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Sustainability Assessment of Reconstructed buildings in Pheta Municipality - A Case of "Purainiya Village"

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Abstract
In context of Nepal, sustainable house means material adobe in nature, cost effective, structural safety, integration of socio-cultural values of life and incorporates the resistance to disaster which deals with coping capacity of people to response during and recovery after disaster. Storm disaster in 31st march force us to think about various aspects regarding reconstruction of residential building design in Pheta Municipality. Rapid reconstruction in Purainiya without studying the contextual issues and problems bring changes in local architectural style and have effects on the livelihood of the community. Local's perception of traditional houses is changing, people believed that the house is not strong to bear windstorm. Similarly, local authorities and municipality are not concern about the preservation of long age architectural identity regarding material and technology.Materials such as bamboo, wood, earth bags, and rammed earth are sustainable materials for the Terai region and also acts as disaster resistance building materials if they are well treated and improved with modern technology to cope with relevant disasters. Thus, not adopting the benefits of local architecture with improvisation to be wind resilient design result in loss of local identity of case area.In the future,tornado can occur in case area or other regions of Nepal, therefore we have to be prepared for response, recovery, and build back better. The main purpose of this research is to identify and address all these problems of the case area through creation of the guideline for sustainable reconstruction approach for the resilient house design taking the specific case area Purainiya and its integration in the post-disaster reconstruction for case of tornado affected area. On the site, there is a gap in actual requirement of design than provided design and till the date limited research regarding wind resilience design, thus it can light upon the basic understanding of reducing the vulnerability and risk through resilient and sustainable houses.

Keywords
Wind Resilient design, Sustainability, Post-Disaster, Reconstruction, Purianiya

1. Introduction

Nepal, a small but beautiful country with diverse culture and geographical features. The country has three distinct regions Himalayan region, hill region and Terai region with unique characteristics. Therefore, settlements are also according to climate, culture, socio-economic aspects of different region.Yearly, Nepal affected by various disasters such as earthquake,flood, landslides, and recently windstorm (tornado).Thus, to overcome from disaster and its consequences various private organization, NGO, INGO and government are taking step forward for recovery and reconstruction programs. As the reconstruction is concern various effort have been implemented on field but results were not fully satisfied solutions.

In context of Bara, It is greatly affected by storm as the society is vulnerable regarding economy, social structure and limited knowledge. In the building design, these factors should be considered to cope with the risk of the hazards and also need to incorporate the hot humid climate to response positively with environment.Reconstruction of settlement should be contextual thus, social, cultural, environmental and economic aspects need to study for sustainable settlement and wind resilience characteristics for strong house. Though the reconstruction was completed on July 2019, people are in transitional phase because rural setting is not same as before disaster. Hence, this research is an attempt to explore various context based aspects of Puriniya for analysis and evaluation to get better

solution for reconstruction from which relevant recommendation can be drawn for establishing sustainable and resilient community through post reconstruction guideline for tornado affected area.

Purainiya is village development committee and people are marginalized regarding basic needs of livelihood. They have low income and income source are agriculture, abroad basis works (remittance), labour works. According to MR. Zakhir Husssain, Ward Chief of Purainaiya, now total number of populations is 1500 and approximately 320 household number. Total destroyed household number is 88 (63 number of HH totally destroyed and other partially damaged). Similarly, religion of case area is muslim and caste are miya, ansari, dewan, khatoon,teli (shah) and lohar. On 31st March 2019, at around 07:45 pm local time, supercell thunderstorm spawned a tornado in the Chitwan National Park, which swept through the districts of Bara and Parsa in southern Nepal, bringing in severe wind, heavy rainfall, hail and thunderstorm.

2. Problem Statement

Tornado affected the Pheta municipality with greater extent, more than 2,400 homes had been damaged and around 900 flattened to the ground [1].In Pheta,ward no.6, 2 and 1 are mostly affected. Maximum number of deaths(10 people death out of 28) in Purinaiya(ward 6)and maximum number of houses were destroyed in Bharbaliya (ward 1). Reconstruction at Puriniya was done in short period of time and approach for house design is similar to design provided on design catalogue for reconstruction of earthquake resistance houses(two-bedroom house),2015 by “Department of Urban Development and Building Construction”, as every reconstruction is unique similar approach is not suitable for different place.Purainiya is different place with different climate with own socio-cultural value,thus its issues and solution should have thoroughly studied and analyzed. As tornado is first time for Nepal there is no guideline and limited research on wind resilience design.Hence,there is gap between actual house design requirement for community than provided house design. Special consideration should give to wind resilience characteristics for house design, but reconstruction did not incorporate all important aspects and also did not include sustainability assessment for wind resilient design.

3. Rationale

Maximum numbers of death due to unappropriated construction of house with brick, cement and CGI sheet before disaster. Therefore, appropriate design for Purainiya must be design and implemented on site through suitable context based approach.Local people desire for RCC building as they believe that traditional buildings are weak and does not resist storm disaster. It is important to study, evaluate and analyze the reconstructed buildings to prepare sustainability guideline for reconstruction of tornado affected area Purainiya and this can be general baseline to follow for assessment of reconstruction for wind resilient house. Hence, to explore the sustainability dimensions for the residential building of case area, various socio-cultural, environmental and economic aspects will be studied. And other hand, wind resilience characteristic will also study and analyze for safe house to reduce the hazard in future. Therefore,research will help to explore characteristics for wind resilience design, also help to conduct sustainability assessment and explain about impact and damages related to wind disaster. Thus, study partially fulfill the literature gap seen in reconstruction of tornado affected area.

4. Research Objectives

Main objective of research was to prepare guideline for sustainable reconstruction approach for case of Tornado affected area

Specific Objectives:

- To study and analyze the socio-cultural, environmental and economic sustainability of reconstructed building for sustainability assessment of case area.
- To understand scenario before disaster and study design, architectural style, and infrastructure related to reconstructed building.
- To explore the wind resilience characteristics of reconstructed house.

5. Methodology

5.1 Research Paradigm

Research paradigm adopted for study is based on pragmatic as there is more focus on ”what works” rather than objective reality.The ontology of the study

is that reconstruction of disaster affected area Purainiya lack sustainability assessment and wind resilience characteristic are not addressed by reconstruction approach.

