Bio-mimicry and Urban Design

A case study of Sheikh Mohammed bin Zayed City

التقليد الحيوي و التصميم الحضري

دراسة نموذج مدينة الشيخ محمد بن زايد للاسكان

by

AHMAD F.M. TIMRAZ

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Dr. Hanan Taleb

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Abstract

The urban planning sector had expanded massively in the last few years since it is facing different challenges and many researchers have been conducted for the best practices to ensure the exposure of the sustainability in the cities.

UAE is looking at the urban planning, and constructing future vision aims to create a sustainable city that can strength the local economy and preserve the environment from the different pollutions sources such as large-scale projects. Adding to that, the concentration of meeting optimum outdoor thermal comforts and reducing negative impacts urban expansion such as the urban heat island phenomena and air and noise pollution.

Many housing projects started to be designed and built in different areas as an approach by the government to ensure best life quality for citizens aiming to integrate sustainable standards to these housing projects as a factor that can conserve the energy and water consumption, as well as integrate the environment with the construction practices to reduce the impacts of buildings on environment and cities in terms of heat pollution and waste generation. One of these projects is "Sheikh Mohammed bin Zayed City" that is used as a case study for this research.

Bio-mimicry design is a scientific field that can help engineers and urban designers find solution and answers to environmental and social sustainable challenges, this works when designers start observing a specific natural life on how it functions and adapts to the atmosphere and surrounding nature. Beehive design and structure was one of the fascinating examples that architects and designers were inspired by. This research proposed a number of urban design ideas that were influenced by the Beehive cell steady shape and its integrated geometry.

The combination between Bio-mimicry design and urban design strategies can enhance the urban microclimate condition and result in an increase level of thermal satisfaction for users of urban spaces. This will comply with the social sustainability as it encourage healthy entertaining outdoor activities that could bring community residence together.

This research studied site orientation and building layout and it was found that both impacts air temperature and wind speed in addition to relative humidity as well as shading coverage layout that was proposed in three different options beside water feature affect on urban areas. It is important to keep exploring and looking for the optimum architectural solution that complies with passive design strategies which enhancing environmental conditions

الملخص

لقد شهد قطاع التخطيط الحضري توسعا كبيراو تطورا في السنوات القليلة الماضية لما يواجهه من تحديات مختلفة وقد تم إجراء العديد من الدراسات و البحوث من قبل العديد من الباحثين لأفضل الممارسات لضمان تمكين المدن من للاستدامة في المستقبل.

و بما ان الإمارات العربية المتحدة تبحث في التخطيط الحضري ، كيفية بناء رؤية مستقبلية تهدف إلى إنشاء مدينة مستدامة قادرة على تقوية الاقتصاد المحلي وفي نفس الوقت الحفاظ على البيئة من مصادر التلوث المختلفة من مثل المشاريع الكبيرى. إضافة إلى ذلك ، التركيز على اجتماع الراحة الحرارية المثالية في الهواء الطلق مع الحد من الآثار السلبية للتوسع العمراني مثل ظاهرة الجزر الحرارية الحضرية وتلوث الهواء والضوضاء.

بدأ مؤخرا تصميم وتنفيذ العديد من مشاريع الإسكان في مناطق مختلفة في الدولة كنهج من قبل الحكومة لضمان أفضل جودة لحياة للمواطنين حيث تهدف التصاميم إلى دمج المعايير المستدامة لهذه المشاريع السكنية مما يساعد في الحفاظ على استهلاك الطاقة والمياه ، وكذلك التكامل في وسائل و ممارسات البناء بهدف الحد من آثار المباني على البيئة والمدن من حيث تلوث الحرارة وتوليد النفايات. أحد هذه المشاريع هو "مدينة الشيخ محمد بن زايد" التي تستخدم كنموذج للدراسة في هذا البحث.

يعتبرمبدأ محاكاة التصميم الحيوي مجالًا علميًا يمكن أن يساعد المهندسين والمصممين الحضريين في إيجاد الحلول والإجابات للتحديات البيئية والاجتماعية المستدامة ، حيث يعمل هذا المبدا عندما يقوم المصممون بمراقبة حياة طبيعية محددة و التركيز على كيفية عملها وتكييفها مع الغلاف الجوي والطبيعة المحيطة. وقد كان تصميم هياكل خلية النحل واحدة من الأمثلة الرائعة التي استلهمها المهندسون المعماريون والمصممون بعد معاينتها و التركيز في نظامها و بنيتها. و قد اقترح هذا البحث عددًا من أفكار التصميم العمراني التي تأثرت بنمط خلية النحل الثابت والهندسة المتكاملة لها. ويمكن الجمع بين محاكاة التصميم الحيوي واستراتيجيات التصميم الحضري لتعزيز الظروف المناخية الحضرية بهدف زيادة مستوى الارتياح الحراري لمستخدمي المساحات الحضرية. مما يتوافق مع الاستدامة الاجتماعية حيث يشجع على الأنشطة الترفيهية في الهواء الطلق والتي يمكن أن تجمع بين افراد المجتمع كافة.

قام هذا البحث بدراسة اتجاه الموقع وتخطيط المبنى ، وتبين أن كلا منهما يؤثر على درجة حرارة الهواء وسرعة الرياح الى جانب الرطوبة النسبية بالإضافة إلى تخطيط تغطية التظليل الذي تم اقتراحه في ثلاثة خيارات مختلفة بجانب اضافة عناصر مائية خارجية تؤثر على المناطق الحضرية.و قد وجد انه من المهم الحفاظ على الاستكشاف والبحث لايجاد الحل الأمثل لكل منطقة و موقع و الذي يتوافق مع استراتيجيات التصميم التي تعزز الظروف البيئية.

Chapter 1: Introduction

1.1Urbanism

The urbanism expansion became a major problem that most countries are suffering from especially when a huge number of the population are living in the urban areas and making 54% of the total population number as taken in 2014. This percentage started to be observed once it was compared in 1950 when only 30% of the world was living in the urban area and the expected percentage in 2050 can reach up to 66% as per (United Nation 2014). The huge increment and preferences of the world population living in urban cities may lead to more environmental problems which should be sorted out before they increase and may be out of control. The trend of the urbanism has become very important to cover the huge population growth which adds more requirements on the present and future needs since the world population increased rapidly in the past years. Because of this growing, and from the vision of obtaining the population needs, the unorganized planning for the urbanism and the future visions in the government sector made it really hard to control the problems caused from that and here it became important to start thinking of a more organized urban planning with a future vision that includes sustainable requirements that can help to maintain the previous problems and to ensure a better future which can be done through researchers and governments.

Urbanism has caused many environmental problems which can be seen from the increments in the atmospheric temperature (Heat Island) and the Co2 emissions at these areas because of the rapid progress in the developments and the high population density. These factors didn't only affect the environment, it also affected the economy, and even the social life. Because in some areas the properties cost had increased and in some other areas it decreased a lot and that made an in equivalent economy bases. At the same time, the huge

developments affected the social life since most of the areas are occupied under construction purposes and investors ignored the open spaces which caused many problems in the society. Countries started to take these challenges seriously and set future plans with current implementation enhancements in order to study all of these problems, and to solve them. the result was at one hand rating systems that evaluate these challenges and provide developers with some options and suggestion to reduce the negative impact f their construction on the surrounding environment and built up area as well as adding objectives and long-term goals that can affect positively in terms of the environment, economy, and society.

Some of the most famous international rating systems are BREEAM that stands for "Building Research Establishment Environmental Assessment Method" and LEED that stands for "Leadership in energy and environmental designs", Also, NABERS is known to be the "National Australian Built Environment Rating System" in addition to Energy Star and other systems that aims to reduce energy consumption as well as slow down the consumption of the raw materials in order to eliminate the negative effect on the environment as well as save the natural resources for future generations.

Mosammam et al. 2016 indicate that sustainability implementation on the urbanism plans can be helpful to preserve the environment by reducing the energy consumption which is produced from the fuel burning and replace them with renewable resources to achieve equivalent ecosystem. however, investors are willing to expand the construction levels which replaces the green areas (landscape) to paved areas and people start to suffer from not having open spaces or green areas for outdoor activates which will impact their comfort and raise depression levels. Adding to that, the big number of buildings that is causing an increase in the temperature degree which decrease the levels of the human comforts and the outdoor thermal comforts as well as add load to the HVAC systems to provide the needed comfort

levels at indoor spaces, and that is what we call it heat island and on urban levels it is called (Urban Heat Island). that is illustrated in the (figure 1.1) below.

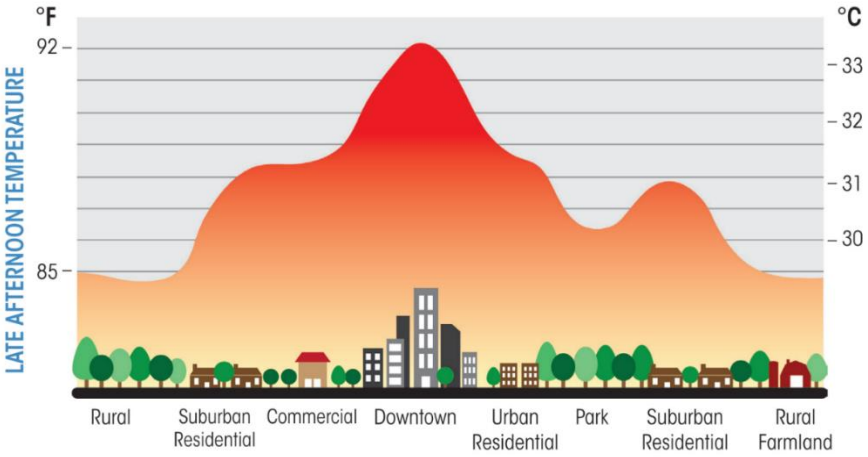


Figure 1.1Urban Heat Island

1.2 United Arab Emirate vision 2030

As per the study that was done by the united nations in 2014, it concluded that 66% of the world population will be living in urban areas and 34% will remain in the rural areas. As per (GCSE, 2015), This is reflected in the United Arab Emirate as well. Since Abu Dhabi and Dubai's populations have increased between 1968 and 2017. And high percentage of population is preferring to work in the city center area of Dubai and Abu Dhabi even if they live in other cities because there are wide roads the connects the whole country together, fast transportations like the cars and metros and finally the income in those two cities are higher compared to the other cities in UAE so that encourages people to work in them. this indeed refers to the increase in Urban density and concentration of population around service facilities and center of cities. In fact, The cities are the most areas that are facing the urbanism problems especially the capital cities. Many reasons have caused the transformation from the rural areas to the cities; fast transportations, better jobs, and more facilities.

Since UAE became one of the trends marks all over the world in terms of architecture and urban design developments, as in the last 15 years the construction development in Dubai and Abu Dhabi sets a benchmark for all biggest, tallest projects as well as the desire to be number one in different aspects such as commercial and entertainment industry. (Ogaily 2015). It was essential due to this development and future expansion targets to study future strategies and plans to face the increase of population growth and rapid expansion in urban development in order to protect future generation and ensure sustainable development over upcoming years. Therefore the government started to develop a long-term vision that consider all seven emirates in general and includes individual strategies that will be implemented in each emirate in respond to its requirements and individuate characteristic it is called (UAE National Agenda) that includes national vision of 2021 where some indicators were set to trace and evaluate the progress of the national plans and set clear targets hat all seven emirates shell work to comply with. these indicators are targeting different fields such as human development, social cohesion and other parameters related to social sustainability in addition to the economic sustainability. Indicators like Non-Oil Real GDP Growth and Gross National Income (GNI) per Capita as well as Net Inflow of Foreign Direct Investment as % of GDP are targeting and evaluating while other indicators are linked to environmental sustainability such as Quality of Air, Transport Infrastructure, Percentage of Treated Waste of Total Waste Generated and Water Scarcity Index in addition to many other indicators related to cultural and national security sustainability.("Vision" 2010)

In compliance with this vision that was launched in 2010 Different sectors of UAE government started to work toward developing and building strong sustainable strategies for future expansion and progress and this includes the construction and master planning industry were research and studied were done to meet the future vision, this was translated in

different aspects such as developing building rating system in Abu Dhabi that is called Estidama as well as Dubai green building rating system that is called Sa'fat. In Abu Dhabi Estidama is considered mandatory for all new project were the Urban Planning Council in Abu Dhabi is supervising and certifying individuals as well as different project that meets the regulation of the green building rating system that is called Estidama which means sustainability in Arabic language were the rating system is divided into five categories named as 1 pearl that is mandatory for all villas and new projects that are less than 75,000 sqm which is considered the lowest level in this system followed by 2 pearl that is mandatory to all government projects, hotels and Masjid projects. While the rest of the levels up to the highest score that is 5 pearl is voluntarily for building owners and developers.

On the other hand, Dubai has implemented on 2007 the Environmental, health, and safety requirement to all construction projects located in Jabal Ali and other free zone areas were a qualified EHS officer or Consultant office shall be added to the project team to ensure complying with the new regulations and conditions. However, in 2011 Dubai launched the Green Building Regulation code that was mandatory for all government project in Dubai and optional to other project developers and building owners Keeping in mind That Dubai Electrical and Water Authority has set earlier on 2008 new design regulation related to green building standards aiming to ensure safe and slow move toward sustainability. And by 2014 there was a total of 44 government buildings constructed in Dubai that complies with the green building regulations, therefore, it was announced as mandatory for other private sectors and added to the approval system in Dubai Municipality online submission portal. (Dubai Government 2011). This, in fact, shows the steady and thoughtful development progress that the government is following in order to ensure sustainable change that is built on the strong foundation and secure infrastructure services. This will allow different local and international

investors to respond to these changes and improvement without deep impact on the market this will also sustain the faith and confidence of different investors in the regulation and decision makers in UAE this will definitely encourage further investments and encourage capital flow to the region and UAE market in specific. this will diversify the income and allow the economy to grow away from oil market and fuel industry. That meets the vision of the government that emphasize on the fact that UAE should be proud when the last Gallon of oil will be deported not depressed or fall in a panic since it has built a strong economy that uses other resources to generate income like smart technology, and innovative products.

1.2.1 Sustainable Urban Development In Abu Dhabi & Dubai

Both Abu Dhabi the Capital city of UAE and Dubai the economical capital of UAE are setting high targets and standards for sustainable development, As H.E Eng. Hussain Nasser Lootah the General Director of Dubai Municipality stated (DM 2016) Dubai is aiming to be one of the top sustainable cities around the globe despite the fact Dubai started later than other megacities, it succeeded in catching up with the competition and stand out in various implementations were we learned from others and set our own vision. UAE launched The national Committee of sustainable development goals complying with United Nation Sustainable Goals that were listed and defined under the title of 2030 Agenda for Sustainable Development announced by UN General Secretary Ban Ki-moon. The first report of this committee was published on April 2017 where each goal is discussed and translated into an action plan. These goals were announced on Sep. 2015 and countries shell respond and achieve within 15 years by setting short-term goals and milestones to trace and evaluate the progress or deterioration in the different parameters. Since UAE is one of the countries that adopted this Goals, the Government set a number of regulation and indicators that respond

and comply with the United nation vision. one of the goals is the Sustainable Cities and communities that are listed as number eleven among the seventeen goals. Different initiatives were taken to meet this goal, one of them is the effort that UAE is putting to build Sustainable communities that ensure responsible energy consumption and help to save environmental resources by providing mass production of homes and master planning project that saves construction waste and implement integrated design development that saves time and initial cost. Some of these projects are set for research and pilot projects as well such as Masdar city in Abu Dhabi and The Sustainable city in Dubai while some other projects set an example in energy saving and reduction of water consumption such as Silicon Oasis in Dubai, In addition to another project that is planned and will be launched by 2020 such as Dubai South District and dessert rose city. ("UAESDGS" 2018). It was found that by encouraging renewable energy implementation and setting strategies for water and electricity efficient consumption as well as reducing solid waste and set sewage water treatment plants, Dubai can set a row model for long-term environmental sustainable urban development city therefore Dubai Municipality is aligning its efforts toward this goal by promoting sustainable urban development strategies that include transportation and waste management (DM 2016). On the other hand, Abu Dhabi was going through massive improvement in term of Urban development since 2009 were the pillars for Sustainable cities starts with Thriving Economy then Vital and Natural Environment, while the third pillar is practical, built environment were strong infrastructure is introduced and finally a healthy and active society. (DMA 2009) However, the report indicates that the UAE was listed Number 88 on an international scale for most livable cities in the world and by 2009 the date of publishing the report it managed to move upward to be number 72 across the world. (DMA 2009) It is noted through the last ten years that Abu Dhabi is developing a sustainable master plan for future expansion and

development by creating different high standard projects that are reflecting the vision of sustainable modern communities starting with Masdar city and Saadiyat island that encourage tourism and attract international investors toward this one of a kind project. as well as Shakhbout City were the master plan is completed by 2015 which is designed to include Housing units and service facilities for UAE nationals meeting the latest standard in sustainable Urban development and environmental requirements. despite the fact that less sustainable projects are taking place in Abu Dhabi it is important to note that Abu Dhabi was the first city in the region that generated its own Green standard rating system (Crowcroft 2013)

Estidama is designed to include three different categories starting with Pearl Building Rating System then Pearl Villa Rating System and third is Pearl Community Rating System were each category is setting guidelines and benchmarks that respond and comply with the requirements of the projects falling under its category.

1.2.2 Housing Projects In UAE

Kerr et. all 2013 found that Abu Dhabi funded 330 AED more over housing projects and social development infrastructure services as well as education and healthcare specialized projects that are planned to be on track over the next five years. However it is obvious that there is a special attention by the UAE government toward Housing projects for Emiratis citizens, were it is believed to be more efficient to develop a major master plan project that are found to be more economical to have such projects rather than giving individual plots for individuals to design and supervise the construction phase at their own, while a specialized construction projects management office can be in charge for supervision and quality insurance as well as reporting to the funding department that will make fund flow easier and

more efficient since it is linked to accomplishment on site. Many Housing Projects are launched and ongoing all supervised by different Authorities such as Sheikh Zayed Housing program, Sheikh Mohammed Bin Zayed Housing, and Shaikh Mohammed Bin Rashid Housing program, were each program is responsible and in charge for developing residential communities served by educational and healthcare infrastructure as well as transportation network beside other fundamental infrastructure like water and drainage system as well as electricity and landscaping areas.

The main players in these project are usually two sectors as per (Kerr et. all 2013) first one is the employer that is either private developer who had owns the land and built a feasibility plan for the required project and targeted users within the general regulation of the local municipality. or in a different case it could be one of the previously mentioned programs was the employer is within the management board of this programs. In both cases, the second player is going to be the contractor and consultant offices who run the technical side of the project and supervise the construction phases starting by obtaining authorities approval over blueprints up to handing over the project to the employer by the end of all phases.

Some of the recent Housing projects are responding to the sustainable standard as these projects are falling under the green rating system either in Dubai or Abu Dhabi or any other city within the UAE, Ajman Housing Project and Sheikh Mohammed Housing Project in Fujairah are an example for the green housing projects in UAE.

1.3 Bio-Mimicry Architecture

Bio-mimicry design can be understood as the combination between studying the scientific features of the natural life such as biological skin layers or birds flying techniques or the shell

structure and incorporate it with the problems that are facing designers and engineers in different sectors in order to set a methodology to sort some solutions for these challenges.

It is interesting that in bio-mimicry design, many disciplines can relate to the natural life and its wide variety of components such as acoustical, chemical or mechanical engineers, in addition to architects, geologists, environmental scientist, and many other different groups who all can relate and seek to understand the different natural forms and implement it in a useful mechanisms and beneficial day to day techniques. Since Human Been history on earth is less and limited compared to other organic feature that was inhabiting this planet long time before mankind do, therefore it is useful to study their survival tools and techniques since sustainability is the target of all creatures and achieving it in the best suitable way is in fact linked to the natural and environmental aspects controlling the built environment that mankind is inhabiting and interacting with. As (Royall 2016) stated, Nature succeeded in sorting out the mechanical and structural challenges that mankind is facing now in their existing chain without side effects such as inactive waste or environment depletion Therefore this topic sets an interesting subject for researchers to explore and examine.

1.3.1 Bio-mimicry definition

Looking for the Term Bio-mimicry in Oxford dictionary will result in "The design and production of materials, structures, and systems that are modeled on biological entities and processes." (Oxford Dictionaries 2018) while Cambridge dictionary refers to it as "the practice of making the technological and industrial design copy of natural process" (Cambridge dictionary 2018). However, the term Bionics was not Known until 1960 when Jack Steels used it to refer to the system that copies function that is originally found in nature (Environmental and Ecology 2018). Despite the fact that "Sagrada Familia" Church that was

designed by the famous Architect Antoni Gaudi which started construction on site in 1882 had a clear structure that sets a strong example for nature driven designs were structural problems were solved using nature forms as columns were modeled to act like branching canopies of plants as shown (fig. 1.2) below adding to the fact that the external perspective is showing a similarity with the termite house as shown in(fig. 1.3) below. Yet the term was not generated or popular at that time until Jack Steels the psychiatrist and engineer used it 78 years later. This indicates that up to that time Architects were inspired by nature and seeking construction solutions for their structural designs from the surrounding organic elements under the definition of Design concept or Inspiration.

The figures below highlights the similarity between the architectural design of the church and the natural copied feature surrounding the project as tree branching and the geometry of the termite house in comparison with the exterior perspective of the church.

Figure 1.2- The Sagrada Familia - Church Geometry

Figure 1.3- The Sagrada Familia - Church Perspective & Termite house structure

In addition to that other examples indicates that nature is considered the source of concept or basic problem-solving method that helped engineers and researchers. such as the bat's high-frequency transmitter that is much more developed than our current radar systems, and the navigation system that birds are using while moving from one climatic region to another during seasons changing without counting on our resources like Wi-Fi and radio waves or updated maps in current GPS devices. In addition to many other examples were nature elements are setting an outstanding example in continues sustainable existing on earth.

When (McDonough and Braungart, 1998) raised the topic in a question form wondering why it is not possible to design a building as a plant that generates Oxygen and sequesters carbon as well as distills water while interacting with soil levels and use solar energy as a fuel. why can't buildings change colors with different seasons? It was a statement that buildings and arhitectural designs should comply with nature not resist it, In order for buildings to sustain nature should be related to as a mentor and row model not as a challenge and obstacle. an early example of bio-mimicry techniques used by mankind is presented in Quran when Qabeel- one of Prophet Adam Sons- replicated the act of Crow to hide his dead brother body "Then Allah sent a Ravan (Crow) which scratched in the ground, that He might show him how to hide the corpse of his brother. He said: 'Woe is me! Am I not able to be even like this Ravan so that I may hide the corpse of my brother?' and then he became regretful." (Al Maidah-32). Another example of early Bio-mimicry approaches was found in the ninth century at Muslims era in Spain where it is believed that Abu al-Qasim Abbas ibn Firnas ibn Wirdas al-Takurini Known as Abbas Bin Firnas was the first one to test the flying mechanism after observing birds and pigeons and trying to replicat its wings structure using genuine feathers. followed by his student Abu al-Nasr Ismael Al-Johari who faced death after launching himself from the minaret of a Mosque in the eleventh century (Muslim Ink 2018).

The bio-mimicry is an attempt to drive mankind ever growing evolution toward a sustainable development where it can resist time challenges and survive over decades to prevent the extinction of mankind like other previous creature, therefore, a sustainable development is considered our adaptive strategies to comply with environmental changes. As stated by Benyus; failures are fossils, after three billion years of continues research, our surrounding nature was found to be the answer to survival" (Benyus, 1998,). Benyus agrees that mankind development should learn and accept nature impact and respect time change.

Under the title of "innovation inspired by nature" Benyus, explains that the term sustainable development emerged when the effort was directed toward finding the balance between mass production to comply with population growth from one side and environmental aspects and resource limitations from the other side where it is needed to consider future generations. many approaches were considered toward sustainable production and bio-mimicry is considered as one of them after (Benyus, 1998)

Another example for the natural inspired design is the DaimlerChrysler's Car shown in figure 1.3 The aerodynamic features of the (Ostracion Meleagris) known as boxfish were studied and simulated using computer modeling software then the structure was built and enhanced with extra details in order to generate the car model. the result was very close to the first inspiring skeleton as shown below figure 1.4 (Zari, 2007) The Bionic car shown in figure 1.3 was found to be more efficient in term of fuel consumption since the model resist less air as it was driven from box fish model and replicate its curves that respond to water resistant that is similar to car facing air resistant.

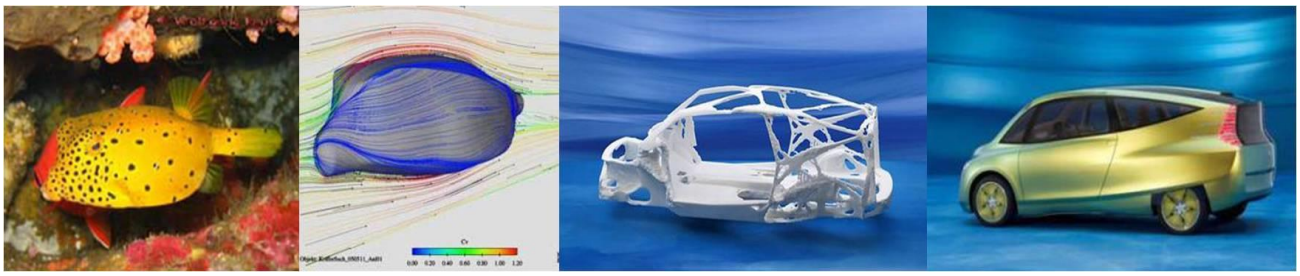


Figure 1.4- Zari, 2007- Daimler Crysler bionic car

However while going for a bio-mimicry idea or design it is essential to remember that the target is an efficient, sustainable design that comply with form and function needs. this does not necessarily mean than any bio-mimicry idea or design is going to be sustainable design or sufficient for users, therefore, it is essential to study the need and the problem in depth in order address it effectively as some solutions might not be convenient on a lifecycle analysis base (Zari, 2007).

1.3.2 Bio-mimicry Design

The implementation of Bio-mimicry in a design can be done in three scenarios and in some designs several scenarios can be used were each of the three scenarios has five options as explained by Zari, 2007 were the first scenario is known as Organism Level were the design replicate a specific organism either in Form, Function, Construction, Material or process as for example if the idea is mimicry of a palm tree then the mimicry of the architecture design will result in a building that looks like the palm tree as Architect Basil Al-bayati present in "Al-Nakhla Telecommunication tower " that was proposed to the ministry of information, Saudi Arabia and the interior design work for the Masjid that was done also by the Iraqi Architect Basil Al-Bayati were the palm tree shape was used for the interior decoration as seen in Fig. 1.5 (Albayati 2018) This was meant to reflect the cultural

iconic element into the building in order to strengthen the identity of the design and link it to the surrounding culture pattern and elements.

Figure 1.5- (Albayati 2018) - Work Index

On the other hand, the mimicry could be processed in the organism scenario as (Zari, 2007) sets the example of a termite were the building or space might work in the same way as the termite were it produces hydrogen for example. Or in a different approach, the Organism Level might be seen in a constructional way were the building, for example, mimics the growth phases of termite in the construction progress. (Zari, 2007)

While the second scenario of Bio-mimicry is the Behavior level that goes also in five different option as Bio-mimicry behavior level in term of Form, for example, where the product looks like it was designed by a termite. Or the selecting of Behavior level in Process scenario where the building would reflect the impression as if it was built by a termite in term of selecting best orientation and designing carefully the ventilation system or replicate the behavior of users within the space that reflects termites function. (Zari, 2007).

Followed by the third level that is known as the ecosystem which replicates the form, for example, which means that the building would look like space were the termites could live in

or replicating the process were the building or the products captures energy from the solar system and store fresh water or stormwater for example. The table below identifies each level of the three levels and gives the example of a termite as per Zari, 2007 express it.

Table 1- A Framework for the Application of Bio-mimicry- Zari, 2007

Level of Bio-mimicry	Scenarios	Example - A building that mimics termites:
Organism level (Mimicry of a specific organism)	Form	The building looks like a termite.
	Material	The building is made from the same material as a termite; a material that mimics termite exoskeleton / skin for example.
	Construction	The building is made in the same way as a termite; it goes through various growth cycles for example.
	Process	The building works in the same way as an individual termite; it produces hydrogen efficiently through meta-genomics for example.
	Function	The building functions like a termite in a larger context; it recycles cellulose waste and creates soil for example.
Behavior level (Mimicry of how an organism behaves or relates to its larger context)	Form	The building looks like it was made by a termite; a replica of a termite mound for example.
	Material	The building is made from the same materials that a termite builds with; using digested fine soil as the primary material for example.
	Construction	The building is made in the same way that a termite would build in; piling earth in certain places at certain times for example.
	Process	The building works in the same way as a termite mound would; by careful orientation, shape, and natural ventilation for example, or it mimics how termites work together.
	Function	The building functions in the same way that it would if made by termites; internal conditions are regulated to be optimal and thermally stable for example
Ecosystem level (Mimicry of an ecosystem)	Form	The building looks like an ecosystem (a termite would live in).
	Material	The building is made from the same kind of materials that (a termite) ecosystem is made of; it uses naturally occurring common compounds
	Construction	The building is assembled in the same way as a (termite) ecosystem; principles of succession and increasing complexity over time are used for example.
	Process	The building works in the same way as a (termite) ecosystem; it captures and converts energy from the sun, and stores water for example
	Function	The building is able to function in the same way that a (termite) ecosystem would and forms part of a complex system it is able to participate in the hydrological, carbon, nitrogen cycles for example.

