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Change in Adaptability of Residential Architecture: Spatial Analysis on Traditional and Contemporary Houses of Bangladesh

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ABSTRACT

This study focused on spatial analysis to identify the changes in adaptability over the last five decades. The features influencing adaptability were selected from the reference study. An appropriate method was used to analyse these features through spatial analysis. Six distinctive typologies of rural houses were selected from six regions. Unlike the traditional houses, the contemporary houses in the same area reflected a different character. Urban houses built since the early and mid-20th century were compared with contemporary houses. After analysing the openness, generality, flexibility, depth, typicality, construction technique, involvement of end-users, and the feedback from the inhabitants, the study identified a significant decrease in contemporary houses' adaptability. Spatial analysis was used to quantify the different features and comparison between traditional and contemporary houses. Though the adaptability had been reduced over time, the latest houses started to achieve better flexibility in some features due to government policy and implementation of statutory building regulations. Further recommendations were provided to enhance the residential architecture's adaptability in future. The study samples were selected from different regions of Bangladesh. Still, the result and policy recommendations can be helpful for other countries, especially with high population density and a developing economy.

1. Introduction

Adaptive architecture can respond to the changing environment, the needs of the inhabitants, and function. Though any building can be modified according to the changing need, the ease of the process and user interaction are essential. Transformable surfaces, modular design, spatial features, and building technology can enhance adaptability^[1]. Socio-cultural impact and

economic condition can influence the acceptance of adaptive architecture to the end-user. Since the initial cost is comparatively higher for adaptable buildings, it is essential to evaluate the long-run benefits of making it feasible for developing countries. An adaptable building's life cycle is significantly longer than the standard residential developments, making it economical in the long term^[2,3]. Moreover, the multifunctional use of spaces, spatial optimisation, and coping with dynamic conditions

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will benefit the high-density cities of developing countries^[4]. Several experimental designs on adaptable architecture reveal that the same space can accommodate different users^[2,5]. In a study conducted by Architect Le Corbusier, a different setup of the same space has been proposed for daytime and nighttime use to accommodate the temporal change in need. The homogenous character of different rooms can enhance adaptability, as we can see in Traditional Japanese garden houses. The homogenous character of space can enhance plurality in use, where we cannot afford transformable building components.

The framework of adaptive architecture consists of drivers, elements of adaptation, methods, and strategies^[1]. Change of function, capacity, or flow of an existing building drives the need to modify the existing organisation of the space. In addition to the climatic influence and site forces, the needs and values of the inhabitants shape the architecture. As a development strategy, it is necessary to keep the undetermined character of the spaces during design and construction to accommodate the users' needs over time. This character of soft use of the spaces is more prominent in the vernacular houses^[6]. On the other hand, the architects define urban houses' spatial organisation, where the end-user is often absent during the development phase. The user's scope of personalised interpretation of space has been accommodated in some housing projects by architect Alejandro Aravena, constructing only half of the house at the initial stage^[7]. This strategy ensured user participation through the later stages of development and made it financially viable. Some other aspects identified from terraced houses in London are transformable to contemporary houses: larger space, simplified construction technique, typical plan, and design for adaptability^[6]. The simplified construction technique and the typical plan are also evident in the vernacular houses of Bangladesh. Urban areas need to accommodate multiple floors in a building and have structural challenges to achieve with simplified construction techniques. We can overcome this challenge using developed technology to enhance the simplified transformation of spaces in later phases by the user with limited skill related to building technology.

The study on the adaptability of residential architecture should incorporate its evolution, typology, and morphology. Researchers around the globe have adopted different criteria to study housing typologies. Physical attributes such as layout, density, degree of privacy, built area ratio, and structural system define some typologies^[8]. In some other studies, social class, ownership type, and historical chronology are considered criteria to define typologies^[9,10]. Historical chronology divided the building

types into different categories according to timeline and style.

This study covered samples from different typologies according to physical, historical and social attributes. Six categories of vernacular rural house samples covered all broad categories traditionally developed in Bangladesh. Early urban houses were recorded with necessary drawings and the spatial features identified with the scientific method. This study can contribute as a reference document and very few other research on architectural detail of traditional houses in Bangladesh. The methodology used in this study developed from in-depth literature studies and examples around the world. Though the method is applied on selective samples from Bangladesh only, this structure can accommodate samples from other places.

Adaptive capabilities are the practical solution to the accommodation problem in the large metropolis, especially in developing countries with limited resources and capacities. However, adaptive architecture is not a new concept in residential architecture, as it has been widely practised in vernacular architecture. The lessons learned from them could eventually be adopted in the current architectural practice. This research aimed to determine the changing trends in the adaptive capacity of residential architecture. Therefore, the research objectives were to identify the relationship between adaptability and spatial parameters, conduct spatial analysis on adaptive characters, compare the adaptive characters of traditional and contemporary residential architecture, evaluate users' experiences and suggestions, and finally provide some recommendations on improving the adaptive capacities of the residential building.

1.1 Traditional Urban Residential Architecture

The evolution of urban residential architecture in Bangladesh can be distinguished into four periodical phases: (i) early urban dwellings in the 17th and 18th century, (ii) planned residential areas in the mid-20th century, (iii) walk-up apartments during post-independence and (iv) contemporary developer-built high-rise apartments^[11]. These phases were also renamed based on their political contexts: (i) pre-colonial, (ii) colonial, (iii) pre-liberation and (iv) post-liberation architecture^[12]. In the 17th and 18th centuries, the early urban dwellings followed a similar spatial layout and joint-family structure as the rural households, with three-court houses in relatively compact space. The outer court, a semi-public space, served as the entry court and was only shared by guests and male members. The inner court was rather more private and restricted to the female members and

close family members. The third court accommodated toilets and kitchen and acted as the service court, which was shared predominantly by the servants and non-family members^[11]. In old Dhaka, shophouses with multi-courts could be found where the outer courtyard entertained domestic industries such as manufacturing and storing handicraft products^[12,13]. Later in the mid-20th century, the urban middle-class generation had influenced the local government to initiate planned residential areas by allotting inexpensive plots for formal and gated single-family houses. Front courts were transformed into front lawns, and long corridors and dining spaces substituted the inner courts. Besides, the ancillary services such as toilets and kitchens were placed more attached to the house. After the independence, the transformation from joint-family to nuclear family and the demand for housing expansion resulted in separate gated houses on the same plot for the next generations and rentable walk-up apartments (up to four-storied) for additional income, abolishing the courts^[11]. The condensed interior arrangement with smaller rooms and utilising dining space to connect the surrounding rooms provided the urban residents more affordability^[12]. However, earlier low-rise residential buildings are being demolished in the contemporary period. Due to inflated land prices and the limited scope of horizontal expansions, the residents prefer the high-rise apartment complexes built by the developers. As a result, common spaces are shared by multiple families, unlike previous single-family residences.

1.2 Traditional Rural Residential Architecture

Several physical and social determinants characterise the diversified traditional rural settlements in Bangladesh. The physical determinants include geophysical location, land formation, climate, construction materials, and technology. On the other hand, religion, indigenous characters, defence, and cultural factors are the prime social determinants responsible for the evolution of the rural settlements^[14,15] classified the rural settlements of Bangladesh into six typologies according to geophysical characteristics - (i) nucleated, and clustered settlements of northern Piedmont and the Barind regions, (ii) scattered settlements in the central delta region, (iii) linear settlements along the dying river in the moribund delta, (iv) dispersed and isolated settlements in the coastal areas and offshore islands, (v) very sparse and linear in the Eastern hilly region and (vi) high-density settlements in the haor basin (Islam, 2003). The hot and dry climate has geographically influenced the traditional architecture of the Barind region. The houses are mostly built of thick earthen walls to provide insulation and elongated shading

devices^[16]. The outer walls often have no opening; as a result, they develop an introverted character. The whole household is kept very dense and compact. Similar compact planning can be found in the haor basin due to the scarcity of elevated lands.

