Systematic Approach To Rehabilitation Of Historic Buildings In Bhutan

Choten Tshering[1] Thongley[2], Yeshi Dorji[3]
Research and Publication Board, College of Science and Technology.
* E-mail: chotentshering06@yahoo.com[1], thongley21@gmail.com[2], yeshidorjigsss2012@gmail.com[3]

Abstract

This paper present the systematic approach of rehabilitation which is aimed to identify the damages caused, assess the failure mechanism, study the challenges related to rehabilitation works and to analyze the corresponding rehabilitation techniques. The study was carried out based on visual inspection and field evaluation of the two sites; Jela Lhakhang and Paro Ta Dzong.

A questionnaire survey was carried out to study the challenges faced during execution of works. Preservation of cultural heritage was found out to be the most challenging of all. After studying the rehabilitation works systematically, a roadmap is proposed based on the study approach.

A comparative analysis between traditional (wall stitching using mud mortar) and modern (using cement mortar) techniques was carried out using Multi-Criterion Decision Making (MCDM) Method. Based on a number of criteria set by the decision maker. Normalizing the alternatives and the criteria, results (for traditional: $C_i = 0.834$ and for modern: $C_i = 0.166$) showed that traditional method of rehabilitation is better than the modern methods of rehabilita-tion techniques.

Key Words : *Rehabilitation, Multi Criterion Decision Making Method, Normalization.*

1. INTRODUCTION

Rehabilitation of historic building refers to the process of correctly revealing the state of a historic building, as it is looked in the past and recovering the same by various measures while respecting the heritage value (Sandbhor & Botre, 2013). Rehabil-itation is defined as the act or process of accurately depicting the form, features, and character of a property as it appeared at a particular period of time by means of the removal of features from other pe-riods in its history and reconstruction of missing features from the rehabilitation period (DCHS, 2012). Heritage structures perform vital role in na-tion's history, culture and signify the richness of it. The practice of maintaining heritage structure has existed as an inherent part of local tradition in Bhutan. This research study is aimed on identifying the various problems encountered and the methods employed to tackle them. This study also focuses on such problems and methodology to handle these problems while respecting the structure's cultural integrity. Moreover, this paper seeks to highlight the need for a greater awareness and the need to take precautionary measures of the immediate effects, and of the long-term issues of heritage structures.

2. METHODOLOGY

For the systematic approach of rehabilitation, a de-tailed survey and documentation for the following heritage sites was carried out first:

1) Jela Lhakhang
2) Paro Ta Dzong

The two sites represent the typical nature (structur-ally and architecturally) of the historic sites in Bhutan. All historic sites in the country are con-structed with the same structural components. The structural components are mainly the stone masonry, timber components and the mural paintings. The two sites are best suited for the study purpose under topic because there is an ongoing rehabilitation work being carried out. The field study includes comprehensive documentation with necessary photographs and measurements of the sites.

2.1 Damages and Failures of Stone Masonry

The failures are due to direct earthquake moments or due to displacement of wooden components during a fire. One of the main reasons for the fail-ures of the historical building in Bhutan is due to the unequal weight of the building along the height and the length of the building. It is often found that the corners of wall are improperly fixed during the construction. The stones are being randomly laid there by no proper bond is being achieved which results in separation at corners during shaking of the building which can be observed.

2.2 Damages of Timber Structure

The typical damages caused on wooden components of the historical buildings are deformation, dislocation, sagging of horizontal members, inclination of vertical members, warping and buckling. The strength of the wood is determined by the experienced carpenters either through visual inspection or sounding test.

2.3 Rehab techniques for stone masonry.

Wall stitching

Wall stitching is one of the best methods of rehabilitating wall cracks. Wall is removed in an inverted triangular shape. Then the new wall is constructed with the same material or similar material to retain the original state of the structure. To retain the original sight, it is plastered with mud. Wall stitching is done in two ways; using mud mortar and cement mortar. For the functional compatibility purpose, mud mortar method is more preferable whereas the cement mortar enhance the structural strength.

