RESILIENCE BUILDING AGAINST EARTHQUAKES *in traditional settlements of Kathmandu Valley*

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Abstract

The Kathmandu valley communities have been facing earthquake disasters once in every 75-100 years. The architecture and settlements in Nepal have responded to earthquakes of both small and large magnitude through the use of indigenous technology. Many of them still remain intact to their shape and size. In the last 150 years however, architecture has been increasingly shaped by external influences rather than by local realities. The use of modern construction materials has arguably not abated the increase in physical, social and cultural vulnerability. The paper is the outcome of community-based participatory research. The paper argues that the socio-cultural attributes are key variables in the resilience of communities to these natural disasters.

Key Words: Resilience, Disaster, Vulnerability, Assessment

I. Introduction

Communities in the Kathmandu valley of Nepal have dealt with earthquake disasters since time immemorial. Written records of earthquake events date back to 1223 A.D. with frequency ranging between 75-100 years or every three to four generations on the basis of historic records. As a result, residents have adapted their residential and public architecture in ways that increase resilience to both large and small tremors (Pujari and Marahatta, 2010). For example, flexible construction of mud, brick and timber limit the failure of buildings as well as increase the reusability of materials. Over the past one hundred and fifty years, however, building technology has been increasingly shaped by global and western influences (Ranjitkar, 2006). The use of the non-local building materials and technologies including cement mortar, metal sections and solid concrete has arguably led to injury and mortality. Because of lack of proper knowledge and discipline of non-local building materials and poor construction supervision, present day structures are presumably vulnerable. This vulnerability is linked with increment in injuries and mortality. Other pivotal aspect is in the uses of these materials and construction technology. There are less or non scope of reuse of such materials in post-disaster scenarios. There is a need to address the issue of limited capacity for rebuilding and other aspects of socio- economic recovery. At the same time, the distribution of financial, human and capital resources needed to cope with earthquake-based disasters is becoming increasingly uneven particularly in the traditional city of Patan of the Kathmandu Valley. This research explores social-ecological resilience to earthquake hazards based on an analysis of the socio-economic and cultural profile of 256 households in the five wards of Patan and on a structural assessment of their built environment (household residences, neighborhoods). This inquiry is not only relevant to this case study but has implications on our understanding of the impacts of earthquakes in other places as well. Scientific evidence on patterns of seismic activity suggest that the occurrence of a major earthquake has long been overdue in this and other highly populated areas of what is geologically described as the "Himalayan Arc". With the aim of contributing to policies and programs for managing earthquake hazards, the results of the study provide evidence on how household capacity and the condition of the built environment are interrelated. This social-ecological perspective can augment our understanding of household resilience or vulnerability to earthquake hazards.

II. Literature Review

There has been significant research related to the impacts of earthquakes or seismic events on many regions of South Asia. Most of these works of the past have highlighted the role that architecture plays in influencing hazard outcomes with only recent attention turning to issues of social and economic vulnerability. This study is influenced by previous research on the combined ways in which the physical environment, social norms and economic conditions create a particular "seismic culture"

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in which certain groups may be more or less vulnerable to hazards (Halvarson and Hamilton, 2007). In the neighboring mountainous regions of India, Pakistan, Afghanistan, it has been noted that “diminishing levels of indigenous hazard knowledge, demographic shifts, gendered livelihood transformations, and the lack of public access to science-based earthquake information have contributed to overall low levels of seismic cultures of prevention in the region” (Halvarson and Hamilton, 2007). In Nepal specifically, there is growing awareness and concern about the vulnerabilities created by modern or non-indigenous architecture and the impacts of household poverty on hazard outcomes (Jimmi, 2006, Maskey, 2009, Lagenbach, 2002, Jigyasu, 2000). These concerns have ranged in inter-disciplinary methodological approach. One of such approach is in-depth interviews with key informants which provide a very detailed perspective on the role of traditional knowledge in Nepalese architecture. Often, contemporary research and analysis have been based on digital satellite imagery (HAZUS) due to the consequent lack of information details available for correlating household level socio-economic data and built environment conditions (Jimmi, 2006).

The socio-economic vulnerability of Nepalese residents as well as the physical vulnerability of buildings is changing as a result of a range of socio-political factors.

