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Principal Component Analysis of Post-Earthquake Reconstruction Opportunities in Nepal's Health Sector Building Projects

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Abstract:- Earthquakes significantly disrupt health infrastructure, leading to loss of life and service interruptions. However, reconstruction phases offer chances to enhance facility, quality and community resilience. This study investigates the potential opportunities for post-earthquake reconstruction of health sector buildings in rural Nepal, employing Principal Component Analysis (PCA) to identify key factors. The analysis identifies four primary opportunity components: Seismic Resilience and Opportunity Framework, Disaster Resilient Health Infrastructure, Rebuilding for Prosperity Program, and International Aid for Economic Growth. The first and most significant component, "Seismic Resilience and Opportunity Framework", explained 33.71% of the total variance with an eigenvalue of 5.394. These four components encompass policies for disaster management, leveraging earthquakes for risk management and anticipatory actions, aligning with the 'Build Back Better' approach, and mobilizing international aid for economic development. The PCA results show that these components explain 56.903% of the total variance in the dataset, underscoring their significant impact on the successful reconstruction of health sector buildings. The study highlights the importance of strategic implementation of these opportunities to enhance the resilience, safety, and functionality of health infrastructure in Nepal. By embracing these insights, policymakers and stakeholders can ensure a robust health system that not only recovers from disasters but also thrives, contributing to the overall well-being of the Nepalese population.

***Keywords**:- Post-Earthquake Reconstruction, Principle Component Analysis, Build Back Better, Opportunities.*

I. INTRODUCTION

Earthquakes can severely disrupt a country's health infrastructure, leading to significant loss of life and the interruption of essential health services. However, post-earthquake reconstruction offers a critical opportunity not only to rebuild but also to enhance the quality of health facilities(Kc et al., 2019). This reconstruction phase, though, faces numerous barriers that can hinder its effectiveness and efficiency. Beyond the physical rebuilding, reconstruction involves fostering confidence, self-respect, self-esteem, self-dependency, mutual support, and mutual trust within the community(Sreelakshmi and Abhijith, 2023). It is a long-term process aimed at developing both human and material resources, with a focus on coordinated efforts towards independence, sustainability, and empowerment(Bass and Dalal-Clayton, 2012).

Post-disaster reconstruction (PDR) is a crucial stage in disaster management, presenting a window of opportunity for community development(Thurairajah et al., 2008). The reconstruction of health sector buildings in Nepal after an earthquake presents a substantial chance to leverage technology and community participation to enhance the efficacy and sustainability of restoration initiatives(Khanal et al., 2024). This study will explore the opportunities for improving the delivery of health services in Nepal, focusing on the development of healthcare human resources, the modernization of health facilities, and the enhancement of healthcare services. Understanding these opportunities is essential for maximizing the impact of reconstruction efforts and ensuring that the Nepalese population can access quality healthcare services. This study examines the potential opportunities associated with post-earthquake reconstruction of health sector building projects in rural Nepal through Principle Component Analysis (PCA).

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II. LITERATURE REVIEW

Table 1 Potential Opportunities Associated with Post-disaster Reconstruction

S. N	Potential opportunities	Sources
1	To construct health sector buildings with additional rooms and other amenities.	(Westoby et al., 2021)
2	Reconstruction using higher quality materials.	(WESTOBY et al., 2019, Adhikari and D'Ayala, 2020, Mahdi and Mahdi, 2013)
3	Aligning well with the BBB (Build Back Better) approach. (BBB approach lessens community vulnerabilities, supports recovery, reconstruction, and rehabilitation, and incorporates risk reduction and resilient practices.)	(WESTOBY et al., 2019, Neeraj et al., 2021, Francis et al., 2018)
4	Enhancements in accessibility for patients with disabilities.	(Westoby et al., 2021, Jeste et al., 2020)
5	Transfer of knowledge between stakeholders.	(WESTOBY et al., 2019, Ugolini et al., 2015)
6	Enhancing the delivery of health sector buildings reconstruction projects.	(Westoby et al., 2021)
7	Enhancing the safety and functionality of health sector buildings.	(Westoby et al., 2021, Adamy and Abu Bakar, 2021)
8	To invest a significant amount of international aid in economic development.	(Le De, 2011, Bănică et al., 2020)
9	Disaster as an opportunity for sustainable development.	(Le De, 2011, Imperiale and Vanclay, 2021, Dube, 2020)
10	Disaster as an opportunity for anticipatory actions.	(Le De, 2011, Moatty and Vinet, 2016)
11	Insurance tools and risk management.	(Le De, 2011, Izumi et al., 2019)
12	Policies for disaster management and community engagement.	(Adhikari et al., 2016, Enshassi et al., 2017)
13	Post-earthquake reconstruction as an opportunity for Employment Generation.	(Shrestha, 2022)
14	Education and capacity building for stakeholders in post-earthquake reconstruction management facilitate program implementation and long-term sustainability.	(Bilau et al., 2018)
15	Post-earthquake reconstruction as an opportunity for Research and Innovation.	(Bonomo and De Berardinis, 2014)
16	Post-earthquake reconstruction as an opportunity for International Collaboration and Partnerships.	(Jean-Gilles, 2023)