5.2 Methodology

Research is explanatory and descriptive in nature. Therefore, strategy required to focus on specific case from wider perspective, so research demand the use of mixed methods. Data types are mixture of qualitative and quantitative.Qualitative data is collected through individual in-depth interviews, direct observation, group discussion using semi-structured and unstructured questions. Whereas, quantitative research includes both field observation and social survey method to understand the phenomena of certain subject and it also obtained from secondary source. The wind resilience factor for house will be studied with literature reviews, which includes structural and non-structural failures of building that need for wind resilient design for sustainable house design and structure analysis through structure analysis tool Etabs 2016. To obtain three specific objective following methods will be conducted:

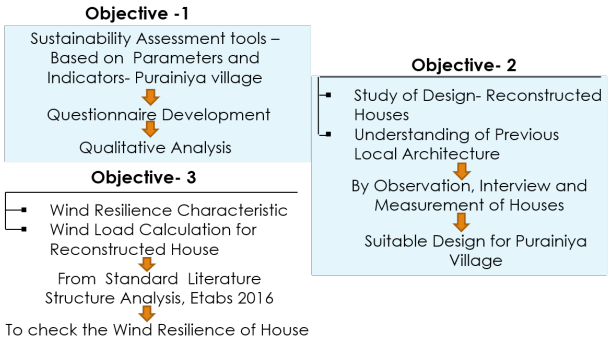

Figure 1: Flow Chart of Working Model to Fulfill Specific Objective

5.3 Research Design

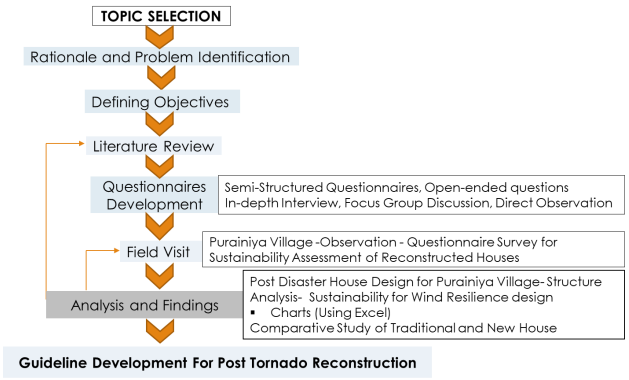

Figure 2: Flow Chart of Conceptual Framework of Research Design

5.3.1 Data Collection Method

Primary data are collected through direct field Observation, household survey,interview with key informant, telephone interview and group discussion. Similarly, secondary are collected by data from Nepal Army, books, journals,government publications reports and websites.

5.3.2 Household Survey

Sample Frame: Sampling frame is the tool from which a sample can be drawn.Sample frame was created considering the major disaster affected village Purainiya for proportionate distribution of building to make it more representatives building of case area. Among the total affected buildings of village 10%-20% sample was taken using statistical table.Data of completely destroyed house numbers in area is 88, thus 15% of sample frame consists of 13.2 numbers sample, thus 13 numbers of sample for social survey in village.

Selection of Indicators: The Indicators were built under three pillars of sustainability i.e., socio-cultural, environment and economic. From the pool of indicators from literature, context specific indicators suitable for sustainability assessment were selected and verified by supervisors. The framework of the research will be generated based on the following list of indicators parameters and their key performance indicators.

Table 1: Indicators Parameters of Socio-cultural sustainability with its key performance indicators

Dimension	Indicators Parameters	Key Performance Indicators
Socio-cultural	Quality of Life	Better services,
		Maintenance- time consuming process
		Social Status
	Indoor environment	Opinion on natural light and ventilation inside all room
	Proximities to facilities	Distance of market, bus stop
		Proximities of Health Centre and School and number of health post within the community
	Comfort	Warm in winter and cool in summer inside the room
	Architecture	Use of local material and construction technique
		Local architectural identity retained or not
		Layout of house -Agricultural lifestyle- functional or not
		Adaptation of future extension without affecting exterior of house
	Cultural Practices	Celebration of festivals and daily lifestyle and way of communication
		New house meets the cultural requirement or not
	Satisfaction	New construction satisfaction- feel that it belongs to you
		Understanding with neighbors is similar as before
	Community Participation	Peoples participation in social activities (Mahila Maitri Surkchit Sthan, club, co-operatives)
		Decision making power in family- both man and woman
		Involvement in decision making regarding design choices
	Disaster Resilience	Wind Resilience Technology adopted in new house or not
		Nonstructural wind resilience characteristic in house considered or not
		Opinion on Resilience of traditional house
	Safety and Security	Strength and stability of New House

Table 2: Indicators Parameters of Environmental and Economic Sustainability

Dimension	Indicators Parameters	Key Performance Indicators
Environment	Healthy Indoor Air Quality	Area of Opening per floor area
		Natural light and ventilation and Insulation
	Climate responsive design	Orientation of house
		Setback all around the house
	Solid waste management	Practices of safe waste disposal
		Habit of solid waste recycle
	Building Material	U- value of materials- wall and roof
		Wind resilience characteristics of materials- Structural and non-structural
		Availability, cost effective/affordability
	Use of Renewable Energy	Cooking fuel
		Lighting and Cooling
		Heating
	Thermal comfort	Indoor temperature˚C
	Access to water supply	Access to drinking water and for irrigation
Economic	Building Adaptability	Affordable, Income Range, Build back
	Maintenance	Need less maintenance than traditional
	Resources Cost	Land, Material and Labour cost
	Sources of Income	Primary and Secondary Income Sources
	Land ownership	Provision of Lalpurja

5.4 Data Analysis and Findings

The analysis has been done based on indicators for case area as mention in above chapter, field observations, measurements and structure analysis of reconstructed house. All the data have been organized and analyzed with the help of charts from excel to get conclusion. Then, required conclusion and recommendations for sustainability assessment of reconstructed house for case area Purainiya will be drawn.

6. Literature Review

6.1 Tornado

According to Glossary of Meteorology, a tornado is 'a violently rotating column of air, in contact with the ground, either pendant from a cumuliform cloud or underneath a cumuliform cloud, and often (but not always) visible as a funnel cloud. For a vortex to be classified as a tornado, it must be in contact with both the ground and cloud bases. Few tornadoes are very distinct to visualize while others are hard to discern, some are very narrow while others are wider than a kilometer[2]. Tornadoes usually occur over land, while hurricanes almost always form over the ocean. A tornado's lifetime is short, ranging from a few seconds to a few hours. A hurricane's life cycle can last from days to weeks. The strongest tornadoes can have wind speeds over 483 kph, but even the strongest hurricanes rarely produce wind speeds over 322 kph [2].