III. Problem Setting

A. Study Area

The first recorded earthquake in Kathmandu Valley of Nepal was on December 24, 1223 (Marahatta, 2009, Pant, 2002). A subsequent earthquake in June 1255 led to the demise of reigning King Abhaya Malla and loss of significant life and physical property in the valley. This earthquake toppled many houses and temples claiming one third of the population (Pant, 2002). There are records of earthquakes in Nepal in the year 1260, 1344 (claiming life of reigning king Ari Malla), 1408, 1681, 1767, 1808, 1810, 1823, 1833, 1834, 1837, 1869, 1897, 1917, 1934, 1936, 1954, 1966 and 1988 AD. All of these events have resulted in considerable damage to life and property in the Kathmandu valley. To understand resilience to such hazards in the contemporary context, it is important to understand aspects about the social setting of the Kathmandu Valley, and the built environment including the architectural history of the region.

Patan is a major part of Lalitpur Sub-Metropolitan City (LSMC) located in the south-western area of the Kathmandu valley of Nepal. According to Central Bureau of Statistics of Government of Nepal (2001) the total population this Sub-metropolitan City is 162,997 with 84,208 males and 78,789 females in 35,000 households. It is very well known for its rich cultural heritage including complex architectural history. There are 22 wards in the Sub-metropolitan City. The case study area contains wards located in the east and central region of the city: wards 11, 12, 7, 8 and 9 (Figure 1). This was considered as the case study area for the research given that it contains some of the oldest and most recent architecture in Patan, with the oldest water spout dating back to the 6th century and the most recent buildings constructed in the last five years. Such old and new buildings are not randomly distributed. As in many cities in the region, architecture in Patan falls generally along a gradient with the oldest buildings located in the centre and the newest along the periphery.

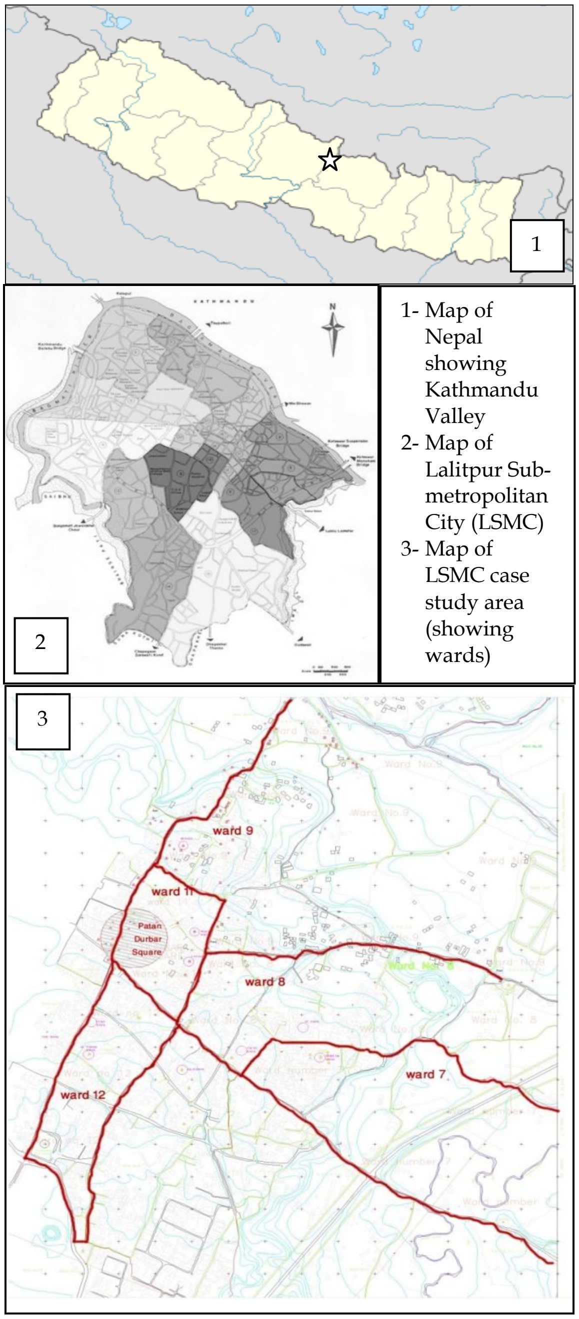

Figure 1. Maps of Wards of Lalitpur Sub-metropolitan City in Kathmandu Valley, Nepal

The oldest architecture in case study area successive ruling dynasties: *Patuko* palace of *Kirat* dynasty,stone pout and inscriptions of the Licchavi dynasty, *Biharas, Bahals* and *Bahils* as well as religious temples of *Malla* dynasty. Similarly, the case study area contains several *Rana* period architectural elements, many of which were renovated after the great earthquake of 1934. The most recent architecture belongs to those people who have migrated from the rural areas to the urban centers. While this is a general pattern, there are variations in the ways that buildings are constructed and renovated and in the profile of residents living in the various settlements. Several lines of evidence show that one or more large earthquakes may have long been overdue in a large fraction of the Himalaya, threatening millions of people in that region.

