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Development of DASH: Design Assessment Framework for Sustainable Housing

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Abstract: The idea of sustainability is based on three pillars—environmental, economic, and social—per the Brundtland report. Housing is a type of architecture with which any occupant can connect. It is a place that supports an occupant's physical, emotional, cultural, and social needs, which support their consciousness. The methodology used here includes an extensive literature review, followed by data collection and analysis in order to understand, achieve, and balance sustainability and its metrics. We could see an evident gap in current green building rating systems regarding the inclusion of social and cultural indicators. There is an inclination for quantitative approaches, such as energy, the environment, and resources. We found that it is viable to identify, recognize, and determine social and cultural indicators that are both tangible and intangible. In most research regarding the sustainable built environment, the participation and feedback are limited to industry experts and professionals, and residents are excluded. This study attempted to fill this gap by collecting data from Indian residents, thus validating social and cultural indicators according to occupants' needs. With the help of indicators discovered in the literature review and by strengthening them further with data collection, a holistic framework was developed to achieve sustainability for housing.

Keywords: sustainable development; sustainability assessment framework; socio-cultural indicators

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1. Introduction

A future that is inclusive, sustainable, and resilient for both people and the planet is what sustainable development advocates for. Measuring the components that indicate the growth of such sustainability is necessary for any field of study or practice [1]. The adoption of sustainable solutions in the built environment faces a significant measurement issue, primarily because no preset list of indicators has been commonly agreed upon [2,3]. To promote sustainable development, the United Nations suggested the "three pillars" structure [4].

This study's goal is to determine a way to more effectively integrate the physical and intangible aspects of housing for socio-culturally focused and sustainable development by establishing a theoretical framework. This study highlights the negligence of socio-cultural indicators in most sustainable design methods, as most sustainability assessment tools (worldwide) appear to be biased toward physical attributes related to energy, the environment, materials, and resources. There is a need to cater to more sustainable housing that is socially and culturally appropriate for the transition to a low-carbon future. In most research regarding the sustainable built environment, the participation and feedback are limited to industry experts, and residents are excluded. This study presents the views of residents regarding the incorporation of socio-cultural indicators and the understanding of sustainability. This study focuses on socio-cultural sustainability: incorporating culture as the fourth pillar of sustainability or as an extension to social sustainability. This study aims to find relevant socio-cultural indicators (tangible and intangible) that are defined by occupants. This study attempts to answer the following research questions:

R1. What are the indicators for social and cultural aspects of housing?

1.1 Which social and cultural indicators are more relatable?
1.2 How do these socio-cultural indicators connect with the built environment?
1.3 Which sustainable design assessment tools are available in developed and developing countries and how have they integrated socio-cultural indicators?
1.4 What are occupants' perceptions regarding the integration of socio-cultural indicators in housing?
1.5 How can we involve occupants and their participation in sustainable design assessment?

R2. How can we incorporate socio-cultural aspects into green building assessment methods for housing?
R3. How can we develop a holistic and balanced framework for sustainable design assessment?
R4. How can we translate the developed framework into a tool?

Through a secondary data review and survey research, this study is intended to find relevant socio-cultural indicators that are occupant-defined. The context of this study is specific to India, with the set of people involved is limited due to restrictions resulting from COVID-19. This article proposes a new theoretical framework for a balanced approach to achieving sustainable housing. This study attempts to answer all research questions mentioned above. However, the answer to the fourth question is not is not covered in this paper. Figure 1 outlines the fundamental research outlook of the study, along with the later outcomes.

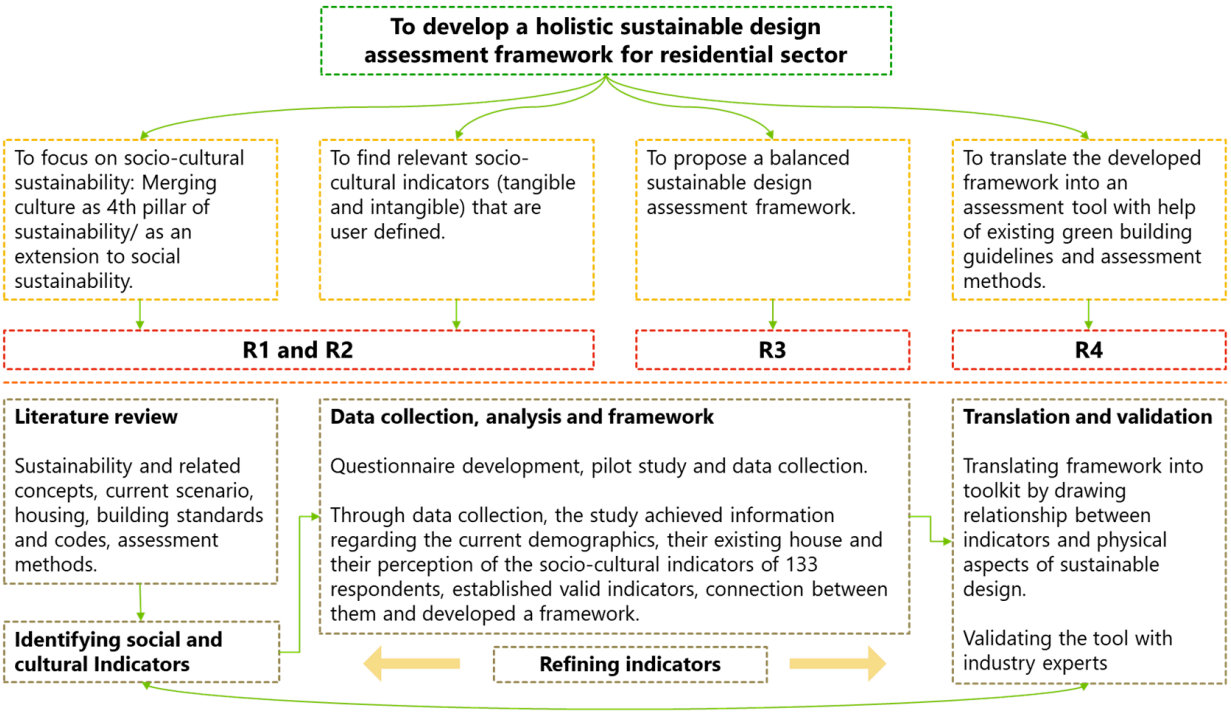

Figure 1. Research outlook for the development of DASH.

2. Situational Assessment

In 2018, the most significant portions of both global final energy usage (36%) and energy-related CO_2 emissions (39%) came from building construction and operations [5]. Progress in energy policy is not keeping pace with the growth of the building sector. Mandatory policies covered less than 40% of energy use and less than half of the CO_2 emissions from buildings in 2017 [5]. Building energy codes set standards for the construction of buildings with better energy performance and are a proven method for reducing building energy consumption [5]. In India, urbanization has led to an expansion in towns and cities

and a rise in the populations of urban regions. In India, where there are 121 million people, 37.7% reside in urban areas, and this percentage is steadily increasing [6]. Urban population growth necessitates more structures for people to live, work, and engage in, leading to more facilities and a predicted increase in electricity demand [7]. India is the fourth largest energy consumer after China, the USA, and Russia. The building sector contributes to about 33% of the total energy produced in the country, with 24% being consumed by residential buildings in the building sector in the [7]. In addition, electricity demand is predicted to rise by five-fold by 2032 and by more than eight times by 2050 [6]. India's urban population is expected to increase to 590 million by 2030, up from 290 million in 2001 and 378 million in 2011 [8]. In 2017, 275 million households were anticipated to exist in India, and this number is expected to rise to 328 and 386 million in 2027 and 2037, respectively. The residential sector's floor area is expected to increase from 15.3 billion square meters in 2017 to 21.9 billion square meters in 2027 [9]. The building industry contributed 8.04% of India's GDP in the period of 2014–2015; by 2025, it is predicted to increase to 16.74% [10]. By 2030, it is anticipated that the total floor space of buildings will expand by approximately 400% and that 20 billion square meters will be added to the built environment [11]. However, the lack of energy efficiency measures and the insufficiency of construction details offer considerable potential for energy savings in terms of both demand and consumption. India must create energy-efficient strategies centered on the residential sector to stop the rising energy demand. Building and construction have significant direct and indirect environmental implications. These services use resources such as energy, water, and other supplies, and they generate waste and emissions during pre- and post-construction, renovation, and demolition. Building standards and codes, certification systems, policies, and green rating systems have been developed and implemented worldwide to minimize environmental impacts through sustainable design [12]. The creation of more sustainable urban development patterns offers a possible resolution for the significant problems experienced in metropolitan areas worldwide. Since the Brundtland Commission's publication of "Our Common Future" in 1987, sustainability and sustainable development have become more commonly connected with cities [13].