III. MATERIALS AND METHODS

This study aimed to explore the potential opportunities related to the reconstruction of health sector building projects in rural Nepal following an earthquake, utilizing quantitative research methods and a cross-sectional design. The study population consisted of client, consultant, and contractor officer-level technical staff who were actively engaged in the post-earthquake reconstruction of health sector building projects funded by the Government of India after the 2015 Gorkha earthquake. A total of 151 individuals participated in the survey, which utilized a questionnaire developed by reviewing previous research articles. The questionnaire included a Likert scale with five ordinal measures ranging from one (1) to five (5) (1=Strongly Agree, 2=Agree, 3=Neutral, 4=Disagree, 5=Strongly Disagree). Participants were asked to prioritize potential opportunities linked to the post-earthquake reconstruction of health sector buildings in Nepal, based on the perceived frequency of occurrence, informed by their expertise and professional experience. Once the data was collected, it underwent processing, cleaning, and preparation for analysis. Principal Component Analysis (PCA) was performed using SPSS version 25 to identify the key components underlying the dimensions of potential opportunities associated with post-earthquake reconstruction efforts.

IV. RESULTS AND DISCUSSION

- *Assessment of the Suitability of the Data for Potential Opportunities*

For assessment of the suitability of data for factors analysis, Kaiser-Meyer-Olkin (KMO) is used to measure the suitability of data for factor analysis. Similarly, Bartlett's test of Sphericity, correlation matrix, and determinant score are computed to detect the appropriateness of the data set for functioning factor analysis (Tabachnick et al., 2013).

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Table 2 KMO and Bartlett's Test for Opportunity of Post-earthquake Reconstruction

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.869
Bartlett's Test of Sphericity	Approx. Chi-Square	622.859
	df	120
	Sig.	.000

The KMO test is a measure that has been intended to measure the suitability of data for factor analysis. In other words, it tests the adequacy of the sample size. KMO test and Bartlett's test of Sphericity were conducted to test the validity of the PCA. KMO values between 0.8 to 1.0 indicate the sampling is adequate. KMO values between 0.7 to 0.79 are middling and values between 0.6 to 0.69 are mediocre. KMO values less than 0.6 indicate the sampling is not adequate and remedial action should be taken. An average value > 0.6 is acceptable for sample a size < 100; an average value between 0.5 and 0.6 is acceptable for sample sizes between 100 and 200 (Tabachnick et al., 2013).

Bartlett's test of Sphericity is highly significant at $p < 0.001$ which shows that the correlation matrix has significant correlations among at least some of the variables. Here, the test value is 622.859 and an associated degree of significance is less than 0.0001. The significant value < 0.05 indicates that factor analysis may be worthwhile for the data set (Loehlin, 2004, Kaiser, 1974, Shrestha, 2021)

It was determined that the factor number is, KMO value .869; Bartlett value $\chi2$ =622.859; df=120 (p=.000) in the scale consists of 16 items. Table 2 illustrates the value of KMO statistics is equal to 0.869 > 0.7 which indicates that sampling is adequate and the factor analysis is appropriate for the data.

- *Factor Extraction for Opportunities Associated with Post-Earthquake Reconstruction of Health Sector Buildings.*

In this study two techniques are used to assist in the decision concerning the number of factors to retain: Kaiser's Criterion (Eigen Value) and Scree Test. The eigenvalue technique was used to determine the number of factors to extract. In this case, only factors with eigenvalues of 1.0 or more were retained. Varimax was used for normalization to reduce the complexity of the factors to maximize the variance in the model.

In multivariate statistics, a scree plot is a line plot of the eigenvalues of factors or principal components in an analysis. The scree plot is used to determine the number of factors to retain in an exploratory factor analysis (EFA) or principal components to keep in a principal component analysis (PCA). As Figure 1 of the scree plot describes that, four latent variables have Eigen value >1.

