Sustainability and Paradigms of Mughal Architecture in Old Delhi 1526 – 1707

By

Rushil Raj Kapoor

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AR2A011
Supervisor: I. Nevzgodin
Department of the Built Environment
Technical University of Delft
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Abstract

The thesis seeks to analyze the Mughal Architecture in Old Delhi from 1526 till 1707. Starting with a brief description about the history of India, it allows the reader to acknowledge the motifs of the Mughal sultanate and how it was established. The writing advances to introduce the six main Mughal emperors in Delhi such as Babur, Humayun, Akbar, Jahangir, Shah Jahan and Aurangzeb respectively. The six emperors not only passed on their architectural knowledge, but also built famous palaces in parts of Delhi that we, in today's day call Old Delhi. Some of these palaces will be analyzed from a sustainable standpoint to understand how the architecture tackled the extreme climate conditions of the region. Through this categorical breakdown of the Mughal Architecture, the thesis aims towards understand and inspiring the use of vernacular architectural sustainability and its positive effects created by its utilization.

Chapter 1

Introduction

New Delhi, the capital of India has a very rich history, that answers to the melting pot of diversity and heritage in the city. The capital has been a victim to the immergence of several dynasties and empires that prospered but also crumbled over time. With one throne being overthrown by another, New Delhi and its surroundings have been the foreground of power for the Khalji Dynasty and Tughlaq Dynasty to the Mughal and British colonial empire[1]. While each paradigm in New Delhi's history has played an important role in embedding cultural heritage, the thesis focuses on the Mughal's that conquered the capital from 1526 up until 1707. This period witnessed the rule of several emperors from Babur up until Aurangzeb. The writing unfolds their architectural influence in a region of New Delhi known as Old Delhi and focuses on the palace and mosque typologies.

The region of New Delhi is known to have extreme climate conditions and temperatures throughout history. The summer months can be as hot as 44.9°C and the temperature during the winter months can drop to 0°C. While these extreme temperatures are not directly linked to climate change, nonetheless, the acute pollution rates and air quality that is concerningly prominent in the city has exacerbated climate change events[2]. With the goal of creating carbon neutral countries by 2050, announced at the G20 summit, more and more countries are

[1] Brown, P. (1964). *Indian Architecture (islamic period)*. D.B. Taraporevala.

[2] Gandhiok , J. (2021, August 11). *Delhi blows hot and cold: Extreme weather events already rising, New Action Plan Soon: Delhi News - Times of India*. The Times of India. Retrieved February 2022, from https://timesofindia.indiatimes.com/city/delhi/writing-is-on-the-wall-as-delhi-blows-hot-and-cold/articleshow/85219384.cms

seeking towards sustainability and green technology[3]. Especially in the built environment, which is a huge contributor to the environmental pollution. For a city like New Delhi, it is interesting to analyze how its descendants, especially during the Mughal regime not only implemented climate control techniques in the vernacular architecture, but to also acknowledge the fact that it was done with minimal technology and great sustainability. The following thesis attempts at answering the question: *How did the evolution of Mughal palace typologies tackle the extreme climate conditions of Old Delhi and what were the vernacular and sustainable techniques used in Mughal Architecture to create thermal comfort for the residents of these palaces?*

While this is not a topic that is completely unheard of, it combines ideas and research together alongside some additional new findings to create a narrative suitable for the research question. There are articles and books that have been written which have influenced the direction of the thesis; "*Indian Architecture"* written by Percy Brown talks about the different Mughal emperors and their architectural innovations. "*Sustainable Architecture Through Islamic Perspective"*, a document written by Maysarah Binti Bakri explains the sustainability measures used in Islamic architecture which is also influenced by the Qur'an. The research in this document used as a reference in the thesis alongside a historical narrative is bridged by the book "*The Formation of Islamic Art"* written by Oleg Grabar. Lastly, inspiration was taken from Asif Ali's "Passive Cooling and Vernacularism in Mughal Buildings in North India: A Source of Inspiration for Sustainable Development" writing that breaks down the different sustainable features in Mughal palaces. While each of these writings

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[3] euronews. (2021, November 1). *G20 leaders make mild pledges on carbon neutrality and coal financing*. euronews. Retrieved February 2022, from https://www.euronews.com/2021/10/31/g20-leaders-turn-to-climate-change-on-last-day-of-summit-as-focus-shifts-to-cop26

focused on specific topics, parts of them were reiterated and expanded to support the writings of this thesis.

The thesis aims on combining pre-existing knowledge and new findings to create a writing that summarizes Mughal history in India from an architectural standpoint. While doing so, it compares and exhibits examples of similarities between Mughal and Islamic architecture, a topic that is very uncommon. These are all supporting topics that aim to elevate and accentuate the topic of sustainability in vernacular Mughal architecture. Mughal architecture is always written and spoken about for its ornamentation and beauty; this thesis evokes a new way of apprehending Mughal architecture.

The goal of this report is not only to answer the research question but is also attempted to be an inspiration to the current and future architects of the country. To use history as an example to promote sustainability and vernacular architecture in order to create a pollution free and green New Delhi for the future whilst repurposing its rich heritage.

The above is achieved by dissecting the thesis into five main chapters. Chapter two intends on introducing the Mughal Dynasty to the reader. It is done by explaining the history of the Mughals and how they emerged in India. Chapter three introduces the reader to the six main emperors of the Mughal empire such as Babur, Humayun, Akbar, Jahangir, Shah Jahan and Aurangzeb respectively. This chapter not only briefly discusses these emperors but also acknowledges the architectural elements introduced by each emperor that was inherited and passed on to the next generations. Chapter four talks about Islamic Architecture, the architectural style incorporated and adapted by the Mughals in Delhi. It identifies the origin of the style and its key features that are visible in the palace typologies.

Chapter five dives into the theme of sustainability and methods of climate control that is investigated through examples of Mughal palaces found in Old Delhi.

Chapter 2

The Origin of Mughal Architecture

Mughal Architecture is a building style that was developed by Mughal emperors from the period of 1526 up until 1707. This era revitalized and adapted Islamic architecture in Northern and Central India. The style combined elements of Indian, Persian and Islamic architecture to produce a remarkable and serene form of architecture with high quality standards because of which, a lot of the edifices still stand today in India.

The style has multiple names other than Mughal Architecture such as Saracenic or even Indo-Islamic architecture. While the buildings were not a product of Saracens, they were an expression of Islam that was imposed and manifested in India. The constant adaptation and evolution of Islamic architecture has taken place over centuries, causing slightly different variants throughout middle east. Similarly, one of the adapted forms known as Mughal architecture has also evolved throughout its existence in India[4]. The style shows a beautiful fusion of Hindu and Muslim craftsmanship that was first implemented under the emperor Babur. Under the reign of Akbar, there was a heavy focus on construction and large-scale development of Mughal buildings. These buildings were primarily made up of red sandstone and a hint of white marble.

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[4] Grabar, O. (1988). *The formation of Islamic art*. Yale University Press.

Mughal architecture was known to be very symmetrical and harmonic. The immanent use of dome structures was an inspiration from Islamic architecture and the use of natural forms such as greenery and water represented the symbolism of nature present in the Qur'an. Great importance was given to the details in the ornamentation of the architectural forms and the style was at its pinnacle under the rule of Shah Jahan. He replaced red sandstone structures with white marble, creating world known architectural heritages. The Mughal form of architecture saw its decline under Aurangzeb[5].

Were there a set number of principles used by each Mughal emperor? Or did the architecture evolve under each emperor? The different architectural and design principles introduced by each emperor is further discussed in the next chapter.

[5] Brown, P. (1964). *Indian Architecture (islamic period)*. D.B. Taraporevala.

Chapter 3

Mughal Emperors and Their Architectural Influence

The Mughal dynasty was developed and expanded under six different rulers. Babur is known to introduce and first establish the Mughal empire in India in 1526. Following Babur, under the throne of his son Humayun, is when Mughal architecture started developing on a larger scale in 1531. This eye-catching and mesmerizing style was further advanced under Akbar in 1556. The period after Akbar, under the rule of Jahangir in 1605 saw a decline in architectural expertise, however Shah Jahan, Jahangir's descendant was known for his excellent taste and design intuition. Mughal architecture had prospered the most under Shah Jahan starting from 1627. Just like the Mughal empire itself, the architectural style also reached its closing stages under the rule of emperor Aurangzeb starting in 1658. It is interesting to see the architectural influence and adaptation introduced by each emperor that led to the development of the style.

Babur (1526-1531)

Although Mughal architecture as a style only fully developed in the sixteenth century, Babur was known to be the founder of the dynasty and architectural style. His ideals and character of being adventurous helped in laying down the foundations and principles of the style. The initial features of Mughal buildings replicated Persian forms; however, Babur was known for his enthusiasm and persistence to create ornamental gardens and similar pleasant features to the buildings that represented forms of nature[6]. Due to his lack of architectural

[6] Brown, P. (1964). *Indian Architecture (islamic period)*. D.B. Taraporevala.

knowledge, he invited the leading architect of the Ottoman empire, Sinan who further invited his Albanian connections to lay down the founding principles of Mughal architecture. This example signifies the importance of external influence in Mughal architecture which came not only in the form of Persian influential architecture but also in the form of expertise of skilled architects from different backgrounds.