Additionally, experts contend that by focusing on urban sustainability, humanity may substantially impact the creation of a more sustainable globe [14,15]. Many rating systems have been developed and applied worldwide to encourage sustainable development. For example, India has sought to improve energy efficiency through mandatory building codes, standards, and voluntary rating programs for buildings and products. With limited resources, sustainable development assists in determining a suitable answer to many issues, such as through physical, cultural, environmental, and economic advancements. Because it is built using local resources and methods with little waste, vernacular architecture reflects the core of sustainability. Culture and its importance in the local and regional terrain are reflected in vernacular architecture. Sustainability improves quality of life by integrating three significant aspects: the environment and the social and economic features of any built environment; thus, it has become a part of both tangible and intangible cultural identities [16]. The tremendous range of climates, topographies, and cultures around the world influences vernacular architecture. Environments, building techniques, uses of materials, and cultural translations in a given region have influenced how vernacular buildings have changed over time. Understanding and using characteristics from traditional vernacular architecture in new structures can have benefits. Vernacular architecture has always been a method of building locally in response to a region's culture, society, and microclimate. With the advent of better equipment and the expertise of local craftspeople, it has progressed. Vernacular architecture is not static; it responds to changing cultures and environments. It is native to its region and contributes to a community's and the environment's long-term viability. Vernacular architecture needs to be analyzed in terms of the changing attitudes toward the built environment [17–20]. Brunskill suggested a classification system for vernacular structures based on their intended use. Domestic arrangements, such as private residences, rest houses, and leisure houses, are designed for

living purposes [21]. Traditional design concepts focus on the function, energy efficiency, human comfort, aesthetics, and economic feasibility of a space, all while considering and adapting to the local environment and culture [22].

3. Sustainability, Indicators, and Assessment Methods

The Brundtland Commission, formerly known as the World Commission on the Environment and Development (WCED), initially introduced the idea of sustainable development in 1987 as part of the report titled "Our Common Future" [13]. Sustainable development was defined in this report as "development that satisfies current demands without compromising the ability of future generations to satisfy their own needs" [13]. In terms of social sustainability, culture occasionally represents a component or dimension. The WCCD report "Our Creative Diversity" was produced because of discussions about the interplay between culture and development that took place during the UNESCO Decade of Culture and Development (1988–1997) [23]. While the social indicator is a well-established component of the concept of sustainable development [13], there is ongoing discussion regarding the need to include a fourth component, the cultural dimension [24–26]. According to Hawkes, while presenting the case for culture as the fourth pillar of sustainability, the researchers contended that cultural vitality is just as crucial to sustainable development as social equality, and they compared cultural diversity to biodiversity [27].

3.1. Understanding Social and Cultural Sustainability

The term social defines human society, the interactions of individuals and groups, or the welfare of human beings as community members [28]. Social sustainability was initially introduced as a part of the concept of sustainable development in the Brundtland Report [13]. Social sustainability was defined during the 1992 Rio Conference as the right to a decent living, inter- or intragenerational community, worldwide social justice, and local engagement in sustainable development processes. Bostrom and Davidson argued that any endeavor to establish socially sustainable societies must first define the "type of society... we want to sustain" [29,30]. Jabareen connected urban planning and design principles, including compactness, mixed use, density, sustainable transportation, and greening, with results in terms of social sustainability [31]. Physical characteristics related to sustainability were listed by Dempsey et al. and are fundamental and quantitative, making them easy to assess for effective planning [32].

Similarly, culture is defined as the set of shared attitudes, values, goals, and practices that characterize an institution or organization and the characteristic features of everyday existence shared by people in a place or time [33]. Cultural sustainability is a developmental approach that preserves all cultural assets, including minority languages, traditional practices, artworks, artifacts, and historic structures and sites [34]. The literature on cultural indicators can be traced at least as far back as the early 1970s [35], as sources of income and employment, including at the local level, cultural infrastructure, cultural and creative industries, sustainable cultural tourism, and cultural heritage all contribute to inclusive economic growth. Hence, it helps improve living conditions, foster community-based economic growth, and empower individuals [34]. Culture is what makes us who we are and forms our identities. There can be no long-term progress without culture. The U.N. General Assembly adopted the "2030 Agenda for Sustainable Development" in September 2015, and they included 17 bold, universal goals for transforming our world [34]. Most of the Sustainable Development Goals (SDGs) recognize the role of culture, including those focusing on quality education, sustainable cities, the environment, economic growth, sustainable consumption and production patterns, peaceful and inclusive societies, gender equality, and food security, according to UNESCO [34].

According to the Brundtland Report and Agenda 21, urban nature has grown for social, cultural, and environmental reasons [13]. Culture, as an ensemble of real vectors of social life, comprises a natural dimension. This dimension must be resurrected to strengthen and make culture's role in sustainable development more tangible [36]. Socially sustainable

communities are equitable, diversified, interconnected, and democratic, promoting a high quality of life. Chiu has also focused on social sustainability and presented it from three interrelated perspectives: development-oriented, environmental, and people-oriented perspectives [37]. Additionally, Oliver and Rapoport demonstrated that tangible and intangible markers are integral for the development of both conventional and vernacular construction and must be considered from a regional and socio-cultural perspective [11,12].

3.2. Codes, Guidelines, and Rating Systems

This section draws attention to Indian policies, codes, and green building rating systems. The broad formulation, implementation, administration, and oversight of the numerous housing and urban development programs are committed to the Ministry of Housing and Urban Affairs. The Constitution (Seventy-fourth) Amendment Act of 1992 granted several responsibilities to urban local authorities because urban development is a state matter [38]. However, through central and centrally sponsored schemes, the government of India supports numerous urban housing projects, urban livelihood missions, and overall urban development, in addition to coordinating and overseeing them. Through proper policy directives, subsidiary legislation, and sectoral programs, the ministry enables the resolution of numerous challenges pertaining to the urban sector for housing and energy.

The government of India initiated the very first effort for energy conservation with the introduction of the Energy Conservation Act, which was published in the Gazette of India in October 2001. The Bureau of Energy Efficiency (BEE) was instituted in 2002 to implement the E.C. Act. Further, the government of India launched the first version of the Energy Conservation Building Code in 2007. The E.C. Act was amended in 2010, with a further update of the ECBC in 2017, which was restricted to commercial buildings. Recent developments, such as a revision in the National Building Code (2016), model building by-laws (2016), and ECBC -R (Eco Niwas Samhita 2018 for the residential sector), have been set to potentially and substantially increase the overall impact on energy savings at the city-level. The importance of energy and its effects on buildings have been recognized and addressed in fundamental building norms and green building certifications. These have been integral for central and state policies, and they apply to almost all buildings.

Green building rating systems assess and measure a structure's environmental performance. Buildings in India are currently rated using three green grading systems. The Green Grading for Integrated Habitat Assessment (GRIHA) has been acknowledged as India's national rating system for finished development projects by the Ministry of New and Renewable Energy (MNRE), the government of India, and TERI. It is a tool for evaluating and rating the environmental performance of a building [39]. Another rating system that is a voluntary, consensus-based initiative is the Indian Green Building Code (IGBC). This rating system would make possible energy-efficient, water-efficient, healthy, more productive, and environmentally friendly factories [40]. An internationally recognized benchmark for designing, erecting, and maintaining high-performance green buildings is the Leadership in Energy and Environmental Design (LEED-INDIA) green building rating system [41]. An in-depth study was performed to understand the overview of these rating systems in terms of categories, weightage, compliance, renewal, and certification and to comprehend the presence of environment, economic, and social indicators.

Figure 2 showcases the current policy outlook for housing and energy in India.

