Journal of Design and Built Environment
E-ISSN: 2232-1500 |Print ISSN: 1823-4208
https://ejournal.um.edu.my/index.php/jdbe
Volume 25, Issue 03, 2025, 107-137

Analysis of Cultural Impact Categories and Subcategories for Cultural Life Cycle Assessment of Traditional Houses in India

Manali Basu[1*], Nagaraju Kaja[1] and Prashanti Rao[1]

[1]School of Planning and Architecture, Vijayawada, Department of Architecture, Krishna Nagar, Vijayawada, India.

*Corresponding author: basumanali94@gmail.com

Article Info:

Submission date: 6th July 2025
Acceptance date: 17th Nov 2025

Keywords

Architecture, Culture, Cultural life cycle assessment, Principal Component Analysis, Traditional houses

Abstract

Culture has significantly influenced the architecture of the traditional houses in different parts of the world. However, it remains unaddressed in the sustainability assessment techniques of such houses. 'Life Cycle Assessment (LCA)' is one such assessment technique that assesses mainly the quantitative aspects associated with them. Previous LCA studies in the context of traditional houses or cultural heritage have mainly focused on the assessment of environmental impacts of restoration or renovation of heritage houses or optimizing their environmental performances. Also, LCA standards exist only for 'Environmental Life Cycle Assessment (E – LCA)' and 'Social Life Cycle Assessment (S – LCA)' which are the 'ISO 14040' and 'Guidelines for Social Life Cycle Assessment of Products' by UNEP / SETAC Life Cycle Initiative (2009) respectively. Therefore, this study aims to analyze the various tangible cultural impact categories and subcategories for developing a framework for 'Cultural Life Cycle Assessment (C – LCA)' of traditional houses, which has been unaddressed in the building LCA studies or LCA standards before. Data has been collected through a questionnaire survey and purposive sampling method has been used to select the sample for the study. A total of 207 respondents, comprising of professionals in the related fields, and common people of age 18 years and above residing in different parts of India took part in the survey. The questionnaire comprises of the basic details of the respondents, followed by questions which are measured on a 5 – point Likert scale, and some open – ended questions as well. The collected data has been analyzed in IBM SPSS Statistics software by using Principal Component Analysis (PCA) method. Results show that 10 out of the 11 cultural subcategories have an influence on the 'spatial organization of the house.' Whereas 'conformity to local climate, geology and geography' mainly influences the impact subcategories such as pattern, type, size and shape of the house under the impact category 'form of the house,' with factor loadings of 0.830, 0.830, 0.769 and 0.742 respectively. The eigenvalue and total variance explained by the component consisting of these four impact subcategories are 2.521 and 63.024% respectively, with a Cronbach's Alpha (reliability) value of 0.804. Since, previous studies have mainly focused on the assessment of quantitative aspects like environmental impacts of traditional houses, and standards exist only for E – LCA and S – LCA, the novelty of this study lies in the fact that it will help in assessing the cultural impacts associated with the transformations in traditional houses during their lifespan as well. The findings of this study will not only help in preserving the housing heritage, but will also help in the incorporation of culture, which is the fourth pillar of sustainability, in the LCA process along with other three pillars of sustainability.

1.0 INTRODUCTION

Culture, in general, can be defined as a set of ideas and values, beliefs, practices and knowledge of certain groups of people, where all these factors affect their attitude and behaviour, and give them a cultural identity (Pizzirani et al., 2014; Farshchi et al., 2016). According to the '1982 Mexico Declaration on Cultural Policies by UNESCO,' culture can be defined as the distinct material, spiritual, emotional and intellectual features that characterize a society. Culture forms the heart of the 'Sustainable Development Goals (SDGs)' and contributes to the social, economic and environmental pillars of sustainability transversally (UNESCO, n.d.). UNESCO classifies cultural heritage into two parts, namely, tangible and intangible cultural heritage. Tangible cultural heritage comprises of the following: (a) movable heritage such as paintings, manuscripts, etc., (b) immobile heritage such as historical buildings and others, and (c) underwater heritage such as underwater ruins, etc. (UNESCO Institute for Statistics, 2009; Ćosović et al., 2019). According to the '2003 Convention for the Safeguarding of the Intangible Cultural Heritage,' intangible cultural heritage (ICH) encompasses knowledge, practices, expressions, representations and know – how that are transmitted from one generation to the other inside the communities, and which undergoes continuous creation or transformation by them, based on their environment and the way in which they interact with history and nature (UNESCO, 2011).

In the context of vernacular architecture, Vehbi et al. (2021) and Murillo Camacho et al. (2023) mentioned that cultural values are highly exhibited in vernacular architecture, and are related to their artistic and historical values, which also include aunthencity as well as integrity. According to Ceylan (2022), vernacular architecture constitues of a region's architectural language which is influenced by the cultural and material aspects throughout history, and which is transferred to the future generations in the form of buildings. The author further mentioned that the unique architectural planning of vernacular architecture highlights a region's cultural richness which should be preserved and protected.

Traditional architecture is commonly referred to as architecture where architects are not involved, as it is built by individuals or by a community itself (Angkasa & Kamil, 2024). Traditional houses can be perceived as any settlement's basic element which results from a culture that is filled with the values of the local communities and is maintained across the various generations (Sardjono et al., 2016). In a study by Hamka and Winarni (2021), the authors mentioned that traditional houses have emerged as cultural products, and are based on cultural aspects such as philosophies, customs, religion, beliefs and others. According to Boudagh and Ghaemmaghami (2011), such houses showcase the past lifestyle and act as a symbol of historical inheritance, thereby creating a cultural identity which fosters a sense of belonging (Asriana et al., 2024).

Several studies in the past have addressed the influence of culture on the architecture of the traditional houses. The aim of Quoc et al. (2024) was to understand the influence of culture on the traditional houses of the mountainous areas of Northern part of Vietnam for providing insights to guide their preservation. In the north western parts of India that include Delhi, Gujarat, Rajasthan and some parts of Uttar Pradesh, Haryana and Punjab, a cross - cultural influence between these different cultural zones has been reflected especially in the architecture of the various residential buildings in different parts of these zones, which have been incorporated with similar concepts such as houses with single or multiple courtyards (Kumari, 2023). Further, the cultural values and beliefs of the people in India have resulted in several traditional houses in different parts of the country, such as the Chittuli of Andhra Pradesh, Pol housing of Gujarat, Ahmedabad, Nalukettu houses of Kerala, Ghotul of Chattisgarh / Madhya Pradesh and others (Srivastava & Das, 2023). In a study by B. and Amirtham (2023), the authors examined the links between the cultural aspects and courtyards only in the transformed traditional courtyard houses of Kumbakonam.

In the context of conservation or restoration of cultural heritage, the implementation of LCA is at a very early stage, though it is being used widely in other sectors (Blundo et al., 2018). However, some studies have highlighted the use of LCA for evaluating environmental impacts related to refurbishment of buildings by focusing on energy efficiency (Vilches et al., 2017). According to Pozzo et al. (2024), there is a growing attention for materials and treatments that are environmentally sustainable for repairing and conserving built cultural heritage. The authors further mentioned that LCA, which is used for comparative evaluation of construction materials, can also be applied to conservation materials, if issues related to the definitions of

reference flows and functional units are addressed properly. As LCA has the capacity to offer an in – depth evaluation of the social, economic and environmental impacts, it will help in shifting to methods that are more environmentally friendly for cultural heritage management, once it starts being used as a decision – making tool (Elnaggar, 2024).

Coming to previous studies that have used LCA in the context of cultural heritage, Blundo et al. (2014) proposed the analysis of environmental, economic and social impacts in the process of restoration and recovery of cultural heritage. In a study by Blundo et al. (2018), the authors proposed a framework by combining LCA with 'Life Cycle Costing (LCC)' and S – LCA for making the management practices involved in restoration of cultural heritage more sustainable. The authors found that LCA can be considered as an efficient method for the improvement of innovative management practices in the restoration of cultural heritage. Endo and Takamura (2021), aimed at evaluating and comapring environmental impacts, in terms of emissions of greenhouse gases and operational energy use, by performing LCA on restoration of heritage residential buildings and construction of new ones in Japan. In a study by Kaoula et al. (2022), the authors aimed for optimizing the environmental performances of four Saharan dwellings which are traditional in nature through LCA by considering the roof majorly, which gives them identity. Two LCAs were performed by Serrano et al.(2022), one for restoring a traditional house of a farmer in Denmark from 1887 by using traditional building materials for continuing the house's actual appearance and the other for renovating it with modern materials to comply with the energy needs of the dwelling along with the environmental performances.

Standards exist only for E – LCA and S – LCA which are the 'ISO 14040' and 'Guidelines for Social Life Cycle Assessment of Products' by UNEP / SETAC Life Cycle Initiative (2009) respectively (Liu & Qian, 2019). The environmental and social impact categories and subcategories are present, along with the environmental and social inventory indicators, which can be used to perform E – LCA and S – LCA respectively. In case of E – LCA, there are two types of impact categories, namely midpoint and endpoint. The endpoint impact category represents environmental damages which are caused to an 'Area of Protection' such as 'human health' or 'biotic natural environment.' While, the midpoint impact category covers an environmental damage, that is somewhere between an emission and the final damage caused on the 'Area of Protection.' In case of S – LCA also there are two types of impact categories, namely Type 1 and Type 2. Type 1 impact categories are those which aggregate results for subcategories which are present in a stakeholder's theme of interest, such as 'human rights.' While Type 2 impact categories are those which model results for subcategories which have a causal relationship that is defined on the criteria, such as 'autonomy.' Subcategories like 'fair salary' or 'working hours' in case of S – LCA, represent impacts within a particular impact category such as 'working conditions of the stakeholder workers' (Andrews et al., 2009). 'Life Cycle Sustainability Assessment' (LCSA), on the other hand, gives combined assessments for environmental, economic and social aspects (Pizzirani et al., 2014).

Therefore, it is observed that past researchers have addressed the influence of culture on the architecture of traditional houses and how they should be preserved, which mainly deals with the architectural attributes of such houses. Also, LCAs of such houses have mainly involved the assessment of the quantitative aspects such as the environmental impacts. However, no study has addressed how the intangible cultural aspects are impacted by the transformations that take place in the tangible aspects of such houses during their life cycle. Further, no such standards or frameworks are there that can help in conducting a C – LCA of such houses by distinctly addressing the cultural aspects associated with them, despite it being regarded as sustainability's fourth pillar nowadays (Sabatini, 2019). Further, culture is also deep - seated in the lives of the people worldwide. According to Pizzirani et al. (2014), this might be due to the following reasons:

a. Failure in distinguishing cultural aspects from social ones.
b. Understanding the dynamic nature of culture.
c. Collection and analysis of data as culture has both tangible and intangible aspects and therefore it will require quantitative, qualitative and also semi - quantitative indicators to analyze both the dimensions of culture, thereby demanding the collection of both quantitative and qualitative data.
d. Understanding the diversity and scale of cultures that exist in various corners of the world.

On the other hand, according to a review conducted by Basu et al. (2024), future LCA or LCSA studies of buildings should also take into account the cultural aspects in them. Therefore, in order to bridge this gap, the main objectives of this study are as follows:

a. To analyze the influences of intangible cultural aspects on the tangible impact categories and subcategories related to the built form of traditional houses, and
b. To develop a C - LCA framework based on the results obtained from the analysis.

Based on the definitions of environmental and social impact categories as discussed before, an impact category in case of C – LCA can be defined as *"the grouping of different impact subcategories based on built form of traditional houses which reflect a change in the same intangible cultural aspect during their transformation(s), into one aspect (Source: By Authors)."* Based on the framework developed, examples of impact categories and subcategories have been discussed in section 3.2 of this manuscript.

Conducting C – LCA with the proposed framework can help in taking sensible decisions while planning the transformations or during the conservation of such houses by analyzing the proposed interventions for the particular impact subcategories by means of suitable indicators for retaining their cultural identity to a greater extent. This will help in preserving the housing heritage, as the traditional family houses help in safeguarding the culture and history of its residents, which further leads to the achievement of cultural sustainability (UNESCO, 2016).

2.0 MATERIALS AND METHODS

2.1 Data collection method

Questionnaire survey method has been used for the data collection process. The questionnaire for the main survey has been developed in six stages as shown in Figure 1. This paper focuses mainly on stages 5 and 6, however, an overview of the first four stages has been presented in brief, before proceeding to the last two stages.

2.1.1 Stages 1 and 2

At the first stage, an intensive review of literature was conducted to identify the various intangible cultural aspects and their influence on the various architectural attributes in traditional houses. At the second stage, a questionnaire was designed based on the secondary data collected in the first stage.

2.1.2 Stage 3

The third stage involved the development of a questionnaire for obtaining expert feedback on the questionnaire prepared in the second stage. The survey was conducted both online and offline, with the aim of understanding whether the questions asked in the questionnaire prepared in the second stage are relevant for the study or not, and if some aspects could be added or deleted before proceeding to the fourth stage. The expert panel was selected through purposive sampling and consists of practicing architects and academicians who have experience of at least 15 years or more, with research interest or expertise in the fields of vernacular and traditional architecture, traditional knowledge systems, cultural heritage documentation, culturally responsive built environment, traditional knowledge systems and other related fields. The questionnaire consisted of open – ended questions mainly. Before starting the survey, the experts were briefed about its intentions. Consent was taken from them for participating in the survey, and they were also informed that all the collected data should be used solely for academic purposes. Along with questionnaires distributed offline, a data set containing all the secondary data was attached, so that the experts can refer to them while giving their valuable feedback. Online questionnaires were circulated through e – mails containing the brief about the survey's intention and Google form link, where along with each question the corresponding data was mentioned. Data collection was done from 19th February 2024 to 3rd April 2024. Four experts (two offline and two online) voluntarily participated in the survey.

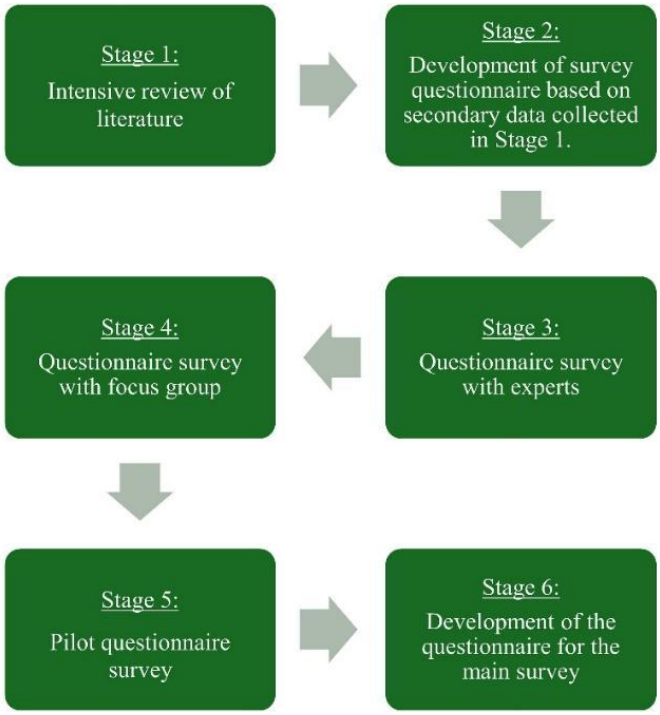


Figure 1. Stages involved in the development of the questionnaire for the main survey (Source: By Authors)

Expert 1 advised to group the cultural aspects under the three main headings as follows: (i) 'religious / cultural preferences,' (ii) lifestyle of the residents' and (iii) 'socio-economic aspects.' According to the suggestion, the cultural aspects have been grouped under the three main headings as shown in (Figure 2).