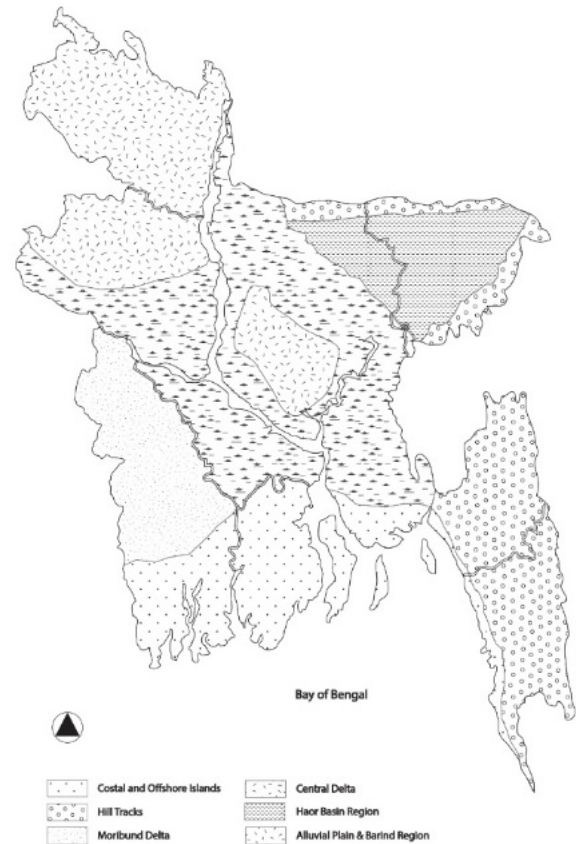


Figure 1. Diversity of rural settlements in the different geophysical regions of Bangladesh (Modified by the author from^[15]).

Unlike Barind tract's mud houses, the haor basin's settlements are constructed with lightweight and perishable materials to withstand heavy rainfall. Diversity of materials and construction systems can also be found in central flood-plain where the dwellers prefer temporary materials and make-shift houses due to decaying during seasonal floods and river erosion. The sand bars and shoals there make it more difficult to establish permanent settlements without embankments. However, a more permanent structure is present in the moribund region due to the inactive delta formation. Settlements are planned there along the bank of the dying river in a linear order. Dispersed settlements are typical in coastal areas to encounter high wind exposure. Cyclone and tropical surges impact the built-forms and their orientation. The protective verandah, locally called 'pashchati', is a unique feature of coastal houses. On the other hand,

hilly settlements carry special architectural features. Their houses are built on elevated platforms to defend wild animals and strength from landslides and runoff. Their settlements are developed very sparsely nearby the freshwater sources. Instead of a traditional courtyard, every house uses a raised platform for harvesting and an additional flat surface. Their houses are richly affected by indigenous characters and their cultural factors.

2. Materials and Methods

2.1 Selection of Sample

The researchers initially selected several rural vernacular house-forms from six different geophysical regions of Bangladesh and four types of traditional urban house-forms. Later, a substantial number (nearly 70) of contemporary residences were selected and thoroughly surveyed. While selecting the contemporary residences, the researchers followed a balance according to the location and size of the floor area. Selected samples were located in four different socio-cultural and regional contexts: core urban areas, semi-urban areas, small townships, and rural areas. The size of the samples was categorised according to three general types: small (below 100m²), average (100m² to 180m²), and large (above 180m²). Irrespective of location and size, the researchers also balanced the ratio of professionally-built houses and DIY (do it yourself) houses for the diversity of the samples.

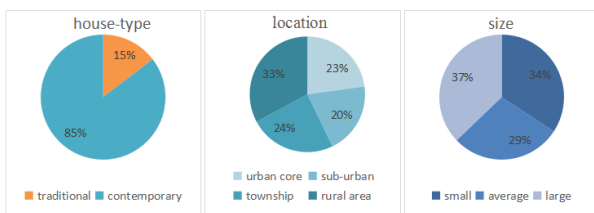


Figure 2. The ratio of samples according to house type, location, and size.

2.2 Data Collection

For the spatial analysis, the floor plan of selected houses was mostly recorded through physical and desktop surveys conducted during 2020-2021. The rest were collected directly from the professionals or the end-users. The documented floor plans were later analysed for spatial analysis. A questionnaire survey was also conducted to collect data on the variables related to current practice and adaptability, such as construction technique, involvement of end-user, and user experience.

2.3 Spatial Analysis

Spatial configurations such as degree of privacy, openness, generality and flexibility, functional sequence, and depth of space are closely related to adaptability. Therefore, our research is initially based on comparing these spatial configurations of traditional and contemporary houses and later identifying the changing trends using qualitative and quantitative measures. Space syntax is a widely used method for advanced spatial analysis in multidisciplinary fields, ranging from housing, retail environments, transport, and urban design to even human psychology, behaviour studies, sociology, criminology, and disaster mitigation^[17,18]. Our research adopted this method as a supplementary tool for analysing spatial configurations in residential dwellings.

2.3.1 Degree of Privacy and Openness

Adaptability is inversely related to privacy. More private spaces are more rigid and thought to be less adaptive as they can not afford spatial alteration or modification without interrupting privacy. Semi-private and semi-public spaces are relatively more adaptable to an alternative use. Unlike privacy, the openness of a space is proportional to adaptability. In traditional houses, outdoors and semi-outdoors were more adaptable as indoor spaces could only accommodate more specific functions. The data on the degree of privacy and openness were prepared through visual analysis of the floor plan. They were later represented in a colour mapping. The plan analysis identified the ratio and changing characters between traditional and contemporary characters using a bar chart.

2.3.2 Generality and Flexibility

Generality is a property synonymous with universality, polyvalency or plurality^[19,20]. The potential capacity to use a space for multiple purposes is termed generality. A singular space is restricted to a specific function only, whereas a general space can accommodate more inter-related activities, adding more adaptability, diversity, and flexibility. Similarly, flexibility is a characteristic that allows alterations and modifications within a space^[20,21]. Flexible spaces are adaptable to any potential change in activities without interrupting the core functions. To collect data on generality and flexibility, the researchers prepared an extensive activity chart and studied the activities through functional sequential diagrams. The activity chart segregated the activities according to generality, flexibility, privacy, and openness. Later the generality and flexibility between the traditional and

contemporary houses were spatially and graphically compared.

2.3.3 Depth Map

The relation between adaptability and the depth of space is rather indirect. A shallow plan is considered less complex and has more simplified connectivity. Shallow spaces can accommodate more generalised and shared functions. On the contrary, deep spaces are often singular and monovalent as they are primarily designed for specific and private activities. Therefore, more depth of space can reduce the generality, thus diminishing the adaptability. Less depth of space is counted as more adaptable. Depth of space was measured through node analysis with convex mapping and justified graph. Convex spaces are visually barrier-free sub-spaces within a room where any straight line connecting two points does not intersect its perimeter^[20]. Convex spaces in residence are generally connected through a doorway or an opening. Convex mapping displays the typicality and shape of the space, whereas a justified graph only shows connectivity. The justified graphs consist of nodes and lines. The nodes and the line respectively denote the convex spaces and connectivity. Justified graphs were produced using AGRAPH software, a spatial tool developed by Manum, Rusten, and Benze (2005) and Manum, Rusten (2009) for analysing nodes and connectivity^[22,23].