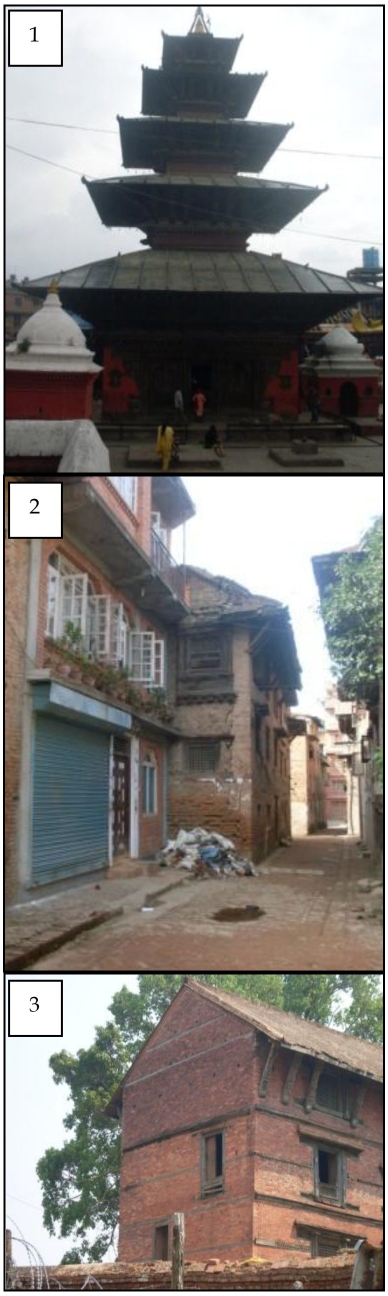

Figure 2. Contemporary architectural types of Kathmandu Valley

(1) Ancient Brick in mud mortar with more than 3 storeys (top) and less than 3 stories (bottom).

(2) Intermediate Brick in cement mortar with more than three stories (front) and less than three stories (back).

(3) Contemporary -RC technology

B. Changing History of the Built Environment of the Patan Region

The built environment is the key to understanding the impact of earthquake events on people in the region. It is through the impacts on buildings that people are most severely affected. It is said that earthquakes do not kill people, rather ill structures do. Previous research on architecture in this region suggests that Nepal's early architects and leaders understood this reality and built their communities and homes accordingly. Through flexible materials and building mechanisms, many of the older buildings in Nepal have withstood multiple earthquakes (Tiwari, 1998). Contemporary architecture conversely tends to be less flexible due to rigid construction systems and materials used.

According to the available data, buildings in Kathmandu could be classified into several types (Figure 2). Traditional buildings constructed from the 6th to 16th century are characterized as having 1-2 stories (excluding *Baiga*: the attic) with load bearing walls made of brick and mud mortar with timber ties and wedges. Where there are taller buildings (greater than 2 stories) they are constructed with thicker walls (1-3 feet) on the main floor with reduced thickness on upper floors. Timber floor joists, struts, wall ties, double framing of window and door openings are common. More recently, timber has been replaced by steel and mud has been largely replaced by the cement mortar which has led to the construction of taller buildings with similar wall thickness.

During the intermediate period, architecture was increasingly influenced by European cultures and institutions. Buildings began to be constructed with steel beams rather than timber beams; sheet metal roofing was introduced and plastering and pointing became common. This led the architecture to imitate the style unknowing the material discipline. This style was adopted by ruling families, aristocrats and some noble families.

Buildings made after first democratic movement in Nepal (period: 1960- 1990) adopted the architecture where structural system was still load-bearing in replacement of mud mortar with cement mortar. Likewise, in this system, the timber joists and floors were replaced with concrete slabs. With such construction details, there appeared the limited anchorage to load bearing walls and consequently lateral movement was common.