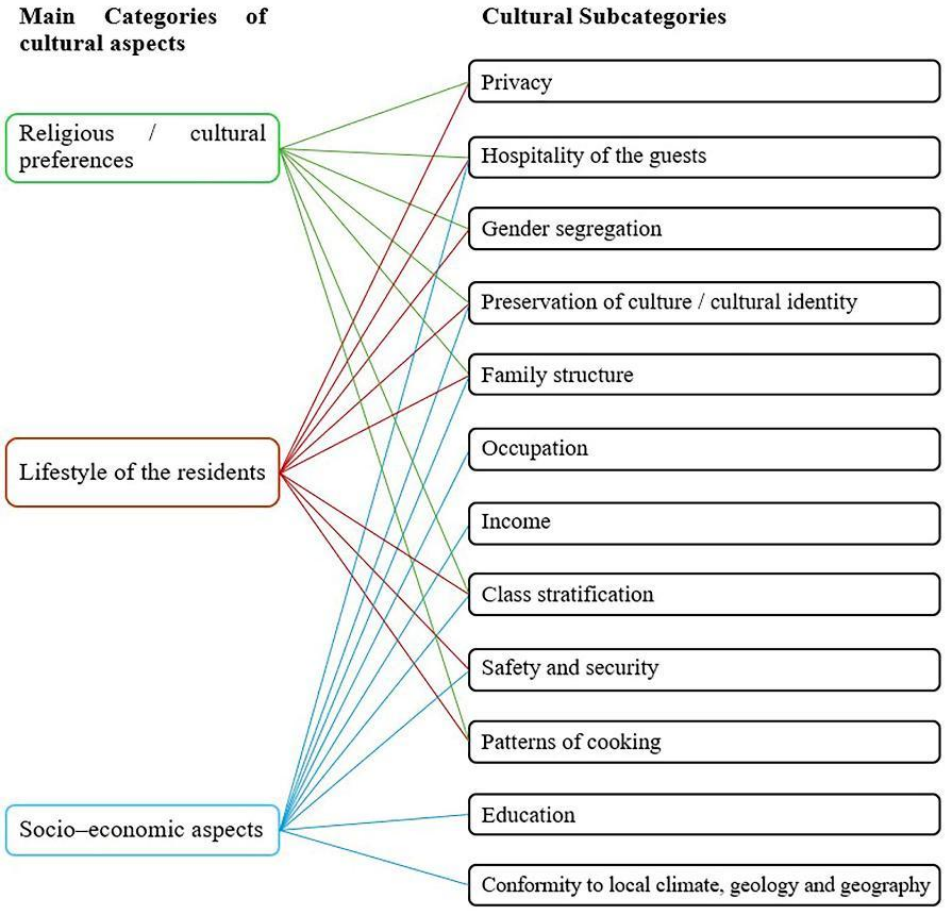


Figure 2. Grouping of cultural aspects under the three main headings as per expert feedback. (Source: By Authors)

From Figure 2, it is observed that some cultural aspects fall under more than one main heading. This gave rise to the four main headings which have been termed as cultural categories, and the sub – headings under them have been termed as cultural subcategories in this study. Figure 3 shows the four main cultural categories 1, 2, 3 and 4, along with the cultural subcategories under each of them.

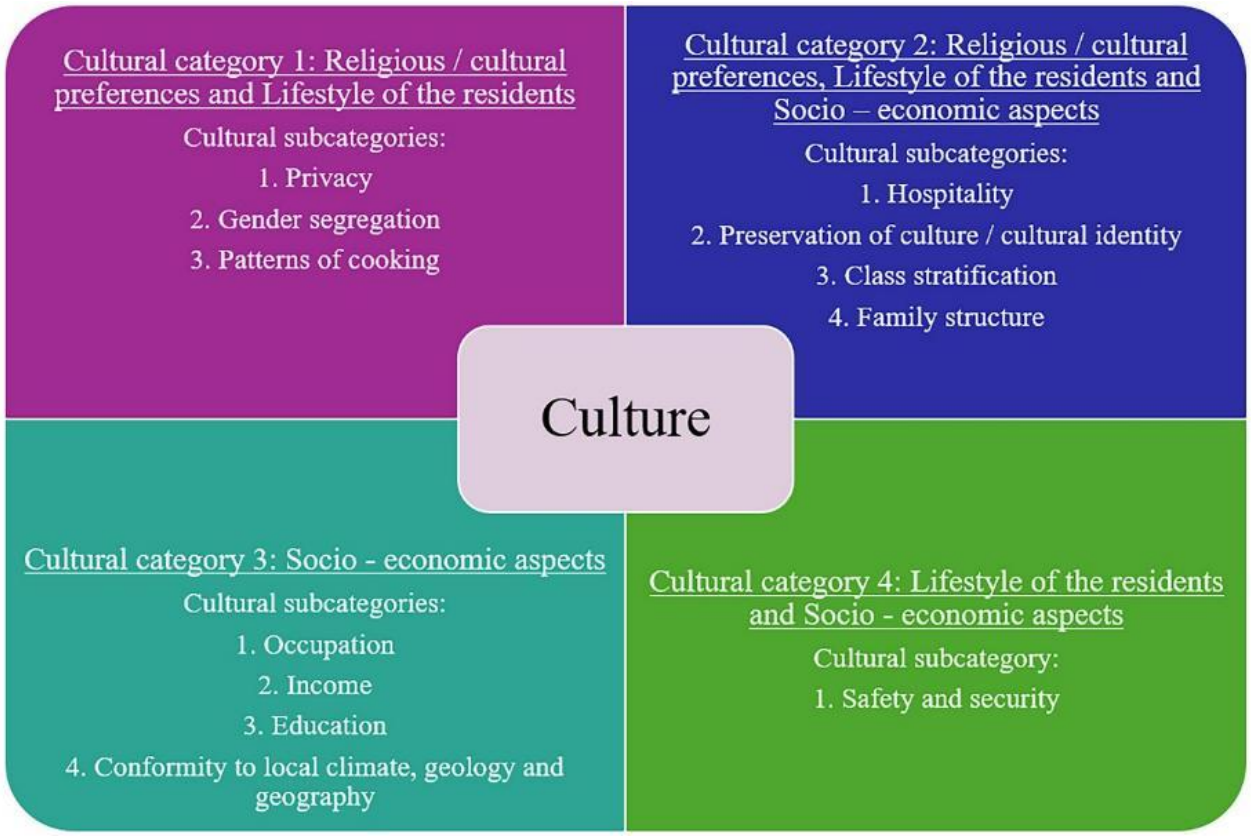


Figure 3. Four main cultural categories and subcategories from review of literature and expert feedback survey (Source: By Authors)

Expert 1 also suggested adding conformity to local climate, geology and geography' along with the other cultural aspects obtained from literature review and further suggested merging the impact subcategories 'position of toilet / bathrooms,' 'orientation of the rooms' and 'position of bedrooms' under the impact category 'spatial organization of the house' into one impact subcategory. Expert 4 suggested adding the impact subcategory 'placement of other entries' under the impact category 'orientation of the house.' All these suggestions have been incorporated along with the secondary data as shown in Figure 4, which illustrates the impact categories and subcategories related to the form of built traditional houses.

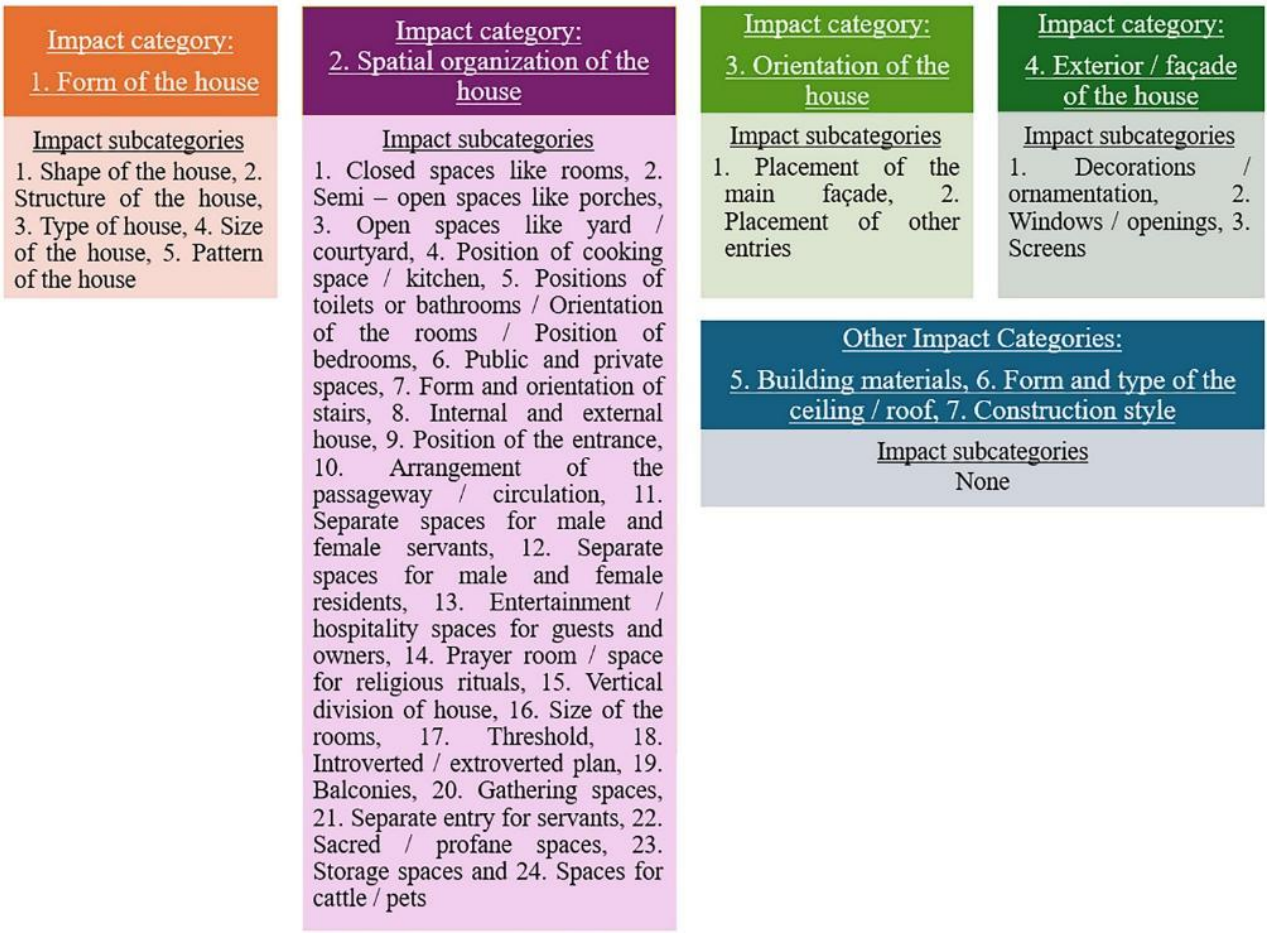


Figure 4. Impact categories and subcategories related to the built form of traditional houses from review of literature and expert feedback survey (Source: By Authors)

2.1.3 Stage 4

The fourth stage involved a questionnaire survey with a focus group with the aim of linking the cultural subcategories as mentioned in Figure 3 with the impact categories and subcategories as presented in (Figure 4). Purposive sampling method was used for selecting the participants which mainly consists of architects. The architects were approached via e – mail containing a brief which stated the intention of the survey and the Google form link. Their consent for participating in the survey was obtained. They were further informed that their responses should be used for academic purposes. Out of the 23 architects approached, 17 took part in the survey voluntarily, which was conducted from 23rd April 2024 to 12th June 2024. After analyzing the data, the impact categories and subcategories were linked with each of the cultural subcategories.

2.1.4 Stage 5 and 6

Method of study

In the fifth stage, the pilot questionnaire survey was conducted, which ultimately led to the development of the questionnaire for the main survey in stage six.

Sample Selection for Stages 5 And 6

Purposive sampling techniques have been used to select the sample, which consists mainly of professionals as well as common people. Professionals include practicing architects as well as academicians with expertise and experience in different fields of architecture such as architectural conservation, sustainable and landscape architecture, urban designing, as well as interior designing. The inclusion criteria for common people are as follows:

1. Respondents can be from any place in India,
2. They should be of age 18 years or above and
3. They should be residing in individual houses which are of age 50 years or above.

The common people have been further informed that if they were residing in a different place away from their native place, then they should respond to the survey by keeping their actual house in their hometown in mind. The age group of the respondents was set as 18 years or above, so that the respondents have spent considerable amount of time in those houses. Also, to understand the changes in cultural values that lead to transformations in traditional houses, understanding the stages of families residing in them becomes important. According to Khan (2013), age group of 30 - 40 years corresponds to a young family stage, where children are young and parents have the authority to control them in terms of territorial control in the houses. Whereas age group of 50 – 60 years corresponds to mature – 2 family stage, where at least one child is married, and where more territorial control is demanded and gained in the houses by the children over their parents. So, these changes in the family structure and in the opinions of children result in transformation of spaces, or elements or components in traditional houses. So, for this study, the age of the individual houses has been set as 50 years or above. Further, a greater number of professionals as compared to common people have been approached for the survey, as professionals have more domain knowledge about the concept under study.

Data collection method for stages 5 and 6

The pilot questionnaire was designed based on the links between the cultural subcategories, and the impact categories and subcategories that were established in the fourth stage. It has been prepared separately for professionals and common people, and the format has been presented in (Figure 5). All items in sections two to seven of the questionnaire are measured on a 5 – point Likert scale. Also, after such questions, there are open – ended questions for the respondents to address any other important aspects apart from the ones already mentioned before. Section eight consists of an open – ended question where the respondents can address any other aspects which has otherwise not been mentioned in the entire questionnaire. However, section seven of the questionnaire has not been discussed in this study.