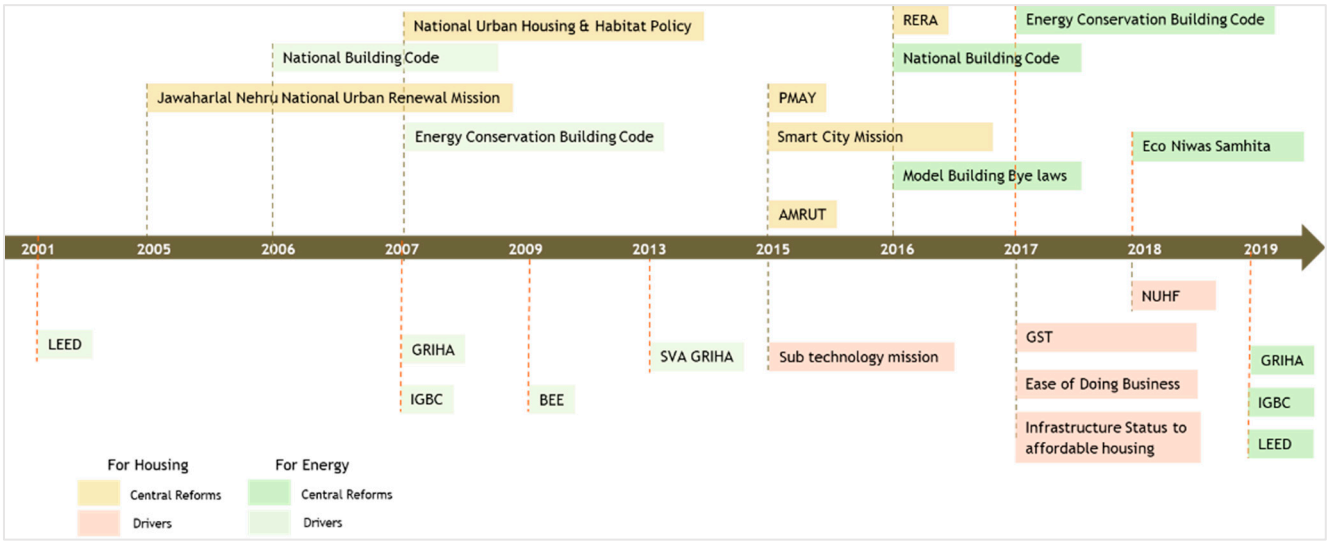

Figure 2. Policy outlook for housing and energy in India.

3.3. Inferences

After an in-depth study of the parameters of Indian green building assessment methods and social and cultural sustainability, we could infer the presence and possibility of identifying tangible and intangible aspects. All of the required information about these indicators was collected by using explanatory documents and their portals. The rating systems are directed towards economic and environmental factors, with a handful of social indicators. Detailed studies of policies, scholarly databases, and reports are required to understand the intangible aspects and their practical applications. In her study, Piparsania highlighted how social and cultural aspects are integrated into existing systems, and that it is viable to identify, understand, and implement these social and cultural indicators for a better sustainable approach [42]. To develop the required social and cultural indicators, we must comprehend how they are developed over time and how they have proceeded with the best possible indicators suited to our scenario. Table 1 presents the indicators extracted during the literature review for each aspect.

Table 1. List of indicators from secondary research.

Indicator	Indicator from Literature	Indicators from Green Building Rating System
Social	Senior Citizen and Child Care, Resident Wellbeing, Transportation, Neighborhood Development, Local Materials, Universal Design, Accessibility, Signage, Safety, Awareness, Proximity to Services and Amenities, Privacy and Safety Measures, Disability Needs, Satisfaction Level	Education and Awareness, Surrounding Density and Diverse Uses, Neighborhood Development, Facility for Physical Wellbeing, Visual Comfort, Universal Accessibility, Positive Social Impact
Cultural	Regional Priority, Cultural Forms and Local Practices, Cultural Diversity, Architecture and Identity, Interconnectedness, Inter-Regional Impact, Quality of Life, Dwelling Functionality, Visuals and Aesthetics, Cultural Spaces, Hierarchy of Space, Adaptability, Cultural Relevance	Regional Priority

Table 1. *Cont.*

Indicator	Indicator from Literature	Indicators from Green Building Rating System
Environmental	Waste Management: Construction and Solid Waste, Hazard Prevention, Recyclable Materials, Green Areas and Vegetation, Use of Locally Available Materials and Technology, Renewable Energy	Site and Topography, Water Management, Energy Efficiency, Air Quality, Renewable Energy, Rainwater Management, Waste Management, Alternate Materials, Construction Management
Economic	Affordability and Durability, Policy and Regulations, Optimization Of Energy and Operations, Local Building Regulations, Economic Viability	Energy Monitoring, Life Cycle Costing, Operation, and Maintenance Protocol, Performance Metering

4. Methodology

4.1. Research Plan

The research plan had five major phases, which are showcased in Figure 3. The first phase of the study started with a context analysis, which included the formulation and find the research gap. The second step involved secondary research based on the current context, in-depth studies on sustainability, housing, energy policies, standards, green building rating systems, and an understanding of social and cultural indicators. The third step comprised the primary research, involving in-depth interviews for a pilot study, requirement prioritization, a user study as part of survey research for occupants, and an understanding of their views about integrating socio-cultural indicators in housing. The final phase led to the development of a holistic and balanced framework for sustainable design assessment. These research phases are linked with the research question, and Table 2 shows how they were approached via design methods.

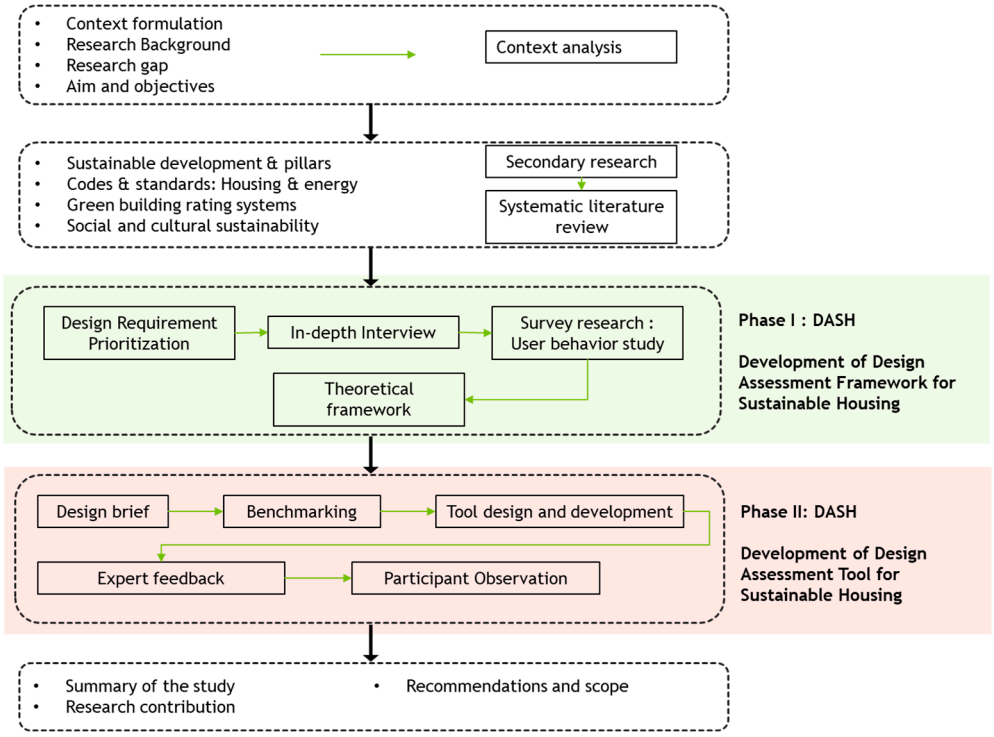

Figure 3. Research methodology for DASH.

Table 2. Stages of research and their methodologies.

Stage	Research Question	Design Method	Research Methodology
Preamble		Context Analysis	Establishing the context and background for research. Identification of the relevant gap, reach, aim, and objectives with the help of the existing literature in journal publications, reports, books, and other relevant published sources.
Literature Review	What are the indicators for social and cultural aspects of housing?	Secondary Research: Systematic Literature Review	Secondary data were reviewed through a systematic literature review on the areas of sustainability and the three pillars, the global and Indian context of sustainable development, housing, the social and cultural aspects of housing, green building rating systems in developed and developing countries, building standards and codes, housing and energy policies, and related concepts. Mendeley was used to manage citations and references throughout the research.
	Which social and cultural indicators are more relatable?		
	How do these socio-cultural indicators connect with the built environment?		
	Which sustainable design assessment tools are available in developed and developing countries and how have they integrated socio-cultural indicators?		
	How can we incorporate socio-cultural aspects into green building assessment methods for housing?		
Phase I: Development of the design assessment framework for sustainable housing	What are occupants' perceptions of the integration of socio-cultural indicators in housing?	Design Requirement Prioritization	The main goal here was to prioritize the inclusion of social and cultural indicators. Identifying the key categories influencing the sustainability of residential buildings, establishing the priority weight for dimensions and categories, and integrating social and cultural dimensions with the environmental and economic dimensions in building sustainability assessment. Incorporating occupants' needs and their perceptions of sustainability and its indicators.
		In-depth Interviews	A pilot study was conducted at the initial stages to understand the questionnaire's scope, the users' behavioral responses, and their understanding. An open-ended comprehensive interview was conducted, and a discovery-oriented method was used to obtain detailed information about a topic from the occupant. The goal was to explore in depth the respondent's point of view, experiences, and perspectives. The duration of each call/interview was approximately around 30–45 min.
	How can we involve occupants and their participation in sustainable design assessment?	Survey research: User behavior study	Residents' and occupants' requirements were collected with the help of a structured questionnaire based on a survey method. The data were analyzed using graphs and statistical analysis was conducted to observe significant correlations among identified variables. The data collected were formulated and analyzed using the SPSS 20.0 statistical software. A total of 133 participants responded and contributed their views to the study.