Those building constructed during 1990s and after are often made of reinforced concrete or RCC. In such cases, the wall no longer bears the load as in previous types. This technology largely relies on the column, beam and slab for the load transmission where the wall acts only as a partition. The shifts towards the use of such new materials and construction technologies have been based on assumptions that they are more stable and consequently safer for residents. Such assumptions may not be fully informed. Recent research has highlighted the vulnerabilities of such materials and building practices with the potential for significant damage during earthquake events (Lagenbach, 1989, Jigyasu, 2002, Marahatta, 2008).

III. Methodology

The research started with an understanding that it is not only the physical vulnerability which is adversely impacting on the overall resilience of the communities rather social and cultural vulnerabilities are also contributing in it. Therefore, research developed a conceptual framework to assess physical, social and cultural vulnerabilities in the communities. In order to assess those vulnerabilities, researchers decided to go to the communities with the concept of community-based participatory research.

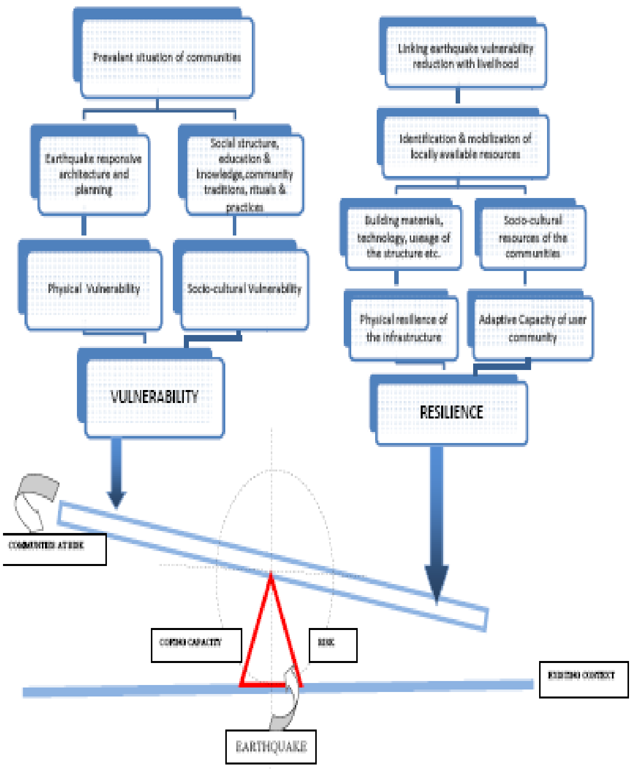

Figure 3. Conceptual framework of Research

The research was designed with active participation of community youths. It was a Community-based Participatory Research where local youths were involved in questionnaire design, case area identification, working as research assistants/enumerators.

A. Survey

The research was based on data collected through the household questionnaire surveys and direct participation in the activities at community level. The strength of this research lies on the involvement of the youth in the data collection process. These 16 to 25 year old youths were not only enumerators trained for the purpose rather they were participating as research assistants. The questionnaire of the survey had two major components: identification of building resilience through physical vulnerability assessment and identification of adaptive capacity through social and cultural vulnerability assessment.

Responses were drawn from 256 households in the selected communities in Patan. Specifically, the paper dealt with the question of social-ecological resilience of Patan households to earthquake hazards. The researchers constructed this notion of social-ecological resilience based on a suite of socio-economic indicators previously defined in the resilience literature as key to adaptive capacity. The ecological resilience component refers to characteristics of the built environment (individual household dwellings) which were established in the existing literature on earthquake hazards.

A survey included 69 questions related to the social and economic profile of the household. Measures of adaptive capacity were chosen based on literature relating to this region of Nepal and in the literature of socio-ecological literatures. Such measures chosen were the following: changes in patterns of economic opportunity, population growth, changes in security of traditional tenure system and knowledge. Key themes of adaptive capacity considered relevant here were knowledge, social capital and socio-economic status. The knowledge was measured by information on earthquake, identification of safer place at home in case of disasters, respondent's family discussion on earthquakes and ancestral knowledge transfer. In terms of social capital, interviewees were asked about familiarity with neighbors, current level of support from their neighbors, participation in community activities and organizations including those related to earthquake disaster prevention as well as respondent's ability to identify the nearest emergency evacuation sites. The Socio-economic status included income, land ownership and vehicle access. Responses were scored and summarized according to three themes. Those households who scored between 0-6 were categorized as LAC (low adaptive capacity), those with a score of 7-11 as MAC (moderate adaptive capacity) and those with a score of 12-19 were labeled as having HAC (high adaptive capacity).

