Economic Assessment of Seismic Retrofitting of Non-Engineered Buildings - Case Study from India

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SUMMARY
The Cost Benefit Analysis (CBA) is one of the most applied tools to assess the effectiveness of earthquake mitigation projects. The paper presents development of economic assessment tool for retrofitting of non-engineered buildings and same is applied to moderate earthquake risk prone district Khandwa of Madhya Pradesh, India. The study integrates approach for data collection, buildings classification, vulnerability assessment, propose retrofitting techniques, estimate reconstruction and retrofitting costing, damage and loss assessment and assess benefits using CBA. For CBA, The Net Present Value method suggested by FEMA 227-228, has been used and modified suiting to local condition. The case-study reveals that the brick buildings show positive NPV from beginning of the project, but mud buildings swings from negative to positive with planning period. The proposed model suits to rural to urban areas and with certain modification and analysis of local data, the model can be used for any target areas.

Keywords: Building typology, Seismic retrofitting. Damage and loss assessment, Cost benefit analysis

1. BACKGROUND

Application of seismic risk mitigation strategies over a large geographical area demands massive resources and infrastructure. Developing countries like India may require extraordinary resources to meet up with such challenges. The limited resources require trade-off between time and resources. In view of such challenges; there is a need for assessing the viability of such project which has social dimensions at large. The Cost Benefit Analysis (CBA) is one of the well-established tools to assess the viability of disaster risk reduction projects. The project appraisal for earthquake mitigation projects play a vital role in making community, policy / decision makers and other development professionals to understand the impact of the earthquake mitigation. The scope of the paper is to explain economic assessment tool for earthquake mitigation through retrofitting of non-engineered buildings. The tool is developed for Pandhana tehsil, moderate seismic prone areas of Madhya Pradesh, Central India. The research encompasses designing the questionnaire format to collect data, classify building types, identify strength and weakness of classified buildings, study and adopt best suited retrofitting techniques, cost estimation of reconstruction and retrofitting of identified building types, develop a tool for damage and loss assessment for tangible and non-tangible assets, followed by assessing benefits using well-established tools for CBA. For the CBA, Net Present Value (NPV) method suggested by FEMA 227-228, 1991 has been adopted and modified using some established models applicable to Indian conditions. The paper further carries out sensitivity analysis of planning period, discount rate and severity of disasters to understand the feasibility of structural mitigation.

2. METHODOLOGY

The methodology is illustrated in Figure 1. The research methodology uses building classes based on Indian Census, 1991 and Indian Standards construction codes. The methodology identifies required parameters, develops questionnaire formats, evolves survey methodology, establish database structure and setup query system. Referring to Indian construction code provisions, structural strength and weakness were evaluated and proposed retrofitting measures of these non-engineered buildings. The adopted retrofitting measures in the proposed model are based on guidelines developed by the Government of Maharashtra (Brzev, 1998). The cost of reconstruction and retrofitting is worked out based on well-established quantity estimation techniques. For cost estimation, an algorithm is developed for the present study. The CBA model is developed based on data collected from 21 villages of Pandhana Tehsil of Khandwa district (Figure 2). The resource prices are applied based on Madhya Pradesh Schedule of Rates and labour charges are derived from district administration. The regression analysis is applied to establish the relationship between various housing parameters and their contribution to the reconstruction, retrofitting cost, damage and losses etc., Two major categories of losses i.e., tangible and non-tangible losses are accounted in this study. The tangible losses include economic losses related to physical damage of buildings. The intangible losses include casualties of mankind and life stock, rental, and functional, relocation and household losses. The casualty estimation includes injuries and death, which adopts Lethality Ratio (Coburn et.al. 1992) with modified parameters and coefficients as per study area. The Lethality Ratio is the function of number of houses, occupancy rate, time of earthquake event, people trapped in collapsed houses and injury distribution at collapse. The coefficients are derived for rental, relocation, functional and household losses. The damages are estimated with and without retrofitting measures. CBA is carried out based on damage and losses to buildings without retrofitting and reduction in damage after retrofitting. For financial assessment, length of planning and effective period is considered with the range of discount rates, which results in NPV. The difference of damage cost between pre and post-retrofitting results in the efficiency of the retrofitting measures. The benefits are realized in terms of damage reduction. CBA has adopted NPV method for economic assessment. The sensitivity analysis for NPV is carried out with respect to project planning period and discount rate. The methodology is applied to set of brick and mud buildings and later to the whole tehsil. The result and the analysis are presented in detail in the following sections.