Table 2. *Cont.*

Stage	Research Question	Design Method	Research Methodology
	How can we develop a holistic and balanced framework for sustainable design assessment?	Theoretical framework	A theoretical framework was developed by focusing on the identified variables and defining the specific viewpoints formulated from the user behavior study and from secondary data.

The data collection and analysis segment were further divided into three major phases, as shown in Figure 4. These three phases consisted of conducting a pilot study and revising the questionnaire, data collection and analysis, and the development of the framework. In the data analysis part, with the help of the SPSS 20.0 statistical software, we conducted a correlation test. The Spearman correlation is a nonparametric measure of the strength and direction of an association that exists between two variables that are measured on at least an ordinal scale—in this case, these were tangible and intangible indicators [43]. The resultant values for Spearman's correlation after conducting the test ranged from 0.0 to 1.0, and their interpretations were as follows: $0.0 \leq \rho \leq 0.2$—very weak agreement/correlation, $0.2 \leq \rho \leq 0.4$—weak agreement/correlation, $0.4 \leq \rho \leq 0.6$—moderate agreement/correlation, $0.6 \leq \rho \leq 0.8$—strong agreement/correlation, and $0.8 \leq \rho \leq 1.0$—very strong agreement/correlation [43].

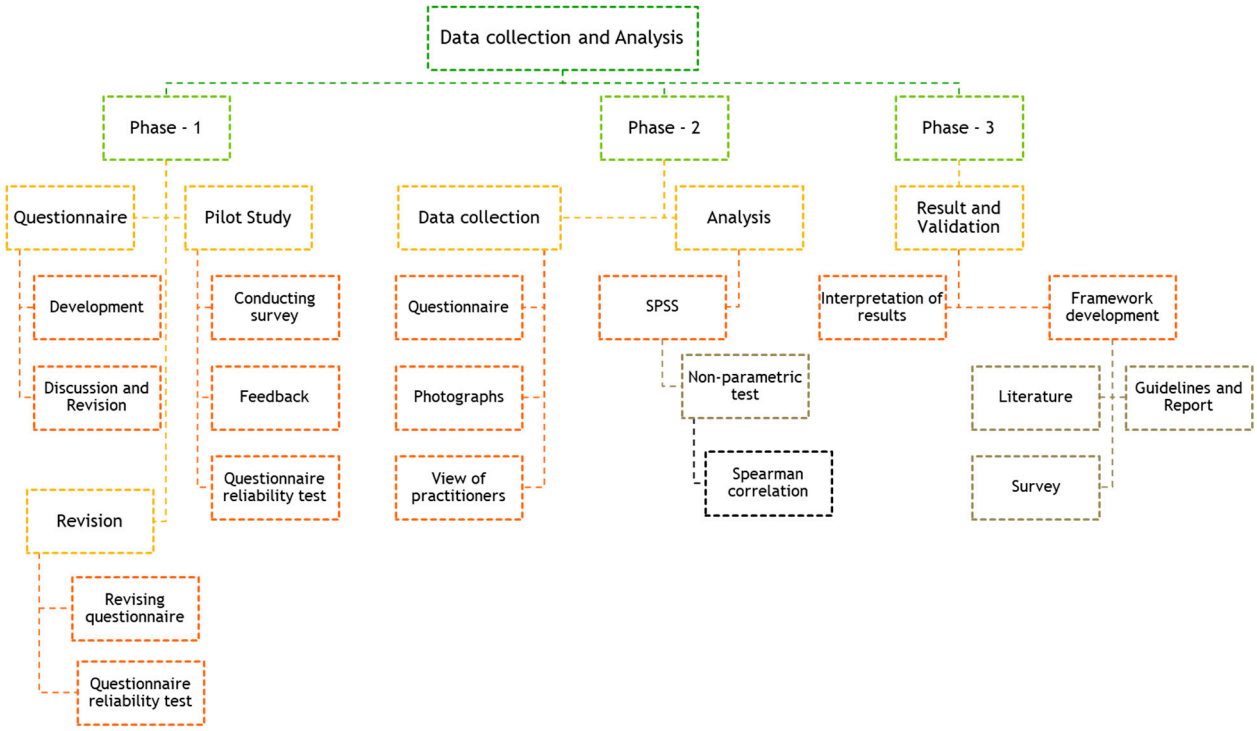

Figure 4. Framework for data collection and analysis.

4.2. Data Collection

Planning and Questionnaire

The requirement was set to find and validate social and cultural indicators. The survey-based data collection was divided into two major parts: a pilot run for validating the questionnaire and a check of its reliability. The data collection process utilized a set of open-ended and semi-structured inquiries. The occupants were also asked to rate their views on selected indicators by using a Likert scale. The document also had the option of uploading images of the house in question for better understanding. The second phase dealt with the collection of data through a survey. Initially, the data collection was a field-

based study that consisted of in-depth interviews and ethnographic research. However, due to the pandemic situation and the circumstances of the wave of COVID-19 in India, the data were gathered using Google Forms. The questionnaire was circulated online through personal emails and other social media platforms, and the nature of the interview changed to audio and video calls. The data collection process utilized a set of structured inquiries during the survey. The occupants were also asked to rate their views on selected indicators by using a Likert scale. As the research had to represent broader cases to provide more insight into the socio-cultural dimension, the studies that were selected represented both modern and vernacular housing development approaches.

A pilot study was conducted initially to understand the questionnaire's scope, the occupants' responses, and their understanding. The pilot study was conducted with a limited set of people from different cities in India. The set of questions, type of option selection method, and a small part of the collection of demographic data were revised based on the respondents' feedback, and a revised questionnaire was prepared. The questionnaire framework is shown in Figure 5. Before conducting the survey, the questionnaire was verified with a reliability test by using Cronbach's alpha in SPSS. An alpha value reaching the subjective value of 0.70 represents an adequate measure of reliability [44]. The output of the resulting value received was 0.736 in this case.

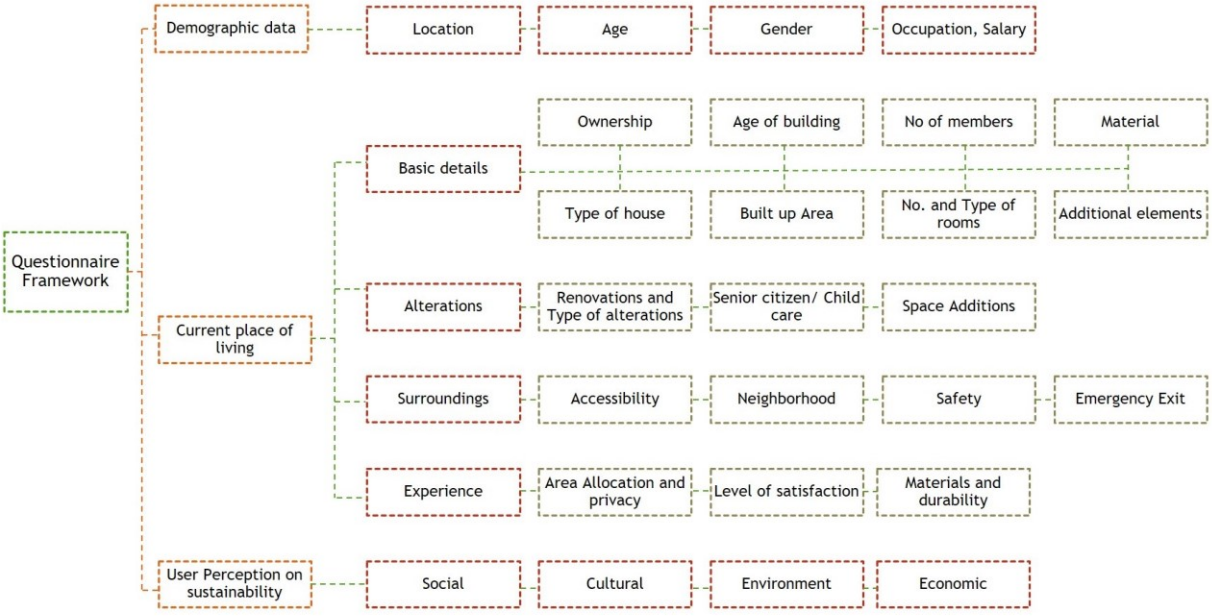

Figure 5. Framework for the design of the questionnaire design.