2.4 Rehab Techniques for Wooden Structure.

Jigsaw fitting method.

This is a traditional method which is usually followed in Bhutan. In this type of method, damaged portion of timber is removed and the same quality of timber is replaced by jigsaw fitting. Here the jigsaw fitting increases strength by 30% than ordinary timber (Avrami, 2000). Due to this reason jig saw fitting is also seen in modern table which are manufactured in factories.

3. Assessment of Challenges Related to Rehabilitation Works

Challenges related to rehabilitation in historical building is classified into technical, economical, materials and management.

3.1 Study for the Needs of Modern Techniques and Equipment

There is a concern of structural strength compromised to preserve the architectural designs. The questionnaire survey for the needs of modern techniques and equipment revealed that 43% as shown in Figure 1 and Figure 2 the respondents feel that these are 'moderately need'.

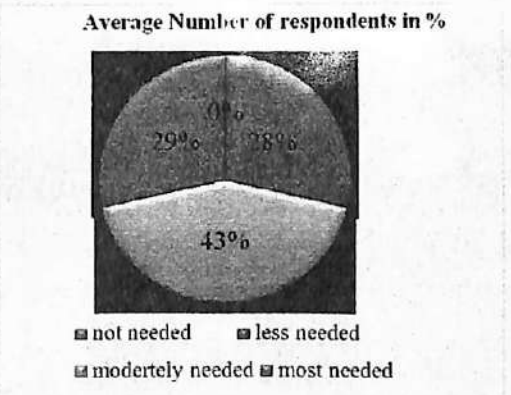

Figure 1:Need of Modern techniques

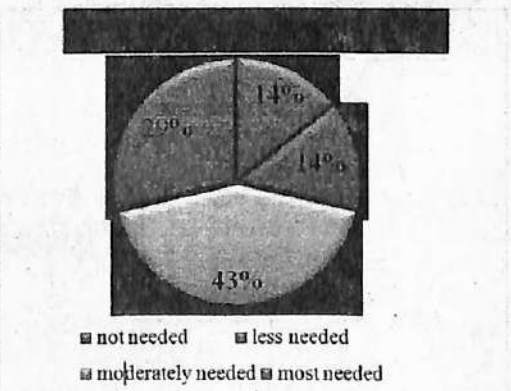

Figure 2: Need of Specialized Equipment

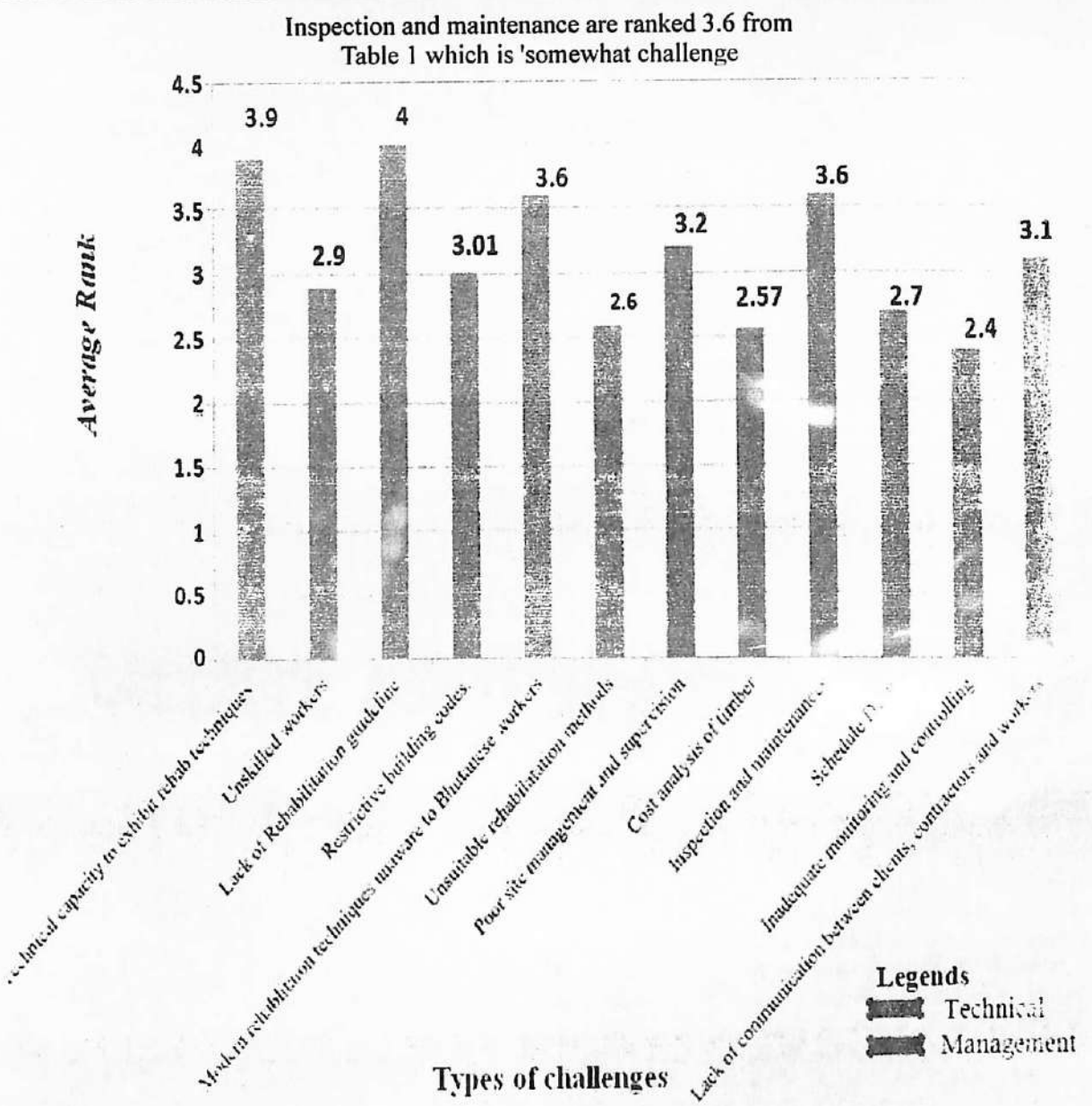

Figure 3: Assessment of challenges: Technical and Management.

a) Technical challenges

The average value for lack of rehabilitation guideline during rehabilitation of historical building was found out 4 from Figure 3 which indicates 'somewhat challenging' from Table 1. There is no guideline for rehabilitation of historical building, as a result designer faces lots of challenges while designing and implementing the works.

b) ing' while rehabilitation of historical building. The regular inspection and maintenance of historical building are difficult because of the site location, cost limit and unavailability of material.

Inspection and maintenance are ranked 3.6 from Table 1 which is 'somewhat challenge