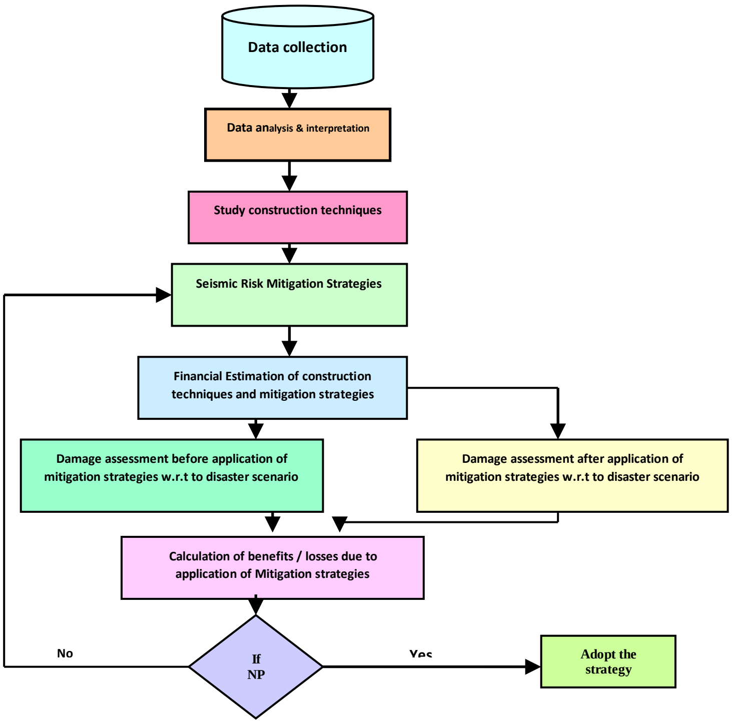

Figure 1. Methodology for the feasibility assessment of seismic retrofitting

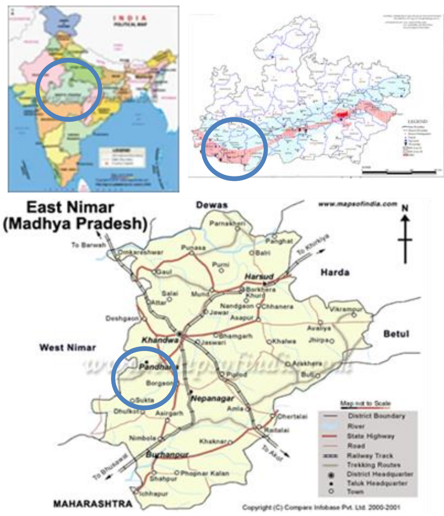

Figure 2. Map showing location of the study area

3. COST BENEFIT ASSESSMENT AND ANALYSIS

3.1. Data Collection

Data collection procedure comprises identification of survey parameters, mode of survey, approach for data structure, database preparation and validation of surveyed data. The data includes geological, geographical, seismological, socio-economic factors, financial parameters, building strength and weakness and demographic information. The building inventory development is another essential component of this study, for which comprehensive data for 4,558 buildings was collected from 21 villages of Pandhana district of Madhya

Pradesh. The survey parameters include metadata, general building information, structural and architectural detailing etc. A team of 16 well-trained engineers were engaged in the building survey. The database format was prepared using FOXPRO® software. The analysis of collected data characterizes certain important parameters such as utility, building configuration, socio-economic factors, performance objectives etc.

3.2. Vulnerability Assessment of Building Typologies and Proposed Retrofitting Techniques

The houses are typically constructed with locally available material. The Figure 3(a, b, c & d) shows common features of brick and mud buildings and their proposed retrofitting methods. The brick buildings are classified as low strength masonry buildings. Referring Indian Code 13828, the building type falls in category B for retrofitting purpose. The general retrofitting measures for brick buildings include provision of lintel, roof, plinth & gable bands and bracing of purlins and rafters at tie level. These bands tie the walls together and ensure integral action and ductile behavior of all the walls of the house in resisting seismic forces. The traditional mud wall construction practiced in Khandwa region is unique. The construction is partially loadbearing and partially framed structure. Based on the building characteristics, the feasible options of retrofitting measures are horizontal, diagonal and X bracing of existing columns, Tee bracing and strengthening of roof elements through bracing purlins and rafters.