6.2 Traces of Tornado at Bara and Parsa

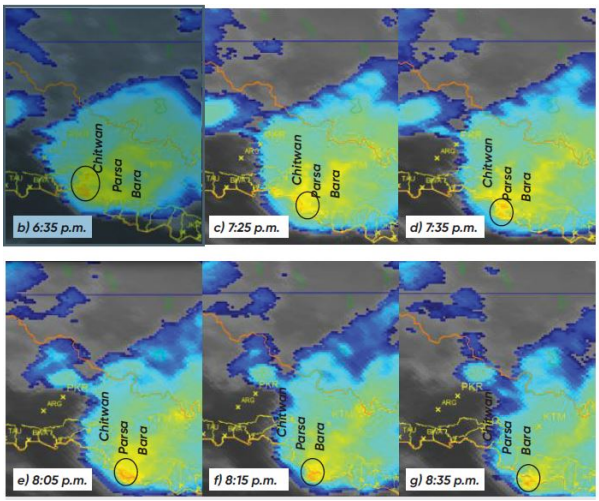

Figure 3: Infrared (IR) images of Himawari-8 showing movement of cloud system from Chitwan district to Bara-Parsa districts. Orange-red color (inside black ovals) represents cooler cloud top temperature and higher cloud top height, indicating strong upward motion and higher storm energy, source:[2]

In case of Bara and Parsa Tornado start from Chitwan and ended to Bara. The infrared images (IR) of Himawari-8 Satellite from 2 p.m. to 8:35 p.m. were used to track the movement of storm associated with the tornado of 31 March 2019 (Figure 8). These images reveal that the storms system that devastated

Bara and Parsa districts was initiated over Myagdi District at around 2 p.m.

6.3 Reconstruction

According to Australia ICOMOS Charter (The Burra Charter) "reconstruction" means returning a place as nearly as possible to a known state and is distinguished by the introduction of material (New or old) into the fabric [3]. The Guiding Principles for reconstruction mentioned below [4]

- "A good reconstruction policy helps reactive communities and empowers people to rebuild their housing, their lives, and their livelihoods.
- Community members should be partners in policy making and leaders of local implementation.
- Reconstruction policy and plans should be financially realistic but ambitious with respect to disaster risk reduction.
- Reconstruction is an opportunity to plan for the future and to conserve the past.
- Relocation disrupts lives and should be kept to a minimum.
- Assessment and monitoring can improve reconstruction must be sustainable.
- To contribute to long -term development, reconstruction must be sustainable.

6.4 Sustainable House

Sustainable houses [5] are those that are designed, built and managed as:

- Healthy, durable, safe and secure, and affordable for the whole spectrum of incomes,
- Using ecological low-energy and affordable building materials and technology,
- Resilient to sustain potential natural disasters and climatic impacts,
- Connected to decent,safe and affordable energy, water, sanitation and recycling facilities and protected from pollution,
- Well connected to jobs, shops, health- and child-care, education and other services,
- Properly integrated into,and enhancing,the social,cultural and economic fabric of the local neighbourhood and the wider urban areas,
- Properly run and maintained, timely renovated and retrofitted.

6.5 General Design Principles for strong Wind Threats

Specific design principles are to be respected to counter the various threats a house may be exposed to. Following are design principles for strong wind [6]:

General design principles for strong wind:

- Break the force of the wind: by means of siting the house behind wind breaking elements such as embankments, dense vegetation etc., or by adding wind breaking elements
- Reduce the number of elements that can hit the house: a vertical root system, ensure that all elements of the house are fixed properly and cannot fly away, reduce the number of other objects that could fly away and hit houses, by storing or fixing them
- Ensure tie down from bottom to top:the house is to be firmly tied to the ground, to avoid it flying off, starting by connecting the roof well to the columns, the columns well to the foundation and anchoring the foundation well into the ground
- Ensure Cross bracing in all planes of the house: All planes of the house are to be equipped with cross-bracing to resist the lateral winds impacting on the house, to avoid the house falling over
- Ensure that wind Pressure cannot build up inside the house: There are two opposite strategies to avoid wind pressure building up inside the house
  - Ensure that wind can flow freely through the house, by ensuring openings on all opposite walls of the house, and by ensuring wind pressure can escape through the roof
  - Ensure that no wind can enter the house, by closing it off completely, including impermeable walling and latched windows and doors

6.6 Sustainability Assessment

Sustainability assessment (SA) is one of the most complex type of appraisal methodologies. Not only this does entail multidisciplinary aspects (environment, economic and social), but also cultural and value-based element. It also supports decision making and policy development in a wider concept.Sustainability assessment is a methodology "that can help decision makers and policy -maker decide what actions they should take and should not take in an attempt to make society more sustainable [7].

Sustainability Indicators (SI): Indicators perform many functions, and which mainly focus on simplification, clarification to make aggregated decision to policy makers. Set of indicators for different countries need be different as it mainly focuses on how to measure, what to expect from measurement, different sustainable development strategies help in creating the framework for indicators. The newly revised CSD indicators contain a core set of 50 indicators and these are obtained from 96 indicators of sustainable development. Similarly, European System of Social Indicators (ESSI) contains a number of housing related indicators such as availability of dwellings, size of dwelling, amenities, affordability of housing, facilities in residential area, environmental quality of residential area,public safety, subjective evaluation of housing conditions and energy consumption.

Elizabeth (2015) mention that sustainable and resilient development principles need to be integrated in design process, so that both sustainable and resilient characteristics can be identified, and tradeoffs can be weighed.To quantify SAF (sustainability assessment framework) resilience and sustainability measures, a taxonomy of measures was developed based on guide documents and technical manuals from the selected SAF tools. In total, 97 resilience measures and 162 sustainability measures were defined within the taxonomy. The measures were organized into two main categories (i.e., resilience and sustainability) and 10 subcategories (i.e., community, structure, energy, water, land/site, material, environment loads, quality of life, economy and others) [8].

6.7 Development of Disaster Resilient Affordable House Design for different Regions Bangladesh

According to article [9] while designing the disaster resilience house following consideration should be incorporated:

- In designing houses, first needs to identify the type and level of hazard then show respect to local materials, technology, local culture, practices and skill of local mason. And, affordability, safety and replicability of the community needs to be high priority.
- In designing and construction of houses, in every region, special attention is given to surrounding environment and sustainable issues by using less material, enhancing durability using effective treatment schemes.

6.8 The Conceptual Approach of Low-Cost Housing for Cyclone Prone Area of Bangladesh

In this article writer explain about the importance of following aspects for LCH for Cyclone Prone Area;

- Baseline for the conceptual approach of “Low Cost Housing for Cyclone Prone Area” that can be implemented in case area for restatement process and participatory approach for success of project.
- To make building wind resilience, it should be tested with structural analysis method a 3d -finite element analysis before reconstruction.
- Design considerations: A four pitched roof is better wind resistance in the cyclone-prone area, diagonal bracing on wall is better resistant to wind, and water content has significant effect on the strength of the wood.