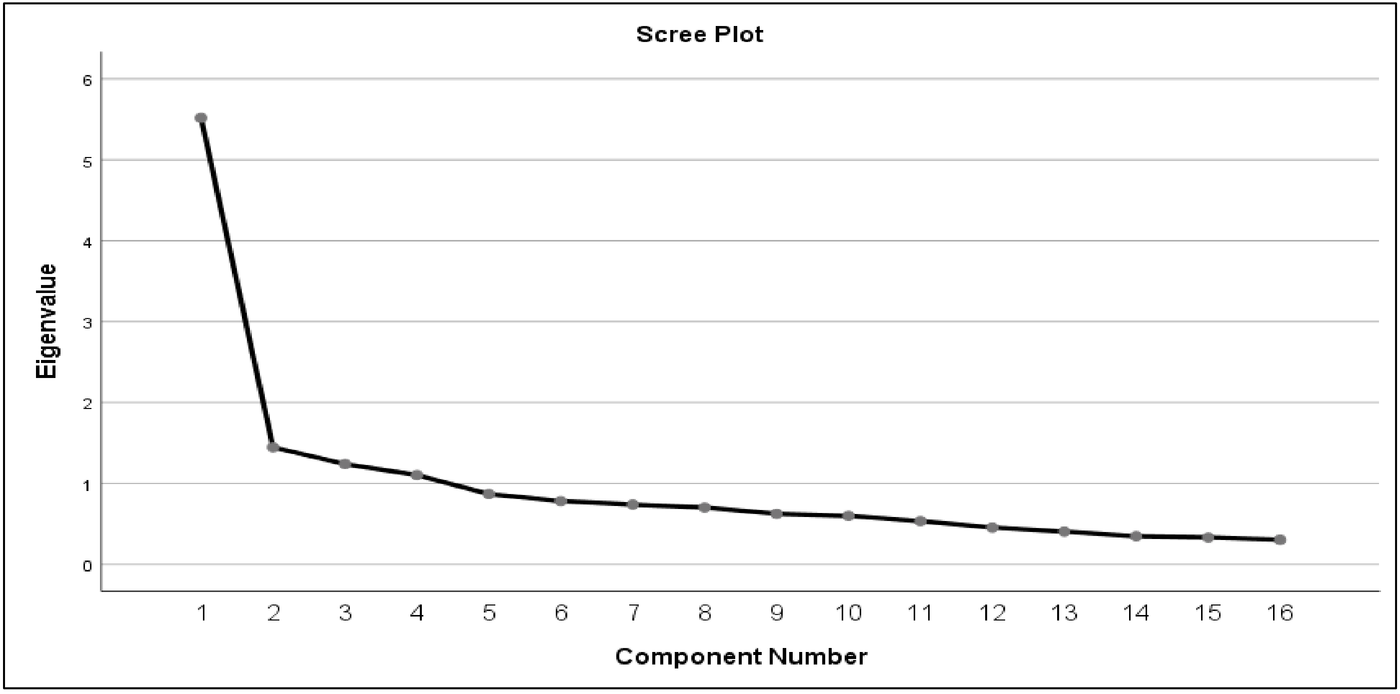

Fig 1 Scree Plot for Potential Opportunities of Post-Earthquake Reconstruction

In Figure 1, for a scree test, a graph is plotted with eigenvalues on the y-axis against the sixteen component numbers in their order of extraction on the x-axis. The initial factors extracted are large factors with higher eigenvalues followed by smaller factors. The scree plot is used to determine the number of factors to retain. Here, the scree plot shows that there are four factors for which the eigenvalue is greater than one and accounts for most of the total variability in data. The other factors account for a very small proportion of the variability and are considered not so much important (Tabachnick et al., 2013).

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Table 3 Eigenvalues (EV) and Total Variance Explained Extraction Method: Principal Component Analysis for Potential Opportunities of Post-earthquake Reconstruction

Total Variance Explained									
Component	**Initial Eigenvalues**			**Extraction Sums of Squared Loadings**			**Rotation Sums of Squared Loadings**		
	Total	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**
1	5.394	33.710	33.710	5.394	33.71	33.710	2.531	15.817	15.817
2	1.382	8.635	42.345	1.382	8.635	42.345	2.523	15.770	31.587
3	1.222	7.636	49.981	1.222	7.636	49.981	2.148	13.425	45.012
4	1.108	6.923	56.903	1.108	6.923	56.903	1.903	11.891	56.903
5	0.914	5.710	62.613						
6	0.746	4.664	67.278						
7	0.710	4.438	71.716						
8	0.690	4.315	76.031						
9	0.640	4.000	80.032						
10	0.615	3.844	83.876						
11	0.533	3.332	87.208						
12	0.527	3.296	90.504						
13	0.428	2.673	93.177						
14	0.383	2.395	95.571						
15	0.372	2.324	97.896						
16	0.337	2.104	100.00						
Extraction Method: Principal Component Analysis.									

