Passive Climate Control for High-Density Buildings in Doha

Using passive design methods in reference to the cultural identity of Doha in a high-density mixed-use and residential development

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Abstract

The recent interest in environmental sustainability for the rapid growth of urban centres in the Gulf emphasises the use of technological solutions to deal with the challenges caused by urbanisation. This is especially true for sub-tropical zones such as Doha, Qatar, where the revival of passive design solutions as a regional and vernacular approach, helps the discourse for the future of sustainable developments in the old downtown area of Doha. The capital city is experiencing the construction of a plethora of glass and concrete high-rise structures due to the cities recent global economic success. These structures highlight the use of active systems for cooling and heating the air tight towers ultimately disassociating the interior environment from the external climate. The strong ties between the industrial and technological sectors are indicators of global affluence, prompting environmental management groups to focus on the efficiency of active cooling/heating technology. This approach is seen as short sighted in sub-tropical regions. The research project will focus on, how can passive climate control design methods be applied to a high-density mixed-use residential development to reflect cultural identity in hot-dry climate conditions?

The literature review of this project considers several design principles regarding passive climate control design and traditional design techniques. A general overview of the passive design principles and cultural considerations are explored as well as specific Qatari/Islamic design principles. The case studies examine the ideas explored in the literature review, such as Masdar Institute in Abu Dhabi and Seef Lusail in Doha.

The architectural design outcome will be a high-density mixed-use residential development that responds to the local climate conditions and cultural identity of Doha. The design will attempt to avoid the use of active systems, such as active heating/cooling systems, and rely on passive means to create climate comfort. The research will provide the tools to use climate information and translate this into formal solutions by means of qualitative data to respond to climate conditions. The result will achieve a revitalised residential area in Msherieb, connecting the past with the present using passive climate control in reference to traditional design techniques as a design driver.
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CHAPTER ONE

INTRODUCTION
1.1 Background of the project

The recent urban developments in the Middle East reveal an absence in the natural evolution of architecture in the region. The focus of this project is on Doha, the capital of Qatar, where the post 1950s exports of oil and gas saw a notable increase in state wealth and a trend towards globalisation. This development resulted in attracting foreign investment and consequently a rapid urbanisation of the capital city. Adopting foreign design principles, construction methods, and materials diminished the local identity and sustainable development of this rapidly homogenising Middle Eastern city.

The dramatic expansion of Doha along the main arterial routes left the downtown area; known as Old Doha, decaying, sprawling, and overcrowding. As a result, the downtown area is in need of regeneration.

The regeneration of Old Doha in Qatar is a plan prompted by the Qatar National Vision 2030 (QNV2030). This initiative, similarly found in other Gulf countries, attracted a number of ambitious concepts to revitalise and sustain an expanding urbanisation and provide better standards of living for the generations to follow. This project, therefore, will explore bridging the past, asserting cultural identity, and developing a climate oriented construction with contemporary capabilities.

Positioned in a flat desert landscape along the coastline of the Arabian Gulf, the Islamic city of Doha is the largest city in Qatar with just over 80% of the population inhabiting the city and its suburban areas¹. The area of this project is Old Doha, south of the emerging business district of Dafinah or West Bay. Old Doha, once the heart of the city, is characterised by its compact neighbourhoods. It is established on three scalar components – the urban environment, the natural environment and the house². The form of the urban plan and buildings are predicated by social factors, privacy and most importantly, climate.

The climate classification for Qatar is positioned in the hot dry arid zone, according to the Köppen-Geiger classification system. The average annual temperature is around 25°C. The hottest month is July, reaching up to 45°C, while the coldest month is January, dropping as low as 10°C. The relative humidity varies between 34% and 75% with an average annual humidity of 56%. Annual precipitation is less than 100mm. Qatar receives high levels of solar radiation, above 6kWh/m²/day³.

² Ibrahim Mohamed Jaidah and Malika Bourennane, The History of Qatari Architecture from 1800 to 1950, (Milano: Skira Editore, 2009), 12
1.2 Project Outline and Research Question

The proposal is oriented towards a high-density mid-rise residential and mixed-use development in the special development zone of Msheireb area in Old Doha. The 2.4 hectare site is located along the Business quarter and the Heritage quarter facing north towards the Arabian Gulf.

This project is part of the Msheireb Downtown master plan guided by a seven step local architectural language, developed by Msheireb Properties:

- **Continuity**: Achieve continuity between the past, present and future.
- **Individual and Collective**: Achieves harmony and cohesion through individual developments bounded by a common language.
- **Space and Form**: Reflects the character and informality of the traditional ‘carved city’.
- **Home**: Delivers exceptional living environment and offer privacy and security, the spirit of family and sense of community.
- **Transition**: Develops a shaded environment with human priority, comfortable and memorable network of spaces.
- **Climate**: Implements technology of old and new to achieve maximum comfort with minimum energy use. Creates shade, minimises heat gains and harnesses natural forces.
- **A New Language**: Builds architectural tradition; rich in reference and strong in resonance understood by all.4

The research question developed for this project considers this architectural language and highlights one of the steps to act as a design driver to come up with a formal outcome:

*How can passive climate control design methods be applied to a high-density mixed-use residential development to reflect cultural identity in hot-dry climate conditions?*

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1.3 Aims and objectives of the project

The old downtown of Doha has poor housing, urban sprawl, decaying infrastructure and utilities. Most of the area must be demolished and rebuilt except for four heritage houses located in the heritage quarter. The juxtaposition of the contemporary globalised West Bay area and the deteriorating traditional Old Doha area shows disconnect between the past and present. The ideas of upholding cultural values and traditional design techniques in architecture have been sacrificed for the sake of 'technological progress'. The eclectic styles of West Bay’s high-rise urban developments have used traditional forms simply as façade treatments, and the openness of the fabric encourages major solar heat gain, causing stress on active cooling systems and energy consumption.

The aim of this project is to develop design principles by using passive climate control techniques embodying Qatari cultural references to connect the past with the present and regenerate old Doha. Inherently, environmental and cultural considerations will be the main determinants for social and economic revitalisation of old Doha.
1.4 Scope and limitation

The scope of this project is to investigate passive climate control and traditional design techniques related to the hot-dry climate of Qatar. This investigation will encompass research associated with the:

- Urban Planning rules
- Building height
- Residential unit floor plan and orientation
- Proximity of one building to another
- Orientation of pathways (Sikkas)
- Traditional cooling components
- Contemporary cooling components
- Basic information regarding building materials
- Sourcing water for landscape in a dry environment
- Public to private transition and spaces
- Programme arrangements
- Hardscape and Softscape

This research will determine the appropriate design for the site in Old Doha. The design principles developed in this project can be applied to several sites. However, this project will apply these principles to only one site in Doha. The research is limited to descriptive research, where the results will be based on the qualitative analysis of climate control methods and basic ethnography of Qatar. This will exclude quantitative analysis of the passive climate control elements used at the building and human experience scale. The optimisation of the design techniques used in the proposed mixed-use residential development can be included in future research. The proposed development is part of a larger development, therefore requirements such as backup power generator rooms and central server rooms are located offsite.
1.5 State of knowledge

This section is a short overview of important literature and precedents in the field of this research topic.