Figure 1: Agra Fort, example of a palace style developed by Babur[7]

Humayun (1531-1556)

Humayun the son of Babur, had a very interesting take on the architectural style. Instead of focusing completely on the building style and the art embedded onto the edifices, he focused on blending Indian architectural styles with the existing Persian ones. His ideologies and additions to Mughal architecture were only

[7] Alexis. (2021, April 1). *Explore the Agra Fort: A UNESCO World Heritage Site*. andBeyond. Retrieved March 2022, from https://www.andbeyond.com/experiences/asia/india/north-india/agra/tour-of-agra-fort/

visible in the famous Humayun's tomb that was completed after his death in 1572. The architectural elements incorporated by Humayun included a very particular dome shape and construction that was only seen in Persia before. Within Persia as well, the dome structure is known to be taken from classical Roman architecture and then adapted within the country[8]. The tomb also included large arched alcoves that lifted the character of the facades. There was a beautiful combination of complex rooms and corridors that made up the interiors, a form of art that only skilled masons could have developed.

As mentioned, the architecture of this period consisted of a very unique dome structure that was executed in a special manner. There was a notable use of a double dome system comprising of an outer and an inner shell. There was a considerable spacing between the shells allowing the outer one to be made of white marble and then inner forming the vaulted ceiling of the hallways. Such a system allowed the inner ceiling to be placed at a lower height without disturbing the proportions of the architecture[9].

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[8] Grabar, O. (1988). *The formation of Islamic art*. Yale University Press.

[9] Brown, P. (1964). *Indian Architecture (islamic period)*. D.B. Taraporevala.

Figure 2: Humayun's Tomb, example of a palace style developed by Humayun[10]

Akbar (1556-1605)

Akbar was known for his architectural achievements as he developed and constructed several structures under his sovereignty. His style of building witnessed a constant usage of red sandstone with a combination of a beam and bracket forming structural system. Alongside red sandstone, white marble was used to emphasis the interiors.

Structural elements with a combination of aesthetics were of great importance as he introduced the phenomenon of Tudor arches as a decorative element in the architecture. Pillar shafts were newly designed to be mutli-sided and the capitals formed bracket supports. Other than the structure, ornamentation was also developed as invariably patterns were laid and carved into the fabric of the

[10] Sinha, S. S. (2022, January 21). *Humayun's Tomb: What are the architectural principles and influences on the famous delhi monument?* Scroll.in. Retrieved March 2022, from https://scroll.in/article/1015522/humayuns-tomb-what-are-the-architectural-principles-and-influences-on-the-famous-delhi-monument

building. Additionally, painting designs were introduced to the inner walls and ceilings. The buildings under the regime of Akbar were magnificent and denoted the spirit of the time. The structural and ornamental characteristics under his empire helped in creating a strong base for the fundamentals of Mughal architecture[11].

Figure 3: Panch Mahal, example of a palace style developed by Akbar[12]

Jahangir (1605-1627)

The successor of Akbar, Jahangir was unenthusiastic about the further development of Mughal architecture and his regime in the architecture world can be labelled as uneventful. His only focus was on creating an ornamental ambience

[11] Brown, P. (1964). *Indian Architecture (islamic period)*. D.B. Taraporevala.

[12] Trawell.in. (2020, November 10). *Panch Mahal, Fatehpur Sikri - timings, history, best time to visit*. Trawell.in. Retrieved March 2022, from https://www.trawell.in/uttar-pradesh/fatehpur-sikri/panch-mahal

in the form of large formal gardens. His regime is known to be the transition period from stone to marble as he was the link between Akbar and Shah Jahan's style of architecture[13].

Figure 4: Shalimar Bagh, example of ornamental gardens developed by Jahangir[14]

Shah Jahan (1627-1658)

The rule under Shah Jahan was known as the golden era of the Mughal period. He was known for his architectural excellence and he brought out the highest degree of perfection in the form of Mughal architecture and style. Under his regime, red sandstone as a building material was replaced by white marble, which transformed the aesthetics and character of buildings.

[13] Brown, P. (1964). *Indian Architecture (islamic period)*. D.B. Taraporevala.

[14] jtdytravels. (2011, October 2). *Srinagar*. I See You See. Retrieved March 2022, from https://jtdytravels.com/tag/srinagar/

Marble, due to its own characteristics, provided the new structures with a delicate grainy texture. It was a very decorative material, providing its own form of ornamentation to the surface of buildings. A new use of material also required new ways of construction and sculpting, fine molds were made on the contours, emphasizing the intricate details and beauty of the material, carefully observed and appreciated by most people.

While the main structures were made out of marble, often plastic was used as a decorative material to enrich the patterns in the stone. Furthermore, there were additional structural alterations. The arches that were curved before Shah Jahan were now foliated. This was done by using nine cusps which resulted in engrailed arches that formed the new architectural features of the period.

The dome was made more bulbous and narrowed down towards the neck which made it ideal for a double dome structure, a technique introduced by his ancestors. Such a dome structure was known to be Persian. The pillars and columns were further detailed with an advancement made on the tapering and baluster shafts. The bracket capitals and foliated bases were improved by adding more ornamental elements. These structures were also made more curvilinear, adding fluidity to the architecture.

All these minute details and improvements made by Shah Jahan to the architecture, not only suggested his skill for the art but also proved that Mughal architecture had reached its pinnacle under his sovereignty[15].

[15] Brown, P. (1964). *Indian Architecture (islamic period)*. D.B. Taraporevala.

Figure 5: Taj Mahal, example of a palace style developed by Shah Jahan[16]

Aurangzeb (1658-1707)

Just like Jahangir, Mughal architecture started to see its downfall under the rule of Aurangzeb. Due to his temperament and faulty ideals, not only did the entire dynasty see its fallings, so did the architecture. There was barely any construction and building development under his regime and the few structures that were built were of very low quality and standards. Hence, architecture is not a well discussed topic under Aurangzeb's rule.

This segment of the thesis helped in understanding the architectural improvements and progress made by each emperor in the Mughal dynasty. While some focused-on ornamentation in the form of greenery and structure, others purely developed structural elements such as the arches and the domes. All in all,

[16] dewereldwonderen. (2021, May 31). *Taj Mahal*. De Wereldwonderen. Retrieved March 2022, from https://www.dewereldwonderen.nl/7-wereldwonderen/moderne-wereldwonderen/taj-mahal/

these elements came together to form the Mughal architectural style. The different elements have helped in providing climate control and thermal comfort in very sustainable ways. The different styles of the emperors are analyzed through Figure 6[17], 7 and 8.

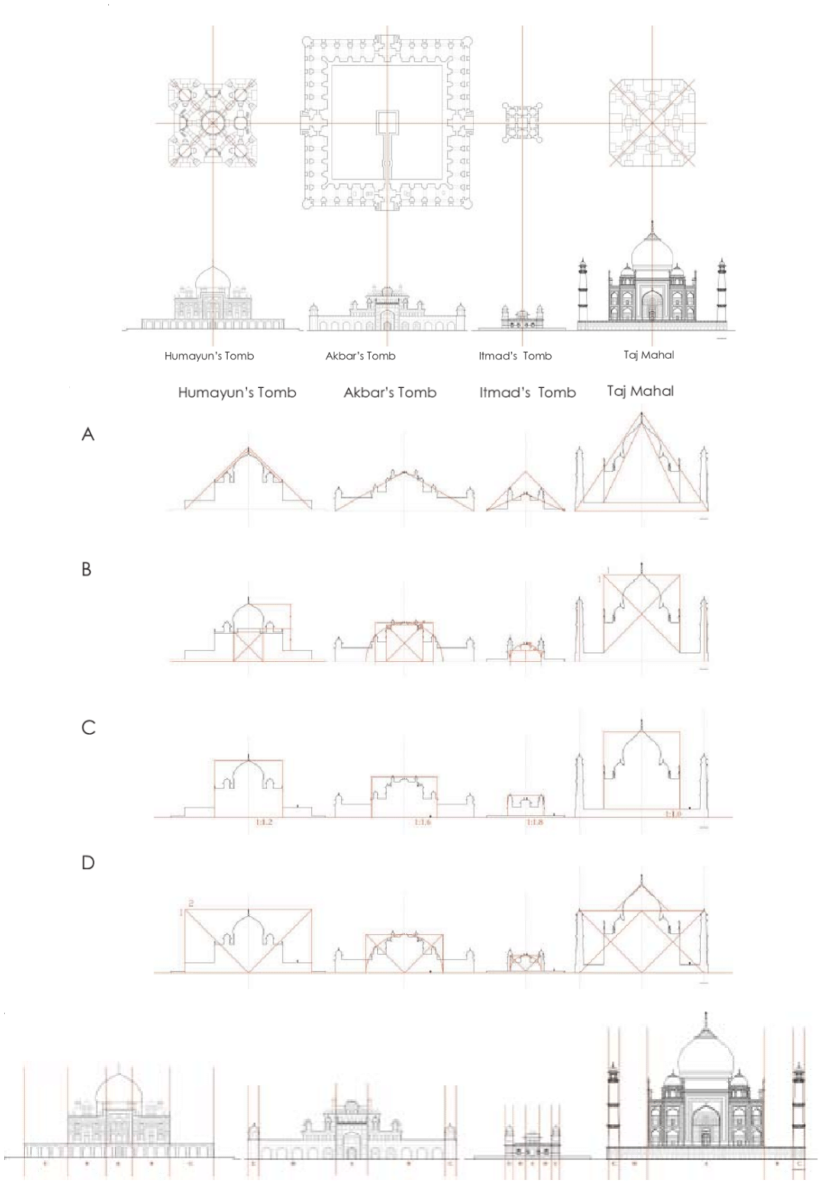
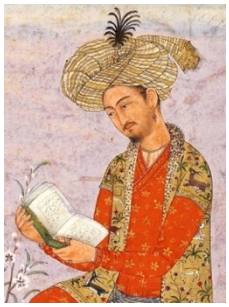


Figure 6: Comparison between the architectural elements introduced by different emperors

[17] Krusche, K. U., Anders, S., Danny, A., & Iva, D. (2010, March). *History, morphology and perfect proportions of Mughal tombs: The secret ... - researchgate*. Researchgate. Retrieved March 12, 2022, from https://www.researchgate.net/publication/43529973_History_Morphology_and_Perfect_Proportions_of_Mughal_Tombs_The_Secret_to_Creation_of_Taj_Mahal

Emperor	Picture	Description
Babur[18]		Babur was known to be the founder of the Mughal empire, while he did not have a large contribution to the architecture, he focused on creating ornamental gardens.
Humayun[19]		Humayun focused on structural elements such as introducing a double dome system found in Persian architecture. He also introduced large arched alcoves that lifted the character of the facades.
Akbar[20]		Mughal architecture under Akbar had highly developed. He heavily used red sandstone as a building material with a hint of white marble for the interiors. Structural elements were a point of focus for the architecture under Akbar. There was a use of Tudor arches, pillar shafts, bracket supports and large-scale ornamentation in the structures.
Jahangir[21]		Jahangir did not have a lot of contribution to Mughal architecture and he was only known to further develop the ornamental gardens.