In selecting the Bio-mimicry level it is important to understand the subject of the design and the function related to it, since the successful process starts by a scold research base that explores all aspects of the project and lists different users requirement and every aspect of the design location and function as for example the Hydrological Center of the University of Namibia that is located in a harsh dessert were rainfall percentage is negligible were the Namibian desert beetle (fig.1.6) lives. it was found that this beetle has a delicate system for water harvesting since it depends on a rugged part of its body to collect water from periodical

fogy winds (Thomas 2018) that is noted to take place six times monthly on an average. and with the help of a wax coating layer and number of channels directing the water drops toward the beetle's mouth. This strategy was replicated in Bio-mimicry Organism level in designing the Hydrological Center at the University of Namibia that was proposed by Matthew Parkes a British architect representing KSS Architects. in addition to that a deeper study was carried in 2011 by Knight as followed by a discussion by Pavilions (2007) aims to understand the material and properties of the beetle in order to develop or suggest a technique or material that helps clearing fogs in critical structures such as airports.(Zari, 2007)

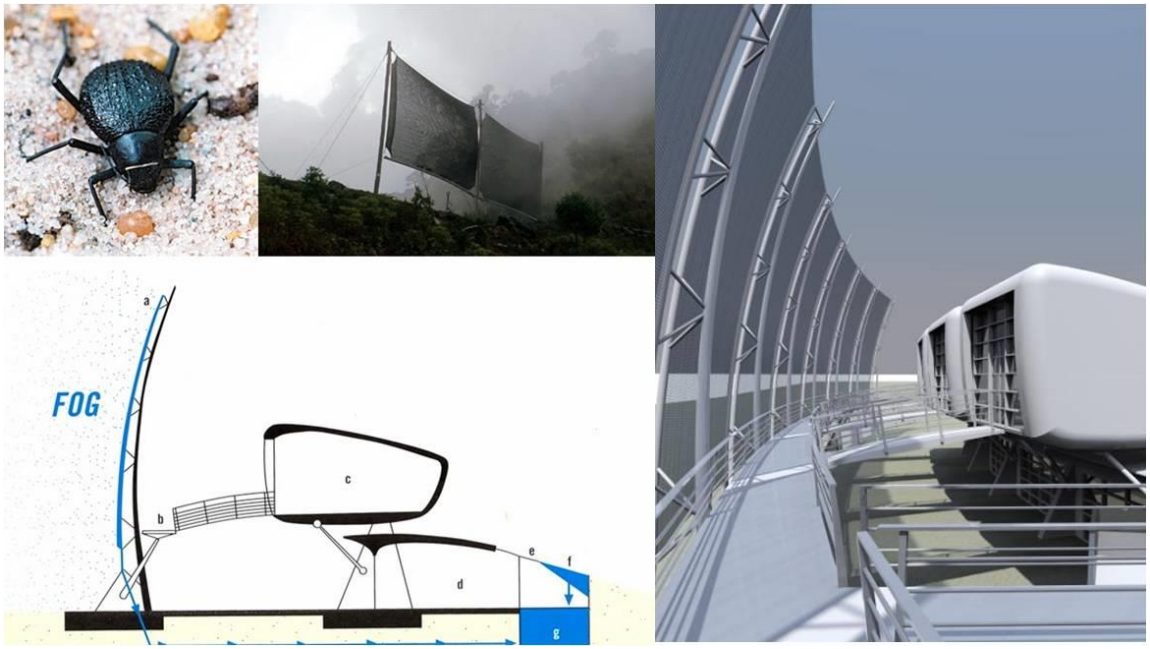


Figure 1.6- Hydrological Center, University of Namibia-Thomas 2018,

another local example of Bio-mimicry designs are the shading-charging stations designed by "D idea Media" and distributed in different location in Dubai for public to enjoy shaded relaxing seats served by a electrical charging spots and interactive touch screen as well as advertising board all under artificial palm tree of six meters height that provides a Wi-Fi service up to 53m radial distance from the tree "Trunk" . Fig. 1.7 below shows one of the 260

units that were located in different public places in Dubai like Zabeel Park beside Burj Al-Arab. and it is expected to expand to Al-Mamzar Park and Dubai Creek Park. (The National 2015). The structure as shown below Figure 1.7 is replicating the shape of a palm tree in response to the cultural and natural background of the users and the location. Since a structure is needed for the purpose of providing Wi-Fi services and electrical connection as well as advertisement space it was designed to be related to the natural elements and adds a unique identity to the concept. This helps the design stand out and succeed when compared to other options as it was based on a deep thoughtful vision that respects both users needs and surrounding requirements and emphasize on the identity and the deep connection between the element and its surroundings. See Figure 1.7 below

Figure 1.7 - Smart Palms installation, a free wifi and mobile phone charging station for visitors at Umm Suqeim beach- The National 2015

It was proven that mankind was learning and replicating from surrounding nature for ages and this is an ongoing continues process that helps to generate a better connection with nature and achieve a sustainable relationship with the environment which will secure mankind surviving on this planet, As expressed by Benyus. Now is the race to rescue. since it was found that humans are at a turning point in their evaluation. (Benyus, 1998).

1.3.3 Bio-mimicry and Sustainability

Nowadays scientist are searching for methods to efficiently incorporate nature elements and mechanisms into man-made world and innovations (Ashaboglu 2018) by adapting the special characteristics of mother nature, different Architects and other industry specialist and engineers according to Selin Ashaboglu might be able to set real sustainable structure in the upcoming days. Also Pawlyn (2016) agrees that testing nature's systems and implementing them within human design can be the answer to many environmental challenges facing man-kind as it is not a new method since Renaissance architects were able to design a dome at the cathedral in florence that was completed in 1436 only after studying and exploring the eggshell structure and strength (Pawlyn 2016)

Another example of the impact Bio-mimicry designs can have over built environment is the shopping mall and office building project built in Harare, Zimbabwe were the concept was driven from a the termite structure in order to ensure comfortable indoor spaces without air-condition this will save energy specially that energy consumption and CO2 emission is the highest within the construction industry.(Pawlyn 2016) therefore utilizing Bio-mimicry study and deep research can help solving environmental problems and find sustainable solutions.

1.4 Research Outline

This research address the impact of a Bio-mimicry concept design on the Urban Design of a housing project in UAE, Guided by a sustainable vision toward enhancing the urban microclimate of the suggested area using passive design strategies inspired by the bio-mimicry concept since nature is believed to hold the answer to challenges and different obstacles people are facing in adapting to the environment and its ongoing evolution process.

It is important to build new vision toward the built environment and the interaction between nature and mankind during their day to day activities.

1.4.1 Problem Statement

The urban settlements are found to be a major attraction for population growth and it is being considered a strong example of its rapid expansion on an international level. The United Arab Emirates is not an exception since in the last eight years the urban master planning projects are recording a strong market demand and accelerating increase in supply. Different master planning project of residential or mixed-use buildings were announced and constructed in different cities within UAE either by private developers or government institution. This is attracting the attention toward the need for a clear and sustainable strategy in order to future proof this projects and the process of development for an upcoming generation in term of natural resources conservation and long-term environmental and social as well as economic impact.

This indeed forms the motivation behind this research since it is considering one of the residential urban design projects in UAE to be used as a case study which is constructed and supervised by a governmental institution that is considering it as a prototype for other projects that will be taking place in different location in UAE, therefore addressing this project for passive design strategies that are based on a Bio-mimicry concept design that was found to be sustainable in both of social and environmental aspect, will help future proofing this project and expand this example to different location around UAE. The focus of this research is build toward environmental and social aspects, however economic aspects were taken into consideration were the proposed design shell not impact or exceed the proposed budget or investment return plans.

1.4.2 Research aim and Objectives

This research is going to evaluate the microclimate enhancement passive design strategies that will be applied to an existing urban design residential project after redesigning it based on a beehive cell. The aim of this study is to understand the impact of the Bio-mimicry concept design over the microclimate of a conventional grid layout design in an Urban residential project. The objectives of this research are as follows:

- Understand the Bio-mimicry design process and levels through Literature review and its potential application in Urban Planning.
- Study the micro-climate features that impact UAE residential master plan projects and the factors that impact these features
- Select three passive design strategies that are found to set a deep impact on over microclimate features.
- Analyze and evaluate the current grid layout urban design project using environmental simulation software.
- Propose a revised urban design for the same project that is inspired and based on the bio-mimicry concept.
- Re-examine and analyze the proposed Design after applying the three passive design strategies using a qualitative approach were each phase generate the base case the next phase.
- finally, compare the final result of the design against the base case current design.
- Propose suggestion and recommendations accordingly.

Chapter 2 : Literature Review

2.1Sustainable Urban Design Development

As United Nation indicates in 2015 report, half of the population and more are occupying the Urban areas and concentrating and high-density cities and by 2015 this is percentage is going to increase to be around 90% that will set a huge load on the infrastructure at these dense communities and threaten to drive big number of problems in economic, social sector in addition to the environmental sector. Since Urban Development (UD) raises high risks in term of social categorizing of citizens and users beside economical load in developing new , extending infrastructure as well as the environmental impact that is found in the shape of harsh microclimate as well as natural resources depletion beside high energy consumption that is linked to CO2 emission and the decrease in freshwater resources as that is all overlapping to generate the global warming phenomena that affect the global safety and threaten mankind existing on earth.

Therefore there is a strong demand for a controlled, well organized urban expansion that responds to the population growth as well as the environmental requirements keeping both in a balance. this will save the economical status and help to secure future generation prosperity. The sense of responsibility toward urban sustainability was translated into actual actions since 1972 when the United Nation brought this topic into attention during the annual conference and used the term Urban Development clearly, However almost ten years later in 1983 Mr. Javier P. who was the General Secretary of the United Nation at that time worked together with the Norway Prime minister who was Gro Brundtland in establishing what is called the Brundtland Commission. It was Formally Known as The World Commission on Environment Development (WCED) that set the base for Public understanding for

Sustainability and its importance as well as introduce some suggestions and recommendations for enhancing the future surviving potential for upcoming generations. This Commission was the first to introduce the " Triple Bottom Line "

The urban sustainability tends to target all the current requirements that were classified into three different titles; the first one is the environmental aspect were all natural resources are extracted from . while some of the resources are not renewable, then there is the social aspect were people interact with each other and bond strong and healthy relationship and finally the economical aspect that guides the development process and considered a big challenge in keeping the balance between environmental limitations and Social requirement that meets a standard, fair economical plan This is Known as the Triple bottom line that was introduced first by John Elkington in 1994. The term was used in an article and explained in depth four years later in a book with the title of Cannibals with Forks: "The Triple Bottom Line of 21st Century Business". see (Fig. 2.1) below were the integration between the three titles are illustrated with a description of each category. (Zak 2015)

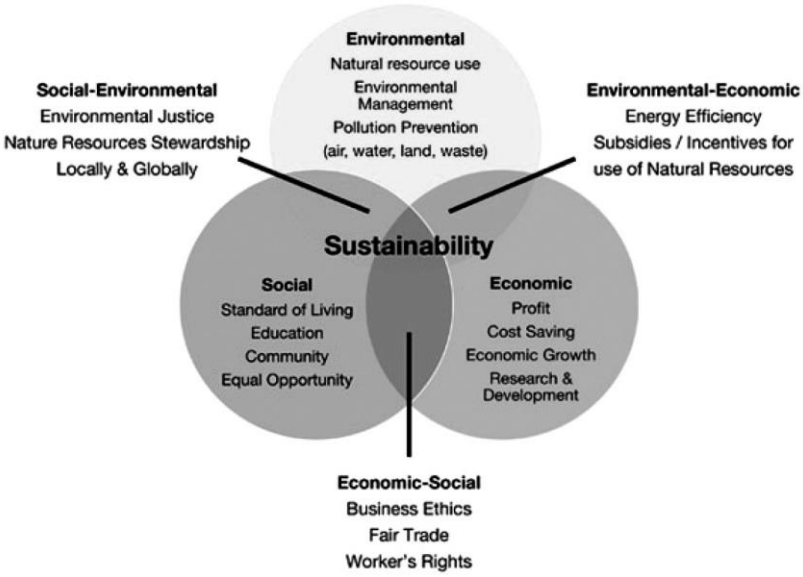


Figure 2.1-Three spheres of sustainability - Zak 2015

The theory of the "triple bottom line" known as 3BL is a practical method that is widely used in business were companies aiming to secure a balance, sustainable development with recognition of users and public interest in addition to environmental surrounding will use this method to evaluate any proposed project or new systems and current ongoing practices, on the other hand, the same method can be applied to any construction project or architectural design that governmental developers or individual landlords are willing to execute. Therefore this method is advisable in developing any master plan communities projects such as residential communists or business districts or any Urban development public services projects such as entertainment Hub or public gardens and open spaces.

The problem in unsuccessful urban projects or communities is that these projects remain existing and obvious as it reflects its mistakes to the surrounding communities and other elements within the city urban fabric that surrounds it. for example, an expansion within an existing community by adding extra number of buildings and residential or commercial units should be done after evaluating the traffic flow increase and the population density in respect to the infrastructure services otherwise a huge traffic jam is going to face all users of the area in addition to shorten in services that will impact the real-estate value of the project this will be reflected on the economical side as well as the social side of the project however the environmental side will not be better since a high-density community with no conscious supply of services will definitely record high numbers in CO2 emission and Air pollution as well as noise pollution and water & energy consumption. since a simple traffic analysis study could have saved the project from this negative scenario and attract the attention of engineers and decision makers to the need for alternative options to secure sustainable urban development. Therefore an early stage of design simulation and building the project over an integrated design approach is needed in order to visualize and set an estimation of potential

risks facing the project in all phases starting by construction period going to commissioning and handover period up to running and maintenance period ending up with destruction or reuse of the project based on its Life cycle analysis.

One of the famous Urban Planning fatal failures is the one in Michigan, Detroit, USA when a supreme court announced what is called " Pole-town Decision" where the permission was given to destroy an entire neighborhood for General Motors to be able to construct an Auto Plant. the action results in relocating 4,200 people after claiming that the new project will cover 140 businesses and one hospital in addition to six churches. This requires a total of $200 Million and cost a cost the city a loan of 150$ Million in federal funds. However, the destruction of a historically social community was aligned with a remarkable economic lost since General Motors failed in meeting the high expectation of the project related to a number of jobs opening that didn't meet half the expected ration even seven years later. in addition to major losses in jobs that were relocated since one-third of that projects closed immediately and turn a high number of citizen into unemployed workers adding load to the social insurance funds of the city and this was not predicted in the business plan of the project. Finally, in 2004, the supreme court in Michigan reversed the decision however the impact on the city is not reversible and continue to result in social, economic and environmental statues. In addition to the economic loss in the previous example, the environmental failure in a financially well-planned project will also threaten the whole business model and drive it to fail remarkably. The World Economic Forum supported this fact in 2015 by addressing the urban planning failures as a distinct risk factor that should not be neglected or underestimated and its long-term impact is not limited. (UN Habitat, 2015). In fact one of the signs that Urban development held unexpected risks and demand deep

research is the fact that 60% of the areas expected to become urban settlements by 2030 was already under construction by 2012, this indicates that the urban expansion and population growth is rapidly increasing and not restricted to any percentage. This adds responsibility to Urban designers and Architects as well as decision makers to understand and carefully analyze the risks and challenges facing each Urban Development proposal and master planning community projects.

2.2 Challenges Facing Urban Developments

UNISDR, 2011 realize that in fast-growing urban centers that are small to medium sized the threaten of disasters and its impact is bigger in comparison to the same risk in a larger area. This is found to be true in different examples, however, preparing the infrastructure of a city to face risks by addressing them earlier and set risk management plan will save social fabric as well as environmental pattern of the city to pass them through the challenge and this will result in string economic statues unlike a fragile community that is not prepared or an environmental factor that is not protected.

One of the many risks facing Cities is the Urban Sprawl that is defined as spreading of development through landscape way far from the population growth in another way it is the urban communities that are far from the city center and is expected to turn to an Auto-dependent communities. These communities sets load over economic state of the city since it requires further investment in Infrastructure services and expansion in traffic networks as highways and public transportation services, In addition to security and supervision demand in order to ensure safety and stability of users and business. On the other hand the environmental impact of urban sprawl is clear in term of reducing natural habitat by turning landscape rural areas into construction sites and urban areas, as well as increase the

percentage of CO2 emission and energy consumption as well as the impact on air quality after changing natural coverage around the city and cutting more trees and losing agriculture lands, as well as biodiversity in addition to impact on public health and other effects as per (SPI, 2018), see below (Fig. 2.2)

However there is a demand for the suburban communities that is away from the city center as it a propose quite atmosphere with a larger plot areas and fewer dens outdoor public areas and services, this is entitled to rich and sector of the urban fabric, however, this social segregation and labeling is considered as a side effect that threatens social sustainability of the communities and the cities as well. (Altan 2015). Since these projects are known to have high real estate value and known for their fast payback in most of the times therefore instead of rejecting and stopping them it is advisable to control it and well plane these project and community expansion in order to eliminate any unexpected risks. this could be established by applying " Smart Growth" development (Environmental Science 2008) as for example create a diversity in term of housing residential units that meet different users with different income statues while designing walkable communities in order for people to interact and socialize together which will eliminate segregation based on financial status. Propose a development design that are economical in order to be affordable for different users and keep the business model successful and feasible in a reasonable time frame that will ensure economic sustainability and allow landlord and project management to offer better maintenance and supervision of the project which will prevent deterioration in service and dissatisfaction of users and degrading of value (Altan 2015).

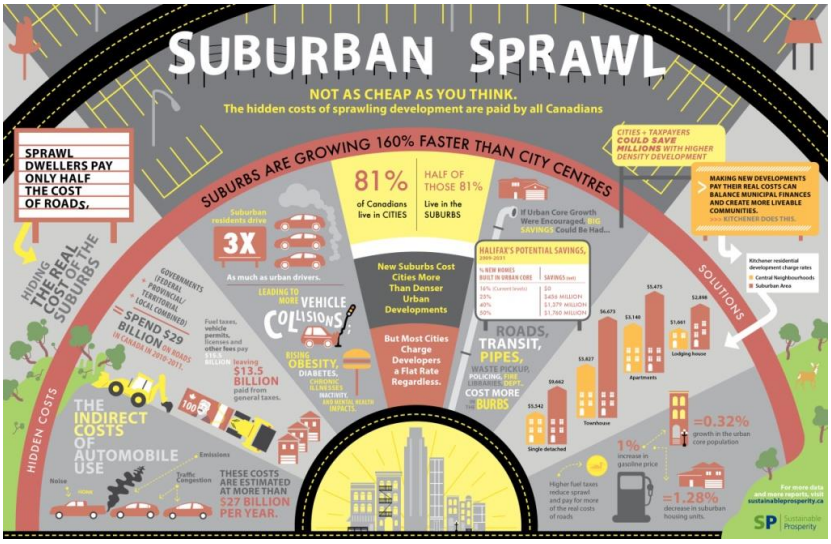


Figure 2.2- Impact of Urban Sprawl- Smart Prosperity Institute 2018

Another challenge facing Urban development is the Global Climate Change that was related to two factors labeled as Natural and Human factors these labels were given by (NASA) the National Aeronautics and Space Administration in the USA. The first factor is the natural cases of climate change such as an active volcano, change in solar energy, ocean currents that impact CO2 concentration since water bodies are holding CO2 from reaching high atmosphere levels.

While the Humane causes are mainly related to activities and consumption behavior to natural resources, energy and land fields as Urban expansion. (AlRustamani 2014). Both causes can align and form a devastating impact over cities that will end up causing a severe damage similar to the case in 2004 when an earthquake followed by a tsunami hits Indonesia at the coast of the Indian ocean were estimated total death reached 280,000 victims despite the fact that there were seven hours between the earthquake and the tsunami waves reaching the coastal line of the six countries affected by the incident but there was no warning system that could help people take caution action such as going to highlands. and evacuate beaches and resorts on the coastal line. Climate change can be seen in different scenarios such as an

increase in air temperature that impacts agriculture and wildlife existing and ice melting that result in an increase in water level and floods in some coastal cities as well. Global warming also can be seen in the desertification increase in some countries as well as precipitation increase in other countries were infrastructure and typography is not prepared to(AlRustamani 2014). such as heat waves that hit Europe and cause several death cases since cities are not prepared for this weather and buildings are designed to face winter low temperature, not summer extreme weather.

Many international entities raised the warning signs declaring that Global warming is driving the human been to the point where its existing is being threatened by different environmental, social and also economical risks. It is accelerating toward a point that cannot be reversed if took place and it will risk future generations as the depletion of natural resources is sever and increasing rapidly. Some observers believe that the 3rd world war will be on freshwater resources, therefore, it is time to take an action before it is too late since Ban-Ki -moon the general secretary of the united nation announce that this generation could be the last one that got the chance indeed to propose a solution.(UN 2015)The United Arab Emirates also as other countries took the initiative for better future and established Ministry of Climate change and environment that is looking after sustainability goals and targets indicators to evaluate progress and suggest enhancements if needed.

2.3 Urban Heat Island

One of environmental challenge indicator is known as Urban Heat Island (UHI) were high-density city center areas with concentration of transportation network and less open spaces for greenery and natural vegetation is recording higher temperature of one or two degrees compared with the surrounded rural-urban settlements that has less population and

higher percentage of natural green covered surfaces. (USEPA.gov 2018). see Fig.2.3 below that represent heat map that shows New York city Urban Heat Islands spots were the temperature is higher than the rural areas within the same country at the same climatic zone.

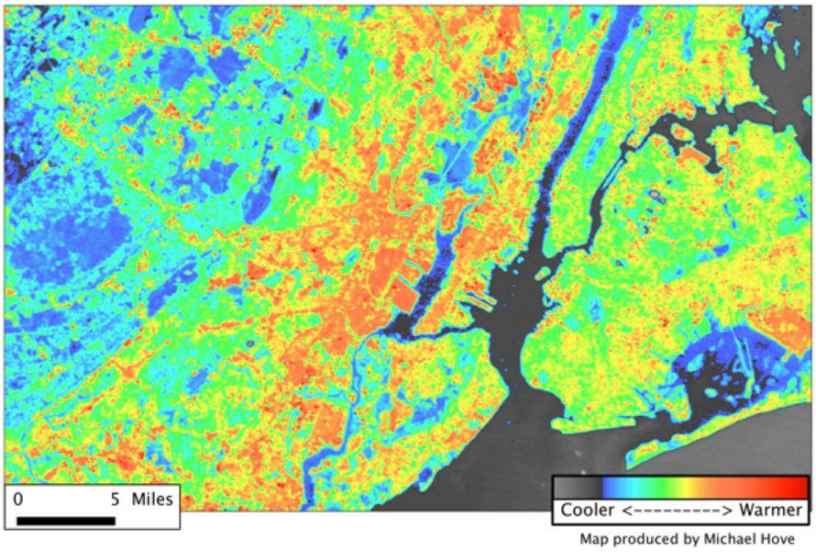


Figure 2.3 - Urban Heat Island- Urban Climate Service center 2017

Urban Heat Islands are linked to different factors such as the construction surfaces that absorbs more heat from solar system beside the lake of evaporative cooling options due to the lake of water surfaces as well as the radiation high percentage that is generated by the close dense construction elements in addition to paving materials with its solar reflective index which is different from the green vegetated surfaces or sand covered areas in rural areas. Not to neglect the impact of cooling systems in Buildings and its impact on the surrounding microclimate.

The impact of these increased heat temperature is severed as it could result in death cases and lost in working days in some countries such as the case in Brussels were number of outdoor working days might be decreased due to the climate change were Air-temperature and radiation as well as humidity (Urban Climate Service Center 2017) The environmental

impact of social and economic factors is clear therefore it is essential to respect the various factors impacts the urban built environment.

In compliance with the international effort to face this Urban challenge, Dubai Municipality introduced a climate adaptation strategies in order to reduce the impact of (UHI) on urban nodes and city centers in Dubai. The Director of Environmental Department, Alia Al-Harmoudi announced that a metropolitan study will be carried that use developed thermal surveying tools in addition to computer programs that would simulate the proposed strategy and evaluate its impact. (GulfNews,2017) this strategy will be implemented as per Al-Harmoudi in three phases first one studies the best international practices with all its side effects and advantages. Phase two will be preparing the long and short-term plan that covers the objectives and its evaluation indicators in addition to project listed as per the priority index and finally phase three will include the time frame structure for applying and execution of the final strategy and linking the project to the performance indicators that are found suitable and the team who will be responsible for follow up. (GulfNews,2017)

Since the impact of Urban Heat Island is not limited to any sector or region, The General Director of Dubai Municipality, Hussain Lootah indicates that the proposed strategy is cover various sectors such as Public Health, Tourism Development, Energy and Water Infrastructure in addition to other sectors like construction and air quality in compliance with UAE Vision 2030 and UAE international agreements with the UN. "Sustainable Development Goals"

2.4 Urban Thermal comfort

Since climate change has been proven to be a reality, not a theory, efforts are directed to eliminate its human causes and control the side effects that result accordingly. One of these results is microclimate change within the urban community either at an individual residential single unite or large master plan mixed-use project. Both are experiencing outdoor and indoor environmental challenges that are against human comfort standards in term of outdoor activities or indoor spaces conditions. Lian Chen, Edward Ng (2012) have explained the human thermal comfort as a link between the human thermal sense and the local microclimate condition and by linking that it can be introduced in different countries at different levels. And in order to reach human comfort level, people are used to consume extra energy that will add high demand on energy plant that is by the end of the day raising CO2 emission that will result in further increase in air temperature and deterioration in quality outdoor spaces as well as indoor satisfaction factor that impacts production and social sustainability on a long term. It is a cycle that needs to be interfered by raising awareness of public about environmental sustainability and enhance individuals behavior toward surrounding natural elements similar to the effort paid by the United Nation and World Bank as well as the United Nations Framework Convention on Climate Change (UNFCCC) that is in charge for creating the legal Frame that work toward to stabilizing Green House Gases as well as the famous Kyoto Protocol that is described as the legal agreement. It is important to know that the whale system is under the supervision of the UN (AlRustamani 2014)

Despite the international interest in facing Climate change challenges there was a limited number of studies that target the urban outdoor thermal comfort in comparison with the indoor thermal comfort researches Spagnolo & de Dear, 2003, Givoni *et al*. 2003) however

the outdoor environment is believed to hold an impact on the indoor spaces and social behavior as a recent research concluded after examining the influence of Urban Micro Climate over the interior spaces in term of the energy consumed for air-cooling machines in Taiwan (Chi Liao, Cheng, Hwang 2015) were it was concluded after site measurements and software simulation tools that the urban areas were exterior temperature is higher recorded an increase in energy consumption for indoor cooling system since indoor temperature also the study found that hours of energy consumption in rural areas were urban heat island is not effecting the communities is less than other communities that are located in dense areas. (Chi Liao, Cheng, Hwang 2015). Meanwhile, very limited number of research covers the impact of Urban Heat Island on hot arid climate communities despite the fact that these areas are more sensitive to the climatic challenge and environmental risks such as lake of freshwater resources and access to agricultural lands.

2.4.1 Thermal Comfort Parameters

In 1972 an extensive research was done by Fanger to study thermal comfort diagrams related to indoor spaces and subject to individuals feeling in respect to the dressing style "to" and activity level yet this formula that was developed to serve indoor spaces can theoretically be used to measure outdoor areas but it should be adjusted and customize since the outdoor microclimate is not as flexible as the indoor space. However in 1987 (Mayer & Höppe) run a deep researches to construct reliable index for indoor thermal comfort and discomfort introduced the idea of Standard effective Temperature Known as (SET) by keeping in consideration five different insulation readings of " Clo" and another six types of activities measured by "met" that refers to the metabolic rate for individuals that is related to age and gender. But these measurements are still not applicable to outdoor comfort since the outdoor

thermal comfort is subject to many additional factors, therefore, Mayer & Höppe (1978) developed the " PET" that refer to the Physiological Equivalent Temperature aiming to overcome this problem by creating a Phsycothermal parameter. By Spagnolo and de Dear 2003 elaborated in the research of outdoor thermal comfort variables and measuring parameters arguing that the indoor equations cannot be used for outdoor spaces without modifications. However, HONJO in 2009 stated that "PET" and "PMV" are the frequent methods used for outdoor thermal comfort, therefore, it was used in the field measurements research-based analysis beside software simulation method that was used to validate and confirm the accuracy of site inspection methodology and software simulation method. on the other hand, Autodesk is one of the leading engineering software developing companies who are behind AutoDesk CFD software that is used to study and evaluate the computerize fluid design around an object or a building and Revit that incorporate Energy efficiency analysis and LEED assessment tools for some features. Autodesk is holding a sustainability workshop that list six factors affecting the Human comfort since these factors are found to be essential in thermal comfort starting by Metabolic rate that indicates that age and gender impact sense of comfort within the space than the clothing insulation since it varies in accordance to the activity within the space and culture in addition to other factors. also, Autodesk Air velocity and Relative humidity hold an impact on users comfort. However, Autodesk claims that air temperature as important as radiant temperature that is reflected from surrounded elements and objects. (Autodesk, sustainability workshop 2017)

2.4.2 Orientation Impact on Thermal Comfort

Building energy consumption responds to sun cast and solar gain according to its orientation.(Autodesk, sustainability workshop 2017) Since Building envelope store based on its thermal mass were each face of the building get different percentage of exposure to sunlight during different time of the day, however it is important while looking for optimum orientation for the building in term of solar gain to consider natural daylight penetration to the interior spaces since the optimum orientation might not be the same in both cases, therefore, understanding the building function and users priorities is important. In addition to that Huynh & Eckert (2012) founds that selecting optimum orientation for building in respond to preferable airflow over the site could result in a reduction of air temperature. However this can be reflected on natural ventilation within the indoor spaces of the building were harvesting fresh air could prevent sick building syndromes and provide better indoor environment for users. (Autodesk, sustainability workshop 2017) not to forget the importance of outdoor visual aspects and social connectivity between surrounding site components and interior spaces based on building function and users requirements.

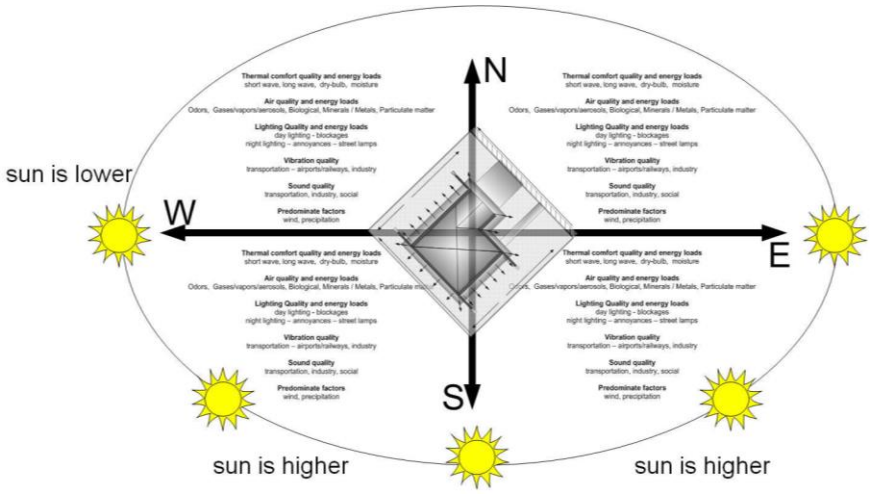


Figure 2.4- Building orientation Hot& dry climate - Robert Bean R.E.T

2.4.3 Building Layout Impact on Thermal Comfort

Building layout was found also one of the factors that impacts urban microclimate parameters such as air temperature and air velocity in addition to humidity that is related to air velocity and other side enhancement that building layout can add to the site such as shading over alleys and pathways that could help reducing air temperature and increase users comfort index (Paramita & Fukuda 2013). Building layout refers also to its height as it was found of a great impact beside the main form layout and opening within the building mass.

Paramita & Fukuda (2013) Concluded that the higher the building structure is the better air temperature it records for the surrounding urban areas especially if green landscaping areas were added to the site. Since higher structure generates higher wind velocity around the site.

