for 21 percent (33) families. The house typology and the resident's experience of a disaster were explored and the analysis is presented in table 2.

The house type of 50 percent of people (77) was a brick structure with a lightweight tin sheet roofing (Patra); 19.5 percent lived in a house made of lightweight sheets (Patra). Twenty-six percent (40) had a single-storied brick house with an RCC roof; 2% lived in a double-storied pacca structure. However, 2.6 percent (4) had a mud house. 54.5 percent of respondents 84 did not experience any disaster, 44 percent (68) had encountered a disaster to a certain extent and 1.3 percent just two had experienced a significant disaster in the past.

Scale items, M and SDs of items were presented in table 3. When a disaster occurs, family earnings stop for a long time (M=3.2792, SD =.57731). People want to leave the house because of possible disasters (M= 1.6818. SD= .87600.)

Data were subjected to factor analysis using principle axis factoring and orthogonal varimix rotation. The output of KMO and Bartlett's Test is shown in table 4.

KMO measure 0.556 indicating the data were sufficient for factor analysis. The Barlett's test chi square value 254.85 $p< .05$ showed that there was patterned relationship between items. Using Eugin value cut off value > than 1.0 there were 3 factors that explain a cumulative covariance of 29.231 %. The scree plot confirms the finding of retaining 3 factors. The table 5 shows factor loadings after rotation using significant factor criteria of 0.5.

The first factor (item 1,2, 7), named as exposure, took factor loading ranging from 0.569 to 0.541. The second factor (item 6,10,11) was named as impact with factor loading ranging from 0.536 to 0.719 and the third factor (item 8,12) named as the anxiety, took factor loading ranging from 0.536 to 0.327. The factor analysis indicated the people's concerns about the exposure of their community to flood and fire where the possibility of landslides is not thought of. The second concern is the impact of a landslide compared to others regarding physical damages, disturbance to family's day-to-day living and financial losses. Finally, the third factor was the fear and anxiety that they possessed about the occurrence of a disaster like a landslide.

Perceived Likelihood of Disasters: The perceived likelihood of disasters and the subsequent threat is shown in fig. 1.

Table 3
Items, Mean and Standard Deviation of Measurement Instrument

Items	Mean	Std. Deviation
likely to have flood	2.3442	.47664
likely to have fire disaster	2.8831	1.01587
likely to have land slide	1.0000	.00000
likely to have earthquake	1.0000	.00000
threat in rainy season	3.1234	.70783
It is likely that I could be harmed in disasters at home	2.7013	.58444
It is likely that my family could be harmed in disasters at home	2.9740	.51065
It is likely that my house could be harmed in disasters more easily than other houses	3.0195	.63112
It is likely that I will have more problems than other households	3.0390	.73993
I feel depressed when my area is affected from rains	2.7013	.45918
likely disasters occurrence make me worry when I come to my place	3.0130	.62609
I think that disasters pose great financial damage	3.0390	.41037
When a disaster occurs my family earning stops for a long time.	3.2792	.57731
I want to leave this house because of the possibility of disasters	1.6818	.87600

Items removed from scale

Table 4
KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.556
Bartlett's Test of Sphericity	Approx. Chi-Square	254.838
	df	66
	Sig.	.000

Table 5
Factor Loading

Factor Name	Item No		Factor Load
Exposure	1	likely to have flood	0.569
	2	likely to have fire disaster	0.810
	7	I will have more damages than other households	0.541
Impact	6	My house could be harmed in disasters more easily than other houses	0.536
	10	When a disaster occurs my family will be in trouble for a long time.	0.607
	11	I think that disasters pose great financial damage	0.719
Anxiety	8	I feel depressed when my area is affected from rains	0.536
	12	likely disasters occurrence make me worry when I come to my place	0.327

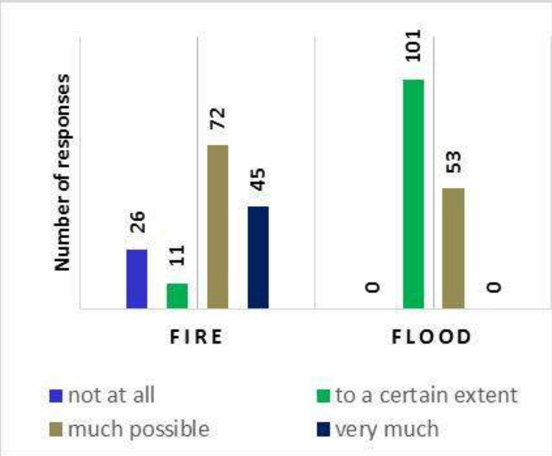

Fig. 1: Likelihood of Disasters

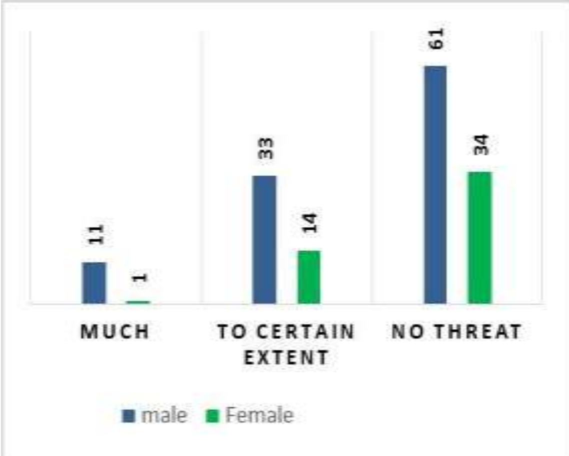

Fig. 2: Threat to the house.