Shah Jahan[22]		Mughal architecture reached its pinnacle under Shah Jahan. He completely switched the structural material to white marble and replaced the curved pillars with foliated arches consisting of nine cusps. The pillars were further detailed through this manner and the dome was transformed into a bulbous one.
Aurangzeb[23]		There was a downfall of Mughal architecture during the reign of Aurangzeb. There were not a lot of edifices built under his empire due to the low quality of his architectural style.

Figure 7: Architectural characteristics introduced by each emperor in a table format

[18] *Babur*. Download million images for free. (n.d.). Retrieved March 2022, from https://stringfixer.com/nl/Babur

[19] Wikimedia Foundation. (2021, December 18). *Humayun*. Wikipedia. Retrieved March 2022, from https://nl.wikipedia.org/wiki/Humayun

[20] *Life history of the mughal emperor akbar*. Biography - Facts, Life History of The Mughal Emperor. (n.d.). Retrieved March 2022, from https://www.culturalindia.net/indian-history/akbar.html

[21] Wikimedia Foundation. (2022, April 11). *Jahangir*. Wikipedia. Retrieved March 2022, from https://en.wikipedia.org/wiki/Jahangir

[22] *Emperor Shah Jahan :: Shah Jahan history, biography, childhood, life achievements & timeline of mughal emperor shah jahan*. About Shah Jahan. (n.d.). Retrieved March 2022, from https://www.tajmahal.gov.in/about-shah-Jahan.aspx

[23] Wikimedia Foundation. (2021, October 23). *Aurangzeb*. Wikipedia. Retrieved March 2022, from https://nl.wikipedia.org/wiki/Aurangzeb

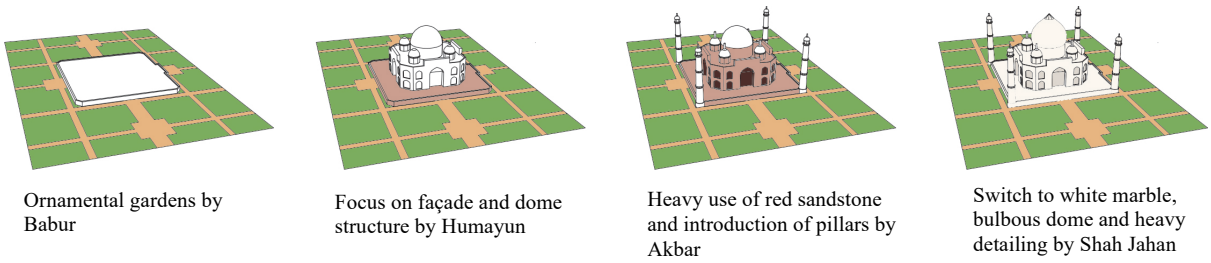


Figure 8: Evolution of Mughal architecture based on the key elements focused on by the different emperors.

There are several references made to Persian architecture that comes under the bigger umbrella of Islamic architecture. Despite the overwhelming varieties of Islamic architecture, what is interesting is that the theme of representation whether in the form of nature through ornamentation or the representation of a style associated to an emperor, did not exist in early Islamic architecture. It was adopted at later stages and one of the final adaptations of this characteristics is visible in Mughal architecture[24].

While the focus of this thesis is to investigate the sustainability aspects of Mughal architecture, it would be interesting to see if any of the methods can be rooted to Islamic architecture. The next chapter unfolds Islamic architecture by discussing the topic of climate control, sustainability and its origins. How did the sustainability motifs come about in Islamic architecture? Was it driven by religion, culture or aesthetics? All of these thoughts are touched upon in the next segment of the thesis.

[24] Grabar, O. (1988). *The formation of Islamic art*. Yale University Press.

Chapter 4

Sustainability in Islamic Architecture

Islamic development and obligations are driven by the Qur'an. Muslims are firm believers of the Qur'an and always refer to the book for societal development and this is also reflected in the architectural style.

There are several references from the Qur'an and Hadiths that promote the vitality and encourage the use of natural resources. These extracts from the religious writings lead to the stance that all elements, species, habitats and ecosystems are a part of a harmonic world created by God. As a consequence, all Muslim's that have "submitted" themselves to God, must respect the laws of nature and its components. While Islam teaches that everything has been created for a certain purpose, it also hints that man's relationship with the environment demonstrates how strong or how unfulfilled his connection is with God. Hence sustainability is one of the most dominant elements in Islamic Architecture. Some of the key features include the use of local materials, natural ventilation, natural lighting, water and building underground[25]. While some architectural features contain symbolism in nature, the others use nature to its advantage creating a sustainable causal effect.

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[25] Bakri, M. B. (2021, October 28). *Sustainability principles in traditional Islamic architecture*. EcoMENA. Retrieved March 2022, from https://www.ecomena.org/sustainability-islamic-architecture/

Local Materials

The use of local materials not only made it easier for the architecture but also benefited the people and that is why it was promoted in Islam. The encouragement of local materials increased business for locals and elevated the quality-of-life in. the locality by improving the income. Apart from social sustainability, the commonly used local materials itself had great benefits.

The materials were crucial for protecting the building and people from the external, harsh conditions. Clay was known to be the optimum and one of the most popular building materials. Besides its great heat isolation and thermal mass, the abundance of the material encouraged its natural usage which also prevented carbon emissions. Other materials such as Brick and Stone were also very popular and were used as early as in the 10th AD. Natural forms of these materials were utilized to create load bearing walls, columns, beams and domes in present day countries such as Egypt, Morocco and Iraq[26].

Building Underground

The concept of building underground was done in order to minimize the effect of the outdoor climate to the inside of buildings. The soil in the form of, for example clay, was used for its thermal mass advantage to create walls and in this case, the thermal mass of the soil was used to create cool rooms under the ground. Traditional basements were more known to be architectural elements in highland Islamic present-day countries such as Iraq, Saudi Arabia, Tunisia and Libya. Most of the other countries had high ground water levels that prevented them from

[26] Bakri, M. B. (2021, October 28). *Sustainability principles in traditional Islamic architecture*. EcoMENA. Retrieved March 2022, from https://www.ecomena.org/sustainability-islamic-architecture/

building basements[27]. The concept of a basement was introduced in Islamic architecture in the period of 637 – 1639 AD.

Natural Ventilation

Natural Ventilation is one of the most important features of sustainability in Vernacular architecture and it was the same for Islamic architecture. Ventilation increases airspeeds which in turn escalates the process of heat transfer from a building to the surrounding environment. Additionally, in hot countries, it would help in reducing moisture and cooling the building.

"Malqaf" was an important architectural feature in Islamic structures that helped the buildings naturally ventilate. The commonly used Malqaf was a roof Malqaf which were placed in one way, following the wind directions[28]. These were first invented in the 14th Century. Another similar feature to create natural ventilation in palaces and other structures was a "Kashtil" also known as a wind tower. This was a slightly more intricate feature that allowed winds to enter from multiple directions.

