JOURNAL OF RESEARCH IN ARCHITECTURE AND PLANNING

Volume 33 Issue 2
ISSN (P) 1728-7715 - ISSN (E) 2519-5050
Journal DOI: www.doi.org/10.53700/jrap_neduet
Issue DOI: www.doi.org/10.53700/jrap3322023

TRANSFORMATION OF PASSIVE DESIGN ELEMENTS FOR ACHIEVING THERMAL COMFORT IN RESIDENTIAL BUILDINGS OF MANSEHRA CITY, PAKISTAN FROM 1990 TO 2019

Muhammad Ashar Awan*, Nazia Iftakhar**, Omer Shujat Bhatti***

Article DOI:
www.doi.org/10.53700/jrap3322023_2

Article Citation:

Awan M. A., et al., 2023, Transformation of Passive Design Elements for Achieving Thermal Comfort in Residential Buildings of Mansehra City, Pakistan From 1990 to 2019, *Journal of Research in Architecture and Planning*,33(2). 19-34.

* Muhammad Ashar Awan, Architect, Environmental Design Health and Nutritional Sciences, Allama Iqbal Open University.

** Nazia Iftakhar, Lecturer, Environmental Design Health and Nutritional Sciences, Allama Iqbal Open University.

*** Omer Shujat Bhatti, Research Associate, Environmental Design Health and Nutritional Sciences, Allama Iqbal Open University.

ABSTRACT

Among the most evolving issues in recent years, there is growing concern over global warming throughout the world. The construction industry has been considered among the major contributors to global warming. The use of building envelope along with the heating, cooling, and lighting design, operations, and infrastructures are the prime factors of this contribution. Due to this reason, the thermal comfort of buildings has become a major concern in building design globally. The following research explored the building design elements used for thermal comfort in residential buildings of Mansehra City of Khyber Pakhtunkhwa province in Pakistan and analyzed its transformation during the last three decades. The study proceeded by documenting and comparing various design elements to understand their transformation within documented time periods i.e. thermal mass, fixed shading devices, and the ratio of open and closed spaces. These elements were evaluated for their effectiveness in providing thermal comfort. It was concluded that these design elements have been adapted and modified with time with little concern for sustainability. It was found that the focus has shifted from building orientation, sun path, and wind directions to aesthetically pleasing forms only which makes them saleable and lack human comfort. The use of passive means to achieve thermal comfort was neglected. The research concludes by suggesting incorporation of appropriate thermal comfort components and methods into effective solutions for improved building designs, lower energy demand, and a better indoor atmosphere.

Keywords: Thermal Comfort, Passive Design, Residential Building, Mansehra City, Global Warming

INTRODUCTION

Urbanization is a serious concern in today's world. Rapid urbanization makes people more vulnerable to climate change impacts (Chai et al, 2022). Buildings are one of the primary sources of climate change and contribute significantly to global warming. Building construction, operation, and utilization have led to emissions of massive CO_2 in the ambient air (Neill, 2020). According to International Energy Agency (IEA) (2019), buildings and their construction are responsible for one-third of total global energy consumption and nearly 40% of annual global CO_2 emissions due to increase in energy consumption by structures. Numerous problems and challenges arise from the building sector in reducing CO_2 emissions (Ali et al., 2020). The exploitation of non-renewable energy resources, poor building design, and lack of sustainability consideration in urbanization have been holding back CO_2 emission mitigation measures in the building sector (Shaikh, 2021). Numerous factors contributed to this increase, including the growing demand for energy used in heating and cooling, increased house air conditioning capacity, and extreme weather conditions. The current state of climate change and the high level of energy consumption in building development are directed to address these global challenges using sustainable building practices.

Pakistan is no exception as a developing country in South Asia, in facing an energy crisis with its shortage and an imbalance between demand and production. Along side, the country is also facing a high population growth rate. The population of the country has increased by 57% and expected to double in the next 30 years (Umar, 2018). Although Pakistan contributes not more than 1% of global Greenhouse Gas (GHG) emissions but has been amongst the most vulnerable country in the region facing climate change and global warming disasters (Abubakar, 2019). The effects of global warming may already be evident in terms of monsoon start and end dates, extreme weather conditions, floods, drought, and other natural disasters (Abbass et al., 2022). Almost 50% of the total primary energy is consumed by residential and commercial buildings in Pakistan that produce more than one-third of total CO_2 emissions (Ghafoor et al., 2020; Rehman et al., 2021). The global energy consumption in residential buildings is highest at 22% (Anwar et al., 2021) with the increase in demand for energy in buildings reaching 24% globally by 2050 (Khan et al., 2022). In this context, the construction of buildings with enhanced energy characteristics is extremely inappropriate. Development in the use of passive techniques in new housing is undoubtedly an avenue that is being reconsidered in many parts of the construction industry (Tatarestaghi et al., 2018).

In Pakistan, the energy consumption by the residential sector is at the highest rate with 45% of overall energy consumption (Maan et al., 2021; Finance Division GoP, 2020). For designing energy-efficient buildings, the building codes of for mager cities are available but most cities are unable to develop proper codes of building bye-laws. Houses are constructed with no climatic considerations. Active systems based on personal choices are used to offer comfortable temperatures inside the houses with more energy use resulted in increase in cost eventually (Mahar et al., 2019). Taking advantage of natural energy flows to achieve thermal comfort is all about passive design. From building orientation to the building envelope, there is a variety of techniques that can be provided to achieve thermal comfort in residential buildings (Rajapaksha et al., 2003). By using appropriate passive design strategies buildings have the potential to save 50 – to 60% of energy (Ali & Rakshit, 2019). Studies reported that building orientation, layout, materials, envelope, thermal mass, window design, and shading provision, provision of courtyards, verandas are fundamental elements that maximize the use of natural ventilation and daylight to improve a building's performance and enhance indoor thermal comfort (Tatarestaghi et al., 2018; Maleki, 2011; Nugroho et al., 2020; Jamaludin et al., 2018; Shaheen et al., 2016; Chahal & Aulak, 2018; Loo et al., 2021).

Climatic challenges in developing countries tend to force the population towards survivability limits. The Earthquake of 2005 in Pakistan was such an event that resulted in revisiting some of the major applicable bylaws across the country. Being a major city hit by the incident, Mansehra as one of the largest cities in the KPK province had to revisit the design paradigm and shift to structural prioritization. Belonging to a highly mountainous region, the city is surrounded by dense forests and serene environments, a large population influx occurred leading to enhanced urbanization. Mansehra today has a better formulation of bylaws after the 2005 earthquake as compared to other small cities of Pakistan. However, these codes focused only on the building's structural elements rather than considering it as a unit. Even so, it was seen that there is a big difference between the existing standards in terms of structure and built form. There are no standards in the regulations relating to passive construction like thermal insulation or air leakage-tightness, etc. This has led buildings to overheat or cool during the changing of summer and winter seasons respectively. The study aims to contribute to the understanding of use of passive design elements in residential buildings to achieve thermal comfort and their transformation over a selected time period in Mansehra city. Multiple studies discuss the residential buildings of Pakistan, relating climatic conditions with the parameters of thermal comfort (Mahar, Amer & Attia, 2018; Nicol et al., 1999; Shaheen et al., 2016; Maan et al., 2021) and found knowledge gaps between the building design and climatic considerations (Mahar et al, 2019).