1.5.1 Literature

The History of Qatari Architecture 1800-1950
By Ibrahim Mohamed Jaidah and Malika Bourennane

Jaidah and Bourennane explored the history of Qatari Architecture from the early 19th century to the mid-20th century before the rapid urbanisation and increase in the state wealth due to oil and gas exploits. This book details the cultural practices and climatic conditions that shaped the traditional Qatari house. The book will support the project by defining the timeline of architecture in Qatar and avoid the disconnect between past and present, allowing for a natural evolution into urbanisation and the technological advancement under passive climate control methods. The authors briefly looked into the future of Qatari Architecture by explaining the underlying structure of the modern urban form but stopping short of the 'how'. For this project, historical passive climate control techniques and cultural practices are studied and applied to taller and denser residential buildings in Msheireb. This book is a study of the past architecture in Qatar so it does not consider the economic viability of the general arrangement of residential units nor the issues of water usage for cooling methods, which this project must take into account.

Passive Building Design: A Handbook of Natural Climatic Control
By Narendra Bansal

Bansal describes the natural climatic control concepts and the elements that create comfortable conditions for occupants and conserve energy in buildings. The book displays a quantitative approach to climate control techniques supplemented by case studies of passive climate controlled buildings from around the world. For this project, the literature is used as a directory for passive climate control concepts, if applicable, to be used in the design of the development in Doha. The book describes passive techniques in a general and experiential manner accompanied by examples of standalone buildings that apply such techniques. This project expands the application of these techniques to an urban scale as well as individual buildings yet narrow down to a specific site with a steady climate. The research will expand on this literature by providing solution for a purely passive development rather than a mix of both passive and active solutions.
Climate Responsive Building: Appropriate Building Constructing in Tropical and Subtropical Regions

By Paul Gut and Dieter Ackerknecht

Gut and Ackerknecht presented the theoretical knowledge for thermal processes and climate responsive design principles. The text describes the practical application of the design principles in sub-tropic and tropic climate zones. This project focuses on the use of design principles applied to hot-arid climate conditions. The design principles described are passive climate control techniques driven by the need for reducing energy consumption and are less reliant on non-renewable energy sources. The literature serves as part of the qualitative research guidelines for the proposed development regarding climate responsive design. The authors addressed the economic and cultural implications as part of the design process. The main factors considered are: the type of building, orientation, vegetation, programme arrangement, materials, shading, and natural cooling. The project will use these design principles for the development of a contemporary building typology as opposed to the low-rise single unit case studies presented in this book.

1.5.2 Precedents

Masdar Institute – United Arab Emirates

By Foster + Partners

Designed by Foster + Partner, Masdar City is the first zero carbon and zero waste development powered by renewable energy\(^5\). Masdar Institute is inspired by Arab traditional architecture where passive climate control systems are used to alleviate stress on active climate control. This research will study the way Foster applies passive techniques to contemporary buildings and outdoor spaces. The relationship between buildings and different social programmes offers an insight to design solutions for negative space and the arrangement of programmes. The difference in programmes between the research project and Masdar City is that the site provides other challenges that require different methods of cooling. The proposed development will employ some of Masdar Institute ideas for taller buildings and rely on active systems only to aid passive systems.

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Xeritown Urban Complex – United Arab Emirates

*By X-Architects*

Xeritown is a 59-hectare urban complex in Dubai providing housing for 7,000 inhabitants. This proposed desert city takes its urban form from the natural environment and local climate. The relationship between climate and urban form will help provide climate oriented urban design rules for the project at a much smaller scale. The urban complex doesn’t detail individual buildings with traditional cooling techniques, however the project is still at the concept stage. The proposed research project will go into the details of individual buildings; the house and transition spaces.

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Seef Lusail Vertical Fareej – Qatar
By X-Architects

Seef Lusail is another proposal aiming to develop a new housing typology similar to the research proposal. The vertical Fareej or neighbourhood is like a traditional neighbourhood, made vertical to deal with population growth and urbanisation. This precedent provides opportunities to study circulation patterns, projecting elements, green spaces, voids and social spaces as part of traditional design methods. This project is less about climate oriented design and more a consideration of socio-cultural factors. The research project will take this work a step further and develop a conglomerate of passive climate control methods and Qatari cultural and social practices.

Figure 4 Seef Lusail Vertical Fareej (Credit: X-Architects)
1.6 Methods

The proposed descriptive research method will use qualitative analysis of historical and contemporary methods of climate control and a brief study of the Qatari/Islamic culture to develop a design methodology.

The problem defined in this research is based on the critical analysis of a selected site. A field of interest is then established and selected literature and precedents will then be reviewed.

The site chosen is Old Doha and the problems identified are; the loss of cultural identity, unsustainable developments and the poor housing conditions of Old Doha. The proposed solution is a mixed-use and residential passive climate controlled development that maintains cultural identity.

The process will be defined as follows:

- **Quantitative data:** Climate data, environmental conditions and planning regulations are recorded. This data provides the limitations for the proposed development. The employment of the psychrometric chart, wind rose, and rainfall data provides calculated data during the design phase.

- **Qualitative data:** Literature and precedents help to develop new ideas and identify the most relevant information. This information is used in the design phase, where concepts are drawn up and evaluated.

- **Result:** If the research does not yield the preferred result then the qualitative data is revisited and the process is iterated.

- **Design:** The developed results are deployed.

During the research process of alternating between the qualitative data and results, a series of iterations between the three scales of the design; urban form, building form, and space and human experience are hand drawn until there is satisfied congruency. Each scale has a role in the passive climate comfort and cultural identity of the proposed development.

Concept computer models are created to vindicate the hand drawn design that may have exaggerated elements to drive the design ideas. The computer model is then refined and analysed iteratively until the intended experience for the occupant is achieved.
1.7 Results of the research

The written document proposed a passive high-density mixed-use residential development, referencing the cultural identity of Qatar. The developed design methods and principles are tools for the urban development project in an environmentally conscious region. The proposed development will achieve a continuity between the past and the present while allowing for a sustainable growth for the future.

The research showed the built elements influencing passive climate control at three scales; the urban scale, the building scale and the human scale. All the scales are interlinked; however, each scale can assist in the thermal comfort of the occupant while referencing the cultural identity of the region. The formal result of this research appears uniquely Qatari, where the urban arrangement and individual buildings design apply traditional and contemporary design concepts harmoniously, to meet the need for high-density residential development in the area.

The project is developed according to the averages of the climate data, therefore, the proposed urban development will require active systems to mitigate the effects of extreme climate conditions. Future works will look into developing the passive systems to deal with the extreme climate conditions.
CHAPTER TWO

LITERATURE REVIEW

This literature review establishes the theoretical position that will influence the proposed development. Several topics are covered, however the literature review does narrow down to a main concept that drives the design. The review provides a critical evaluation of the material available and identifies the principles for the further development of the proposed development in the Msheireb area of Doha; the capital of Qatar.
2.1 Ecological High-rise

The Msheireb area in Doha is undergoing planning changes to permit the construction of taller buildings. One solution for urbanisation of Old Doha is to use high-rise typologies. To consolidate the idea of a high-rise typology with the concept of passive climate control Ken Yeang, a pioneer in ecological high-rise buildings, describes how the physical and climate conditions of the site influence the formal outcome of the structure.