[27] Bakri, M. B. (2021, October 28). *Sustainability principles in traditional Islamic architecture*. EcoMENA. Retrieved March 2022, from https://www.ecomena.org/sustainability-islamic-architecture/

[28] Sun, E. (2017, April 4). *Malqaf*. Global Ecovillage Network. Retrieved March 2022, from https://ecovillage.org/solution/malqaf/

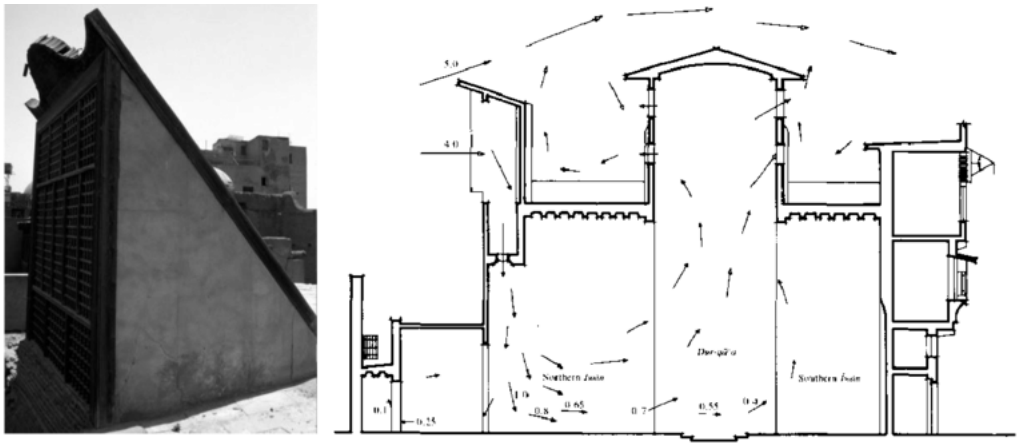

Figure 9: Example of a Malqaf and the wind circulation around it[29]

Natural Lighting

Sunlight has a symbolic representation in Islam, it highlights the greatness of God and is the main source of light, hence it was a key feature to consider in Islamic architecture. In modern day architecture, windows are the biggest entities for thermal gain and loss, creating uncomfortable conditions within building structures. With high temperatures being common to most Islamic countries, the architecture tackled the natural lighting with a concept known as "Mashrabiya". It is a traditional Islamic architectural element that allows the penetration of wind and at the same time blocks the direct sun, creating cool environments. They were used to cover balconies and building openings. While the sunlight and airflow were controlled with the help of a Mashrabiya, it was also used as a privacy tool, by blocking views to the inside. They were normally made out of wood cones and

[29] Calautit, J. K. S. (2016, July). *Www.researchgate.net*. Design and optimisation of a novel passive cooling wind tower. Retrieved March 2022, from https://www.researchgate.net/profile/John-Kaiser-Calautit/publication/280239289_Application_of_a_Passive_Cooling_Wind_Catcher_within_the_Built_Environment_Numerical_and_Experimental_Analysis/links/55aef1d208aed614b09a7c5d/Application-of-a-Passive-Cooling-Wind-Catcher-within-the-Built-Environment-Numerical-and-Experimental-Analysis.pdf

marble plasters and were first invented in Egypt[30] in the middle ages (15th Century).

Figure 10: Example of a Mashrabiya, used to block direct sunlight[31]

Water

Like sunlight, water in the form of rain also had a very symbolic representation in the Qur'an. Islam considers rainwater as a grace as it benefits the surroundings,

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[30] ASHOUR, A. Y. M. A. N. F. A. T. H. Y. (2018). Islamic Architectural Heritage: Mashrabiya. *WIT Transactions on The Built Environment*. https://doi.org/10.2495/iha180211

[31] Caballero, P. (2018, September 18). *Mashrabiya Mosque / nudes – nuru karim*. ArchDaily. Retrieved March 2022, from https://www.archdaily.com/901551/mashrabiya-mosque-nudes-founder-and-design-principal-nil-nuru-karim

living beings and nature[32]. Since rainwater had such a significant meaning in Islam, the architecture incorporated systems such as rainwater harvesting to collect and preserve water. Such type of a vernacular and sustainable concept is still omnipresent and important in present day architecture.

Due to the importance of nature presented in the Qur'an, nature and natural phenomenon's have been utilized throughout Islamic architecture to make it a very sustainable form of architecture using vernacular forms. While sustainability measures slightly differed based on the location and climate conditions, key elements such as use of local materials, underground structures, natural ventilation, natural lighting and water were common to most buildings.

What is important to understand is that "Islamic" does not mean art of a particular religion. For a majority of the buildings, it has little to do with the faith of Islam. Instead, a more appropriate interpretation of "Islamic" is the civilization and its culture in which the majority of the citizens or the emperors preach the faith of Islam[33].

The next segment of this thesis will analyze the sustainability measures in Mughal palaces in Old Delhi. Did elements from traditional Islamic architecture get passed on to Islamic-Mughal architecture? Were there similar vernacular sustainable styles and what additional features were added to the palaces that not only represented Islamic architecture but also curated it to the extreme conditions of Old Delhi?

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[32] Aurien, A. (2018, July 12). *13 blessing virtues of rain in Islam*. AZislam.com. Retrieved March 2022, from https://azislam.com/virtues-of-rain-in-islam

[33] Grabar, O. (1988). *The formation of Islamic art*. Yale University Press.

Chapter 5

Sustainability in Mughal Architecture

The Mughal empire is famously known to rule the Indian subcontinent from the period of 1526 up until 1857. This period saw a large-scale development of architectural forms carried on and inspired by the Islamic sovereignty. As discussed in the previous chapters, not only was the architecture unique and very distinguishable, but it was also very sustainable. This chapter will look into the common sustainable Islamic architectural practices used by the Mughals as well as additional techniques developed in the architecture to tackle the extreme heat of Old Delhi. The sustainability and climate control aspects will be analyzed through key Mughal structures in Old Delhi such as Jama Masjid and Red Fort. Additionally, references will be made to structures such as Agra Fort and Panchmahal to support the arguments made.

Green Spaces

The gardens of paradise that are written about in the Qur'an are a large inspiration for the Mughals to develop the landscape architecture around their buildings. The Mughal architecture not only used green spaces to symbolize extracts of the Qur'an, these gardens and parks also uplifted the quality of the environment. The air quality entering the palaces was so pure and this is due to the microclimate created by this greenery, in the surroundings. Additionally, by adding vegetation to these green spaces, evapo-transpiration was accelerated. It is a process in which

vegetation directly increases the amount of water vapor in the air, reducing the temperatures. This made the garden areas very comforting and serene[34].

As you can see in Figure 11, Jama Masjid had these green buffer zones in the four corners of the edifice. Although the building was a mosque and that people were not permanently living in the facility, the green spaces created a cooling effect making it comfortable for people to pray inside the building as well as in the courtyard during the hot summer months.

Figure 11: Jama Masjid from a bird's eye view. Green buffer zones can be seen in the four corners[35]

[34] Ali, D. A. (2014, May 25). *Passive cooling and veranacularism in Mughal buildings in North India: A source of inspiration for sustainable development*. Academia.edu. Retrieved November 2021, from https://www.academia.edu/3571042/PASSIVE_COOLING_AND_VERANACULARISM_IN_MUGHAL_BUILDINGS_IN_NORTH_INDIA_A_SOURCE_OF_INSPIRATION_FOR_SUSTAINABLE_DEVELOPMENT?pop_sutd=false

[35] Aerial, A. (2019, June 5). *Delhi, India - 5 june 2019: Aerial view of devotees at prayer during eid al-fitr at jama masjid mosque. Eid al-Fitr is a religious holiday celebrated by Muslims that marks the end of Ramadan. stock photo*. Westend61. Retrieved March 2022, from https://www.westend61.de/en/imageView/AAEF00347/delhi-india-5-june-2019-aerial-view-of-devotees-

Red Fort is known to have several architectural innovations but is also known for its large garden spaces. The huge garden areas that connect to the building premises is known to be called "Nahr-i-Bihisht" which translates to "the fusion of palace and gardens, a metaphor for paradise". A special garden in the Red Fort, called Hayat Bakhsh Garden followed the Chahar-bagh layout that is famous to Persia can be seen in Figure 12. This quadrilateral garden layout contained several types of trees, plants, flowers bearing different types of fruits, vegetables and nuts[36]. The Cypress tree symbolized death and eternity while the fruit trees represented life and hope. The Mughal supremacy was also known as 'soft power' due to the high emphasis of nature in the architecture. Once again, it not only had symbolic references, but it also created micro-climates inducing a cooling effect in the hot summer months of Old Delhi.

[36] Das, D. (2020, April 15). *The Red Fort: Know more about its architecture, and its resplendent gardens based on the concept of Chahar Bagh*. The Dispatch. Retrieved March 2022, from https://www.thedispatch.in/the-red-fort-know-more-about-its-architecture-and-its-resplendent-gardens-based-on-the-concept-of-chahar-bagh/

Figure 12: Chahar Bagh garden layout in Red Fort[37]

Use of Water

On the theme of nature, water in the form of fountains as well as ponds complemented the gardens and additional green spaces. With a similar functionality as green buffer zones, water bodies naturally cool the warm winds blowing above them, releasing a very comforting breeze to the inside of the palaces. In some Mughal buildings, water was utilized for climate control in the form of moats, surrounding the palace. In some cases, it was exhibited in the form

[37] Travis, & Sonya. (2012, December 27). *Silk Road and trans-Himalayan – the end of an epic journey*. Sonya and Travis. Retrieved March 2022, from https://sonyaandtravis.com/category/travels/india/

of fountains even within the interiors of structures and interestingly in the case of Red Fort, a stream was created that passed through the flooring of the entire palace. A lot of palaces also promoted sustainability by storing water. Whether it was rainwater or ground water, often it was stored in wells that had interesting architectural functions[38].

The Qur'an considers water as grace as it benefits nature and its beings. What better a place to symbolize the importance of water, than a mosque. As seen in the Figure 13, the very epicenter of the huge edifice is a courtyard with a central pond. While the water body itself is quite small, the socio-sustainability topic would suggest that people would loiter around the pond during the warm days, as the water would create a natural cooling effect.

[38] Ali, D. A. (2014, May 25). *Passive cooling and veranacularism in Mughal buildings in North India: A source of inspiration for sustainable development*. Academia.edu. Retrieved November 2021, from https://www.academia.edu/3571042/PASSIVE_COOLING_AND_VERANACULARISM_IN_MUGHAL_BUILDINGS_IN_NORTH_INDIA_A_SOURCE_OF_INSPIRATION_FOR_SUSTAINABLE_DEVELOPMENT?pop_sutd=false

Figure 13: Water body in the middle of the courtyard in Jama Masjid[39]

In the case of Jama Masjid, the water body is found on the inside, in the center of the mosque. Whereas in Panchmahal a palace in Fatehpur Sikri, a town close to Old Delhi, it is the exact opposite. The Panchmahal palace is completely surrounded by water, once again symbolizing the importance of water but also acting as a natural ventilation tool, making the space ideal and popular amongst the residents during the summer months.