In China also the impact of Building arrangement was studied in order to understand its influence over microclimate and energy load by Deng, Wong & Zheng (2016) It was concluded that the impact of building layouts on Mean Radiant Temperature and air velocity is more than the impact on air temperature despite the fact that Sky view factor that was studied by Envi-Met shows a relationship between Air Temperature and mean radiant temperature were both were affected by the height of the building and its arrangement. On the other hand Deng, Wong & Zheng (2016) proves that the Energy consumption is influenced by building arrangement and shape regarding cooling load for interior spaces. However the research of Deng, Wong & Zheng (2016) covers only N-S direction as shown below in Fig.2.5 were building arrangement that were tested in group one are illustrated in 3D view, The first group used square plan building forms while the second group shown in Fig. 2.6 used rectangular plan building form for the same analysis.

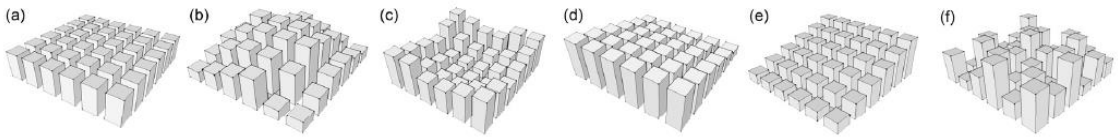


Figure 2.5 Group 1, Perspective view of different arrangement options- Deng, Wong & Zheng 2016

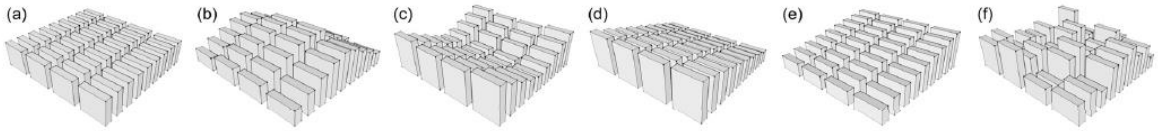


Figure 2.6 Group 2, Perspective View of Different arrangement options- Deng, Wong & Zheng 2016

2.4.4 landscape material and water bodies Impact on Thermal Comfort

Since Urban Microclimate parameters were found to be affected by the Urban Landscape factors, Thani, Mohamad & Jamaludin (2013) proves that Relative Humidity and air temperature can record different readings at the same urban community based on the landscape character and surface properties of the area. It was also concluded that urban greenery in hot arid climate areas could enhance the microclimate morphology that would enhance thermal comfort at outdoor areas based on the case study of Putrajaya in Malaysia. In addition to that Thani, Mohamad & Jamaludin (2013) found that Bioclimatic elements such as vegetation, water bodies and soft landscape can be used as cooling strategies during daytime as it was found that these areas recorded lower temperature zones in comparison with other hard surfaces like pavement and asphalt areas.

These results align with Akbari et al, (1997) where it was found that Urban vegetation impacts energy demand for cooling requirements of indoor spaces since outdoor condition impact the building envelop and adds load to the cooling and/or heating systems.

Also, Setaih, Hamza & Townshend (2013) agree that in hot and dry sessions it is beneficial to use surface material that helps cool down the microclimate condition and support it with vegetation and water landscape elements as well as shading features either big trees or light canopies that help reduce solar radiation and enhance the thermal environment. The research also indicates other cooling techniques that enhance thermal comfort in outdoor spaces like Building arrangement that harvest prevailing wind and light material for building elevations as illustrated in Figure 2.7 below. (Setaih, Hamza & Townshend. 2013)

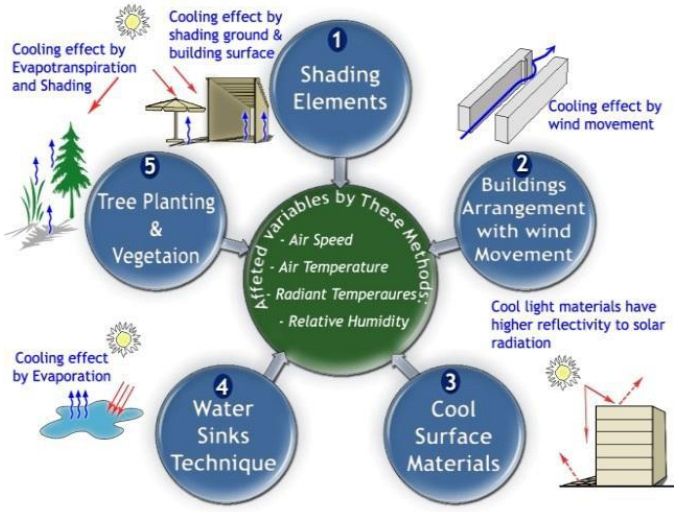


Figure 2.7- Cooling strategies in urban areas- Setaih, Hamza & Townshend (2013)

2.4.5 Shading elements Impact on Thermal Comfort

Other researchers also covered the importance of urban shading strategies such as the study in Amman, Jordan where the analysis was done to evaluate the impact of tree shading on building energy consumption. Abdul Aziz (2014) results align with previous readings were it was concluded that shading reduces energy consumption while this research adds the fact that trees can be used as shading elements that have the same impact over the building. this

result was generated based on a simulation model that assets in comparing and analyzing the effect of the tree over building consumption rate. (Abdul Aziz, 2014)

another recent study finds that using air temperature only as an evaluation method for thermal comfort is misleading since the perceived thermal condition can record a difference of few degrees between shaded areas and other areas exposed to the sun. This study was carried in Tempe, Arizona was Middle et al. (2016) finds that during spring thermal comfort increased remarkably in shaded areas compared to the non- shaded areas at the same time, also summer and fall session records the same result with different percentage which proves that shading patterns designed by tall buildings sometimes or trees and artificial structure some other times can impact human comfort level at outdoor spaces as it impacts perceived thermal conditions rate (see figure 2.8). Despite the fact that this study covers youth and healthy group of people who form the survey respondents but it sets quite attractive results that can be carried further for more studies and examination (Middel et al. 2016)

Figure 2.8 - Royal Poinciana. - Tree shading users of public space- Abdul Aziz, 2014

2.5 Beehive and Bio-mimicry Design

The Beehive was found to be one of the most interesting structure in the nature designed by a very organized community that built the base of a various number of research and studies covering the life cycle of Bee and its social hierarchy. Biologist tends to observe closely the behavior of Bee and the progress of their communities since it is very close hierarchy to the human communities and its social hierarchy was each group has a designated task and responsibilities while even the biological characteristic of each bee is different based on the task and responsibility within the community.

The Beehive attracts attention for its structure and many examples of mankind structure could be found were a replicating of the Beehive was attempted such as the ancient hut located in Ireland and Scotland (see fig. 2.9 below) some of these are dated back to 4,000 years however it is more complex than it looks like as these units provided comfortable natural heating strategies for users.

Figure 2.9 - ancient beehive-inspired hut in Ireland - fliker.com/mirsasha

In a deep observation for natural components the basic principles of structure can be visible such as the Beehive design were bees are designing their home, production units and

protection shelter at once. this is really fascinating and the accuracy of the Hexagonal grid is inspiring in its simplicity yet stability form that reflects incredibly smart and safe layout that responds to Bee's social as well as functional needs. Another recent example of beehive inspired structure is the (Hexa-grid) structure system for tall buildings that was introduced by Dr. Peyman at Seoul conference. The system carries many advantages in term of environmental sustainability since it consumes 10-15% less steel as a raw material compared to the conventional system for the same case study of 80 floors height tower that was analyzed using ETAB computer simulation program. The structure is believed to be more efficient in term building weight as tall buildings tend to have a heavy structure that requires more foundation material while this system reduces columns that reduce overall building weight. Dr. Peyman & Kim (2011) stated that there is nothing new under the sky, however, this does not indicate that limits of innovation were reached since there are no limits to improvement and progress. (Fig.2.10) below represent the difference between the Hexagrid structure and the conventional structure for the same building model generated from the computer simulation program were the core sheer force and displacement under wind was tested and the result indicates that the new system is more stable and suggest promising solutions for tall building structure designs.

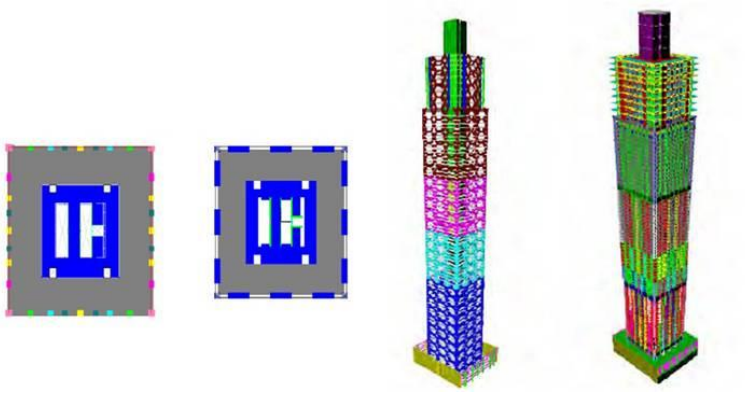


Figure 2.10 - 3D View and Plan for Structure Analysis - PA'S Properties/ the structure of Peyman A. Nejad

Another proposal for the Beehive inspired architecture is presented by Architect Rory Newal and Lucy Richardson was a residential tower of 220-meter height was generated using the Hexagonal grid at the exterior elevation. The building was designed in London and the architect suggested some exterior cells to be used as vertical gardens that enhance the surrounding microclimate and respond to the tower users however this design remains at concept stage and was is not developed yet. (Dr. Peyman & Kim, 2011)

The natural geometry is fascinating for many architects, Bjark Ingels the Architect in Big.dk says the ability of honeycomb to strengthen natural scene for the users perspective and visual aspects is remarkable. Ingels adds Architects are amused and inspired by the compactness, artistic mound - shaped pattern created by this tiny bees.

Geometry is an important factor in Design and in architectural formation specially either in term of layout plan or three dimensional perspective view, the relation between different elements in the design and its interrelation angels are responsible for the impression these designs creates either acceptance or rejection of public viewers and public in addition to the meaning and stability it generates for users. Therefore Pourjafar, Mahmoudinejad & Ahadian (2011) finds that geometry forms the main core for architectural lows and that this geometry

can be generated from nature by creating an interactive cycle (see figure 2.11) of specialist who work together and add their knowledge to each other database in order to create a bio-mimicry design that responds to sustainable requirements at all sides; Social , environmental and financial sustainability. (Pourjafar, Mahmoudinejad & Ahadian 2011). Also Bakirlioglu (2012) agrees with Macnab (2012) and El Ahmar (2011) in following Bio-mumicry design spiral that either start by discovering a natural model and studying its potential implementation and ending up by setting a number of principles and strategies generated from that natural model and incorporate it in the design process. (see figure 2.12 a) (Bakirlioglu 2012).

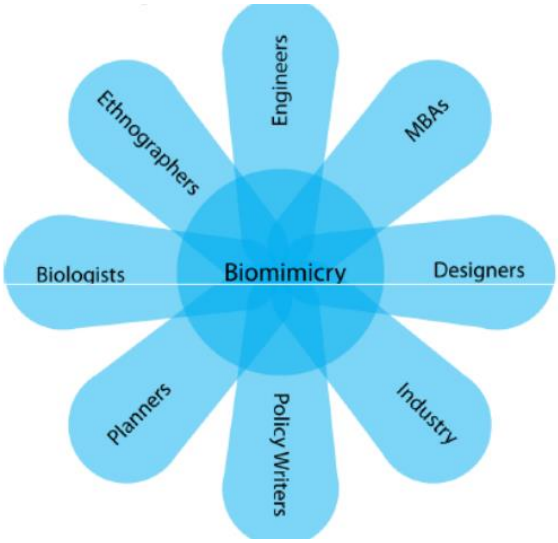


Figure 2.11 - Creating the Conversation between nature and human science-

The other option is going the other way when a challenge is hitting engineers or designers they tend to relate it t nature and explore potential solutions from natural models by starting with defining the problem or the function needed and understanding its challenge then search for similar models in nature that wither share the abstract shape or similar mechanism of behavior were the function is similar to the challenge facing designers and engineers. then going deep and extracting the principles of the selected model from nature could carry the

answer to the challenge and help in setting the principles for a solution that can be evaluated and tested at further stages. (see figure 2.12 b) (Bakirlioglu 2012).

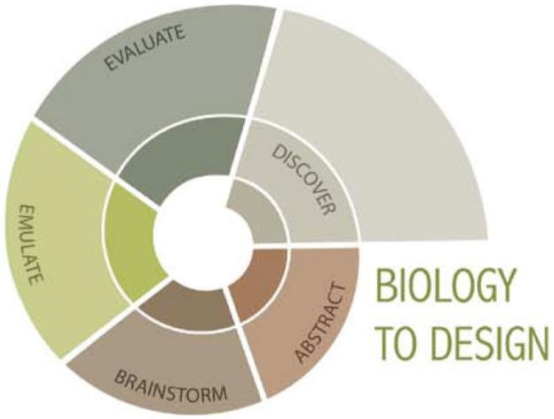


Figure 2.12 a - Biomimicry Design Spiral -Bakirlioglu 2012

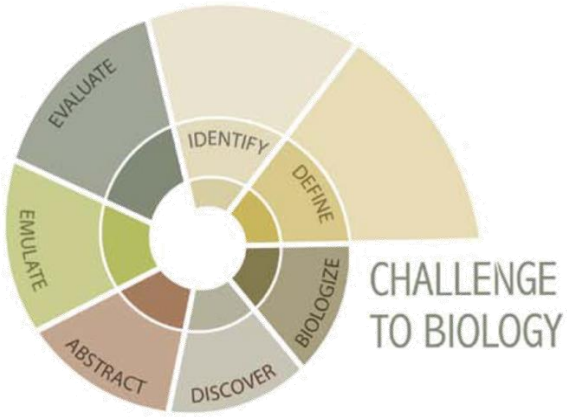


Figure 2.11 b - Biomimcry Design Spiral- Bakirlioglu 2012

This approach in design was found to result in number of benefits as Bakirlioglu (2012) concluded some advantages are for architects who can produce designs inspired from existing environmental models that help to create a tailored design for the specific location and users that respond to their specific needs and that can result in more sustainable solutions and optimized architecture designs driven from optimized natural model, this helps in facing limitation of resources as Vahidi (2009) concluded since all creature of nature are fighting for the same basic life requirements as food, water, safety that secure its existing. This conclusion is also supported by Maglic (2012) by stating that design should enhance human surviving opportunities in addition to natural components and surrounding environment too since the human race will not stand alone if nature fails to survive due to mankind behavior.

2.6 Beehive Inspired Urban Design

The animal kingdom most inspiring engineers sets a tremendous example for architects and engineers by looking at the stable, strong connected hexagonal units in the beehive. Bees and

especially honeybees are an interesting model for understanding communication strategies and social behavior in addition to the focused production process.(Yadav, et. all. 2017) Bees today record more than twenty thousand species presenting a different pattern of behavior entitled to the task of each bee and its duty within the comb in addition to the specific characteristics. Some of them are building Beehives undergrounds while other species build it over high trees and some other are even brave enough to build it at residential unites structure like walls and roofs and in many cases, people are designing designated farms for bees looking after this outstanding insects. And it is not likely that human and bee's colonies are losing their interaction soon since this insect is providing mankind with a lot of vital resources to serve as food and important medical components in addition to many other benefits related to honey and bee's colonies.

In this research the Form and layout of the hexagonal unite in the bee's beehive has inspired the study to enhance the social character of an existing residential community was a conventional grid system is used to design the plots and services within the area at the current stage while the study is exploring the environmental impact at the outdoor surrounding the units if the Hexagonal grid shape was implemented in the design. This is targeting the social sustainability as well as environmental sustainability since the enhancement in the microclimate around the villas is found to enhance the social activities and interactive behavior of users within the space.

This research is using "challenge to design" method in implementing bio-mimicry design strategies to the current existing case study project. where the problem was defined as poor thermal comfort level at outdoor spaces that result in poor social connectivity within residential plot users due to lack of interaction and social outdoor behavior. The urban design layout was examined and enhanced based on the inspiring geometry of the Beehive

Hexagonal grid in this research at chapter four while the results and discussion are presented in chapter five of this thesis.

Chapter 3: Methodology

3.1Introduction

This chapter is covering and discussing the research methods that are used at other research papers and thesis and compare it in term of information resources and objectives for the research in addition to the result and final conclusion based on the limitation and challenge these papers and researchers were facing in implementing each method.

The tools and strategies besides different techniques that are needed in each phase of this research will be discussed and explained in the second part of this chapter after introducing and justifying the selected methodology for this research and addressing the parameters that are used to evaluate the research results. The methodology is selected after going through Literature review phase that explores the advantages and disadvantages of each method based on previous research paper were similar objectives and other research conditions are used.

The aim of this comparison is to understand and select best methodology for this study that complies with the objectives listed earlier and respond to the aim within the available resources and time frame. Since each research is following a different path based on its goals and research questions that need to be concluded with answers in lighted by the requirement of the research case study subject for the study.

3.2Review of Similar Research Topics

As discussed earlier, many researchers investigated the bio-mimicry design and its potential in solving current design problems and challenges. One of these challenges is the

outdoor micro-climate since many studies were addressing this topic aiming to enhance outdoor thermal comfort parameters in order to achieve higher users satisfaction. Different researchers aim to understand the impact of bio-mimicry design over microclimate parameters using different methodologies such as Literature review, field measurements, virtual model simulation. However, one or more of these methods can be used in the research.

In this chapter, the various methods will be discussed and analyzed in term of advantages and disadvantages and their compliance with this research objective. This chapter will also discuss the tools needed for each method such as the software simulation programs needed for building the virtual model and running the simulation in addition to the measuring instrument needed for a field visit.

3.3 Literature review approach

A literature review is known to be the study method that was built using other studies as fundamental data after looking for particular research topic or question (Kitchenham, 2004) and (Myllarniemi 2015). It is needed to fill a gap in current topic or understand the way that a theoretical research is supported by calculations and numerical data, or build the relationship between fragmented results related to one topic. (Kitchenham , 2004)

This method can be used alone in the study such as the case of a lecture or conference report or it could become a supported method in a research topic such as master or Ph.D. thesis or a scientific paper. This method is essential to bring researchers up-to-date with latest results and findings related to the research subject and help to build full understanding of different aspects related to the topic. This shell helps the researcher set study questions and objectives that could be generated from previous works.

In this research, the Literature review is conducted to understand the previous attempts in constructing a bio-mimicry architectural solution for master planning projects beside understanding the impact of different micro-climate parameter in hot-arid climate and hot-humid climate regions in order to enhance these parameters to ensure users thermal comfort.

AlRustamani (2014) followed exploratory research method that was used to understand the impact of UHI on Dubai. This approach helps in case the research problem is not well defined by conducting Literature reviews at the first phase followed by interviews and ended by a case study review that examines and analyze the different results and similar findings between phase one the literature review and phase two the interviews from the selected research location that is considered Dubai in this research. (AlRustamani 2014). In chapter two of this research, the Literature review helped in setting the exact parameters for this research and define the research scope in order to fulfill the aim and objectives of this study. However this cannot be the only methods that are used in this research since it holds weaknesses such as the accuracy of information and result in term of location and time since many of the research papers are not done within the geographical limits that this study in considering and focusing on and not at similar time of the year or relevant weather data as this research target. Therefore the literature review can only serve as a support benchmark and guideline for the progress of this study.

3.4 Computer simulation approach

Chapter two of this study highlighted a number of current studies were computer simulation models were used to evaluate the microclimate parameters and compare different scenarios in a virtual environment. As an example Huynh & Eckert (2012) disagree in using Literature review as a core source for information in studying the impact of Urban Heat

Islands and indicate the need for computer simulation model to compare different scenarios of microclimate parameters enhancement strategies that were used over a selected case study site in the south area of Vietnam. The model was built using Envi-met Simulation software however it was not intended to extract absolute information related to Air Temperature from this model. Also, Paramita & Fukuda (2013) found it important to use computer simulation models and existing case study in Kitakyushu city to evaluate the air quality and micro-climate calculations based on a virtual model built using the Envi-met software. This meets the method selected by Taleb & Abu-Hijleh (2013) who were evaluating the impact different urban configuration on Temperature in Dubai using a computer simulation model that was built by Envi-met software also. In addition to Wang, Berardi & Akbari (2015) who also used Computer simulation model that was built to reflect an existing site in Toronto where the case study was selected to understand the impact of Urban Heat island over different zones of the city. Similar to the method used by Akbari et al(2001) earlier despite the fact different software was used to build the model which is DOE-2 that is an energy simulation program for buildings that helps in understanding the impact of Roof color range from light to dark colors and the effect of shade over the indoor energy consumption of a building. On the other hand, Deng, Wong & Zheng (2016) used Envi-met as a simulation model software that helped to understand the impact of building layout over micro-climate parameters that will result in affecting energy requirement of the buildings located in a dense area in China.

The study of Oklahoma city by Zhang, Jin & Leach (2017) also used virtual model that was built using Weather Research Forecasting model (WRF) in coordinate with satellite MODIS image that indicated surface temperature at the selected site subject of the research, however the research concluded that this software failed to simulate the weather data in an accurate way but it reproduced some of the micro-climate parameters in a reasonably

acceptable range such as wind speed and direction plus surface temperature in addition to energy flux. (Zhang, Jin & Leach 2017) but since the satellite image is dated 2003 and the simulation model is done in 2017 it was found that a recent, updated benchmark resources as needed to strengthen the research and its variables.

It was concluded from previous readings that computer simulation models supported by field measurements are a most compatible method that was used to evaluate and study thermal comfort and microclimate parameter enhancements. Therefore these two methods will be used for this research with respect to the limitations that face this study.

3.5 Numerical model and software simulation program

This research aims to study the impact of bio-mimicry design modification over the microclimate parameters in order to evaluate the improvement and enhancement in thermal comfort index, therefore, it is not feasible to build the physical models on site and apply the changes of each scenario and consider field measurements as the only method for this research. It is important to use a virtual model that would build the weather data with the geographical information in addition to the architecture details of the project all in one platform that is user-friendly and easy to read in term of the final result and changing parameters.

This is known to be the numerical model where the input data is provided by users and testing environment is controlled by a number of variables that can be adjusted and altered to meet the requirements of each scenario and proposed design. This will save time since researchers are not limited to the time of the year this research is conducted as it can be running for summer even if the current time is winter and the model can be tested for a full year without really waiting one year for the result of each month. this is known to be one of

the advantages for the computer simulation model in addition to the fact that this saves resources and cost since no physical manpower is needed on site for building the proposed design or taking actual readings using instruments and devices that could be rented.

However, the computer simulation method requires a qualified users who are capable to input the data and extract the output result in order to conduct a reliable analysis based on these results. Therefore this method needs a validation process prior research process.

In the next part of this chapter, the research present number of recent studies that used the selected software where a validation process was done by recording field measurements and compare it against software simulation for the same day and time. These will be considered solid validation for this research since the same software is used in the same city for the same period of time that is the summer session in Dubai and readings will be examined against the national weather data generated by the Ministry of presidential affairs-The National center of meteorology to ensure that results of the basic-current design represent the existing case.

3.6 Software selection and justification

Numerical simulation is one of the most recent tools that can be used to test the urban climatic configurations since urban climate could cover a wide area that limits the possibility of accurate site measurements. Many programs are used for this purpose such as BES City Sim that was used in different scale projects going from small neighborhoods up to entire big scale cities. This software is used to study Urban Heat Flux in Kumar, & Krob, (2005) However this software has a number of limitations such as CFD analysis that cannot be conducted using the virtual model of this program since the number of buildings and its morphology is limited. Therefore it was found unpractical to use this program for this study.

As a result of previous readings and literature review presented earlier, Envi-Met was found the most compatible software that meets this study aim and objective and respond to researcher skills and time limits as proven by Huynh & Eckert (2012) and Paramita & Fukuda (2013) in addition to Taleb & Abu-Hijleh (2013) who also used Envi-met program for the simulation model similar to Wong & Zheng (2016) who agreed that Envi-met helps in understanding the enhancement of Microclimate parameters by designing different scenarios and testing each parameter while all other factors are fixed in the virtual model.

This complies with the conclusion that this software has been used widely in testing the urban planning configurations in terms of climatic aspects and its impact of the outdoor thermal comforts for different users in residential, housing projects or commercial areas. due to different categories that are built into the program database that supports the analysis of agriculture effects, wind flows direction and speed, and the relations with the buildings and urban designs. It is also efficient in simulating the surrounding air or surface temperature, humidity levels, and the shadows wither they are artificial shades or shades caused by buildings. Adding to that, it can show the effect of using different landscape coverage materials on the outdoor environment and the transfer levels of the heat from the buildings to the outdoor environment. All of this configuration support the researcher in determining the best thermal comfort levels and best practices to enhance the outdoor environment.

This software has been developed widely and that's why it took its popularity nowadays by being used in many simulations for the last 10 decades (Brose al. 2016) which reflect the improvement and developed research and modification that it passes throw in addition to being trusted method worldwide for reliable results. Therefore this is the software that will be used in this study for the simulation and analysis phase.

As mentioned earlier, many urban simulations have been done by many researchers using Envi-met, and it can be considered one of the most popular software in terms of testing the landscapes, Envi-met is a software that depends on the distances of the X-Y-Z grid where the distance is set as per users decision. the assigned area that needs to be tested shall be drawn on SPACES were a limit of 60 units in each axis is set as shown below (fig 3.1) were the model domain is presenting different basic settings that control the model building process. Brose al. 2016) indicates that There are two applications which can be used in the Envi-met simulation; Core and helper. The Core applications are not easy and they consume much time in building the assigned study. But the helper application, they are easier in terms of building the models knowing that they are limited compared to the first application but they still can give the required results (Brose al. 2016) Also the basic settings include the designated location that was chosen in specific Latitude and longitude representing Dubai City with time zone indication GMT+4. see (fig. 3.1) below.

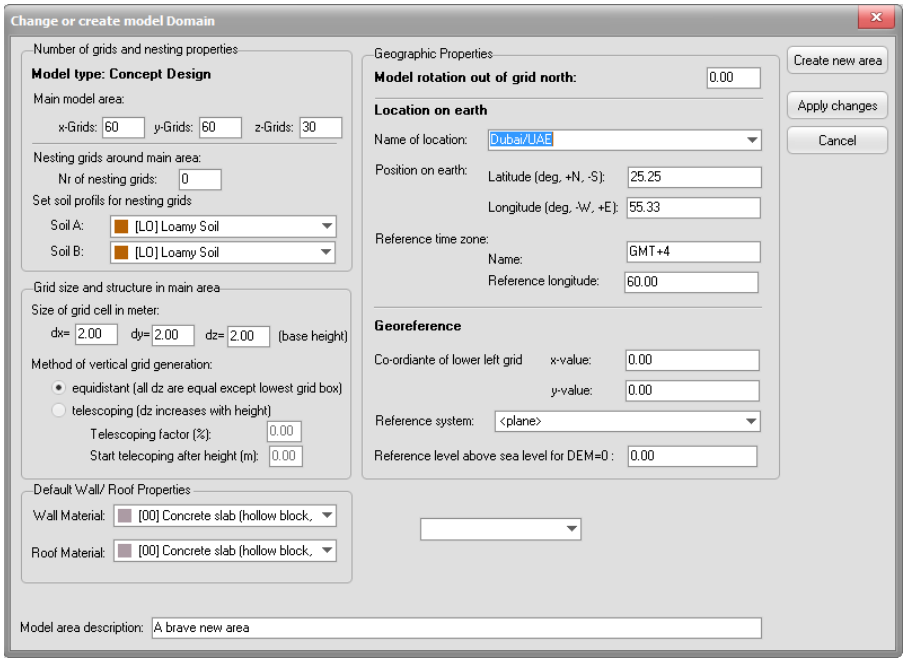


Figure 3.1- Basic settings - Envi-met software

For the effectiveness of this software, this research will be tested and simulated using the Envi-met software since it showed very accurate results as presented in previous work for different number of researchers that were done with different researchers in addition to the basic-current case that were tested at the beginning of the project to ensure the software calibration . Accordingly, the researcher will use the latest version of the Envi-met software since the latest version has shown many developments in software applications compared to the old one and that can be shown in its ability to give different materials and test their thermal aspects on the buildings' envelops. This feature can show more simulations of the envelope behavior which can be helpful to reduce the heat transfer and reduce the urban heat island effect caused by the buildings.

The research method and simulation software both were chosen by the author to investigate the required research parameters based on study objectives first and time and budget limitation second in addition to nature of research case study and its compliance with previous similar researchers and study analysis. The Envi-met showed clear efficiency and accuracy in giving results and simulations output that can be discussed and compared to understand the difference between the base case design and the proposed designs that would help in finalizing an optimal design were all parameters related to this study are enhanced based on the bio-mimicry proposed strategies, This allows the researcher to choose Envi-met as the main tool for the research investigation. Adding to that, this research can give results to show that this software is capable of future studies once it gives accurate and logistic results that can be tested and implemented.

3.7 Research case study

As per to the research objectives, a study is going to be done for a specific case study representing residential project that was selected as "Sheikh Mohammed Bin Zayed Housing Project" to test the outdoor thermal comforts after conducting bio-mimicry passive design strategies inspired from the Beehive cell design that can be implemented on the project site to enhance the outdoor environment which will positively be reflected on public Thermal comfort index. The case study site covers 249.4 hectares, located in the border of Kalba and Fujairah, with a distance of 4km south of Fujairah Airport and 5km exactly from Fujairah city. It is called "Sheikh Mohammed Bin Zayed Housing Project" and it is one of many models replicated in different areas in UAE since it is Emirati Housing projects financed by the government as explained earlier in chapter one. The site is surrounded by hills and earlier to construction the assigned contractor runs a major leveling phase to ensure flat topography on site as per the architectural and structural design requirements. the adjacent project is close to an industrial area called "Al-hayl".

3.7.1 Site and Project Analysis

This project was selected since the author has a deep knowledge about the different aspects of the construction phase as well as sustainability aspects and certificate that was given for this project however the author declares clearly that there is no any conflict of interest with the research and its result and conclusions.

The project complies to Urban Planning council guidelines therefore it was essential to conduct a deep site analysis by the Urban planning consultant office in order to fulfill the need for responsive design that complies with natural environmental aspects see (fig.3.2) in term of optimum building orientation especially since dust barriers are needed in this area to

ensure healthy air quality for residence. see (fig. 3.3) keeping in mind that wind direction is north and northeast most of the year (MBZFC 2015). In addition to that, the need for shading elements and strategies is essential since the environment is harsh and intense sun radiation beside high temperature requires careful urban treatment.