Yeang’s, *The skyscraper bio-climatically considered*, takes the concept of passive climate control to the next step, calling it Bioclimatic architecture. This not only provides thermal and visual comfort but also exploits the environmental resources for low-energy consumption. Yeang recognises the implications of bio-climatic design in terms of a building’s character “The fundamental premise is that the understanding and incorporation of the external and internal environmental aspects of the skyscraper will contribute to its architectural expression.”7 Some regionalist expression can be achieved by simply designing to the local climate conditions. The research project also considers Yeang’s opinion that a building must incorporate, “… economics, culture, building programme, site contours, views etc.”8 The result is that buildings within the same city won’t look similar. Yeang goes on to rationalise the need for climate responsiveness in the capitalist era, where profit is at the top of the agenda when designing high-rise buildings, “The most obvious justification for the bioclimatic design approach to the skyscraper is the lowering of life cycle, financial and energy costs which arises from lowering the energy consumption in the operations of the building”9. Yeang recognises that all details of the high-rise building such as partitions and vertical circulation must be taken into consideration when applying ecological design. The aim of passive climate control in the research project is for thermal comfort. This literature is used as a general overview of sustainable solutions for the high-rise typology in a specific region and provides a justification for the design outcome through the use of passive climate control methods.

Yeang’s high-rise projects in the Middle East fail to address specifications of the materials used and the negative implications of the high-rise buildings in specific regions. For example the Ghorfa Tower in Kuwait, an arid desert climate, is a 43-story skyscraper that applies a lot of passive and green technology to create thermal comfort. The height of the structure is to be questioned if it is appropriate for the region when considering passive climate control in

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terms of solar heat gain and natural ventilation. This example clarifies that Yeang’s research doesn’t always consider the appropriateness of the building typology to the site.

Paul Gut and Dieter Ackerknecht provide general guidelines for the shape and volume of buildings in hot-arid regions in their book; *Climate Responsive Building*, mentioning “The heat exchange between the building and the environment depends greatly on the exposed surfaces. A compact building gains less heat during the daytime and loses less heat at night. Therefore, the ratio of surface to volume is an important factor.”10 Yeang’s idea of a high-rise may not be the best option for this project, rather breaking a high-rise into several mid-rise buildings in a compact urban form will prove to be a better solution. Gut and Ackerknecht also acknowledged that the socio-cultural, as well as the functional requirements, could define the building form.

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2.2 Towards Regionalism

Jeffrey Cook, an associate professor in Arizona State University, uses the term regionalist to “… denote the dominance of regional considerations in designing the human-made environment. All architecture and urbanism by the accident of geographic location has region and can be called regional. Regionalist as a term and as a goal implies a designed fit to region”\(^\text{11}\).

Cook critiques modernist architecture; “Industrial culture is presently characterized by the international trivialization of human life. For instance, the glass box continues to be reproduced as a design solution in all climates and in all locations as a symbol of being modern, as an image of technology, and as a celebration of irresponsible wealth. An examination of this current architectural artefact using any scientific, intellectual, or experiential criteria reveals how trivial this response is in comparison with known alternatives”\(^\text{12}\). Cook highlights the need for designing buildings based on climate, so that architecture may establish and communicate the culture and character of the region. Regionalism in Doha is not a new concept; architecture has always been designed in this way until the mid-20\(^{\text{th}}\) century. The research project will liberate the compact mid-rise typology from its globalised trend and promote passive climate control techniques to act as a design driver while maintaining a cultural identity. The literature provided a justification for pivoting away from the high-rise solution to new typologies that focus on traditional design.

2.3 Referencing Qatari Tradition

Ibrahim Mohamed Jaidah and Malika Bourennane are pioneers of a new architectural movement in Qatar that combines the influence of traditional Islamic architecture with contemporary expression. They explore the history of Qatari Architecture in regard to traditional space arrangement and local passive climate control technology that respects cultural identity and provides comfort for the people living in the region.

The authors describe the form of the traditional urban environment as a development inspired by the single family home. This form, expanding and subdividing into residential clusters occurs along the main roads leading to the town centre. There is an element of random urban growth that occurs in these residential clusters.

For the scale of this project, it is not possible to expand in such a way; the research project must adhere to existing planning regulations and the urban environment. One method to create an appropriate urban form is by using the architectural language of Msheireb, the idea of the ‘carved’ city.

Jaidah and Bourennane discuss several key space types that have become essential for residents; these include the

- **Majlis**: A formal room for receiving guests
- **Iwan**: A vaulted hall the opens up to the courtyard
- **Qa’a**: The main hall of a house
- **Ghurfah**: A room
- **Hamam**: Bathroom
- **Sahn**: Courtyard
- **Khazina**: Storage room
- **Riwaq**: Arcade (transition space)

These traditional spaces are shaped not just by cultural practices but also by climate conditions13. To simplify the terms mentioned, the authors, categorised them into four kinds of space; private, semi-private, semi-public and public. With these four categories, it is easier to translate the traditional Qatari house into a contemporary typology. Not only does the literature provide explanation of spatial arrangements in dwellings it also describes the traditional climate control technology used to create comfort for the occupants;

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• **Badgir**: Multidirectional wind towers. Found mainly on the roof and is the highest point of a building used to guide wind into buildings or spaces.

• **Malqaf**: Unidirectional wind scoops. Can be used on external walls, ground or roof. Used to guide wind into buildings or spaces.

• **Mashrabiya**: Wooden screens used as shading. These screens are used in conjunction with water to create the cooling effect.

• **High Thermal Mass**: The traditional Qatari house uses thick walls with high mass, primarily mud and stone blocks. The roof is constructed using timber beams known as Danshal beams overlaid with Basgill, a type of bamboo, and Mangharour, a woven mat, then covered with a mud finish.

Jaidah and Bourennane provide many examples of two-storey dwellings using these systems and spatial arrangements. Hassan Fathy, in *Natural Energy and Vernacular Architecture*, argued “There is a clear need to further develop the traditional systems based on natural resources. Before inventing or proposing new mechanical solutions, traditional solutions in vernacular architecture should be evaluated, and then adopted or modified and developed to make them compatible with modern requirements.”

The literature does not provide direct solutions on how the proposed mixed-use and residential mid-rise development project can reference Qatari traditions, however, as Fathy suggested, the traditional systems must be modified.

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2.4 Microclimate

A microclimate is a climate affected by the site and design. The project site is in a maritime zone where temperature fluctuations are minimised, there is a slightly higher humidity during the peak summer period and the sea-land breeze is the prevailing wind.

Paul Gut and Dieter Ackerknecht discussed in their book; *Climate Responsive Building*, the appropriate passive design techniques that can be implemented to achieve the desired microclimate. They listed the following techniques for building in a hot-dry climate:

- Compact design and inward facing for protection from the sun and unwanted winds.
- Minimum surface area and openings exposed to the east and west.
- Allow cool winds to access building and ventilation.
- Allow for natural light.
- Shade windows, openings, outdoor areas, walls and roofs
- Enclose courtyards to allow for cool air to pool, protect from harsh winds, shade and develop adequate ventilation
- Shade high thermal capacity walls from the east and west to absorb heat during the day and release during the night. Most suitable materials include solid earth, stone or brick walls.
- Orient openings towards prevailing breeze that can be shut or opened when needed.

Gut and Ackerknecht explain that evaporative cooling integrated into a passive design, such as the wind towers with the aid of fans, are required during extreme conditions\(^\text{15}\).

This literature will aid the research project in the design for the specific site in Old Doha. However, these techniques must translate into a use for the design of taller typology buildings and take into consideration the integration of these techniques for a vertical neighbourhood, rather than just a compact arrangement of a low-rise single dwelling.