3.3. Estimation of Reconstruction and Retrofitting Cost

11% of Brick and 6 % of mud buildings are selected for the cost estimation on random basis to avoid biases. The estimation of construction cost and its application to the large number of buildings commence with calculating the cost of sample dataset. It is imperative to analyze parameters which attribute the most to overall cost of construction. It is observed that the large numbers of parameter are contributing towards the cost of construction. Since the cost of manpower and material has been increased in last three years, the cost escalation factor is included. Based on present official rate, it is assumed that the manpower cost has increased by 15 % and the material cost has gone up by 10%. The rationale has been derived from the Schedule of Rates, published by Public Works Department, Government of Madhya Pradesh. To establish the relationship between various cost contributing parameters, regression analysis was conducted. Those parameters, which are significantly contributing the overall cost of construction, were considered for the estimation. The considered parameters are length of building, width of buildings, depth of foundation, width of foundation, thickness of wall, height of building, height of gable, number of longitudinal walls, number of transverse walls and roof projection. Based on these parameters, All Possible Regression Analysis (Equation 1) was carried out. Further, the regression equations were checked for linearity, normality, variance, serial correlation, outliers, multicollinearity and predictability.

$$Y_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \ldots\ldots + \beta_p x_{ip} + \varepsilon_i \quad \textbf{(1)}$$

For estimating the cost of retrofitting for brick and mud buildings, using all possible regression, four parameters, which significantly contribute to the cost aspects, are considered. These are Length_bldg, Width_bldg, Gable_ht and Projection. In All Possible Regression analysis, it is found that there is no much difference in R^2 and Root MSE for three and four parameters. Since gable height is playing significant role in cost of retrofitting so, all four parameters have been considered for the cost estimation. The regression equations are checked for linearity, normality, variance, serial correlation, outliers, multicollinearity and predictability.

3.4. Damage Assessment before and after Retrofitting

The tangible and non-tangible losses are estimated based on FEMA 227-228 methodology. The tangible losses include economic losses related to physical damage of buildings, is calculated. The intangible losses include casualties of mankind and life stock, rental, and functional, relocation and household losses, which are estimated.

(a) Tangible loss (structural damage assessment of brick and mud buildings): It is assumed that the damage at various intensities will fit to the linear multiple regression models. IS code 1893:2002, Comprehensive Intensity Scale (MSK 64) provides the grades of damage for various types of buildings. This scale is considered as the key for assessing the damage. Past few decades, many earthquakes have occurred in developing and under-developing countries like Iran, India, Pakistan, Turkey, Nepal, Afghanistan and South East Asian counties. These countries have experienced colossal losses of non-engineered construction. The damage profile of these mega earthquakes explained the damageability of such building types. These facts present fare understanding about the extent of losses to non-engineered buildings. The assumption about damage is also drawn, based on past experience of earthquakes in the region. For establishing the proportion of damage to the buildings, a set of building data is considered for the calculation. Based on above stated criteria, the damage profile is generated for earthquake intensities ranging from VI to VIII. Based on the damage to typical buildings, the cost of repair at varying intensities is calculated. The cost of repair is based on material, manpower and man-days. The cost of repair to the damage is treated as the damage cost. The damage ratio is calculated for set of sample datasets. In case of brick buildings, for intensity VI, VII and VIII, the expected damage ratio is 10 %, 20 % and 30 % for brick and 35 %, 50 % and 60 % for mud buildings respectively.