Not enough literature was available related to the residential buildings of Mansehra region. The purpose of the study was to assess the transformation of residential buildings with time and the objective was to evaluate and compare selected passive design parameters including thermal mass, fixed shading, and the ratio of open and closed spaces in residential buildings of Mansehra over three decades. Three houses were selected, documented and examined from each decade that is 1990-1999, 2000-2009, 2010-2019 as a sample for a true representation of the population based on the similarity of design replication in the explored overall context.

STUDY AREA:

Mansehra, situated in the Hazara Division of Khyber Pakhtunkhwa province has a total area of 4579 km² and has urban population of 87,657 out of a total population size 1,556,460 comprising about 49% male and 51% female population (Pakistan Bureau of Statistics, 2017). Located at 34°14' and 35°11' North latitude and 72° 49' and 74° 08'

East longitude, Mansehra is surrounded by Batagram and Kohistan districts from the north, Muzaffarabad district of Azad Jammu and Kashmir in the east, Abbottabad and Haripur districts in the south and Swat district in the west (Shakir & Ahmed, 2011) as shown in Figure 1. The city serves as a catchment area for towns such as Kaghan Valley, Batgram, Balakot, Shinkiari, and Baffa and provides urban infrastructure, social services, transportation, and employment to these smaller towns.

The climate of the district is warm in summer and cold in winter. The northern part, where there are high mountains, is cold in summer and very cold in winter due to the snow-capped mountains. Mansehra City consists of three types of land uses including residential, commercial, and industrial (Shakir & Ahmed, 2014). Most of the building stock is between ten and fifty years old. As stated by the Pakistan Bureau of Statistics (2017), the annual population growth rate of the city is 4.62%, which is higher than the annual growth rate of 3.58 percent projected (Pakistan Bureau of Statistics, 2017). The expansion of the city can be seen in Figure 2.

METHODOLOGY:

The research was primarily a comparative study in which diverse types of data were collected. The total housing units recorded an increase of 239275 in 2017 as against 172040 in 1998 (Pakistan Bureau of Statistics, 2017). The urban development of the city was visualized through Google Earth images. From the images, the housing growth was studied and marked in different sectors including housing growth during the 1990s, 2000s, and 2010s. Three of these areas were identified as having a representation of houses from each decade based on their construction period. The areas included are Safdar Road, Mohalla Dub No. 1, and

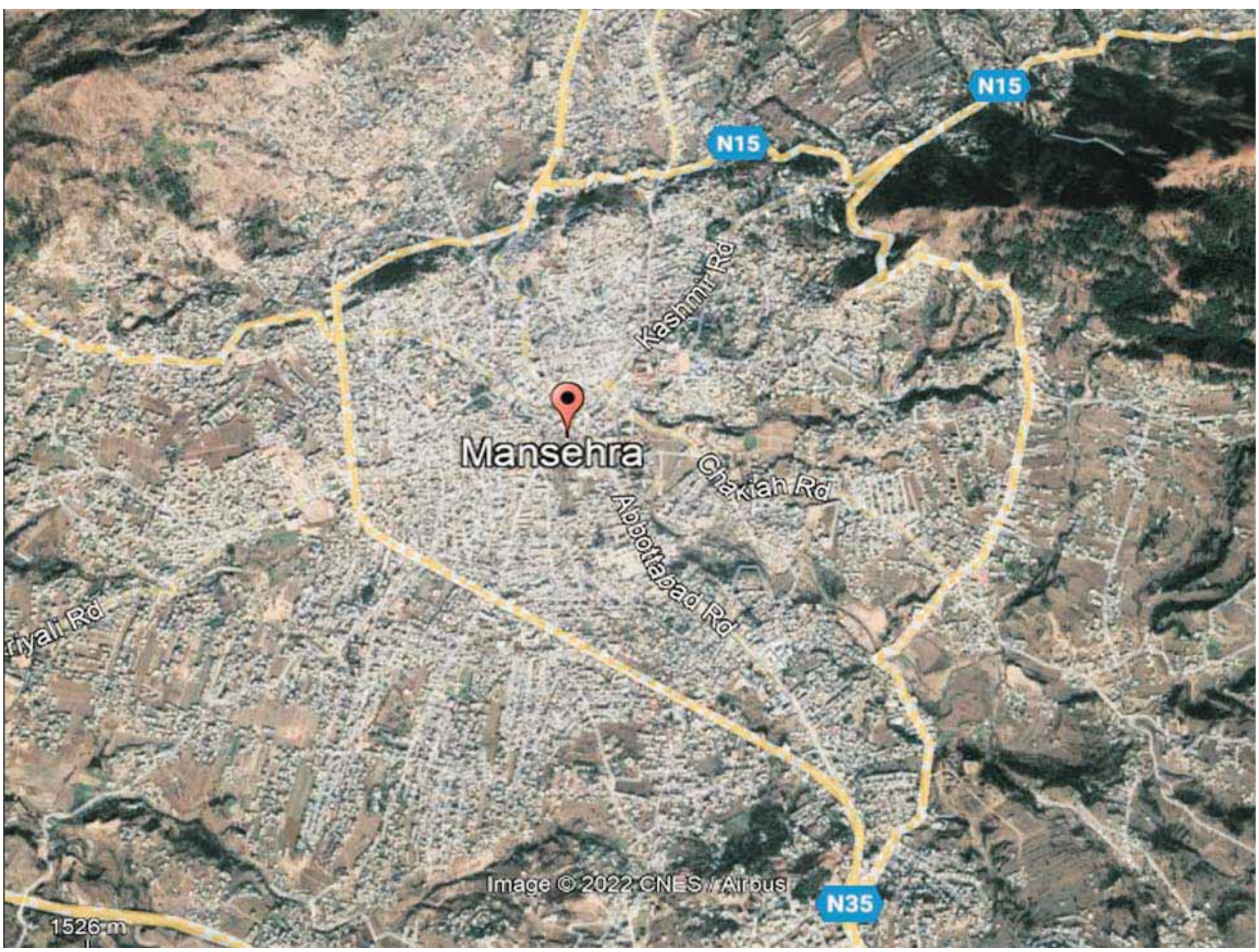

Figure-1: Location map of Mansehra district.
Source: Google Earth, 2022.