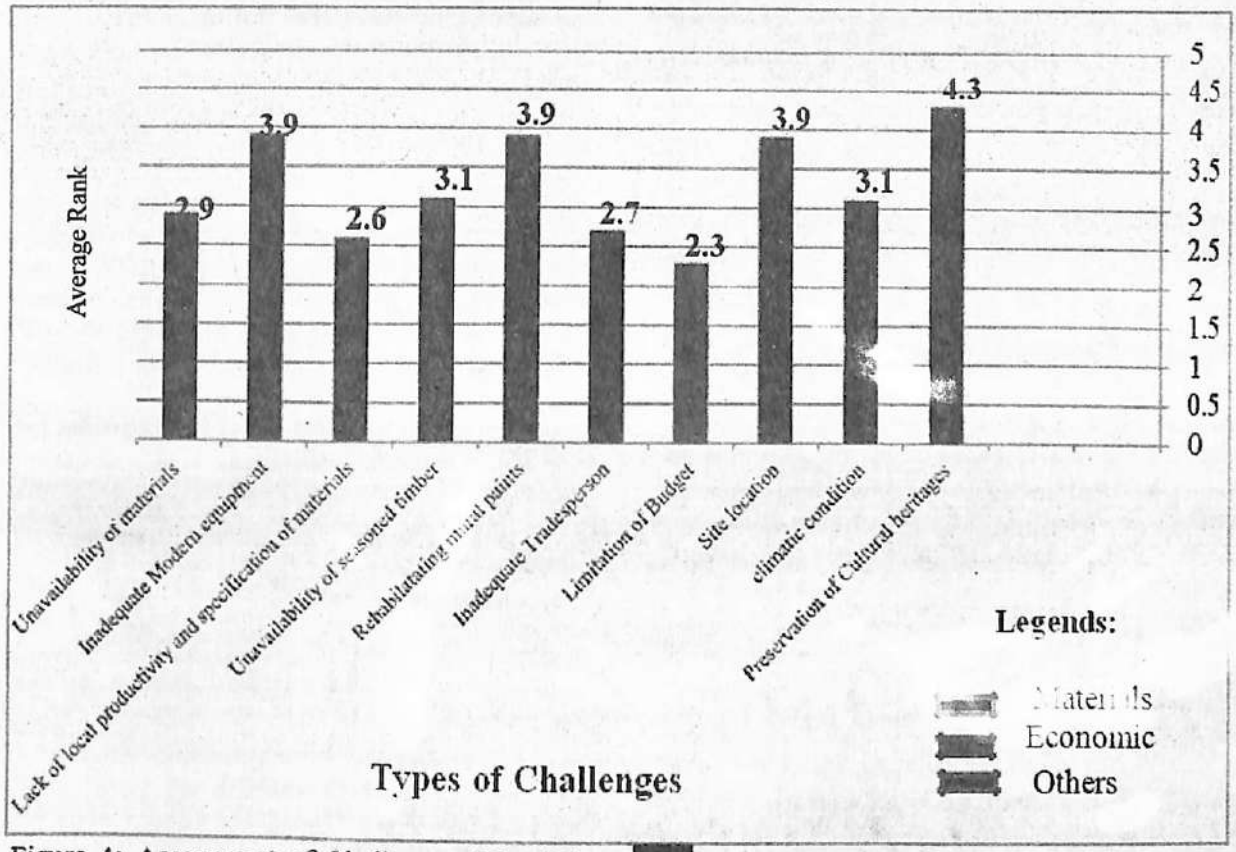

Figure 4: Assessment of Challenges: Material, Economical and others

c) Material challenges

From Figure 4 the inadequacy of modern equipment is ranked 3.9 which 'somewhat challenging' from table 1. The modern equipment's needs accuracy while handling and labors are not able to use it properly and efficiently.

d) Economic challenges

From Figure 4 it is clear that the cost is ranked 2.3 which are 'less challenging' according to the analysis shown in Table 1. The certain amount of budget is allocated to rehab and maintenance of the build-ings. So cost is not a matter, if the other challenges are being taken care.

Table 1 shows the various challenges ranked based on the questionnaire survey. Based on the average rankings by the respondents, the classification of the challenges are done into the following categories as shown in the Table 1.

From Table 1, the unskilled workers, unavailability of labor, schedule delay and limitation of budget comes under the 'less challenging' (ranks vary between 2.1 to 3) during the rehabilitation.The modern rehabilitation techniques, lack of commu-nication between clients, contractor and workers, inadequate modern equipment, rehabilitating mural paints and site location are 'somewhat challenging' (ranked 3.1 to 4).