Table 3 demonstrates the eigenvalues and total variance explained. The extraction method of factor analysis used in this study is principal component analysis. Before extraction, sixteen linear components are identified within the data set. After extraction and rotation, there are four distinct linear components within the data set for the eigenvalue > 1. The four factors are extracted accounting for a combined 56.903% of the total variance. It is suggested that the proportion of the total variance explained by the retained factors should be greater than 50%. The result shows that 56.903% of common variance shared by 16 variables can be accounted for by four factors. This is the reflection of the KMO value, 0.869, which can be considered good and also indicates that factor analysis is useful for the variables. This initial solution suggests that the final solution will extract not more than four factors. In the scope of the study, it was determined that there are 4 factors with an eigenvalue greater than 1. The variance explained by the first factor is 33.71% with Eigenvalue of 5.394; the variance explained by the second factor is 8.635% with Eigenvalue 1.382; the variance explained by the third factor is 7.636% with Eigenvalue 1.222; the variance explained by the fourth factor is 6.923% with Eigenvalue 1.108.

➢ *Factor Rotation and Interpretation for Potential Opportunities*

Table 4 Extraction Method: Principal Component Analysis for Opportunities of Post-earthquake Reconstruction

Opportunities of Post-earthquake Reconstruction	**Components**			
	Seismic Resilience and Opportunity Framework	**Disaster Resilient Health Infrastructure**	**Rebuilding for Prosperity Program**	**International Aid for Economic Growth**
Policies for disaster management and community engagement.	.795			
Earthquake as an opportunity for anticipatory actions.	.647			
Post-earthquake reconstruction as an opportunity for Insurance tools and risk management.	.624			
Education and capacity building for stakeholders in post-earthquake reconstruction management facilitate program implementation and long-term sustainability.	.609			
Aligning well with the BBB (Build Back Better) approach.		.811		

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Transfer of knowledge between stakeholders.		.708		
Enhancing the safety and functionality of health sector buildings.		.673		
Post-earthquake reconstruction as an opportunity for International Collaboration and Partnerships.			.763	
Post-earthquake reconstruction as an opportunity of Research and Innovation.			.756	
Post-earthquake Reconstruction as an Opportunity for Employment Generation			.649	
To invest a significant amount of international aid in economic development				.842
Enhancing the delivery of health sector buildings reconstruction projects.				.677

- *Component 1: Seismic Resilience and Opportunity Framework*

Component one is labeled as the 'Seismic Resilience and Opportunity Framework' which is considered a major potential opportunity for post-earthquake reconstruction in health sector building construction projects which contains four items that strive for policies for disaster management and community engagement, earthquake as an opportunity for anticipatory actions, post-earthquake reconstruction as an opportunity of insurance tools and risk management and education and capacity building for stakeholders in post-earthquake reconstruction management facilitate program implementation and long-term sustainability and have a correlation of 0.795, 0.647, 0.624 and 0.609 with component 1 respectively. The component 'Seismic Resilience and Opportunity Framework' explained 33.71% of the total variance with an eigenvalue 5.394. According to (Guo, 2012) Sichuan post-earthquake reconstruction provided opportunity of seismic Resilience and opportunity framework. Previous studies (Pandey, 2019, Islam et al., 2020, Zubir and Amirrol, 2011, Samaddar et al., 2015, Baytiyeh and Naja, 2013) also proved that policies for disaster management and community engagement is one of the opportunities for post-earthquake reconstruction in health sector building construction projects. (Kiser et al., 1993, Tekeli-Yeşil et al., 2010, Le De, 2011) also verify that earthquake as an opportunity for anticipatory actions. (Le De, 2011) state that post-earthquake reconstruction as an opportunity for insurance tools and risk management. (Bilau et al., 2018, Thapa and Pathranarakul, 2019) also verified that education and capacity building for stakeholders in post-earthquake reconstruction management facilitate program implementation and long-term sustainability.