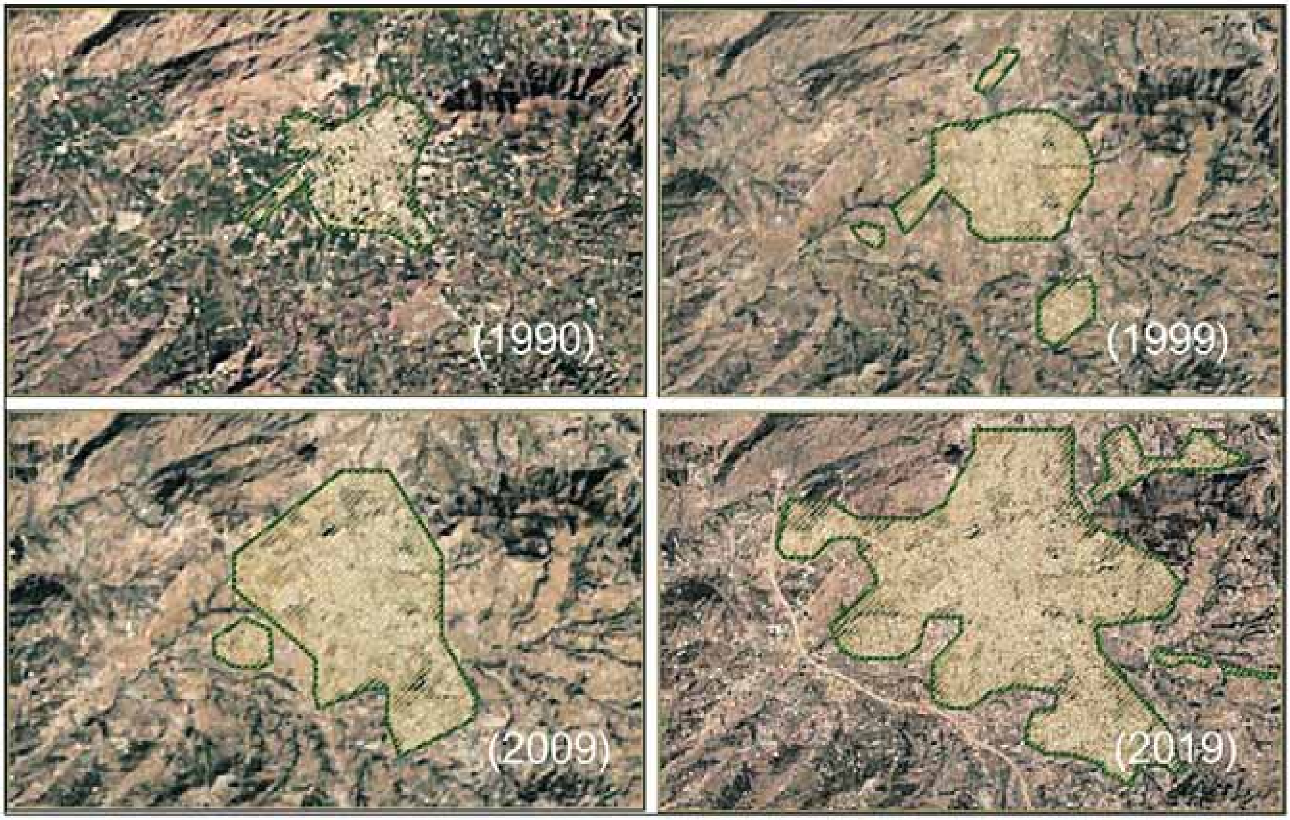

Figure-2: The expansion of Mansehra city from 1990 to 2019.
Source: Google Earth, 2021

Dub No. 2 as mentioned in Figure 3. Three houses were carefully chosen from each area. The selection criteria of houses were determined by the plot sizes that is one house from 5 to 7 Marla (152-212 sq. yds.), one house from 8 to 10 Marla (242-302 sq. yds.), and one house from 18 to 22 Marla (544-665 sq. yds.). After selection, analysis was done by comparing the selected passive design elements in selected houses. Software including Google Earth, AutoCAD, and Google Sketch up were used for the task.

FINDINGS:

Initially, in the context of Mansehra city, the concept of Mohallah or Neighbourhood respect was followed and people preferred to have similar size plots but over the last two decades the morphology has been segregated and even the most common form of land and development now have variation of plot sizes as well as housing units. Hence based on the housing unit size, economic and social groups have also originated breaking a monotony previously followed. The selection of areas was based on the availability of houses represented from each decade with size variations. All houses were evaluated based on the provision of selected passive features including thermal mass, fixed shading devices, and the ratio of open and closed spaces. Primary data was collected by mapping out a target area where houses from all three decades were located. Further, the data was analyzed by comparing selected passive elements in houses representing different decades. The collected data were tabulated and interpreted as percentages in SPSS version 22 and Microsoft Excel 2016 for analysis. Following are the details of selected houses from different decades.

Figure-3: Selected areas of Mansehra city.

Selected Houses from 1990-1999:

The houses were evaluated from selected localities to examine the passive features representing during 1990-1999. The variations in plot size contribute to differences in the design elements and open areas. The comparative analysis offers insights into shared and distinctive passive design features that characterizes the region. From thermal mass to open courtyards, the synergy of construction elements and their response to climatic conditions paints a vivid picture of thoughtful, context-specific architectural choices in this vibrant urban setting. The plan of the first house with 20 marla (600 sq. yds. approx.) plot size from Safdar Road shown in Figure 4 contains a front courtyard and veranda (a). No setback on the west side, resulting in west side windows with projections opening directly into the street (b). Veranda projection provides shade and serves as a sitting area (c) and east side windows with overhang projection (d). The next house from Dub No. 1 with 10 marla (300 sq. yds. approx.) plot size is shown in Figure 5. It consists of front courtyard and veranda acting as a sunspace, covered with a glazed surface partition (a). Internal windows in the courtyard have projections for reflected and diffused sunlight (b). There is a sitting area under the covered veranda for shade (c) and windows provided at the west side with projections and roof projection for shading (d).

The house details exhibited in Figure 6 from Dub No. 2 have a plot size of 7 marla (210 sq. yds. approx.) showing a courtyard and semi-covered veranda on the front side (a).

Table-1: Comparison between selected passive design elements of houses from 1990-1999.