4.3. Protocols and Other Measures

The process utilized a set of open-ended and semi-structured inquiries during the data collection. Ethical consent was obtained from all of the participants in cases in which voices and videos were recorded or any other data were collected before the interview or data collection. Before filling out the questionnaire, the respondents were informed in detail of the survey's intent and objectives. The participation of the respondents in this study was voluntary.

The survey form contained a set of questions with a group of options from which to choose. The document also allowed upload images of houses to be uploaded for a better understanding. All participants were informed of the inclusion and exclusion criteria beforehand: they had to be current residents of India, be over the age of 18, and have any gender, employment area, or economic background. It was alright if they did not want to disclose their gender type, employment, or any personal information.

4.4. Data Analysis

The study was conducted with a limited set of participants from different cities in India. A total of 133 residents participated in the survey. All of the data were analyzed by using multiple graphs and charts. A list of tangible and intangible indicators related to existing and sustainable housing scenarios was shared for this analysis. The indicators were expressed to the occupants in informal statements and were not directly presented. The context of this study is specific to India.

The following graphs in Figures 6–17 depict the nature of data collected and the responses. These graphical data are related to the demographics and current housing of the occupants.

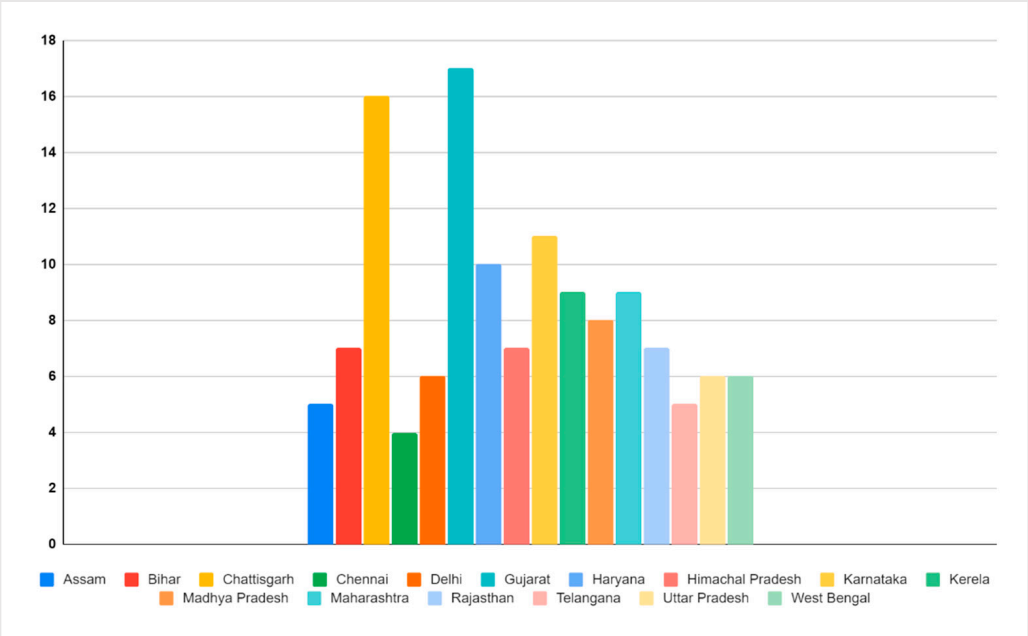

Figure 6. Survey outcomes on location of the occupants.

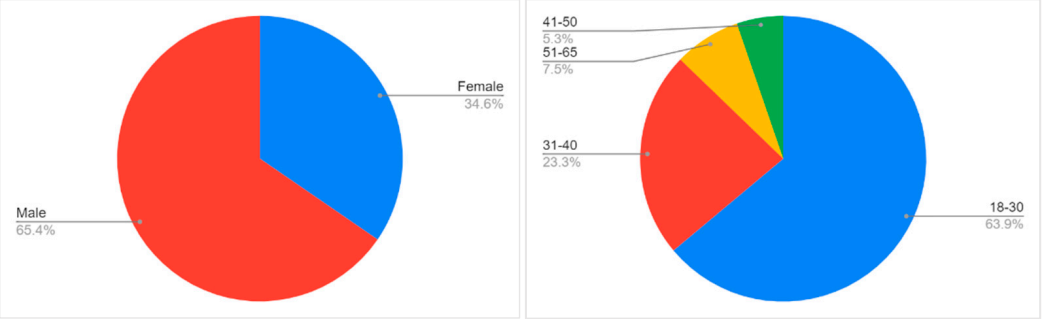

Figure 7. Survey outcomes on the gender and age range of the occupants.

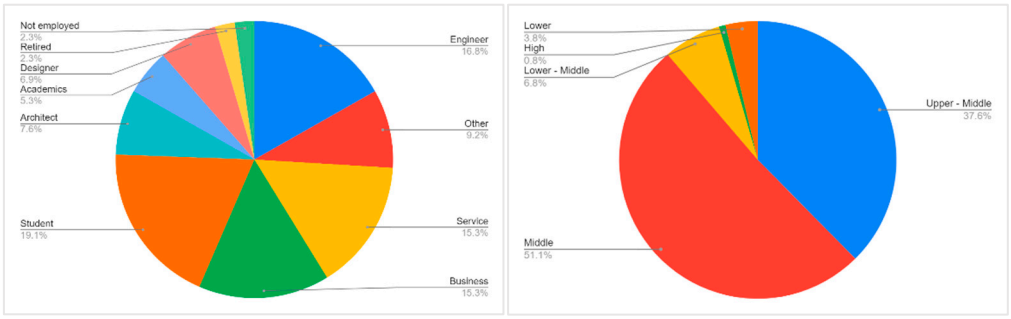

Figure 8. Survey outcomes on the occupation type and income group of the occupants.

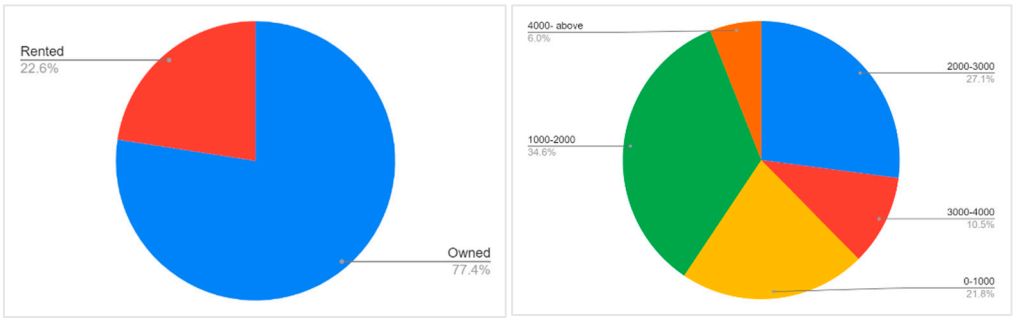

Figure 9. Survey outcomes on the type of ownership and built-up area of the houses.

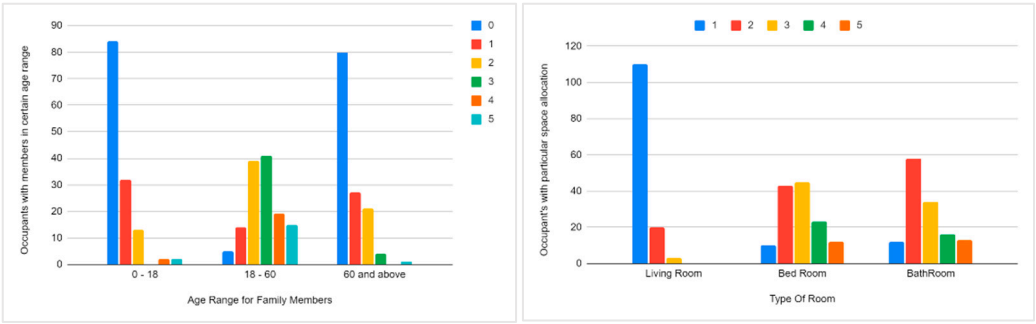

Figure 10. Survey outcomes on the number of family members and types of rooms in occupants' houses.

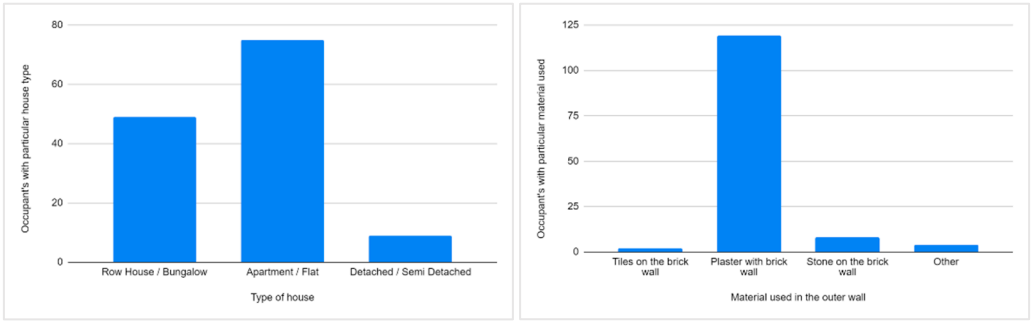

Figure 11. Survey outcomes on the type of house and material used in the outer walls.