2.5 Living Passive

Much of the traditional building design of Qatari Architecture is based on passive design techniques that suit the local climate. This section of the literature review discusses the use of traditional building techniques for the proposed Qatari residential and mixed-use building, helping to provide thermal comfort for the occupants.

Narenda Bansal’s *Passive Building Design: A Handbook of Natural Climatic Control*, describes the main concepts as: reduction or the increase of solar heat gain; reduction or increase of internal heat gain; reduction of heat transmission into the building; increase or reduction of heat loss and the use of earth walls for humidity control16. This list of concepts can be applied to the many climatic conditions that affect the comfort level of the occupants. The literature suggests that there is a correlation between energy consumption and comfort level. Many of these concepts deal with active climate control systems in Qatar. Bansal lists the data required to be analysed, to then translate into building design; site selection, orientation, determination of solar angle, arrangement and shape of the building, positions and sizes of the openings and selection of building materials17.

The challenge of the climate of Qatar is during the harsher months, temperatures can be up to 40°C. This high external temperature exposes a serious limitation on the efficacy of passive techniques. Gut and Ackerknecht argue, “it seems almost impossible to fulfil today’s higher requirements and create a comfortable, cool indoor climate for living and working during the hot season with only traditional methods and without additional technical means”18.

Kenneth N. Clark’s, *Desert Housing*, mentioned additional influences in the design of desert housing such as; cultural considerations, governmental planning regulations, and the impact of non-renewable resources19.

The book provided a way that local climate studies can be used as data to provide formal solutions for this research project. Bansal describes the basic science behind passive climate controlled buildings. With this information, the research can look into formulating new passive climate control solutions in conjunction with traditional design techniques for high-density buildings in the Doha region, without imposing foreign ideas.

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2.6 Passive Thermal Comfort

The main purpose of passive climate control in the research project is human thermal comfort. It is therefore important to understand thermal comfort standards before implementing passive design strategies.

Doreen Kalz and Jens Pfafferott, define human thermal comfort as the thermal equilibrium when the “human body and its surroundings and the person’s expectation of the surrounding conditions are satisfied”20. This definition was derived from the ASHRAE standards. Kalz and Pfafferott apply a static approach to thermal comfort, “The criterion for thermal comfort is stipulated as an average operative room temperature of 24.5°C for the summer and 22°C for the winter period, with a tolerance range depending on the predicted percentage of dissatisfied occupants: ±1.0°C, ±1.5°C, and ±2.5°C”21.

Antony Wood and Ruba Salib argued against the use of the ASHRAE standard as the static approach is seen as a narrow definition for thermal comfort, which cannot be easily achieved by means of passive climate control. The authors argue that there are different influences on occupants of buildings that use passive systems as opposed to active systems. A passive system inherently influences the preference and tolerance of the occupant extending the tolerance over a wider temperature range. There is a lower expectancy for the homogeneity of air temperature and humidity than with an active system. This is due to the adaptive nature of people within their context. Therefore, the comfort zone defined in this literature is between 18°C and 24°C with relative humidity between 30-60%22.

According to the literature, using passive systems in a climate such as Doha does not have to adhere strictly to the operative room temperature required for optimum comfort level, rather people who occupy a well-designed passive building with adaptive qualities will be comfortable for most of the year, the exception will be in extreme climate conditions. With this in mind, Wood and Salib adapt an adaptive thermal comfort standard which takes cultural, social, climatic and contextual factors into account. Adaptive in this case, means building occupants have control over their environment, further extending the normal range of comfort. This concept corresponds well with the traditional Qatari practice, where gathering spaces will be located in different locations in the house depending on the climate.

The final design will not only aim to satisfy the occupant physiologically but also target the psychological sense of comfort. This can be achieved by providing people with a degree of

22 Antony Wood and Ruba Salib, Natural Ventilation in High-Rise Office Buildings, 1st ed. (Florida: CRC Press, 2012), 21
control over any source of thermal discomfort. The analysis of thermal comfort is an important part of the research project as this factor gives the architectural design the means to adapt to the climate changes throughout the year. The research project will rely on building adaptation and human behaviour to provide thermal comfort.
CHAPTER THREE

PRECEDENT REVIEW

The precedent review provides a critical analysis of existing and proposed material, highlighting elements to be developed and applied to the proposed mixed-use residential development. This investigation establishes the necessary design tools for a rational process to take place achieving the desired design narrative.
3.1 Masdar Institute – Abu Dhabi

Designed by Foster + Partner, Masdar City is the first zero carbon and zero waste development powered by renewable energy. The Masdar Institute is inspired by Arab traditional architecture where passive climate control systems are used to alleviate stress on active climate control.

Figure 6 Site Plan of Masdar City (Credit: Mahayleyyah)
Orientation: The building is oriented N-E to S-W to minimise the solar exposure on the external walls. One side of the pathways will always be shading for occupants to walk outdoors. Openings are oriented towards the sea breeze from the N-W.

The pathways are oriented so they are shaded at one side throughout the day. The sun rises later in the morning and sets earlier in the evening so the data for 6am and 6pm is not recorded.
The covered threshold openings are ~4m tall with permeable material allowing breeze to come in freely.

**Thresholds:** The building is oriented N-E to S-W to minimise the solar exposure on the external walls. One side of the pathways will always be shading for occupants to walk outdoors. Openings are oriented towards the sea breeze from the N-W.

The gates are generally permeable for the breeze to flow freely, they are made of meshed wood. Unlike the private areas the semi-public courtyards and surrounding buildings benefit from a space that doesn’t retain cool air. This is due to the heat transfer that occurs between the outside ambient air and the courtyard environment. The timber acts as a humidity control for the air.
The institute has an underground level that expels the indoor warm air through a pipe that relies on the pressure difference (different to the traditional technique). The windcatcher component is required to be three meters above the roof as the roof has solar panels that create a ‘heat haze’. This phenomenon warms the air surrounding the panels.

The square footprint of the traditional windcatcher allows for positive and negative pressures that let a breeze flow through the interior and exterior spaces and expel stale warm air. The triangular shape is more efficient, only taking in air to the underground space. The warm air moves out of the ground level.
Windcatcher: The windcatcher designed for Masdar Institute mimics the traditional windcatcher found in the UAE. The traditional windcatcher, works for the interior spaces rather than being a stand-alone feature. The windcatcher catches the breeze at higher altitude and conducts it to the space below.

GRC Facade: The façade form is wavy, to lower the surface area for solar heat gain. The shape efficiently shades the floors below and ground level. ‘Mashrabiya’ or decorative screens are also used to shade the openings. The required thermal conductivity can be achieved by the double layer external wall. The panels have high thermal conductivity while the inner wall has low thermal conductivity. The use of GRC panels cannot be considered as highly sustainable due to the cement content in the material. The traditional timber screen is a much more sustainable option and a readily available material. An example of timber screens implemented on a large scale project is the Aldar Central Market building in Abu Dhabi.
Xeritown is a 59-hectare urban complex in Dubai providing housing for 7,000 inhabitants. This proposed desert city takes its urban form from the natural environment and local climate. The development considers seven natural and environmental forces including wind, sun, water, climate reactive living, energy, soil and social interaction. This review will look at five of these conditions that relate to the research project.

Xeritown promotes a pedestrian-oriented city. A network of spaces on several scales, ranges between blocks to districts, provides different levels of social interaction. The public spaces help create an identity for its residents and neighbouring communities share the experience.
3.2.1 Social Interaction and Community

**Pedestrian Surface:** Sikkas or pathways are a mix of several widths adjacent to public attractions and commercial spaces. Paths intersect and form spaces for social interaction. Public pathways are not directly E-W or N-S so there is shading on the pedestrian surface.