S. #	Selected Elements	Passive	Design	House No. 1	House No. 2	House No. 3
1	**Thermal Mass**	Walls	Material	Brick	Brick	Brick
			Width	9 inches	9 inches	9 inches
		Floors	Material	PCC	PCC	PCC
		Roof	Materi	RCC	RCC	RCC
			Width	6 inches	6 inches	6 inches
2	**Fixed Shading Devices**	North	Material	-	-	-
			Size	-	-	-
		East	Material	-	-	RCC with a roof extension
			Size	6’x 2’ x 5’	-	2’extended from wall
		West	Material	RCC with a roof extension	RCC with a roof extension	-
			Size	Shed from all sides of windows	Shed from all sides of windows	-
		South	Material	RCC with all roof extension, Veranda	RCC with all roof extension, Veranda	RCC
			Size	70’x 8’x 6’	-	32’x 10’x 6’
3	**The Ratio of Open and Closed Space**	Total Area		600 sq. yds	300 sq. yds	210 sq. yds
		Covered Area		230 sq. yds	150 sq. yds	80 sq. yds
		Semi Covered Area		60 sq. yds	42 sq. yds	42 sq. yds
		Open Area		300 sq. yds	78 sq. yds	48 sq. yds
		% Covered Areas		40	50	58
		% of Open Areas		60	50	42

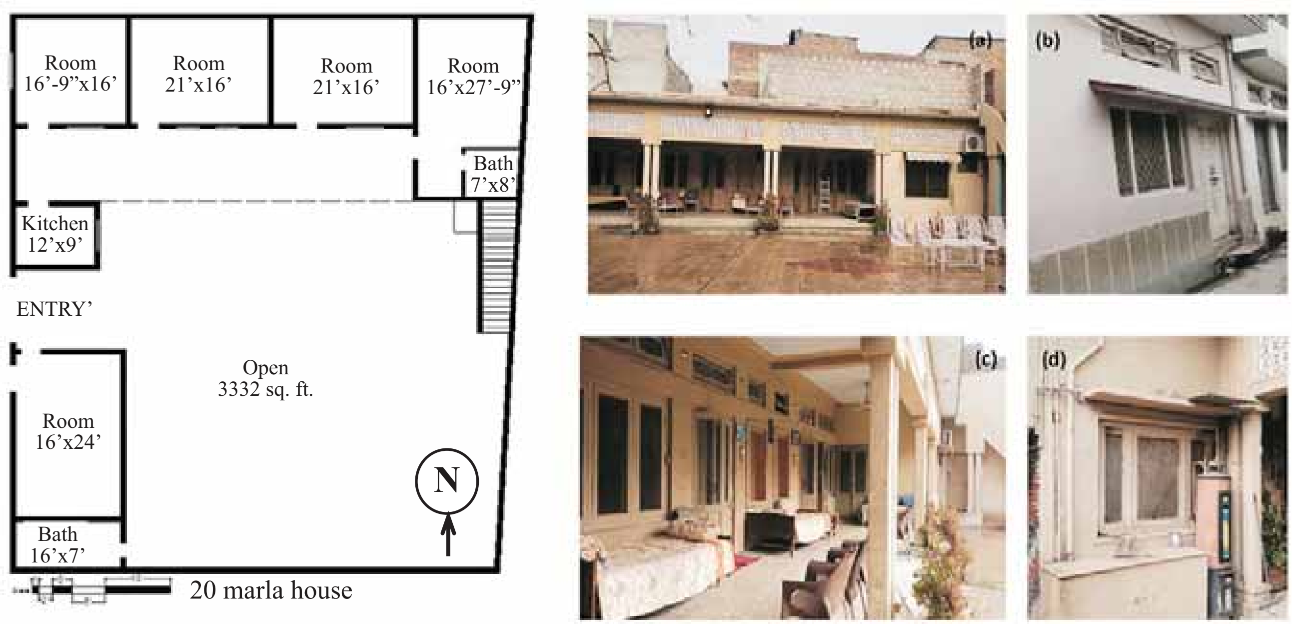

Figure-4: Plan and views of house no. 1, Safdar road.

Figure-5: Plan and views of house no. 2 Dub no. 1

Projections over the veranda, windows, and ventilators allow protection from direct sunlight (b). Roof extensions toward the south, some merged with the front side courtyard (c) were also recorded. Table 1 shows a detailed comparison of all three selected houses. All houses have 9 inches-thick brick walls, plain cement concrete flooring, and common use of RCC roofs in all houses. All houses had roof extensions toward the south, sometimes merged with the front side courtyard. Veranda was identified as a significant element in all houses, varying in size. Provision of windows with shading and projections is also a common characteristic of these houses. East side windows are shaded with a 2-feet projection due to roof extension. Courtyards with Semi-open areas were located on the south side. The percentage of open area ranged from 43 to 60 percent based on plot sizes. The comparison highlights the common passive design features in houses from 1990-1999, including the use of verandas, roof extensions for shading, and specific window shading strategies. The variations in plot size contribute to differences in the design elements and open areas.

Selected Houses from 2000-2009:

Further, the selected houses from 2000-2019 reveal nuanced approaches to passive design and spatial organization. While

Figure-6: Plan and views of house no. 3, Dub no. 2.

the structural fundamentals remained consistent, the introduction of front terraces, changes in flooring materials, and strategic use of roof projections reflect an emphasis on both aesthetics and functional considerations. The varied approaches in each house highlight the adaptability of architectural designs to the specific needs of different plot sizes and orientations on Safdar Road during this timeframe. Figure 7 shows the first house has a plot size of 17 marla (512 sq. yds. approx.) from Safdar Road where windows and projections detailed in the front view (a). East side window carries an overhang, which is more of a design element (b). The south side has a roof extension acting as a projection, thus no overhangs are given for windows (c). The next house with 10 marla (300 sq. yds. approx.) plot size from Dub No. 2 is shown in Figure 8. A terrace can be seen on the first floor acting as a semi-covered area on the ground floor (a). South side windows along the setback are extended and have overhang projection (b). A shaded front area on the west side due to the terrace, allows indirect light (c). Northside has car porch covered with a terrace to give shade from direct sunlight (d).

The house mentioned in Figure 9 from Dub No. 1 covers the area of 7 marla (210 sq. yds. approx.). The front courtyard was attached to a semi-covered veranda (a). Well-lit veranda with indirect sunlight and sitting facilities (b) makes a comfortable semi outdoor space. East side window has extended roof projection acting as overhang(c). Table 2 shows a detailed comparison of selected houses. The wall size remained 9 inches thick, but a shift to marble flooring was observed. RCC roof thickness is standardized at 6 inches. Front terraces emerged as a common element, creating semi-covered verandas on the ground floor. Verandas are characterized by linear planning, covering the entire length with widths ranging from 7 to 12 feet and occupying 10 to 20 percent of the plot size. 2 feet of fixed RCC roof projections are provided on the east and west sides. Absence of shading is observed on the north side. The open area constituted approximately 30 to 36 percent of the total plot size. These are setbacks of 1.5 to 2 feet from boundary walls. Courtyards were paved with limited or no vegetation among selected houses. The analysis indicates a shift in flooring materials, the introduction of front terraces, and a decrease in the percentage of open areas during the 2000-2019 period. The strategic use of roof projections and setbacks reflects an evolving approach to passive design, emphasizing both aesthetics and functionality in the architectural landscape during this period of construction.

Selected Houses from 2010-2019:

The dynamic architecture during 2010-2019, found traditional design elements coexist with contemporary materials and spatial considerations. The blend of functionality, aesthetics,

Figure-7: Plan and views of house no. 1, Safdar road.