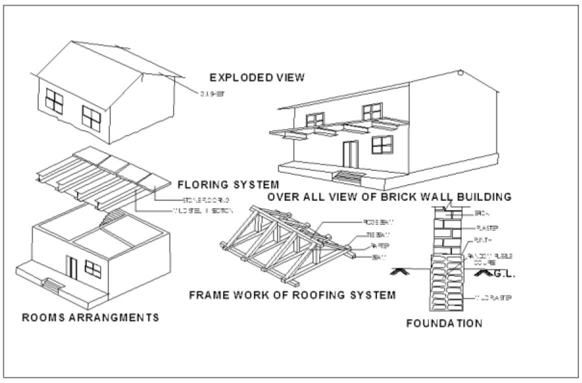

Figure 3.a. Features of typical brick building

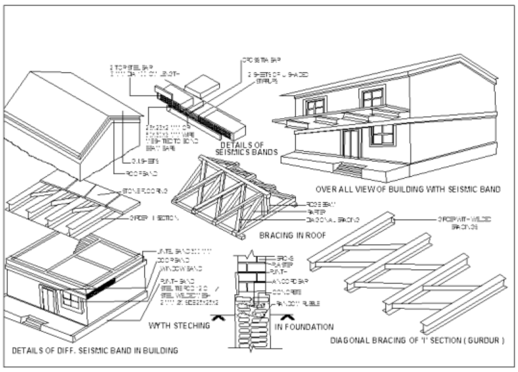

Figure 3.b. Proposed retrofitting techniques for brick building

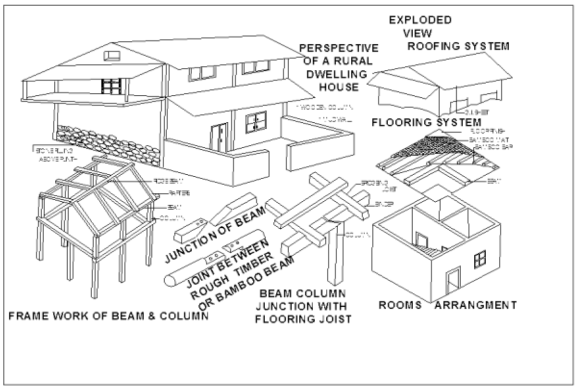

Figure 3.c. Features of typical mud building

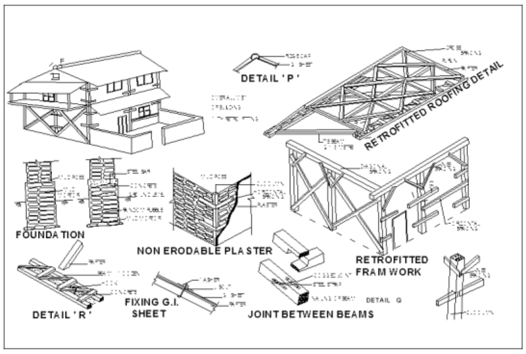

Figure 3.d. Proposed retrofitting techniques for mud building

(b) Casualty estimation: The lethality ratio proposed by Coburn, is applied for casualty estimation. Equation 2 explains the parameters contributing to the casualty estimation. The parameters are estimated and adjusted to the pilot study areas. The model is developed on the basis of four major factors i.e., Population per building (M1), Occupancy at Time of Earthquake (M2)), Occupants Trapped by Collapse (M_3) and Injury Distribution at Collapse (M4) and Number of houses (Noh). The coefficients for casualty estimation are presented below.

$$M = Noh \times (M1 \times M2 \times M3 \times M4) \quad \textbf{(2)}$$

Noh = Number of Buildings

Parameters for Mud Buildin		Parameters for Brick Building	
$M_{1=}$ Population per building		$M_{1=}$ Population per building	
M_1=	5.378	M_1=	5.3786
$M_{2=}$Occupancy at the time of earthquake			
$M_{2\text{-}1}$ = Occupancy at day time	40%	$M_{2=}$ Occupancy at the time of earthquake	

M_{2-2}= Occupancy at night time 95%
M_{3} = Occupants trapped by collapse
VI Nil
VII 5%
VIII 30%
M_4=Triage injury category
Dead or UnsaveableM_{Mud}4-1 10 %
Life threatening cases needing immediate medical attention M_{Mud}4-2 30 %
Injury requiring hospital treatment M_{Mud}4-3 40 %
Light injury nor necessary hospitalization M_{Mud}4-4 20 %

M_{2-1} = Occupancy at day time 40%
M_{2-2} = Occupancy at night time 95%
M_{3} = Occupants trapped by collapse
VI Nil
VII 05%
VIII 30%
M_4 = Triage injury category
Dead or Unsaveable M_{Mas}4-1 20%
Life threatening cases needing immediate medical attention M_{Mas}4-2 30%
Injury requiring hospital treatment M_{Mas}4-3 30 %
Light injury nor necessary hospitalization M_{Mas}4-4 20%

(c) Rental losses and assessment: The rental cost for the type of buildings is worked out based on the locally available information. The rental loss (FEMA-227, 1991) is a function of functionality loss of buildings due to damage and rental charges per day. The functionality losses (LOF) are the function of built-up area and man-days required for repair.

$$RT = R_{Loss} \times LOF \quad \textbf{(3)}$$

R_{Loss} is the function of percentage of replacement cost per day. For brick and mud buildings, the annual rental charges are calculated at 8 % of replacement cost.

$$R_{Loss} = (\text{Reconstruction Cost}) \times 0.08/(12 \text{ x } 30) \quad \textbf{(4)}$$

The functionality loss is calculated for a set of buildings. Expected damages at various intensities are calculated and the man-days are estimated for repair such buildings for the range of earthquake intensities. The regression analysis is performed considering built-up area of buildings and restoration time and relationships are established. It is assumed that the relationship is linear. The rental cost for brick and mud buildings are calculated on the basis of percentage of reconstruction cost. The rental charges are worked out on per day basis.

(d) Relocation Loss: The relocation cost is considered same as rental losses, therefore, the value of relocation loss is equal to rental losses.