**Public Attraction and Commercial Space:** The fractured arrangement of the public and semi-public spaces occur in the centre of the development. This fracturing suggests that certain public spaces are occupied at different times of the day or year according to seasonal changes.

3.2.2 Wind

- Cool breeze from the sea
- Turbulence created by rugged skyline
- Cool breeze through buildings

Figure 19 Pedestrian Surface (Credit: X-Architects)
Figure 18 Public Attraction and Commercial Space (Credit: X-Architects)
Figure 20 Physical Model Responding to Wind (Credit: X-Architects)
The buildings are oriented to channel cool wind from the N-W through the development while blocking warm wind from S-E. The rugged urban fabric and vegetation on the S-E end deflects warm wind away from the narrow streets and prevent turbulence. Dubai has relatively high humidity in comparison to Doha, therefore, Xeritown can afford to have wide linear streets open to the N-W without causing much discomfort.

### 3.2.3 Landscape

The urban development is made up of 50% built and impervious surfaces and 50% softscape. This is important to reduce the heat island effect as well as providing shading, humidity control and improved air quality.
3.2.4 Sun

The orientation of the development is not only important for wind, but it is also crucial for minimising solar radiation. Although the development is predominantly oriented East-West, it is also crucial for individual units within the building to be oriented correctly.

Observation: Placing solar panels on the windward side, as seen in this development, should be prevented and seen as undesirable as the radiative heat generated will be carried through to the rest of the development.

3.2.5 Water and Biodiversity

The orientation of the development is not only important for wind, but it is also crucial for minimising solar radiation. Although the development is predominantly oriented East-West, it is also crucial for individual units within the building to be oriented correctly.

Observation: Placing solar panels on the windward side, as seen in this development, should be prevented and seen as undesirable as the radiative heat generated will be carried through to the rest of the development.

The figure shows a section of the development responding to the sun. Facades are designed to take on solar radiation, while the compact urban form shades facades, courtyards and interior alleyways. Shaded arcades provide shade, and PV panels create energy for lighting. Placing solar panels on the windward side is observed as undesirable due to the radiative heat generated.

Greywater is reused for irrigation, while irrigation of vegetation helps create a microclimate and attracts flora and fauna to the site. Greywater is used by way of water-saving appliances to conserve water resources.
The microclimate benefits from the growth of vegetation. A study of the vegetation found in Xeritown shows trees and groundcover must handle the harsh desert conditions as well as require little water for irrigation to survive. The scarcity of water in the area will need appropriate water management. The use of grey water from the development helps alleviate the need for fresh water for irrigation.

Vegetation helps mitigate the heat island effect and provide a comfortable atmosphere on the active ground level for pedestrians.

3.2.6 Climate Responsiveness

The previous factors were all climate responsive however in this analysis of climate responsive design are formal building outcomes. Two housing typologies are studied; the apartment building and the townhouse.

Figure 28 shows the double surface facade allows for efficient cooling of the exterior walls of the building. This is especially useful on the East and West end walls where there is high solar heat gain.

Figure 27 Types of Vegetation in Xeritown (Credit: X-Architects)

Figure 28 Building Facade and Urban Compactness (Credit: X-Architects)
Figure 28 to 30 represent the climate responsiveness for an apartment typology. The semi-public terraces created in this case study promote social interaction between residents. Figure 31 to 33 represent the climate responsiveness for a townhouse typology.
Cool air is taken in and expelled through individual wind towers attached to the residential units below.

The courtyards provide a safe and pleasant environment for social and family life.

Naturally ventilated parking with pedestrian street entrance and shaded arcade from the main arterial route.
3.2 Seef Lusail Vertical Fareej – Doha

The vertical Fareej or neighbourhood is a traditional neighbourhood made vertical to deal with population growth and urbanisation. The vertical neighbourhood development displays circulation patterns, projecting elements, green spaces, voids and social spaces as part of traditional design methods.

This site is similar to the research project, both are located on a coastal zone where temperatures do not fluctuate drastically between day and night. The orientation of the development is E-W taking in the cool sea breeze during the day. Surrounded the development with vegetation will allow cooler winds to come from the land breeze during the night. The compact and irregular form of buildings throughout the development maximises shading.

The East and West side look quite exposed to solar heat gain, however, the requirement of maximising the value of developments facing the sea is an important part of the global socio-economic make-up of the liveable city.

Figure 34 Seef Lusail Site Plan (Credit: X-Architects)
The vertical neighbourhood attempts to translate the traditional residential house typology to a tower typology to address urbanisation. This is achieved by defining the floor plates of the tower then inserting the different unit sizes in between the floor plates to create a Fareej or a neighbourhood.

The mix of unit sizes ranges from one bedroom to three bedrooms slotted in between the floor plates. The facade of each unit is not on the same plane of the adjacent unit along the whole face of the building. This creates shading for surrounding units. The units arranged here are not restricted to one storey.
The vertical neighbourhood uses a combination of traditional passive climate control techniques and contemporary technology to create comfort for the occupants in a traditional neighbourhood.
3.3 Education City Housing – Doha

Courtyard with vegetation

Transition

Courtyard shading. In conjunction with non-shading courtyard creates positive and negative pressures

Three to four storey buildings contain one to two units per floor with a balcony.

Horizontal shading to stop summer sun and allow winter sun to enter

Vertical louvres used to shade East and West sun. The material used in this system is wood

Double wall made of solid inner wall layer with white GRC panel offset 1m from the inner wall

Double roof made up of a solid flat roof layer and an aluminium screen layer
To cope with the high number of student residents the complex must build upwards. The private and semi-private spaces are extruded upwards with several floors.

**Observation:** The only visible passive design techniques used for this complex are the double roof/wall system, roof and wall shading screens and compact urban form. The traditional windcatcher is used around the city however is not found in the residential complex itself.
CHAPTER FOUR

DESIGN

This section is explored through three scales informed by the design driver identified as passive climate control. The first scale is the urban form determined by environmental and climate conditions. These conditions are non-variable conditions that provide the limitations for expression of the urban form. The second scale is the building form and space, determined by the microclimate desired for optimum comfort of occupants. The third scale is the human experience through space and individual housing units, where climate comfort is achieved and cultural identity is expressed in the contemporary typology. The three scales are interlinked to provide passive climate comfort and display cultural identity.
4.1 The Urban Form

For this scale, a site analysis will be carried out and design responses drawn and modelled according to the environmental and climate conditions.

In Figure 43 the red highlighted area is the 2.4-hectare site for the proposed mixed-use residential high-density development. The regional prevailing winds come from the N-W also known as Shamals. These winds generally carry warm winds and on occasions 20-meter sandstorms from the Arabian Peninsula. The prevailing breezes come from the N-E sea breeze and S-W land breeze. The climate is described as a hot-arid climate in a maritime zone. In these climate conditions, each edge of the site must have a different treatment as a response. The N-W edge must act as a protective non-permeable edge to divert the warm winds and sandstorms away from the rest of the development. Constructing the protective side to be over 20 meters high is crucial to deflect sandstorms horizontally. The N-E and S-W edges must be semi-permeable, where the breeze is allowed to flow through under a controlled manner, in order to avoid discomfort by removing too much moisture from the air. The prevailing breeze is important to the urban form as it allows for passive humidity control, ventilation and cooling. The breeze is further utilised at the building and human scale. The S-E edge faces minimal breeze, as it is protected by the rest of the buildings in Msheireb. This edge has a high permeability for pedestrians and low building heights to create a harmonious urban flow with adjacent developments in Msheireb.
May-July regional prevailing winds blow from the N-W carrying sandstorms on some occasions.