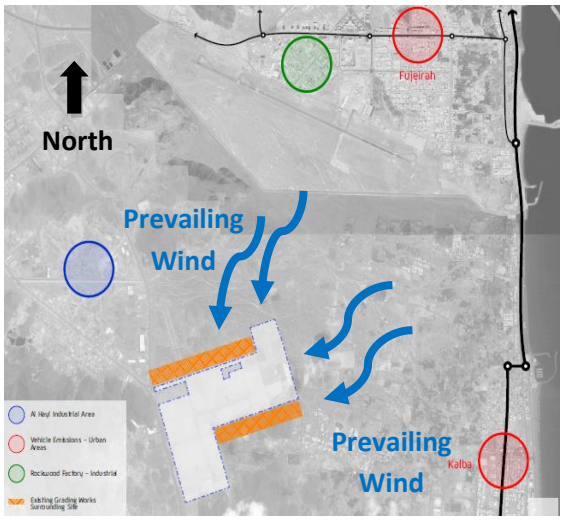


Figure 3.2 Site location- MBZFC,2015- edited by author

Figure 3.3- Dust wind on site- MBZFC, 2015

This project was selected as a case study since the author has a deep knowledge about the different aspects of the construction phase as well as sustainability aspects and certificate that was given for this project however the author declares clearly that there is no any conflict of interest with the research and its result and conclusions.

The project consists of two phases; Phase A consist of four blocks with a total of 417 residential villa while phase two is referred to as Phase B where a total number of 742 villas distributing over 7 blocks with 2 service blocks at the north side of the plot. see (fig 3.4) presenting the zoning distribution for the villas indicating a number of villas in each block

and phases of construction were current ongoing phase A is highlighted in Red and phase B that will be constructed later is highlighted in Blue.

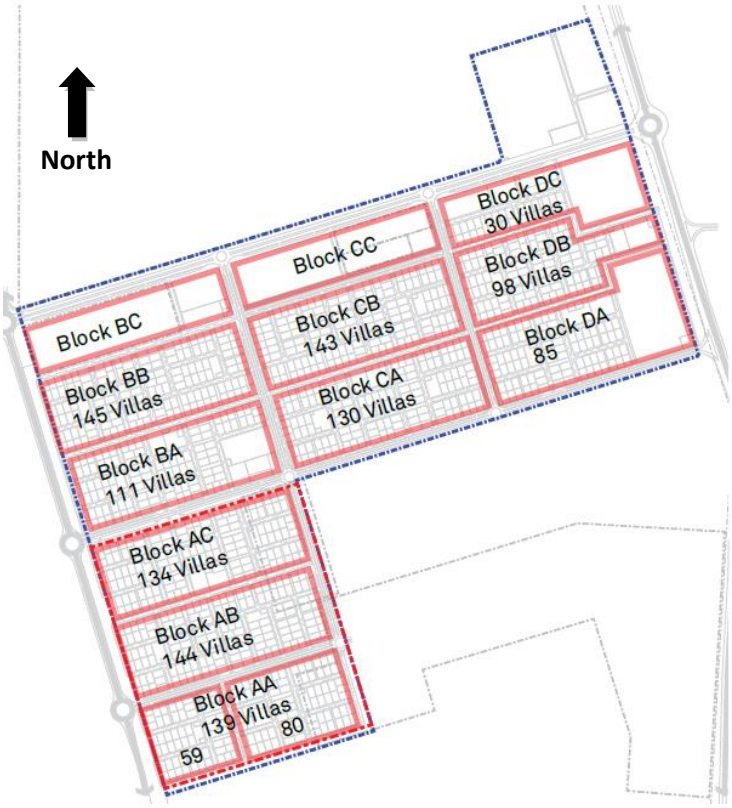


Figure 3.4- Zoning Plan - MBZFC, 2015

For the purpose of this research the selected area that will be subject to the simulation analysis is Block AC and Block AB see (fig. 3.4) were total number of villas is 278 units designed to be between four and five bedrooms and served with one Masjid with a capacity of 650 people and a retail grocery area as well as outdoor green spaces for public use.

3.8 Research Plan and Limitations

The aim of this research as explained earlier in chapter one is to examine the effect of the design strategies over the microclimate parameters were the proposed design is inspired by bio-mimicry concept driven from the beehive cells form. This study is presented in phases as

shown in the diagram below where the first phase is the base case analysis were the current design is built using the Envi-met software and the result will be used in phase two as a benchmark for enhancement and comparison. In phase two the orientation of the project will be tested to find out if the current orientation is the best possible scenario or there is a room for enhancement. This will be discussed and elaborated later in chapter 4 and five.

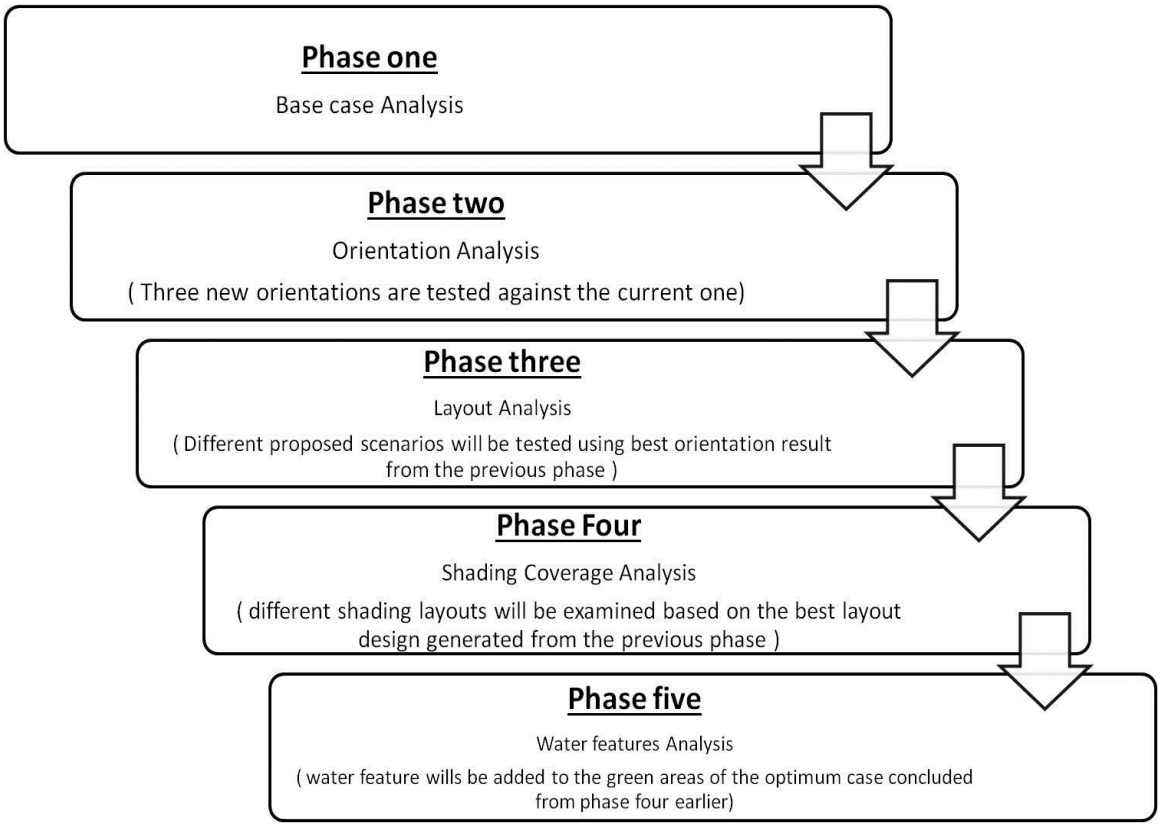


Diagram 3.1- Research outline - Illustrated by Author

The third phase of the research as shown in the diagram above will analyze three different proposed layouts inspired by the cell shape of beehive while respecting the optimum orientation found from the previous phase and always evaluate the enhancement in microclimate parameter based on thermal comfort standards and base case design result since the target is to upgrade and improve the users experience and comfort level with the

proposed design. The optimum case in phase three will be considered the base case for phase four were three different layouts for master shading element that covers open areas and pedestrian pathways will be tested in order to evaluate its impact on the thermal comfort level and decide on the best-proposed shading layout. Finally, in phase five, the impact of water features will be tested to decide whether it is recommended to add a water feature in outdoor public spaces or it will not enhance the thermal comfort of the public at these spaces.

The research benefit from previous literature reviews in executing the simulation process and will discuss the result of each phase of similar research and previous studies done. This will help in setting deep understanding of the proposed strategies and the relation between different microclimate parameters. Ultimately this comparison and analysis, supported by a discussion help figuring out what is the optimum recommended strategies that suit this case study and can have a potential impact on other housing projects in UAE.

Eventually, the target is to enhance the outdoor thermal comfort within the housing project that could be set as a role model for future projects and other master planning developers to follow in order to enhance overall urban areas in all aspects whether environmental, social or even economic aspects. this would result in the solid Sustainable Urban development process.However, this research is facing some challenges and limitation that were taken into consideration such as time limits were the research objectives sets summer session as the subject of this research, however, the Author is conducting the research during winter session, therefore, no site visit or field measurements were done since it will not reflect required data. and only recorded weather data from the ministry of Presidential affairs were used as input data for the simulation software. On the other hand cost and manpower is limited to personal budget and researcher efforts only, therefore, there was no possibility to do any physical model replicating the proposed designs as well as the current base case in a

smaller scale. Finally, due to a software limitation in term of Drawing area were grid of 60x60 unite is given, partial zone was selected to be drawn since the complete site cannot be built as a virtual model and maintain reckonable scale for the drawing unites. In another words the larger the drawing area is the more small scale elements within the site will be neglected such. and it would not be accurate to use different files for different zones of the site. Therefore one zone can be used as a sample for the full impact of each strategy.

3.9 Summary

This chapter presented a various number of similar research studies done based on different methods. The author studied each method to understand its compliance with this topic and its gaps and weaknesses toward this research objective. starting by literature review that was used by AlRustamani (2014) that built its defense on this method on the believe that the topic is relatively new to the public therefore exploratory research method is needed at this case, however Huynh & Eckert (2012) disagree in building the research results and conclusion on Literature review only similar to Paramita & Fukuda (2013) and Taleb & Abu-Hijleh (2013) as well as Wang, Berardi & Akbari (2015) who support the fact that computer simulation model is needed to validate field measurements and literature review information as Akbari et al(2001) did earlier.

In term of the simulation software, different programs were reviewed and evaluated against the requirement of this research and compliance to the researcher background and skills as well as required output data. It was found that the latest version of Envi-met 4 with its science license meets the requirements and sets a solid platform for building the model and run different proposed scenarios at the selected time under the designate weather conditions.

After selecting the research method and simulation software, the research case study project were studied and analyzed to understand its special criteria in term of topographical characteristics and surroundings traffic networks and projects as well as its components and functional buildings that shall not be canceled or neglected in any proposed scenario since this research is limited to the outdoor thermal comfort parameters not the functional or economic value of the project, therefore, the number of the unites shell nit be reduced and all services shell remain efficient for users. The feasibility of the project and the architectural design will not be compromised in any suggested design.

The simulation process and will be done in five phases were the selected final scenario of each phase will consider as the base case for the next phase. While the microclimate parameter will be examined based on the thermal comfort level, in reference to the literature review and local as well as international standards related to human comfort index.

The next chapter will explain the virtual model setup and the project basic settings used for the base case as well as the fixed and changeable parameters for both weather details as well as project details.

Chapter 4: Case Study Model setup

4.1 Introduction

In addressing the bio-mimicry design strategies as a sustainable option for residential housing projects and while considering Sheikh Mohammed bin Zayed City in Fujairah the case study for this research. The research was conducted using computer simulation software to examine the proposed designs and strategies as recommended by Huynh & Eckert (2012) and Paramita & Fukuda (2013) beside Wang, Berardi & Akbari (2015).

This chapter comprehensively explains different tools and parameters in addition to an evaluation process that was used in this study, propped by standards and benchmarks that are complemented by literature review discussion and conclusions.

As mentioned earlier in chapter three section 3.1 the study is conducted in five phases. the outcome of each phase forms the base of the next phase in which the research is following a linear progress ends with a number of results and findings that are discussed objectively to conclude the research topic with recommendations that comply with the research objectives and reply to the problem statement that was presented in chapter one earlier.

4.2 Parametric Analysis

In nowadays fast-track production line and consumers demand for innovation and fast solutions for growing challenges, it is essential to control cost and reduce the time and ensure fast development process including urban development and architectural design analysis.

Therefore it was a substantial need to incorporate parametric analysis process will help that evaluating different design parameters in a significant period of time with a limited cost. As the CEO of ANSYS, Cashman J. anxiously stated: " Being wrong today is greater in cost than ever while being right and innovative is also great for rewards like never before". Being able to examine and optimize the proposed design or suggested strategies allows architect and urban designers the opportunities to eliminate any side effects or wrong decisions on site while saving stakeholders from paying the big compensating cost to overcome these mistakes when they are on the big scale. (ANSYS, 2011)

Since there is no justification for not using simulation analysis method to evaluate different design parameters and asset the selection of optimum scenarios, this research focus on the result of Envi-met 4 simulation process of each phase were the changing design parameters were evaluated while keeping other fixed parameters the same over all phases of the analysis process. This helps in eliminating the impact of a various number of design parameters that are not subject to this study.

The design is composed of a number of parameters that were categorized in this research for two parts; constant parameters and inconstant parameters. see (diagram 4.1) below that illustrates the different parameters in each category, starting with the constant parameters that are related to any architectural details of the villas or any other building on site, Site location and border is also a constant parameter that is not changing or modified over the research phases since it is out of the Author control and it is not related to the objectives of this study. All constant parameters remain the same from the first phase was the base case model is built and analyzed in order to ensure that these parameters do not impact the overall result at any further stages. Inconstant parameters are those subject to analysis and their values are examined at each phase to understand the impact of the proposed scenario. These parameters

are used to determine the compliance of the proposed design with the benchmark and evaluating standard and criteria as discussed earlier in the literature review.

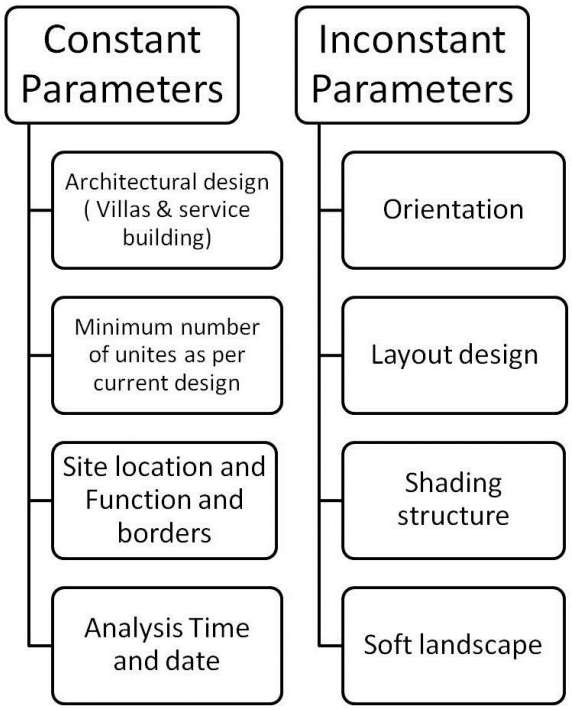


Diagram 4.1 - Project parameters - Illustrated by Author

The analysis process is also counting on evaluation parameters that are examined at each proposed scenario at the simulation results for all phases in order to assess the impact of the inconstant parameters over the project at each phase. These evaluating parameters are influenced by previous Literature review and similar research topics that used same variables in the assessment of different simulation results. The table below represents the evaluation parameters that will be presented and traced at each scenario in chapter five.

Table 4.1 - Evaluating variables and the units used for this research

Evaluating Parameters	**Unites**
Air temperature	C˚ (Centigrade)

Wind Speed	m/s (meter per second)
Relative Humidity	Percentage

These variables are meeting Chi Liao, Cheng, Hwang (2015) that linked human comfort at outdoor spaces with the microclimate variables that impacts public behavior at outdoor spaces as well as indoor spaces since these microclimate variables drive users to seek comfort levels by consuming energy at indoor spaces or evacuating outdoor public spaces in order to avoid discomfort. Therefore tracing the changes in these variables that aligns with the modification on the design and proposed urban scenarios will help to generate results that explain the impact of beehive cells geometry over the master plan of the selected project.

4.3 Virtual Model Development

The research is following computer simulation method as discussed earlier in chapter three at 3.6 Research method selection and justification were the selection was built according to similar research studies and previous literature reviews such as Huynh & Eckert (2012) and Paramita & Fukuda (2013) who encouraged this method for similar research topics in addition to Taleb & Abu-Hijleh (2013) and Wong & Zheng (2016) who supported using Envi-met program for similar analysis. Therefore the current existing design was studied and built into a virtual model using the Envi-met4 program. As discussed earlier in chapter three, 3.7.1 site and project analysis, the project consists of housing units served by retail stores and public green spaces as well as Masjid and other infrastructure services.

Due to the limitation of the software working platform, it is not possible to study the full site all at once, therefore, one area was selected to be the subject of this analysis. However the analysis does not impact function within the space or the proposed number of residential

units since this is out of this research scope of work and it will impact the feasibility study of the project that is also not covered in this research, Also the dimension of the plots was fixed over all phases and proposed scenarios since this is also one of the architectural details of the project that will not be discussed or analyzed in this study.

On the other hand, the project set complete vehicles and pedestrian route network that covers all the site as shown in (fig 4.1) below were the full networks is introduced in red color bold lines that represent main streets and dotted red lines indicating secondary routes and orange lightweight lines representing allays and inner pedestrian routes.

Figure 4.1 - Proposed circulation plan - MBZFC 2015

The circulation plan cover pedestrian rout as well as private cars ways and parking spots on the side of the roads a shown below (fig 4.2 a & b) this is also out of the research scope of work and therefore it is one of the fixed parameters in building the virtual model.

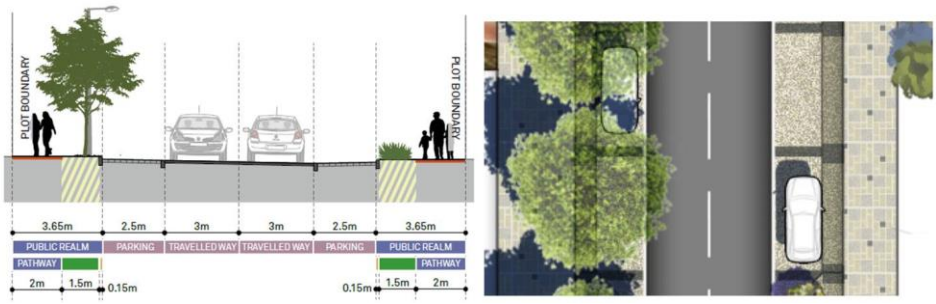


Figure 4.2 (a) typical roads section (b) Photoshop illustration for the roads aerial view - MBZFC 2015

In this research, the simulation analysis is covering the first phase of the project that includes total of 278 residential private villas in addition to one retail area located beside the central Masjid that serves the community as shown below in (fig. 4.3)

Figure 4.3-Residential blocks illustration - MBZFC 2015

Figure 4.4 - Selected Area for analysis - MBZFC 2015

The selected area includes five main green spaces and central public space that is linked with the Masjid and connected to the retail area as shown above in (Fig. 4.4). The project brief by the developer indicates that each plot is within the selected area is 24m X 36m and

this was fixed for all proposed designs however the layout and dimension for the public spaces were modified based on the proposed concept as presented later in this chapter.

4.3.1 Research Variables and Parameters

As discussed earlier in this chapter, this research follows Parametric analysis method were two categories of parameters were assigned the first category is known as constant parameters that are fixed and kept out of the proposed strategies and design modifications and the second category is the inconstant parameters that represent the parameters subject for study at this research. as presented in (table 4.2)below. In addition to the evaluating variables that assists in while discussing the impact of the proposed design and strategies over each parameters these are maintained the same for all phases since they respond to the main objectives of this research that aims to enhance the outdoor thermal comfort for users in order to encourage better utilizing of these spaces that will impact social sustainability as well as enhance environmental sustainability.

Table 4.2- Project Parameters and evaluation variables

Constant Parameters	Architectural Design	Height, Elevation material, and openings, Function...etc
	Minimum Number of units and plot area	Proposal should not reduce current number of residential units or individual plot dimension
	Site Location and border	The project location and outer border are fixed as per current base case.
	Time and Date of simulation	The simulation analysis is conducted on 27 July for four hours starting from 12:00 to 16:00 as this is found to be the peak hours.

Inconstant Parameters	Orientation	Tested in three additional directions beside the current base case
	Layout Design	Three options are introduced that were inspired by Beehive cells geometry
	Master Shading Structure	Three scenarios were introduced in compliance with circulation behavior of users
	Soft Landscape Features	Implementing water feature to study its impact on microclimate condition.
Evaluating Variables	Air temperature C˚	Measured for peak hours in meter cullies
	Wind speed m/s	Measured for peak hours in meter per second
	Humidity Levels %	Measured for peak hours in Percentage

The previous table presents the constant parameters that includes simulation date and time that was selected base on the peak summer day in 2017 see (fig. 4.5) that was found to be 27 July as per weather cast records that indicates the peak air temperature at 14:00 to be 48 C˚ that feels like 55 C˚ while minimum air temperature was recorded at 05:00 at 33 C˚.

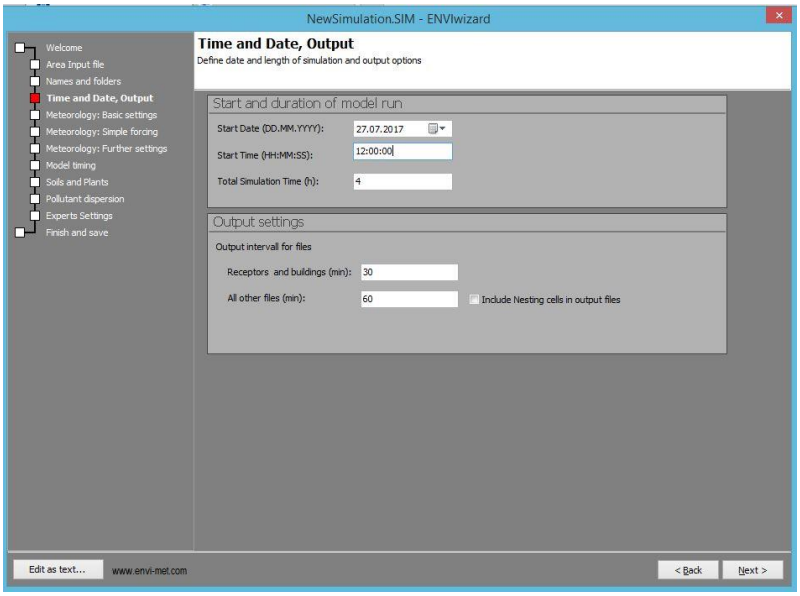


Figure 4.5- Simulation Date and time - Envi-met interface

On the other hand, the humidity levels went below 35% while the peak levels record 40% on shore at the same day, These records were used as initial weather input data in the simulation process as shown below (Fig. 4.6) below.

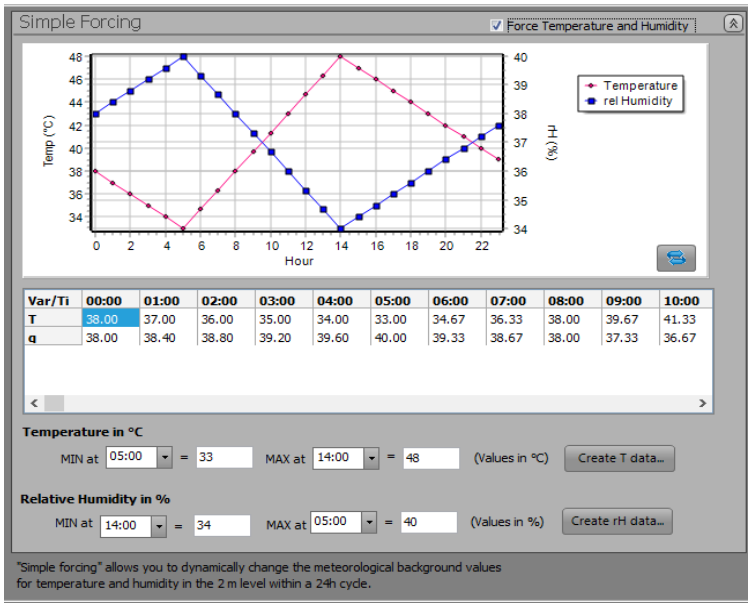


Figure 4.6 - Metrology, initial weather data - Envi-met Interface

4.3.2 Phase one -Base case Software Modeling

As described earlier in chapter 3 section 3.8 this research is conducted through five phases starting with phase one where the current existing urban design is built in the virtual model using Envi-met 4 program. following Huynh & Eckert (2012) recommendation and Paramita & Fukuda (2013) who used this software to analyze the outdoor thermal comfort in addition to Taleb & Abu-Hijleh (2013) who conduct the study of green surface impact over urban design thermal conditions using also Envi-met similar to Wong & Zheng (2016) who followed the same path. The model was built as shown in figure (4.7) below based on the fact that residential units are 10 meters height while Masjid height was assumed to be 15 m height since it was not constructed yet on site. on the other hand, the green spaces were

traced from the previous map presented in (fig. 4.4) earlier and standard green grass cover was used as landscape material.

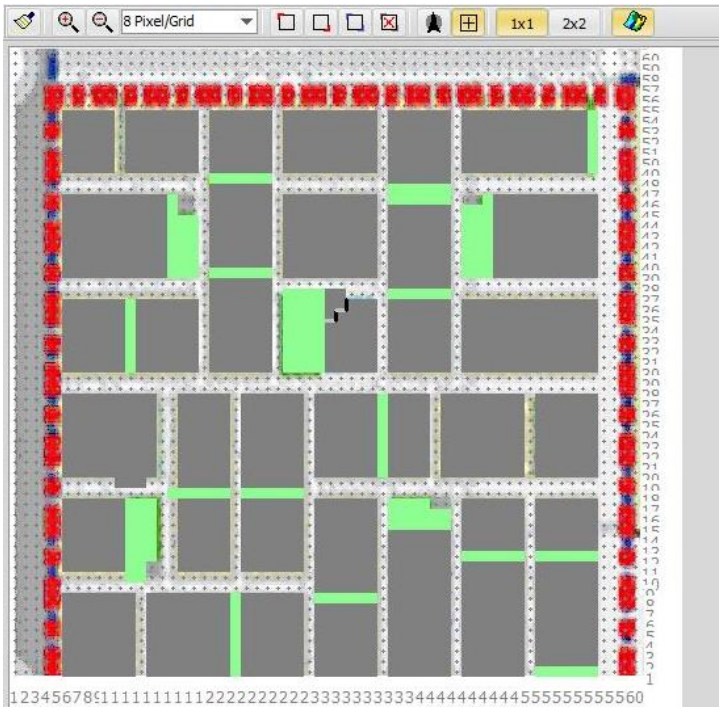


Figure 4.7 - Base Case model, illustrated by Author - Envi-met interface

The program used a grid system were X-Y-Z values are adjusted by users based on project dimension and scales, therefore in this research the grid is 6m on X-axis and 6m on Y-axis while it is 2m on Z axis since it is a low height project and facade details are neglected therefore no details were given for building elevations. The simulation process run for four hours on 27 July and the results will be discussed in chapter five of this study.

4.4 Phase Two- Orientation Analysis

Many research and studies concluded that Orientation of a building impacts its indoor thermal comfort such as Huynh & Eckert (2012) who not only consider the interior impact of building orientation but concluded that surrounding thermal comfort for users can be enhanced by the selecting optimum buildings orientation that surrounds the public space. and

since this becomes an initial request for many building regulation codes and standards around the world, it was essential to consider it within the technical platform that architects and urban designers are using nowadays such as Autodesk software since (Autodesk, sustainability workshop 2017) declare the fact that buildings respond to orientation modification since this impacts the sun cast and exterior envelop solar gain which eventually impacts energy consumption within the indoor spaces. Similarly, Revit program incorporate Ecotech features were optimum orientation is suggested to users based on the location and topography of the site as well as built-in weather details.

This section explains the different scenario proposed for site orientation as well as evaluation variables that were used as shown in (Table 4.1) below, while the result of the simulation process and its discussion will be presented in chapter five of this study.

Table4.3- Structure of phase two structure- Author

First Proposed Orientation (Base case Mirrored over Y axis)	Air temperature	Results will be compared to current design in phase one that is considered the base case for this phase
	Wind speed	
	Humidity level	
Second Proposed Orientation (First proposed Orientation Mirrored over x-axis)	Air temperature	
	Wind speed	
	Humidity level	
Third Proposed Orientation (Base case Mirrored over X axis)	Air temperature	
	Wind speed	
	Humidity level	

4.4.1 Proposed scenarios and simulation process

Since Orientation impacts thermal condition of urban spaces, The current design was flipped three times over Y and X axis to examine the effect of different orientations over the master plan microclimate conditions by analyzing output results of Air Temperature, Wind speed and Humidity for each scenario at four peak hours starting at 12:00 to 16:00 on 27th July. The model was given different North angel at the basic setting domain (see figure 4.8) to adjust the model without manipulating any constant parameter that was assigned earlier.

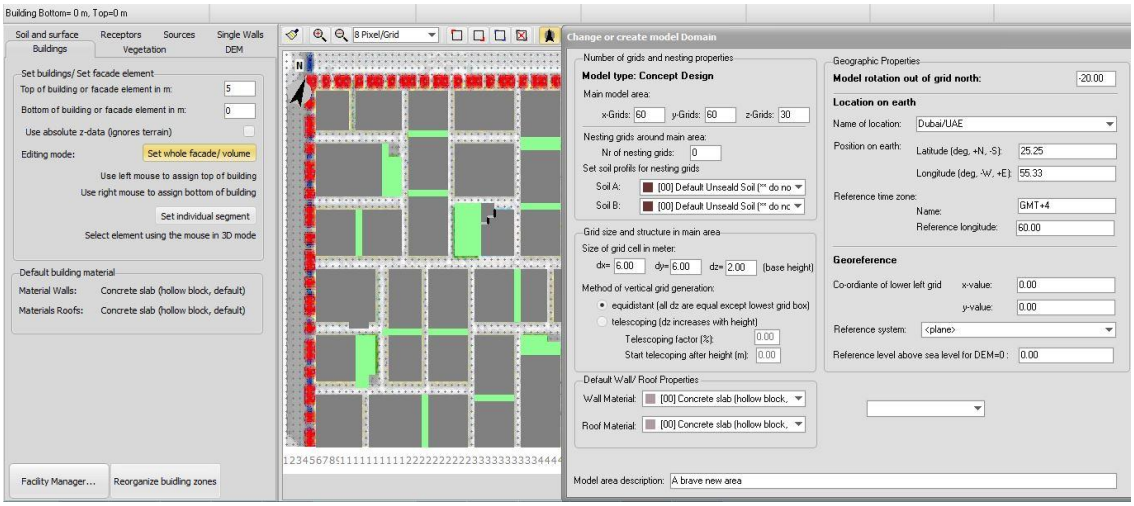


Figure 4.8 - Basic settings window, adjusting North angel- Envi-met interface

Figure 4.8 above present the basic settings for the current base case model that were tested in phase one and the north arrow is illustrated at the drawing platform is matching the north direction for the current base case design as shown below (fig. 4.9) where the site is highlighted on Google map view.