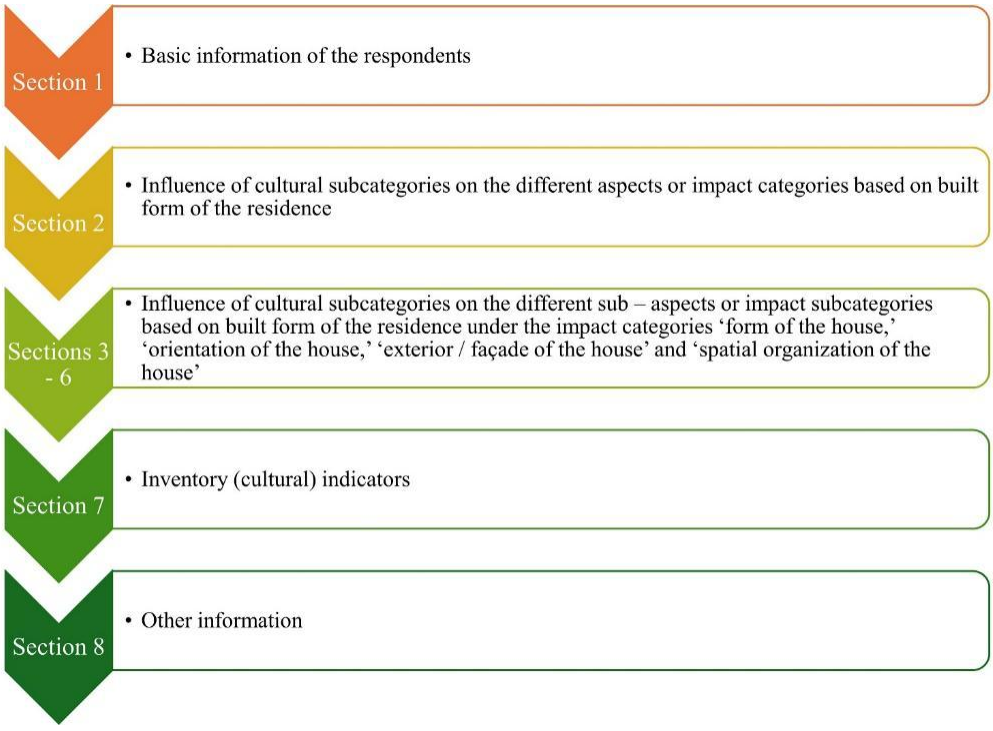


Figure 5. Questionnaire format for professionals and common people *(Source: By Authors)*

25 questionnaires were considered for checking the reliability and internal consistency of the pilot questionnaire survey. Data was collected from 18th June 2024 to 12th July 2024. All the respondents, including both professionals and common people, responded to all sections of the questionnaire. 'Cronbach's Alpha' was calculated for each construct by using the IBM SPSS Statistics software. While calculating the 'Cronbach's Alpha,' the 'scale if item deleted' option was checked. Based on the output, cultural subcategories were excluded from the original construct as presented in the questionnaire, one at a time, and the process was repeated until the maximum values of 'Cronbach's Alpha' were achieved for each of the constructs representing the various impact categories and subcategories. For the impact category 'construction style' of the house, the maximum value of 'Cronbach's Alpha' obtained was 0.672 which is smaller than the acceptable range of

'Cronbach's Alpha' which is 0.70 (Khairul et al., 2018). So, the construct related to it has not been considered for further study. The values of 'Cronbach's Alpha' for the original constructs as presented in the questionnaire as well as their maximum values with the retained cultural subcategories have been provided in the Supplementary materials (Part A). Revision of the pilot questionnaire according to the output of the reliability test led to the development of the final questionnaire for the main survey in the sixth stage. Examples from the questionnaire have been presented in the Appendix. Data was collected from 16th August 2024 to 14th December 2024. 207 respondents in total took part in the survey. All the respondents, including both professionals and common people, responded to all sections of the questionnaire.

Research ethics followed in stages 5 and 6

The questionnaire was distributed among the professionals and common people both offline and online through Google forms. Before distributing the questionnaire offline, the respondents were briefed about the survey's intention. For the questionnaire distributed online, the respondents were approached via e - mail with a brief of the study's intention and the Google form link. It was also mentioned in the questionnaire that all responses received from the participants will solely be used for academic purposes, and further informed consent was obtained. Participation of the respondents was voluntary in this study.

2.2 Method of Analysis

'Principal Component Analysis (PCA)' method has been used for analyzing the collected data rather than Common Factor Analysis. PCA helps in generating lower dimensions known as principal components by reducing data which provides a summary of features and preserves as much information as possible from the actual dataset (Lever et al., 2017). Whereas Common Factor Analysis is used when any study aims at identifying the latent constructs that are accountable for the variations of the measured variables (Gaskin & Happell, 2014). Therefore, for this study, PCA has been used for analyzing the data since its sole aim is to transform the data into minimum number of dimensions to identify only the key tangible aspects in traditional houses that are influenced by each of the cultural subcategories. IBM SPSS Statistics software has been used for performing the PCA. The following steps have been considered for carrying out PCA:

i. Assessing the data's suitability: The sample size for this study is 207, which is a suitable and fair sample size according to (Comrey & Lee, 1992). Also, since too many variables are there in this study, so PCA has been conducted by using the 'IBM SPSS Statistics software' which considers Pearson correlation matrix or covariance matrix for conducting the analysis as mentioned in a study by Marôco (2024), because according to Rigdon and Ferguson (1991), polychoric correlations might not outperform Pearson correlations when sample size is less than 300 to 500, and there are too many variables, even though Likert scale data is ordinal in nature. Further, while analyzing the data for each of the cultural subcategories, correlation coefficients which are less than 0.3 in the correlation matrix have been eliminated one at a time until all the coefficients are above 0.3, and also the presence of multicollinearity in the data has been checked, as in that case the inferences about the data might not be reliable (Shrestha, 2020). For this study, the correlation matrix for each of the cultural subcategories with the retained impact subcategories have been presented in the Supplementary materials (Part C).
ii. Determinant Score: The determinant score of the correlation matrix has been used to identify the presence or absence of singularity or multicollinearity.
iii. Checking the Sampling Adequacy: 'Kaiser-Meyer-Olkin (KMO) test' and 'Bartlett's Test of Sphericity' have been used for assessing the sample size adequacy and testing the null hypothesis, where a KMO value of 0.8 – 1.0 signifies adequate sampling, 0.7 – 0.79 signifies average or moderate sampling, 0.6 – 0.69 signifies mediocre sampling. A significant value less than 0.05 for 'Bartlett's Test of Sphericity' signifies that a factor analysis is suitable for the dataset (Shrestha, 2021). A factor's eigenvalue shows the amount of total variance explained by that factor. Factors with eigenvalues more than one have been retained as values above one show that more common variance is explained by that factor as compared to unique variance (Kaiser, 1970; Verma, 2013).
iv. Number of factors that can be extracted: For determining the initial number of unrotated factors, Eigenvalues and Scree Test have been considered (Shrestha, 2021).
v. Factor rotation: According to Bryant and Yarnold (1995), it is a process in which the eigenvectors are rotated to achieve simple structure. It can be either orthogonal which means that the factors are uncorrelated or oblique which means that the factors are correlated (Shrestha, 2021). For this study, PCA has been performed for each cultural subcategory by considering 'direct oblimin' rotation at the first

stage and the correlation coefficients between the obtained components have been checked at every stage whenever any item has been eliminated. Whenever at any stage all the correlation coefficients are not above 0.32, the rotation method has been changed to 'varimax' and whenever all the correlation coefficients are above 0.32, the rotation method has been changed back to 'direct oblimin,' and all such stages have been presented in the Supplementary material (Part B).

vi. Checking Communality values: For sample size less than 100, an acceptable average value is greater than 0.6, and when sample sizes are between 100 and 200, the acceptable average values are between 0.5 and 0.6 respectively according to Tabachnick and Fidell (2013) and (MacCallum et al., 1999). In this study, items having communalities less than 0.5 have been eliminated from the analysis.

vii. Factor loading: According to Hair et al. (2009), a factor loading of 0.40 is needed for significance when the sample size is 200. So, in this study, the factor loadings below 0.4 have been suppressed.

To conduct the PCA, the various tangible impact categories and subcategories in the traditional houses have been grouped together under each of the cultural subcategories according to their influence on them and then the analysis has been conducted.

3.0 RESULTS

3.1 Basic Information of the Respondents

A total of 207 respondents participated in the survey who were selected through purposive sampling method. The age groups (in years) of the respondents (both professionals and common people) have been presented in (Figure 6). The mean age in India was 31.35 years in 2024 according to GlobalData (n.d.), and 28.8 years is the median age in India in 2025 (Worldometer, n.d.). From the results also, it is observed that the percentage of respondents in the age groups 18 – 24 and 25 – 34 are on the higher side and accounts for a total of 85% of the respondents who took part in the survey, therefore showing that there is a dominance of the younger generation in this study.

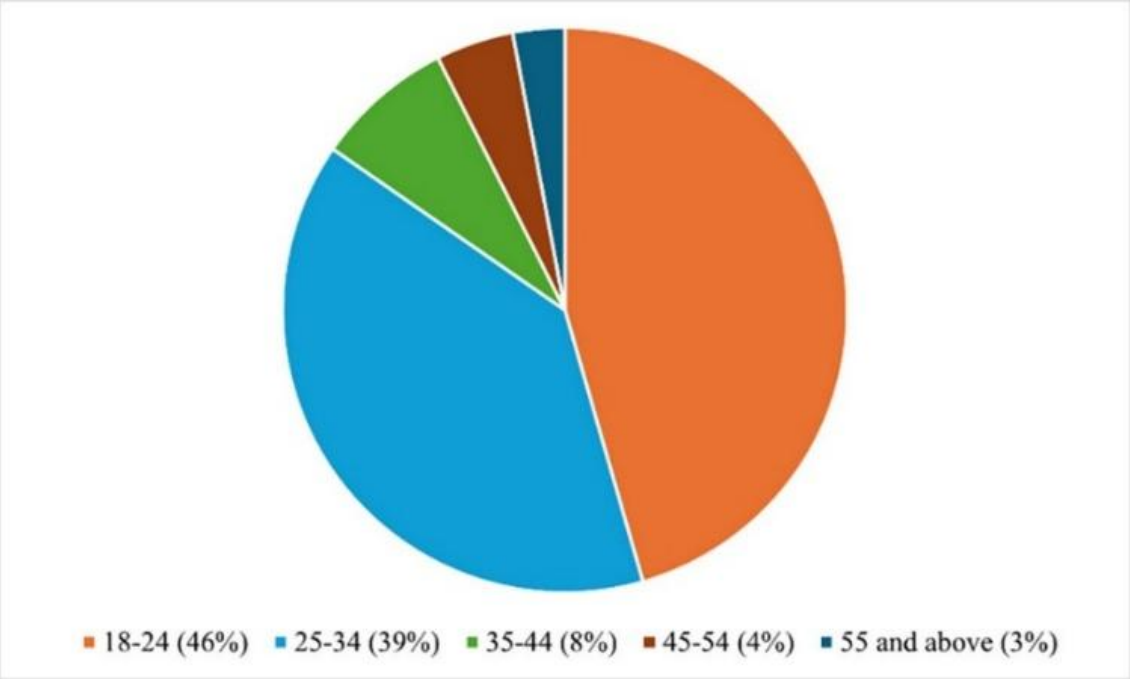


Figure 6. Age groups (in years) of the respondents *(Source: By Authors)*

The gender of the respondents, including both professionals and common people, has been presented in (Figure 7). The results show that the percentage of female respondents is higher (59%) as compared to male, which shows that females are more actively engaged in studies related to culture and traditional housing.

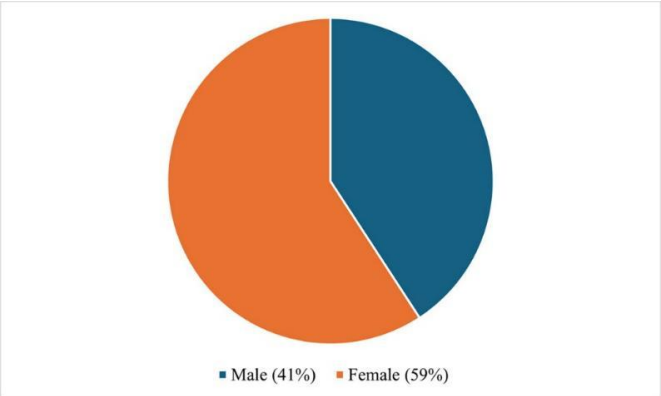


Figure 7. Gender of the respondents *(Source: By Authors)*

The type of the respondents, whether professionals or common people, has been presented in (Figure 8). Since more professionals were approached for the questionnaire survey because of their expertise and experience, from the results, it is observed that the percentage of professionals is on the higher side (94%) as compared to common people. This shows that there is a dominance of professionals in this study, and therefore, the results obtained from PCA analysis do not represent common people.

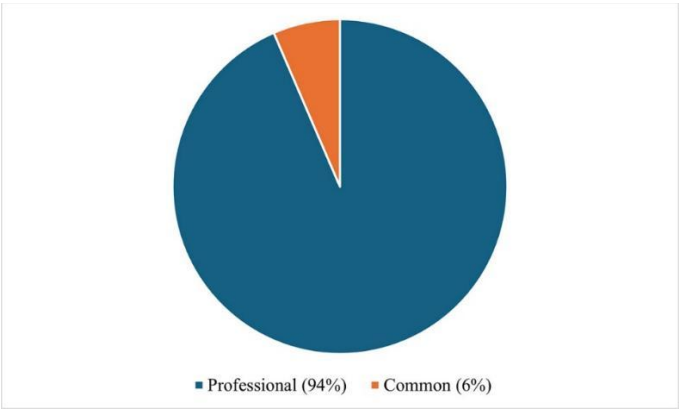


Figure 8. Type of respondents *(Source: By Authors)*

3.2 Results of PCA

Table 1 shows the determinant values obtained from the correlation matrices for each of the cultural subcategories with the retained impact subcategories, and it is observed that all the values are greater than 0.00001. 'Conformity to local climate, geology and geography' has the highest determinant value (0.290), while 'occupation' has the lowest determinant value (0.005).

Table 1. Determinant values of the correlation matrices for each of the cultural subcategories with the retained impact subcategories *(Source: By Authors)*

Sl. No.	Cultural Subcategory	Determinant values
1.	Privacy	0.010
2.	Gender segregation	0.008
3.	Patterns of cooking	0.275
4.	Hospitality	0.143
5.	Preservation of culture / cultural identity	0.015
6.	Class Stratification	0.009
7.	Family Structure	0.211
8.	Occupation	0.005
9.	Income	0.098
10.	Education	0.610
11.	Conformity to local climate, geology and geography	0.290
12.	Safety and Security	0.102

The results obtained from the 'KMO and Bartlett's test of Sphericity' for each of the cultural subcategories with the retained impact subcategories have been presented in Table 2, which shows that the sampling is adequate, moderate and mediocre for nine, two and one cultural subcategory / subcategories respectively, and the data is suitable for analysis. 'Gender segregation' shows the highest 'KMO Measure of Sampling Adequacy' value (0.938), while 'education' shows the lowest (0.654).