2.3.4 Typicality

Simplicity and similarities in floor plan, room size, shape, and connectivity are referred to as typicality. A uniform structural grid, convex space, and open floor plan can also accelerate the typicality of a space. Typicality is opposite to uniqueness, according to Rem Koolhaas, as typical architecture has no specificity^[6]. It is easily adaptable because its activities could easily be replaced or altered with another typical room. Typical rooms are economical and easily constructible. A simple convex mapping and visual analysis of the plans of different house types was conducted in terms of size, shape, opening, and overall configuration to identify the rooms with similar spatial attributes.

2.4 Survey and Non-spatial Methods

The information on socio-cultural aspects of residential developments was recorded from the survey. There are many factors that cannot be directly identified from the visual features of the house. For example, the construction technique can be identified, but the residents' level of knowledge on that technology is collected through a

questionnaire survey. The survey also identified the involvement of the end-users at the construction time. Their reflection on the usability and adaptability of the house is recorded here.

2.4.1 Construction Technique and Adaptability

Construction technique has a significant impact on adaptability since it can limit the user's scope of modification or expansion of space in later stages^[6]. 'Hard technology' adopted by the engineers and architects during construction time is the main reason. Though it does not mean the advanced construction techniques are always 'Hard technology'. Modular design, prefabricated building elements, and modifiable components can significantly enhance the house's adaptability^[3]. Surface, module, spatial features and technical systems support the adaptation process^[1]. These issues have been analysed in selected samples of traditional and contemporary houses. The adaptability of the traditional houses was possible with simple construction techniques. With the change in need and context, taller residential buildings became necessary to fulfil the housing demand. Though it is not possible to use the same simple techniques in most contemporary buildings, transformative building components can ensure the adaptability of contemporary residential apartments^[24].

Construction technique, use of local materials identified from the physical survey and literary evidence recorded to define the level of adaptability of different study samples (Figure 3). Some contemporary rural houses are still using traditional materials and construction techniques. However, urban house construction has changed drastically in recent years. So we could not collect the construction photos of the traditional urban house, but we acquired some idea from the literature study and physical evidence from surveying the old buildings. Many rural houses also use modern construction materials and advanced techniques these days. The existence of traditional and contemporary rural houses in the same compound is presented in the bottom left picture of Figure 3. Urban multistoried building construction was surveyed to record the highly used construction technology of the present time.

2.4.2 Involvement of End-user

Tenants of the houses are not always involved during the development phase of the building. Especially in contemporary houses, many of the tenants buy ready apartments according to their needs. Involvement of the inhabitants is a significant issue to enhance houses'



Figure 3. Change in construction technique of traditional and contemporary house

adaptability ^[1,2]. Architects can keep an opportunity for future inhabitants to further develop the houses in later stages to accommodate their changing needs with time. It is not about a perfect design at the beginning but creating a framework for an efficient layout to guide the development over time that allows the further contribution of the users. Social housing in Chile, designed by architect Alejandro Aravena provided half of the house constructed initially and the rest of the spaces to be developed by the user at the later stage ^[7].

In the selected contemporary house samples, the participants responded to their involvement during the design and construction of the time. The questions regarding the rented, bought, or personally developed house reflected the involvement of the end-users during the development process. Some participants also reflected their views in the open-ended questions regarding the scope of involvement in this process. We also identified the houses designed by professionals and found a significant number of houses actually designed by the owners themselves. They also answered the question regarding knowledge and personal skill on construction techniques used in their own house.

2.4.3 User Feedback

One hundred sixty-seven residents responded to the questionnaire survey regarding the adaptability of their own house. We tried to collect responses from male and female users to get a complete picture. The samples were divided into three types according to the size of the

residential unit: up to 800 square feet categorised as the small unit and above 1800 square feet unit size classified as the large unit. The rest of the units are considered mid-sized residences. In the survey, one-third of the participants were female, and small residential units were fewer (Figure 4).

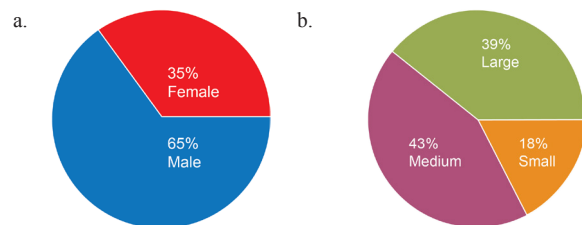


Figure 4. Ratio of female and male participants (a), the ratio of small, medium and large size units owned by the participants (b)

We have conducted the survey during the pandemic lockdown period to compare the use pattern of different rooms in normal situations and pandemics. Due to the lockdown situation, the same space was used for additional functions like home office and online education. This situation helped the inhabitants to evaluate the possibility of using the space for alternative use. They identified the spaces with high adaptability, where they could perform new types of activities that were not necessary for regular situations. The participants also identified the spaces where the activity pattern was not changed due to lack of adaptability and dedicated functional use of the particular space. They also reflected on the existing volume of different spaces and possible changes in the scale of those

spaces to improve the adaptability of the house. It helped us determine the priority of end-users.

3. Results

3.1 Spatial Analysis

In this section, we have analysed the study samples in terms of spatial quality. Selected residential house types from six rural areas and three traditional urban house types were analysed in the first step to get a comparative idea on the degree of openness, multifunctional use of different spaces and simplicity of the house plan in terms of spatial configuration and connectivity. In the 2nd stage, contemporary houses from 4 different settings were analysed with the same method. The types used here are rural, small town, fringe area of city, and core city. 4 typical samples were selected from 70 selected samples within these four categories and presented in the analysis stage.

3.1.1 Change of Privacy and Openness

Openness and degree of privacy followed a changing trend in traditional and contemporary houses. Figure 5 shows that openness was prominent in traditional rural and urban dwellings, particularly hill tract houses. In those houses, openness was provided by courtyards, backyards, lawns, gardens, ponds, etc. Indoor spaces were limited to 20% in most traditional rural houses except in the Barind tract, where the compact arrangement due to climatic considerations resulted in nearly 30% indoors. The ratio of indoor spaces had a surging trend in most traditional urban dwellings. Moreover, semi-outdoor spaces have traditionally featured in the Barind tract, haor basin, and coastal houses to a greater extent and existed in the hill tracts and from early to post-independence urban houses to a lesser extent. These spatial arrangements enhanced adaptability in the traditional dwellings.

On the other hand, openness is outrageously neglected in contemporary dwellings due to the densification of house plans and forms (Figure 6). Consequently, the degree of privacy was gradually rising as dwellers preferred invisible partitions and separate rooms for adolescents and children. Semi-private and semi-public spaces in residential buildings, such as prayer rooms, family temples, study rooms, restrooms, verandah, etc., were dominantly placed into more private zones. Smaller outdoor spaces like open balconies, terraces, and roof gardens substantially replaced the larger outdoor areas such as courtyards, lawns, and gardens. Due to strict building codes in metropolitan urban areas, at least

25% of outdoor and percolated green space has been provided recently, albeit mostly in peripheral or non-usable areas. The near-extinction of semi-outdoor spaces in contemporary houses was one of the most significant changes found. As a result, adaptability was significantly reduced in contemporary dwellings.