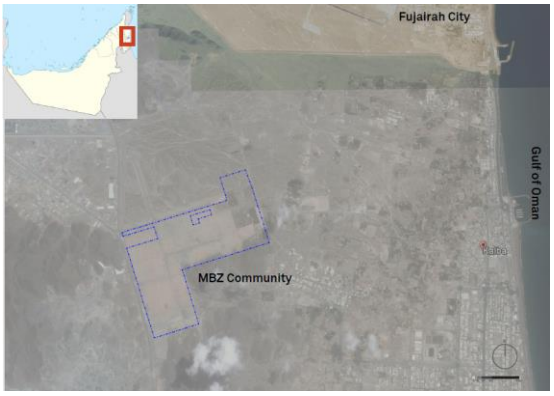


Figure 4.9- Site location on Google map view - MBZFC 2015

The simulation process starts with the first proposed orientation where the current master plan design is mirrored around the Y-axis (Flipped Vertically) which drives the north arrow from being on a 30˚ angel to 330˚ angel as shown below (fig.4.10). However, all project constant parameters were fixed and the same base model was used only by saving another copy in order to eliminate any chance of miscopying the same initial data from the base case.

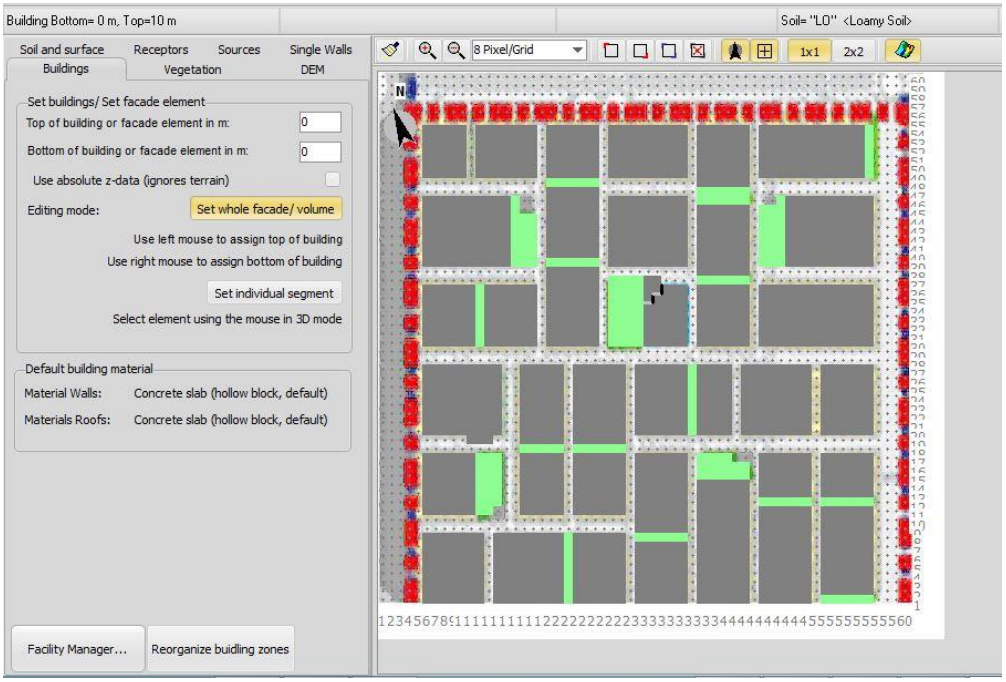


Figure 4.10- First proposed Orientation model, illustrated by Author - Envi-met interface

The model was then analyzed through the simulation portal in the Envi-met package software that generates output data to be used by Leonardo that is also included with the Envi-met software package and it is the portal that helps to illustrate the output information into readable maps that represent different data including microclimate variables such as Air temperature, Wind speed, Humidity levels.

The same process will be followed for the second proposed orientation and the third proposed orientation and final results will be presented and discussed later in chapter five of this study where it will be compared against the base case results to determine the optimum orientation that suits climate condition as well as project characteristics.

4.5 Phase Three- Layout Analysis

As discussed earlier in Literature review, Layout configuration for buildings within an urban project or a master plan for a residential or mixed-use project has a deep impact on the microclimate parameters at the urban, public areas between the buildings. this was concluded by Paramita & Fukuda (2013) where it was found that building heights within the site create higher thermal comfort especially when green areas are added to the landscape surroundings. Also, Deng, Wong & Zheng (2016) found that building layout impacts wind velocity and mean radiant temperature. Since wind velocity and Temperature are considered viable variables of this region climate and it is important to enhance the thermal comfort by reducing humidity and increasing wind speed as well as working on dropping the temperature within the public urban spaces in order to provide users with better outdoor experience, it was essential to explore different Layout options based on the optimum orientation figured from phase two earlier that will be considered the base case for this phase.

The below (table 4.4) represent the structure of phase three and the evaluation variables for each scenario as well as Number of residential blocks at each proposal, keeping in mind that the minimum number of villas and service is not less than the current existing design since the project feasibility and economic statues is out of this research scope of work and the proposed change in residential unites was result of the layout change and it is not related to any architectural change in the villas design or plot total area despite the fact that Layout one suggest beehive plot shape holding same villa dimension and bigger total area .

Table 4.4- Phase three structure

Layout Option one	Total No. of villas is **290**	Air temperature	Results will be compared against Optimum orientation results from phase two that is considered the base case for this phase and includes **278** villas
		Wind speed	
		Humidity level	
Layout option two	Total No. of villas is **292**	Air temperature	
		Wind speed	
		Humidity level	
Layout Option three	Total No. of villas is **288**	Air temperature	
		Wind speed	
		Humidity level	

4.5.1 Proposed scenarios and simulation process

Different layout proposals were influenced by the geometry of the beehive cells, it was fascinating to notice how a big number of bees are living within the beehive, protecting this structure that they create from scratch and working on feeding newborn bees as well as

producing honey all in a spectacular arrangement and timing. This was inspiring since the same vision is required at this case study, where individuals are seeking a design that helps interact in a successful way and become more productive as organized as individual without losing the community conception with surrounding neighbors. The proposed designs respect the private territory for each family by protecting the individuals unite of the residential plot which is the base for family structure however the designs, on the other hand, introduced common public areas that encourage social interaction in term of green areas and public community gardens that were inspired by the Beehive cell shape and designed in three different layouts. These public spaces are covered with grass and open for different activities as per public interests. The aim of proposing three different layouts is to examine the impact of each proposed layout on the microclimate parameter within the site and evaluate the enhancement of thermal comfort level for each layout. This will help to generate the best layout out of the three proposals that will be considered as the base case for phase four later.

The proposed layout is following the best orientation results from the previous analysis and the same model is used in order to eliminate any changes that might impact the fixed parameters that were discussed earlier in section 4.3.1 of this chapter. However Envi-met 4 was used again for this simulation since it is the selected simulation software for this research as Taleb & Abu-Hijleh (2013) were this simulation software was used to evaluate the impact of different layout configuration over urban microclimate similar to Wong & Zheng (2016) who also used this software to study the impact of building layouts over wind speed.

Therefore this phase aligns with previous proposed literature review studies and depends on Envi-met 4 to determine the best behavior of thermal comfort in each layout proposal as shown below in (figure 4.11) was the first proposed layout is illustrated and the linear circulation network is introduced in addition to 38 open green spaces shown below in green

shade while the central area is designated for the Main Masjid and the retail spaces that are linked to it as in the current base case were the 290 villas are served by one Masjid and retail shop for grocery and another day to day needs see (figure 4.11) below,

This design provides small green zones that serve approximately eight villas so that each residential block has an accessible green area within less than 15 min walking. as shown below (figure 4.12) this proposal the Concept is based on Beehive cell grid system however the cell shape here is only conceptual and the real plot area is hatched in brown color an shown in rectangular area that holds the dimension of 26m x 34m making total of 884m^2 compared to current base design were each plot is 26m x 36m making total of 864$m^{2.}$

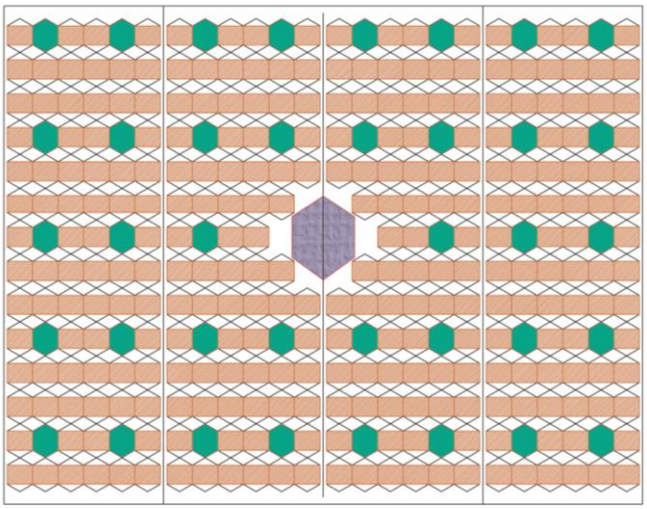


Figure 4.11 - Layout option 1 - 38 green spaces proposed in Beehive cell shape

designed by Author illustrated by Adobe Photoshop

Keeping in consideration that the distance between each two plot edge facing each other is 20m that is more than the required setback by Dubai Municipality with indicates a minimum of 12 meters setback at front elevations. Therefore the design complies with standards and includes the one-way driving path needed for the circulation network.

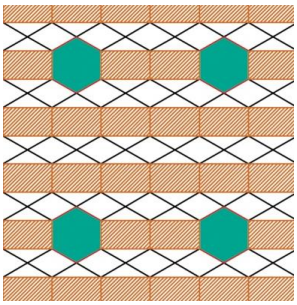


Figure 4.12- Layout option 1 - enlarged residential zone - designed by Author
illustrated by Adobe Photoshop

The second proposed Layout includes a total of 292 residential villas and complements the unite of 12 residential villas in one unite as shown below (figure 4.13). This block designed was considered the designing unite for the proposal and moreover it was repeated and distributed among the site area in compliance with Dubai municipality regulations in addition to the needs and requirement of a comfortable circulation network for both driveways and pedestrian paths, However the green areas were also considered and represented in a beehive cell shape and distributed among the site while considering maximum walking distance for between any villa and green public area not to exceed 20min. see (figure 4.13) below.

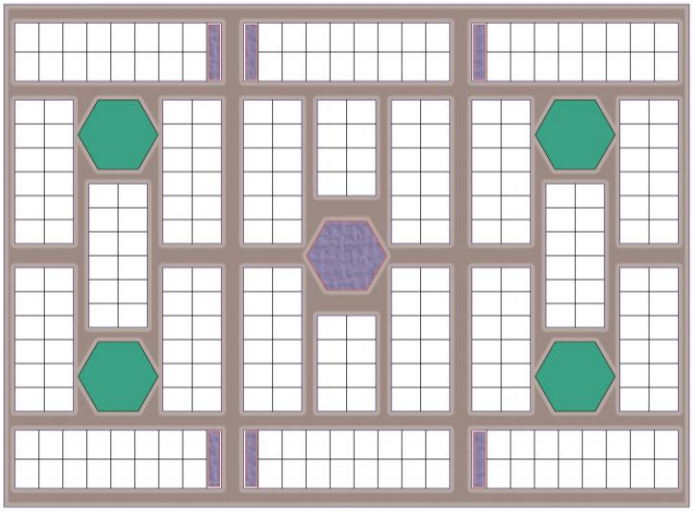


Figure 4.13- Layout option two - 4 green spaces proposed in Beehive cell shape

designed by Author illustrated by Adobe Photoshop

This proposal also keeps the Masjid and all serves surrounds it at the central of the site in respect to the cultural and social background of the site users in addition to the fact that this area designed to serve the entire site so keeping it at an equal distance from all users is recommended since it includes grocery shops and day to day needs as households or stationary or any other requirements served by retail areas as it is in the current proposed design. Also, other site services are located at the edge of the site where it sets under the project management responsibility such as transformer rooms and telecom connections. This proposal designed each plot to be 32m x 39m making a total of 1248m^2 That is more than the current base design by 384m^2 yet it has 14 villa extra. See figure 4.13 above.

The Third Proposed Layout is similar to the second proposal but includes six green spaces instead of four and also consider the central area as Masjid without open space surrounds it while distributing retail shops and services within the green areas in order to serve each group of villas without being centralized within the site. as shown below (figure 4.14). The design also limits the access points to this zone of the project with the side six openings and keeps the two other sides without driveway access only pedestrian links as shown (fig4.14).

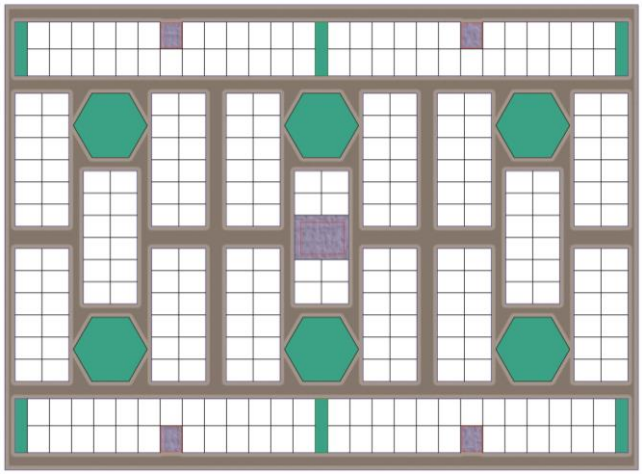


Figure 4.14- Layout option three - 6 green spaces proposed in Beehive cell shape

designed by Author illustrated by Adobe Photoshop

The proposal keeps the Masjid at the central area similar to previous proposals, however it replicates the beehive cell geometry to be used as the green spaces shape in six different areas within the site as shown above in figure 4.14 in order to serve bigger number of residents with less walking distance and encourage outdoor social activities since the green areas are introduced as public gathering hub to socialize and interact with each other in response to social sustainability objectives of this research. On the other hand, total number of villas in this design is 288 with ten villas extra than the current base case, however, the total plot area is similar to the previous proposal that is 1248m^2 which exceeds current design by 384m^2 as explained earlier without compromising on service areas or pedestrian walkways as well as driving network.

4.6 Phase Four- Shading coverage Analysis

In the third phase of this research, the optimum layout proposals result from phase two is considered as the base case for shading structure proposals that aims to enhance the thermal comfort of residence while using outdoor areas. This is based on previous literature review

were it was found that shaded areas impact users thermal comfort index and impacts buildings energy consumption as Abdul Aziz (2014) while studying Amman, Jordan case study and the impact of different trees over the surrounding microclimate as it was found that trees generate shading that enhances thermal comfort in public areas as well as reduces energy demand for buildings that are affected by this shade. Also Middle et al. (2016) supports this result in the study of shading impacts over public thermal satisfaction in Tempe, Arizona since the result of the public survey concluded that shade enhance the thermal comfort an outdoor areas in summer session, as well as spring and fall where people respond to air temperature under shade, is different from others who are exposed to direct sunlight.

This phase presents three different shading proposals that are tested and examined in term of their impact on microclimate variables that are used to evaluate different proposed scenarios as discussed earlier in section 4.3.1 of this chapter. The simulation process is based on the virtual model that was used in the previous phase and found to be the optimum case The three proposed designs are arranges as shown below (table 4.5) as each design is tested using the same simulation software selected earlier.

Table 4.5- Phase Four structure

First Shading layout	One side of the roadway at 15m height excluding green space	Air temperature	Results will be compared against Optimum Layout design results from phase three that is considered the base case for this phase
		Wind speed	
		Humidity level	
Second Shading layout	Two sides of the roadway at 15m height including green space	Air temperature	
		Wind speed	
		Humidity level	
Third Shading	Covers only main roads and full	Air temperature	

layout	green spaces at 18m height	Wind speed	
		Relative Humidity percentage	

4.6.1 Proposed scenarios and simulation process

Since the studying different types of trees and their impact over microclimate parameters is not within the scope of this research, the shading impact will be tested base on light structured shading element located at 15 m and 18 m height covering partial areas of the public spaces around the residential units. And since this study covers the peak hours from 12:00 to 16:00, therefore, the horizontal shading elements will be considered since the sun is almost perpendicular on the ground at this time of the day.

First shading layout is considering the total height under the shading element to be 15m that is covering one side of the roadways and fully covers the four green public spaces as in figure 4.15 below where the master plan is presented in Envi-met, Space working platform. were the magenta hatched area represent the shading covered area.

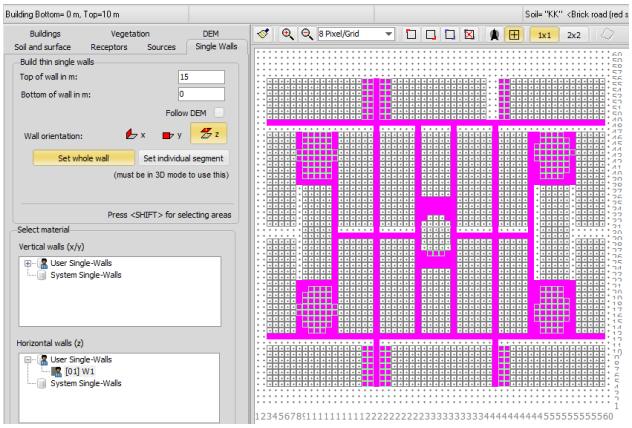


Figure 4.15- First Shading layout- Author illustration by Space/ Envi-met program

This proposal aligns the total height of the shading structure with the total average height of the design of the villa in order to avoid any distraction at the front facade of the villa and

avoid any visual obstacles for residents using indoor spaces and pedestrian at outdoor areas. However the material of the shading structure is not subject of this research despite a number of other studies are addressing this topic, yet this will not be discussed or studied at this analysis, therefore, the material was kept the same for all three options at this phase.

The second shading layout is considering the same height of 15m as the first shading layout but in this option, the green public spaces are not covered while the roadways are covered on both sides see (figure 4.16), unlike the first option where it was covered on one side.

This option aims to study the impact of the shade from the roadways over the surrounding spaces such as the public green spaces and other building which would impact the overall microclimate parameters within the site.

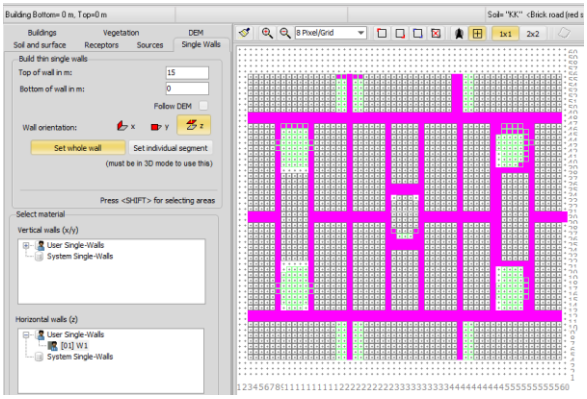


Figure 4.16- Second Shading layout- Author illustration by Space/ Envi-met program

The Third shading layout is considering the height of 18m unlike the first and second proposals since it covers some villas as well as shown in (figure 4.17) but in this option the green public spaces are fully covered unlike the second option and on the other hand the only the main roads are covered with shading structure while other secondary roadways are left exposed. This option aims to study the impact of the shade from buildings over secondary

roadways in order to understate if it makes a difference having shading elements at narrow spaces between buildings of the shade generated by surrounding buildings is enough.

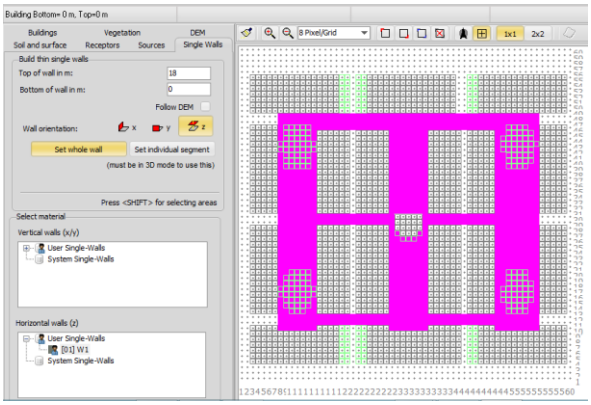


Figure 4.17- Third Shading layout- Author illustration by Space/ Envi-met program

4.7 Phase Five- Water features Analysis

In compliance with previous literature reviews were many studies highlighted the impact of soft landscaping and ground cover over the thermal comfort of users such as Thani, Mohamad & Jamaludin (2013) who finds that microclimate variables such as Humidity and air temperature would vary from one location to another at the same urban community in response to surface materials similar to Setaih, Hamza & Townshend (2013) who recommends the use of cool material in hot and dry climate regions that will enhance thermal comfort beside water surfaces and evaporation cooling strategy introduced with vegetation ground cover as well as Akbari et al, (1997) earlier who agrees that outdoor plantation impacts indoor energy demand since the building envelope is interacting with the surrounding microclimate at the site. Therefore it was found essential to test the impact of adding water bodies to the green public areas at the site in order to evaluate the impact of the

water bodies over the surrounding microclimate and understand if it was recommended at this case study to introduce this strategy within the site since it was noted that the proposed landscape design includes different ground cover material and wide areas of grass and green vegetations and variety of plants, however, no water features are proposed.

This phase considers the optimum shading layout proposal as the base case since it results from the previous phase introducing the optimum enhancements of all previous four phases and adding water features to the open public spaces will be the final phase of this analysis in order to conclude this study with the recommended strategies that suits this case study the most and discusses the mechanism in which these strategies helped to enhance thermal comfort index for users and helped to approach environmental and social sustainability at a micro scale within this master plan urban project.

This analysis was also conducted using Envi-met software since it allows adding water surface at any designated area. and since the program offers two options to be used first one is deep water bodies that are available under soil and surface features or water fountain of 4 m height that is available at sources however for this study the water fountain of four meters height was selected to be located at the center of the public green spaces. and the result of the simulation of this phase in addition to all previous phases will be presented and discussed in the next chapter of this research while the conclusion will be presented in chapter six later.

4.8 Summary

This chapter was presenting the structure of the simulation analysis phase guided by the previous literature review studies that were presented and discussed earlier in chapter two and it also explains the software simulation process details that were discussed earlier in chapter three and highlights the initial program setup and input data. Also the research parameters and evaluating variables were introduced in this chapter as it was categorized into three groups starting by Constant parameters that form the base for the virtual model and are out of this study scope of work, therefore, it remains fixed overall analysis phases while the inconstant parameters are forming the target of examination at each phase of this simulation analysis were the evaluating variables are used to determine the efficiency of the proposed design strategies or layout options and help decide the optimum enhancement for microclimate components that impacts the thermal comfort of users.

The structure of the simulation phases was introduced earlier in chapter three section 3.8. however, in this chapter, each phase was elaborated and discussed in term of initial input data and the inconstant parameters that are being evaluated in addition to the evaluating variables that complies with literature review studies and similar research topics.

In the next chapter of this research the results of the simulation analysis will be discussed and compared against similar results for other studies and studied in term of its compliance with this research aim and objectives.

Chapter 5: Result and discussion

5.1 Introduction

After going throw chapter three where computer simulation was selected for this study based on previous literature review and similar case studies, Envi-met was found to be the most compatible software that respond to this research objective similar to Huynh & Eckert (2012) and Paramita & Fukuda (2013) in addition to Taleb & Abu-Hijleh (2013) who agree that Envi-met is an efficient tool to be used in analyzing and testing microclimate parameter enhancement in response to different proposed scenarios which were also proven by Wong & Zheng (2016) therefore this chapter presents and discuses the outcome results that were generated through five simulation phases as explained earlier in chapter four.

The results of the simulation for each scenario is illustrated by LEONARDO 2014. It is an output platform for the ENVI-Met 4 numerical simulation analysis carried earlier on other

working platforms. It is used to extract the numerical data as a colored plan where a legend is produced to explain results in a graphical readable presentation.

In this chapter, the results will be discussed and compared against other similar case studies from the literature review in order to understand how this case is similar to other studies or different in term of each parameter respond to the proposed scenarios and design strategies. this chapter also explains different factors that impact microclimate components and their interactive relationship with the master plan inconstant parameters that were discussed earlier in chapter three and four. the structure of this chapter is illustrated in fig.5.1 below.

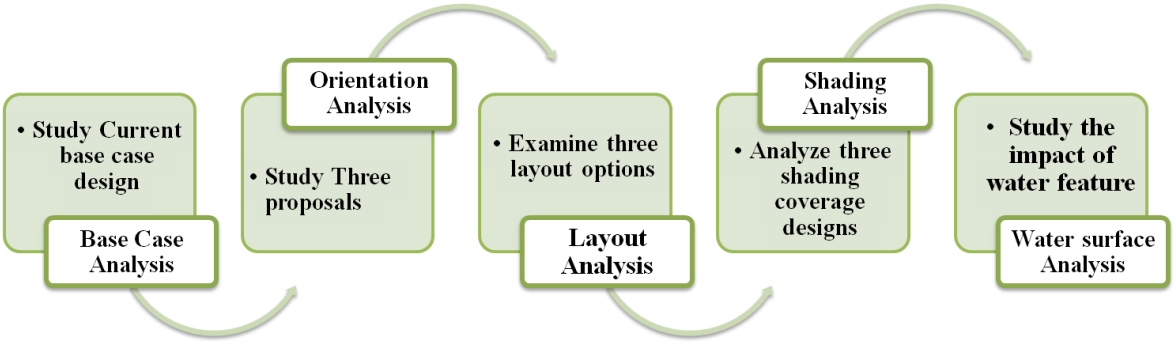


Figure 5.1- Simulation Analysis structure in chapter five - Illustrated by Author

5.2 Phase one - Base case Analysis

As discussed earlier in chapter four, the simulation process starts by building the current existing design on Envi-met4 and running the simulation for four hours as discussed earlier in chapter four section 4.31 where the constant, inconstant and evaluating variables are listing in table 4.2. And since date and time is one of the constant, fixed parameters, therefore, it will be assigned in each and every phase in order to eliminate any change in

results related to the time of day factor. In addition to that as discussed earlier chapter four section 4.2 the simulation analysis covers part of the current existing case study project that see (fig.5.2) and (fig 5.3) below as it represents the selected area for this research analysis and the green surface number and location in addition to the vehicles network main roads and secondary roads as well as the location of the central Masjid and retail, grocery shops

Figure 5.2 - Selected area for simulation process - MBZFC.2015

Figure 5.3 - Master plan of he case study project - MBZFC, 2015

While building the base case model it was essential not to change any of the architectural features related to building heights or landscape material since it is out of this research scope of work and it is considered within the constant parameters as listed in Table 4.2 earlier in chapter 4, However, the residential units were built as solid masses in 10 m height as shown below figure 5.4 that capture work platform while building the base model.

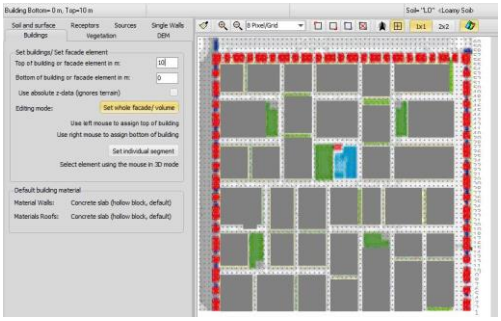


Figure 5.4 - Building Base model on Space/Envi-met - Done by Author

5.2.1 Phase one - Result and discussion

After simulation, the existing design of the selected area within the case study master plan the results were extracted using LEONARDO 2014 software in order to generate the graphical maps that help us understand how different areas within the same master plan can have different thermal conditions and users would record different thermal satisfaction rate.

The result of the base case is presented below in (table 5.1) as shown the wind speed is recording stable speed over the four hours that are known to be peak hours in this location however the humidity varies within a range of 5% from 35.93% at its maximum to 31.81% at its minimum record as shown in the table below while the Air temperature is recording an average of 43.56 C° over the peak hours as shown below in (table 5.1)

Table 5.1- Evaluating variables records for the base case - Simulation results by Author

Time	**R.H %**	**Wind Speed m/s**	**Air Temp. C°**
13:00	35.93	1.16 - 2.33	> 42.13
14:00	34.38	1.16 - 2.32	> 44.02
15:00	32.87	1.15 - 2.31	> 44.32
16:00	31.81	1.16 - 2.31	> 43.79
Average	**33.74**	**1.16 - 2.31**	**43.56**

The graphical presentation of the numerical data is illustrated below in (fig 5.5) that shows four maps generated by LEONARDO 2014 that is related to the Envi-met4 software package as discussed earlier. These maps are representing Air temperature data over the selected four hours in which the legend at the right side of the maps indicates the value of the color presented on the map. In this case, the map has a unified color that is referring to the highest value recorded. The maps are presenting building masses in dark navy blue color.

The plan also indicates the north direction, as well as each maps, has its hour presented on the right top corner , In addition to the project date that was selected to be 27 July as discussed earlier since it records highest Temperatures over 2017, therefore, this day was selected to conduct the simulation process since enhancement of thermal condition at this day is definitely going to be reflected over other days that are recording lower temperature readings and are considered less challenging compared to the peak day of the year.

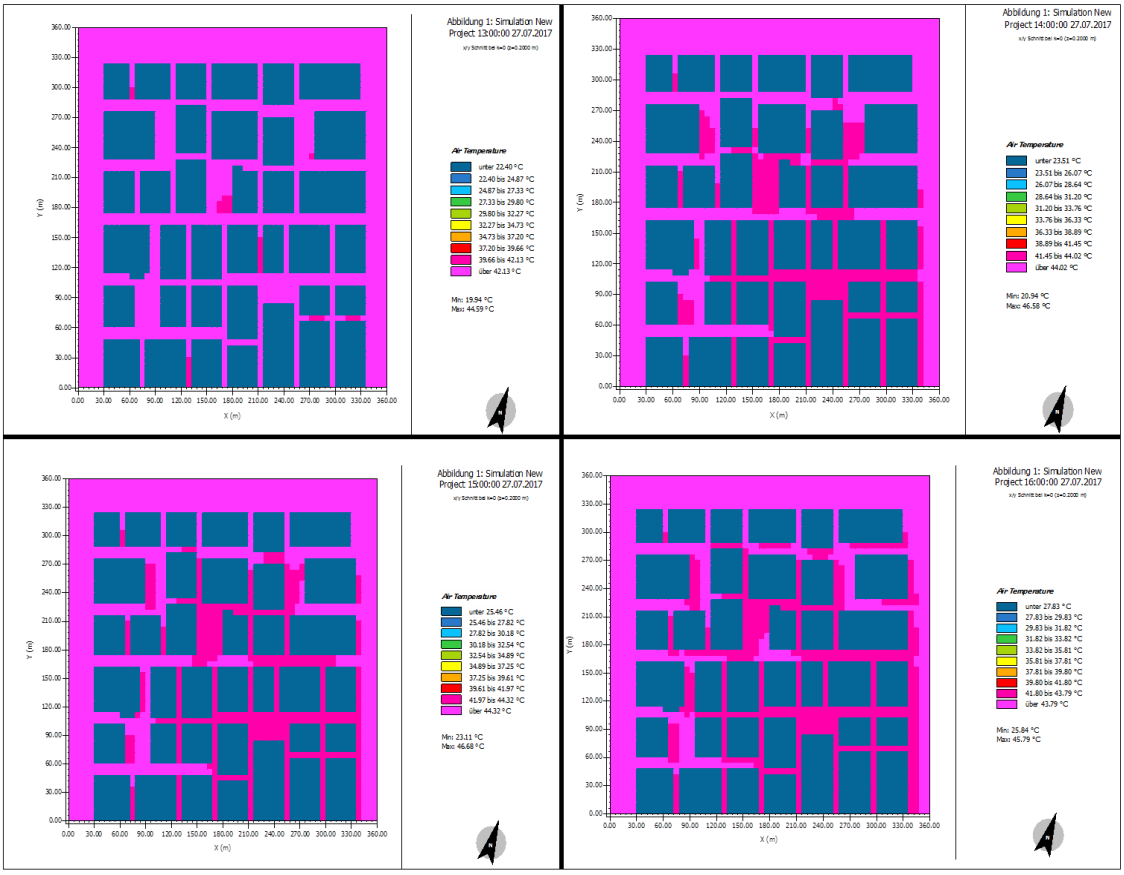


Figure 5.5- Air Temperature Maps - Leonardo 2014 done by Author

On the other hand, fig.5.6 below represent the wind speed maps where a range of 1.16m/s to 2.31m/s on average is recorded, the maps reflect different color range for the wind speed between buildings since it is affected by road width and open spaces or sharp edges.