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[39] Ekabhishek. (2022, February 27). *Jama Masjid, Delhi*. Wikipedia. Retrieved March 2022, from https://en.wikipedia.org/wiki/Jama_Masjid,_Delhi

The most interesting function of water can be seeing in the Red Fort. It almost seems that the multiple ways of using water in a sustainable way, are all put together in this fortification. Red Fort consists of fountains, both on the inside and on the outside, ponds alongside the gardens and water streams running parallel to the heavy thermal mass walls, a crucial architectural feature also visible in the Agra Fort. These narrow water streams not only function as a drainage system but since they are open, they also cool down the heavy walls that store a lot of the summer heat. There is also a very important channel of water flowing through the ground, cutting across the palace. This once again acts as a heat absorber, creating thermal comfort.

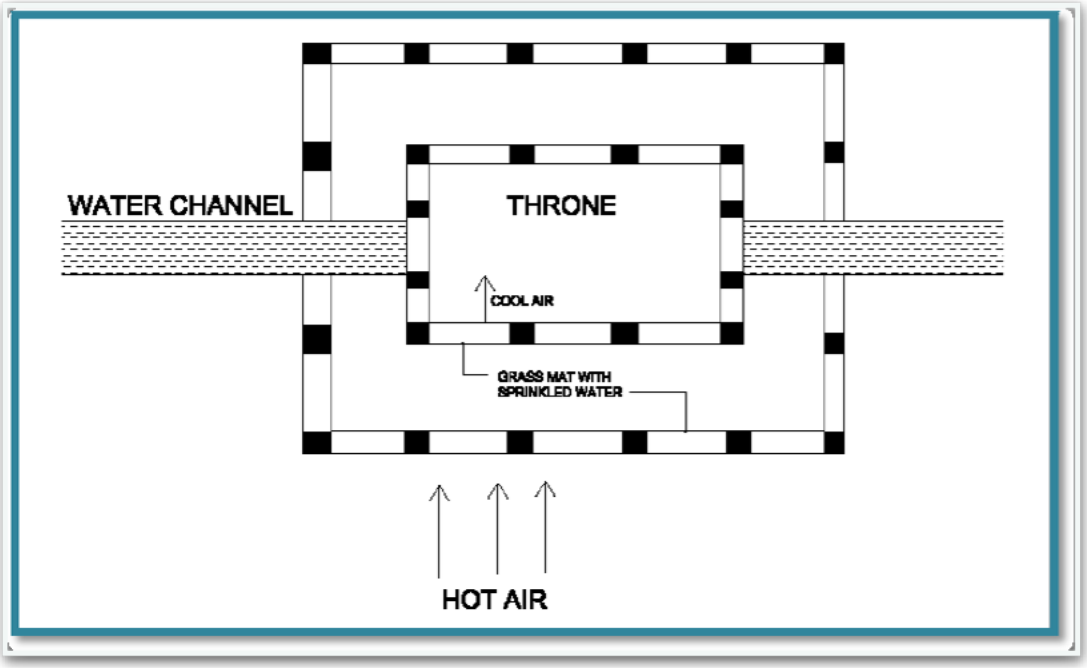

Figure 14: Diagrammatic representation of the water channel flowing through the middle of Red Fort[40]

[40] Ali, A. (2012, October 12). *Passive cooling and vernacularism in mughal ... - researchgate*. Researchgate. Retrieved March 2022, from https://www.researchgate.net/publication/267627217_Passive_Cooling_and_Vernacularism_in_Mughal_Buildings_in_North_India_A_Source_of_Inspiration_for_Sustainable_Development

Another very intriguing architectural concept found in many palaces like the Red Fort is a water storage well. The sustainability aspect of this system is that a lot of the ground water and rainwater is collected and stored in these wells. However, the architecture built around it, makes it even more important when it comes to climate control. These wells are built in indoor spaces with steps around it, as you can see in the section of Figure 15. This type of a structure is known as a step-well system. The step wells have an opening directly above the water, allowing warm air to enter. The water would then cool the air and the breeze flowing through the steps made it so comforting that these steps in this room was often utilized as a resting space.

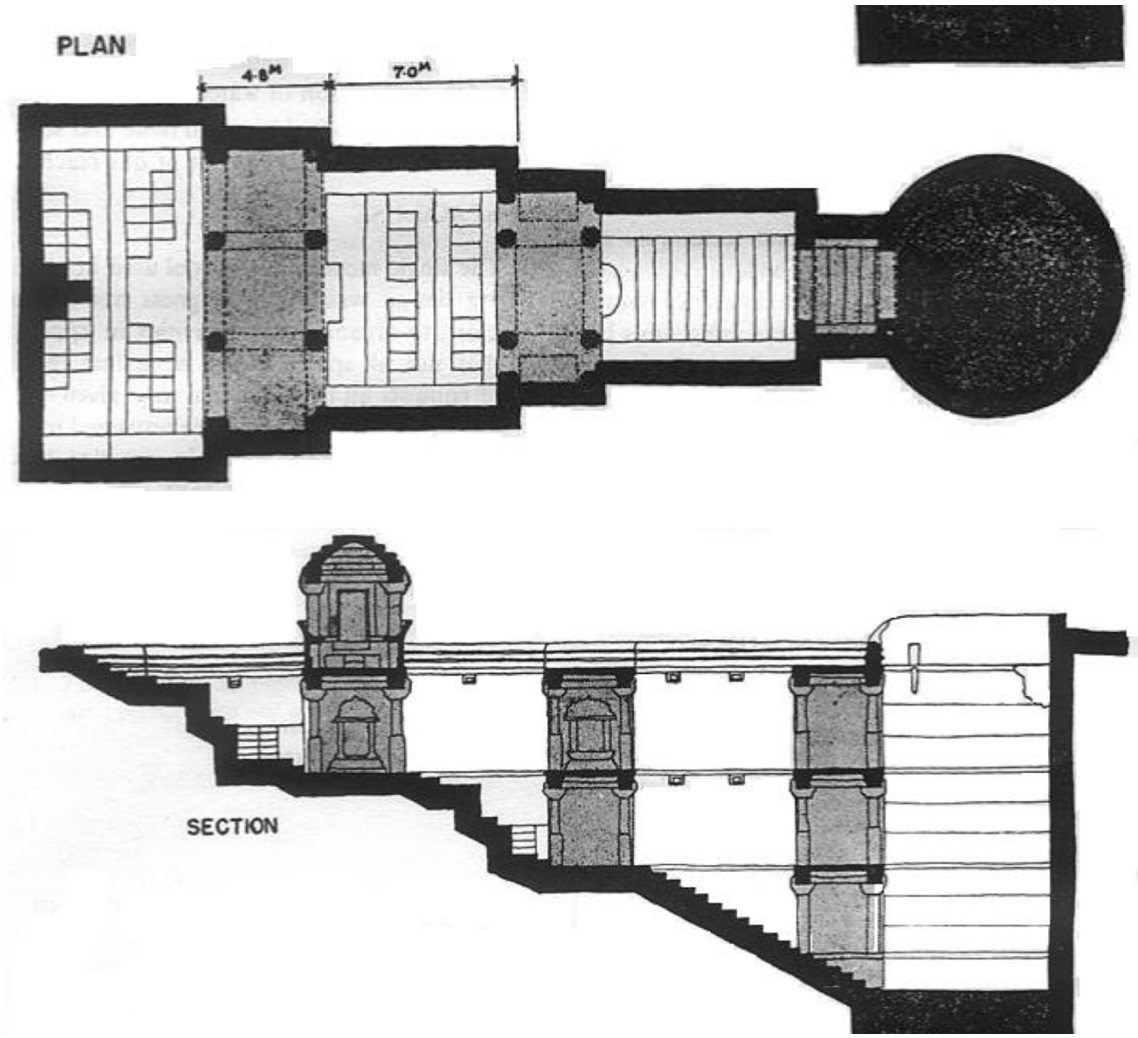

Figure 15: Plan and Sectional representation of the step-well system found in palaces[41]

[41] Ali, A. (2012, October 12). *Passive cooling and vernacularism in mughal ... - researchgate*. Researchgate. Retrieved March 2022, from

Did You Know? (Evolution of Step Wells)

The thesis briefly discusses the sustainable measures of step wells in Mughal architecture, however, the concept of step wells in India has a long history. The very first form of step wells can be dated back to the 200– 400 AD period in Gujarat. It was in the form of a bath like pond in the Uperkot caves in Gujarat. The first developed form of step wells was located in Dhank, Gujarat in 550-625AD. Following this, there was a further development of step wells in Gujarat in Bhinmal (850- 950AD)[42].

Step wells were initially rudimentary structures that were dug deep into the earth for the sole purpose of water storage[43]. It was essentially used to provide a yearlong of water supply in regions of India that were exposed to extreme heat and dry climate conditions. These step wells were used for water storage, bathing, irrigation and washing purposes in Gujarat where these structures were coined as "vavs". From Gujarat, the concept of a step well was spread up north to Rajasthan the dessert area of India as well as to the Mughal ruling parts of North India[44].