3.1.2 Changes in General and Flexible Spaces

The activity chart in Figure 7 clearly showed that the number of indoor activities had surged immensely in contemporary houses. Most outdoor and semi-outdoor activities in traditional dwellings were later occurring indoors in recent houses. In traditional houses, the courtyards were the most generic space. Multiple social (recreational activities, festivals, and social gatherings), economic (harvesting, animal farming, gardening, etc.), and domestic (cooking, bathing, drying, etc.) activities took place. These activities in the courtyards could also be altered or transformed according to the user's preference and temporal, diurnal, and seasonal changes. Therefore, they also had more flexible characters. Besides, the semi-outdoor verandah was another polyvalent space that accommodated numerous formal and informal activities such as meetings, family gatherings, dining, resting, studying, cooking, craft-making, etc. Sleeping and storing were the only notable specific activities that were held indoors. Lately, in contemporary houses, most formal and domestic activities such as meetings, dining, cooking, bathing, etc., were held indoors instead. The neighbourhood streets in the small towns and rural areas and the rooftop terraces in the urban and semi-urban regions became the only place for social gatherings. The indoor spaces in the urban and semi-urban apartments were more specific, except the dining spaces that could be conditionally and occasionally considered the only generic space there. As a result, those contemporary apartments were deficient in flexibility and generality than their traditional counterparts.

3.1.3 Transformation of Connectivity and Depth

The justified graphs in the depth analysis (Figure 8) found that the mean step depth in traditional houses was relatively lower than in contemporary apartments. Mean depth had been moderate and limited to 4-5 steps in the rural houses except in the Barind tract and haor basin because of their consolidated and compact house plan. Besides, the internal rings or bypass connectivity, instead of corridor-type connectivity, could be found in the rural houses of Barind, haor, coastal and hilly regions. In most rural houses, courtyards were the most accessible

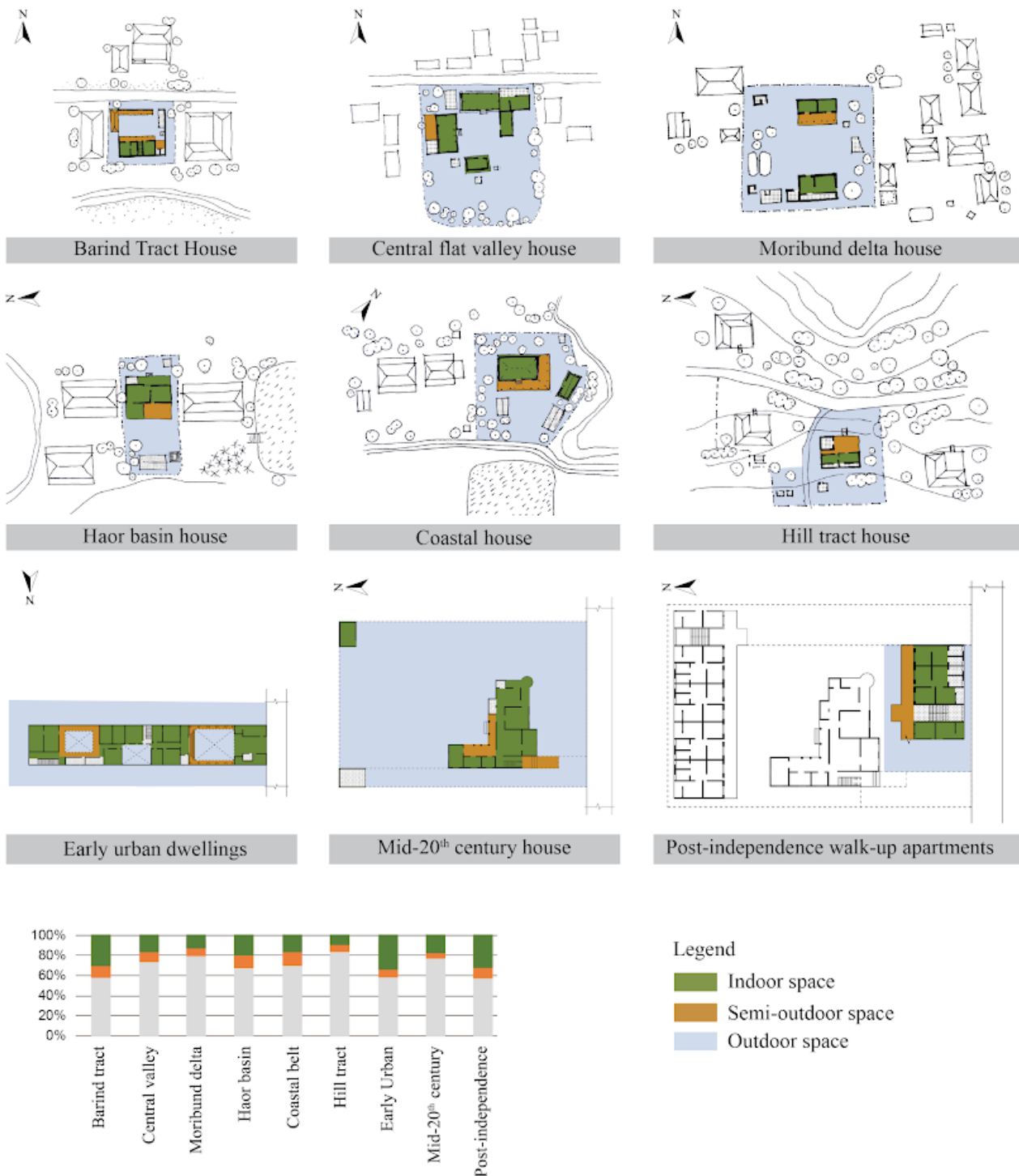


Figure 5. The ratio of openness in traditional rural and urban houses (Urban house plans modified by author from ^[11,12]).

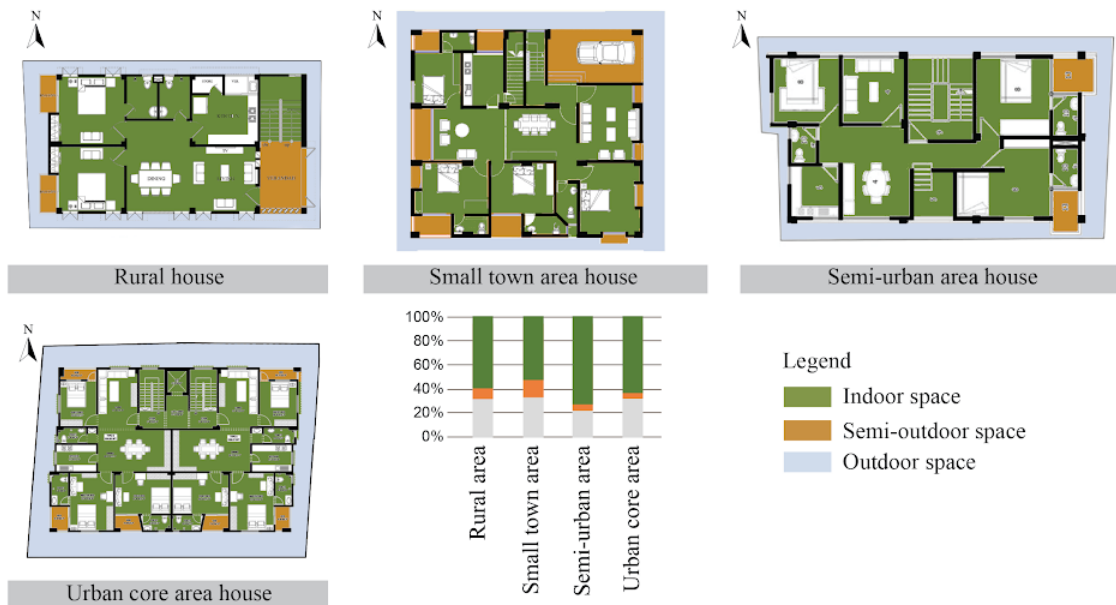


Figure 6. The ratio of openness in contemporary houses.