(e) Property Loss: The property losses are calculated based on past experience of earthquake damage. During the survey, specific household survey was also conducted. Other survey tool like passive observation and personal interview were also implied to estimate the household items and personal property of house owners. Based on their household items, an average cost was calculated, before and after retrofitting, which is summarized in Table 1.

$$\text{Personal Property Loss} = (\text{Cost of Replacement}) \text{ x Proportion of Damage} \quad \textbf{(5)}$$

The household asset cost is correlated to reconstruction cost. Considering these factors, the property loss assessment is carried out. The process results in property loss (%) estimation.

Table 1. Coefficient of property losses before and after retrofitting

Brick Buildings		Mud Buildings	
Before earthquake retrofitting, the proportion of property damage (% of Reconstruction cost)		Before earthquake retrofitting, the proportion of property damage (% of Reconstruction cost)	
Intensity VI	15 %	Intensity VI	50%
Intensity VII	30%	Intensity VII	70%
Intensity VIII	50%	Intensity VIII	90%
After earthquake retrofitting, the proportion of property damage (% of Reconstruction cost)		After earthquake retrofitting, the proportion of property damage (% of Reconstruction cost)	
Intensity VI	10 %	Intensity VI	35%
Intensity VII	20%	Intensity VII	50%
Intensity VIII	35%	Intensity VIII	65%

3.5 Average Effectiveness of Retrofitting (ERE)

The reductions in losses are calculated based on effectiveness of retrofitting measures which is in turn treated as benefits. The reduction in rental, functional and property losses are calculated by simply multiplying the average effectiveness of retrofitting for all types of buildings. For calculation of ERE, Set of brick and mud buildings are considered. Applying the formulae mentioned below, the damage cost is worked out before and after the retrofitting. The coefficient of effectiveness of retrofitting for brick and mud buildings are calculated (Table 2). These coefficients are used for calculation of benefits accrued from the retrofitting measures.

Average effectiveness= ((Damage before retrofitting–Damage after retrofitting)/Damage before retrofitting)) ×100 **(6)**

Table 2: Effectiveness of retrofitting

Type of construction	Effectiveness @ Intensity VI	Effectiveness @ Intensity VII	Effectiveness @ Intensity VIII
Mud	28.2	20.7	15.6
Brick	36.48	31.03	24.99

3.6 Economic Appraisal Factors

The economic parameters include discount rate and planning horizon, which defines the feasibility of mitigation investment. The discount rate is used to calculate the present value of benefits, which will occur in the future. Increasing the discount rate lowers the present value of future benefits and thus lowers the benefit-cost ratios. For present study, the NPV is calculated for varying discount rates viz., 2.5 %, 3%, 4%, 5%, 7.5% and 10 %.The planning horizon is the time period over which the economic benefits of strengthening programs are realized. The typical planning horizons are 20 to 30 years. Longer planning horizons compute more future benefits and thus increase benefit / cost ratios. Short planning horizons captures future benefits for fewer years and thus result in lower benefit/ cost ratios.

3.7 Feasibility Assessment and Analysis

The expected NPV of a seismic retrofitting investment (FEMA 227/228-1991) is the sum of the present value of benefits expected to accrue each year over the planning period, the present value of the salvage value of the retrofitting investment at the end of the planning period, plus the present value of expected deaths avoided by seismic retrofitting, minus the initial cost of the retrofitting. The expected NPV model is thus defined as

$$NPV = -INV + \frac{B_1}{1+i} + \frac{B_2}{(1+i)2} + ... + \frac{B_T}{(1+i)T} + \frac{V_T}{(1+i)T} + VDA_t\left[\frac{1-(1+i)^{-T}}{i}\right] \quad \textbf{(7)}$$

Where: INV is the cost of the rehabilitation; B_t is the expected annual benefit attributed to the retrofitting in year t; V_T is any change that the retrofitting will have on the salvage value of the buildings in the terminal year T; VDA_t is the annual value of expected deaths / injury avoided by retrofitting of buildings to life-safety standards T is the length of the planning horizon which should reflect the effective life of the retrofitting; and i is the discount rate. In this model, each year's expected benefit is discounted to its present value and then added together to yield the total expected NPV.

The cost of the retrofitting (INV) includes direct engineering/construction costs and, if desired, other indirect costs. The salvage value of the retrofitting investment is the change that the retrofit will have on the value of the buildings at the end of the planning horizon. The planning horizon (T) is the time period, typically 20 or 30 years, over which future benefits are estimated. The discount rate 'i' is the annual percentage rate by which future benefits are discounted to NPV.