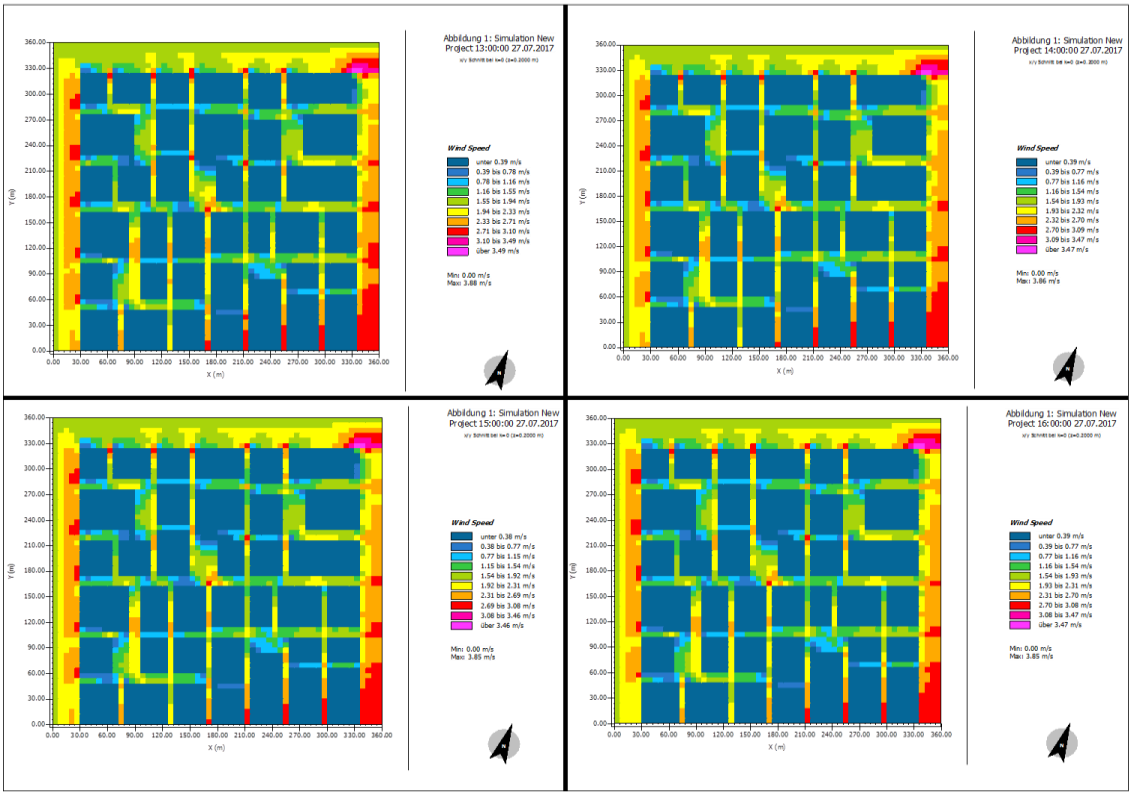


Figure 5.6 - Wind Speed Maps - LEONARDO 2014 done by Author

The humidity values over four hours were also illustrated in four maps nu LEONARDO 2014 as shown below (fig 5.7). The maps are showing unity in the distribution of relative humidity value over different areas of the master plan. As indicated on the legend the relative humidity records an average of 33.74 % over the four hours selected for simulation.

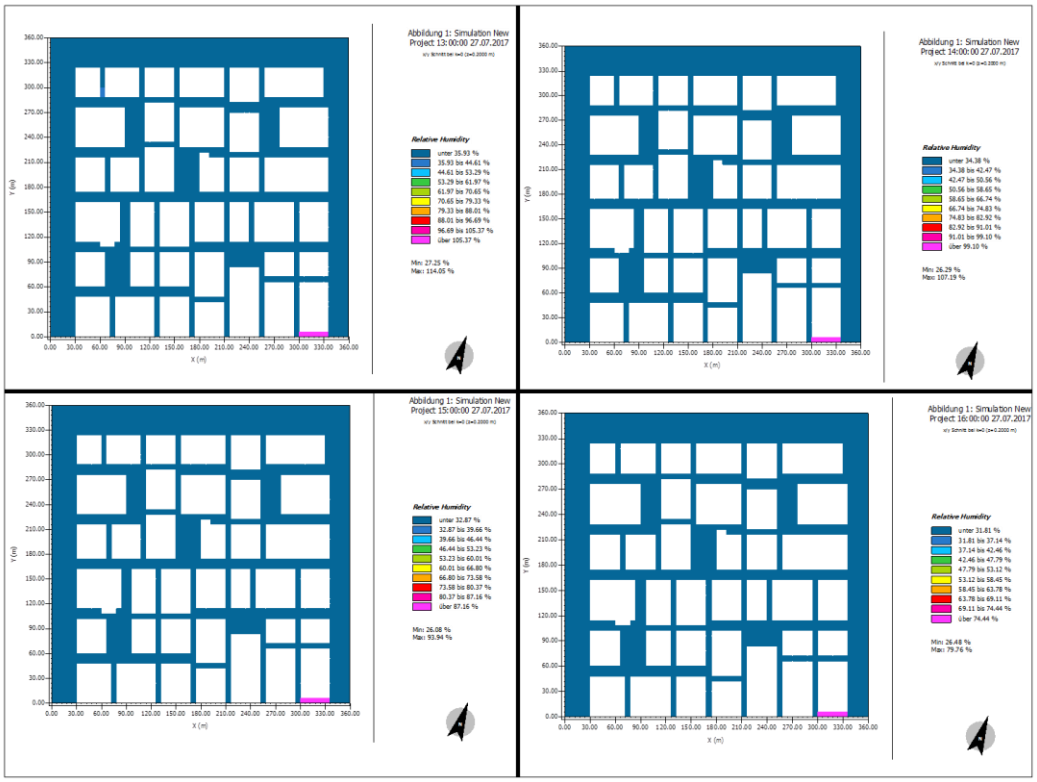


Figure 5.7-- Relative Humidity Maps - LEONARDO 2014 done by Author

These results are related to the current existing design of the project that was selected as a case study for this research, the aim of this simulation in phase one is to set the benchmark for further results generated after applying the enhancing strategies that were inspired by the Beehive cell geometry.

However, phase two of this simulation is addressing orientation since it was proven that building orientation within the site plays vital role in thermal comfort index for users by impacting different microclimate variables such as Wind speed and mean radiant temperature as concluded by Huynh & Eckert (2012)

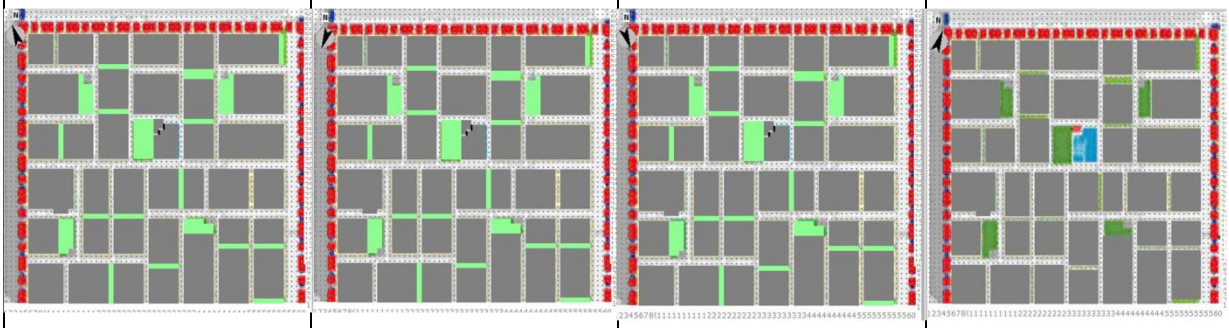
5.3 Phase Two - Orientation Analysis

As discussed earlier in chapter four, The design developer who is in charge for the architectural details for the case study project claims that the optimum orientation was selected in order to maximize the impact of wind speed within the site, However this was tested and examined to validate this claims and understand the difference between each orientation over the microclimate condition in term of wind speed and other variables covered in this research such as Air temperature and relative humidity.

In order not to change any of the constant parameters within the project the same model of the base case simulation was used again by giving it a new name and resave it for further analysis. This will maintain the constant parameters discussed earlier in chapter four, fixed and steady over all the simulation process. Since the base case was examined on phase one, this phase will examine three additional orientations and compare it the base case design.

The different orientations are shown below in Table 5.2 were the existing site limits were preserved and the change was limited to residential blocks within the site as realized from a north arrow direction. Since the working Platform of Space / Envi-met4 allows the User to enter the North degree within the initial Basic project model domain as shown in Fig 4.8 chapter 4 section 4.4.1earlier.

Table 5.2 - Proposed Orientation options

First Proposed Orientation	Second Proposed Orientation	Third Proposed Orientation	Existing Base Case
			
Base case Mirrored over Y axis	First proposed Orientation Mirrored over x-axis	Base case Mirrored over X axis	current design in phase one that is considered the base case for this phase

5.3.1 Phase Two- Result and discussion

The analysis process in phase two is similar to the process in phase one where the same evaluating variables are used to examine the results that were generated using LEONARDO 2014 similarly to the previous method. As well as the same virtual model that was used earlier in base case analysisis since the constant parameters should remain fixed. therefore the simulation was done over the same period of time, on the same day that was used in phase one, which is 27 July starting from 12:00 to 16:00. The following table includes the simulation, numerical results (see table5.3) of the First proposed orientation option followed by the color maps fig. (5.8) that indicates the distribution of the numerical values over the site. The maps shows a unified distribution of air temperature value over the site.

Table 5.3- Evaluating variables records for the 2nd phase first option - Simulation results by Author

Time	**R.H %**	**Wind Speed m/s**	**Air Temp. C°**
13:00	< 36.53	1.15 - 3.46	> 42.27
14:00	< 34.73	1.15 - 3.44	> 44.11
15:00	< 33.74	1.15 - 3.44	> 44.27
16:00	< 32.24	1.14 - 3.43	> 43.78
Average	**33.74**	**1.15 - 3.44**	**43.60**

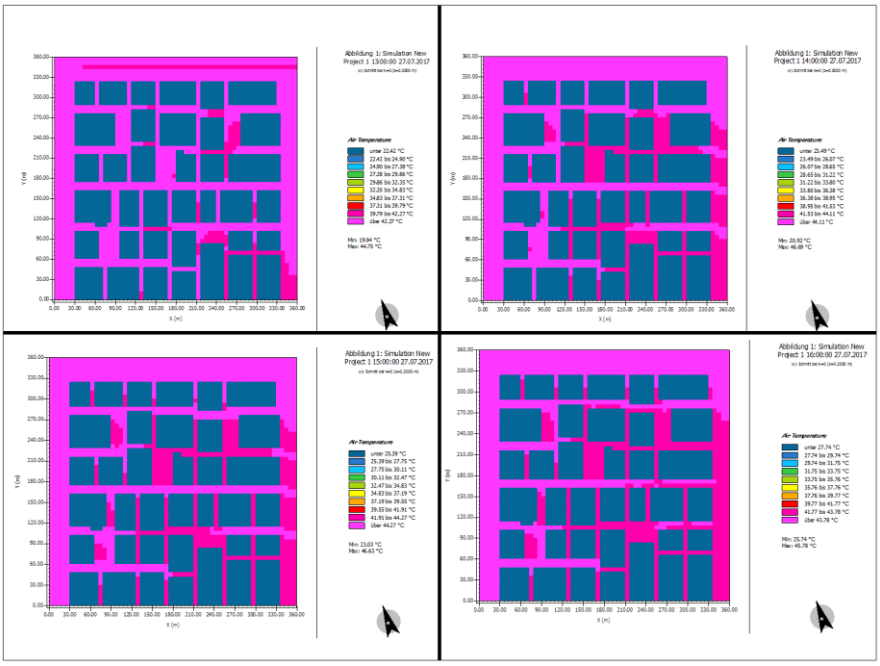


Figure 5.8- Air Temp. Maps - LEONARDO 2014 done by Author

Also the wind speed was simulated for the first option of orientation and the result as shown in table 5.3 earlier shows stability similarity at some zones with the base orientation where the minimum value recorded is 1.15m/s, however, some corners records higher speed compared to the base case where it records 3.46 m/s as shown below in (fig. 5.9) while the

maximum value recorded in the base case was 2.33m/s. Humidity numerical results were also reflected in graphical colored map see below (fig 5.10).

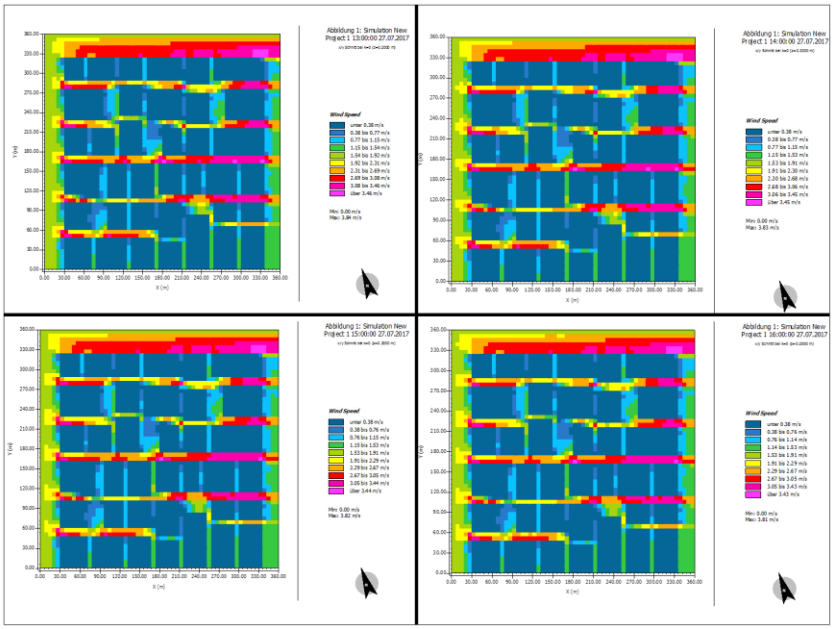


Figure 5.9- Wind speed Maps - LEONARDO 2014 done by Author

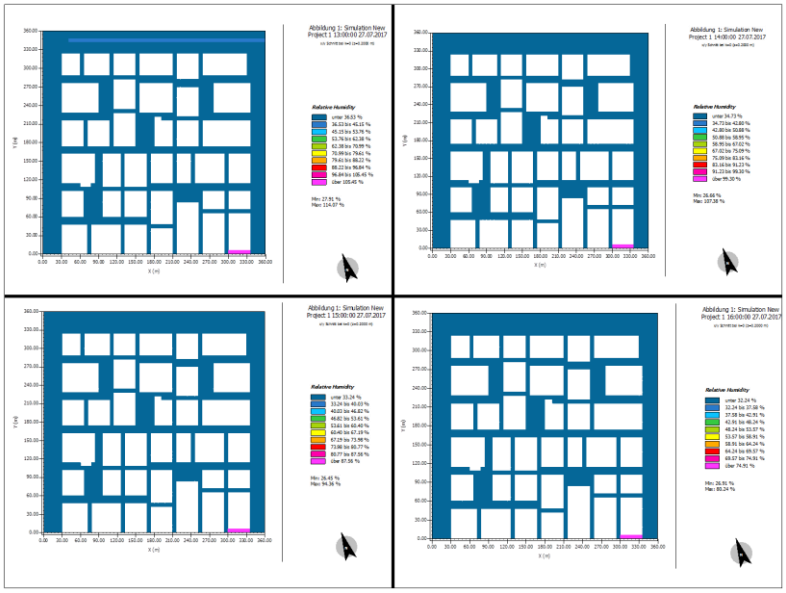


Figure 5.10- Relative Humidity Maps - LEONARDO 2014 done by Author

By comparing the base case Average results to the first orientation option it was found that the only difference was in the maximum wind speed value were it records 2.31m/s in the base case while the first orientation option records 3.46m/s as shown below in (fig 5.11) where a sample map was selected to compare between both results, keeping in mind that the result recorded over four hours was almost the same with no big difference. The maps represent an increase in wind speed at the right side of the site as shown in the dotted area illustrated at the left side map that indicates the first option orientation map.

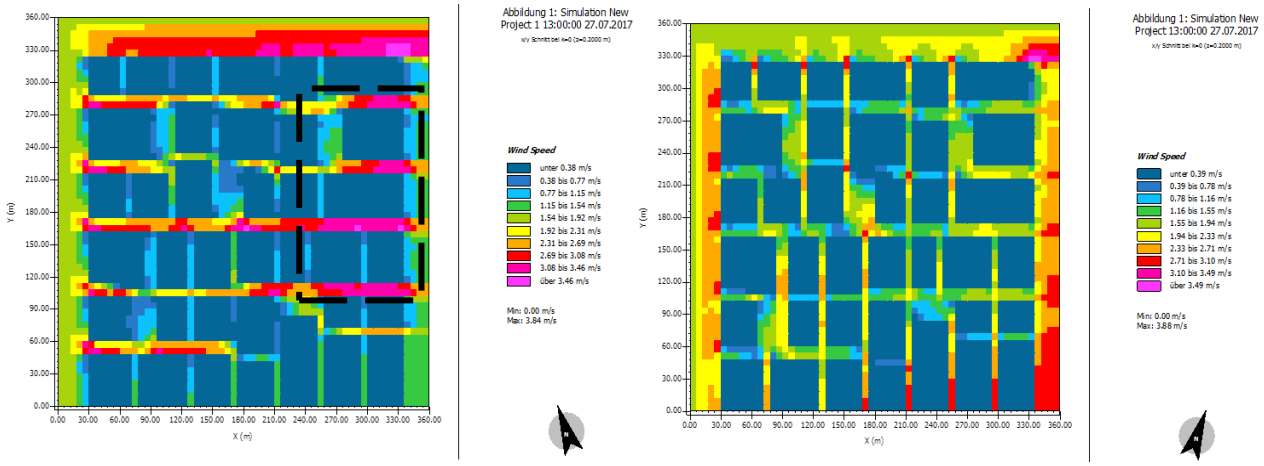


Figure 5.11- Wind speed at 13:00 in Base case (right)and first orientation option (left) - LEONARDO 2014 done by Author

After that the second orientation option was examined following the same process, using the same virtual model used earlier in phase one also on 27 of July from 12:00 to 16:00 and the result are listed below table 5.4 where results started to vary from the previous simulation since Air temperature and Relative Humidity start to have a range and different values cross the site as shown below in the graphical maps figure 5.12

Table 5.4- Evaluating variables records for the 2nd phase the second option - Simulation results by Author

Time	**R.H %**	**Wind Speed m/s**	**Air Temp. C˚**
13:00	28.97 - 31.9	1.07 - 2.71	42.41- 44.24
14:00	27.61 - 30.14	1.06 - 2.70	43.42 - 45.58
15:00	27.31 - 30.05	1.05 - 2.69	43.95 - 45.52
16:00	27.66 - 30.35	1.04 - 2.69	43.24 - 45.05
Average	**27.88 - 30.61**	**1.04 - 2.69**	**43.25 - 45.09**

The air temperature values in this simulation record a maximum value of 45.09 C˚ at the right side of the project site while the left area has a low temperature of 43.25 C˚ on average as shown below (fig. 5.12) in the maps representing four hours of simulation.

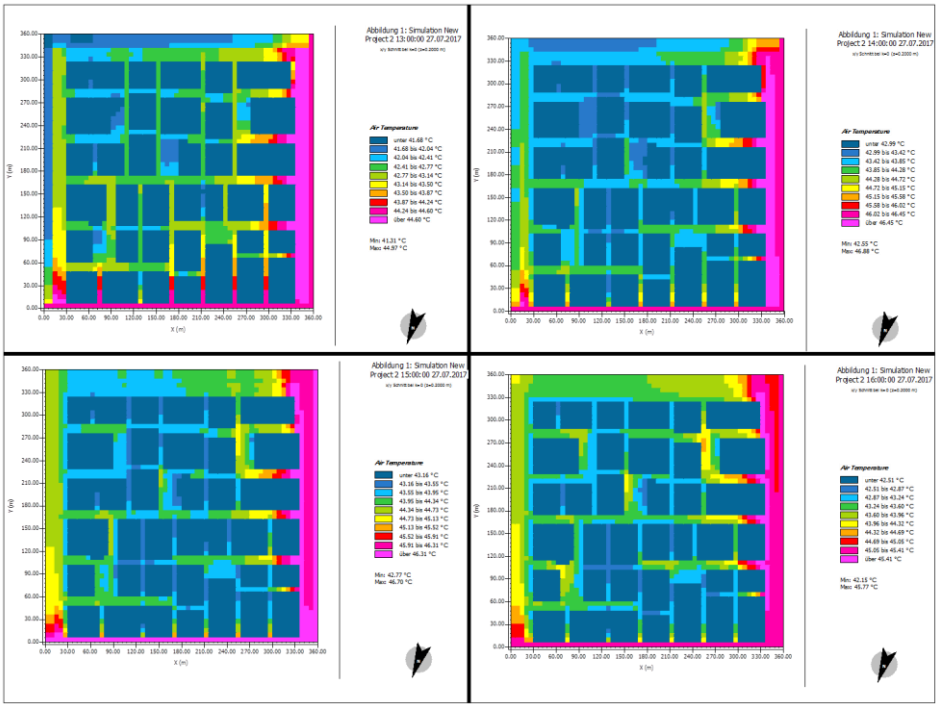


Figure 5.12 - Air Temp. Maps - LEONARDO 2014 done by Author

While wind speed records lower values than previous option and the base case as seen below (figure 5.13) that shows wind speed over different areas.

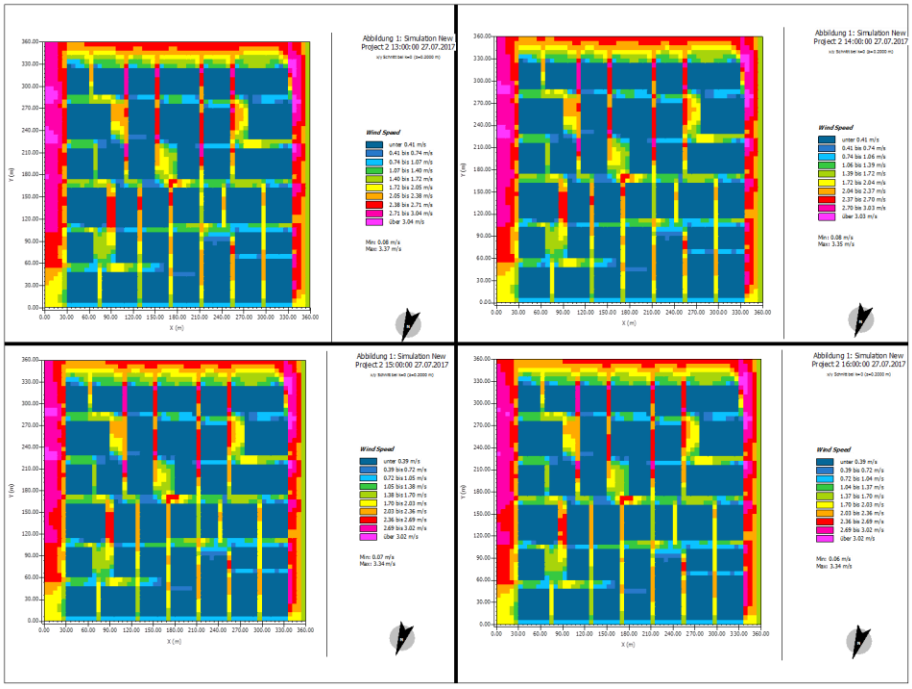


Figure5.13 - Wind speed Maps - LEONARDO 2014 done by Author

Also relative Humidity records different readings over the site areas since it goes from 27.88% in some areas to 30.61% in other areas on average as shown below in the graphical maps (figure 5.14) this is in fact lower than the previous value in the first orientation option and lower than the value results from the base case simulation presented earlier.

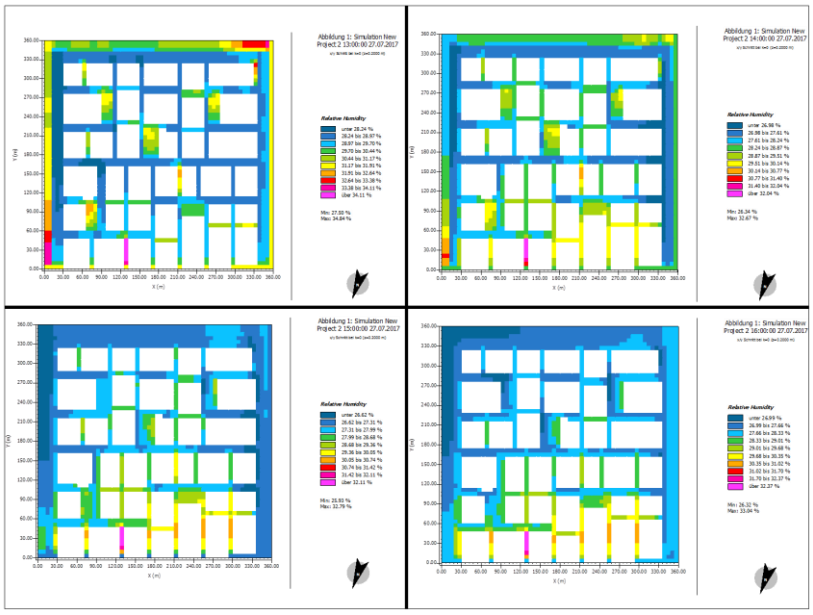


Figure 5.14 - Relative Humidity Maps - LEONARDO 2014 done by Author

This option records an increase in air temperature on an average by 2 C° compared to the previous two simulations even with the difference in values over the site this can be linked to the decrease in Relative humidity as well as wind speed.

Later on, the third orientation option was tested in a similar way to the two options earlier using the same virtual model as explained earlier and the simulation runs exactly on the same day and time. The results were as listed below in (table 5.5)

Table 5.5 - Table 5.4- Evaluating variables records for the 2nd phase 3rd option - Simulation results by Author

Time	**R.H %**	**Wind Speed m/s**	**Air Temp. C°**
13:00	29.36 - 31.46	1.12 - 2.88	42.34 - 44.50
14:00	27.5 - 29.28	0.76 - 2.85	43.53 - 46.15
15:00	27.26 - 29.25	0.76 - 2.84	43.52 - 45.90
16:00	27.61 - 28.82	0.76 - 2.84	43.2 - 45.30

Average	**27.93 - 29.70**	**0.85 - 2.85**	**43.14 - 45.46**

The third orientation option records results that are close to the second option, however, it is higher than the base case and option one in term of maximum value of air temperature as shown below in (fig. 5.15) that shows the graphical map for air temperature over four hours.

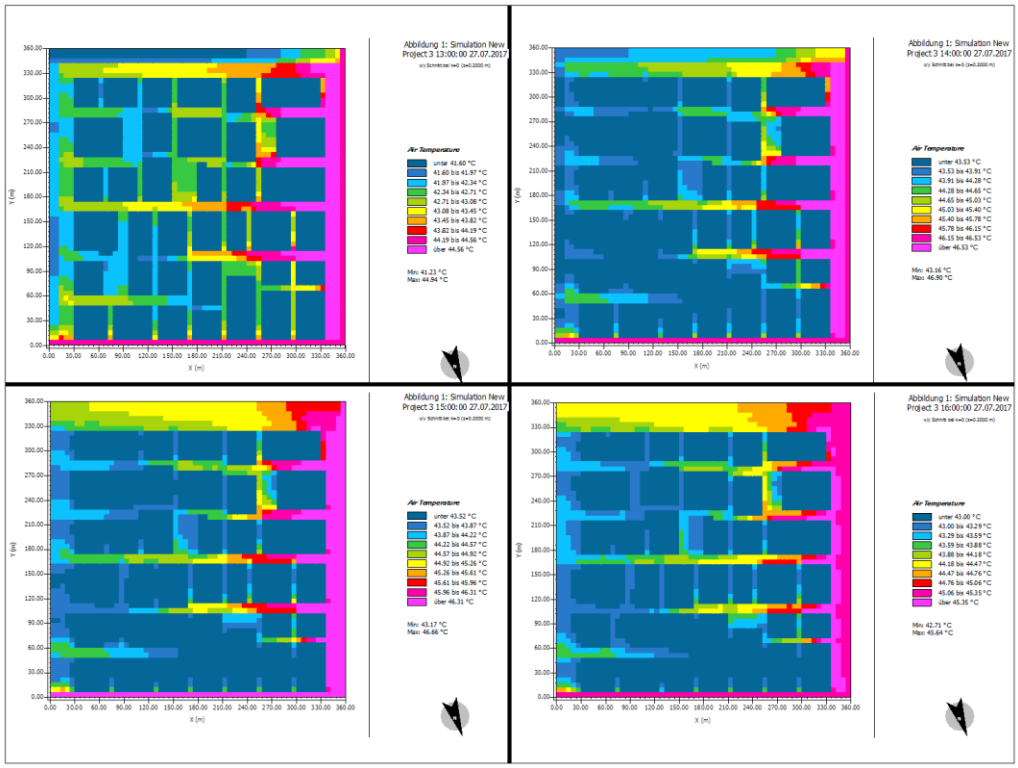


Figure 5.15 - Air Temp. Maps - LEONARDO 2014 done by Author

The wind speed records the lowest value overall previous orientation options as seen in below (figure 5.16) that represent wind speed distribution over different areas within the site.