7. Case Study and its Finding

7.1 Understanding of Local Architecture of Purainiya

Traditional building of Purainiya consists of bamboo mat envelop with mud mortar and khapada roof or brick mud mortar, khapada, wood door and brick mud mortar, khar roof as building materials. Use of local material is sign of sustainability in terms of affordability, environmental balance and preservation of traditional architecture and function of lifestyle. On the contrary, khapada need to repair yearly and bamboo mat or brick mud mortar wall need timely repair, maintenance cost is more for local resident and also time consuming according to respondents. But one thing that almost half of the respondents were aware about benefits of local materials that is cool indoor environment in summer. Though, it has benefits regarding thermal comfort and affordability, traditional building like of Mr. Hussaunain Mia Ansari lack the appropriate natural light inside the house. On the other hand , height of building is also not enough for climate of area (only 8’-10” due to limitation in construction technique)

Typical layout of traditional house of Mr. Hussainain Mia Ansari:

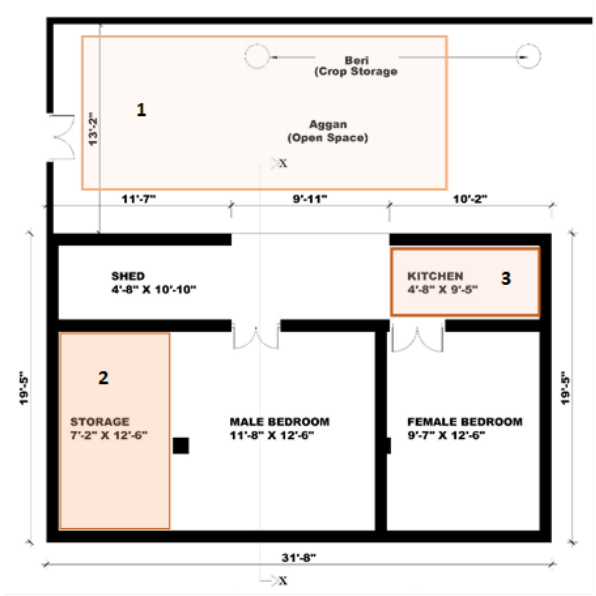

Figure 4: Layout of Traditional Building

Figure 5: Different Spaces of Traditional House, Purainiya

1. Entry Porch of Traditional House
2. Store within room, khapada roof without insulation
3. Semi Open Kitchen at Verandah

7.2 Impacts of Tornado on buildings and losses due to them

Purainaiya have mixed type of houses i.e traditional, fusion and modern. Total household number is 320 and out of 88 damaged houses 63 HH were completely damaged (according to ward chief). Maximum numbers of death (10 out of 28 deaths), because existing houses before storm were constructed with brick mud mortar or brick cement mortar with roof of khapada or corrugated galvanized iron (CGI) or asbestos without proper skill of house construction for wind resistance design. From survey, it seen that maximum houses were of Khapada roof 54% and Cement Brick 39%.

As wind disaster is first time for Nepal local people and mason are not trained or known to technique and detail about connection/ joint detail thus, maximum houses were damage due to weak joint between wall and roof, maximum roof blown away by wind pressure. Similarly, no guideline for reconstruction, structural strength through provision of pillar, sill and lintel band and strong connection between foundation to wall and wall to roof was not considered for wind resilient design before.

In case area, weak points such as weak door, window system, holes and gaps cause damages during the storm due to wind and after the storm through water ingress. Traditional house consists of small opening without window and locking system also weak points from where ingress of wind and water were causes of damages and failure of structure as well.

7.3 Existing Reconstruction Scenario and Design of Reconstructed House

There are five main plans (A, B, C, D and standard type) for reconstruction at tornado affected areas Bara and Parsa districts. General plan layout with semi opened small kitchen with verandah at entry, two medium size rooms, and one toilet of standard type house seen in Purainiya village.

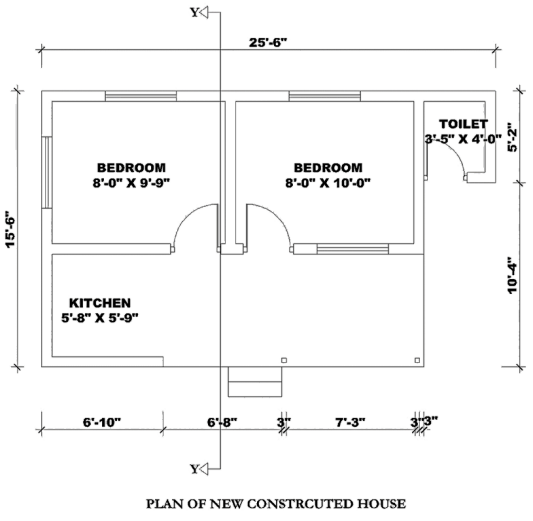

Figure 6: Plan Layout of Reconstructed House

7.3.1 Real issues on Purainiya regarding Reconstructed houses

- Not concerned about orientation and layout of the house but they need big spaces for living and economic structure is main reason that they are satisfied with reconstruction
- They construct extra room or house to fulfill the requirement of spaces and kitchen space not utilized for cooking purpose but used for other works as mud stove causing smoke
- Lack of quality workmanship due to rapid construction, misuse of house as storing the bike and other purposes due to presence of RCC house, toilet not used in many house due to less capacity of soak pit for big family
- No communication between government and local community.
- Loss the essence of Local Architecture ;Mud mortar brick/bamboo construction and khapada roof, use of new materials for reconstruction
- Most essential factor, "wind load" which is not considered in reconstruction
- Partial damages in the site were compensate with certain fund provision, which is not appropriate solution, there must be awareness and knowledge among local community regarding repair or restore the house with wind resilience characteristics to avoid further damages in future.

8. Analysis and Discussion

All the selected indicators for assessment of reconstructed houses, infrastructure and surrounding of Purainya were thoroughly analyzed. However, few major indicators have been included below:

8.1 Analysis of Socio-cultural Dimensions

Quality of life: New reconstruction brings certain level of quality in their life, but more than half respondents does not feel any change in social status due to house and some believe it bring certain upliftment in their lives, as shown in chart below. All respondent said that house consume less time for maintaining the house than bamboo mat wall construction, i.e. mud mortar coating on wall in certain time interval and repair of khapada, which result in free time for other productive work. All reconstructed houses have toilet, few respondents out of 13 shows dissatisfaction regarding toilets capacity. Furthermore, 54% houses don't have provision of open drainage and there is no provision of pipeline for drinking water, use hand pump for water resources. Therefore, quality of life in Purainiya is partly sustainable.