Assuming that expected benefits are constant each year is equivalent to assuming that the annual probabilities of future earthquakes of various intensities are constant and that the effectiveness of the retrofitting in reducing casualties, damages and losses is also constant. The expected annual benefit, which accrues from the retrofitting, is the sum of expected avoided losses accounting for the expected annual probability of damaging earthquake. The expected annual benefit is assumed to be the sum of avoided building damages, rental losses, relocation expenses and personal property losses. The expected annual benefit of rehabilitating a group of buildings to meet life-safety earthquakes standards is thus defined as :

$$B_t = \sum_{M=VI}^{VIII} EAE^m \left[\sum_{t=1}^{N} \sum_{N=1}^{n} BD_{sf}^m + RT_{sf}^m + REL_{st}^m + PP \right] \quad \textbf{(8)}$$

Where: EAE^m is expected number of earthquakes annually by Modified Mercalli Intensity (MMI) ranging from VI-VIII; BD_{st}^m is building damages avoided by social function and facility classes, and MMI; RT_{st}^m is rental losses avoided by social function and facility classes, and MMI; REL_{st}^m is relocation expenses avoided by social function and facility classes, and MMI; PP is personal property losses avoided by social function and facility classes, and MMI; VDA_t is the annual value of expected deaths avoided by rehabilitating buildings to life-safety standards. In this equation, the first summation symbol indicates that expected annual benefits must be summed over expected earthquakes with MSK ranging from VI to VIII. The second and third summation symbols indicate that expected damages and losses avoided must be calculated separately for each combination of category of buildings (N) and facility classification (t) and then summed. Avoided damages and losses means the reduction in expected damages and losses in retrofitted buildings versus those expected in without retrofitted buildings of the same category.

3.8 Case Study Results and Analysis

(a) Single brick and mud building: Following the described methodology, the damage cost of building before and after retrofitting is calculated for the sample brick and mud building. The analysis of CBA is carried out to understand the sensitivity of investments with respect to discount rate, planning period and damage scenarios. The NPV sensitivity analysis is carried out for (1) effects of changing the planning period with fixed discount rate, (2) changing the discount rate with fixed planning period, (3) period for profit realization at varying scenarios and (4) comparison of NPV for temporal changes. The Table 3 shows the incremental factors wrt changing discount rate for two building classes. The discount rate is fixed and planning period is changed from 5 years to 30 years for defined disaster scenario. The Table 4 shows that there is a decline in increment factor. The trends are same for brick and mud buildings. For brick buildings, the increment factors are higher than mud buildings. If the discount rate increases from 2.5 % to 5 and 10 %, the decline rate of increment factor is steeper for all building type. For understanding the investment sensitivity, the planning period is fixed and rate of discount is varied. The sensitivity of NPV changes are measured for two planning periods i.e. 5 years and 30 years. For this study, the increment factor is projected as ratio of NPV from 2.5 % to 10% discount rate. In such case, there is decline in NPV increment factors for both building classes. It is observed that as the damage scenario increases from VII (day) to VIII (Night), there is no much variation in decline rate, irrespective of the building type. The decline rate is independent of planning period, i.e. same ratio has been observed for mud and brick buildings for 5 years and 30 years, so benefits will be achieved for classes of buildings.
Assessment of the period for profit realization: For checking the effectiveness of discount rate and planning period, it is necessary to check the span of investment returns, which is treated as benefits. The Table 5 provides the information about time required in months to realize the benefits from implementing the retrofitting projects for single brick and mud building. For brick building, at intensity VII (Day) and VII(Night), same trend is reflected. It is observed that as the severity increases, the span of benefit realization decreases. The same trend is also observed in Intensity VIII (Day) and VIII(Night).
Comparison of NPV for temporal scenario: It is found that the severity increases at night times because of maximum occupancy. The retrofitting gives better results for increased severity. The analysis shows that if planning period is fixed and severity is changed, there is lesser decline in NPV for night scenario than day time. In both cases, it has been observed that the span of benefits realization shortens by 50-60 % irrespective of the building class.

(b) Sample brick and mud buildings: The methodology was applied on set of randomly selected 196 brick and 194 mud buildings from pilot study villages. The results obtained from NPV analysis for sample set of brick and mud buildings are critically analysed for range of scenarios. The Table 6 summarizes the characteristics of the NPV analysis. The feasibility of retrofitting for the mud and brick buildings is worked out and observed that the accrued benefits are dependent on planning period, discount rate and annual frequency of earthquake intensities. For sample buildings, two most relevant scenarios (1) Period of benefit realization (2) Effect of temporal changes on return, are studied in detail as these will be highly important for policy planners and project managers.