Figure-8: Plan and views of house no. 2, Dub no. 2.

and adaptability to modern construction practices suggests a distinct approach to architectural design during this period. The house mentioned in Figure 10 is 17 marla (512 sq. yds. approx.) located at Dub No. 2. There is an open courtyard (lawn) and semi-covered veranda at the front (a). Setback at the west side have windows with overhangs along with extended roof projections (b). The other house is at 9 marla (272 sq. yds. approx.) from Safdar Road is shown in Figure 11. A semi-covered veranda and terrace were visible from the front side (a). No specific projections over windows are noted, but an overall wall projection is present (b). Figure 12 shows the front view of the house located at Dub No. 1 (a). West side has windows with projections (b). The front view showcases a semi-open and open area (c), while the east side has a window with its projection detail (d).

Table 3 has a detailed comparison of all three selected houses from the selected houses of 2010-2019. Consistent 9-inch wall thickness was used across all houses. Two out of three houses were constructed using blocks, indicating a shift in construction materials. Common use of 6-inch RCC roofs in all houses. Marble emerged as the prevalent flooring material. Two houses featured 2 feet roof extensions from the east and west sides, complementing window projections.

Figure-9: Plan and views of house no. 3, Dub no. 1.

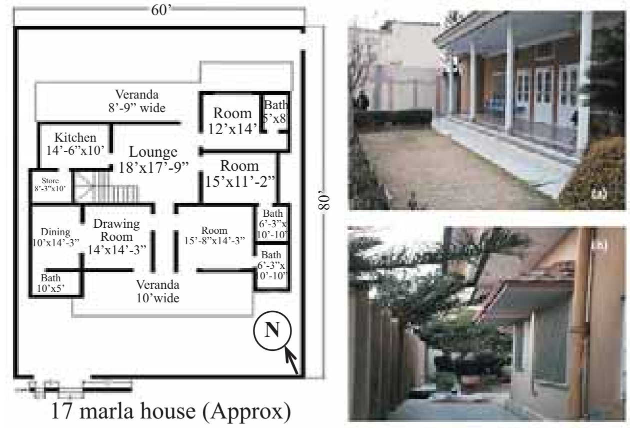

Figure-10: Plan and views of house no. 1, Safdar road.

Table-2: Comparison between selected passive design elements of houses from 2000-2009.

S. #	Selected Elements	Passive Design		House No. 1	House No. 2	House No. 3
1	**Thermal Mass**	Walls	Material	Brick	Brick	Brick
			Width	9 inches	9 inches	9 inches
		Floors	Material	Marble	Tiles	Tiles
			Width	1 inches	1 inches	1 inches
		Roof	Material	RCC	RCC	RCC
			Width	6 inches	6 inches	6 inches
2	**Fixed Shading Devices**	North	Material	-	-	-
			Size	-	-	-
		East	Material	RCC	RCC roof extension	-
			Size	2.5 feet projected roof	8' x 12" x 6"	-
		West	Material	-	-	RCC window projections
			Size	-	-	6' x 1.5' x 6"
		South	Material	RCC	RCC Veranda & Windows shade	RCC Veranda
			Size	7'x 2.5'x 6'	14' x 16" x 6" & 6' x 1.5' x 6"	40' x 8' x 6'
3	**The Ratio of Open and Closed Spaace**	Total Area		512 sq. yds	330 sq. yds	210 sq. yds
		Covered Area		300 sq. yds	219 sq. yds	135 sq. yds
		Semi Covered Area		30 sq. yds	39 sq. yds	38 sq. yds
		Open Area		120 sq. yds	72 sq. yds	53 sq. yds
		% of Covered Areas		70	67	58
		% of Open Areas		30	42	42

Figure-11: Plan and views of house no. 2, Dub no. 1.

Figure-12: Plan and views of house no. 3, Dub no. 2.

Where one house had a roof projection from the north side, serving as parking and laundry space. A reduction in the percentage of open area, now ranging from 27 to 30% of the total area. Semi-covered areas are utilized for parking. Therefore, a continuation of certain design elements, like semi-covered areas and roof extensions, with changes in construction materials were observed during 2010-2019. The shift towards block construction and the utilization of marble for flooring signify adaptability to contemporary construction practices. Additionally, the reduction in open area percentages suggests a more compact use of space.

Table-3: Comparison between selected passive design elements of houses from 2010-2019.

S. #	Selected Elements	Passive Design		House No. 1	House No. 2	House No. 3
1	**Thermal Mass**	Walls	Material	Brick	Hollow Brick	Blocks
			Width	9 inches	6 inches	6 inches
		Floors	Material	Marble	Marble	Marble
			Width	1 inches	1 inches	1 inches
		Roof	Material	RCC	RCC	RCC
			Width	6 inches	6 inches	6 inches
2	**Fixed Shading Devices**	North	Material	RCC window Shade	RCC roof extension	Veranda
			Size	6’ x 1.5’ x 6”	2 to 4 feet wide	8’ x 12” x 6”
		East	Material	RCC roof extension	RCC roof extension	RCC roof extension / RCC Window shade
			Size	5’ x 1.5’ x 6”	2 feet wide	2 feet wide / 5’ x 1.5’ x 6”
		West	Material	RCC roof extension	RCC roof extension	RCC roof extension / RCC Window shade
			Size	2 feet wide	2 feet wide	2 feet wide / 5’ x 1.5’ x 6”
		South	Material	Veranda	-	-
			Size	25’x 8” x 6’	-	-
3	**The Ratio of Open and Closed Space**	Total Area		512 sq. yds	270 sq. yds	210 sq. yds
		Covered Area		360 sq. yds	195 sq. yds	15 sq. yds
		Semi Covered Area		23 sq. yds	60 sq. yds	15 sq. yds
		Open Area		128 sq. yds	15 sq. yds	33 sq. yds
		% of Covered Areas		70	72	71
		% of Open Areas		30	28	29

DISCUSSION:

Protection from radiant solar gain is the prime strategy in warmer climates for achieving thermal comfort. Without incorporating shading, building surfaces absorb excessive heat, raising the surface temperature. Therefore, it is important to shade the openings in buildings in such a way that it protects from summer sun and allows winter sun within the building. A transitional change can be seen in the selected case studies from 1900 to 2019. The concept of the veranda is observed to disappear from 2010 onwards. The reduction in the south shading area from 20% to 5% with an increase in build-up area from 50% to 70% was recorded. East and west side shading remained consistent but no separate shading for windows was used from 2010 onwards. The orientation of rooms toward the south with the presence of a courtyard and veranda enters air into the internal spaces during summer as well as allows ambient sunlight to come into the rooms as shown in the typical section of the model house from 1990-1999 (Figure 13).