Table 1: Shows the analysis of the types of challenges

Rank	Category	Types of challenges
0.0-1	No idea	
1.1-2	Not challenging	
2.1-3	Less challenging	• Unskilled workers • Unsuitable rehabilitation techniques • Unavailability of materials. • Lack of local productivity and specification • Inadequate trade person • Limitation of budget • Cost analysis of timber • Schedule delay • Inadequate monitoring and controlling
3.1-4	Somewhat challenging	• Technical capacity to exhibit rehab techniques. • Lack of rehabilitation guidelines. • Restrictive buildings codes • Modern rehabilitation techniques • Lack of communication between clients and contractors • Inadequate modern equipment • Unavailability of seasonal timbers • Rehabilitating mural paints • Site location • Climatic condition • Poor site management and supervision • Inspection and maintenances
4.1-5	Extremely challenging	• Preservation of cultural heritage

4. Multi Criteria Decision Making (MCDM) Method

Multi Criteria Decision Making (MCDM) Methods are decision-support procedures used in many fields allowing the evaluation and comparison of a set of alternatives when many evaluation criteria are involved. Ranking the alternative solutions leads to the identification of the optimal solution, which better performs in respect to all relevant goals. The method is employed in the project to analyze the different techniques used for rehabili-tating failure in a structural component.

4.1 Traditional method of wall stitching.

The basic procedure followed in this method is such that the damaged portion of wall is being removed first, manually, in a triangular shape. Then the stones are shaped into required dimensions and placed with properly mixed mud mortar.

4.2 Modern method of wall stitching.

The difference in this method is the use of cement mortar rather than using mud mortar. This limited difference is not only the factor that results to comparative analysis. The analysis is based on six different criteria set on the perspectives from both the methods.

Table 2: Evaluation criteria.

Group	Symbol	Description
Economical/ Technical/management	C_1	Requirement of skill labor
	C_2	Functional compatibility
	C_3	Strength of structure
	C_4	Cost effect
	C_5	Duration of work
	C_6	Effectiveness of technique

4.3 Descriptions of Evaluation Criteria

The criteria that have a significant influence on the final decision are considered. It depends on the specific feature of the building and on its destination. In both the methods, the need of skill labor is essential.

4.4 Weighting the Evaluation Criteria

A quantitative evaluation of the relative importance (weight) of each criterion to the final decision is needed. The weights will amplify or deamplify the evaluations of the alternatives in order to reflect how much each criterion is im-portant relatively to the others in the choice of the best solution.

The approach used herein to compute weights W_i of the criteria C_i (i = 1, 2, ...6) is based on pairwise comparisons of criteria and Eigen Values Theory. The matrix of 6 by 6 matrix is being computed to get the weightage of individual criteria.

1	4.5/4.3	4.5/3.7	4.5/3.3	4.5/2.9	4.5/2.3
4.3/4.5	1	4.3/3.7	4.3/3.3	4.3/2.9	4.3/2.3
3.7/4.5	3.7/4.3	1	3.7/3.3	3.7/2.9	3.7/2.3
3.3/4.5	3.3/4.3	3.3/3.7	1	3.3/2.9	3.3/2.3
2.9/4.5	2.9/4.3	2.9/3.7	2.9/3.3	1	2.9/2.3
2.3/4.5	2.3/4.3	2.3/3.7	2.3/3.3	2.3/2.9	1

The matrix is solved by using the Power Method. Weightage (W) = {**1.00, 0.95, 0.82, 0.73, 0.64, 0.51**}.

4.5 Ranking of the Alternatives and Selection of the best wall stitching Solution.

The selected MCDM Method is the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). It was developed based on the geomet-

Table 3: Decision Matrix D.

A1	0.22	1	0.27	19338.34	7	1
A2	1	0.04	1	31310.59	8	0.43

Table 4: Normalized Decision Matrix R

A1	0.215	0.999	0.261	0.525	0.659	0.919
A2	0.977	0.039	0.965	0.851	0.753	0.393

rical concept that the best alternative must have the shortest distance to an *ideal* solution (A*) and the farthest distance to a *negative-ideal* one (A−) (Hwang & Yoon, 1981).