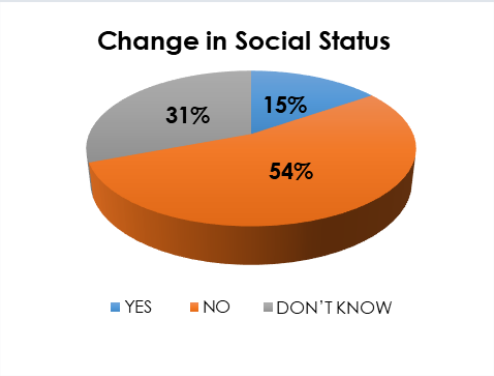

Figure 7: Change in Social Status due to House

Proximities to facilities: In case area services and facilities are not sufficient and existing situation can entail the degrade state of community. Unpaved roads of the village cause difficulties in the traveling to different places.They have to travel farthest distance of 1.25km (25-40 minute by foot) to reach tempo station at Pheta and bus stop at main road. For market area and bank, they need to go to Pheta marketplace or Kalaiya market, which is 1.1km (25 minutes) distance from core settlement. There are two banks one Global IME and other is NIC Asia and only one public school i.e Shree Nepal Rastriya Prathamik Vidhyalaya used as community spaces for gathering and discussion. Due to poor quality, children goes to Pheta for private education, mainly male, female goes to Madarsa (religious place for education-Masjid) to learn Urdu. Establishment of one health post within community after disaster but not efficient , they depends upon hospitals at Birgunj and Kalaiya.

Architecture: Identity of community lies within the architectural style, daily lifestyle, ritual, culture, social values or belief.Local architecture of Purainiya is sustainable with use of local material and technique, which are familiar to them. And function of house is agriculture based including spaces like shed for livestock,and grain storage space and other. Material (concrete hollow brick, steel, insulated puff sheet and UPVC door and windows) used for reconstruction are imported from outside not local, thus not known to local people and mason. High cost and carbon footprint through long travel distance made these materials unsustainable and require skill manpower from Birgung or Kalaiya if they have to build this

house again. Loss of the local architectural style with introduction of completely new architecture.

Disaster Resilience House: To evaluate the layout of house design, it lack safe room, which is enclosed room to protect people from wind disaster.On the other hand, local's perspective regarding traditional house is changing, they believe that it is weak as they faced so much damage during storm and RCC construction is stronger. Responses regarding opinion about strength of "Traditional House",30% respondents said can improve, 30% said can't improve and 40% said don't know. Knowledge and awareness play key role for understanding about advantage of traditional architectural style but,local people are not aware about it's benefits. Adopting local architecture with innovation in technique can preserve the identity and can be wind resilient as well.

8.2 Analysis of Environment Dimension

Healthy Indoor Air Quality: According to NBC 206 code the area of opening for habitable room must be minimum 1/8th of the room area and for toilet natural ventilation must be 1/16th of toilet area. Above table shows the floor area and opening area in reconstructed house is sufficient for each room and within standard. And for toilet natural ventilation is also according to standard. Each room have two windows which are sufficient for natural day light and no provision of separate ventilation. All respondent said natural light and ventilation is sufficient.

Table 3: Calculation for sufficiency of light and ventilation in Reconstructed house

Room	Floor area ratio in square foot	Area of opening in square foot	Opening to floorarea ratio
1	78	32	0.41
2	80	32	0.4
Toilet	13.68	4	0.29

Climate responsive design: Another important aspect is orientation of house, in Terai. Long side wall of house should be faced north south, overhang on south and west side for diffuse light inside the house. As shown in chart in Figure 8, orientation of reconstructed houses are random.

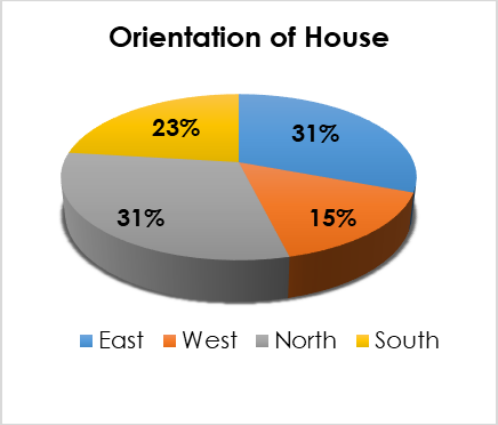

Figure 8: Orientation of Reconstructed Houses

Building Material: Following table shows the U-value and embodies energy of materials use for reconstructed houses. Both wall and roof material have low U-values, means slow heat transfer and better indoor environment.

Table 4: Building Material and U-value and embodied energy

Description of Material	Reconstructed House	U-Value (W/m2 -K)
Material for wall	Hollow Concrete Block	0.43
Material for roof	Insulated Puff Sheet	0.297

Despite of thermal comfort characteristics of these materials, essential factors such as affordability, cost effectiveness and availability of these materials are not sustainable. Because materials are not locally available, high cost, long travel distance to reach site and disposal after use are also doubtful.These material can be wind resilient with proper training for local mason and structure analysis of materials to check the strength for wind resistance characteristics, which assumed to be not done in Purainaiya. And, non-structural members also need to carefully design, construct, such as windows, doors and other parts. Construction technique can enhance the strength of materials therefore, careful consideration should given in construction phase but ignored during reconstruction. Thus, wind resilience characteristic of materials is partly sustainable.

8.3 Analysis for Economic Dimension

Source of Income: From chart below, it's clear that the maximum numbers of local are active in tailoring and services. Least number of people depend upon agriculture, driving and cutting tree. Local people are

shifting their economy from agriculture to other works such as services, labour work at abroad are result of various issues such as rental farming land, lack of new technique of farming training and knowledge causing low profit in agriculture. Therefore, government should encourage local people with training, provision of seed, incentive for promotion for better income opportunities and upliftment of livelihood of people. Aboard basis work for should be minimized to develop community and country.

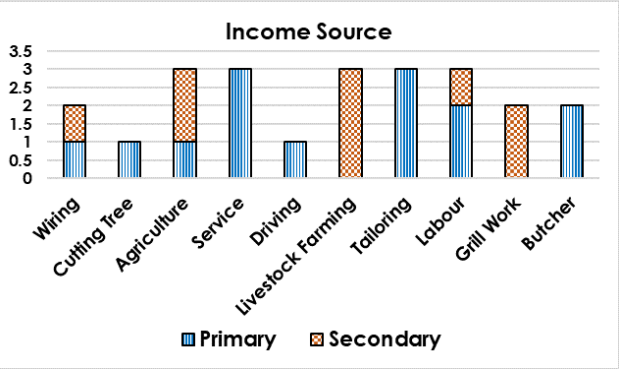

Figure 9: Income source of Local People of Purianiya

Building Adaptability: Responses from field shows that less than 46% people have average 20,000 to 50,000 income, 39% have less than 20,000 income range and difference are not huge. And family size is also large with less number of employed members. These are reason that local people don't have confidence to build back by own. Among total respondent 77% people said they cannot build the house on their own in future.