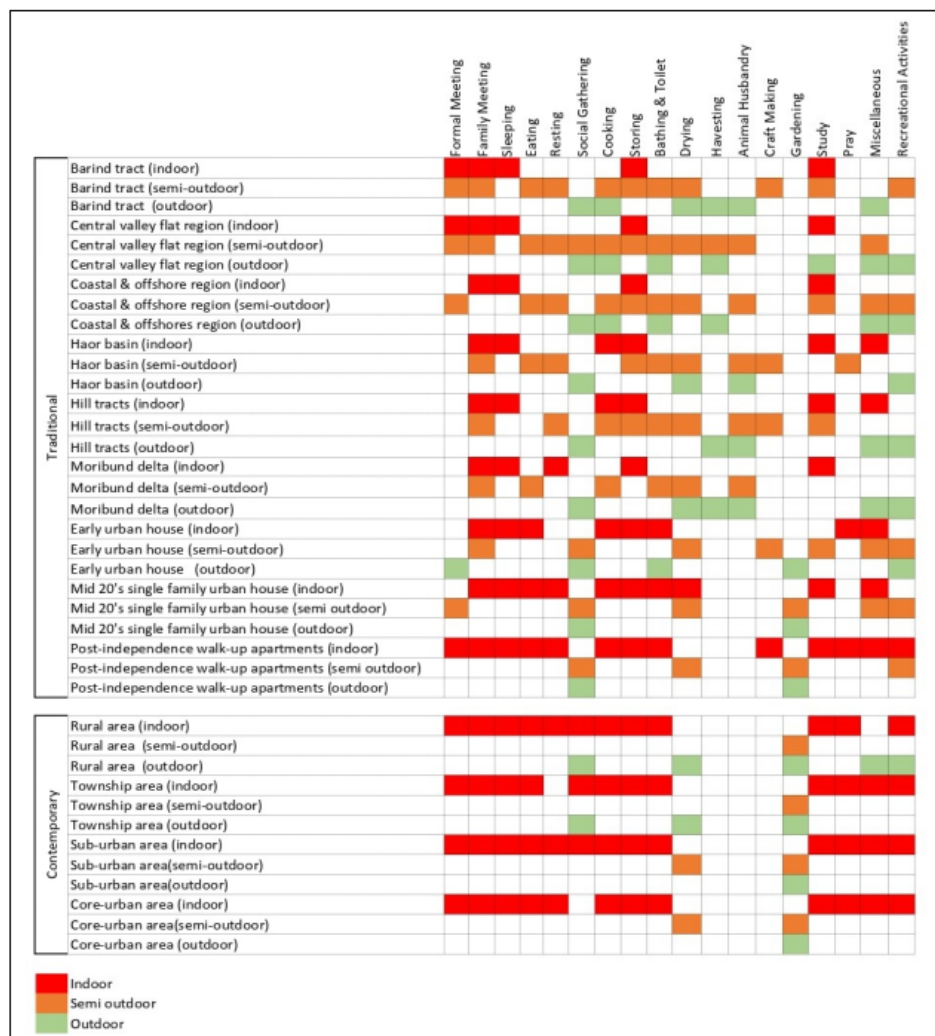


Figure 7. The activity chart in traditional and contemporary houses.

and focal point, connecting nearly 4-8 other individual spaces. Later in the traditional urban dwellings, the mean depth was slightly surged to accommodate more private and isolated rooms. Corridor-like connectivity was introduced to connect those isolated rooms as in the post-independence walk-up apartments. Both corridors and internal rings were present in the mid-20th century single-family houses. Eventually, the mean depth had increased to an average of 6-8 steps in contemporary apartments. The dining space became the most interconnected space instead of courtyards. Excessive use of corridors in rural, semi-urban, and core urban houses was found, as internal rings were rarely used and limited to townhouses. Cul-de-sac or isolated spaces had dominated contemporary dwellings. Those isolated spaces were generally used for specific and private activities. Overall, spaces connected by internal rings were more flexible than spaces connected by corridors or cul-de-sac spaces. Therefore, generality and adaptability were comparatively less in contemporary houses.

3.1.4 Decreasing Trend in Typicality

Typicality in the contemporary urban houses followed a distinctive changing trend. Traditional houses had prototypical rooms and minor variations in plan within the same region. As shown in Figure 9, the ratio of convex spaces was more in the rural house plans. The rooms were more simple and uniformly shaped. The structural grids were almost similar, and structural members were located in the peripheral walls, making an open internal floor plan. Nearly 60%-80% area in the traditional rural dwellings was typical and easy to adapt. Among them, coastal houses showed the most uniform and adaptive character that helped them to survive climatic vulnerability. In contemporary rural and urban houses, the ratio had drastically dropped below 40%. The floor plans had lost their open character as partition walls, and structural members divided the internal space into smaller sub-spaces. Besides, as the types of rooms had increased, the rooms were built of different shapes and sizes. Structural grids were also not similar inside, making the interior spaces less flexible and adaptable.

3.2 Survey Data Analysis

In this part, we have presented the survey findings and non-spatial type of analysis. Socio-cultural dimension of housing included with simple illustration and chart. The user feedback from the survey was also analysed to identify the residential spaces people are using for diverse functions and the spaces with low capacity to

accommodate multiple activities.

3.2.1 Changes in Construction Technique

Most of the rural houses involved vernacular material and construction techniques in the past (Figure 10). Traditional rural houses could be built, repaired and maintained easily by the inhabitants. The contemporary rural house also includes factory-made material and advanced construction techniques to cope with the increased demand. At the same time, the scope of further development by the end-user at later stages became difficult. Even in rural areas, most of the inhabitants have minimal knowledge about their own house construction. Almost everyone had some construction skills using the vernacular materials in the past.

On the other hand, the urban houses used complex construction techniques and heavy equipment for house construction. General people cannot avail this type of facility to construct or repair their own house. Only skilled workers can build urban houses. This scenario is more complicated now—professional developer companies taking charge of construction in most multistoried houses. Especially the high-rise residential buildings became necessary in large cities to meet the housing demand. The current practice in the housing market of Bangladesh does not allow further modification of residential units of these multistoried buildings. So the adaptability of spaces is significantly low these days.