The Mughals transcended the functions of step wells and made them more ornamental and meaningful. Many if not most Mughal palaces such as Humayun's Tomb and Taj Mahal had intricately detailed step wells. The high use

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[42] Wikimedia Foundation. (2022, April 7). *Stepwell*. Wikipedia. Retrieved March 2022, from https://en.wikipedia.org/wiki/Stepwell#:~:text=The%20stepwells%20were%20constructed%20in,the%2011th%20to%2016th%20century.

[43] Benipal, Z. (2019, October 26). *A tale of the forgotten and soon to disappear stepwells of India*. https://www.outlookindia.com/outlooktraveller/. Retrieved March 2022, from https://www.outlookindia.com/outlooktraveller/see/story/68975/a-tale-of-the-forgotten-and-soon-to-disappear-stepwells-of-india

[44] Lautman, V. (2013, June 28). *India's Forgotten Stepwells*. ArchDaily. Retrieved March 2022, from https://www.archdaily.com/395363/india-s-forgotten-stepwells

of symmetry and the complex artisanship to form deep pits with multiple layers of steps, made the entire architectural feature very important in Mughal edifices. Other than the beautiful details and craftsmanship used to create relics, the step wells also were very popular for social functions such as female gatherings and resting places.

Natural Ventilation

For regions with hot climate conditions, it is often observed that the window size, direction and shape is developed in such a way that it causes a difference in pressure between the inside and outside of a building. This leads to a natural flow of wind, creating a cooling effect. While such methods were used in the Mughal architecture, there were additional methods of creating natural ventilation.

The geometry of a building can directly help in reducing energy consumption. Even though there were not many technological advancements in the Mughal period, passive cooling and thermal comfort was achieved through precise architectural geometry. One such example is the use of a Dome roof structure. A domed roof structure is very common to Islamic architecture all around the world. It not only makes the architecture distinguishable, but it also has vernacular passive cooling characteristics and hence it is used in hot climate, Islamic countries. A domed roof is considered to be more efficient than a flat roof. In Mughal India, a dome roof structure was not only advantageous due to its thermal capabilities, but it was also incorporated for its structural benefits with the construction materials used at the time. Studies suggest that passive cooling is

achieved through domed roofs in summer months with a much inferior consumption of energy due to several reasons[45]:

i. There is a thermal lag that is achieved by using materials such as stone and brick to develop the dome. This means there is an ideal temperature difference between the interior and exterior, both during day and night.
ii. Due to the round and pointed top, the roof has a lower surface area exposed to the sun as compared to a flat roof. Therefore, less heat enters through the roof.
iii. As hot air rises, a roof tends to trap this hot air within the interiors. With a height advantage of a domed roof, the heat is trapped at much greater height as compared to a flat roof. This keeps the human height level cooler.

Both, Red Fort and Jama Masjid have multiple domed roofs. This is a key representation of Islamic architecture but is also very useful for natural ventilation. Both these architectural wonders also have 'minars' also commonly known as minarets. These are the tall and slim towers that can be found in multiple Mughal palaces. Even though there is a lack of information regarding the passive cooling functions of these towers, as per the previous chapter about Islamic architecture, one can assume that the 'minars' are very similar to 'kashtils'. The purpose of these towers, from a sustainability perspective, could be to create a wind passage to the interiors through the towers, creating a passive cooling and natural ventilation effect[46].

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[45] Soleimani, Z., Calautit, J. K., & Hughes, B. R. (2016, August 17). *Computational analysis of natural ventilation flows in geodesic dome building in hot climates*. MDPI. Retrieved March 2022, from https://www.mdpi.com/2079-3197/4/3/31

[46] Imam, S. M. N. (2003, December). *(PDF) ventilation in a mosque – an additional purpose the ...* Ventilation in a Mosque – an Additional Purpose the Minarets May Serve. Retrieved March 2022, from https://www.researchgate.net/publication/272293471_Ventilation_in_a_Mosque_-_an_Additional_Purpose_the_Minarets_May_Serve

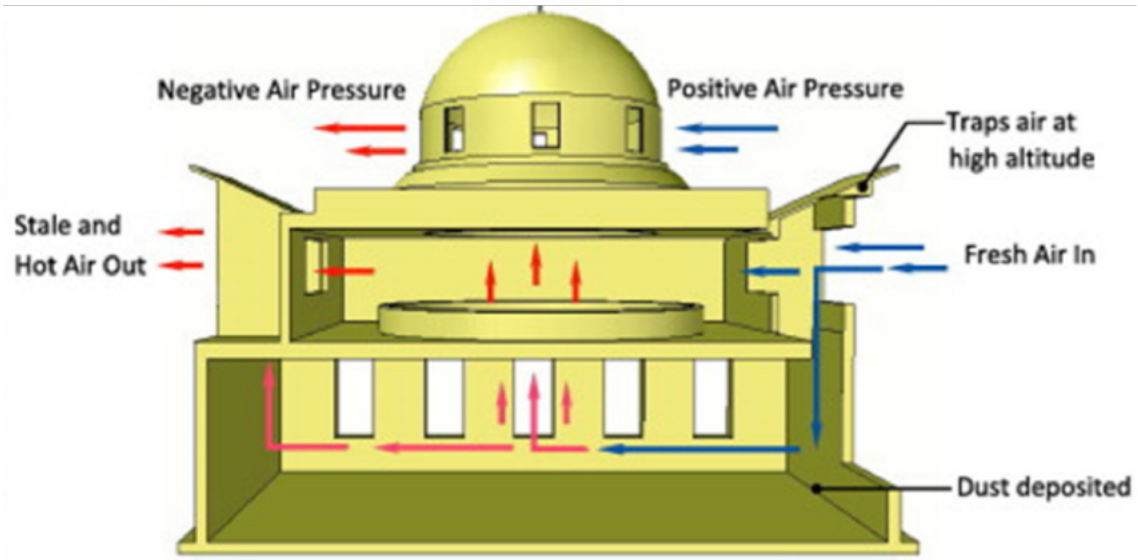


Figure 16: Simulation diagram showing the pressure difference and wind flow in a dome structure[47]

A unique example of natural ventilation in Mughal architecture is the example of Panchmahal in Fatehpur Sikri. The building is asymmetrical and scales down from the bottom to the top. The top storey has a domed canopy and the two floors below it has a very open arched façade on multiple sides. This allowed a lot of cross ventilation to occur, making it an ideal place for Akbar's wives to enjoy their pleasant summer evenings. The architecture creates a wind flow system which is very similar to a 'badgir wind catcher' originated in Persian architecture.

[47] Soleimani, Z., Calautit, J. K., & Hughes, B. R. (2016, August 17). *Computational analysis of natural ventilation flows in geodesic dome building in hot climates*. MDPI. Retrieved March 2022, from https://www.mdpi.com/2079-3197/4/3/31

Figure 17: Panch Mahal in Fatehpur Sikri, and its canopy roof system[48]

Natural Lighting and Shading

The area of Old Delhi, throughout history has been blessed with plenty of natural sunlight. In present day, the technology advancement has allowed people to cool their households with air conditioners, creating thermal comfort despite the hot outdoor temperatures. However, the Mughal period did not have such technology. They used architecture as a tool to both, take advantage of, and allow a lot of

[48] Gosahin. (n.d.). *Panch Mahal Agra, architecture, built, timings, entry, images*. Gosahin. Retrieved March 2022, from https://www.gosahin.com/places-to-visit/panch-mahal/

natural lighting to improve the quality of spaces, as well as minimize the amount of direct sunlight entering the buildings to prevent overheating.

Glass is a crucial material that allows natural light to enter buildings however, the material did not exist in the 16th century. The Mughal architecture was developed in such a way that there were several openings created all around the palaces and other edifices. These openings not only had a similar role as glass, to allow sunlight to enter, they also allowed cross ventilation to occur, consequently causing a cooling effect in the palaces.

A key architectural feature in Mughal architecture was the concept of a 'Jaali' also known as a lattice. These are specifically designed pores, embroidered into the façade. These lattices can be seen in several rooms with different special functions, these include bedrooms, terraces and corridors. The lattices not only played a very aesthetical role, but their main function was also to block the sunlight from directly entering spaces. The multiple pores in the façade, very intrinsically blocked the light from the outside but also created panoramic views to the outside from the inside. These 'Jaalis' were also utilized to create privacy. It blocked the view from the outside, making it ideal to be placed in the bedroom facades[49].