According to the respondents, the disaster types that may occur mostly were a flood followed by fire. However, as per respondents, there was no possibility of landslides and earthquakes. The threat to their house due to the disaster was severe for 30% of respondents. For 45% of people, it was a moderate level and for 25%, it was not significant; however, not a single person rated their house as safer from disasters.

The respondent's concern about how a likely landslide affects them and their community is examined. Analysis indicated that 74% were worried about their family wellbeing that was the highest followed by concerns about impact on the house that was for 60% respondents. About 57% respondents were concerned with their personal safety, however, 49% perceived impact on the whole neighborhood (fig. 3).

Physical Vulnerability Assessment: Physical vulnerability of sampled houses was examined with six constructs: roofing type, structural typology, vertical configuration, position from steep slope, quality of construction and the state of maintenance. The section of Warje slum was selected having steep to moderate slope. The details of level of vulnerability (LV) are presented in table 6 where LV1to LV4 denotes low to high vulnerability.

It is observed that more than 50% of houses have roofs with low resistance being made of lightweight material secured by placing heavy material on the top. Many houses had a flat roofs. RCC roofs in GI or Asbestos sheets were not adequately tied to the parent structure, making them vulnerable to separating in case of a structure's movement. About 26% of such houses were rated as LV2. About 23% of the houses having RCC roofs just placed on the load-bearing structure are rated as VL1, considering the lack of structural strength in the absence of beams and columns (Fig. 4).

Fig. 3: Perceived impact of a landslide

Table 6
Level of Vulnerability

Roof	LV	Position from Steep slope	Score
Flat roof in Reinforced Concrete	LV1	Less than 5 m	LV 1
Flat roof in GI or Asbestos sheet	LV 2	Greater than 5 m	LV 2
Pitched or flat roof with stone/heavy material placed on the top	LV 3	On the Steep Slope	LV 3
Structural Typology		**Quality of Construction**	
Stone Masonry	LV 4	Good	LV 1
Brick Masonry	LV 3	OK	LV 2
RC frames with infill walls	LV 2	Bad	LV 3
Patra	LV 1	**State of Maintenance**	
Vertical Configuration		Good	LV 1
Regular	LV 1	OK	LV 2
Irregular	LV 2	Bad	LV 3

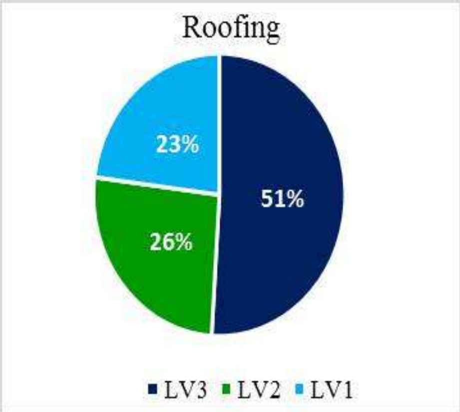

Fig. 4: Roofing typology

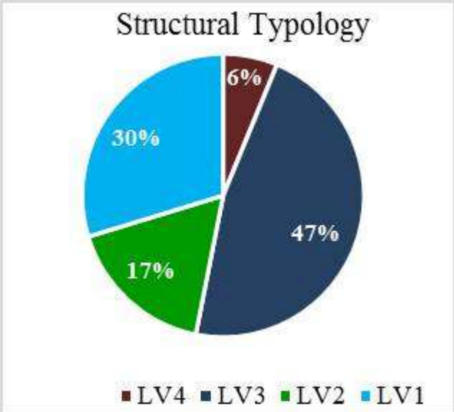

Fig. 5: Structural typology

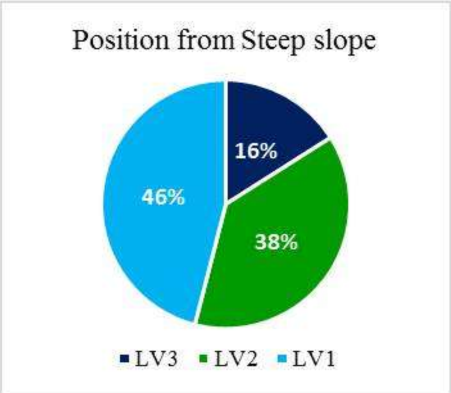

Fig. 6: Location

Fig 7: Quality of Construction

The observation indicated that 6% of the houses used stone masonry without following standards and were found highly vulnerable (V4). Brick masonry construction typology is used for 47% of houses with substandard mortar, with or without plaster and rated significantly vulnerable (VL3). The houses using RCC were not adequately designed as many had missing beams, columns and heavy infills are rated as vulnerable to a certain extent (VL2). However, houses made out of lightweight sheets referred to in the local dialect Marathi "Patra" were used for constructing the house and were rated marginally vulnerable (VL1) (Fig. 5). About 16% of the houses either located on the edge of the slope or at the foot of the slope are rated highly vulnerable (V3), 38% of houses located near the unstable slope are rated vulnerable to a certain extent (VL2) on exposure to a landslide. 46% of houses are not located very close to the slope, but the likelihood of soil settlement considering the soil characteristics is rated as vulnerable (VL1) as shown in fig. 6. The highly substandard quality of construction observed for 46% of houses renders them highly vulnerable (VL3). About 33% of houses used substandard quality material and were poorly executed and rated marginally vulnerable (VL2). 21% of houses followed the standard practices to a certain extent.