3.2.2 Changing Trends in the Involvement of End-user

In the past, most rural people had the essential skills in constructing their houses and traditional knowledge about house planning. This traditional knowledge included the thumb rule of room size, structure made of vernacular materials, and the basic planning of the residential units. The user could plan and construct the houses at later stages when any expansion or modification was necessary. The construction technique in the urban area involved skilled labours with comparatively advanced technology and material. The design and planning were according to the need and guidance of the owner and assisted by professionals. Though the end user's involvement was not possible, the owner was the leading decision-maker of the design. In the contemporary period, houses in rural areas still involve most end-users in the design decision-making process. However, due to the use of factory-made building materials majority of the rural houses are being constructed by hired masons. A very few general users still have the skill to construct their housing due to using

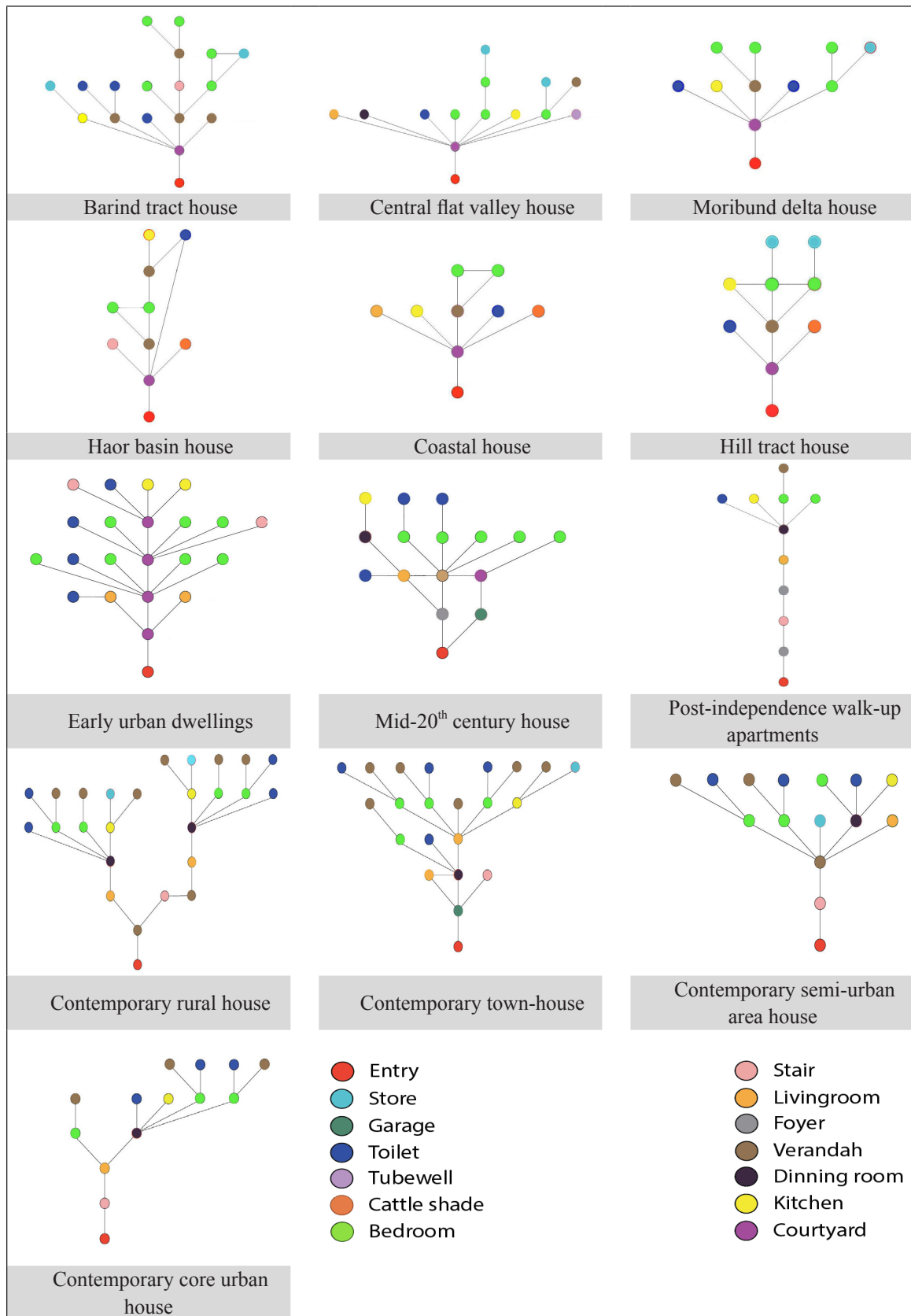


Figure 8. The J-graph in traditional and contemporary houses.

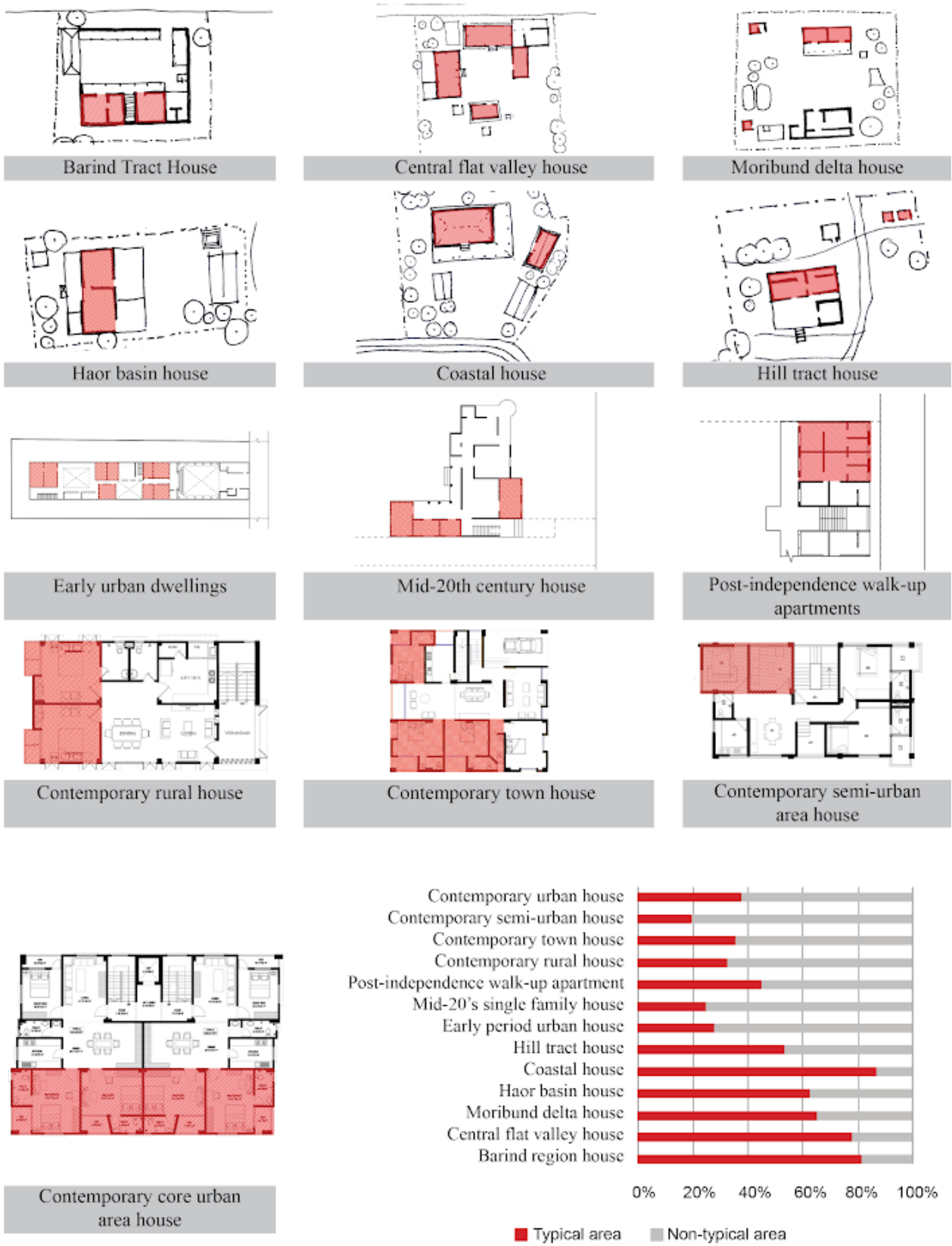


Figure 9. Typical spaces in traditional and contemporary houses.