B. Assessment of Built Environment

Currently, the vulnerability of buildings to earthquake hazard is classified according to established criteria (Table 1) generated by Nepali Earthquake/structural engineering experts. (Poudel et al., 2009). We used these criteria to assess each home in the study region. Through surveys, a score was applied (1/0) for each. Summary of scores are found in Table 1. In this analysis, on the basis of summary of scores, each household building was classified according to the themes of NR (not resilient), MR (moderately resilient) and HR (highly resilient). The highest scores were those of 5-6, house that scored 3-4 were moderately resilient buildings and those that were not resilient scored as 0-2. The challenge with this assessment tool is that there is tremendous variation and complexity within each building owing to their age and technology. What was initially a vertically regular building, for example has over time, become more vertically irregular due to the ad-hoc additions to the structure made by each successive generation (Ranjitkar, 2006). Older parts of the buildings may use brick, timber and mud whereas more recent additions are of cement concrete.

The following table describes the criteria and rationale for assessment of the vulnerability of buildings in the study.

	Characteristics of Built Environment	Explanation and Examples
1	Material and construction technology Brick with Mud Mortar *(2 and less than 2 storey=1)* *Brick with Mud Mortar (more than 2 storey=0)* *Brick with Cement Mortar (2 and less than 2 storey=2)* *Brick with Cement Mortar (More than 2 storey=1)*	Traditional building materials technologies are considered more resilient. Modern building materials including brick, cement, and steel are less flexible and more brittle in situations of lateral movement.
2	Vertical and horizontal irregularity *Yes=1* *No=0*	Irregularity in building structures can make them more vulnerable to collapse in lateral movement. Regularity in their horizontal and vertical form can be a buffer to lateral movement.
3	Existing physical condition *Good=1* *Not good=0*	Existing physical condition (e.g. damage from previous earthquakes) also affects the resilience.
4	Accordance to by-laws *Yes=1* *No=0*	Local governments in Nepal have adopted building codes which have considered earthquake safety as an inevitable condition.
5	Age of the structure *> 50 years=1* *< 50 years=0*	If the building is older, it is likely to be more vulnerable.
6	Number of users *< 10 people=2* *10-20 people=1* *20 and more people=0*	Occupants of the building also are a crucial component for vulnerability. In engineering terms, live load (load from people, furniture etc.) is equally contributing for vulnerability as the dead load (load from the structure).
7	Percentage of openings *Less than 40%=1* *More than 40%=0 (limited to load bearing structures)*	In load bearing structures, perforation contributes for increment of weakness against lateral disaster. Therefore, fewer openings are recommended.
8	Number of storey *Re: material and construction technology*	Taller the building, impact of inertia force increases. Hence earthquake engineering suggests height restriction to increase the resilience against earthquake.
9	Presence of vulnerable elements in the building *Yes=1* *No=0*	This is not directly linked to the possible damage to the superstructure of the building however, unsupported, free standing elements in the building could cause fatality and hence contributing to the vulnerability. Therefore, it also has to be considered while assessing the vulnerability.

Table 1. Criteria used for Rapid Vulnerability Assessment Tool
Source: (Poudel et al., 2009, Murthy, 2002)

IV. Analysis

This section presents the results of the surveys with 256 residents in five wards within Patan area of Lalitpur Sub-metropolitan City. In addition to presenting data from two separate research efforts, the paper shares an analysis of the correlations between adaptive capacity and the physical vulnerability of household residences.

Physical Vulnerability - Physical vulnerability is assessed using Rapid Vulnerability Assessment (RVA) tool (Poudel et. al 2009). In earlier research works, buildings were scored as either being vulnerable or not vulnerable. However, we adapted the use of these criteria into a low, medium, high ranking classification system to account for more variation in the conditions of buildings assessed.

The following table presents the vulnerability of the buildings in each of the surveyed wards.

Ward	Number of Household surveyed	% of household		
		NR (Non Resilient)	MR (Moderately Resilient)	HR (Highly Resilient)
7	53	49	45	6
8	56	39.2	44.6	16.1
9	69	23.2	62.5	14.5
11	32	25	68.8	6.2
12	44	20.5	56.8	22.7

Table 2. Physical resilience of the built structures in selected wards

Focusing on physical conditions alone cannot, however, provide insight about the total resilience of residents to earthquake hazards. This research also delved into the adaptive capacity of the selected communities. In order to arrive at a scoring system for adaptive capacity, the criteria presented in Tables 3, 4 and 5 are formulated.