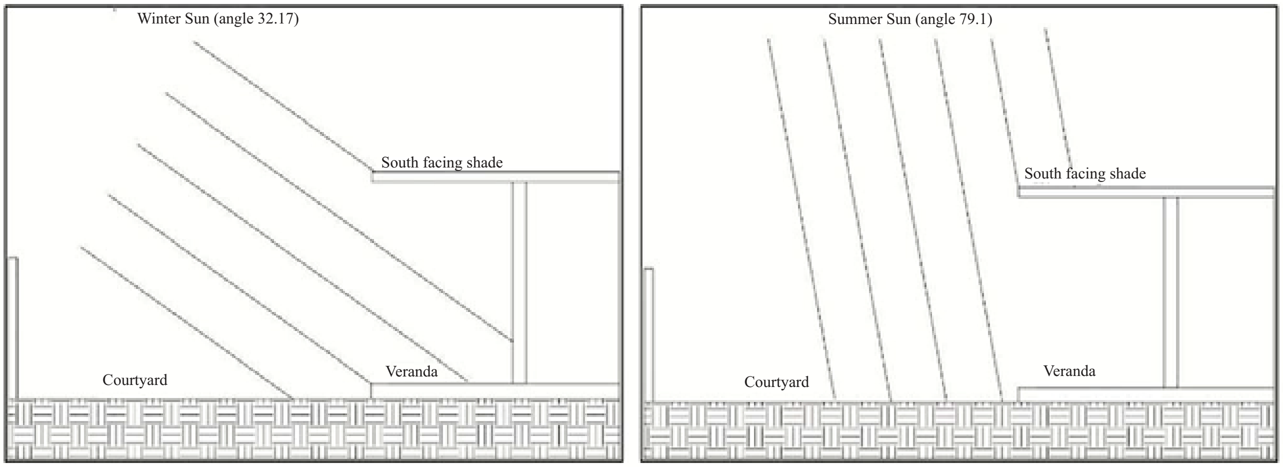

Figure-13: Section of typical house from 1990-1999 with summer and winter sun angle.

It is quite evident from the figure that the walls are completely protected from direct exposure to the sun during summers and winters. East and west sun exposures are problematic. Summer morning and afternoon sun altitude angles are so low that overhangs are seldom effective. The best alternative for these orientations is egg-crate shading. The windows and walls of 1900-1999 houses were totally exposed on the west and east sides. Exposed walls with window projections of 1.5 feet from the west and east sides allow morning and afternoon sun. A typical section of the 2000-2019 house (Figure 14) depicts that the walls are exposed to the south side with 2 feet setback from boundary walls and the central veranda provides shading and protection from direct solar gain into the rooms.

The walls are not completely protected through the roof projection during summer and are completely exposed on the south side. Also, the roof extended projection failed to protect the wall and windows from the summer heat, whereas during winters the boundary wall blocked some portion of the sun heat but the exposed walls take maximum sunlight. The east and west sides of the buildings were partially protected because of the small setback from the boundary walls. Illustrations shown in Figure 15 are model of houses developed in Google Sketch from the three-decade time period showing the effectiveness of overhangs on different sides during summer and winter seasons.

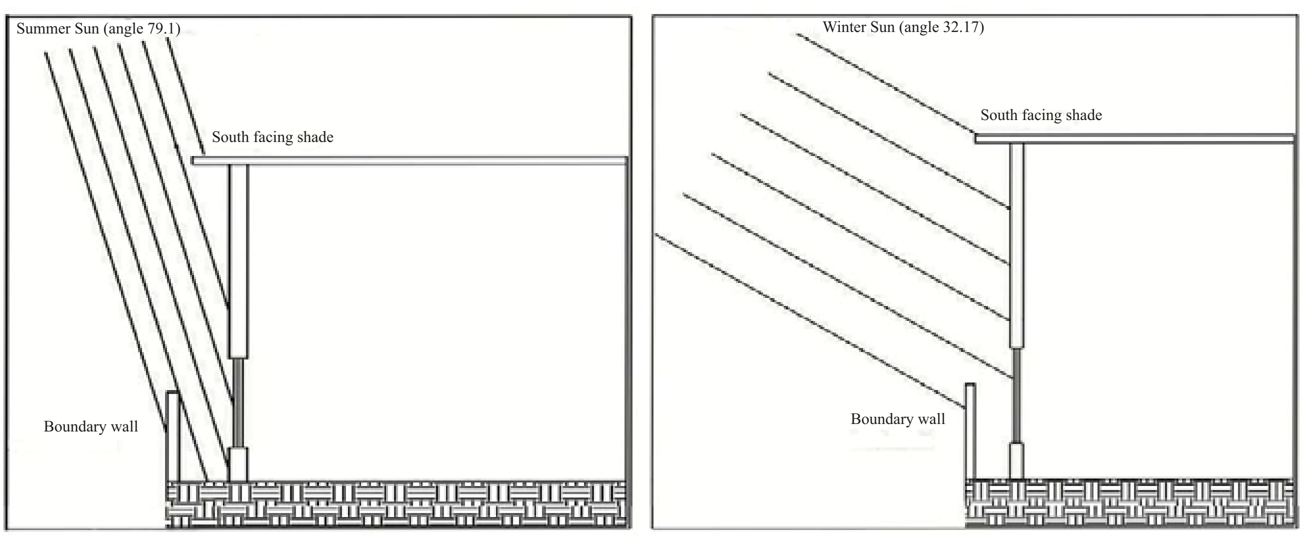

Figure-14: Section of typical house from 2000-2019 with summer and winter sun angle.

The existence of courtyards varied from 1900 to 2019. In the selected houses, the courtyards have been observed on the south side for maximum solar gain during winter seasons. Air circulates within buildings due to incident sun rays in the courtyard during summers. During 1990-1999, the open area was observed to be between 43 to 60 percent. Oriented on the south side, semi-open and open areas help in unobstructed and high airflow. Whereas, the percentage of open area during the 2000-2019 time is between 30 to 36 percent. During this time, the concept of a courtyard starts to vanish from the houses as only one house of this time was found with courtyard. The sizes of open spaces were also reduced and not sufficient to create a good airflow pressure difference. Setbacks of 1.5 to 2 feet from boundary walls on the right and left have also been observed but these cannot be considered as open space.

Finally, from 2010 to 2019, the open area is seen to further reduce to between 27 to 30 percent. With the increase in the covered area, open areas are now also used for parking. Although, the veranda as a semi-covered space can be seen in a few cases. Setbacks of 2 feet from the right and left sides form boundary walls that cannot be treated as open space for proper airflow and can be used for circulation only. Figure 16 shows the transition of open areas during the selected time frame.