Period for profit realization at various scenarios: To check the effectiveness of discount rate and planning period, it is necessary to analyse the span of investment returns, which is treated as the benefits. In case of brick buildings, at most critical scenario VIIIN, the benefit is realized within 5 months, which is much faster than other scenarios.

Table 3: Comparison of Increment Factors for brick and mud buildings with respect to change in discount rate

Scenario	Increment Factors for brick and mud building discount rate (%)					
	2.50 %		5.00 %		10.00 %	
	Brick	Mud	Brick	Mud	Brick	Mud
VIDN	11.86	10.51	10.56	21.02	11.08	8.20
VIID	8.17	7.98	6.69	6.52	5.12	4.94
VIIN	6.05	5.76	4.81	4.56	3.40	3.21
VIIID	5.35	5.18	4.22	4.09	2.96	2.86
VIIIN	4.84	4.77	3.81	3.76	2.67	2.63

Table 4: Sensitivity of increment factors with varying scenario, fixed planning period and varying discount rate (2.5% to 10 %)

Scenario	Planning Period			
	5 year		30 Years	
	Brick	Mud	Brick	Mud
VI	2.75	2.24	2.95	2.87
VIID	1.69	1.66	2.70	2.69
VIIN	1.39	1.35	2.47	2.43
VIIID	1.31	1.29	2.37	2.34
VIIIN	1.26	1.25	2.28	2.27

Table 5: Comparison of period (Months) of benefit realization for single brick and mud

Scenario	Discount Rate											
	2.50%		3%		4%		5%		7.50%		10%	
	Type of											
	Brick	Mud	Brick	Mud	Brick	Mud	Brick	Mud	Brick	Mud	Brick	Mud
VIDN	40.1	37.1	40.8	37.6	42.1	38.7	43.6	47.4	47.9	43.5	53.1	48
VIID	30	29.9	30.2	29.8	30.9	30.7	31.8	31.7	34.2	34.4	37.2	37.6
VIIN	17.7	15.6	17.8	15.7	18.2	16	18.5	16.4	19.6	17.5	20.8	18.8
VIIID	11.3	9.2	11.4	9.3	11.6	9.4	11.8	9.5	12.4	9.9	13.2	10.3
VIIIN	5	4	5	4	5	4.1	5.1	4.2	5.3	4.3	5.4	4.5

In case of mud buildings, as the scenario severity increases, the period of profit realization decreases and falls within designed planning period.

The returns of benefits are faster in the brick buildings. The mud buildings are showing poor benefit returns. However as the damage scenario becomes critical (VIIIN), it is observed that irrespective of type of buildings, the period of benefit returns are realized in the beginning of the project implementation. The criticality of the scenario influences the benefits. The scenario at night time realizes early benefits in mud buildings by 25% - 30% of day time while in brick types, it is about 50 % earlier than day time.

Table 6: Comparison of period (months) of benefit realization for sample brick and mud buildings

Scenario	Discount Rate											
	2.50%		**3%**		**4%**		**5%**		**7.50%**		**10%**	
	Brick	Mud	Brick	Mud	Brick	Mud	Brick	Mud	Brick	Mud	Brick	Mud
VIDN	19.26	210	19.45	216	19.84	252	21.37	312	21.48	720	22.94	1536
VIID	20.14	228	19.89	240	20.35	300	20.85	360	22.25	720	23.89	1320
VIIN	13.88	136	13.92	138	14.15	198	14.39	216	15.09	360	15.92	720
VIIID	10.75	96	10.82	99	10.98	108	11.15	114	11.64	126	12.22	162
VIIIN	5.37	24	5.45	27	5.6	33.12	5.76	34.68	6.19	39	6.65	43.2

(c) Tehsil level brick and mud buildings**:** The methodology has been applied to selected 21 villages and later applied to 80 villages of Pandhana tehsil. The scope of the paper is to present the methodology and its applicability to the larger administrative boundary called tehsil. In broader sense, the distribution of housing type and characteristics are same at tehsil and district level. The model is applied to tehsil level, considering the fact that it is not possible to collect information for such larger area which has more than 80 villages. For precise assessment, it is necessary to collect information from secondary sources. For the same, Census data 2001 is used. The feasibility assessment is carried out based on data projection method and Census information. Mainly the correlation is established based on Population and housing units from census 2001.

The analysis is carried out for finding the sensitivity of investments with respect to discount rate, planning period and damage scenarios. At tehsil level, most relevant scenarios i.e. period for benefit realization and effect of temporal changes, are analysed for both types of buildings.