Table 2. Results of 'KMO and Bartlett's Test of Sphericity' for each of the cultural subcategories with the retained impact subcategories *(Source: By Authors)*

Privacy		
'Kaiser-Meyer-Olkin Measure of Sampling Adequacy'		0.910
'Bartlett's Test of Sphericity'	Approx. Chi-Square	937.873
	df	36
	Sig.	<0.001
Gender segregation		
'Kaiser-Meyer-Olkin Measure of Sampling Adequacy'		0.938
'Bartlett's Test of Sphericity'	Approx. Chi-Square	980.634
	df	36
	Sig.	<0.001
Patterns of cooking		
'Kaiser-Meyer-Olkin Measure of Sampling Adequacy'		0.737
'Bartlett's Test of Sphericity'	Approx. Chi-Square	263.252
	df	6
	Sig.	<0.001
Hospitality		
'Kaiser-Meyer-Olkin Measure of Sampling Adequacy'		0.855
'Bartlett's Test of Sphericity'	Approx. Chi-Square	396.286
	df	10
	Sig.	<0.001
Preservation of culture / cultural identity		
'Kaiser-Meyer-Olkin Measure of Sampling Adequacy'		0.932
'Bartlett's Test of Sphericity'	Approx. Chi-Square	845.423
	df	36
	Sig.	<0.001
Class stratification		
'Kaiser-Meyer-Olkin Measure of Sampling Adequacy'		0.929
'Bartlett's Test of Sphericity'	Approx. Chi-Square	948.799
	df	36
	Sig.	<0.001
Family structure		
'Kaiser-Meyer-Olkin Measure of Sampling Adequacy'		0.813
'Bartlett's Test of Sphericity'	Approx. Chi-Square	316.998
	df	10
	Sig.	<0.001
Occupation		
'Kaiser-Meyer-Olkin Measure of Sampling Adequacy'		0.911
'Bartlett's Test of Sphericity'	Approx. Chi-Square	1053.473
	df	55
	Sig.	<0.001
Income		
'Kaiser-Meyer-Olkin Measure of Sampling Adequacy'		0.848
'Bartlett's Test of Sphericity'	Approx. Chi-Square	471.528
	df	15
	Sig.	<0.001
Education		
'Kaiser-Meyer-Olkin Measure of Sampling Adequacy'		0.654

'Bartlett's Test of Sphericity'	Approx. Chi-Square	100.770
	df	3
	Sig.	<0.001
Conformity to local climate, geology and geography		
'Kaiser-Meyer-Olkin Measure of Sampling Adequacy'		0.792
'Bartlett's Test of Sphericity'	Approx. Chi-Square	252.373
	df	6
	Sig.	<0.001
Safety and Security		
'Kaiser-Meyer-Olkin Measure of Sampling Adequacy'		0.855
'Bartlett's Test of Sphericity'	Approx. Chi-Square	463.850
	df	15
	Sig.	<0.001

From the scree plots obtained from the analysis, it is observed that for 11 cultural subcategories, only one component has eigenvalue greater than one. Since only one component has been retained in such cases, no rotation took place in the final stage. Only for the cultural subcategory 'occupation' there are two components which have eigenvalues greater than one. According to Shrestha (2021), the proportion of the total variance explained by the factors that are retained should be at least 50% as a general rule, and in this study, the total variance explained by all the obtained components for each of the cultural subcategories are above 50%. Further, the 'Cronbach's Alpha' value has been calculated to check the reliability of the obtained components and for 11 cultural subcategories the values are above 0.70, except for the cultural subcategory 'education,' and so it has not been included in further study. The following sections present the summary of the component(s) consisting of the key impact subcategories influenced by the various cultural subcategories under the four main cultural categories.

3.2.1 Cultural Category 1

Table 3 shows the summary of the component consisting of the key impact subcategories influenced by 'privacy.' It is observed that 'privacy' highly affects the spatial organization of traditional houses, and its influence on the 'position of the toilet or bathroom / orientation of the rooms / position of bedrooms' is the highest.

Table 3. Summary of the component with key impact subcategories influenced by 'privacy' *(Source: By Authors)*

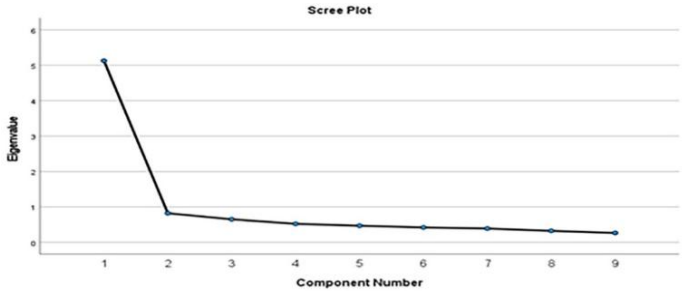
		**Eigenvalue =** 5.127 **Total variance explained** = 56.971%	
Component 1 (Spatial organization, Orientation and Exterior / façade of the house)	**Factor Loading**	**Communality after Extraction**	**Reliability (Cronbach's Alpha)**
Position of toilet or bathrooms / Orientation of the rooms / Position of bedrooms	0.793	0.629	0.905
Closed spaces like rooms	0.777	0.603	
Internal and external house	0.775	0.600	
Introverted / extroverted plan	0.757	0.573	
Windows / openings	0.745	0.555	
Balconies	0.741	0.549	
Separate spaces for male and female servants	0.741	0.549	
Placement of other entries	0.735	0.540	
Semi - open spaces like porches	0.727	0.529	

Table 4 shows the summary of the component consisting of the key impact subcategories influenced by 'gender segregation.' The factor loading of 'position of the entrance' is the highest on component 1, which is followed by the 'form and orientation of stairs.' Therefore, it shows that in the traditional houses, due to a strong distinction between the men and women of the house, the positions of the main entrances were planned in such a way, so that the outsiders and especially the male visitors could not directly access the inner sanctum of the houses. Similarly, there used to be different staircases for the public and the residents of such houses, for restricting the visitors or outsiders to the public spaces of the houses only.

Table 4. Summary of the component with key impact subcategories influenced by 'gender segregation' *(Source: By Authors)*

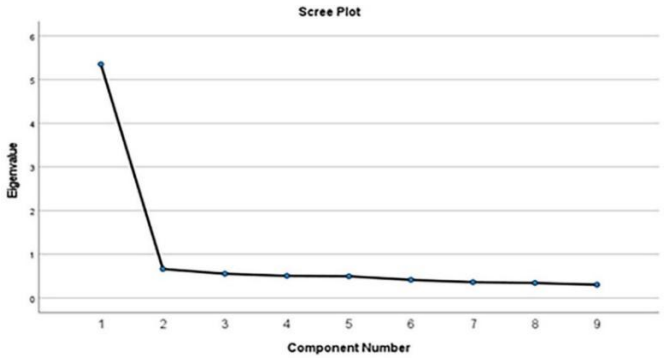
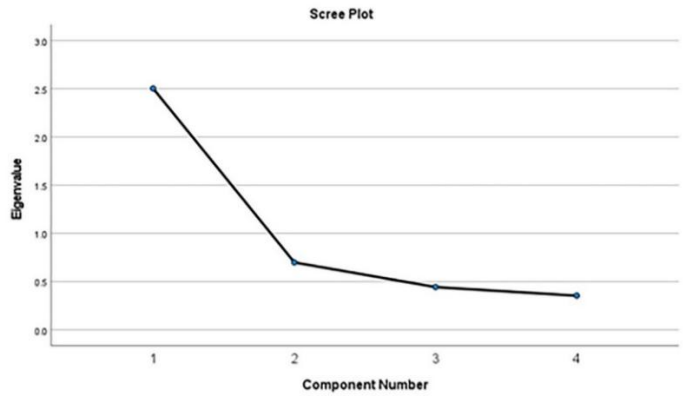
<table>
<tr><td colspan="2" rowspan="2"> 
</td><td colspan="2">Eigenvalue = 5.351</td></tr>
<tr><td colspan="2">Total variance explained = 59.456%</td></tr>
<tr><td>Component 1 (Spatial organization and Exterior / façade of the house)</td><td>Factor Loading</td><td>Communality after Extraction</td><td>Reliability (Cronbach's Alpha)</td></tr>
<tr><td>Position of the entrance</td><td>0.807</td><td>0.651</td><td rowspan="9">0.914</td></tr>
<tr><td>Form and orientation of stairs</td><td>0.804</td><td>0.646</td></tr>
<tr><td>Arrangement of the passageway / circulation</td><td>0.803</td><td>0.644</td></tr>
<tr><td>Vertical division of house</td><td>0.802</td><td>0.643</td></tr>
<tr><td>Balconies</td><td>0.772</td><td>0.596</td></tr>
<tr><td>Position of cooking space / kitchen</td><td>0.758</td><td>0.574</td></tr>
<tr><td>Semi - open spaces like porches</td><td>0.744</td><td>0.554</td></tr>
<tr><td>Screens</td><td>0.723</td><td>0.523</td></tr>
<tr><td>Entertainment / hospitality spaces for guests and owners</td><td>0.720</td><td>0.519</td></tr>
</table>

Table 5 shows the summary of the component consisting of the key impact subcategories influenced by 'patterns of cooking.' It is observed that the factor loading of 'internal and external house' is the highest on component 1. Therefore, it illustrates the fact that since mainly the women of the houses were involved in cooking, the kitchens or the cooking spaces were generally incorporated in the internal houses or in the inner sanctums of the houses for ensuring privacy needs of the women.

Table 5. Summary of the component with key impact subcategories influenced by 'patterns of cooking' *(Source: By Authors)*

		**Eigenvalue** = 2.503 **Total variance explained** = 62.582%	
Component 1 (Spatial organization and Exterior / façade of the house)	**Factor Loading**	**Communality after Extraction**	**Reliability (Cronbach's Alpha)**
Internal and external house	0.822	0.676	0.800
Position of the entrance	0.808	0.652	
Prayer room / space for religious rituals	0.787	0.619	
Windows / openings	0.746	0.557	

3.2.2 Cultural Category 2

Table 6 shows the summary of the component consisting of the key impact subcategories influenced by 'hospitality.' The factor loading of 'position of the entrance' is the highest on component 1 followed by 'arrangement of the passageway / circulation.' This shows that the entrances to the houses, and the circulation patterns were planned in such a way that ensured proper hospitality of the guests, and at the same time helped in maintaining the privacy needs of the residents. Component 1 further illustrates a correlation between 'hospitality,' and 'entertainment / hospitality spaces for guests and owners' and 'gathering spaces' that are present in traditional houses, where various festivals or occasions are celebrated.

Table 6. Summary of the component with key impact subcategories influenced by 'hospitality' *(Source: By Authors)*

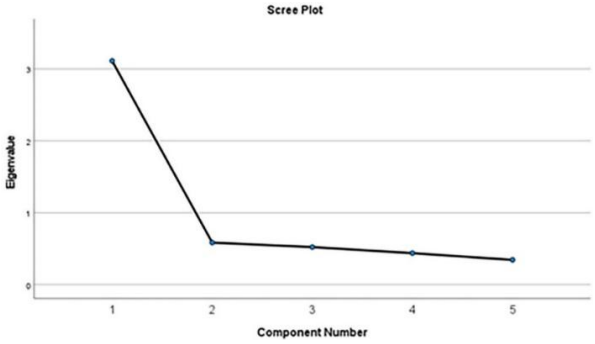
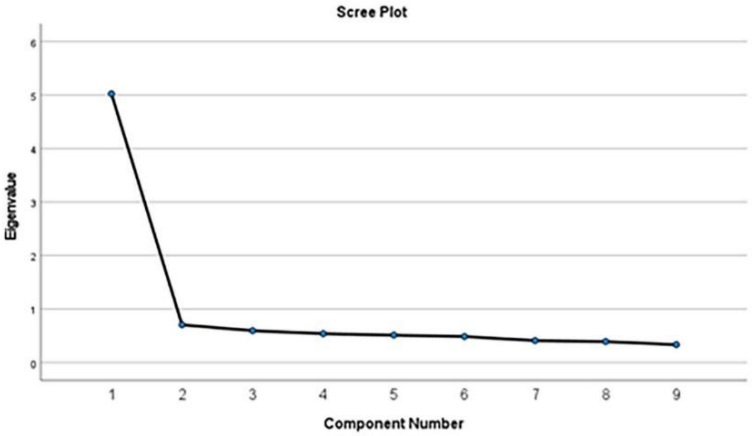
		**Eigenvalue** = 3.113 **Total variance explained** = 62.259%	
Component 1 (Spatial organization of the house)	**Factor Loading**	**Communality after Extraction**	**Reliability (Cronbach's Alpha)**
Position of the entrance	0.843	0.711	0.847
Arrangement of the passageway / circulation	0.822	0.676	
Introverted / extroverted plan	0.763	0.582	
Entertainment / hospitality spaces for guests and owners	0.761	0.580	
Gathering spaces	0.752	0.566	

Table 7 shows the summary of the component consisting of the key impact subcategories influenced by 'preservation of culture / cultural identity.' Component 1 illustrates a correlation between preservation of cultural identity, and 'gathering spaces,' ornate decorations or ornamentation, followed by prayer rooms or spaces where religious rituals are performed in traditional houses. Therefore, it can be said that such spaces or elements help in preserving the cultural identities of such houses to a great extent.

Table 7. Summary of the component with key impact subcategories influenced by 'preservation of culture / cultural identity' *(Source: By Authors)*

<table>
<tr><td colspan="2"> 
</td><td colspan="2">Eigenvalue = 5.024

Total variance explained = 55.819%</td></tr>
<tr><th>Component 1 (Spatial organization and Exterior / façade of the house)</th><th>Factor Loading</th><th>Communality after Extraction</th><th>Reliability (Cronbach's Alpha)</th></tr>
<tr><td>Gathering spaces</td><td>0.797</td><td>0.635</td><td rowspan="9">0.900</td></tr>
<tr><td>Decorations / ornamentation</td><td>0.763</td><td>0.582</td></tr>
<tr><td>Position of the entrance</td><td>0.757</td><td>0.572</td></tr>
<tr><td>Semi - open spaces like porches</td><td>0.743</td><td>0.552</td></tr>
<tr><td>Prayer room / space for religious rituals</td><td>0.741</td><td>0.549</td></tr>
<tr><td>Internal and external house</td><td>0.740</td><td>0.548</td></tr>
<tr><td>Balconies</td><td>0.732</td><td>0.536</td></tr>
<tr><td>Public and private spaces</td><td>0.729</td><td>0.532</td></tr>
<tr><td>Screens</td><td>0.719</td><td>0.517</td></tr>
</table>

Table 8 shows the summary of the component consisting of the key impact subcategories influenced by 'class stratification.' It is observed that the factor loading of 'threshold' is the highest on component 1, followed by 'position of the entrance,' vertical spatial layering and others. This shows that 'class stratification' highly influenced the way in which the thresholds or entrances were planned for restricting the movement of certain people inside the houses depending on the classes to which they belonged, or allowing them only in public spaces on the ground floor, while upper floors catered mainly to the family members.