Sym	Indicator	Score	
I_EQ	Information on earthquake	Yes=1	No=0
FD	Family discussion on earthquake	Yes=1	No=0
I_SAFE	Identification of safe place at home	Yes=1	No=0
A_KT	Ancestral knowledge transfer	Yes=1	No=0

Table 3. Indicators and scores for Knowledge

Sym	Indicator	Score		
EQ_PPD	Involvement in earthquake preparedness program	Yes=1	No=0	
C_ACT	Involvement in community activities	Yes=1	No=0	
H_NBR	Helping neighborhood	Yes=2	Sometimes=1	No=0
CBDRR	Interests in CBDRR	Yes=1	No=0	
A_ES	Availability of space for emergency shelter	Yes=1	No=0	
CES	Adequacy and physical condition of space for ES	Yes=1	No=0	

Table 4. Indicators and scores for Social Capital

Sym	Indicator	Score	
INC	Income	> 10000=1	< 10000=0
A-1	Asset -1 (Land ownership)	Yes=1	No=0
A-2	Vehicle	Public Transportation (PT)=0	Bicycle (BC)=1
		Motorbike (MB)=2	Car (CR)=3
		Bicycle+Motorbike (BC+MB)=3	Bicycle+Car (BC+CR)=4
		Motorbike + Car (MB+CR)=5	Bicycle+ Motorbike+Car (BC+MB+CR)=6

Table 5. Indicators and scores for Socio-economic Status

According to the analysis, we arrive at the conclusion of adaptive capacities of selected wards as follows:

Ward	Number of Household surveyed	% of household		
		LAC (Low Adaptive Capacity)	MAC (Moderate Adaptive Capacity)	HAC (High Adaptive Capacity)
7	53	37.7	7	53
8	56	21.5	8	56
9	69	30.4	9	69
11	32	18.8	11	32
12	44	27.3	12	44

Table 6. Result of Adaptive Capacity of selected wards

This research also sought to find out the extent to which the adaptive capacities of residents (Table 6) mitigate the risks due to physical conditions. For example, does adaptive capacity compound or offset the problems identified in household infrastructure? The majority of households in all wards were categorized as having moderate adaptive capacity.

Ward	Number of Household surveyed	Function of (AC + BR) / 2 = Total Resilience		
		Low Total Resilience	Moderate Total Resilience	High Total Resilience
7	53	43.35	7	53
8	56	30.35	8	56
9	69	26.8	9	69
11	32	21.9	11	32
12	44	23.9	12	44

Table 7. Total resilience of selected wards

The following table gives a general overview of the results.

	Building Resilience	Adaptive Capacity	Total Resilience
Low/Non	31.38	27.14	29.26
Moderate	55.54	67.4	61.47
High	13.1	5.46	9.28

Table 8. Analysis of results

This also could be reflected in the following figure:

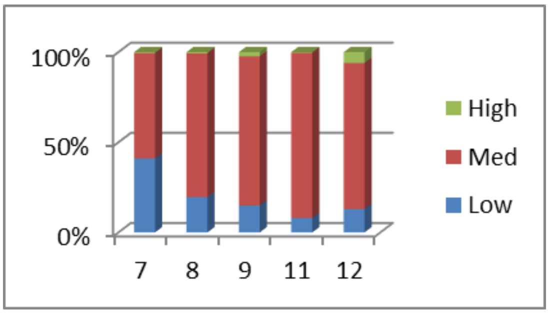

Figure 4. Resilience chart of wards

The results shown in Table 8 indicate that assessing merely the physical vulnerability of the building or their resilience cannot give a holistic picture of Total Resilience against earthquake disasters. Therefore, adaptive capacity has also to be considered in assessing vulnerability. The adaptive capacity in this case has suggested the affects level of total resilience.

The result also shows that 75 households are categorized as low resilient, 157 households moderate resilient and 24 high resilient in the selected case area.

V. Conclusion

Based on the analysis, it can be said that assessing the socio-economic vulnerability is equally important as physical vulnerability for building the resilience. Therefore, earthquake vulnerability assessment has to incorporate the physical as well as socio-cultural attributes of communities and built environment. Moreover, increasing the adaptive capacity of individual households can increase the total resilience of the community.

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