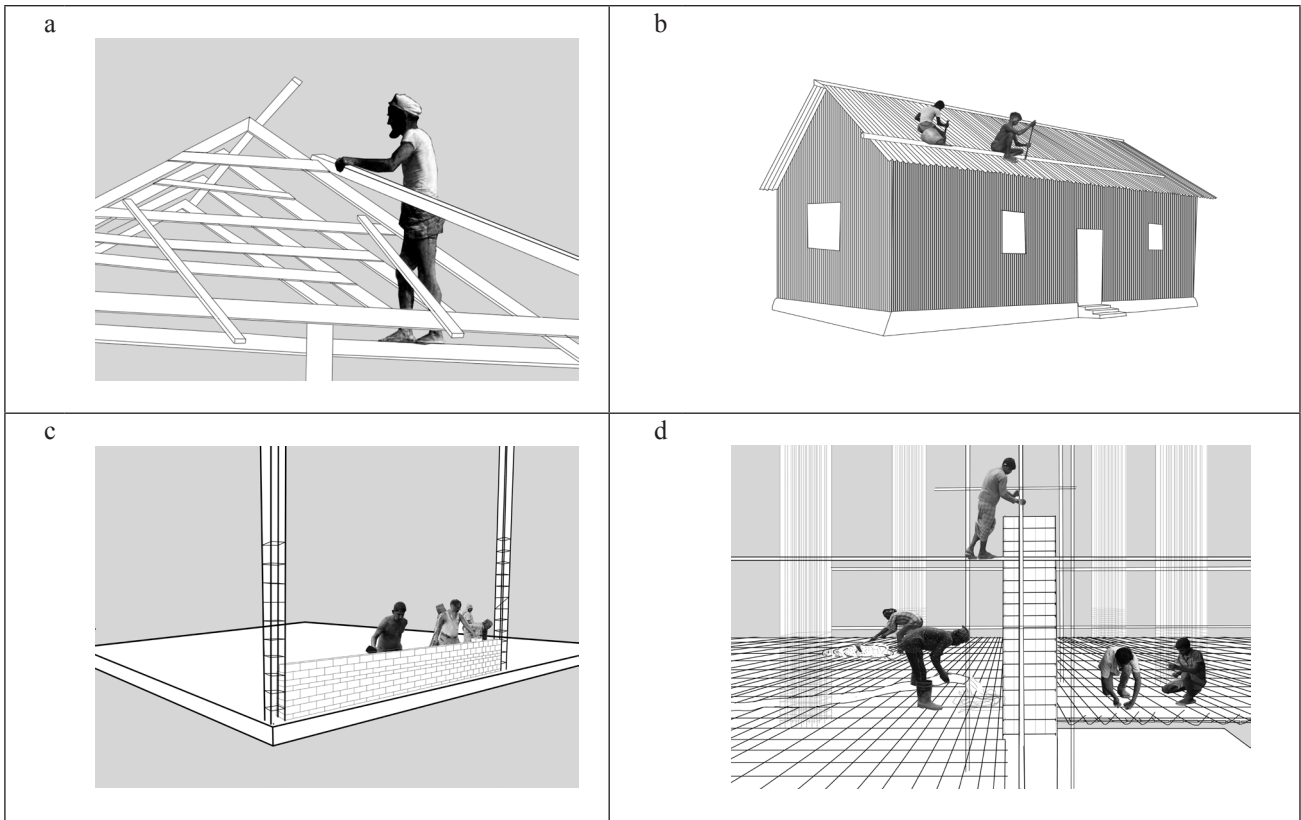


Figure 10. Construction of traditional rural houses (a, b) Contemporary rural house (c) and contemporary urban house (d)

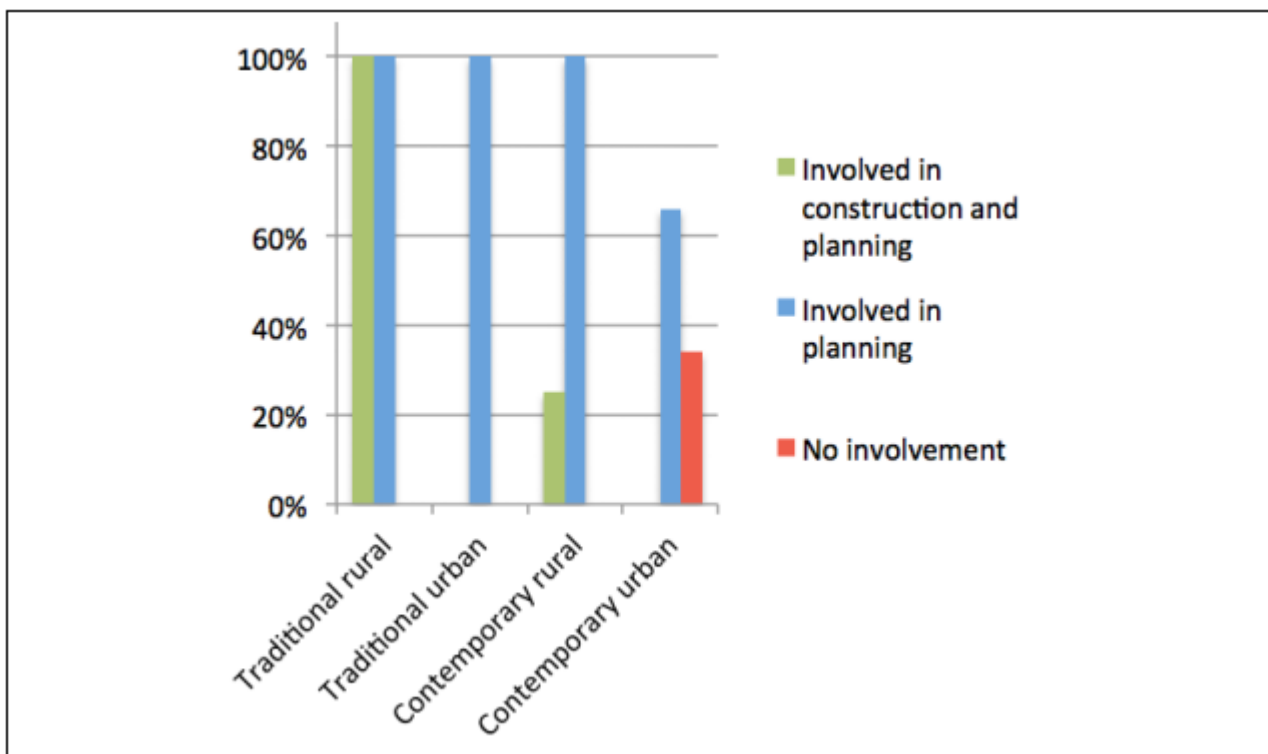


Figure 11. Different levels of involvement in traditional and contemporary house development in rural and urban areas.

complex modern construction techniques. Excluding the slums, the formal houses are always built by skilled professionals in the urban areas. Even in some cases, the ultimate user of the housing units is unknown until the construction is completed. Almost one-third of the study samples from the contemporary urban category were rented or sold to a user who can choose if the housing unit satisfies his need for space but cannot participate during the design phase or make any adjustment during their stay. Figure 11 shows a significant decrease in the involvement of end-users in the design and development works of contemporary houses.