Table 8. Summary of the component with key impact subcategories influenced by 'class stratification' *(Source: By Authors)*

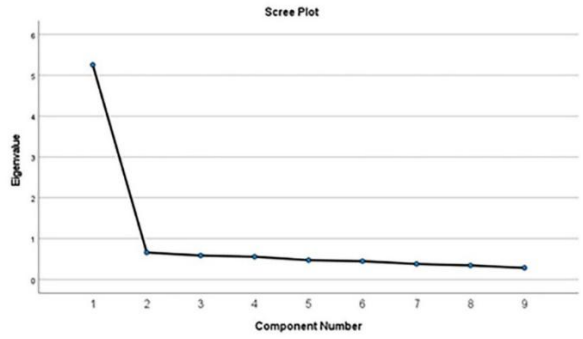
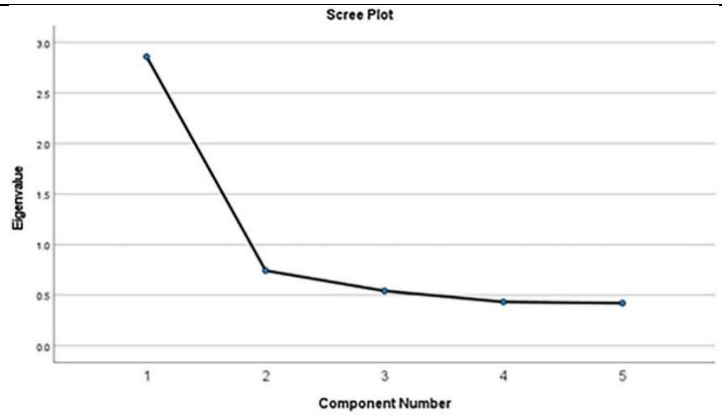
		**Eigenvalue** = 5.255 **Total variance explained** = 58.394%	
Component 1 (Spatial organization of the house)	**Factor Loading**	**Communality after Extraction**	**Reliability (Cronbach's Alpha)**
Threshold	0.810	0.657	0.910
Position of the entrance	0.785	0.616	
Public and private spaces	0.781	0.610	
Balconies	0.773	0.597	
Vertical division of house	0.769	0.592	
Position of cooking space / kitchen	0.758	0.574	
Storage spaces	0.744	0.554	
Entertainment / hospitality spaces for guests and owners	0.742	0.550	
Introverted / extroverted plan	0.711	0.505	

Table 9 shows the summary of the component consisting of the key impact subcategories influenced by 'family structure.' It is observed that 'family structure' mainly influences the 'spatial organization of the house' and component 1 illustrates a correlation between 'family structure' and impact subcategories such as the external house and inner sanctum of the house, followed by entertainment or hospitality spaces and vertical spatial layering, and others.

Table 9. Summary of the component with key impact subcategories influenced by 'family structure' *(Source: By Authors)*

		**Eigenvalue** = 2.859 **Total variance explained** = 57.187%	
Component 1 (Spatial organization of the house)	**Factor Loading**	**Communality after Extraction**	**Reliability (Cronbach's Alpha)**
Internal and external house	0.792	0.627	0.812
Entertainment / hospitality spaces for guests and owners	0.782	0.611	
Vertical division of house	0.771	0.595	
Separate spaces for male and female residents	0.720	0.519	
Introverted / extroverted plan	0.713	0.508	

3.2.3 Cultural Category 3

Table 10 shows the summary of the components consisting of the key impact subcategories influenced by 'occupation.' Component 1 for 'occupation' shows that it mostly influences the 'spatial organization of the house.' The factor loading of entertainment / hospitality spaces is the highest on component 1 followed by balcony spaces, plan of the house, storage spaces and others. Component 2 for 'occupation' illustrates a correlation between professions of the residents and elements such as windows and screens, followed by the pattern of the houses and open spaces such as yards or courtyards.

Table 10. Summary of the components with key impact subcategories influenced by 'occupation' *(Source: By Authors)*

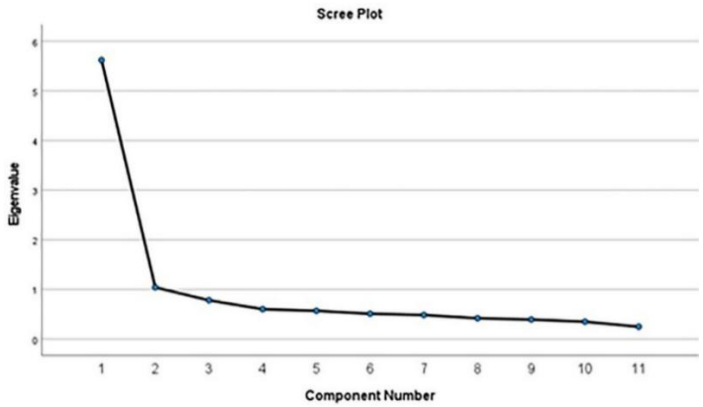
<table>
<tr><td colspan="2" rowspan="3"> 
</td><td colspan="2">Eigenvalue of component 1 = 5.617</td></tr>
<tr><td colspan="2">Eigenvalue of component 2 = 1.040</td></tr>
<tr><td colspan="2">Total variance explained by the components = 60.514%</td></tr>
<tr><td>Component 1 (Spatial organization of the house)</td><td>Factor Loading</td><td>Communality after Extraction</td><td>Reliability (Cronbach's Alpha)</td></tr>
<tr><td>Entertainment / hospitality spaces for guests and owners</td><td>0.910</td><td>0.703</td><td rowspan="7">0.874</td></tr>
<tr><td>Balconies</td><td>0.835</td><td>0.687</td></tr>
<tr><td>Introverted / extroverted plan</td><td>0.793</td><td>0.579</td></tr>
<tr><td>Storage spaces</td><td>0.717</td><td>0.512</td></tr>
<tr><td>Vertical division of house</td><td>0.650</td><td>0.533</td></tr>
<tr><td>Separate spaces for male and female residents</td><td>0.631</td><td>0.513</td></tr>
<tr><td>Internal and external house</td><td>0.554</td><td>0.506</td></tr>
<tr><td>Component 2 (Form, Spatial organization and Exterior / façade of the house)</td><td>Factor Loading</td><td>Communality after Extraction</td><td>Reliability (Cronbach's Alpha)</td></tr>
<tr><td>Windows / openings</td><td>0.919</td><td>0.735</td><td rowspan="5">0.814</td></tr>
<tr><td>Screens</td><td>0.844</td><td>0.766</td></tr>
<tr><td>Pattern of the house</td><td>0.642</td><td>0.575</td></tr>
<tr><td>Open space like yard / courtyard</td><td>0.456</td><td>0.547</td></tr>
<tr><td colspan="3">Rotation Method: Oblimin with Kaiser Normalisation</td></tr>
</table>

Table 11 shows the summary of the components consisting of the key impact subcategories influenced by 'income.' Component 1 for 'income' shows that there is a correlation between the financial conditions of the residents and the entertainment / hospitality spaces, followed by vertical spatial layering, plans, types and patterns of the houses, and the ornate decorations / ornamentation present in the houses.

Table 11. Summary of the component with key impact subcategories influenced by 'income' *(Source: By Authors)*

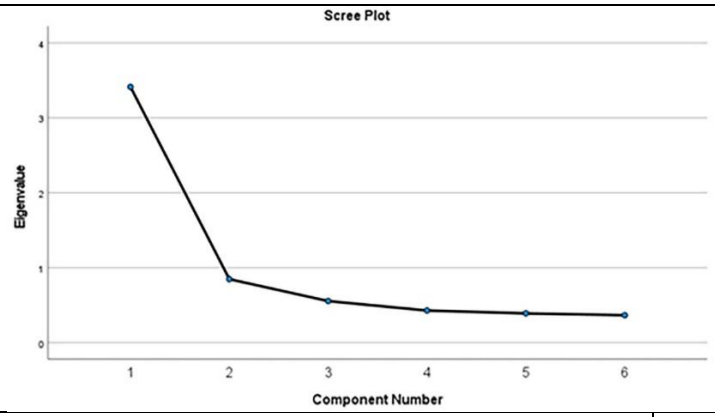
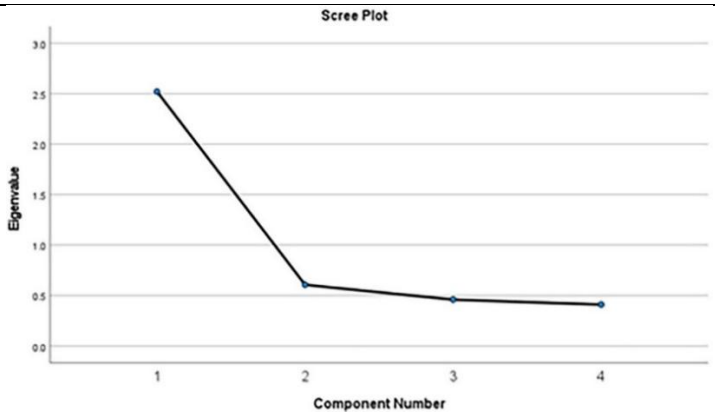
	**Eigenvalue** = 3.413 **Total variance explained** = 56.887%		
Component 1 (Form, Spatial organization and Exterior / façade of the house)	**Factor Loading**	**Communality after Extraction**	**Reliability (Cronbach's Alpha)**
Entertainment / hospitality spaces for guests and owners	0.793	0.628	0.848
Vertical division of house	0.774	0.599	
Introverted / extroverted plan	0.743	0.552	
Type of house	0.742	0.551	
Pattern of the house	0.737	0.543	
Decorations / ornamentation	0.735	0.540	

Table 12 shows the summary of the components consisting of the key impact subcategories influenced by 'conformity to local climate, geology and geography.' It is observed that the local climate, geology and geography mainly influence the form of traditional houses. Component 1 illustrates a correlation between the climate, geology and geography of a place and the patterns, types, sizes and shapes of the houses located in those places.

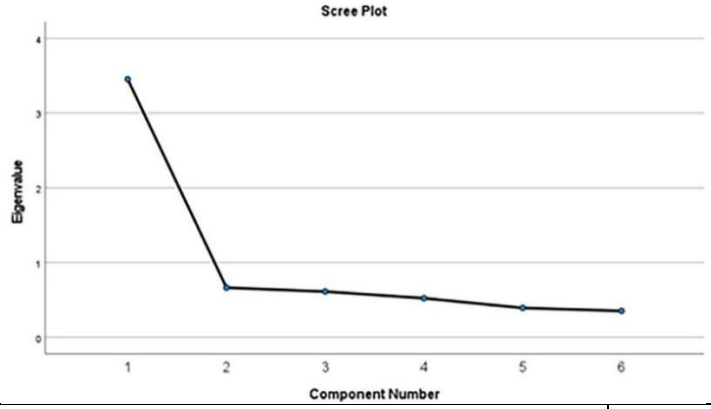
Table 12. Summary of the component with key impact subcategories influenced by 'conformity to local climate, geology and geography' *(Source: By Authors)*

	**Eigenvalue** = 2.521 **Total variance explained** = 63.024%		
Component 1 (Form of the house)	**Factor Loading**	**Communality after Extraction**	**Reliability (Cronbach's Alpha)**
Pattern of the house	0.830	0.690	0.804
Type of house	0.830	0.689	
Size of the house	0.769	0.592	
Shape of the house	0.742	0.550	

3.2.4 Cultural Category 4

Table 13 shows the summary of the components consisting of the key impact subcategories influenced by 'safety and security.' Component 1 for 'safety and security' illustrates a correlation between the safety and security needs of residents with the positioning of the entrance, distinction between public and private spaces, internal and external houses, and others.

Table 13. Summary of the component with key impact subcategories influenced by 'safety and security' *(Source: By Authors)*



Eigenvalue = 3.454

Total variance explained = 57.570%

Component 1 (Spatial organization of the house)	**Factor Loading**	**Communality after Extraction**	**Reliability (Cronbach's Alpha)**
Position of the entrance	0.780	0.608	0.852
Public and private spaces	0.774	0.599	
Form and orientation of stairs	0.769	0.592	
Gathering spaces	0.751	0.565	
Size of the rooms	0.748	0.560	
Internal and external house	0.728	0.530	

Figure 9 shows a summary of the PCA results for all the 11 cultural subcategories versus the impact subcategories or impacted architectural attributes. Since, in this study, factor loadings below 0.4 have been suppressed, colour – coding has been done for factor loading values ranging from 0.400 to 1.000. Based on a previous study by Piparsania and Kalita (2022), values between 0.400 - 0.600, between 0.601 - 0.800 and between 0.801 - 1.000 have been interpreted as the cultural subcategories having moderate, strong and very strong influences respectively, on the corresponding impact subcategories, and have been colour – coded as shown in (Figure 9). It is observed that 'occupation' has a moderate influence on open spaces such as yards or courtyards, and internal and external houses, with factor loading values of 0.456 and 0.554 respectively. 'Gender segregation,' 'patterns of cooking' and 'hospitality' influence the position of the entrance very strongly, however, it is influenced the most by 'hospitality' with a factor loading value of 0.843. Both 'gender segregation' and 'hospitality' very strongly influence the arrangement of the passageway or circulation spaces inside the traditional houses, however, the influence of 'hospitality' on it is the highest with a factor loading value of 0.822. It is further observed that the highest factor loading values are 0.919 and 0.910, which illustrates the fact that occupation of the residents very strongly influences the windows or openings and the entertainment or hospitality spaces respectively in traditional houses.

Cultural Subcategories	Impact subcategories (Impacted architectural attributes)																												
	Position of toilet or bathrooms / Orientation of the rooms / Position of bedrooms	Closed spaces like rooms	Internal and external house	Introverted / extroverted plan	Windows / openings	Balconies	Separate spaces for male and female servants	Placement of other entries	Semi - open spaces like porches	Position of the entrance	Form and orientation of stairs	Arrangement of the passageway / circulation	Vertical division of house	Position of cooking space / kitchen	Screens	Entertainment / hospitality spaces for guests and owners	Prayer room / space for religious rituals	Gathering spaces	Decorations / ornamentation	Public and private spaces	Threshold	Storage spaces	Separate spaces for male and female residents	Pattern of the house	Open space like yard / courtyard	Type of house	Size of the house	Shape of the house	Size of the rooms
Privacy	0.793	0.777	0.775	0.757	0.745	0.741	0.741	0.735	0.727	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gender segregation	-	-	-	-	-	0.772	-	-	0.744	0.807	0.804	0.803	0.802	0.758	0.723	0.720	-	-	-	-	-	-	-	-	-	-	-	-	-
Patterns of cooking	-	-	0.822	-	0.746	-	-	-	-	0.808	-	-	-	-	-	-	0.787	-	-	-	-	-	-	-	-	-	-	-	-
Hospitality	-	-	-	0.763	-	-	-	-	-	0.843	-	0.822	-	-	-	0.761	-	0.752	-	-	-	-	-	-	-	-	-	-	-
Preservation of culture / cultural identity	-	-	0.740	-	-	0.732	-	-	0.743	0.757	-	-	-	-	0.719	-	0.741	0.797	0.763	0.729	-	-	-	-	-	-	-	-	-
Class stratification	-	-	-	0.711	-	0.773	-	-	-	0.785	-	-	0.769	0.758	-	0.742	-	-	-	0.781	0.810	0.744	-	-	-	-	-	-	-
Family structure	-	-	0.792	0.713	-	-	-	-	-	-	-	-	0.771	-	-	0.782	-	-	-	-	-	-	0.720	-	-	-	-	-	-
Occupation	-	-	0.554	0.793	0.919	0.835	-	-	-	-	-	-	0.650	-	0.844	0.910	-	-	-	-	-	0.717	0.631	0.642	0.456	-	-	-	-
Income	-	-	-	0.743	-	-	-	-	-	-	-	-	0.774	-	-	0.793	-	-	0.735	-	-	-	-	0.737	-	0.742	-	-	-
Conformity to local climate, geology and	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.830	-	0.830	0.769	0.742	-
Safety and security	-	-	0.728	-	-	-	-	-	-	0.780	0.769	-	-	-	-	-	-	0.751	-	0.774	-	-	-	-	-	-	-	-	0.748

Legend		
Ranges	Interpretation	Colour - coding
0.400 - 0.600	Moderate influence	
0.601 - 0.800	Strong influence	
0.801 - 1.000	Very strong influence	
No fctor loading (-)	-	

Figure 9. Summary of PCA results (Source: By Authors)

Figure 10 shows a part of the framework for C – LCA with the intangible cultural categories and subcategories, and the impact categories and subcategories based on built form of traditional houses as obtained from the PCA analysis. Since section seven of the questionnaire, which deals with the inventory (cultural) indicators, has not been discussed in this study, it has not been mentioned in the framework. Based on the definition of cultural impact categories as discussed before in the 'introduction' section, from Figure 10, it can be said that throughout the lifespan of traditional houses, transformation(s) in impact subcategories such as 'closed spaces like rooms' or 'internal and external house' or 'balconies' under the impact category 'spatial organization of the house' will reflect a change in 'privacy,' and further in the religious or cultural preferences, and lifestyle of the residents. Similarly, transformation(s) in impact subcategories such as 'decorations / ornamentation' or 'screens' under the impact category 'exterior / façade of the house' will reflect a change in 'preservation of culture / cultural identity,' and further in the religious or cultural preferences, lifestyle and socio – economic conditions of the residents.