- *Component 2: Disaster Resilient Health Infrastructure*

Similarly, the second component entitled as 'Disaster Resilient Health Infrastructure' is considered as second major potential opportunities for post-earthquake reconstruction in health sector building construction projects, which explained with 8.635% variance with eigenvalue 1.382. This component contained three items such as aligning well with the BBB (Build Back Better) approach, transfer of knowledge between stakeholders and enhancing the safety and functionality of health sector buildings and have correlation of 0.811, 0.708 and 0.673 with component 2 respectively. This component is explained with total variance 8.635% and eigenvalue of 1.382. According to (Rouhanizadeh et al., 2020) post disaster reconstruction provides opportunity to build disaster-resilient health infrastructure. Furthermore, (Westoby et al., 2021) also verify that aligning well with the BBB (Build Back Better) approach, transfer of knowledge between stakeholders, enhancing the safety and functionality of health sector buildings are the opportunities of post-earthquake reconstruction.

- *Component 3: Rebuilding for Prosperity Program*

The component 3 is considered as third potential opportunities of post-earthquake reconstruction marked as 'Rebuilding for Prosperity Program' in health sector building construction projects. It contains three items namely post-earthquake reconstruction as an opportunity of international collaboration and partnerships, policies for disaster management and community engagement and post-earthquake reconstruction as an opportunity for employment generation and which have a correlation of 0.763, 0.756, and 0.649 with component 3 respectively. This component contained explained with total variance 7.636% and eigen value 1.222. (Jean-Gilles, 2023) also stated that post-earthquake reconstruction as an opportunity of international collaboration and partnerships. (Brand and Nicholson, 2016) identifies post-earthquake reconstruction as an opportunity of research and innovation.(Shrestha, 2022) also stated that post-earthquake reconstruction as an opportunity of employment generation.

- *Component 4: International Aid for Economic Growth*

Component 4 is marked as fourth potential opportunities of post-earthquake reconstruction 'International Aid for

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Economic Growth' in the health sector building construction projects. It contains two items namely to invest a significant amount of international aid in economic development and enhancing the delivery of health sector buildings reconstruction projects and which have a correlation of 0.842 and 0.677 with component 4 respectively. This component contained explained with total variance 6.923% and eigen value of 1.108. According to (Paudel and Le Billon, 2020) international aid for economic growth is one of the opportunity during post-disaster reconstruction. (Smith, 2016) also signifies that a significant amount of international aid in economic development is one of the opportunities in post-earthquake reconstruction. The post-earthquake reconstruction programs provide opportunity of enhancing the delivery of health sector buildings reconstruction projects (Westoby et al., 2021).

Table 5 Cronbach's Alpha for Second-Order Component Analysis for Potential Opportunities of Post-Earthquake Reconstruction

Component	Cronbach's Alpha
Seismic Resilience and Opportunity Framework	0.726
Disaster Resilient Health Infrastructure	0.731
Rebuilding for Prosperity Program	0.712
International Aid for Economic Growth	0.708

The internal consistency is confirmed by calculating Cronbach's alpha to test the instrument's accuracy and reliability. The adequate threshold value for Cronbach's alpha is that it should be > 0.7. In Table 5 the component Seismic Resilience and Opportunity Framework, Disaster Resilient Health Infrastructure, Rebuilding for Prosperity Program, and International Aid for Economic Growth have Cronbach's alpha values 0.726, 0.731, 0.712, and 0.708 respectively, which confirmed the reliability of the survey instrument. It shows that the variables exhibit a correlation with their component grouping and thus they are internally consistent.

V. CONCLUSION

Based on the comprehensive analysis conducted through Principal Component Analysis (PCA) to identify potential opportunities associated with post-earthquake reconstruction of health sector buildings in Nepal, several key insights have emerged.

Firstly, the findings reveal four major components of potential opportunities in post-earthquake health sector building reconstruction. These components are categorized as Seismic Resilience and Opportunity Framework, Disaster Resilient Health Infrastructure, Rebuilding for Prosperity Program, and International Aid for Economic Growth. These components encapsulate critical aspects such as policy engagement for disaster management, leveraging earthquakes as opportunities for anticipatory actions and risk management, aligning with the 'Build Back Better' approach, and mobilizing international aid for economic growth and innovation.

Secondly, the eigenvalue analysis underscores that these four components together explain a significant proportion of the total variance in the dataset, accounting for approximately 56.903% of the variability. This suggests that focusing on these identified opportunities can significantly impact the successful reconstruction of health sector buildings post-earthquake, enhancing their resilience, safety, and functionality.

In conclusion, the PCA analysis has effectively distilled the multifaceted potential opportunities into distinct components, offering a clear roadmap for policymakers, stakeholders, and the broader community involved in post-earthquake health sector reconstruction in Nepal. By strategically embracing and implementing these opportunities, Nepal can achieve a resilient and robust health infrastructure that not only bounces back from disasters but thrives in the face of challenges, contributing to the overall prosperity and well-being of its citizens.

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