[49] Ali, A. (2012, October 12). *Passive cooling and vernacularism in mughal ... - researchgate*. Researchgate. Retrieved March 2022, from https://www.researchgate.net/publication/267627217_Passive_Cooling_and_Vernacularism_in_Mughal_Buildings_in_North_India_A_Source_of_Inspiration_for_Sustainable_Development

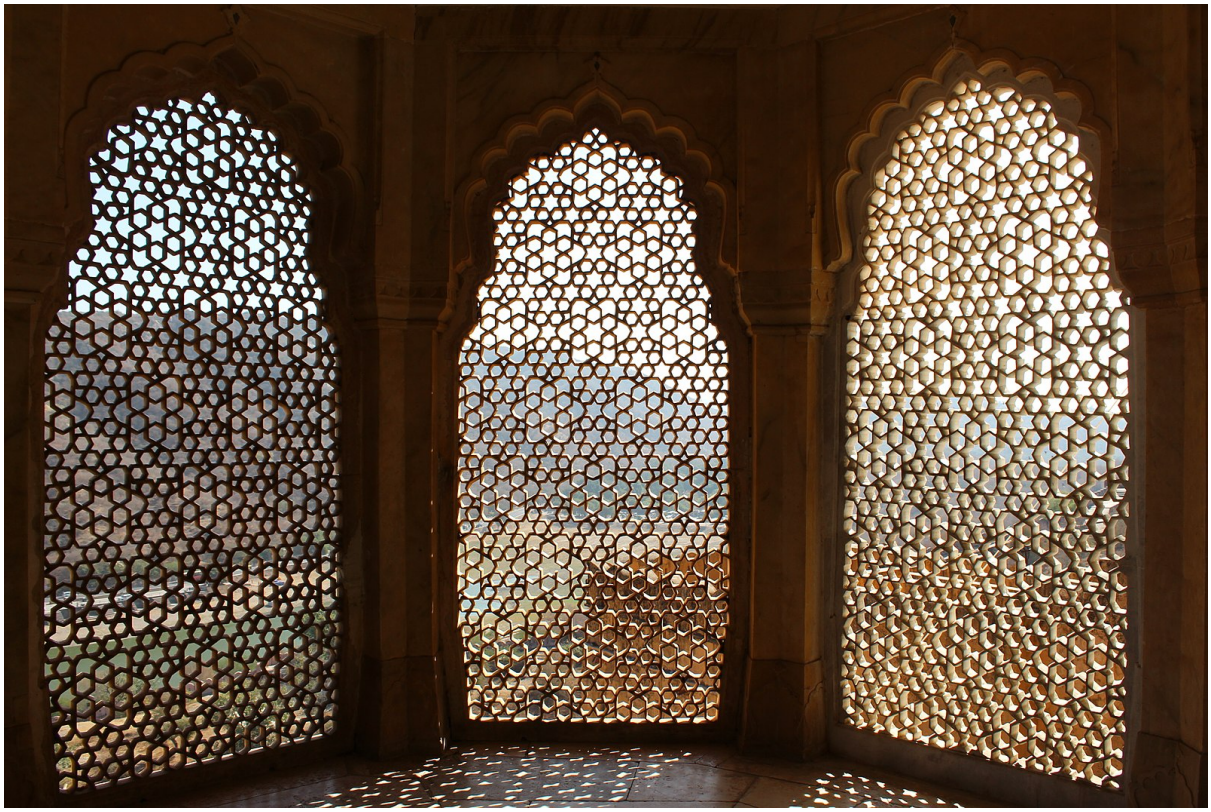


Figure 18: Jaali structure in Mughal palaces[50]

Sun shading systems were also incorporated in many spaces such as verandas and open rooms where the emperor's throne was placed. These sun shaders were made out of jute and grass mats that were often sprinkled with water to once again create a cooling effect to the inside. Lastly, a common concept in architecture which is also used in present day- cantilever's, were also predominant in most of Mughal architecture. These casted large shadows and created sitting spaces for residents. All these natural lighting and shading features were present in most Mughal buildings including Red Fort and Jama Masjid.

[50] Chayandunks7. (2016, December 20). *Category:Islamic architecture*. Wikimedia Commons. Retrieved March 2022, from https://commons.wikimedia.org/wiki/Category:Islamic_architecture?uselang=it

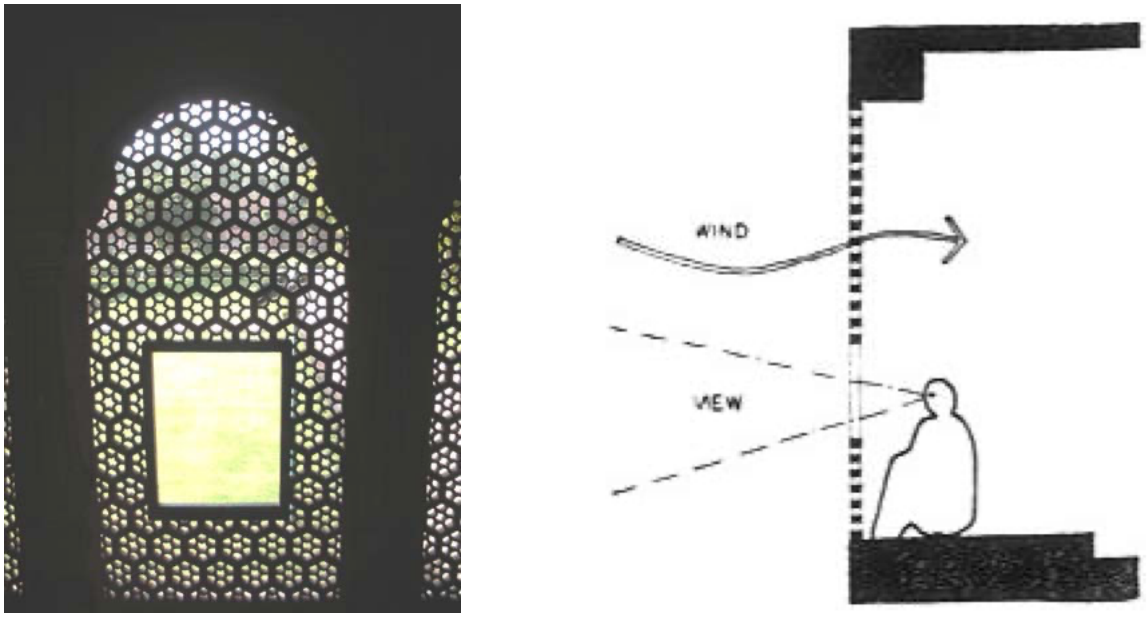


Figure 19: Another example of a Jaali system alongside a diagram showing its functions[51]

Materiality and Thermal Mass

Mughal architecture is known to excessively and solely use materials such as stone and marble. These heavy mass and thick materials have a high thermal mass property which means that they can block and store heat over a longer period of time. Thermal lag, a concept mentioned previously in this thesis is also a key property of these materials. This means that during the extremely hot summer days, the walls made out of stone and marble would block and store the heat for a long period, preventing a lot of heat from entering the interiors. And during the nighttime, the heat would slowly get released making it thermally comfortable during the cool nights.

Red sandstone and white marble are the most commonly used materials both in Jama Masjid and Red Fort. The name Red Fort itself is derived from the

[51] Ali, A. (2012, October 12). *Passive cooling and vernacularism in mughal ... - researchgate*. Researchgate. Retrieved March 2022, from https://www.researchgate.net/publication/267627217_Passive_Cooling_and_Vernacularism_in_Mughal_Buildings_in_North_India_A_Source_of_Inspiration_for_Sustainable_Development

prominent color of the Red Sandstone walls. White marble was more commonly used as an interior's material however, in the case of Taj Mahal, the entire building envelop and façade was also built out of marble. Both red sandstone and white marble are naturally found material making them very sustainable and environmentally friendly. These were local materials used at the time, making it an efficient tool for construction that also benefited the architectural style of creating arches and domes. The fact that these palaces and other functional Mughal buildings have survived and with lasted all these years, also adds to the argument of how sustainable the materials were and still are.

Courtyard Spaces

Like many other architectural elements discussed throughout the thesis, a courtyard is a very common and important element in Mughal Islamic Architecture. Often being the center of a palace, or a space that makes the plan of a building internally oriented; a courtyard due to its vast openness causes cross ventilation. Often the center of a courtyard is either occupied by green vegetation or by water in the form of a fountain or pond. These additional elements also increase the cooling effect, making the courtyard a very social space[52].

While in some palaces such as the Red Fort, there was more emphasis on adding greenery to the courtyard space, in other examples such as Jama Masjid, the courtyard had a small water body, and the rest of the space was open. This

[52] AuthorKhushbu Soni An Architecture graduate with a postgraduation in Urban Design and an Educationist by profession. She is on a constant quest for knowledge be it through reading, Soni, A. K., & An Architecture graduate with a postgraduation in Urban Design and an Educationist by profession. She is on a constant quest for knowledge be it through reading. (2022, January 21). *Importance of courtyards in various cultures - RTF: Rethinking the future*. RTF | Rethinking The Future. Retrieved March 2022, from https://www.re-thinkingthefuture.com/rtf-fresh-perspectives/a1624-importance-of-courtyards-in-various-cultures/

interplay of open courtyards with the other architectural building elements, created a flow of winds and a subsequence release of heat radiation from the heavy walls. This cooling effect is shown in the Figure 20.