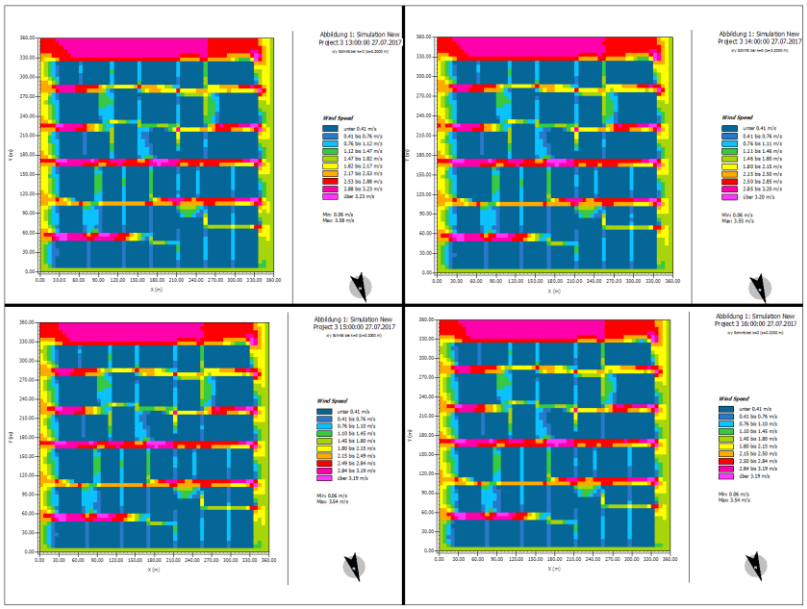


Figure 5.16 - Wind speed Maps - LEONARDO 2014 done by Author

Humidity also hits lowest values as shown in (fig.5.17) compared to previous options however it is close to the second orientation option results that were presented earlier.

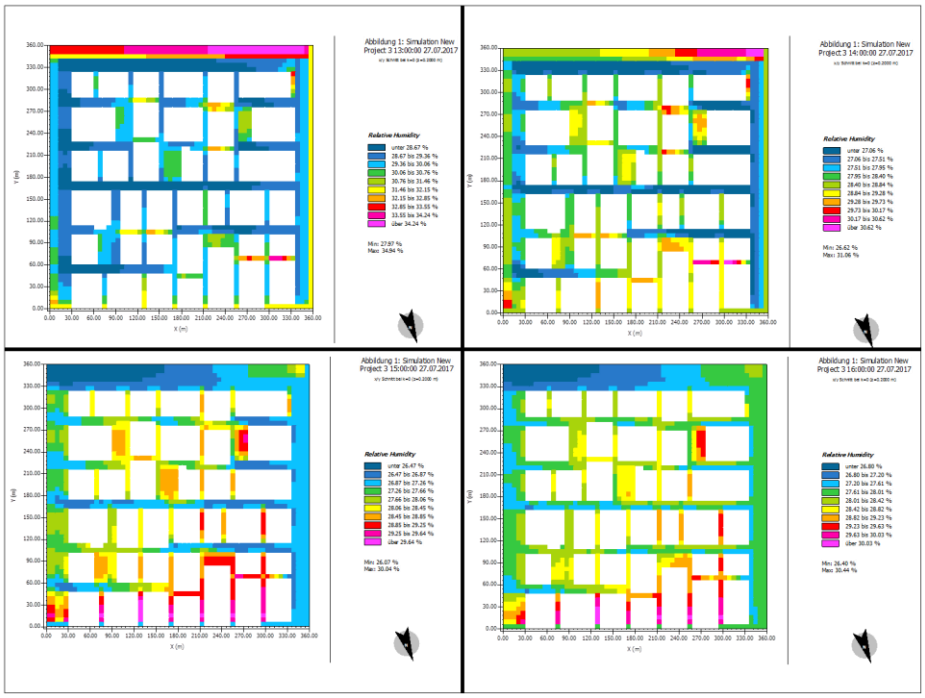


Figure 5.17 - Relative Humidity Maps - LEONARDO 2014 done by Author

After studying all previous orientation options and after comparing the results against the base case orientation that were presented earlier in phase one. It was found that the current existing orientation is the optimum orientation since it has the lowest air temperature with fair wind speed as well as relative humidity. Since option two and three has higher air temperature value by 2C˚ at least. And option one has the same relative humidity and slightly higher air temperature but the wind speed increase remarkably at one area of the project and since it is a small area as discussed earlier in figure (5.11) therefore the decision was to go for the current orientation and consider it the base case for the next phase.

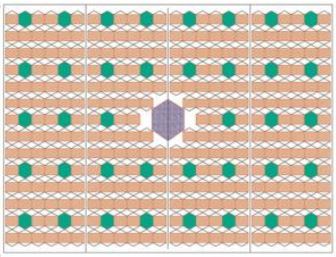
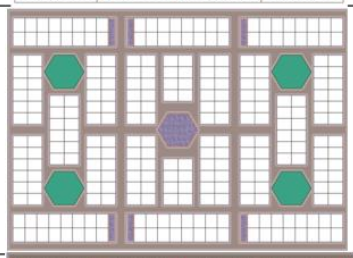
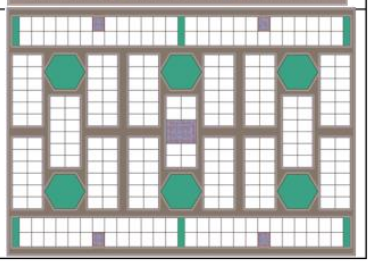
5.4 Phase Three - Layout Analysis

This phase address the layout configuration of the case study since it was proven earlier in the literature review chapter two that Layout impacts thermal comfort satisfaction for users since it impacts microclimate parameters as found by Paramita & Fukuda (2013) and also proven by Deng, Wong & Zheng (2016) when it was concluded that energy consumption of a building is affected by the building layout as results from the virtual model simulation that was used in the research. Therefore this is listed to be the second phase of this research simulation analysis where the optimum orientation that results from the previous phase will be used as a benchmark for the results of this phase.

The three different layout configurations were inspired by the beehive cell geometry as explained earlier in chapter 4 section 4.5 and as discussed earlier in chapter two that the method implemented in this research is "challenge to design" where bio-mimicry organism level was followed using form scenario as per Zari, (2007) Framework table introduced earlier in chapter one section 1.3 where three levels of bio-mimicry implementations were described each with the five potential scenarios for the implementing procedures.

This phase examines three different layout proposals (see table 5.6)below and test the evaluating variables results against the base case design for this phase that is considered the current existing design as explained in the previous phase.

Table5.6 - Layout options and details - Prepared by Author

Layout Option one	Total No. of villas is **290** Total No. of green spaces **38**	
Layout option two	Total No. of villas is **292** Total No. of green spaces **4**	
Layout Option three	Total No. of villas is **288** Total No. of green spaces **6**	

5.4.1 Phase Three- Result and discussion

The first layout option was designed as an exact beehive cell grid where the cell shape was used as the unit which forms horizontal and vertical lines that locate villas beside each other keeping green open space as a social hub and activity center to serve around eight villas at a time within a minimum walking distance from each villa, this aims to encourage outdoor activities and use the green space as semi- public area so residents would feel safe and comfortable knowing each other and building social connection between eight families using the shared space that is served by grocery shop. while the central area is left for the masjid.

The design was examined using Envi-met4 also as discussed in the methodology selection chapter three earlier. The outcome results were similar over the four hours analysis starting by 12:00 to 16:00 on 27 of July since date and time is a constant parameter in this research.

The results of layout first option are introduced below in table 5.7 as numerical values as an average reading over the four hours that forms the peak of the day and the benchmark results that are related to the base case simulation analysis that will be used for comparison.

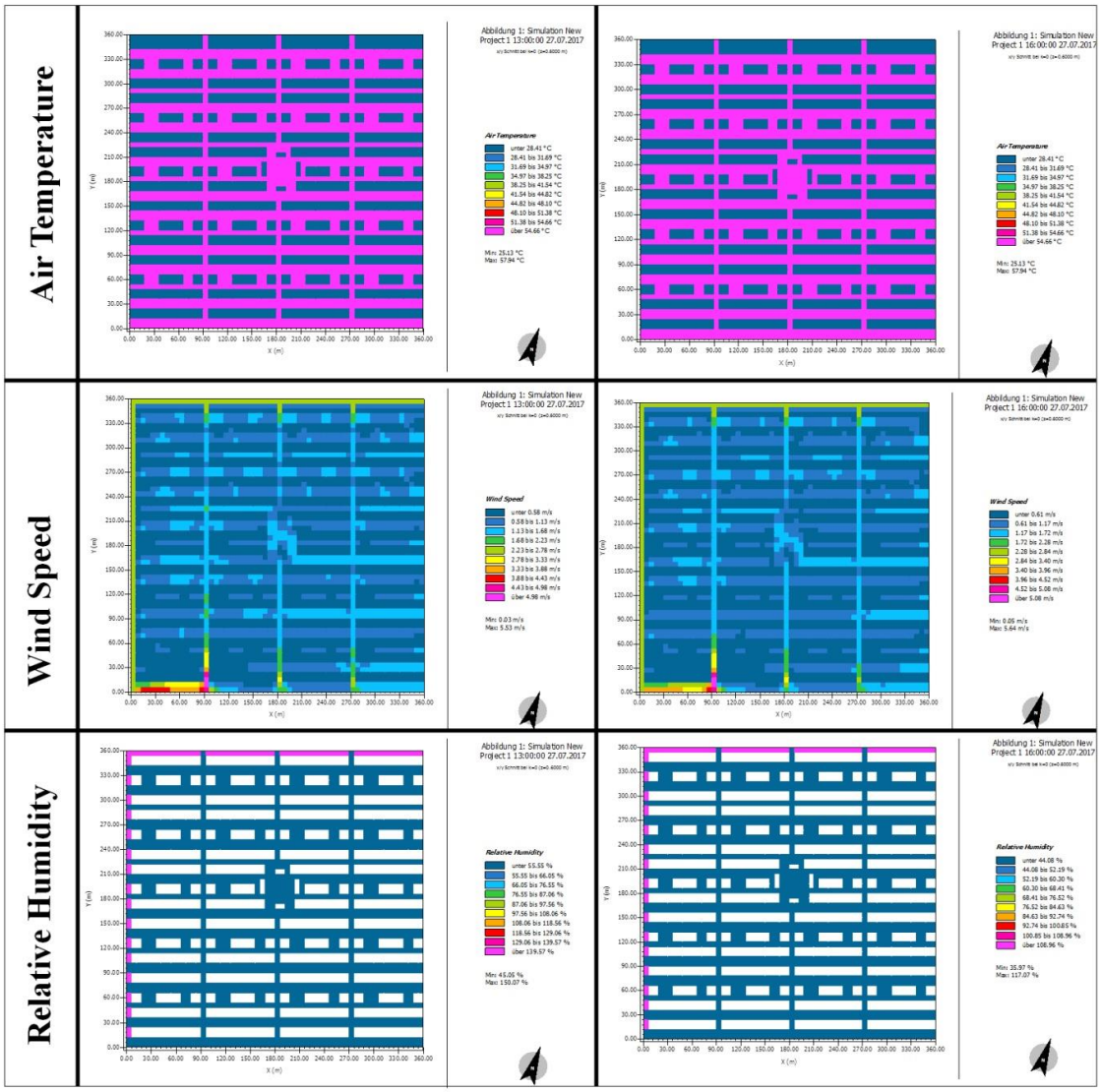
Table 5.7 - Simulation results of First Layout Option - Prepared by Author

	Relative Humidity %	Wind Speed m/s	Air Temperature C˚
Layout first Option Average results	55.2	1.13 – 1.72	54.6
Base Case Average results	33.74	1.16 - 2.31	43.56

The results indicate an increase in the relative humidity percentage since the maximum value recorded is 55.2 % while the base case has an average of 33.74% also the wind speed was reduced since the highest value recorded was 1.72m/s and table 5.8 below indicates a unified distribution of the speed values all over the site while the base case records 2.31m/s as the highest value and the map presented earlier in figure 5.6 shows that wind speed is not similar in all areas of the site. On the other hand Air temperature also increased to be 54.6 C˚ as shown below in figure 5.18. where the Air temperature is also unified cross the site.

The results were also generated in graphical colored maps using LEONARDO 2014 as previous simulations see Table 5.8 below it represent the first hour of the simulation that is 13:00 and the last hour of the simulation that is 16:00 which in facts reflects the average of the simulation period for the Air temperature results as well as wind speed and relative humidity. The above maps indicate the unified values for the evaluation variables over the site areas, unlike previous simulations where maps are showing a range of values over the different areas within the site.

Table 5.8 - Simulation map of First Layout Option - Prepared using LEONARDO 2014 by Author



Then the simulation analysis proceeds with the second layout option That follows almost the same residential blocks distribution and vehicles network but added four public green spaces that are covered with grass and 50cm height shrubs. The shape of this green spaces replicates the beehive cell shape while the location of these green spaces within the site helps to keep the walking distance short and comfortable for users.

The results of the simulation analysis are introduced below in table 5.8 as numerical values of the average readings over the four hours in addition to the base case simulation result and the first layout option for comparison and to help understand the change and impact of each design over the microclimate condition.

Table 5.9 - Simulation results of second Layout Option - Prepared by Author

	Relative Humidity %	Wind Speed m/s	Air Temperature C˚
Layout 2nd Option Average results	52.19	2.88 – 3.47	43.39
Layout 1st Option Average results	55.2	1.13 – 1.72	54.6
Base Case Average results	33.74	1.16 - 2.31	43.56

The results indicate a reduction in the relative humidity percentage compared to the first option since the maximum value recorded is 52.19 % compared to 55.2% in the first option while the base case maintain the lowest value over both options since it has an average of 33.74%. The wind speed, on the other hand, was increased compared to both results in base case analysis and first option analysis as seen in table 5.9 above however table 5.10 below

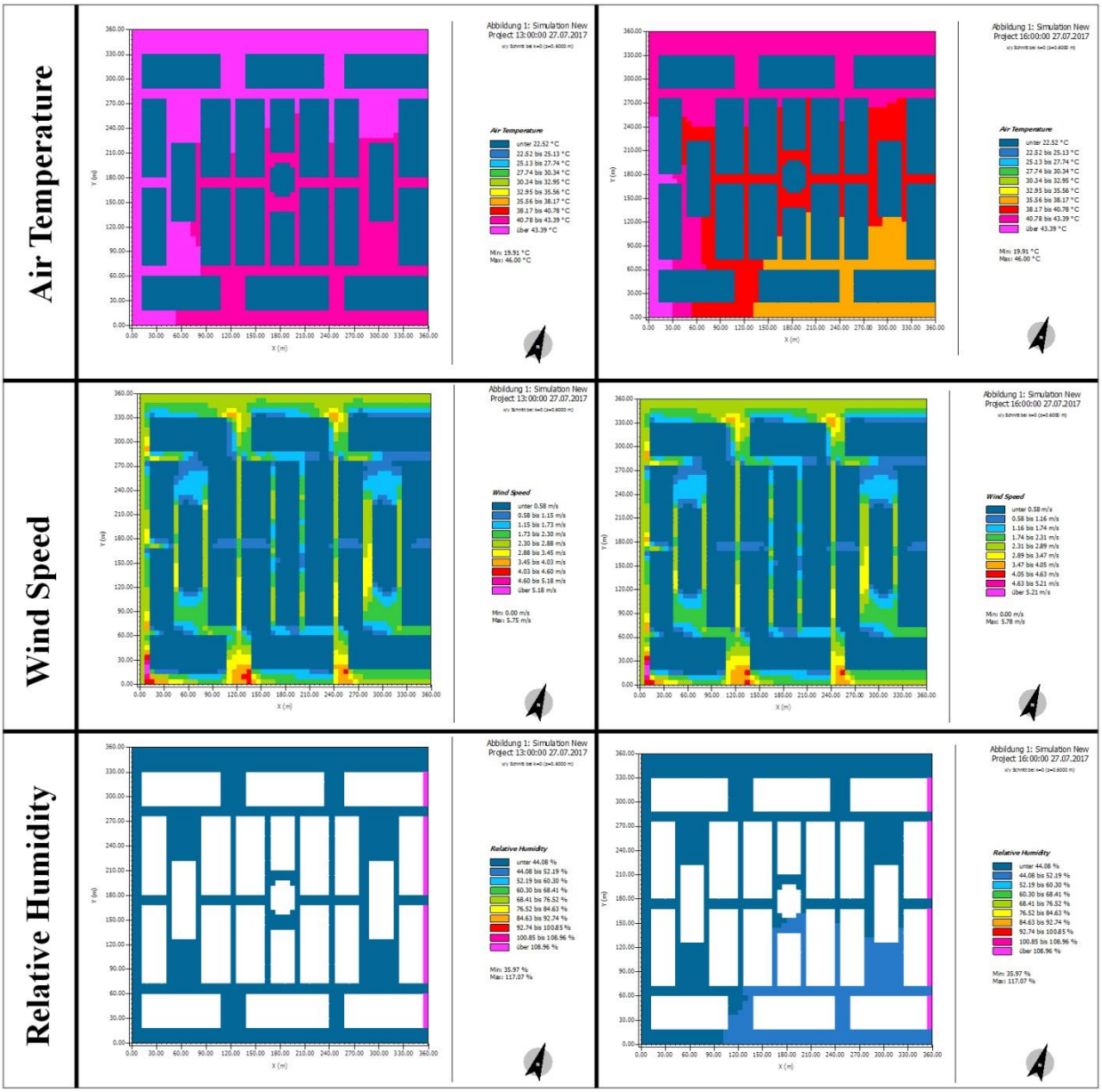
indicates differences in wind speed values all over the site similar to the base case distribution illustrated earlier in figure 5.6.

As for the Air temperature records, the results indicate a reduction compared to the first option values and this is believed to be linked to the increase in wind speed but the result is close to the base case with less than 1 C˚ difference.

In this layout option, it is noted that the humidity has a higher value compared to the base case and this is related to the big areas of green spaces that are covered with grass and 50cm shrubs that engage in the evaporation cooling process.

The previous Numerical results were also generated in Graphical maps that represent the color legend and its reflection on the site using the same pregame that was used earlier. The below table 5.10 illustrates the maps of the simulation process on 13:00 and 16:00 as in the previous simulation.

Table 5.10- Simulation map of second Layout Option - Prepared using LEONARDO 2014 by Author



For the third Layout option the design was close to the second option but with adding another two green spaces beside the previous four and maintain the central location of the Masjid with keeping the retail shops that are serving residents distributed at the green spaces boundaries in which it will encourage walking and using outdoor spaces for social and different sport activities.

The design was simulated using the same software as previous cases while keeping the constant factors fixed such as time, date and initial weather data. The results are presented in Table 5.11 below with the base case results and first and second layout options too in order to compare and discuss differences in numerical value as well as select the optimum scenario.

Table 5.11 - Simulation results of Third Layout Option - Prepared by Author

	Relative Humidity %	Wind Speed m/s	Air Temperature C˚
Layout 3rd Option Average results	48.55	1.43 – 2.86	43.89
Layout 2nd Option Average results	52.19	2.88 – 3.47	43.39
Layout 1st Option Average results	55.2	1.13 – 1.72	54.6
Base Case Average results	33.74	1.16 - 2.31	43.56

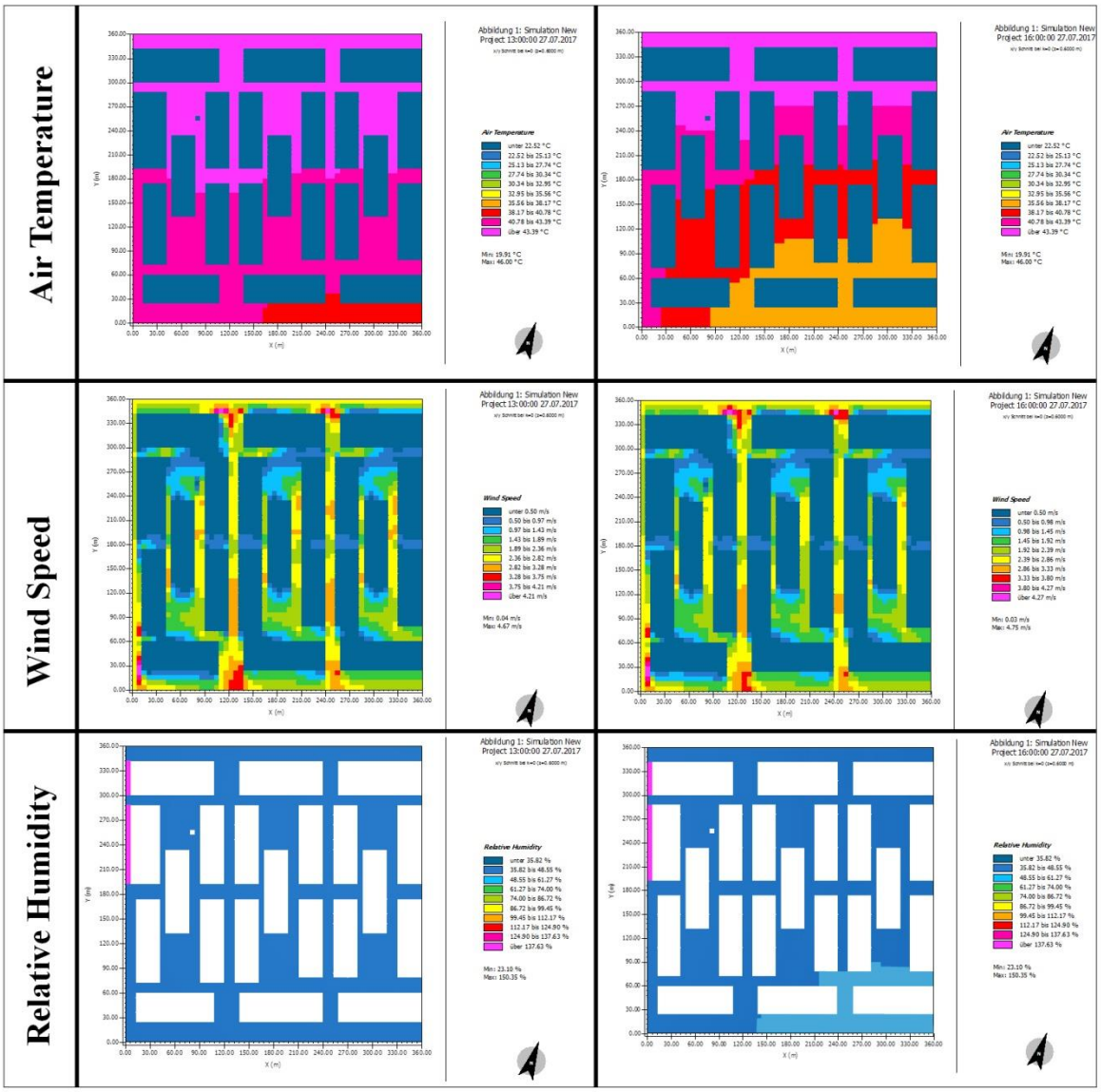
The results show that Humidity decreased by 3.69% simultaneously with the decrease in wind speed and the inconsiderable decrease in Air temperature since the difference between Second layout option and third layout option is less that 1C˚ as shown in table 5.11 above.

The results indicate that Second layout option has the lower Air temperature compared to all other options and the base case design and also has the highest wind speed range which impacts thermal comfort index. however, the Relative humidity in the second option is higher than the base case records and the third option but it is still within comfortable range and it helps drive the Air temperature low. And by looking at the results it is clear that the first

layout option has a high relative humidity level in responding to the reduction in wind speed but the Air temperature records its highest value compared to all other options.

The results of the third layout option were also illustrated in graphical colored maps as in table 5.12 below with the side legend indicates the values distribution over the site and between buildings. These maps are representing the first hour of the analysis that is 13:00 and the last hour of the analysis which is 16:00 of 27 July.

Table 5.12 - Simulation map of second Layout Option - Prepared using LEONARDO 2014 by Author



Based on all previous simulations of phase three and the study of the results as numerical values of graphical maps, it was found that the Second layout option presented earlier in table 5.6 is the optimum option for project layout with four public green spaces and central Masjid and social space at the center of the project that serves the 292 villa's around it.

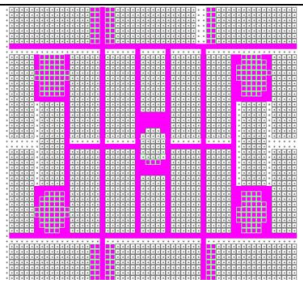
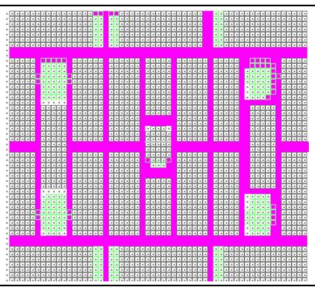
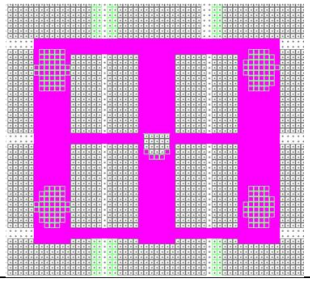
5.5 Phase Four - Shading coverage Analysis

The fourth phase of this research is testing the impact of three different shading coverage layouts on the thermal condition at the site as discussed earlier in chapter four. This examination complies with previous similar studies such as Abdul Aziz,(2014) who explored the shading impact on Average energy consumption for building at the case study site in Amman, Jordan. followed by Middle et al. (2016) which concluded that during summer, spring and fall session, shading areas are recording less Air temperature on reel feeling scale for youth and teenagers in Tempe, Arizona and this is related to the thermal comfort index as well as microclimate condition.

This phase examines three different shading layout coverage over public spaces and transportation network within the site as well as pedestrian walkways see figure 5.13 below.

The result of this phase for each option will be compared to the optimum case that results from the previous simulation since it is considered to be the base case for this phase

Table 5.13- Proposed Shading layout options

Shading Option one	15m shade covering one side of the main roads and full green areas as secondary pedestrian walk ways	
Shading Option two	15m shade Covering full transportation network and pedestrian walk ways but keeping green spaces open to sky	
Shading Option three	18m shade covering main roads and green spaces only	

5.5.1 Phase Four- Result and discussion

After running the simulation through the Envi-met4 program as discussed earlier and using LEONARDO 2014 later to generate graphical color legend maps to illustrate the numerical values of the microclimate variables that were used over the previous phases to evaluate and compare the thermal condition of each proposal.

The Numerical results are extracted and listed in Table 5.14 below where the first shading coverage layout records an average range of 1.78 - 3.56 m/s wind speed over the site and relative humidity of 44.85% while Air temperature has an average of 44.59 C˚. The numerical results are also presented in the graphical map in figure 5.18 below that represent Air temperature cross-section through the site over the four hours of simulation that are a

constant parameter in this study. The results indicate that Air temp. increased compared to base case based on the decrease in Relative humidity.

Table 5.14 - Shading coverage first layout option, Prepared by Author

	Relative Humidity %	Wind Speed m/s	Air Temperature C°
Shading coverage Option one	44.85	1.78 - 3.56	44.59
Base Case	52.19	2.88 – 3.47	43.39

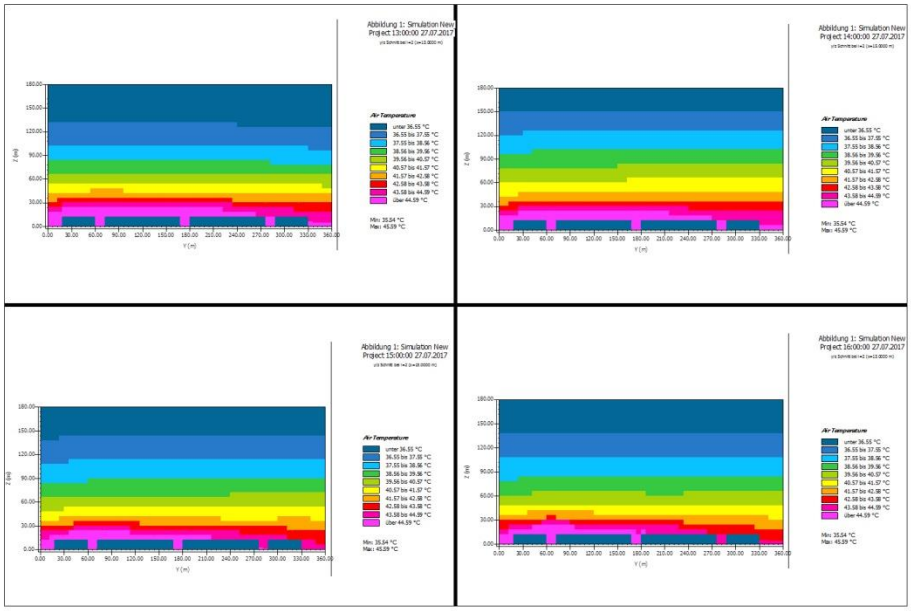


Figure 5.18 - Air temperature Section, Shading coverage first layout option - LEONARDO 2014 BY Author

Also, wind speed and humidity results were illustrated into graphical maps since it is important to understand the distribution of the numerical values over different site areas and explore the impact of the proposed shading layout over different public spaces. Therefore the wind speed maps are presented below in figure 5.19. It is obvious through the colored maps that the maximum wind speed is located only at the parameter of the site while between

buildings wind speed is considered low as per the maps and the legend attached. In addition to Relative Humidity percentage that is presented below is (fig.5.20).