2.4 hectare site in the Msheireb area of Old Doha for proposed mixed-use and residential high density development. Msheireb is within the confines of four arterial routes, Al Rayyan Road, Al Diwan Street, Jassim bin Mohammed Street and Wadi Mushireb Street.

Climate in Doha can be described as hot-arid climate conditions.

- Annual rainfall <100mm
- Hottest months are between May - October where temperatures are above 30°C
- Coldest months are between November - April where temperatures can drop down to 15°C

Figure 43 Site Plan
Orientation of buildings to stop unwanted warm air and sandstorms.

Day time sea breeze is allowed to pass through indirectly controls air temperature and humidity.

Night time sea breeze is allowed to pass through indirectly. Controls air temperature and humidity.

Building height and compactness must redirect unwanted warm air and sandstorms away from the rest of the developments.

Rough urban fabric decrease effects of turbulence from prevailing winds.

Figure 45 Site Plan and Edge Treatment of Proposed Development

Figure 44 Elevation and Wind Response
4.1.1 Urban Configuration

The urban form is resolved by examining the idea of translating the single unit traditional courtyard house to a taller building typology. The traditional courtyard house is expanded to a 30m by 30m courtyard building capable of inserting several small individual units along the edge. The courtyard will be explored further in section 4.2 at the building scale.
A linear composition of the courtyard buildings is drawn up as a starting arrangement. The linear arrangement is then manipulated to respond to the climate. Several arrangements are explored and physical models are created reaching the preferred urban form to develop further in this chapter. Rearranging the linear configuration according to climate allows for unique transition, and social spaces utilizing breeze and mitigating solar exposure.
The first configuration seen in Figure 49 is a basic urban form to work from and critically analyse. The configuration allows the breeze to flow through; however, a great measure of turbulence will occur in the public courtyard. During high winds from the North, the Venturi effect will increase wind speed and will create uncomfortable conditions for pedestrians. Shading will be an issue for pedestrians during summer as the pathways are on the N-S and E-W axis. The Western edge is quite open to sandstorms and warm winds from the N-W.

Figure 50 shows the urban form is a radial configuration, orienting the pathways towards the cool sea breeze, and shades from the sun. This form is much more compact than the previous building arrangement. The urban form has the potential for creating wasted space with units not fitting appropriately on the floor plates according to climate conditions. The compactness limits the breeze flowing through to the S-E edge.
Figure 51 is a combination of the previous urban forms, controlling breeze and solar exposure on the pedestrian level. This configuration provides an opportunity to manipulate the floor plans to suit passive climate comfort at the building and human scale. Figure 52 to Figure 54 shows the proposed urban configuration responding to the prevailing winds in an experiment with smoke. The smoke symbolises the wind reacting to the urban form.

The breeze infiltrates through to the end of the development effectively. The courtyard at the S-W doesn’t receive much breeze, however, ground windscoop resolve this issue.

Figure 52 Plan view showing breeze from the S-W

The breeze is controlled to flow slowly through the development without allowing strong breeze to create discomfort for pedestrians.

Figure 53 Plan view showing wind from North-West
Unwanted wind from the N-W diverted away from development.

Wind filters through openings and stopped at the courtyard. The rest of the development does not get affected. Pathways are safe from the wind due to orientation, compactness and width.

Figure 55 Plan view showing breeze from North

The prolonged unwanted wind from the N-W is diverted away from the development due to the rough urban fabric.

Figure 54 Elevation view showing wind from North-East
4.2 Building Form and Space

Now the urban form is resolved, the applications of traditional and contemporary design methods for passive climate control are employed to create the building form and space. The primary factors governing the microclimate are shading from solar radiation and thermal mass. The secondary factor includes ventilation. These factors are graded on the level of importance for thermal comfort. Other factors include planning regulations, aiding in densities, coverage and height of buildings.

4.2.1 Shading

Mitigating solar radiation is a crucial factor in creating passive climate comfort. Several shading techniques have been explored in the case studies in the previous section. However, there are limitations to be considered such as allowing for sufficient daylighting, and Doha’s planning regulations.

The Sikka, or pathway, for pedestrians, is oriented to avoid direct E-W and more importantly, N-S orientation so one side of the footpath is always shaded for pedestrians to walk or rest. Mid-day, during summer, in Doha is the most challenging part of the day as the angle of the sun is at 88°. To deal with this, a setback of only the ground floor allows the building to cantilever above the footpath providing more efficient shading mid-day. Additionally, this provides a human-oriented design that allows for a larger flow of pedestrians without compromising shading as shown in Figure 56.

![Figure 56 Shaded Pedestrian Sikka/Pathway](image)
To maximise the time for shading along the pathways throughout the day, a compact organisation of buildings is favourable. There are several implications, as mentioned before, regarding the daylighting and planning regulations. The Qatar National Master Plan dictates rules regarding the minimum building separation as shown in Table 1.

<table>
<thead>
<tr>
<th>Min.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3m</td>
<td>Non-habitable window/no window to non-habitable window/no window</td>
</tr>
<tr>
<td>4.5m</td>
<td>Habitable window to non-habitable window/no window</td>
</tr>
<tr>
<td>8m</td>
<td>Habitable window to habitable window</td>
</tr>
<tr>
<td>12m</td>
<td>Front facing façade</td>
</tr>
</tbody>
</table>

Table 1 Minimum building separation minimum rules

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Figure 58 Summer and Winter Shadow
The sun path study of the proposed urban development illustrates the method of minimising solar exposure using building and space arrangements. The winter sun path allows for adequate shading for buildings and courtyards throughout the day. The summer sun path is more exposed to the sun however the angle of the paths and compactness of buildings allow for shading in certain areas for adequate pedestrian comfort.

The width of the pathways is determined by planning the floor plans of the buildings. With the taller buildings found on the West and North sides of the development, protecting from the N-W prevailing winds, daylighting can be an issue. To resolve this problem, the main floor plates of each building are narrowed while doubling the single unit height, and gaps between units providing more daylight to permeate on to the pedestrian pathway. This is illustrated in Figure 60.

Shading is not only applicable to occupants directly, but it should also be applied to buildings. Thermal radiation is an issue if walls and roofs are directly exposed to the sun for a prolonged period of time, especially during summer. Wall and roof screens that have a relatively low thermal mass are a useful way to keep the building cool. The installation of the screens has to be on surfaces that have access to the daytime breeze, as the space between the high thermal mass surface and the low thermal mass screen can heat up. The South edge, receiving no

![Figure 59 Sun Map Diagram](image-url)

![Figure 60 Double Height Floor Plates for Daylighting](image-url)
breeze during the day, will rely on the roof shading that cantilevers far enough to shade the below wall during summer; as illustrated in Figure 61.

![Figure 61 Roof Screen for Shading](image)

### 4.2.2 Thermal Mass

The traditional Qatari house uses 500mm-600mm thick high mass materials with low conductivity and high heat capacity\(^{25}\). Maximising Net Floor Area in residential buildings is crucial in today’s economic and urban environment. Paul Gut and Dieter Ackerknecht describe an efficient method to reduce the thickness of the external thermal mass. Expanding on the shading of walls and roofs using screens, Figure 62 shows the use of a porous thermal mass material for re-emission of radiant heat, reflective surface for reflection of radiant heat, ventilated cavity reducing conductive heat transmission, and screen reducing direct solar heat gain\(^{26}\).