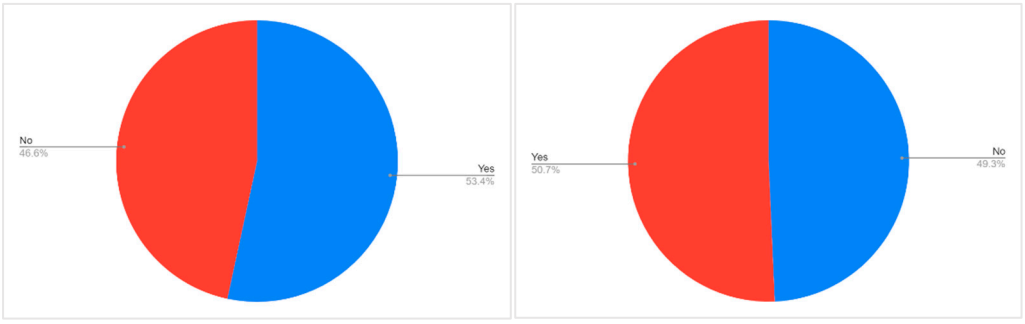

Figure 12. Survey outcomes on preferences for renovation and provision of additional space.

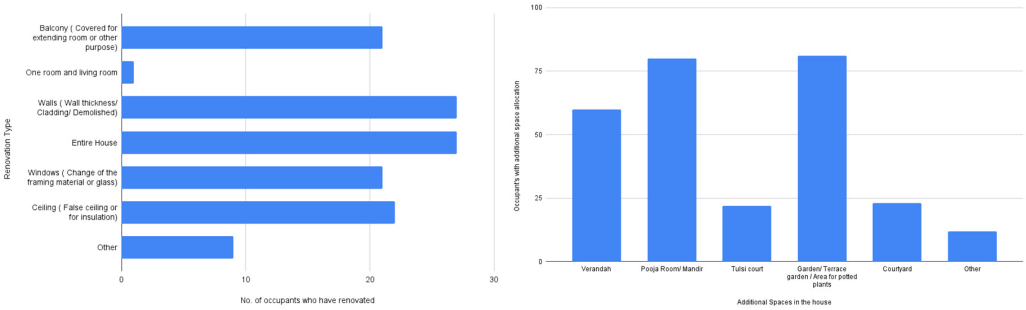

Figure 13. Survey outcomes on renovation types and types of additional spaces.

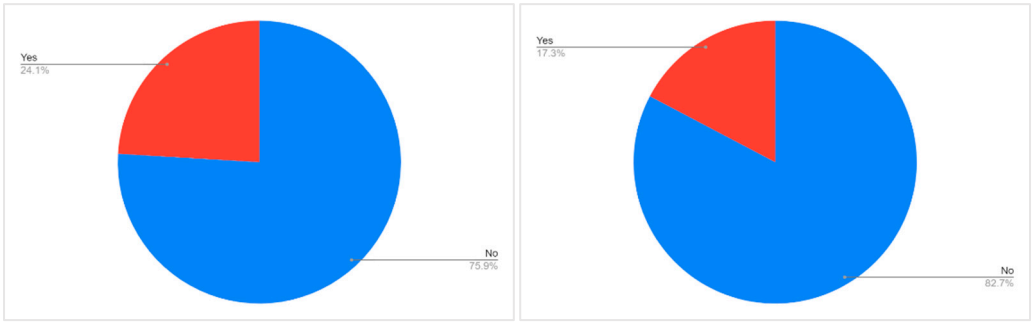

Figure 14. Survey outcomes on alterations made for children/senior citizens and discomfort faced in daily activities.

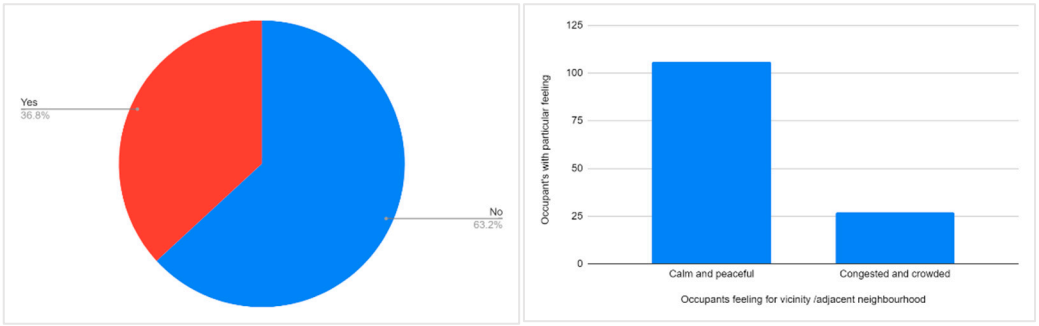

Figure 15. Survey outcomes on provision of emergency exits and feelings regarding vicinity.

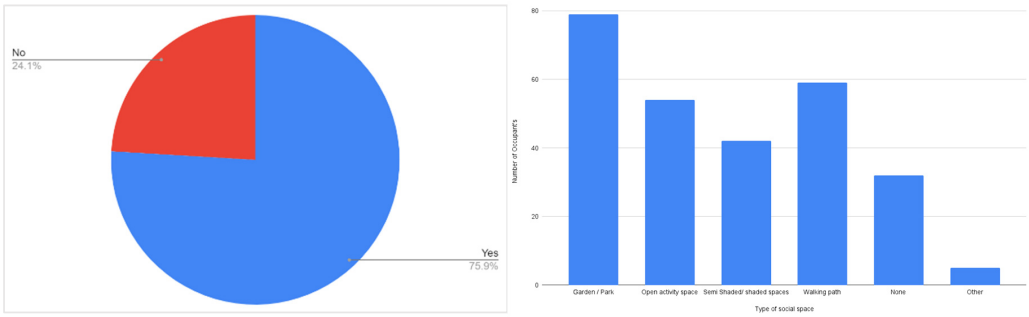

Figure 16. Survey outcomes on provision of social space and type of social space.

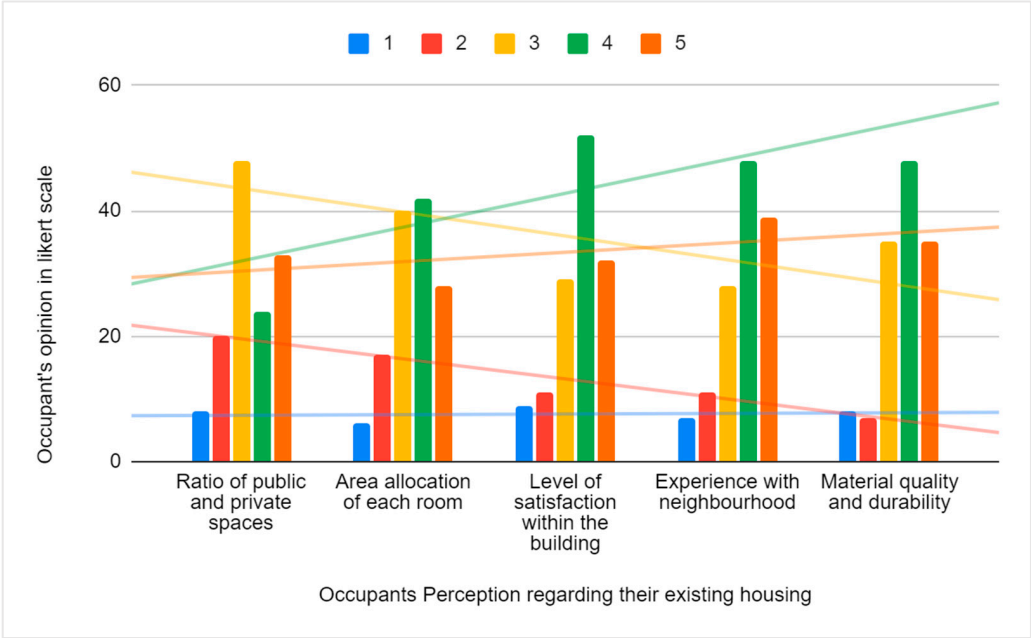

Figure 17. Survey outcomes on occupants' perceptions of the existing housing scenario.

The data analysis was directed by a survey analysis in the form of graphical charts, which were further analyzed with the SPSS statistical software. The survey analysis allowed the interpretation of the raw data as insightful information. After the review, the indicators were re-analyzed, and the selected indicators were brought forward to understand their correlations.