Resource cost: Cost of Land: 20 Lakh per Katha and labour Cost: 600 per day. The cost of new house for constrcution is not affordable for local, and if they have to build the house by their own, the cost of house will be increased than 4 lakh 82 thousand, because materials and technique are not locally available and need skilled mason.

8.4 Wind load calculation for Wind Resilience of Reconstructed House:

As far as wind load or pressure is concern, it seems to be neglected due to rapid reconstruction to provide shelter for people of Purainiaya village. To check the strength of reconstructed houses, structure analysis was performed. thus, structure analysis was performed for through the help of Etabs 2016 with particular wind pressure (equal to tornado). Following are calculation for wind load; F = (Cpe – Cpi)x A x Pd,

In reconstructed house, hollow concrete block use as building envelope, insulated puff sheets for roof covering and truss of 2" X 2" square pipes for purlin and 1.25" x 1.25" square pipes for struts and rood ties on steel square post (3"x3") of column

Type of slope and building: Access is not provided to sloping roof

Terrain categories: Open terrain with well-scattered obstruction having height generally between 1.5m to 10 m

Building/ Structure Class: Structures and or their components such as cladding, glazing, roofing, etc, having maximum dimension (greatest) horizontal or vertical dimension less than 20 m.

Now, from the structural analysis of the reconstructed house, results are found, they are as following:

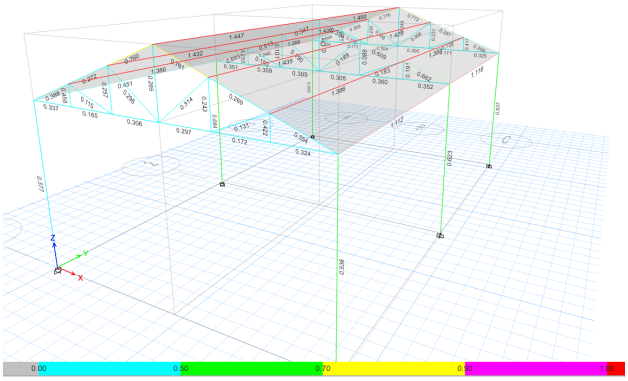

Figure 10: P-M Ratio (Shear Moments on Truss Members) of Failed Structure, source: Structural Analysis on Etabs 2016

8.4.1 Finding, Analysis and Discussions from Structure Analysis

Assuming 58 m/s wind speed as basic wind speed, considering tornado. From the structural analysis (etab 2016), results show that structural member (purlin) of reconstructed house pass in strength but fail in deflection, therefore structure failed.

From the analysis result, there is need to increase the size of purlins and similarly, to support the purlin, column size also needs to increase respectively to get safe structure in wind pressure of 182 km/hr to 246 km/hr (51 m/s to 68 m/s). Hence, it shows that reconstruction was done without wind load calculation of building. Sustainability always seek to address the safety of house; therefore, high priority

should give to wind load calculation by structure analysis using analysis tool (i.e. Etabs 2016) after the finalization of design as it decide whether design can resist the wind pressure or not. Permissible shear force-moment ratio for structural elements should be less than 1 that can be seen in result with appropriate section of purlin, post, rafter and struts. Since, lateral force by wind is much higher than the seismic forces on one storey structure of such dimensions, therefore seismic design is neglected.

On the other hand, strong joint connection between roof, and wall, wall and foundation are also important for strength of house and non-structural members also play important role to enhance the wind resilience characteristics of house. These consideration also important for reconstruction. Figure 11 explains about the mistakes in construction:

Figure 11: Mistakes during construction phase, site observation

- Circle symbol:Joint point of strut and rafter
- Square symbol:Joint point of purlin and rafter

1. Just projection from wall no proper connection on toilet truss, require additional connection to support roof panel.
2. Purlin should rest on joint of strut (normal to Rafter) for uniform load distribution.

8.5 Analysis for achieving Wind Resilience:

- Tree plantation around the cluster of settlement. Heap of mound around the settlement can provide certain degree of protection during storm.
- Most preferable shape for case area is round to deflect maximum amount of the wind on surface of house envelope, however it is not functional. Therefore, simple rectangle or square shape house without any projection is best for Purainiya. Irregular shape, longer structure needs to avoid and need to keep the shorter sides of the house facing the most critical wind direction, ratio of house shape should within be 3:1 ratio.
- Good governance is important factor for sustainable community. Purainaiya should be well prepared to promote and implement the proper byelaws or related policy, which focus on preparing building guideline including wind resilience for reconstruction or construction of building for case area.
- Introduction of innovative and improved technique of construction (modifying the traditional technology with modern technique for strong and stable structure).
- Use of CSEB (compressed stabilized earth brick) instead of concrete block can be better sustainable. It is wind resilient material as explain in article by [10] and similarly, more resilient and sustainable roof should be explored for wind resilient construction.
- Inside the house there should be provision of safe room to protect the people during storm hazard, if there is no possibility of providing wind resistance building

8.6 Scale of Sustainability

Based on responses from questionnaire survey and standard from literature review for sustainability of community through wind resilient design is analysed and expressed in chart to get findings or results for Puriniya village. Analysis of sustainability assessment regarding socio-cultural, environmental and economic dimensions were taken total 22 indicators parameters. And for sustainability measurement criteria of house divided into three categories low sustainable, medium sustainable and high sustainable. These categories were analysed in the scale of 3 ranges of percentages, which are 0%-33% and 34%-66% and 67%-100%. Beside questionnaire survey and in-depth interview, various other methods such as measurements, observations, standard literature and wind load calculation through ETABS for data analysis were key considerations for further analysis to get results.