The use of thermal mass in houses from 1990-2019 has not changed much but shifted from bricks to blocks. Since blocks are more economical and take less time to construct as compared to bricks. Both materials have heat retention and compensate for their low insulation value. The insulating rating (R-value) for the 4-inch-thick brick wall is 0.8 per

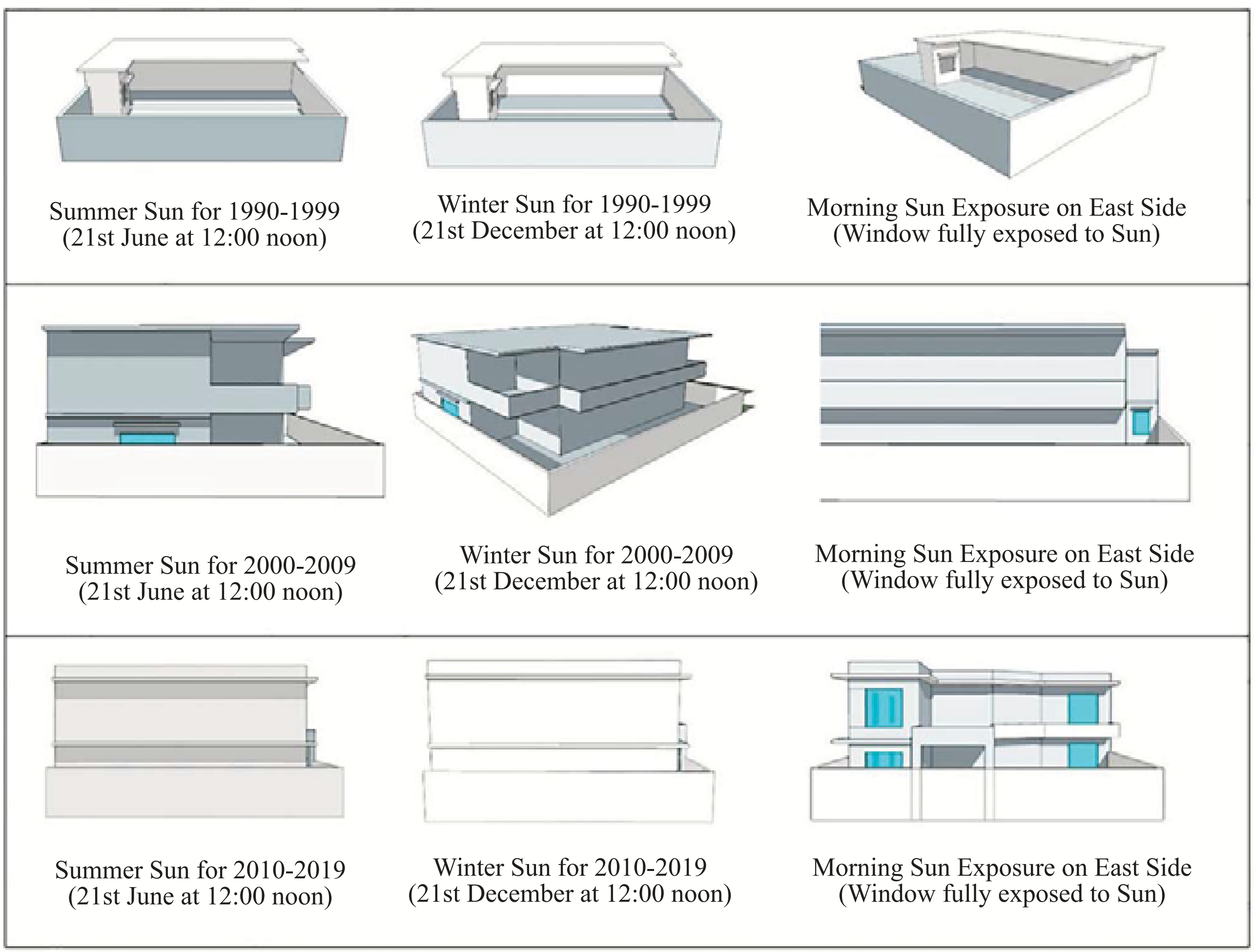

Figure-15: Effectiveness of shading devices during different times of the year of selected houses.

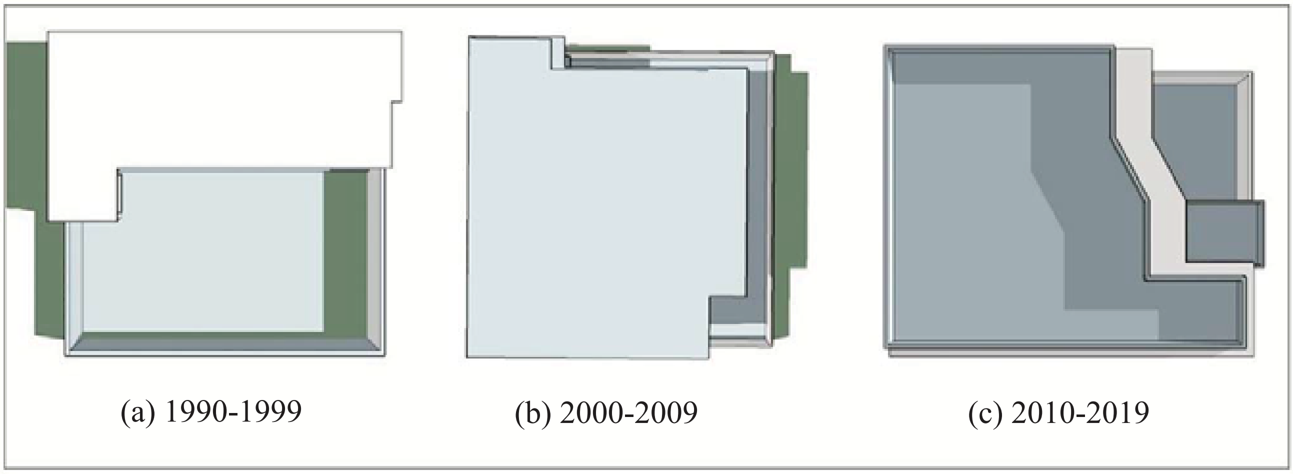

Figure-16: Transition of the open area from the top view of the model houses.

square feet whereas, the R value of the 8-inch conventional concrete block wall is 1.11 per square feet. Bricks have higher thermal mass than blocks which allows them to absorb more heat.

CONCLUSION

With lack of exploration of the passive design elements of the housing units towards end users' satisfaction and transformation from multiple timelines explored, the study was able to contribute to the existing body of knowledge in the following ways.

The study concluded that the windows or roof projections were consistent features from all selected houses. It clearly showed that people do consider the climatic conditions of Mansehra city over the modern-day outlook though in the current context it adds value to the saleable price of the housing unit as an asset. Sufficient shading was found in the south side but at the east and west sides shading with projections was not enough to fulfil the thermal comfort needs. It was though not comfortable as per discussion with multiple respondents, yet considering Mansehra a cold city in the overall context of the country, public lack of Eastern side projects and having ample sun during winters was evident. Though, the orientation of houses according to the sun's path was not the focus of design but people do have considered it along with Qibla direction (direction to Holy Kaaba) in the design of internal spaces. Kiln fired bricks was the main material or construction element that was extensively replaced by concrete blocks that have low insulation value though cost effective and easy to manufacture and procure in the context. Open and semi-open spaces including verandas and terraces are missing in recent times. This highlighted a transition from the traditional to more synthetic approach of a modern day villa without considering the implications of local culture and climate in design of a housing unit. Hence it has resulted in an increase of the ratio of the covered area from the previously built houses. The use of passive design elements to achieve thermal comfort was neglected and more space was occupied through built form. The new designs (2000-2019) are more focused on aesthetics than previous times (1990-1999). Hence the aesthetic transformation has started taking the respondents or indeed end users towards a loose target resulting in poor thermal performance of the house in long run. As a result, they consume more energy for heating and cooling of spaces and also have a negative impact on the overall environment along with increased energy demand. These have triggered lack of thermal comfort and increase cost of running and operations of houses. The study directs that building design should incorporate both passive and active strategies for thermal comfort with respect to the environment and climatic conditions in future design of the housing units in Mansehra. Local passive practices like south open courtyards with vegetation, verandas, and open terraces need to be revived with a modern touch to keep intact the aesthetics need. This will help to reduce energy demands and will help to maintain rising temperatures. It will also revitalize the old aspects of deep beauty, and sustainability with a sense of place, which is completely missing in modern design.