Assessment of the period for profit realization at various scenarios: To analyse the effectiveness of discount rate and planning period, it is necessary to check the span of investment returns, which is treated as benefits. The Table 7 summarizes the information about time required in months to realize the benefits from implementation the retrofitting projects in Pandhana tehsil. The analysis shows the period of benefit realization is consistent in brick buildings with respect to discount rate in all scenarios. However there is sudden moderate increase at discount rate of 10 %.

As the earthquake scenario changes from day to night, the period of benefit realization decreases. For scenario VIIN, there is a reduction of about 28 % in period in benefit realization compare to VIID. The period of benefit realization drops by about 40 % for VIIIN. The reduction in rate is irrespective of discount rate. The mud buildings are showing consistency in period of profit realization, which is irrespective of discount rate. For larger region, the profit realization is very fast. There is no much change observed in scenario day and night for any intensity as the population of building is large and intangible losses are large.

Table 7: Comparison of period (months) of benefit realization for buildings types from Pandhana tehsil

Scenario	Discount Rate											
	2.50%		3%		4%		5%		7.50%		10%	
	Brick	Mud	Brick	Mud	Brick	Mud	Brick	Mud	Brick	Mud	Brick	Mud
VIDN	26.56	0.52	26.87	0.52	27.55	0.52	28.28	0.51	30.41	0.50	32.95	0.51
VIID	30.24	12.71	29.34	12.67	30.26	12.87	31.25	13.08	34.02	13.69	37.25	14.41
VIIN	21.74	12.07	21.80	12.02	22.26	12.18	22.76	12.35	24.20	12.85	25.94	13.45
VIIID	15.07	21.87	15.19	22.07	15.45	22.51	15.73	22.99	16.53	24.38	17.49	26.08
VIIIN	8.96	19.01	9.07	18.89	9.30	18.65	9.54	18.38	10.19	18.42	10.90	19.41

For brick buildings, at the discount rate of 2.5 %, the benefit return period at varying intensities from VIDN to VIIIN, ranges from 26.56 months to 8.96 months. The mud buildings are showing very good benefit returns from the beginning. At this discount rate, the mud buildings are accruing benefits after half month for damage scenario VIDN. However as the scenario becomes critical, the return is realized in 19 months. It is observed that for brick buildings, at 2.5% discount rate, as the scenario changes from VIDN to VIIIN, the period has decreased substantially. The temporal changes in scenario also change the net present value. The scenario at night time shortens the span for benefit realization.

At 5 % discount rate, the brick buildings are realizing benefits in 28.28 months. As the scenario changes, the period of benefit realization reduces. It is observed that for the brick buildings for various scenarios ranging from VI to VII, the time to realize the benefits ranges from 31 to 22 months. It is also observed that for any fixed scenario, as the rate of discount increases, the span of benefit realization prolongs. However the changes are marginal. At 5 % discount rate, the mud buildings are getting benefits after half month of project commencement. Period of benefit returns are independent of rate of discount. There is no significant change observed at any damage scenario at varying discount rate.

At Intensity VIII, it is found that brick buildings are performing better. At 2.5 % discount rate, brick buildings are realizing returns in 8.96 months. As the discount rate changes, there is non-significant increments observed in benefit return. For the same scenario for mud buildings, the benefits are accrued in 19 months.

4. RECOMMENDATIONS FOR APPLYING THE MODEL

The Project Appraisal model largely depends upon annual frequency of earthquake in the region. It is important to conduct detail study related to site specific seismic hazards. The vernacular housing typology is necessary to be studied and should include existing load path, material, structural and architectural configuration and expected seismic performance. The data has to be collected not only related to structural configuration, but also pertaining to socio-economic, environmental and other important issues like housing condition, age, utility etc,. The extensive data should be collected for smaller geographical area. The statistical modeling could be applied to establish the retrofitting and damage cost at varying intensities. It is difficult to estimate the damage cost for the area which has not been affected by earthquake for long and is highly seismic vulnerable. In particular situation, it is difficult to understand the performance of vernacular building with respect to earthquake shaking. In such case, various available damage models could be applied to understand the expected damage.

Statistical tools could be applied to calculate the cost for a random set of similar set of data. It is necessary to perform rigorous testing through statistical models for set of data. If the relationship is precise and accurate, the results will be closer to the actual values even for large region. The cost of resources for retrofitting and replacement of building components is very important for overall project evaluation. The cost of resources should be collected from the study area.

There are various models available for assessing the feasibility of mitigation projects. Most commonly used model is CBA. The appraisal models are largely dependent upon precision of investment cost. Emphasis is required for accurate estimation of investment. The rate of discount and planning period are governing factors, which makes the profit to be realized. A careful selection is needed for rate of discount and planning period.

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