The screens must be of a low thermal mass material to allow the cavity to be cooled quickly during the night. Timber is an eco-friendly and low-cost material, traditionally used in Qatar for construction, and can be effectively used as wall and roof screens. An example of the large scale use of timber is found in Abu Dhabi, Aldar Central Market.


Timber material allowing heat transfer to cool space at night

Direct solar heat

East/West Wall

Cool breeze

Figure 62 Wall Screen

Figure 63 Aldar Central Market Timber Façade (Credit: Archdaily)
4.2.3 Ventilation

Air movement is an important part of climate comfort for occupants on the microclimate scale. It is useful to rid the space from the warm stagnant air and replace it with cool air. This is a secondary factor in passive climate control, because if the surrounding microclimate is not shaded, and the material is not appropriate for the hot-arid climate, then air movement will be of little benefit. Traditional Qatari residential buildings relied on two types of air movement: air movement by pressure, and air movement by convection27.

Air movement by convection in this urban development is created by the application of courtyards to each building. The courtyard takes advantage of the low density of warm air and produces a pool of cool air. Cool air constantly replaces warm air creating a steady air flow. This can especially be observed on the ground level where commercial spaces are located in a loggia space allowing cool air to flow freely as the spaces outside the building heat up during the day. Figure 49 illustrates the application of this phenomenon to the design.

![Figure 64 Courtyard Air Movement by Convection](image)

Air movement by pressure can be controlled and turned into an advantage by the use of wind catchers and wind scoops. These passive climate control methods are useful for cooling and ventilating individual residential units as well as courtyards. The Badgir or wind catcher relies on the difference in pressures between the windward and leeward sides at the highest point of

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the building. The windward; positive pressure side, takes in the fresh sea breeze and releases it into the unit or courtyard, accordingly, the warm stale air moves up into the vent to be expelled out at the leeward; negative pressure side, from the unit or up into the sky from the courtyard. Figure 65 shows the process of air movement through the wind catcher. In extreme conditions, active systems are integrated within the wind catcher in the form of fans and integrated evaporative cooling systems. Integration with technology means thermostats can be utilized to provide options to automate this process.

Figure 65 Windcatcher Cross-Section

The Malqaf or wind scoop is much more flexible with its location, as long as the intake is placed where the breeze is cooler than the air at the outlet. Figure 66 and 67 show where the Windscoops are utilised in the development. The Windscoop can be used on the walls of the building where there are cool sea breeze flows into the individual units, and on the roof where wind can be channelled similarly to the Windcatcher.
Figure 66 Ground Windscoop Cooling Leeward Buildings

Figure 67 Roof and Wall Windscoop
4.2.4 Planning

The Qatar National Master Plan requirement for a high-density residential development, known as the R5 Zone, is designated as 300-360 person per hectare or 160-190 dwellings per hectare. This provides an aim for density requirements for this development and dictates the maximum outdoor areas that can be provided in mid-rise buildings. The maximum building coverage is 50% of the site where much of the landscaping will consist of greenery. This will also mitigate the heat island effect, and provide a comfortable pedestrian microclimate. The maximum height for the high-density mixed-use residential development in Msheireb is 28m tall or ~7 floors. The tallest building will be on the N-W edge where it is tall enough to block the undesired prevailing winds from the N-W. The parameter of Msherieb consists of tall buildings that vindicate the tall structure on the edge of the development. This is possible due to the tribal culture that defines areas by wide roads traditionally.28

4.2.5 Building Form

The building form and space is developed from the urban form scale. The results of the urban form are overlaid with passive climate control solutions at this scale. This does not include components such as wind catchers, wind scoops and materiality in the experimental models as they are assumed to be fit for purpose based on the precedent review. The 1:1000 scale physical models are tested for wind response as seen in Figure 52 to 54, and the 3D CAD

massing models are tested for shading performance as seen in Figure 58. The results show the proposed development effectively controls prevailing winds.

4.3 Human Experience

The urban form and building form have already dictated most of the experiences affecting the occupants in the proposed development design. This part of the design focuses on the details of passive climate control and cultural identity.

The proximity of buildings in the proposed development design creates adverse effects to the air pressure. This starts from the urban form where air flows through narrow channels in between buildings. This increases wind velocity where pedestrians can feel discomfort from the loss of humidity in the air. When those channels open to a wide public courtyard, turbulence will be generated; this creates discomfort for the occupants. This type of air movement can be controlled by using trees on the ground level to allow the wind to flow in a controlled way.

In hot-arid environments, kitchens are generally detached from the rest of the residential unit due to the high internal heat gain. The internal walls of the residential unit will have little heat storage for effective night purge. The kitchen will be attached to the unit, so a partition wall with low heat transmittance is implemented in the design. The most effective wall is a 300mm hollow brick block wall where heat transmittance is at an acceptable range of 1.10 kcal/hm²°C²9. The kitchen will require a heat-escape flue that extracts the internal heat generated inside and a reasonable intake of cool air from the outside.

Water features are useful for human comfort in hot arid conditions where evaporative cooling is required to cool and humidify the air. Vegetation is used for extra shading, humidity control, and generally improves air quality. The shortage of water in Doha must be addressed in order for the implementation of these natural features. Greywater reuse is a sustainable solution for irrigation in this proposed development. These natural features will mostly exist in the open public, and semi-public spaces occupied for a prolonged period, such as courtyards.

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Greywater from residential units is reused for irrigation. Using greywater by way of water saving appliances.

The irrigating of vegetation from greywater is under the soil to avoid evaporation. Irrigation of vegetation helps microclimate and attracts flora and fauna to the site.

Figure 69 Vegetation in the proposed development

Figure 70 Cross-section shows greywater reuse

Green spaces and vegetation are placed in public and semi-public spaces.
Maintaining cool air in the courtyard can be challenging when a breeze is freely flowing through it. To extenuate the pooling of cool air in the courtyard, space will be recessed below ground level by a meter. In this case, when the air warms up it will rise and consequently be replaced by cool air.

Cultural practices are an important part of the Qatari lifestyle. One of the most important factors that define the Qatari culture is the public to private spaces that establish programmes and programme arrangements throughout the mixed-use and residential development. Traditionally, the organisation of public, semi-public, semi-private and private is established on a horizontal plane at ground level. This build typology poses a challenge as this development can be a public thoroughfare, and vertical organisation of space is needed. The spaces have mostly been identified by the climate responsive design already established at the larger scales. The ground level will be defined as a public realm where markets, coffee shops and a prayer space are placed for public use. The semi-public space is limited to only the residents of the buildings in the development. This area uses bridges to connect all buildings together and create a safe space for social interactions between residents. The semi-private areas are only accessed by residents in direct proximity to the individual residential units. The area will have a covered outdoor space and a social space for guests. The private areas are exclusive to the residents of the individual units.
Figure 72 Section A-A 3D CAD model of horizontal and vertical space arrangement

Figure 73 Plan view of space arrangement
The organisation of these areas promote the cultural expression of social interaction, and the heightened level of safety and comfort as occupants get closer to their private residential units.