REFERENCES

Abbass, K., Qasim, M.Z., Song, H. Murshed, M., Mahmood, H., Younis, I. 2022. A review of the global climate change impacts, adaptation, and sustainable mitigation measures. *Environment, Science and Pollution Research*, *29*, 42539–42559.

Abubakar, S. M. 2019. Pakistan 5th most vulnerable country to climate change, reveals Germanwatch report. *The Daily Dawn*, *December 4, 2019*.

Ali, K. A., Ahmad, M. I., Yusup, Y. 2020. Issues, Impacts, and Mitigations of Carbon Dioxide Emissions in the Building Sector. *Sustainability*, *12* (18), 7427. https://doi.org/10.3390/su12187427

Ali, S. F., Rakshit, D. 2019. Utilization Passive Design Strategies for Analysing Thermal Comfort Levels Inside an Office Room Using PMV-PPD Models. In: Tyagi, H., Chakarborty, P., Powar, S., Agarwal, A. (eds) Solar Energy. *Energy, Environment and Sustainability*, Springer, Singapore, 35-57.

Anwar, M.W., Ali, Z., Javed, A. Din, E., Sajid, M. 2021. Analysis of the effect of passive measures on the energy consumption and zero-energy prospects of residential buildings in Pakistan. *Building Simulation, 14*, 1325–1342 (2021).

Chahal, K. S., Aulakh, R. S. 2018. Impact of Courtyard Planning on Spatial Design. Malaysian hospitals. *Procedia-Social and Behavioral Sciences*, *105*, 171-182.

Chai K-C., Ma X-R., Yang Y., Lu Y-J., Chang K-C. 2022. The impact of climate change on population urbanization: Evidence from China. *Frontiers in Environmental Science 10,* 945-968.

Finance Division Government of Pakistan, 2015. Pakistan Economic Survey 2019-20. *Economic Adviser's Wing, Finance Division Government of Pakistan, Islamabad*.

Ghafoor, G. Z., Sharif, F., Khan, A. U., Hayyat, M. U., Farhan, M., Shahzad, L. 2020. Energy Consumption and Carbon Dioxide Emissions of Residential Buildings in Lahore, Pakistan. *Polish Journal of Environmental Studies*, *29* (2), 1613-1623.

International Energy Agency. 2019. *Global Status Report for Buildings and Construction 2019*, IEA, Paris.

Jamaludin, A. A., Hussein, H., Tahir, K. M. 2018. Satisfaction of Residents Towards Internal Courtyard Buildings. *Journal of Design and Built Environment, 18* (2), 61-69.

Khan, M., Khan, M. M., Irfan, M., Ahmad, N., Haq, M. A., Khan, I., Mousa, M. 2022. Energy performance enhancement of residential buildings in Pakistan by integrating phase change materials in building envelopes. *Energy Report, 8,* 9290-9307. .

Loo. S-H, Lim, P. I., Lim, B. H. 2021. Passive design buildings: A review of configuration features for natural ventilation and daylighting. *Journal of Physics: Conference Series*, 2053

Maan, Y. A., Akhtar, M., Jamil, M. 2021. Role of Building Sector in Consumption of Energy in Pakistan. *Sir Syed Journal of Education & Social Research, 4*, (2), 236-242. .

Mahar, W. A., Verbeeck, G., Singh, M. K. & Attia, S. 2019. An Investigation of Thermal Comfort of Houses in Dry and Semi-Arid Climates of Quetta, Pakistan. *Sustainability, 11* (19):5203.

Mahar, W. A., Amer, M., Attia, S. 2018. Indoor thermal comfort assessment of residential building stock in Quetta, Pakistan. *European Network for Housing Research (ENHR) Annual Conference 2018*. Uppsala University, Uppsala, Sweden.

Maleki, B. A., 2011. Shading: Passive Cooling and Energy Conservation in Buildings. *International Journal on Technical and Physical Problems of Engineering (IJTPE), 9* (3), 72-79.

Neill, P. 2020. Construction industry accounts for 38% of CO2 emissions. *Environment Journal*.

Nicol, J. F., Raja, I. A., Allaudin, A., Jany, G. N. 1999. Climatic variations in comfortable temperatures: the Pakistan projects. *Energy and Buildings, 30* (3), 261-279.

Nugroho, A. M., Citraningrum, A., Iyati, W., Ahmad, M. H. 2020. Courtyard as tropical hot humid passive design strategy: case study of Indonesian contemporary houses in Surabaya Indonesia. *Journal of Design and Built Environment, 20*, (2), 1-12.

Pakistan Bureau of Statistics. 2017. Census Survey, Government of Pakistan.

Rajapaksha, I., Nagai, H., Okumiya, M. 2003. A ventilated courtyard as a passive cooling strategy in the warm humid tropics. *Renewable Energy, 28* (11), 1755-1778.

Rehman, A. U., Ghafoor, N., Sheikh, S. R., Kausar, Z., Rauf, F., Sher, F., Shah, M. F., Yaqoob, H. A. 2021. Study of Hot Climate Low-Cost Low-Energy Eco-Friendly Building Envelope with Embedded Phase Change Material. *Energies*, *14,* 3544. .

Shaikh, N. A. 2021. Carbon footprint and construction industry. *Pakistan & Gulf Economist*, *January 11, 2021*.

Shakir, M. M., Ahmed, S. 2014. Economic functioning of secondary cities of Pakistan and its integration with the physical land use: Case of Larkana and Mansehra. *Journal of Research in Architecture & Planning, 16*, 33-54.

Shaheen, N., Arif, S., Khan, A. 2016. Thermal Performance of Typical Residential Building in Karachi with Different Materials for Construction. *Mehran University Research Journal of Engineering & Technology, 35* (2), 189–198.

Tataresta ghi, F., Ismail, M. A., Ishak, N. H. 2018. A Comparative Study of Passive Design Features/Elements in Malaysia and Passive House Criteria in the Tropics. *Journal of Design and Built Environment*, *18* (2). 15-25.

Umar, M. A. 2018. Population control a way to tackle climate change. *The Express Tribune*, *April 30, 2018*.