8.7 Result from the Analysis

8.7.1 Socio-cultural

According to result from analysis as shown in table 5, among 25 key performance indicators, 4 indicators are high sustainable, 12 indicators are medium sustainable and 9 are low sustainable in socio- cultural dimensions

8.7.2 Environmental

According to result from analysis(table 6), among 14 key performance indicators, 6 indicators are high sustainable, and 8 are low sustainable in

Table 5: Result of Socio-cultural Analysis Dimension

Parameters	Key Performance Indicators	Results
Quality of Life	Better services,	**Medium Sustainable**: In two houses, they have combined toilet, and other houses have individual toilet but not enough size septic tank for sewerage and provision of open drainage
	Maintenance- time consuming	**High Sustainable:** Less time consuming than in old house
	Social Status	**Low Sustainable:** 15% people feel change in social status due to house
Indoor environment	Opinion on natural light and ventilation inside all room	**High Sustainable:** 100% people feel enough light and ventilation inside the house
Proximities to facilities	Distance of market, bus stop	**Medium Sustainable:** 21- 40-minute distance by foot
	Proximities of Health Centre	**Low Sustainable:** Above 40-minute distance by vehicle
	Proximities of School	**Medium Sustainable:** 21- 40-minute distance by foot
	Number of health post within the community	**Medium Sustainable:** At least one health center inside the community
Comfort	Warm in winter and cool in summer inside the room	**High Sustainable:** 77% people feel warm in winter and 46% feel cool in summer
Architecture	Use of local material	**Low Sustainable:** Imported and expensive material
	Construction technique	**Medium Sustainable:** If they have to build this house, local mason can build but they don't have enough skill
	Local architectural identity retained or not	**Medium Sustainable:** Retained some elements of traditional architecture, layout is similar to old house.
	Layout of house -Agricultural lifestyle	**Medium Sustainable:** Same as old but not functional, some use the house for bike storing, kitchen used outside the house, extension of spaces seen in many houses
	Adaptability regarding future expansion	**High Sustainable:** 31% houses change the layout of house, but other people have plan to change layout
Cultural Practices	Celebration of festivals and daily lifestyle and way of communication	**Medium Sustainable:** Some space is functional for daily lifestyle and communication
	New house meets the cultural requirement or not	**Low Sustainable:** Does not meet the cultural requirement
Satisfaction	New construction satisfaction- feel that it belongs to you	**Medium Sustainable:** Less belonginess than previous house
	Understanding with neighbors	**Low Sustainable:** 31% people said good as before
Community Participation	Peoples participation in social activities (Mahila Maitri Surkchit Sthan, club, co-operatives)	**Medium Sustainable:** Maximum male participation and few female start participation
	Decision making power in family	**Medium Sustainable:** In absence of male, female make decision in family in some houses.
	Involvement in design choices decision making	**Low Sustainable:** Local not involved in decision making regarding design choices
Disaster Resilience	Wind Resilience Technology adopted or not	**Low Sustainable:** No provision of safe room and no structure analysis
	Non-structural wind resilience characteristic considered or not	**Low Sustainable:** No strong Joint Connection and holes/ gaps in between wall and windows or doors, bad window/door locking system
	Opinion on Resilience of traditional house	**Low Sustainable:** 30% people said strength traditional house can be improved
Safety and Security	Strength and stability of New House	**Medium Sustainable:** 31% people worried about workmanship and its consequences

Table 6: Result of Analysis, Environment Dimension

Parameters	Key Performance Indicators	Results
Healthy Indoor Air Quality	Area of Opening per floor area	**High Sustainable:** All room have area of opening within 1/8th of the room area (Acc. to NBC 206 code standard)
	Natural light, ventilation and Insulation	**High Sustainable:** 100% people said light and ventilation are sufficient and its comfortable inside through appropriate insulation on wall and roof
Climate responsive design	Orientation of house	**Low Sustainable:**31% houses have longer side North-South
	Setback all around the house	**High Sustainable:** 100% Setback all around the house
Solid waste management	Practices of safe waste disposal	**Low Sustainable:** Burn the solid waste for disposal, and through wastewater in open drainage and open area
	Habit of solid waste and wastewater recycle	**Low Sustainable:** 0% of people practice -compost/recycle /reuse for waste management
Building Material	U- value of materials- wall and roof	**High Sustainable:** Low U-value of wall and roof material
	Wind resilience characteristics of materials-Structural and non-structural	**Low Sustainable:** No Strength check through structure analysis, not skill mason for construction of house
	Availability, cost effective/affordability	**Low Sustainable:** Use of imported, expensive materials-contribution in carbon footprint
Use of Renewable Energy	Cooking Fuel-for cooking	**Low Sustainable:** Maximum house use, firewood for cooking
	Lighting and Cooling	**High Sustainable:** 100% houses use electricity
	Heating	**Low Sustainable:** 100% houses use firewood
Thermal comfort	Indoor temperature˚C	**High Sustainable:** 100% people feel comfortable inside
Access to water supply	Access to drinking water and for irrigation	**Low Sustainable:** For drinking water used ground water table and use it without filtration and for irrigation use 20 feet deep ground water table.

Table 7: Result of Analysis, Economic Dimension

Parameters	Key Performance Indicators	Results
Building Adaptability	Affordable, Income Range,	**Medium Sustainable:** 46% Family with monthly income between 20,000 -50000
	Build back by owner	**Low Sustainable:** 23% people said they can build by own
Maintenance	Need less maintenance than traditional	**High Sustainable:** Can easily maintain house yearly
Resources Cost	Land, Material and Labour cost	**Low Sustainable:** All said not affordable
Sources of Income	Primary and Secondary Income Sources	**Medium Sustainable:** Income based on Services outside the proximities of area
Land ownership	Provision of Lalpurja	**Medium Sustainable:** More than half houses have Lalpurja out of 63 destroyed houses, 41 houses with lalpurja were reconstructed

environmental dimensions analysis.

8.7.3 Economic

According to result from economic analysis(table 7), among 6 key performance indicators, 1 indicator is high sustainable, 3 are medium sustainable and 2 are low sustainable.

9. Conclusion

Reconstruction approach for post-disaster reconstruction is the most essential aspect to understand the level of hazard, need, requirement, various other dimensions of sustainability and it can be different for different regions or countries. Similar approach may not work for different regions and disasters. Therefore, in the case of Purainiya post-disaster reconstruction must integrate sustainability and resilience. Better implementation of reconstruction should guide by sustainability assessment including wind resilience characteristics for wind resilience design. Wind resilience design for the house is the most desired solution for reconstruction at case area.

In conclusion, reconstruction approach for tornado affected area need to be done according to requirement and need of people and their involvement in decision making for design choices, use of local material and mason with innovative technique of construction, affordability, social structure, strength of house regarding wind load (using structure analysis of finalized design), other characteristics such as non-structural members impact during disaster and various strategies to make house wind resilient regarding planning of settlement, shape and size, consideration in byelaws for proper implementation. Above all, preparation of guideline to follow for quality assurance regarding wind resilient design implementation as it is the most crucial phase in reconstruction.