Areas such as the semi-private and private areas need to be addressed for climate comfort. The semi-private area will be adjacent to the outside of the residential units where a patterned timber screen is separating the area from the outside. This provides the benefit of a pleasant shaded area where cool air continuously flows through to cool the building courtyard during the day. The private areas, or the residential units, differ in the arrangement and shading elements depending on the location within the development. There are several types of residential units found in the proposed development seen in table 2.

<table>
<thead>
<tr>
<th>Type</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Studio</td>
<td>75 m²</td>
</tr>
<tr>
<td>1 Bedroom</td>
<td>100 m²</td>
</tr>
<tr>
<td>2 Bedrooms</td>
<td>125 m²</td>
</tr>
<tr>
<td>3+ Bedrooms</td>
<td>150+ m²</td>
</tr>
</tbody>
</table>

Table 2 Residential Unit Types

Figure 74 Semi-Private area and Roof Area

The individual residential units in each building are generally oriented in a specific direction to minimise solar radiation. The East and West walls have relatively small surface areas to the North and South walls due to the effects of solar radiation. The façade of units, mainly featuring on the outside edge of the proposed development, are treated to react to the macroclimate on a human scale. Figure 75 shows the overall location and orientation of units on each building, and Figure 76 to Figure 78 provides the explanation for the programme arrangements and features applied in the three individual units to provide passive climate comfort for its occupants. The residential units located inside the development may not require the same treatment as the exterior edge as they are affected by the microclimate.

There are a total of 320 individual units, ranging from studio to 3+ bedroom apartments, in this development allowing for well above the minimum of 300 person per hectare required by The Qatar National Master Plan.
The two bedroom unit has an area of approximately 125m². This unit is located on the West edge of the development where the façade has a timber screen for efficient passive cooling of the external wall of the building. The internal walls are low heat capacity allowing heat to escape efficiently. Air flows freely through bedroom walls for efficient cooling. The kitchen is insulated from the rest of the unit by 300mm hollow brick walls and contains a separate passive ventilation system.

The studio room unit has an area of approximately 75m². This unit is located on the North edge of the development where the façade is naturally shaded. Like the unit above, the internal walls are treated appropriately and ventilated accordingly. A Windscoop is added to utilize the breeze approaching from the North. The West wall doesn’t require further treatment as above because of the existing shading provided from the neighbouring building. A Mashrabiya screen is used on the walls facing the courtyard to allow cool air to enter from the shaded outdoor space.

The one bedroom unit has an area of approximately 90m². This unit is facing the South-East of the development. The South facing wall is exposed to high solar heat gain so the wall is much thicker than the East. The window on the East has vertical shading and windows on the south have horizontal shading. Bedrooms are located away from the South and West façade for the comfort of occupants during the night.
4.4 Formal Outcomes

The passive and traditional design techniques implemented on the existing site conditions form the mixed-use and residential development and provides unique characteristics to the final design.

![Figure 79 Plan view of the proposed mixed use residential development](image)

The implementation of passive and traditional design techniques in this project portrays a much more profound human experience than solely thermal comfort. The design achieved visual continuity between the past and present, common language throughout the development, the character of the traditional city, privacy and security, and comfortable and memorable social spaces. The research inherently contributed to a visual representation of the architectural language developed by Msheireb Properties.

![Figure 80 Perspective view of the proposed mixed use residential development](image)
Figure 81 Street view of development from the North-West

Figure 82 Arial view of development showing the overall composition of the residential block
Figure 86 North elevation facing the sea

Figure 85 South elevation facing the rest of the Msheireb development

Figure 83 East elevation facing the desert and low-rise developments

Figure 84 West elevation facing the sea and the rest of the Msheireb development
Figure 87 Entrance from north edge

Figure 88 Public courtyard
Figure 89 Public market space

Figure 90 Green courtyard space and coffee house
Figure 91 Elevator in semi-public space

Figure 92 Green semi-public space with vertical shading screens
Figure 93 Semi-private space

Figure 94 The highest point in the development looking down
5.0 Conclusion

This research explores the passive climate control design and regional design in Qatar. The proposed passive, high-density, mixed-used residential urban development came in response to the unsustainable, rapid urbanisation, and loss of cultural identity in building forms in the Gulf regions. The case study selected for this research is the capital of Qatar; Doha. This document is set out to connect the past with the present, and to create environmental and cultural sustainability for the future of architecture in Doha. The design driver for this project is passive climate control design techniques in reference to the Qatari design principles. It is based on qualitative research explored in the literature review. The precedent reviews and experiments are carried out to highlight the expected results.

The research provides tools to translate climate information into formal solutions by exploring climate comfort at three scales: urban form, building form, and the human experience. The first scale, the urban form, explores the effects of macroclimate on the overall urban configuration. The urban form is limited to well-defined constraints not related to climate, such as planning regulations, and the existing built environment. The aim of the urban scale is to control the breeze and mitigate solar exposure for the comfort of occupants. Controlling breeze, and mitigating solar exposure on the pedestrian level is achieved by relying on building heights, pathways orientation, building compactness, and the number of openings and access ways to prevailing winds. The second scale, the building form, applied the passive design techniques found in the traditional house to a contemporary building typology. The techniques explored are: courtyards, thermal mass, ground level pedestrian pathway widths, roof and wall shading screens, and mechanical passive systems (such as the wind scoops and wind catchers.) The mechanical systems used are passive; however, in extreme climate conditions, power is required to reach the acceptable climate comfort for occupants. At the final scale, the human experience is focused around the thermal comfort of occupants, and cultural identity of Doha to determine the design decisions on individual residential units. These decisions include orientation, space arrangements, façade treatment, and the treatment of public to private spaces.

The literature review and case studies help to rationalise the design decisions made at each scale of the development. This research contributes to the revitalisation strategies proposed for the Old Doha region using existing knowledge in passive design techniques and the cultural identity in Qatar. The research found much of the passive climate control architecture is synonymous with the cultural identity in the Gulf region. As the population grows in the capital city, the architecture will adapt accordingly to maintain the cultural values in Doha.
The proposed development applies passive design techniques from case studies, not in a maritime zone in Qatar, and is not suitable during the limited periods of extreme climate conditions in the year. During the extremely cold days of the year, the research is limited in providing alternative active heating systems to satisfy the thermal comfort of occupants.

Subsequent research in this field will widen the scope by exploring alternative programmes with a demanding degree of complexity regarding internal heat gain such as on-site backup power generators, central server rooms, and indoor communal spaces in buildings. Further research will examine the optimisation of the passive climate control systems to deal with extreme conditions using quantitative data to prove efficiency comparative to active systems for climate comfort. Given more time, the proposed development would apply passive evaporative cooling towers, and investigate the function of different programmes associated with passive design in individual residential units.
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7.0 Appendix
Depression in the courtyard pools air to keep space cool during the day.

Wall wind scoop allows breeze to flow through to the individual units and hot air is expelled through wind catcher.

Hot air flows out of the courtyard into the atmosphere.

The cool shaded pathways provide cool air to flow through the semi-private and private area through to the courtyard.

The shaded roof receives cool air from the prevailing breeze.

This part of the development does not receive the cool sea breeze. The cooling is provided using wind scoop found on the North edge of the development. The outlet for hot air is found on the roof as a chimney.

Cool air flows into the heated courtyard from the atmosphere.

Cool air flows between the building and screen on the West edge.

Hot air from the insulated kitchen rises through the chimney.

Wind catcher takes in cool air from the windward breeze and expels the hot air from the leeward side.
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