Sl. No.	Main Cultural category / categories	Cultural Subcategory / Subcategories	Impact categories based on built form of the house	Impact subcategories based on built form of the house
1.	Religious / cultural preferences and Lifestyle of the residents	1. Privacy	1. Spatial organization of the house	1. Position of toilet or bathrooms / Orientation of the rooms / Position of bedrooms, 2. Closed spaces like rooms, 3. Internal and external house, 4. Introverted / extroverted plan, 5. Balconies, 6. Separate spaces for male and female servants, 7. Semi - open spaces like porches
			2. Orientation of the house	1. Placement of other entries
			3. Exterior / facade of the house	1. Windows / openings
		2. Gender segregation	1. Spatial organization of the house	1. Position of the entrance, 2. Form and orientation of stairs, 3. Arrangement of the passageway / circulation, 4. Vertical division of house, 5. Balconies, 6. Position of cooking space / kitchen, 7. Semi - open spaces like porches, 8. Entertainment / hospitality spaces for guests and owners
			2. Exterior / facade of the house	1. Screens
		3. Patterns of cooking	1. Spatial organization of the house	1. Internal and external house, 2. Position of the entrance, 3. Prayer room / space for religious rituals
			2. Exterior / facade of the house	1. Windows / openings
2.	Religious / cultural preferences, Lifestyle of the residents and Socio – economic aspects	1. Hospitality	1. Spatial organization of the house	1. Position of the entrance, 2. Arrangement of the passageway / circulation, 3. Introverted / extroverted plan, 4. Entertainment / hospitality spaces for guests and owners, 5. Gathering spaces
		2. Preservation of culture / cultural identity	1. Spatial organization of the house	1. Gathering spaces, 2. Position of the entrance, 3. Semi - open spaces like porches, 4. Prayer room / space for religious rituals, 5. Internal and external house, 6. Balconies, 7. Public and private spaces
			2. Exterior / facade of the house	1. Decorations / ornamentation, 2. Screens
		3. Class stratification	1. Spatial organization of the house	1. Threshold, 2. Position of the entrance, 3. Public and private spaces, 4. Balconies, 5. Vertical division of house, 6. Position of cooking space / kitchen, 7. Storage spaces, 8. Entertainment / hospitality spaces for guests and owners, 9. Introverted / extroverted plan
		4. Family structure	1. Spatial organization of the house	1. Internal and external house, 2. Entertainment / hospitality spaces for guests and owners, 3. Vertical division of house, 4. Separate spaces for male and female residents, 5. Introverted / extroverted plan
3.	Socio - economic aspects	1. Occupation	1. Form of the house	1. Pattern of the house
			2. Spatial organization of the house	1. Entertainment / hospitality spaces for guests and owners, 2. Balconies, 3. Introverted / extroverted plan, 4. Storage spaces, 5. Vertical division of house, 6. Separate spaces for male and female residents, 7. Internal and external house, 8. Open space like yard / Courtyard
			3. Exterior / facade of the house	1. Windows / openings, 2. Screens
		2. Income	1. Form of the house	1. Type of house, 2. Pattern of the house
			2. Spatial organization of the house	1. Entertainment / hospitality spaces for guests and owners, 2. Vertical division of house, 3. Introverted / extroverted plan
			3. Exterior / facade of the house	1. Decorations / ornamentation
		3. Conformity to local climate, geology and geography	1. Form of the house	1. Pattern of the house, 2. Type of house, 3. Size of the house, 4. Shape of the house
4.	Lifestyle of the residents and Socio – economic aspects	1. Safety and security	1. Spatial organization of the house	1. Position of the entrance, 2. Public and private spaces, 3. Form and orientation of stairs, 4. Gathering spaces, 5. Size of the rooms, 6. Internal and external house

Figure 10. Part of the C – LCA framework as per the results obtained from the PCA analysis *(Source: By Authors)*

4.0 DISCUSSIONS

The results obtained from PCA show the influence of the various intangible cultural subcategories and further the main cultural category / categories on the impact subcategories based on built form of traditional houses. It is observed that 10 out of the 11 cultural subcategories mainly influence the various impact subcategories under the impact category 'spatial organization of the house.' Similar findings have also been presented by previous researchers such as Rahim et al. (2017) and Farshchi et al. (2016), where the authors addressed the influence of culture in the spatial organization of Malay houses and spatial hierarchy in traditional dwellings in Kashan respectively. However, the influence of the cultural subcategory 'conformity to local climate, geology and geography' is observed majorly on the impact subcategories under the impact category 'form of the house.' This finding aligns with a previous study done by Angkasa and Kamil (2024), where the authors mentioned that the hilly terrain and risk of earthquake in Nias island have influenced the

oval shape of traditional Nias houses, which makes them more aerodynamic as well. Also, Makinde (2015), said that the physical form of houses not only reflects the culture of its residents, but it is itself a component of culture. These findings also align with a study by Rapoport (1969), where the author said that the form and organization of the houses are influenced to a great extent by the 'cultural milieu' to which they belong, and further said that the positive purpose of a house is to create an environment that suits best with the way of life of people.

The single component obtained from the analysis of the impact subcategories influenced by 'privacy' shows that the factor loading of 'position of toilet or bathrooms / orientation of the rooms / position of bedrooms' is the highest with a value of 0.793, which means that while deciding the position or orientation of such spaces in traditional houses, the privacy needs of the residents played a major role. In the context of Western culture, Hall (1969) classified four zones of 'interpersonal' distance as 'intimate,' 'personal,' 'social' and 'public' zones with distances ranging up to 18 inches, 18 - 48 inches, 48 inches - 12 feet, and exceeding 12 feet respectively. Therefore, based on this classification of zones, in the context of traditional Indian houses also, it can be said that spaces such as bedrooms have been positioned away from the public zones, for ensuring the privacy of residents.

For the cultural subcategories 'gender segregation,' 'hospitality' and 'safety and security,' the factor loading of 'position of the entrance' is the highest with values of 0.807, 0.843 and 0.780 respectively. So, the position of the entrances in such houses were planned in such a way so as to ensure proper hospitality of the guests, while ensuring safety and security as well as privacy of the residents, especially women, at the same time. Cultural subcategories such as 'patterns of cooking' and 'family structure' largely influence the arrangement of the 'internal and external house' or the inner sanctum, which is the private area of a house, and external house. The finding related to influence of cooking patterns on the arrangement of the internal and external houses aligns with a previous study conducted by Raj and Suresh (2022), where the authors mentioned that the kitchen in traditional Indian houses is a closed space, located away from living areas or other open spaces in the external areas of the houses, as it conventionally emerged as a space which is restricted for the women of the family, thereby placing it in private areas inside the inner sanctum of the houses.

From the results, it is observed that the contribution of the 'gathering spaces' is the most in creating and preserving the cultural identity of the traditional houses, as it has the highest factor loading among all other impact subcategories influenced by the cultural subcategory 'preservation of culture / cultural identity' with a value of 0.797. The cultural subcategory 'class stratification' has a major influence on the 'threshold' in such houses, which shows a factor loading value of 0.810. According to Sadanand and Nagarajan (2020), in the Indian context, threshold serves as a transition place, often located between the outside and inside, or between different interior spaces or totally outside, and it forms an essential part in traditional houses (Tzortzi & Saxena, 2024). On the other hand, according to Rajras (n.d.), class system in India started during the British rule, which led to the emergence of the rich and the poor classes. It mainly deals with an open stratification system which might be based on social, economic, educational or cultural status, etc. So, it can be said that in traditional houses belonging to the upper classes, the residents allowed people from their own classes only, while restricting the entry or movement of the lower classes to certain spaces inside the houses by means of thresholds. The 'entertainment / hospitality spaces for guests and owners' are mostly influenced by the cultural subcategories such as 'occupation' and 'income' of the residents, where it shows factor loading values of 0.910 and 0.793 respectively. However, for the cultural subcategory 'education,' the 'Cronbach's Alpha' value of the construct with the retained impact subcategories is less than 0.70, and also the sampling is mediocre, so it has been excluded from further study and has not been included in the framework presented in the previous section.

From the results, it is observed that the tangible aspects in the traditional houses, in the form of the various impact categories and subcategories as discussed in this study help in portraying the culture of the residents, which is an intangible aspect. Therefore, it can be said that a transformation in these tangible aspects of the traditional houses will also reflect a change in the intangible cultural aspects of the residents over time, as at different stages of their lifespan, the form of the dwellings speaks about the changes in culture and the cultural identity of a place (Thaman, 2002). Such houses became a cultural identity for their residents or a particular place at the time of their initial construction, as the intangible cultural values of the residents got translated into the tangible aspects of the traditional houses at that stage, which reflect their actual character, and which can be considered as a benchmark for conducting the assessment. Hence, performing a C – LCA with suitable cultural indicators which will help in quantifying the amount of transformations that will take place due to the

interventions proposed for the different tangible aspects in such houses can help in understanding whether the intangible cultural aspects which are reflected in them will be retained or will they get lost over time.

A scoring method can be developed, and cultural performance scores can be used to assess the proposed interventions. A higher cultural performance score shall indicate that only the changes that are essential have been made while preserving the character of the houses altogether, and a lower score shall indicate a gradual loss in their cultural identities due to major additions and / or alterations. The cultural indicators can be quantitative, qualitative as well as semi - quantitative in nature to analyze both the tangible and intangible dimensions of culture. Some of the examples of such indicators include:

a. Maintaining required amount of privacy in the house with outsiders, visitors or servants (Galal-Ahmed, 2010). This indicator can be used to analyze impact subcategories such as 'position of toilet or bathrooms / orientation of the rooms / position of bedrooms,' 'internal and external house,' 'semi – open spaces like porches,' 'vertical division of house' and others. Required data can be collected through interviews with residents, questionnaire surveys and documentation of different spaces inside the houses through floor plans. Floor plans shall include original floor plans of the house during initial construction as well as the ones with proposed interventions. If original floor plans are not available, then they can be drafted by taking physical measurements and also according to the information received from the residents. Data obtained from interviews and questionnaire surveys can be analyzed by using content analysis and scoring methods respectively. Data obtained from documentation can be analyzed by using methods such as 'Justified graph analysis,' 'Visibility graph analysis,' 'Isovists analysis' and 'Agent movement analysis.' For example, for mathematically analyzing the justified plan graph, the floor plans collected should be studied first, followed by the preparation of a convex map (Lee et al., 2016), which gives a perspective of the building's top view, and shows the connections between the internal spaces that include doors, stairs and entrances. After that mathematical analysis can be carried out in eight steps, with the first step being counting the number of nodes, represented by the letter K (Ostwald, 2011). In the next step, the 'Total Depth (TD)' can be calculated (Ostwald, 2011). At this stage, the cultural indicators can be quantified or scored by calculating and comparing the TD of the original floor plans and the ones having the proposed interventions, and the percentage (%) of change in TD can be found out. The TD obtained from the original floor plan can be taken as a benchmark. The percentage of change in TD can be presented in the form of ranges and scored accordingly, where minimum change in percentage of TD will be assigned the highest score, while maximum change will be assigned the lowest. In this way more sensible interventions can be implemented to gain maximum score and to preserve the original character of the houses to a greater extent. The remaining steps involving the calculation, comparison and scoring variables such as 'Mean Depth (MD),' 'Relative Asymmetry (RA),' 'integration (*i*)' and 'control value (CV)' can be done in a similar way. 'Justified graph analysis' can also be performed by using tools such as 'Justified Analysis of Spatial Systems (JASS).'

b. Maintaining privacy needs of the residents through the positioning of the fenestrations with respect to the surrounding houses and streets (Galal-Ahmed, 2010). This indicator can be used to analyze impact subcategories such as 'introverted / extroverted plan,' 'windows / openings' and others. Required data can be collected through interviews with residents, questionnaire surveys that deal with questions for understanding the number of fenestrations in the houses, and documentation of the positions, sizes and shapes of the fenestrations. Documentation shall include original configurations of the fenestrations during initial construction, and also the proposed interventions. If original configurations are not available, then they can be documented in a similar way as mentioned for the previous indicator. Data obtained from interviews and questionnaire surveys can be analyzed by using content analysis and scoring methods respectively. Data obtained from documentation can be analyzed by using methods such as 'Potential Visual Exposure Index (PVEI)' and 'improved Potential Visual Exposure Index (I-PVEI).' Zheng et al. (2021) proposed the concept of PVEI, which helps in the evaluation of the quality of building opening's visual privacy by quantifying the amount of visual penetraion to the opening. Zheng et al. (2022) proposed the concept of I-PVEI for evaluating privacy risks of visual exposure along building facades in a dense residential environment. The authors also presented the respective formuale for calculating both PVEI and I-PVEI. In this case, for quantifying or scoring the cultural indicator, the PVEI or I-PVEI values of each of the fenestrations in their original configurations can be calculated and compared with the PVEI or I-PVEI values of the proposed interventions. This will

help in understanding whether visual privacy remains the same or not. If visual privacy changes, then the calculation of these values can help in understanding the percentage (%) of change in the visual privacy. Also, when traditional houses were built, there used to be fewer buildings around them. Since more buildings are coming up nowadays around such houses, these calculations can help in understanding whether visual privacy is retained or lost. The percentage of change in visual privacy can have certain ranges and scored in a similar manner as the first indicator. In this case, a higher score shall signify that only necessary changes have been made, thereby maintaining the privacy needs of the residents.

c. Maintaining privacy needs of the residents through the orientation of the house (Galal-Ahmed, 2010). This indicator can be used for analyzing impact subcategories such as 'balconies,' 'placement of other entries' and others. Here also, calculating the values of PVEI or I-PVEI can help in the quantification or scoring of the cultural indicator in the same manner as mentioned before.

d. Incorporating cultural spaces in the houses that reflect the ideology or belief of a place (Piparsania & Kalita, 2021). This indicator can be used to analyze impact subcategories such as 'prayer room / space for religious rituals,' 'entertainment / hospitality spaces for guests and owners,' 'gathering spaces' and others. Required data can be collected through interviews with residents, questionnaire surveys that deal with questions for understanding the number of such spaces in the houses, and documentation of the spaces through floor plans. Documentation through floor plans, and analysis of interview and questionnaire data shall follow the same processes as mentioned for other indicators before. Data obtained from documentation can be analyzed by calculating and comparing the volumes of such spaces in the original plans with the ones having the proposed interventions, for finding out whether there is a change in the volume or not. If there is a change, then the percentage (%) of change in volume can be scored in the same manner as mentioned for the other indicators before.