Let X_{ij} indicate the performance measure of the i-th alternative (i = 1, 2) in terms of the j-th criterion (j = 1, 2, ..., 6), evaluated in the previous sections. All the X_{ij} have to be collected in the decision matrix D = $[X_{ij}]$.

The normalization of X_{ij} values, each of those being characterized by different units, has to be done.

$$R = /\sqrt{\Sigma^{2}} = 1^{2}$$

The next step is weighting the R matrix by multiplying each value of the j-th column by the weight (W_j) of the j-th criterion. This leads to obtain the weighted normalized decision matrix,

$V = [W_j r_{ij} = V_{ij}]$.

$V = W X R$.

In particular, the ideal solution A* is obtained by taking for each criterion the "best" performance value among A1 and A2 (indicated by an asterisk). Conversely, the negative-ideal solution A− is composed by considering for each criterion the "worst" performance measure among the alternatives (indicated by a minus).

Let Si* and indicate the distance of Ai to A* and A−, respectively. The TOPSIS Method ranks alternative solutions in terms of the so-called relative closeness.

$$Ci^{*} = 6Si\text{-}/(Si^{*} + Si\text{-}).2 \qquad Si^{*} = \sqrt{\Sigma} = 1 \ (V\,ij - Vj^{*}) \qquad Si\text{-} = \sqrt{\Sigma} = 1 \ (V\,ij - Vj\text{-})$$

Table 5: Weighted Normalized decision Matrix V.

A1	0.215	0.949	0.214	0.383	0.422	0.469
A2	0.977	0.039	0.791	0.621	0.482	0.201

quate monitoring (ranked 3.1 to 4) are found

Table 6: Ideal solution A* and negative Ideal solution A-

A*	0.215	0.949	0.214	0.383	0.422	0.469
A-	0.977	0.039	0.791	0.621	0.482	0.201

Table 7: Final Choice of alternatives

Wall Stitching	A1	0.068	0.344	0.834
Concrete Jacketing	A2	1.344	0.268	0.166

The obtained Si*, Si-, and Ci* values for the two alternatives under examination are reported in Table 7. Alternative A1 (traditional) results to be the best one, with a relative closeness, C_1^*, equal to 0.834. Therefore, traditional method is more suitable for wall stitching.

In traditional method of wall stitching cost involved is not that high because the labors and material are readily available.

Whereas in the case of modern method the cost involved is much higher functional compatibility is much lower compared to traditional method. The traditional method preserves the cultural heritage which is the ultimate aim of rehabilitation of his-torical buildings.

5. CONCLUSION

In this study the various challenges faced during the ongoing rehabilitation of historical building are classified into technical, economical, management, cost and material. The preservation of the cultural heritage was found out 'extremely challenging' 4.3 from Figure 4. This is because the workers feel that the handling of the cultural heritage during the rehabilitation is very difficult due to lack of expe-rience.

The challenges like limitation of budgets, unavailability of material, schedule delay and inade- out 'somewhat challenging'.

In the Multi Criteria Decision Making, the choice of the technique to implement wall stitching strategy in rehabilitation of historical building involves several sets criteria. The choice of the relevant criteria is dependent on the experience of the decision makers. For the investigated case, result indicates the traditional method as the better choice of rehabilitation. From Table 7 the traditional method is 0.834 which is greater than 0.166 in case of modern method. This clearly shows, in wall stitching the traditional is the best solution.

In systematic approach of rehabilitation of historical buildings, the series of strategic planning is done to retain and preserve the cultural heritage. The repair process requires the continuous and systematic, starting from the identification of the structure failure till the technique implementation. The main components for systematic restoration involve site investigation, diagnosing and correcting deficiencies. The advantage o ystematic approaches reduces the time delay and the cost involved in the project. In systema ic approach of rehabilitation of the historical building, the selection of skilled labors and materials are important.

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