10. Recommendation

10.1 Wind resilience design

- Reduce vulnerability: Careful assessment and preparation before reconstruction and use of local material and technique with improvisation in strength through various technique.
- Structure analysis of building after design finalization.
- Incorporation of wind resilience characteristics; Planning of settlements, shape of building, proper byelaws or guide to follow and considerations for structural and non structural member.

10.2 Socio-cultural

- People centered approach: People Participation in decision making
- To avoid the segregation in society ; Proper byelaws or rules for construction, maintenance and monitor for residential building
- Preferred choice in design; Acoording to economic status, basic need, family size, socio-cultural values
- Need inclusion of agricultural function: Storage of grain, space for livestock
- Understanding about cultural values of local lifestyle; architects/engineers/technical facilitators must aware about these important aspects
- Preservation of Architectural identity and consideration for future extension; Need proper ”Guideline for Wind Resilient Design”

10.3 Environment

- Need to promote local material and technique to reduce carbon footprint with the provision of byelaws or code
- Must consider orientation, window size, overhang on south side (Hot climate)
- Improvement in infrastructure for better livelihood and water treatment, recycling and rainwater storage for dry season
- Waste management through segregation of waste, composting, reuse of things

10.4 Economic

- Most essential dimension for case area; Improvement of local economy by focus on agriculture not remittance (abroad basis work)
- Low cost house with structure analysis; contextualized according to need of local

10.5 Guideline for Reconstruction of Tornado affected area

10.5.1 Basic framework for reconstruction

Sustainable reconstruction need to follow certain steps in different phases, such as before reconstruction, during reconstruction and after reconstruction. These are shown in following tables:

Table 8: Phase 1- Before Reconstruction

Before Construction	
Understanding the issues and problems- socio-culture, environment and economic dimensions related to community through sustainability assessment	Resources for sustainable livelihood, socio-cultural structure, healthy environment variables, economic stability safety and security related to house and architectural features of community.
Exploration and knowledge regarding wind resilient design and characteristics	Structure analysis of design, consideration for adopting wind resilience characteristic for residential building, attaining safety reading non-structural members such as joint connection avoiding hole or gaps, strong locking system for door and windows, durable door and window.
Preparation of sustainability framework for wind resilient design	Both sustainability and wind resilient characteristics need to be integrated for reconstruction of post tornado affected area
Execution of Assessment	Detail assessment of society and house, includes questionnaire survey, individual interview and group discussions, observation, measurement
Strategy for better implementation of design-preparation of guideline for reconstruction (Byelaws or regulation)	Preparation of Byelaws for reconstruction is must - People centred approach for guideline, as people know their needs and requirement better. Communication between government, international or national organization and community should be established throughout the process.
Decision for approval of house design	Local people should involve in decision making for design choice with technical facilitators, architects and engineers. Awareness among local people to about wind resistance design and benefits of local architecture.
Establish the building code or building regulation for wind resilience design	Structural analysis -Strength testing should be done for wind resilience design- Wind resilience characteristic for design (shape, joint connection, planting around the settlement) -provision of at least safe room inside the house.
Provision of temporary shelter	Need to build the temporary shelter for time period of reconstruction to assure safety and security of affected people.

Table 9: Phase 2 and 3- During Reconstruction and After Reconstruction

During Construction	
Good Quality Material for construction	Use of Sustainable and Wind resilient and Affordable material
Technical supervision and monitoring	To assure the implementation of correct design and quality assurance during construction - to follow up the regulations or code provided for wind resilience design
After Construction	
Monitoring committee for maintenance of house and surrounding.	Local committee should take charge for maintenance of reconstructed building – timely monitoring for maintenance of house and surrounding – criteria for future expansion, sanitation and drainage, infrastructures and other characteristic for wind resilience through planting.
Technical supervision and monitoring	To assure the implementation of correct design and quality assurance during construction - to follow up the regulations or code provided for wind resilience design
Revision of rules and regulation or byelaws for reconstruction from project experiences	After the completion of reconstruction, there are many experiences negative and positive, thus accordingly revision of rules and regulation for preparation of guideline- must be implemented in rules or regulation if positive and must eliminate the criteria which result negative impact to avoid mistakes in reconstruction

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References

[1] Sabina Shrestha. Nepal storm: Entire village mourning 'but for others, it is a festival'. www.aljazeera.com, 4 2019. https://www.aljazeera.com/blogs/asia/2019/04/nepal-storm-entire-village-mourning-festival-190404071315807.html.

[2] Archana Shrestha, Dhiraj Pradhananga, and Jagadishwor Karmacharya. Report on bara parsa tornado. Technical report, Government of Nepal Department of Hydrology and Meteorology,ICIMOD,Small Earth-2001, 6 2019.

[3] The Burra Charter. The australia icomos charter (the burra charter) for the conservation of places of cultural significance. www.gdrc.org. http://www.gdrc.org/heritage/icomos-au.html.

[4] Abhas K.Jha, Jennifer Duyne Barenstein, Priscilla M. Phelps, Daniel Pittet, and Stephen Sena. *Safer Homes, Stronger Communities, A hand book for Reconstrcuting after Natural Disasters*. The World Bank, 1818 H treet NW, Washington ,DC 20433, USA, Washington DC 20433, 2010.

[5] Oleg Golubchikov Badyina and Anna. Sustainble housing for sustainble cities, a policy framework for developing countries. Technical report, UN-Habitat, Nairobi, 2012.

[6] Housing, Ministry of Housing Building Research Institute, and Public Work. Standard guideline for rural housing in disaster prone area of bangldesh. Technical report, Housing and Building Research Institute,Ministry of Housing and Public Works,Government of the People's Republic of Bangladesh, Dhaka, Bangladesh, 2 2018.

[7] Serenella Sala, Biagio Ciuffo, and Peter Nijkamp. A systemic framework for sustainability assessment. *Ecological Economics*, pages 314–325, 2015.

[8] Elizabeth Chisolm Matthews. Integrated sustainability and resiliency assessment methodology for the design of single-family residential structures subject to wind and flood hazards. 2015.

[9] Mohammad Shariful Islam and Tahsin Reza Hossain. Development of disaster resilient affordable house design for different regions of bangladesh. *Research Gate*, 2017.

[10] Ece Erdogmus, Benjamin Wagner, Linsey Rohe, Eric Garcia, Avery Schwer, Fabio Matta, and Esther Obonyo. Design of compressed stabilized earthen wall systems for high-wind resistant residential unit construction. In *AEI 2015*, pages 409–420. 2015.