Coming to system boundaries that are considered for LCA, according to Lim et al. (2018), E – LCA or LCA quantitatively predicts and assesses the total amount of emissions that might take place from construction materials over their entire lifespan, starting from manufacturing to disposal of a building. According to Andrews et al. (2009), LCC helps in the compilation and assessment of different types of costs associated with a wide range of products, that range from buildings to trains and others, during their entire life cycle, from cradle-to-grave. According to Poulsen and Jensen (2004) and Andrews et al. (2009), 'Working Environmental LCA (WE – LCA) helps in compiling and evaluating possible working environmental impacts on humans, who are associated with a product system, throughout its life cycle. According to Andrews et al. (2009), S – LCA or socio – economic LCA helps in assessing the possible positive as well as negative impacts associated with a product along their entire life cycle, starting from raw materials extraction and processing to final disposal. But coming to C - LCA, since it involves an assessment of cultural impacts of traditional houses during their lifespan, the system boundary (phases or stages) that can be considered include mainly the construction and user phases. This is because the intangible cultural values of the residents took a tangible shape in the form of such houses during their initial construction phase, which gave them a cultural identity, and transformations take place during the user phase only. The other types of LCAs consider the entire cradle-to-grave, and sometimes the reuse, recycle and recovery stages as well, because they deal mainly with understanding the environmental, economic or social impacts of a product. In such cases, it is observed that cultural aspects associated with the products are not taken into consideration. However, in case of S – LCA, 'cultural heritage' has been mentioned as a subcategory under the stakeholder category 'local community' (Traverso, et al., 2021). But this 'cultural heritage' subcategory mainly helps in assessing if an organization respects local cultural heritage and recognizes that all members of a community have rights in pursuing their cultural development (Traverso, et al., 2021). But in case of C – LCA, all the impact subcategories as mentioned in Figure 10 help in assessing the impacts on the intangible cultural categories and subcategories, due to transformations that take place in them during the lifespan of traditional houses. Therefore, such an assessment shall help in understanding whether the cultural identities associated with the houses are retained or lost with time. Because of all these reasons, demolition and processing phase cannot be considered in case of C – LCA, as pulling down of a traditional house will completely remove the cultural identity associated with it. Based on the tangible impact categories and subcategories, the entire building can be considered as the functional unit for conducting a C – LCA.

In general, use of LCA or E – LCA in construction industry helps architects, engineers, policymakers and other relevant stakeholders in identifying the most sustainable construction materials, as LCA provides a clear picture of the environmental impacts of the materials throughout their lifespan (Bahramian & Yetilmezsoy, 2020; Munir et al., 2023). LCA can also help in quantifying the benefits of construction practices, and provide support in adopting the most sustainable ones (Ebeh et al., 2024). By assessing the impacts of management practices in construction sites, LCA further helps in identifying strategies that are most effective in reducing environmental degradation during construction (Kabirifar et al., 2020). LCC helps in the identifcation of processes and materials that are most efficient as well as sustainable, thereby reducing costs of materials, and expenses for waste disposal. S – LCA promotes responsible material sourcing from suppliers who stick to fair labour practices, and environmental management that is sustainable in nature (Ebeh et al., 2024). LCSA, on the other hand, helps decision – makers in making more sustainable choices by assessing all three pillars of sustainability together (Elnaggar, 2024). In the context of cultural heritage conservation, LCA generally helps in selecting materials and construction methods that are environmentally friendly, encourages participation of stakeholders and ensures that practices involved in the restoration processes are sustainable in nature (Başçıl et al., 2024). Similarly, in case of C – LCA also, the interventions proposed for the different architectural attributes in traditional houses can be assessed and compared by using the cultural indicators as mentioned before. As discussed earlier, a scoring method can be developed based on the percentage of change that shall take place by implementing a certain intervention. So, the proposed C – LCA framework can be used by architects, engineers, interior designers and other relevant stakeholders during the conservation and / or restoration phase(s) of traditional individual houses which are of age 50 years and above, for identifying intervention(s) with higher cultural performance scores that can be implemented for preserving the cultural identities of the houses altogether. It will further help the policymakers in formulating more sensible heritage conservation policies regarding the extent of transformations that can be proposed or done to the impact categories and subcategories mentioned in the framework. Since lower cultural performance scores will signify a gradual loss in the cultural identities of the houses, the policymakers can mention a certain cutoff score in the policies, which should be followed by the stakeholders involved in the transformations of such houses for planning the interventions (additions or alterations) more sensibly.

The proposed C – LCA framework has been developed by taking into consideration the traditional houses in the Indian context. Although the impacted architectural attributes as mentioned in the framework might be the same in other contexts, the intangible cultural aspects such as ‘family structure,’ ‘religious / cultural preferences,’ ‘class stratification,’ ‘conformity to local climate, geology and geography’ and others, influencing such attributes in the Indian context might significantly vary from those in other regions. Therefore, future studies can focus on further modifying the proposed framework which can be applied for conducting C – LCA of similar architectural typologies in other regions.

5.0 CONCLUSIONS

Culture has played a crucial role in the architecture of traditional houses, but despite that it has not been acknowledged in the assessment techniques of such buildings. Therefore, the main objective of this study is to develop a C – LCA framework by incorporating intangible cultural aspects along with the architectural attributes in traditional Indian houses which are influenced by them. Data for this study has been collected through a questionnaire survey. A total of 207 respondents, who have been selected through purposive sampling method, participated in the survey. PCA method has been used to analyze the data collected in IBM SPSS Statistics software. From the results, it is observed that a change in the ‘spatial organization of the house’ will impact 10 out of 11 cultural subcategories, except ‘conformity to local climate, geology and geography’ which mainly influences ‘form of the house.’ From the summary of the PCA results, it is observed that occupation of the residents very strongly influences the windows / openings and entertainment or hospitality spaces in traditional houses with the highest factor loading values of 0.919 and 0.910 respectively. While, on the other hand, open spaces such as courtyards, and internal and external houses are moderately influenced by the occupation of the residents, with the lowest factor loading values of 0.456 and 0.554 respectively. So, a C - LCA can be performed by implementing the framework developed in this study with the help of suitable cultural indicators, in the same manner as E – LCAs or S – LCAs are conducted by using the respective standards. Such an assessment process will help in understanding the cultural impacts of the traditional houses apart from their environmental, economic and social impacts.

As a future scope of this study, a scoring method can be developed. The architecture of traditional houses during their initial construction phase can be considered as a benchmark. Cultural performance scores can be used to assess the proposed interventions for the architectural attributes. A higher cultural performance score shall indicate that only changes that are essential have been made, and a lower score shall indicate a gradual loss in the cultural identity due to major additions and / or alterations. Such an assessment technique can be used by architects, conservation architects, heritage conservation organizations, policymakers and other relevant stakeholders for preserving the housing heritage in India and maintaining both the intangible and tangible cultural identities associated with them.

Also, there are certain limitations of this study which can be addressed in future research. Firstly, the C – LCA framework in this study has been proposed for traditional individual houses of age 50 years and above in the context of India. However, the cultural aspects influencing the architectural attributes in traditional houses in other countries might significantly vary from those in India, thereby limiting the generalizability of this framework to other regions. So, future studies can further modify the proposed framework for conducting C – LCA of similar architectural typologies in other contexts. Secondly, although the sample size for this study, comprising of 207 respondents, is a fair and suitable sample size, future studies can consider a larger sample size for arriving at conclusions and further modifying the proposed framework. Thirdly, the percentage of female respondents in this study is higher (59%) as compared to male, which can influence perceptions regarding domestic culture such as private spaces or inner sanctum of a house. Fourthly, the percentage of professionals who took part in the survey is significantly higher (94%) as compared to common people, so the results of this study do not represent common people. So, future studies can consider equal percentage of male and female participants and include a greater number of common people to avoid bias in cultural perceptions.

ACKNOWLEDGEMENT

This study is a part of an ongoing PhD research work of the corresponding author at the School of Planning and Architecture, Vijayawada, India, under the supervision of the second and the third authors.

6.0 REFERENCES

Andrews, E. S., Barthel, L.-P., Beck, T., Benoît, C., Ciroth, A., Cucuzzella, C., . . . Weidema, B. (2009). Guidelines for Social Life Cycle Assessment of Products. UNEP/SETAC Life Cycle Initiative.

Angkasa, Z., & Kamil, E. M. (2024). Passive Cooling in Indonesian Traditional Dwellings and Its Relationship with Geographical Location. Journal of Design and Built Environment, 24(01), 01-16. https://doi.org/10.22452/jdbe.vol24no1.1

Asriana, N., Khidmat, R. P., Jaya, M. A., Ujung, V. A., Satria, W. D., & Andriani, R. (2024). Syntactic analysis of traditional houses in urban kampung. Built Heritage, 8(25). https://doi.org/10.1186/s43238-024-00140-5

B., V., & Amirtham, L. R. (2023). Links Between Culture, Social Benefits and Courtyards: The Traditional and the Transformed Courtyard Houses of Kumbakonam, Tamil Nadu, India. ISVS e-journal, 10(4). Retrieved from https://isvshome.com/pdf/ISVS_10-4/ISVSej_10.4.2.pdf

Bahramian, M., & Yetilmezsoy, K. (2020). Life cycle assessment of the building industry: An overview of two decades of research (1995–2018). Energy and Buildings, 219, Article 109917. https://doi.org/10.1016/j.enbuild.2020.109917

Başçıl, D., Karakaş, Ç. E., & Bulut, N. (2024). Potential Role of Life Cycle Assessment for Cultural Heritage Conservation Practices in Türkiye. SETSCI Conference Proceedings 20, 125-132. https://doi.org/10.36287/setsci.20.16.125

Basu, M., Kaja, N., & Rao, P. (2024). Study on Life Cycle Assessment and Life Cycle Sustainability Assessment of Buildings: A Review. Journal of The Institution of Engineers (India): Series A, 105, 749–766. https://doi.org/10.1007/s40030-024-00831-3

Blundo, D. S., Ferrari, A. M., del Hoyo, A. F., Riccardi, M. P., & Garcia Muiña, F. E. (2018). Improving sustainable cultural heritage restoration work through life cycle assessment-based model. Journal of Cultural Heritage, 32, 221-231. https://doi.org/10.1016/j.culher.2018.01.008

Blundo, D. S., Ferrari, A. M., Pini, M., Riccardi, M. P., Garcia, J. F., & Fernandez del Hoyo, A. P. (2014). The life cycle approach as an innovative methodology for the recovery and restoration of cultural heritage. Journal of Cultural Heritage Management and Sustainable Development, 4(2), 133-148. https://doi.org/10.1108/JCHMSD-05-2012-0016

Boudagh, M., & Ghaemmaghami, P. (2011). The typology of traditional houses in Tabriz. In C. A. Brebbia & L. Binda (Eds.), Structural Studies, Repairs and Maintenance of Heritage Architecture XII, Vol. 118 (pp. 87-98). WIT Press.

Bryant, F. B., & Yarnold, P. R. (1995). Principal-components analysis and exploratory and confirmatory factor analysis. In L. G. Grimm & P. R. Yarnold (Eds.), Reading and understanding multivariate statistics (pp. 99–136). American Psychological Association.

Ceylan, S. (2022). Vernacular architecture of Turkish Eastern Black Sea region: a case study in Senoz (Büyükdere) Valley. Open House International, 47(3), 513–532. https://doi.org/10.1108/OHI-08-2021-0174

Comrey, A. L., & Lee, H. B. (1992). A First Course in Factor Analysis (2nd ed.). Lawrence Erlbaum Associates, Inc.

Ćosović, M., Amelio, A., & Junuz, E. (2019). Classification Methods in Cultural Heritage. Proceedings of the 1st International Workshop on Visual Pattern Extraction and Recognition for Cultural Heritage Understanding Co-Located with 15th Italian Research Conference on Digital Libraries (IRCDL 2019), 13-24.

Ebeh, C. O., Okwandu, A. C., Abdulwaheed, S. A., & Iwuanyanwu, O. (2024). Life Cycle Assessment (LCA) in Construction: Methods, Applications, and Outcomes. International Journal of Engineering Research and Development, 20(8), 350-358. https://ijerd.com/paper/vol20-issue8/2008350358.pdf

Elnaggar, A. (2024). Nine principles of green heritage science: life cycle assessment as a tool enabling green transformation. Heritage Science, 12(7), Article 7. https://doi.org/10.1186/s40494-023-01114-z

Endo, Y., & Takamura, H. (2021). Evaluation of Life-Cycle Assessment Analysis: Application to Restoration Projects and New Construction in Alpine Climate, Japan. Sustainability, 13(7), Article 3608. https://doi.org/10.3390/su13073608

Farshchi, H., Arfaei, F. S., Kashan, V. A., & Jamali, F. (2016). Manifestation of Culture in Traditional Architecture of Iranian House Based on Old Houses in Kashan. Modern Applied Science, 10(2), 185-193. http://dx.doi.org/10.5539/mas.v10n2p185

Galal-Ahmed, K. (2010). Achieving socio-cultural sustainability in the design of the government-sponsored single family houses in the UAE: the case of Al Ain. Proceedings of the Sustainable City 2010, the Sixth International Conference on Urban Regeneration and Sustainability, 139 - 151.

Gaskin, C. J., & Happell, B. (2014). On exploratory factor analysis: A review of recent evidence, an assessment of current practice, and recommendations for future use. International Journal of Nursing Studies, 51, 511-521. https://doi.org/10.1016/j.ijnurstu.2013.10.005

GlobalData. (n.d.). The Mean Age in India (2021 - 2029, years). https://www.globaldata.com/data-insights/macroeconomic/the-mean-age-in-india-139012/

Hair, J. F., Jr., Black, W. C., Babin, B. J., & Anderson, R. E. (2009). Multivariate Data Analysis (7th ed.). Prentice Hall.

Hall, E. T. (1969). The hidden dimension. Anchor Books.