Using the SPSS software, data were categorized into variables, and the values were coded [43]. A common technique for connecting survey questionnaires or Likert-type survey responses is Spearman's rho.

The results from the Spearman correlation test displayed in Figure 18 show the connections between all of the variables; moderate, solid, and powerful connections are shown, and they are color-coded with yellow, blue, and green. This test further established the correlations among all variables. Apart from two categories (continuity in building style for a community and locally available materials and technology), which were linked with only seven variables and others that were linked with 12, the others can be seen to be linked with at least 16, which exceeds 19 categories for nine variables.

Particulars	Locally available materials and technology	Continuity in building style for a community	Visual privacy to principal areas of house	Maintaining hierarchy of spaces	Flexibility to customize/renovate the house	Abide to compliance	Common meeting areas or interactive spaces	Reflection of cultural values and beliefs	Architectural connect with local identity	Ease of accessibility to spaces	Special Provision	Less operational and maintenance cost	Provision for safety and security	Ample daylight and ventilation	Low Noise Transmission	Provision for rain water harvesting	Affordable management practices	Renewable energy source/ passive design	Sharing ideas about sustainability	Proximity to local services and transportation
Use of locally available materials and technology during construction	1.000	0.541	0.506	0.364	0.342	0.413	0.457	0.405	0.392	0.413	0.304	0.395	0.403	0.366	0.393	0.364	0.403	0.509	0.553	0.445
Continuity in building style for a community	0.541	1.000	0.497	0.441	0.353	0.366	0.383	0.338	0.271	0.358	0.332	0.416	0.379	0.335	0.329	0.430	0.337	0.363	0.406	0.330
Visual privacy to principal areas of house	0.506	0.497	1.000	0.466	0.536	0.576	0.517	0.462	0.449	0.538	0.364	0.480	0.521	0.502	0.584	0.491	0.515	0.526	0.522	0.586
Maintaining hierarchy of spaces	0.364	0.441	0.466	1.000	0.439	0.512	0.515	0.377	0.432	0.489	0.459	0.403	0.489	0.474	0.479	0.430	0.419	0.351	0.348	0.527
Flexibility to customize/renovate the house	0.342	0.353	0.536	0.439	1.000	0.766	0.518	0.572	0.548	0.674	0.639	0.593	0.659	0.582	0.623	0.592	0.582	0.617	0.566	0.739
Abide to compliance	0.413	0.366	0.576	0.512	0.766	1.000	0.687	0.632	0.554	0.667	0.624	0.579	0.602	0.589	0.700	0.631	0.618	0.628	0.557	0.700
Common meeting areas or interactive spaces within premises	0.457	0.383	0.517	0.515	0.518	0.687	1.000	0.567	0.522	0.567	0.508	0.473	0.523	0.591	0.620	0.553	0.524	0.641	0.569	0.591
Reflection of cultural values and beliefs	0.405	0.338	0.462	0.377	0.572	0.632	0.567	1.000	0.636	0.613	0.469	0.499	0.453	0.471	0.575	0.484	0.478	0.537	0.518	0.592
Architectural connect with local identity	0.392	0.271	0.449	0.432	0.548	0.554	0.522	0.636	1.000	0.643	0.506	0.525	0.431	0.422	0.578	0.584	0.513	0.613	0.581	0.654
Ease of accessibility to spaces	0.413	0.358	0.538	0.489	0.674	0.667	0.567	0.613	0.643	1.000	0.626	0.657	0.696	0.582	0.649	0.662	0.628	0.636	0.643	0.727
Special Provision	0.304	0.332	0.364	0.459	0.639	0.624	0.508	0.469	0.506	0.626	1.000	0.672	0.547	0.609	0.499	0.504	0.569	0.441	0.392	0.594
Less operational and maintenance cost	0.395	0.416	0.480	0.403	0.593	0.579	0.473	0.499	0.525	0.657	0.672	1.000	0.728	0.614	0.713	0.627	0.657	0.572	0.482	0.663
Provision for safety and security	0.403	0.379	0.521	0.489	0.659	0.602	0.523	0.453	0.431	0.696	0.547	0.728	1.000	0.726	0.702	0.615	0.697	0.566	0.530	0.678
Ample daylight and ventilation	0.366	0.335	0.502	0.474	0.582	0.589	0.591	0.471	0.422	0.582	0.609	0.614	0.726	1.000	0.693	0.494	0.721	0.489	0.406	0.627
Low Noise Transmission	0.393	0.329	0.584	0.479	0.623	0.700	0.620	0.575	0.578	0.649	0.499	0.713	0.702	0.693	1.000	0.626	0.694	0.618	0.547	0.698
Provision for rain water harvesting	0.364	0.430	0.491	0.430	0.592	0.631	0.553	0.484	0.584	0.662	0.504	0.627	0.615	0.494	0.626	1.000	0.641	0.787	0.715	0.691
Affordable management practices	0.403	0.337	0.515	0.419	0.582	0.618	0.524	0.478	0.513	0.628	0.569	0.657	0.697	0.721	0.694	0.641	1.000	0.640	0.571	0.669
Provision to add a renewable energy source/ passive design measure	0.509	0.363	0.526	0.351	0.617	0.628	0.641	0.537	0.613	0.636	0.441	0.572	0.566	0.489	0.618	0.787	0.640	1.000	0.802	0.685
Sharing ideas about sustainability	0.553	0.406	0.522	0.348	0.566	0.557	0.569	0.518	0.581	0.643	0.392	0.482	0.530	0.406	0.547	0.715	0.571	0.802	1.000	0.635
Proximity to local services and transportation	0.445	0.330	0.586	0.527	0.739	0.700	0.591	0.592	0.654	0.727	0.594	0.663	0.678	0.627	0.698	0.691	0.669	0.685	0.635	1.000

Figure 18. Spearman correlation test.

We established indicators denoting sustainable design's social and cultural aspects through a study of the literature. After the data analysis, we were able to validate the relations between these indicators. Figure 19 shows the final list of indicators considered for the study to develop the framework.

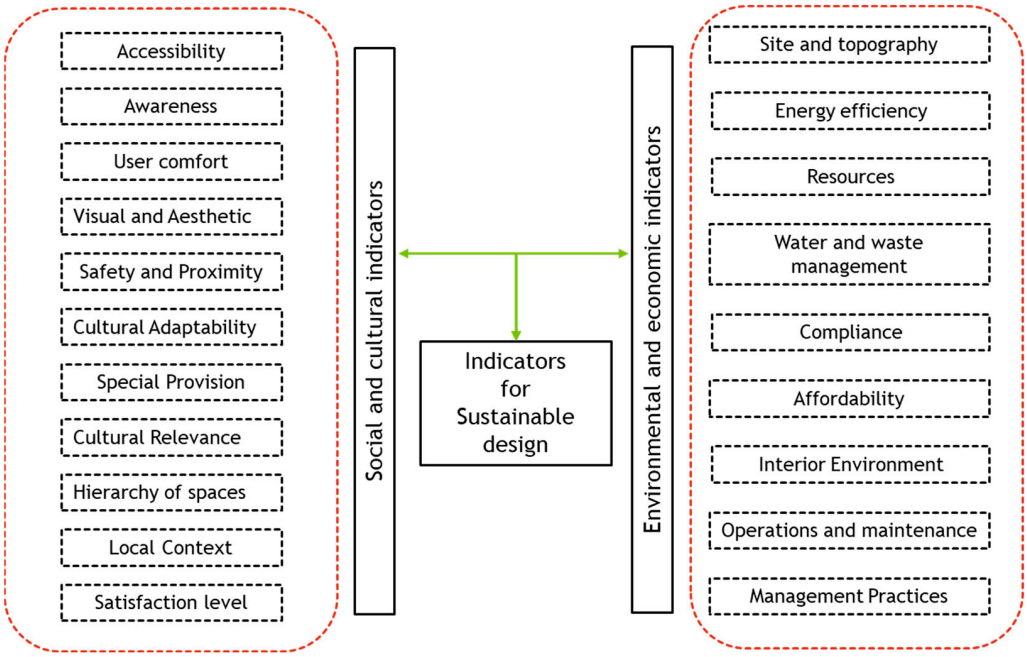

Figure 19. List of indicators that were considered for the study.

5. Discussion

This study shows how the scope of sustainability indicators differs from that of the existing rating methods and frameworks. This difference could be primarily due to residents' perceptions or inclinations towards more social and cultural aspects. Another reason for the change in the scope of indicators could be a lack of awareness among occupants. In addition, occupants' responses also explain another indicator in addition to those identified in the existing literature and frameworks.