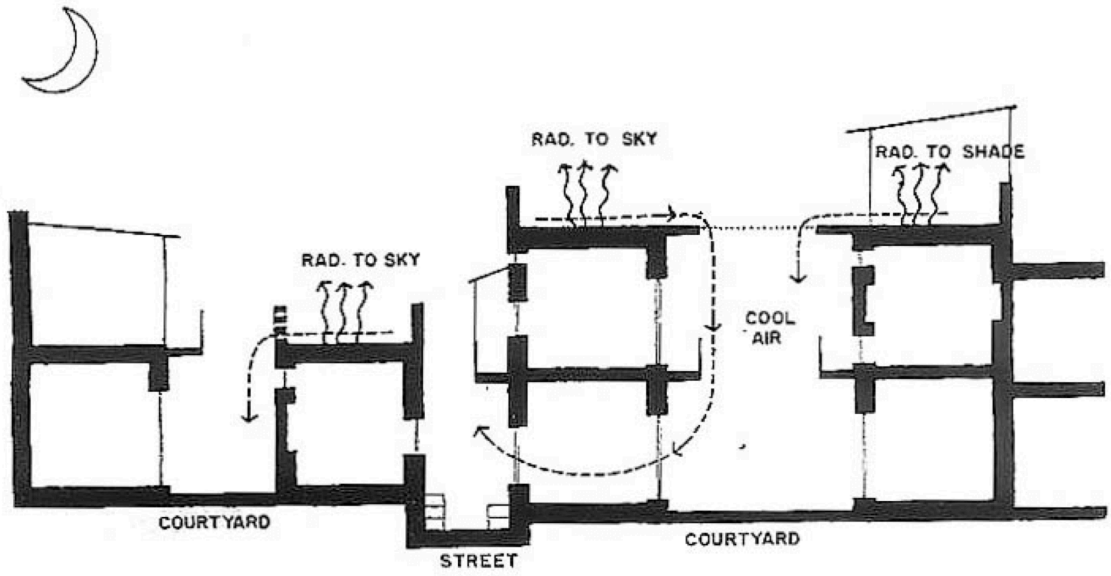
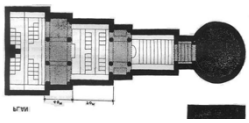
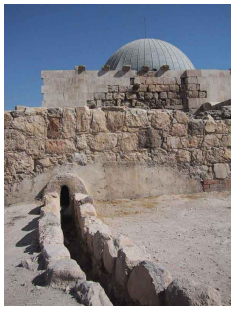
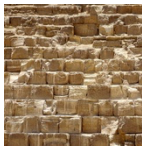


Figure 20: A combination of thermal mass walls and courtyards, creating a cooling effect[53]

One can clearly state that multiple ways of climate control were used in Mughal architecture to tackle the extreme climate conditions of Old Delhi. The use of architectural elements such as courtyard spaces and lattices in the facades, created thermal comfort zones that also blocked the direct sunlight. Nature was used to human advantage in the form of water, green spaces and natural ventilation through winds, in order to lower the temperatures and create a cooling effect. These methods indicate that multiple ways of climate control were used simultaneously and also in a very sustainable manner through vernacular architecture. These strategies could be adapted to modern architecture in India by using some elements mentioned, based on the available space and feasibility. The climate cooling strategies also varied from one Mughal edifice to another. This

[53] Ali, A. (2012, October 12). *Passive cooling and vernacularism in mughal ... - researchgate*. Researchgate. Retrieved March 2022, from https://www.researchgate.net/publication/267627217_Passive_Cooling_and_Vernacularism_in_Mughal_Buildings_in_North_India_A_Source_of_Inspiration_for_Sustainable_Development

depended on the architectural principles of the building alongside the design approach in order to make the building aesthetic and complete. Figure 21 gives a clear comparison between the sustainability elements used in Mughal architecture and whether it has any links to the overarching umbrella of Islamic architecture.

	Mughal Architecture	Mughal Example	Islamic Architecture	Islamic Example
Green Spaces	Green sustainability in the form of gardens		Was not a focus point in Islamic architecture	
Water	Water used for cooling through fountains and streams. Water storage done through step wells		Rainwater harvesting systems on roof tops[54]	
Natural Ventilation	Use of dome structures to create pressure differences and wind circulation		Use of a 'Malqaf' system for wind circulation	
Natural Lighting and Shading	Lighting and shading done by the use of a 'Jaali' system		Similar system as a 'Jaali' known as 'Mashrabiya'	
Materiality	Use of building materials such as red sandstone and white marble[5556]		Use of building materials such as clay and natural stone[5758]	 

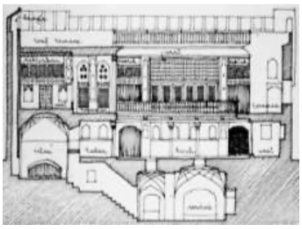
Courtyard Space	Found in all Mughal palaces		Lack of courtyards however, a predominant usage of basements[59]	

Figure 21: Comparison of sustainability elements, between Mughal and Islamic architecture to see if there are any similarities.

[54] *Water harvesting (i)*. Center for the Study of the Built Environment. (n.d.). Retrieved March 2022, from https://www.csbe.org/water-harvesting-i

[55] *White marble texture background with high resolution in seamless pattern for design art work and interior or exterior wall mural*. White Marble Texture Background With High Resolution In Seamless Pattern For Design Art Work And Interior Or Exterior Wall Mural-Tumm8899. (n.d.). Retrieved March 2022, from https://www.wallsheaven.co.uk/wall-murals/white-marble-texture-background-with-high-resolution-in-seamless-pattern-for-design-art-work-and-interior-or-exterior.-A149209914

[56] *Dholpur Red Sandstone*. Dholpur Red Sandstone by Goyal Stone Art from Dholpur Rajasthan | ID - 3531786. (n.d.). Retrieved March 2022, from https://www.exportersindia.com/product-detail/dholpur-red-sandstone-3531786.htm

[57] Facilitator, C. (2020, February 8). *Use of different types of clay in construction*. Constro Facilitator. Retrieved March 2022, from https://www.constrofacilitator.com/use-of-different-types-of-clay-in-construction/

[58] paulkunzeDE. (2019, June 18). *A close-up of the bricks from one of the pyramids in Egypt*. iStock. Retrieved March 2022, from https://www.istockphoto.com/nl/foto/piramide-bakstenen-gm1156292688-315084585

[59] Haraty, H. J. S., Raschid, M. Y. M., & Yunos, M. Y. M. (2018). *Morphology of Islamic traditional Iraqi courtyard house toward holistic Islamic approach in new residential development in Iraq*. International Journal of Engineering & Technology. Retrieved March 2022, from https://www.sciencepubco.com/index.php/ijet/article/view/18883

Discussion

Due to the high quality of construction, structural strength and low pollution rates, the Mughal buildings and palaces required very low maintenance. In today's day, Delhi is known to be one of the most polluted cities in the world and due to the extremely low air quality, one can observe the consequences in the Mughal structures that still stand. White marble edifices such as the Taj Mahal are turning yellow in color due to the high degradation of the material. Other buildings have cracks developing in the ceilings, and step wells are collecting dust, moss and mosquitos due to the stagnant water and pollution.

Preservation of these buildings and architectural heritages is crucial but also improving the air quality and reducing pollution is a must. One should be motivated to use sustainable ways of climate control and building construction to reduce pollution rates in the built environment. Mughal architecture is a prime example for inspiration to use vernacular and sustainable means of architecture.

Applying all the sustainability measures used in Mughal architecture to modern day stand-alone houses in Delhi might not be very practical and economical, however, inspiration and the use of some elements can be very well added to modern day houses. The use of greenery through gardens and interior plantations is one such aspect that could be incorporated. Creating a miniature courtyard with a fountain or water body would also be helpful. Lastly, the use of a simplified "Jaali" system for sun shading and ventilation could be proposed to a modern household.

An interesting theme to cover as a continuation of the thesis topic is the social sustainability movements and dynamics within Mughal architecture. How did the

sustainable vernacular architecture influence the social dynamics of the residents and how did people interact with each other in specific architectural spaces such as the step wells, ornamental gardens, courtyards and corridors behind the “Jaali” system? If mimicked in today’s architecture, would the Mughal style also have a social impact on modern social dynamics?

Another topic to investigate is the sustainability aspects and technology advancements introduced by the British in the colonial period in India that took place after the Mughal sovereignty. Were there any sustainability advancements with low tech and vernacular architecture? Or did the technology bring in new systems and instruments of climate control? Was this the reason for a pollution escalation in Delhi?

The topics and rhetorical questions mentioned above can further support and improve the topic of investigation. It could also help in answering and finding solutions for the current pollution rates in Delhi from a built environment standpoint.

Conclusion

The Mughal sovereignty were known for their immense interests in art and craftsmanship. They left their trademarks in the form of fine and intricately detailed architectural forms such as palaces, mosques and gardens. While the world appreciates the architecture and the topic of interest normally being the monumentality, heritage and ornamentation of the structures, this thesis analyzed the edifices through a topic that is often not related to Mughal architecture.

Due to the fact that Old Delhi has always had extreme climate conditions throughout history, the Mughals brought in architectural styles from countries with similar climates such as Persia, Turkey, Egypt etc. Signs of development started under the throne of Babur. The architecture was further developed under Humayun and Akbar, while reaching its pinnacle and prime under the rule of Shah Jahan. And the Mughal empire reached its downfall under Aurangzeb. The six different rulers of the Mughal dynasty contributed to the architecture over the years to create mesmerizing buildings that are still spoken about. The topic of interest throughout the thesis is the vernacular and sustainable ways of climate control used through the architecture to tackle the extreme summer heat of Old Delhi.

Architectural elements such as “Malqaf” and “Mashrabiya” from the Middle East, were adapted and used in Mughal architecture in the form of dome structures for ventilation and “Jaali” systems for natural lighting and shading. These alongside other forms of climate control such as green spaces, water cooling systems, materiality, and courtyard spaces helped in creating thermal comfort within the Mughal structures during the peak heat of Old Delhi.

With the rise in technology and societal advancements, unsustainable and environmental polluting ways of climate control have been incorporated with in households in Delhi. The consequence of this is that Delhi is now one of the most polluted cities in the world. The aim of the thesis was not only to inform the reader about Old Delhi's architectural history from 1526 to 1707, but it also aims to inspire people to use traditional, vernacular and sustainable ways of climate control introduced by the Mughal empire. This helps in answering the question, *how did the evolution of Mughal palace typologies tackle the extreme climate conditions of Old Delhi and what were the vernacular and sustainable techniques used in Mughal Architecture to create thermal comfort for the residents of these palaces?*

The goal is to revitalize Mughal architectural heritage by implementing its elements in modern housing in Delhi. By doing so, it would widen the positive spread of sustainability in the form of climate control to reduce pollution rates, and at the same time it would encourage people to interpret and learn from Mughal architecture in new ways other than the norms.

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