Hamka, & Winarni, S. (2021). Comparative Understanding of Traditional Architecture based on Literature Review: Refining the Definition of Traditional Architecture. International Journal of Architecture and Urbanism, 5(3), 252-262. https://doi.org/10.32734/ijau.v5i3.7219

Kabirifar, K., Mojtahedi, M., Wang, C., & Tam, V. W. (2020). Construction and demolition waste management contributing factors coupled with reduce, reuse, and recycle strategies for effective waste management: A review. Journal of Cleaner Production, 263, Article 121265. https://doi.org/10.1016/j.jclepro.2020.121265

Kaiser, H. F. (1970). A second-generation little jiffy. Psychometrika, 35, 401–415. https://doi.org/10.1007/BF02291817

Kaoula, D., Rahmani, S., Lemita, I., Zemirli, M. A., & Semahi, S. (2022). Life cycle assessment of traditional Saharan houses: Towards a sustainable building? Journal of Building Engineering, 57, 104782. https://doi.org/10.1016/j.jobe.2022.104782

Khairul, M. Z., Ismail, S., & Saleh, A. L. (2018). Contractor's Performance Appraisal System in the Malaysian Construction Industry: Current Practice, Perception and Understanding. International Journal of Engineering & Technology, 7(3.9), 46-51. https://doi.org/10.14419/ijet.v7i3.9.15272

Khan, T. H. (2013). Houses in Transformation: Search for the Implicit Reasons. Springer.

Kumari, N. (2023). Cross-Cultural Influences in Traditional Residential Architecture of Northwestern India (15th – 20th Century). International Research Journal of Engineering and Technology (IRJET), 10(06), 221-237. Retrieved from https://www.irjet.net/archives/V10/i6/IRJET-V10I634.pdf

Lee, J. H., Ostwald, M. J., & Gu, N. (2016). A Justified Plan Graph (JPG) grammar approach to identifying spatial design patterns in an architectural style. Environment and Planning B: Urban Analytics and City Science, 45(1). https://doi.org/10.1177/0265816665618

Lever, J., Krzywinski, M., & Altman, N. (2017). Principal component analysis. Nature Methods, 14(7), 641-642. https://doi.org/10.1038/nmeth.4346

Lim, H., Tae, S., & Roh, S. (2018). Analysis of the Primary Building Materials in Support of G-SEED Life Cycle Assessment in South Korea. Sustainability, 10(8), Article 2820. https://doi.org/10.3390/su10082820

Liu, S., & Qian, S. (2019). Evaluation of social life-cycle performance of buildings: Theoretical framework and impact assessment approach. Journal of Cleaner Production, 213, 792-807. https://doi.org/10.1016/j.jclepro.2018.12.200

MacCallum, R. C., Widaman, K., Zhang, S., & Hong, S. (1999). Sample Size in Factor Analysis. Psychological Methods, 4(1), 84-99. https://doi.org/10.1037/1082-989X.4.1.84

Makinde, O. O. (2015). Influences of socio-cultural experiences on residents' satisfaction in Ikorodu low-cost housing estate, Lagos state. Environment, Development and Sustainability, 17, 173–198. https://doi.org/10.1007/s10668-014-9545-6

Marôco, J. (2024). Factor Analysis of Ordinal Items: Old Questions, Modern Solutions? Stats, 7(3), 984-1001. https://doi.org/10.3390/stats7030060

Munir, Q., Abdulkareem, M., Horttanainen , M., & Kärki, T. (2023). A comparative cradle-to-gate life cycle assessment of geopolymer concrete produced from industrial side streams in comparison with traditional concrete. Science of The Total Environment, 865, Article 161230. https://doi.org/10.1016/j.scitotenv.2022.161230

Murillo Camacho, K. S., Fouseki, K., & Altamirano, H. (2023). Sustainability and Energy Efficiency in the World Heritage Site of the Historic Centre of Mexico City. Heritage, 6(9), 6343-6357. https://doi.org/10.3390/heritage6090332

Ostwald, M. J. (2011). The Mathematics of Spatial Configuration: Revisiting, Revising and Critiquing Justified Plan Graph Theory. Nexus Network Journal, 13, 445–470. https://doi.org/10.1007/s00004-011-0075-3

Piparsania, K., & Kalita, P. C. (2021). Interpreting Social and Cultural Sustainability for Housing. Simpósio de Design Sustentável: Sustainable Design Symposium, 628-639. https://doi.org/10.5380/8sds2021.art21

Piparsania, K., & Kalita, P. C. (2022). Development of DASH: Design Assessment Framework for Sustainable Housing. Sustainability, 14(23), Article 15990. https://doi.org/10.3390/su142315990

Pizzirani, S., McLaren, S. J., & Seadon, J. K. (2014). Is there a place for culture in life cycle sustainability assessment? The International Journal of Life Cycle Assessment, 19, 1316–1330. https://doi.org/10.1007/s11367-014-0722-5

Poulsen, P. B., & Jensen, A. A. (2004). Working Environment in Life-Cycle Assessment. SETAC Press.

Pozzo, A. D., Masi, G., Sassoni, E., & Tugnoli, A. (2024). Life cycle assessment of stone consolidants for conservation of cultural heritage. Building and Environment, 249, Article 111153. https://doi.org/10.1016/j.buildenv.2023.111153

Quoc, B. T., Dinh, T. N., & Quang, K. M. (2024). Impacts of Culture on Traditional Housing Architecture of Ethnic Minority in the Vietnamese Northern Mountains. Journal of Design and Built Environment, 24(02), 01-18. https://doi.org/10.22452/jdbe.vol24no2.1

Rahim, Z. A., Majid, N. H., & Denan, Z. (2017). Assessment on Cultural Aspects in Housing Design in Urban Areas. Science International (Lahore), 29(4), 917-922. http://www.sci-int.com/pdf/636397812160341978.pdf

Raj, S. J., & Suresh, A. K. (2022). From closeness to openness:Repositioning of the Indian kitchen and restructuring of the gender system. Interiors, 12(2-3), 246-267. https://doi.org/10.1080/20419112.2022.2154996

Rajras. (n.d.). Chapter 2: Caste and Class in Indian Society. https://rajras.in/ras/mains/paper-1/sociology/caste-and-class-in-indian-society/

Rapoport, A. (1969). House form and culture. Pearson; Facsimile edition.

Rigdon, E. E., & Ferguson, C. E. (1991). The Performance of the Polychoric Correlation Coefficient and Selected Fitting Functions in Confirmatory Factor Analysis with Ordinal Data. Journal of Marketing Research, 28(4), 491-497. https://doi.org/10.1177/002224379102800412

Sabatini, F. (2019). Culture as Fourth Pillar of Sustainable Development: Perspectives for Integration, Paradigms of Action. European Journal of Sustainable Development, 8(3), 31-40. https://doi.org/10.14207/ejsd.2019.v8n3p31

Sadanand, A., & Nagarajan, R. V. (2020). Transition Spaces in an Indian Context. Athens Journal of Architecture, 6(3), 193-224. https://doi.org/10.30958/aja.6-3-1

Sardjono, A. B., Hardiman, G., & Prianto, E. (2016). Characteristics of Traditional Houses in the Old Town of Kudus City, Indonesia. International Journal of Scientific and Research Publications, 6(2), 109-118. Retrieved from https://www.ijsrp.org/research-paper-0216/ijsrp-p5017.pdf

Serrano, T., Kampmann, T., & Ryberg, M. W. (2022). Comparative Life-Cycle Assessment of restoration and renovation of a traditional Danish farmer house. Building and Environment, 219, 109174. https://doi.org/10.1016/j.buildenv.2022.109174

Shrestha, N. (2020). Detecting Multicollinearity in Regression Analysis. American Journal of Applied Mathematics and Statistics, 8(2), 39-42. https://doi.org/10.12691/ajams-8-2-1

Shrestha, N. (2021). Factor Analysis as a Tool for Survey Analysis. American Journal of Applied Mathematics and Statistics, 9(1), 4-11. https://doi.org/10.12691/ajams-9-1-2

Srivastava, A., & Das, B. K. (2023). Vernacular Architecture of India: An Overview. Journal of the International Society for the Study of Vernacular Settlements ISVS e-journal, 10(7), 435-448. Retrieved from https://www.researchgate.net/publication/373018409_Vernacular_Architecture_of_India_An_Overview

Tabachnick, B. G., & Fidell, L. S. (2013). Using Multivariate Statistics (6th ed.). Pearson.

Thaman, K. H. (2002). Shifting sights: the cultural challenge of sustainability. Higher Education Policy, 15(2), 133-142. https://doi.org/10.1016/S0952-8733(02)00004-1

Traverso, M., Valdivia, S., Luthin, A., Roche, L., Arcese, G., Neugebauer, S., . . . Zamagni, A. (2021). Methodological Sheets for Subcategories in Social Life Cycle Assessment (S-LCA) 2021. United Nations Environment Programme (UNEP).

Tzortzi, J. N., & Saxena, I. (2024). Threshold Spaces: The Transitional Spaces Between Outside and Inside in Traditional Indian Dwellings. Heritage, 7(12), 6683-6711. https://doi.org/10.3390/heritage7120309

UNESCO. (2011). 2003 Convention for the Safeguarding of the Intangible Cultural Heritage.

UNESCO. (2016). Re|shaping cultural policies: a decade promoting the diversity of cultural expressions for development.

UNESCO. (n.d.). Culture.

UNESCO Institute for Statistics. (2009). 2009 UNESCO Framework for Cultural Statistics.

Vehbi, B. O., Günçe, K., & Iranmanesh, A. (2021). Multi-Criteria Assessment for Defining Compatible New Use: Old Administrative Hospital, Kyrenia, Cyprus. Sustainability, 13(4), Article 1922. https://doi.org/10.3390/su13041922

Verma, J. P. (2013). Data Analysis in Management with SPSS Software. Springer, India.

Vilches, A., Garcia-Martinez, A., & Sanchez-Montañes, B. (2017). Life cycle assessment (LCA) of building refurbishment: A literature review. Energy and Buildings, 135, 286-301. https://doi.org/10.1016/j.enbuild.2016.11.042

Worldometer. (n.d.). India Demographics. https://www.worldometers.info/demographics/india-demographics/

Zheng, H., Wu, B., Wei, H., Yan, J., & Zhu, J. (2021). A Quantitative Method for Evaluation of Visual Privacy in Residential Environments. Buildings, 11(7), Article 272. https://doi.org/10.3390/buildings11070272

Zheng, H., Wu, B., Zhang, J., Yan, J., & Wei, H. (2022). Refining the potential visual exposure index for the assessment of residential visual privacy: a three-dimensional study. Journal of Asian Architecture and Building Engineering, 22(3), 1458–1475. https://doi.org/10.1080/13467581.2022.208572

Appendix

Directions for answering the questions in Sections 2 - 6:
For the questions mentioned in **Sections 2 - 6, five options** have been given for each of the cultural subcategories. Kindly put a tick mark (✓) for selecting the most appropriate option to give your opinion for each of the cultural subcategories.
Legend:
1 = Not at all influenced, **2** = Slightly influenced, **3** = Somewhat influenced, **4** = Very influenced and **5** = Extremely influenced

Section 2: Influence of Cultural subcategories on the different tangible aspects or Impact categories (Building materials and Form and type of the ceiling / roof) based on built form of the residence

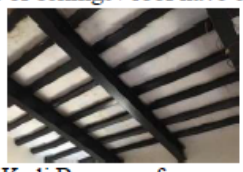
2.1 **Question:** How do you think the ***Building materials*** *used in residential buildings* are influenced by the following cultural subcategories?

	Cultural subcategories	1	2	3	4	5
a.	Preservation of culture / cultural identity	☐	☐	☐	☐	☐
b.	Income of the residents	☐	☐	☐	☐	☐
c.	Conformity to local climate, geology, and geography	☐	☐	☐	☐	☐

2.2 **Question:** How do you think the ***Form and type of the ceiling / roof*** *in residential buildings* is influenced by the following cultural subcategories? (some examples of ceilings / roof have been presented below)


Conical roof


Flat roof


Kadi Barga roof


Wooden false ceiling


Sloped roof

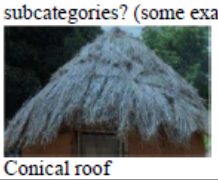
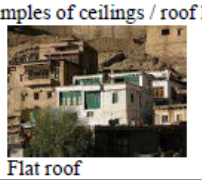
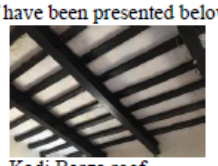
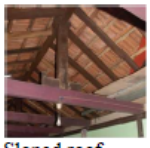
	Cultural subcategories	1	2	3	4	5
a.	Income of the residents	☐	☐	☐	☐	☐
b.	Conformity to local climate, geology, and geography	☐	☐	☐	☐	☐

2.3 **Question:** Is / Are there any other factor(s) that influence the formation / transformation of the above – mentioned tangible aspects or impact categories in residential buildings?

Examples of questionnaire items from the final questionnaire prepared for the professionals for the main survey *(Source: By Authors)*

Directions for answering the questions in Sections 3 - 7:
For the questions mentioned in **Sections 3 - 7, five options** have been given for each of the cultural subcategories. Kindly put a tick mark (✓) for selecting the most appropriate option to give your opinion for each of the cultural subcategories.
Legend:
1 = Not at all influenced, **2** = Slightly influenced, **3** = Somewhat influenced, **4** = Very influenced and **5** = Extremely influenced

Section 3: Influence of Cultural subcategories on the different tangible aspects or Impact categories (Building materials and Form and type of the ceiling / roof) based on built form of the residence

3.1	**Question:** How were the ***Building materials*** *used in your house* influenced by the following cultural subcategories?					
	Cultural subcategories	**1**	**2**	**3**	**4**	**5**
a.	Preservation of culture / cultural identity	☐	☐	☐	☐	☐
b.	Income of the residents	☐	☐	☐	☐	☐
c.	Conformity to local climate, geology, and geography	☐	☐	☐	☐	☐
3.2	**Question:** How was the ***Form and type of the ceiling / roof*** *in your house* influenced by the following cultural subcategories? (some examples of ceilings / roof have been presented below)					
	 Conical roof  Flat roof  Kadi Barga roof  Wooden false ceiling  Sloped roof					
	Cultural subcategories	**1**	**2**	**3**	**4**	**5**
a.	Income of the residents	☐	☐	☐	☐	☐
b.	Conformity to local climate, geology, and geography	☐	☐	☐	☐	☐
3.3	**Question:** Did any other factor(s) influence the formation / transformation of the above – mentioned tangible aspects or impact categories in your house?					

Section 4: Influence of Cultural subcategories on the different tangible sub - aspects or Impact subcategories based on built form of the residence under the main Impact category of Form of the house

4.1	**Question:** How was the ***Shape*** *of your house* (for example, square, rectangular, L – shaped and others) influenced by the following cultural subcategories?					
	Cultural subcategories	**1**	**2**	**3**	**4**	**5**
a.	Privacy of the residents	☐	☐	☐	☐	☐
b.	Hospitality of the guests	☐	☐	☐	☐	☐
c.	Family structure	☐	☐	☐	☐	☐
d.	Conformity to local climate, geology, and geography	☐	☐	☐	☐	☐
e.	Safety and security of the residents	☐	☐	☐	☐	☐

Examples of questionnaire items from the final questionnaire prepared for the common people for the main survey *(Source: By Authors)*