Sustainability is a vital part of both intangible and tangible resources. Socio-cultural factors are merely proposed rather than explicitly stated in most standards. However, a building's architectural characteristics alone do not place it in its proper setting. Home design should embody social, aesthetic, and environmental ideas and incorporate all necessary elements to create an indoor atmosphere that would suit an individual's or a group's lifestyle. According to Dohr, Portillo, Oliver, and Rapport, physical and intangible indicators are crucial for a regional and sustainable approach, since they are intertwined in the creation of contemporary and vernacular architecture [11,12]. According to Abel, vernacular architecture excels at blending structures into different contexts to create a natural synergy with the climate, architecture, and individuals [45]. Sustainable architecture is defined as architecture that is based on natural principles and environmental values and performs to meet local needs and socio-cultural systems [46]. Subic's desktop review examined how many vernacular architectural examples and themes (such as culture, society, economy, environment, resources, and practices) relate to one another [47]. The evaluation techniques used for green buildings all seem to favor quantitative measures of energy, environmental, and resource use.

The framework comprises the three pillars of sustainability with a fourth dimension of culture. The framework developed here represents practice-related components of socio-culturally sustainable building, as shown in Figure 20. The variables were derived from an existing database that includes green building certifications, policies, and other guidelines. There are not many references to the socio-cultural aspect of sustainability in these documents, so this study discussed these indicators through the existing literature from UNESCO and other researchers.

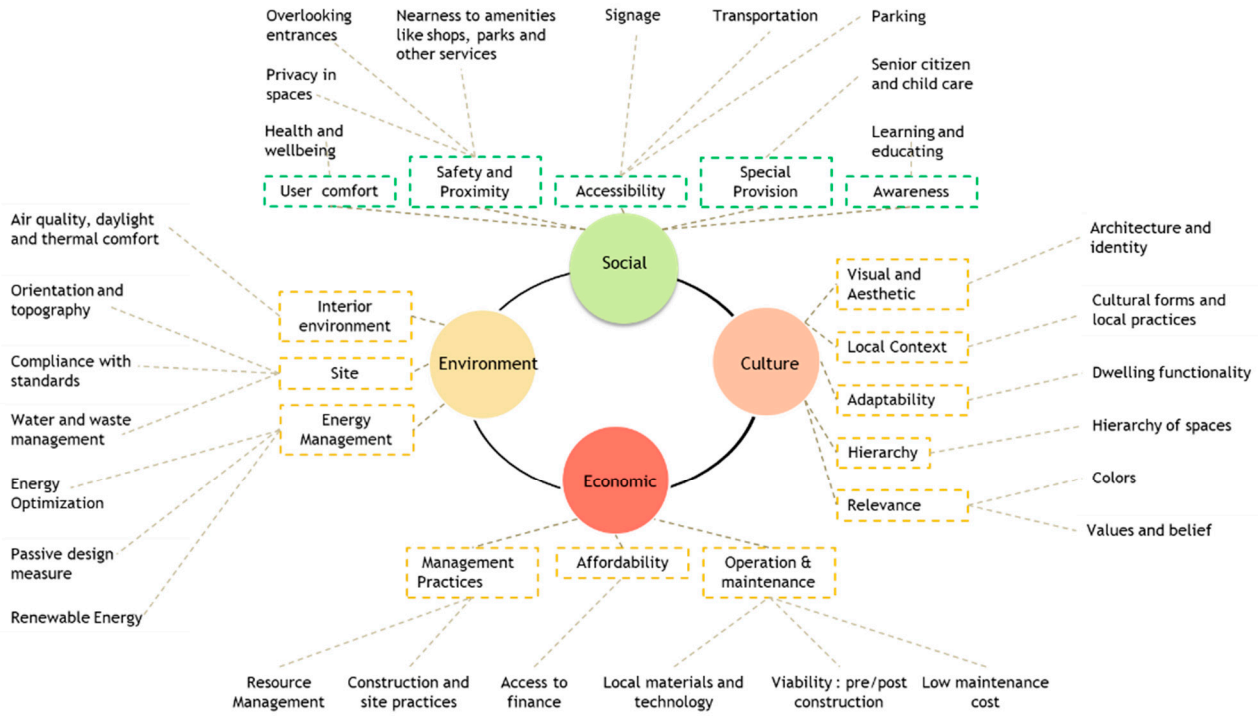

Figure 20. Development of DASH: Design assessment framework for sustainable housing.

The framework above showcases the social, environmental, economic, and cultural indicators and interpretations from this study that helped in the development of the framework in a summarized form. This study was intended to create a socio-cultural framework for housing based on a rational collection of complementary physical and intangible variables. The social and cultural indicators of the primary research were supported by the collection of secondary data, which also portrayed that existing sustainability frameworks, policies, evaluation tools, and guidelines lack socio-cultural elements and the integration thereof. This study suggests a practical and implementable framework that can be merged into an existing evaluation tool or standard code.

The dotted lines that connect categories to the main headings directly influence each other. The categories were derived based on the respondents' perceptions of sustainability with respect to residential dwellings and their relationships. This framework attempts to integrate tangible and intangible aspects by combining their values with that of the built environment. This framework will be further translated in order to propose a new sustainable design assessment system for residential buildings. It will also help deliver enhanced regional and area-driven sustainable developments in locations with similar backgrounds.

6. Conclusions

The foundation of this study was based on the concept of sustainability suggested by Brundtland Commission, which is based on three pillars: environmental, economic, and social. The study's first objective was to focus on socio-cultural sustainability—integrating culture as an extension of social sustainability or considering culture as the fourth pillar. Figure 21 was developed while keeping this objective in mind and by integrating culture with social sustainability. The framework adheres to Brundtland's concept of sustainability and further contributes to the simplification of the framework for easy application.

Figure 21. DASH: Revised framework.

This research seeks to create a holistic approach to sustainable development by suggesting a more balanced framework. The framework is based on a defined set of tangible and intangible indicators that were established based on primary research findings and are supported by the existing literature. It was found in this study that most existing sustainability frameworks, assessment tools, and guides do not adequately consider the social and cultural aspects or occupants' needs.

To examine occupants' and residents' perceptions and suggest indications for a holistic, sustainable strategy, this study interviewed people currently residing in India and collected data from them with a survey. It was also discovered that most frameworks for evaluating the sustainability of the built environment strongly emphasize economic and environmental factors. Due to their irrational nature, social and cultural indicators are rarely included in assessment methods. Due to their elusiveness and complexity, socio-cultural parameters have not been understood. This work fills this void by suggesting intangible social and cultural elements that can be efficiently and successfully included in existing green building assessment tools, guidelines, and standards. As a result, it provides a substantial theoretical and practical contribution.

The paper outlines discussions with participants on translating socio-cultural markers into environmental and physical parameters. The findings will be tested and validated when the framework is further translated into a tool. The process will translate intangible factors into quantifiable criteria, which can later be applied to any Indian green building system or used by experts in design and planning. This study can be concluded with the following takeaways points:

- It was noted that residents' feedback might be more effectively incorporated into existing assessment techniques with a positive impact on satisfaction. Assuming that residents' needs and requirements are considered, in a scenario regarding waste management, the waste of building materials due to alterations and renovations should be reduced. Considering this, residents will be cautious in using materials and in their management, and this could help increase the sustainability of residential projects through awareness, cost cutting, and optimal use of supplies.
- This study demonstrates that housing residents consider socio-cultural design based on a coherent knowledge of interconnected indicators that emphasize a residential home's significance and confirm the value of the occupant's involvement in the design process.
- This research fills knowledge gaps by demonstrating how intangible socio-cultural indicators and tangible design standards relate to one another and how they can be incorporated into frameworks for evaluating sustainable buildings.
- This study deals with concerns that aid in both the academic and practical implementation of sustainable design assessments for the understanding and reflection of socio-cultural indicators. This study illustrates that sustainable housing includes the socio-cultural values of its residents.
- This study supports a process for identifying, evaluating, and incorporating sustainability indicators related to socio-cultural sustainability into the building evaluation process.
- This study shows that residents can participate in the development of sustainability goals and the selection of the primary metrics and indicators used for evaluation.

This study can be used by scholars, researchers, and professionals in the development of similar frameworks for different contexts. In addition, it can be used as a foundation for developing a tool or translating the framework into any suitable application format. In future studies, the sample size can be increased to include more residents/occupants across the country in order to achieve diversified results and for the data to be more reliable and valid. Ethnographic research can be carried out to obtain more in-depth insights. This study combined a set of tangible and intangible indicators that provide value to sustainability requirements of the built environment. This study can be used to recommend a new sustainability approach for housing, a roadmap for a holistic approach, and a set of indicators. These indicators can be used to form an assessment method for new housing

development projects. In similar circumstances, it can also promote regional and socio-cultural improvements. This study can be considered when developing similar framework for other states and countries.

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