3.2.3 User Feedback and Identification of Scopes

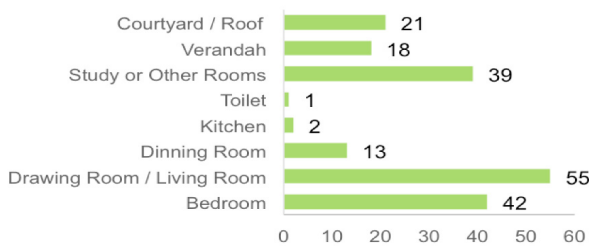


Figure 12. Spaces with high adaptability

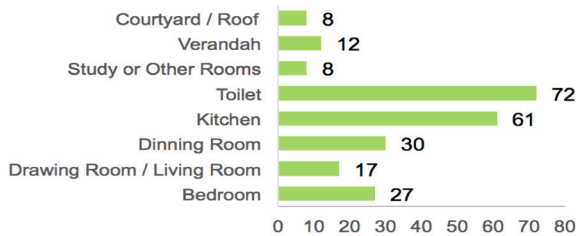


Figure 13. Spaces with low/ no adaptability

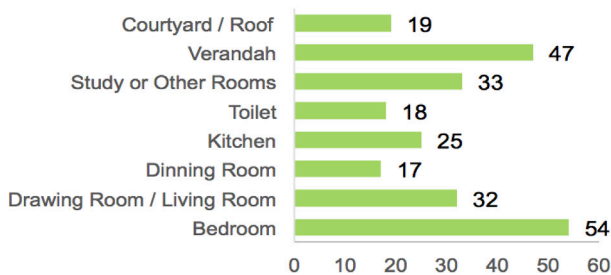


Figure 14. More spaces to be allocated at these areas for better adaptability

According to the survey feedback from inhabitants, the living room was the most adaptable space in the home that accommodated the most diversified types of functions, especially during the pandemic period (Figure 12). The bedroom was the second most adaptable space where online class and home office activities had taken place, especially for the small houses with no study room or family living space with adequate privacy when required. If there was a study space, then this type of function

mostly took place there. On the other hand, spaces for dedicated service functions like kitchens and toilets were the least adaptable space (Figure 13). Predictably, these types of spaces can not host diverse functions. Outdoor spaces are not much available in contemporary houses. Roofs are the alternative to ground-level open spaces for typical urban houses. A considerable number of users had identified open spaces like courtyard or roof and semi-outdoor spaces (veranda) as spaces with adaptability. We had also asked the participants' opinions on where to allocate more spaces to achieve better adaptability. Bedroom, living, study room received the highest importance among the interior spaces (Figure 14). Semi-outdoor spaces also received high-level importance to allocate larger spaces. From the open-ended question part on how to make the houses better in terms of living conditions, the importance of semi-outdoor spaces had obtained a high priority. This is not only for the possible multipurpose use but also to increase the openness of the living units to invite nature and enhance livability.

4. Discussion and Recommendations

According to spatial analysis and survey feedback, semi-outdoor and outdoor spaces can enhance adaptability. Due to high land prices and space limitations, it will be challenging to provide ground level open courtyards or gardens. In that case, the roof should be utilised as an open space. Roof gardening has already become popular. The local government is also supporting this type of initiative with reduced holding tax and other incentives. Since the residential building density is much higher, the multistoried multifamily apartment cannot satisfy all the needs of individual residents only with the roof level community space. Open terraces and an adequate number of semi-outdoor spaces should be provided at different levels of multistoried residences. Comparing the contemporary residences, we found that the proportion of open spaces are higher in core city area compared to other urban areas. Statutory building guidelines ensured at least 20-25% green space at each residential plot. In addition to this green area, other community spaces and paved open spaces are also ensured in this type of house. Integrated design of these outdoor spaces in residential zones can enhance the living standard more.

The indoor spaces with modular structural grid, simple circulation layout and adaptable zoning of service functions can enhance adaptability. Especially for multistoried buildings, the position of service cores is important to enable diversified plans at a different level. The spatial arrangement of the residential units reflected through depth map analysis indicated that effective use

of common spaces as nodes could simplify the linkage. Architects should analyse the plan using a depth map to identify the level of simplicity in terms of functional linkage and further improve it.

The typicality of rooms in terms of size and configuration will increase the capability of transforming one functional space into another functional use. It can be further enhanced with the use of transformative building components. With the introduction of modern building technology, we lost the opportunity of transforming building components by the residents on their own. Practically we cannot start using the vernacular methods, and the inhabitant cannot acquire the traditional construction skill. Instead, using factory-made transformative building components like a movable wall, operable building façade, and expandable floor slabs will be useful to increase adaptability. Prefabricated building components with multiple assembling options can enable the users to choose the components according to their needs. This type of element can be attached or detached from core building components to allow changing the volume of space if necessary.

Apartment developers dominate the contemporary housing market in the cities. The prospective residents of those apartments get involved after the design of the residential units has been finalised. In most cases, the consumers choose from the already constructed building. In fact, the ready apartments are gaining more popularity, though they fail to satisfy the user demand fully. The business model of the apartment type housing market should be reshaped to enhance the participation of end-users in the design and development process and thus enhance adaptability.

5. Conclusions

Global climate, housing policies, real estate economy, and construction technology - all these sectors have experienced drastic changes in recent years. Besides, during the current covid-19 pandemic, the healthcare and communication system has also undergone massive rethinking and restructuring. Architecture should also evolve with these social, technical, and environmental changes. The capacity to transform according to time, user's need, and environment are regarded as adaptability. Architecture should be adaptive during post-occupancy diagnosis and retrofitting of buildings to sustain for more extended periods. Adaptive architecture is more flexible and durable. Therefore, it is ultimately cost-effective in the long term. Besides, it can provide a permanent solution to complex housing problems in developing countries, as it is time and space-saving. The adaptive architecture allows

the end-users to participate in the design development phase directly. Lessons from traditional architecture also indicated the implementation of adaptive capabilities. The traditional architecture was more sustainable and long-lasting because of its inherent adaptive capacities developed through the users' needs, skills, and experience.

On the contrary, real estate agencies dominated the contemporary housing sectors. Their typical apartments for mass production were not environmentally responsive and socially communicative to the gradual changes in the behaviour pattern and needs of the end-users. This research focused on identifying the differences of adaptive characters of traditional and contemporary residential architecture. The research methodology adopted both spatial and non-spatial analysis. Spatial measures searched the relation of adaptability with privacy, openness, connectivity, depth, typicality, and flexibility. Non-spatial measures searched for construction techniques and involvement of user groups in the design development phases. In parallel, the researchers conducted a questionnaire survey to communicate with the end-users and collect their responses and suggestions. The changing patterns of adaptive measures were evident in both spatial and non-spatial analysis of traditional and contemporary houses. The contemporary houses showed a significant drop in openness, typicality, and flexibility. The degree of privacy and mean depth of space had unexpectedly risen. Even the design development and construction process excluded the users as the construction technology experienced massive overhaul and became more complex for the native users. Eventually, the building and the users were losing their adaptive capabilities, which was a prime concern of this research. The researchers recommended several suggestions to overcome this concern. Further research on the sustainability parameters of adaptive architecture could prove influential in solving this problem.

Author Contributions

The 1st author contributed in developing concepts, methodology, and analysis. The 2nd author assisted in methodology and analysis and the 3rd author contributed in survey analysis and illustrations.

Conflict of Interest

The authors declare no conflict of interest.

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