However, they compromised in providing strengthening measures considering likely damages due to landslide and were rated as vulnerable (VL1) as in fig. 7. About 58% of houses were in bad shape due to ill maintenance, 25% were maintained to a certain extent while 17% were in a comparatively better state but still not adequately maintained to have enough strength and capacity to resist a landslide (fig.8). The vertical configuration of 65% of houses was exemplary.

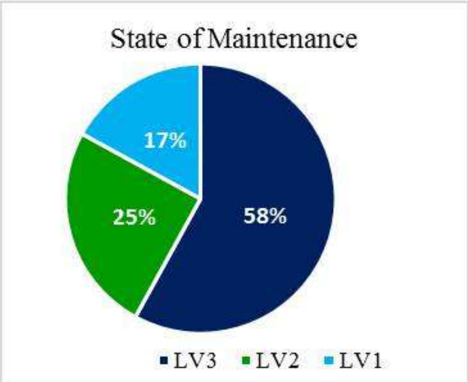

Fig. 8: Maintenance Level

However, 35% of houses with irregular vertical configuration projections without proper support, attics and lofts used as functional space or for storing heavy material made them significantly vulnerable.

The research examined slum dwellers' capacities, solidarity and perception of disaster occurrence, focusing on landslides. It is uncovered that various spatial, social and environmental characteristics are responsible for rendering the living areas located on hill slopes vulnerable to disasters. The analysis uncovered the people's perception of a landslide, where their multiple capacities and solidarity surfaced to respond to such an event. It is established that slum dwellers will continue living, recreating spatial, social and environmental characteristics ignoring the likelihood of a disaster such as a landslide unless Government bodies take proactive measures.

It is established that these areas constitute disastrous urbanscapes occupied with socially and spatially vulnerable communities. The densely populated area with poorly constructed houses located abutting each other increases vulnerability whereas illegality and lack of essential services increase disaster proneness. The political, economic and organizational capacities are compromised to a more significant extent forcing the community for a continual living in disastrous conditions.

The analysis indicated that slum dwellers living in hazardous locations face disasters frequently, particularly heavy rains. Their socio-spatial vulnerability depends on the physical environmental condition that is highly deficient. Besides, the socio-economic conditions generated in their lifetime add to their vulnerability. The absence of financial resources and lack of knowledge result in least protection motivation that does not directly arouse and sustain against a potentially disastrous situation. It is noticed that their response is non-protective due to denial, fatalism, or wishful thinking. People living in slums in the area under study tend to underestimate the danger due to a lack of experience with landslides.

This aspect hinders preparedness intentions during a possible event. In dealing with uncertain risks, people's acceptability of a hazard and decision-making process is based on directives and information provided by Government bodies and experts. In such cases, less trust in authorities results in lower risk perception.

People found denial mode and did not accept the likelihood of a landslide and its adverse impact. They refused to take any measure to strengthen. Most of the respondents do not have adequate information; the lack of trust in regulatory bodies and experts affects their coping mechanisms. Extreme events such as landslides and floods create hazardous conditions and impact human systems, depending on the existing vulnerabilities in the living environment.

Conclusion

The probability of a disaster unfolds the vulnerability of populations impacting communities functioning and social welfare. The difficulty in improving the capacity of a community to resist landslides is attributed to the inability of people to conceptualize landslides that have never occurred in the area under investigation. People's acceptance of the likelihood of landslides is conditioned by their immediate past, limiting their thought processes. They visualize the future as a mirror of that past. The knowledge and information about such low-probability hazards are to be enhanced to increase the memorability and imaginability to realize their perceived riskiness, irrespective of the evidence.

The frequent occurrences of landslide-induced accidents in urban slums have caused significant damage to life and property in the recent past. This phenomenon warrants architects, planners and local governments to identify and analyze risk areas to manage and prevent such hazards with required emergency planning measures. The resistance of a building against a landslide depends on the physical and geographical aspects of a building. Therefore, to avoid damage and minimize the intensity of a landslide, it is necessary to increase the resistance of buildings.

The physical vulnerability of such a location is to be reduced, considering the magnitude, the impact of a likely disaster on structural elements and exposure values. A building's physical vulnerability is the expected degree of loss due to the impact of an event that depends on factors such as the type of element at risk, its resistance and the presence of protective measures. Such features need to be enhanced to save the disadvantaged population living in slums located on hill slopes.

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