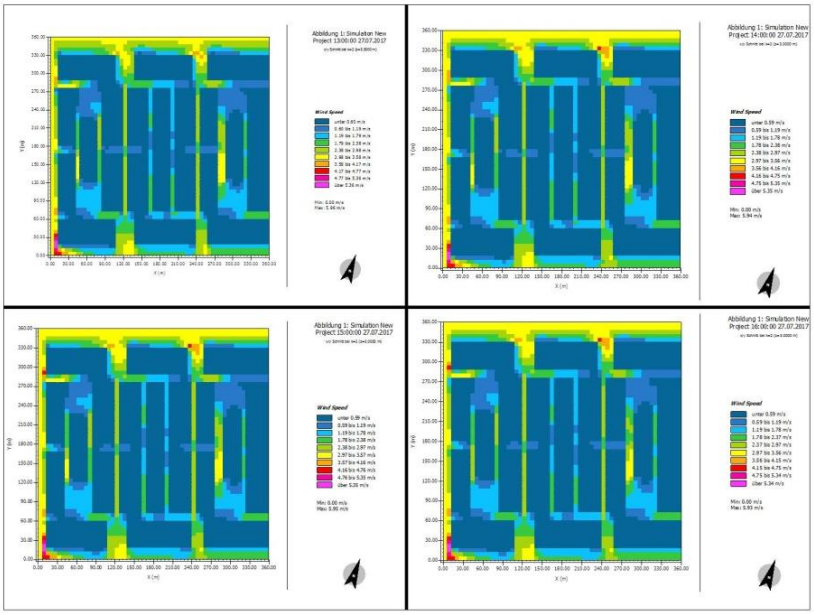


Figure 5.19 - Wind speed maps, Shading coverage first layout option - LEONARDO 2014 BY Author

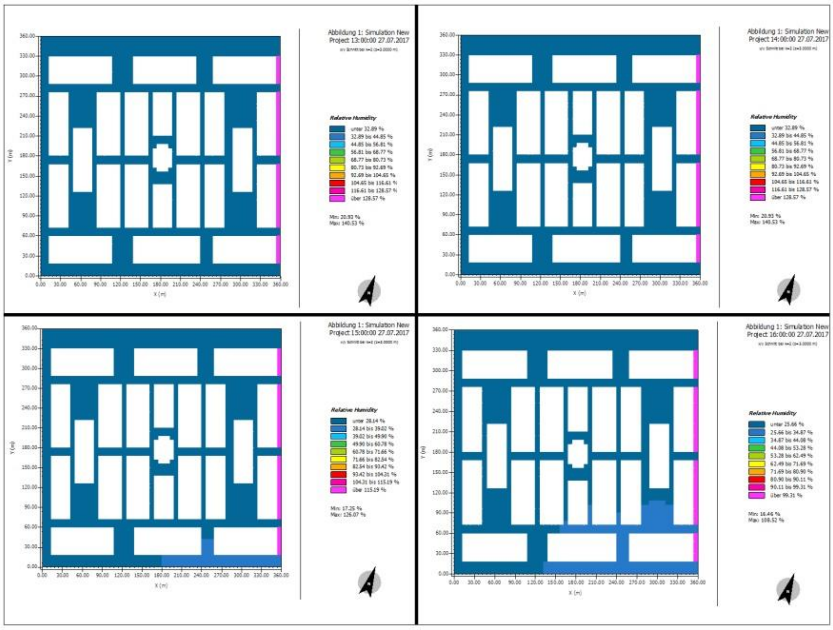


Figure 5.20- Relative Humidity percentage maps, Shading coverage first layout option -

LEONARDO 2014 BY Author

Second shading layout coverage was also simulated in order to compare results with the base case and first layout option that was presented earlier. Keeping the same virtual model as discussed in chapter four in order to eliminate any modifications or changes in the constant parameters such as Architectural details or day and time of simulation. This proposal covers all walking and driving ways and aisles surrounding green public spaces but it keeps the green surface open to sky, unlike the previous option.

The result of the second simulation is listed below in table 5.15. Where air temperature records 42.5 C˚ that is almost one degree less than the base case result. and 2C˚ less than the first shading coverage layout. Since Relative humidity is connected to air temperature, This reduction in air temperature was found to be justified since Relative humidity percentage has gone up to 56.1% that is the highest value so far among all other simulation results. The air temperature results are illustrated below in figure 5.21 where site cross section is presented

Table 5.15 - Shading coverage second layout option, Prepared by Author

	Relative Humidity %	Wind Speed m/s	Air Temperature C˚
Shading coverage Option two	56.10	1.58 - 3.16	42.5
Shading coverage Option one	44.85	1.78 - 3.56	44.59
Base Case	52.19	2.88 – 3.47	43.39

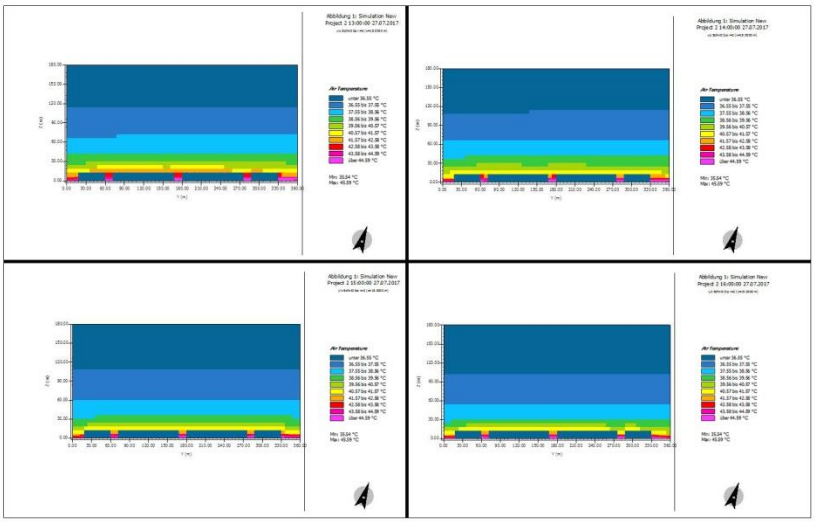


Figure5.21- Air temperature Section, Shading coverage second layout option -

LEONARDO 2014 BY Author

On the other hand, Relative humidity percentage was also represented in graphical maps using LEONARDO 2014 as shown below figure 5.22.

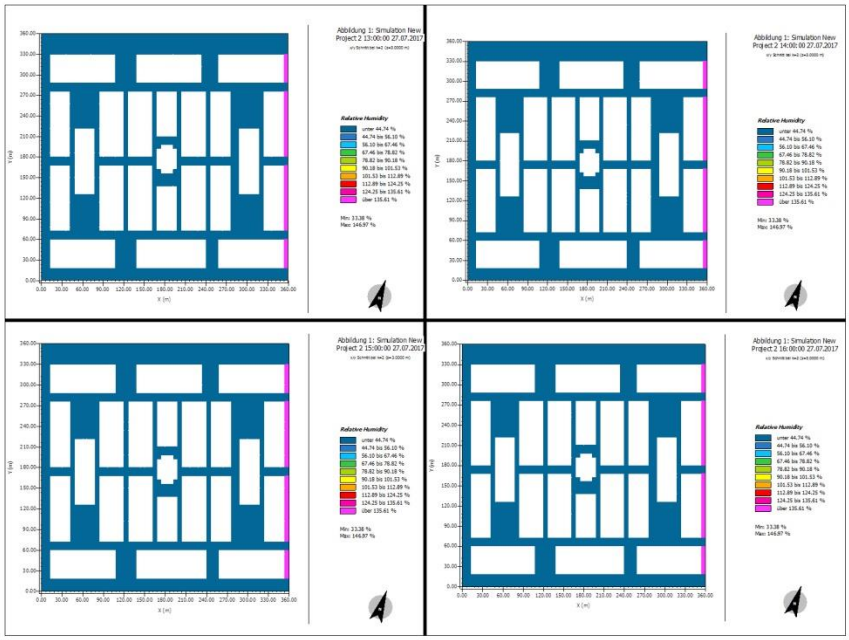


Figure 5.22 - R.H percentage maps, Shading coverage second layout option -

LEONARDO 2014 BY Author

Since relative humidity and wind speed are connected it was essential to study the wind distribution over the site as shown in fig. 5.23 below and compare it to the previous options. It was found that wind distribution over the site is similar to the previous case with slightly more penetration within pedestrian walking aisles located on 120m X-axis and 240m X-axis.

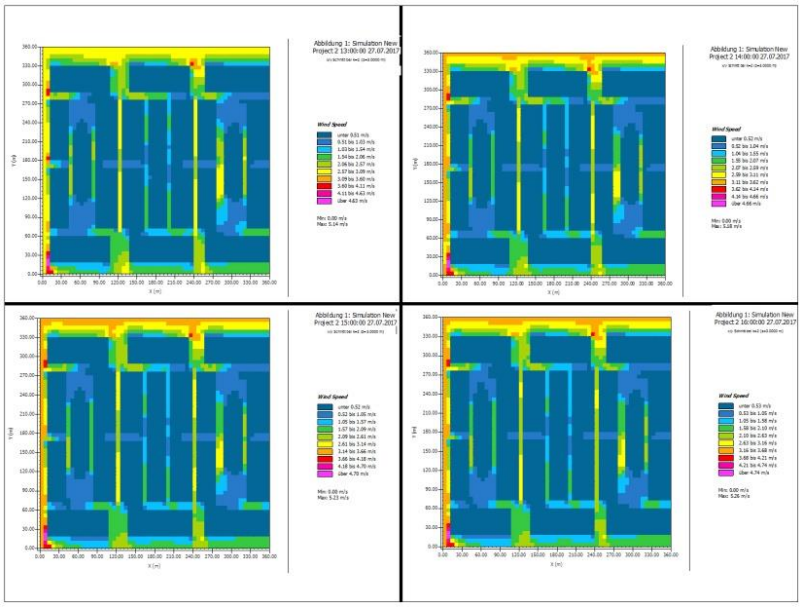


Figure 5.23 - Wind speed maps, Shading coverage second layout option - LEONARDO 2014 BY Author

The third shading coverage layout option is different from other two option since it raises the shading structure up to 18m above ground level, unlike previous two options where the height was 15m aligned with the top level of the residential villas at the site. This proposal cover the green spaces and all main roads while keeping secondary roads open to the sky.

The simulation results for this proposal are listed below in Table 5.16 in addition to the base case results and previous two options in order to compare them and study the differences.

The third option records of air temperature indicate an increase of 0.38 C˚ compared to the base case and 1.27C˚ compared to the second shading coverage layout however it is still lower than the first shading coverage layout option. This increase in Air temperature is linked to the decrease in Relative Humidity percentage compared to the second option. however, the wind speed range was the highest compared to other options and base case results that are also impacting the relative humidity percentage and associating in raising the air temperature.

Despite the fact that wind speed in the third option is higher than the second option, the impact of higher relative humidity over air temperature is required to reduce actual air temperature records beside reducing reel feel temperature for users of the space since both values can vary most of the time and reel feel temperature impact users satisfaction and thermal comfort more than recorded air temperature actual values. beside that, the difference in wind speed is not big therefore the impact of wind velocity will still impact users of the outdoor space and help to raise thermal comfort by reducing the relative humidity impact.

Table 5.16 - Shading coverage Third layout option, Prepared by Author

	Relative Humidity %	Wind Speed m/s	Air Temperature C˚
Shading coverage Option three	44.5	1.85 - 3.6	43.77
Shading coverage Option two	56.10	1.58 - 3.16	42.5
Shading coverage Option one	44.85	1.78 - 3.56	44.59
Base Case	52.19	2.88 – 3.47	43.39

The third shading coverage layout numerical results are illustrated by LEONARDO 2014 in graphical colored maps and cross-section in order to help evaluating the thermal condition of different areas within the site. The air temperature is presented below in figure 5.24 where the cross section of the 4-hour simulation process is presented with describing legend beside.

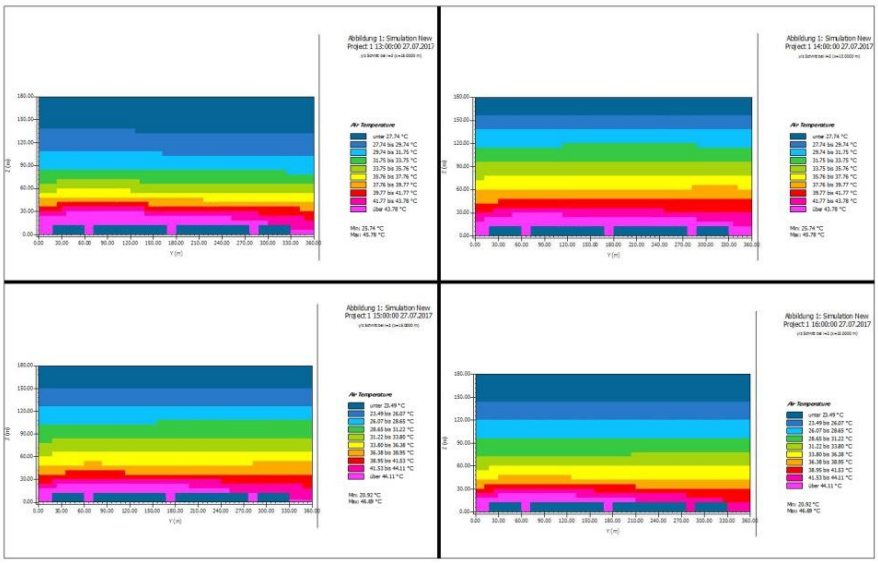


Figure5.24 - Air temperature Section, Shading coverage third layout option - LEONARDO 2014 BY Author

The wind speed results were also illustrated in the colored map in figure 5.25 below representing different values for air velocity over different areas of the site. The maps indicate that both option two and option three of shading coverage layout are similar in air distribution over the site and between buildings.

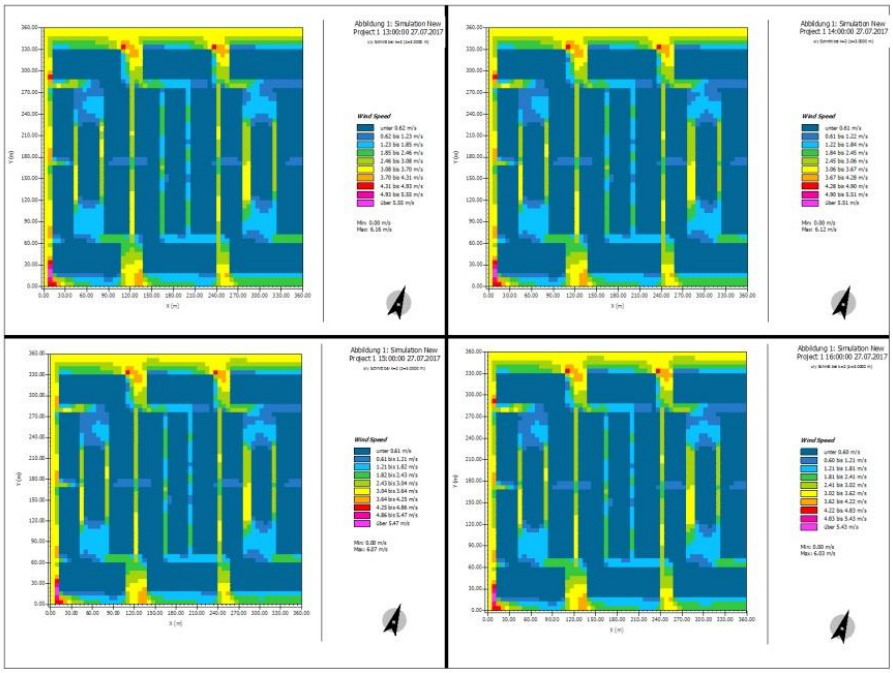


Figure 5.25 - Wind speed maps, Shading coverage second layout option - LEONARDO 2014 BY Author

The Relative Humidity results were also illustrated on the master plan for the four hours that were considered as the peak hours of the day. Below figure 5.26 indicates that relative humidity continues to have unified value all over the site in this simulation similar to all previous simulations that were done earlier in this research.

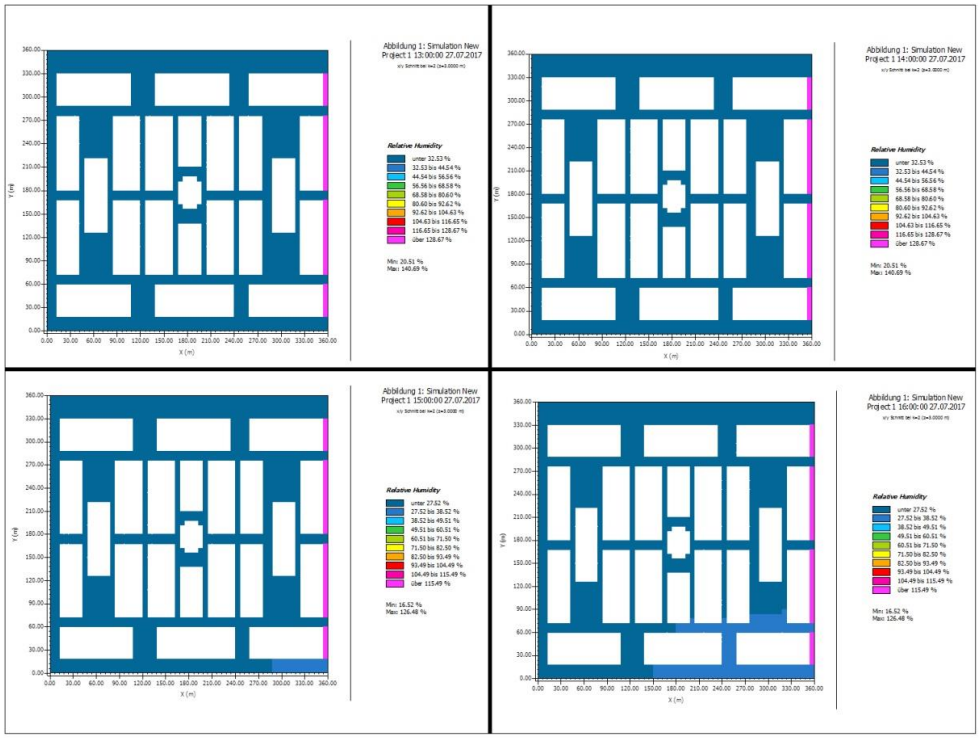


Figure 5.26- Humidity percentage maps, Shading coverage Third layout option -

LEONARDO 2014 BY Author

After running the previous three simulation analysis and comparing the numerical results as well as studying the graphical illustration of the values over the master plan, It was found that the optimum scenario is the second one where shading structure is located on 15m height and covering all transportation network including pedestrian walkways and driving road but keeping green spaces open to sky while these spaces are covered with grass surface and 50cn shrubs. This option has the lowest air temperature with a comfortable relative humidity percentage and wind speed average.

Therefore the second option will be used for the next simulation phase as the base case that will be subject to further potential enhancement strategies.

5.6 Phase Five - Water Feature Impact Analysis

Since this research concern is about the microclimate at the case study site and the enhancement of the outdoor thermal comfort satisfaction for users and residents it is important to understand different aspects that impact the microclimate parameters. through previous literature reviews, it was found that some studies highlight the importance of landscaping and ground cover such as Akbari et al, (1997) that founds a relation between cooling energy demand for a building and the surrounding urban vegetation in term of high trees and ground cover shrubs. Also, Thani, Mohamad & Jamaludin (2013) concluded that Bioclimatic elements can be used in urban spaces as one of the cooling strategies during daytime in hot dry climate conditions. Similar to Setaih, Hamza & Townshend (2013) where it was found that landscape materials in term of ground cover or water features or plantation can be used to in cooling down the surrounding urban spaces in hot and dry countries. Since water features such as fountains and artificial waterfalls are common landscape accessories, This phase of the research examine the impact of four meters high water fountain located at the center of each one of the four green public spaces as shown in figure (5.27) below that represent the optimum master plan that results from phase three earlier. The water fountain is represented at the center of the green space. The water feature will be 4m X 4m covered with water as shown in figure 5.28 and has a 4m high central water pole.

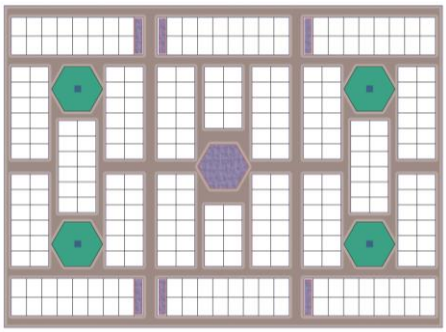


Figure 5.27 - Master layout with water fountain - Illustrated by Author

Figure 5.28 - water playground in Ontario- taken by Author

5.6.1 Phase Five- Result and discussion

In this phase, the water fountain was added to the virtual model that result as the optimum case from phase four earlier. Envi-met4 was used again to examine the impact of the water fountain over the surrounding areas by testing the records of the evaluating variables that were used to study the enhancement and proposed scenarios of the Inconstant parameters at this research. The results of this simulation are listed below in table 5.17 with the results of the base case that was collected from the optimum scenario by the end of phase four.

Table 5.17 - Water Feature proposed scenario results, Prepared by Author

	Relative Humidity %	Wind Speed m/s	Air Temperature C˚
Base Case (Shading coverage option two)	56.10	1.58 - 3.16	42.5
Water feature proposed layout	60.81	1.2 - 3.0	40.43

The above results indicate that water feature raised the humidity levels by 4.71% since it is 16 m^2 of water with four-meter high water pole in the center, however, this helped reducing air temperature around 2C˚ and wind speed was also reduced. These values were illustrated on a colored cross section as shown below figure 5.30 that represent Air temperature values.

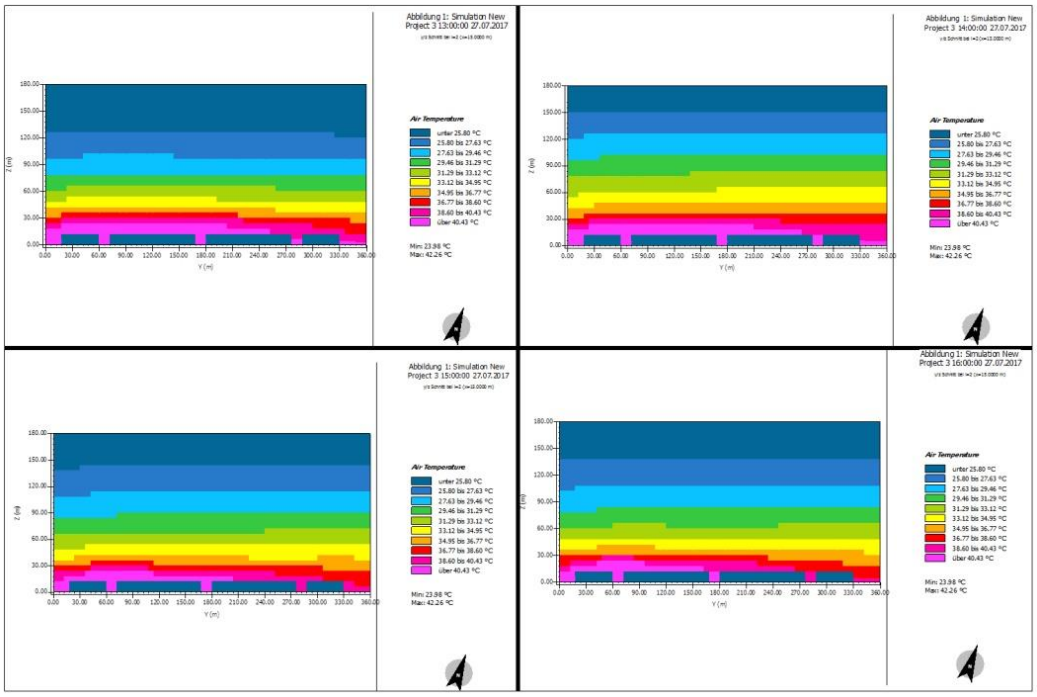


Figure 5.30 - Air temperature Section, water fountain proposal - LEONARDO 2014 BY Author

The wind speed was illustrated also in a graphical colored map as shown below in figure 5.31 since this helps in understanding the impact of water fountain over the green space areas at this case study. It is noted that wind speed slow down over the green spaces that are located at the north part of the project since the dark blue color is only at the top areas more than the other two green areas located at the south side of the project where the lighter blow which reflects higher speed is covering the lower green areas.

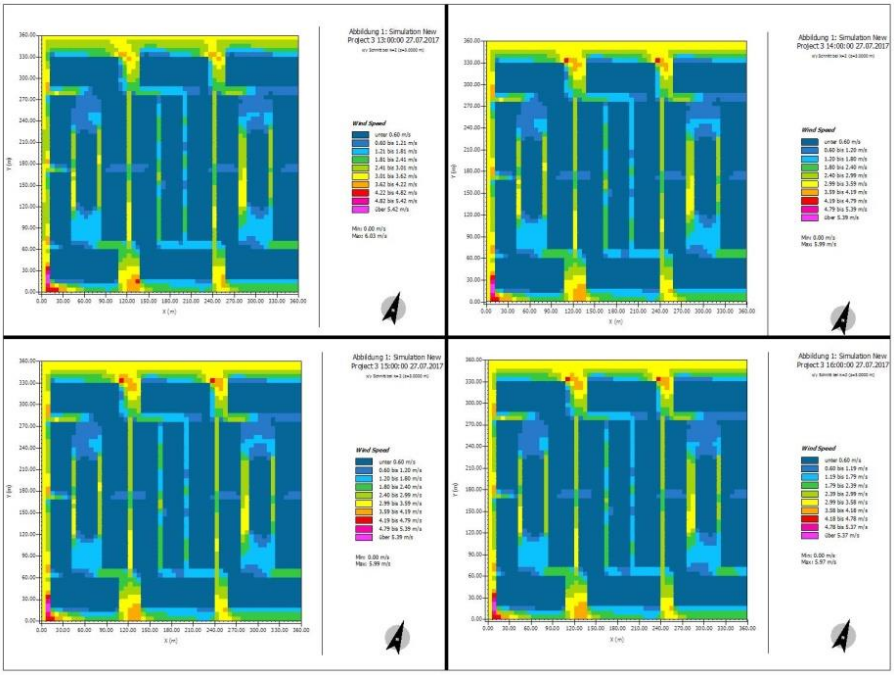


Figure 5.32 - Wind speed maps, water fountain proposal - LEONARDO 2014 BY Author

The relative humidity was also illustrated by a cross-section that penetrates the site parallel to the Y-axis as shown in figure 5.33. The section reflects an increase in R.H percentage

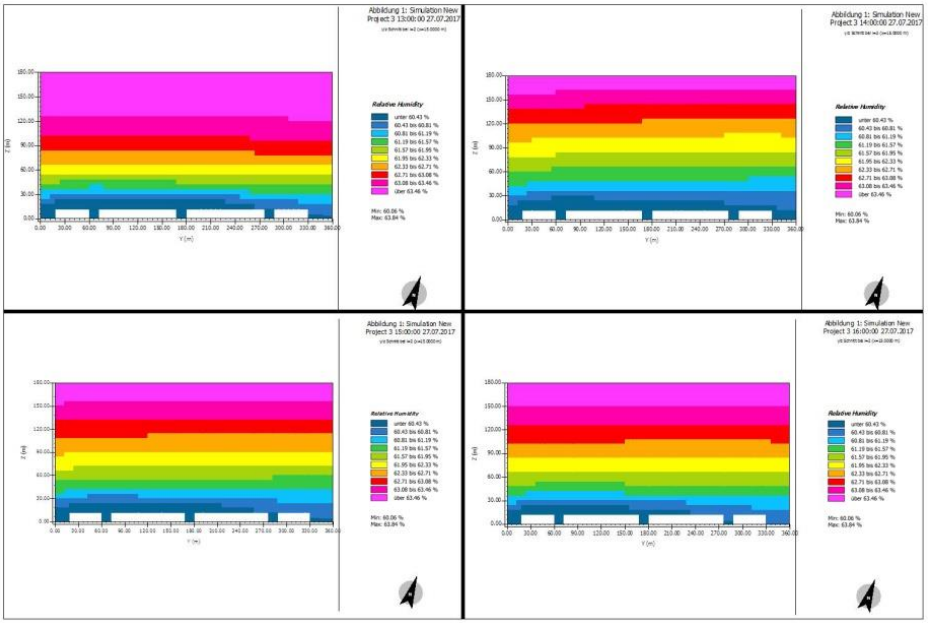


Figure 5.33 - Relative Humidity cross section, water fountain proposal - LEONARDO 2014 BY Author

The Previous analysis indicates that water features or water ground coverage are able to reduce air temperature recorded value by raising up relative humidity percentage in urban spaces however in this case study the relative humidity reaches 60.8% in order to reduce the air temperature to 40.4 C˚ that is found to be uncomfortable for outdoor activities or pedestrian thermal comfort index. Keeping in mind that this simulation runs on 27 of July where local newspapers indicate that it is the hottest day of the year.

Since this research does not cover the potential impact of urban vegetation and ground cover material as Akbari et al, (1997) and Thani, Mohamad & Jamaludin (2013) did. It is concluded that water feature at its own cannot enhance the thermal comfort index remarkably since Thani, Mohamad & Jamaludin (2013) suggest that water features are one of the proposed options besides paving material and vegetation similar to Setaih, Hamza & Townshend (2013) who finds that urban surface material can ne use as one of the strategies to cool down urban spaces but other strategies are also needed for a general passive design enhancement package.

5.7 Summary

This chapter discussed the results of the simulation analysis related to each phase of the five phases of this research. An elaborate discussion and comparison of results and recorded values for all proposed scenarios and options were done in order to understand the impact of each parameter and the evaluate the enhancement of the thermal condition.

The result of the four phases were compared to the result of the base case and it was found that the current orientation of the project sets the optimum option compared to the other three options presented in phase two while phase three address the layout options where the second option that includes four green public spaces was found to be the best option compared to the other two scenarios. later the shading coverage layout was examined by proposing three different options and running the same simulation process that was used earlier to test the impact of each option on the microclimate condition by comparing the outcome results for the evaluating variables starting with Air temperature then wind speed and finally relative humidity. It was found that covering all transportation network such as main roads and pedestrian side walkways will help reducing air temperature and to enhance thermal comfort level. And later the water feature impact was examined by adding water fountain at the center of each green space. however, results were not encouraging and further studies are needed.

Chapter 6: Conclusion

6.1 Inference and Finding

Since it is important to have new perspective toward the Built environment and establish new vision related to the joint relationship between nature and urban settlements, It was found important to research new strategies that could pave the way for sustainable practices related to different aspects of everyday life such as building construction sector and transportation as well as energy consumption and many other areas that need enhancement.

This research emphasizes on the need to integrate bio-mimicry vision toward an urban design that responds to the challenges current engineers and designers are facing. since nature was always the mother of many inventions. It is believed that it holds answers to the difficulties that mankind is facing today in term of environmental sustainability or resource rapid depletion and other challenges. This motivates many architects and engineers to reach out to nature components such as animal colonies or biological structure, seeking for inspiration and guiding tools in what is called Bio-mimicry designs.

Because UAE holds a vision toward sustainable future, efforts were directed to develop and encourage sustainable housing projects where the process and the design guidelines follow sustainable integrated design. In which it responds to environmental concerns such as global warming, Urban heat islands, high energy consumption and many other issues. The government of UAE is funding Housing projects that can be taken as a prototype project in which the process of designing and constructing these master plan project can be enhanced and developed in order to set a row model for other private development project in which the process of designing and constructing these project shall meet higher sustainable standard

and integrate passive strategies as well as active systems in order to meet UAE Vision 2021 goals and objectives.

The case study of this research is one of the housing projects in UAE located near Fujairah city and called "Mohamad Bin Zayed city" the project consist of residential units dedicated to UAE nationals with religious and retail service areas located within the site, serving residents beside public parks and social areas. The project is divided into two phases of construction where phase one is setting the selected case study areas in this research.

The research founds through a literature review that Envi-met4 is a successful choice to conduct the simulation analysis for the five phases of this study. The software meets the requirement of this research since it provides SPACE the working platform that is used to build the project master plan and then assist users with the required initial weather data that will be added in configWizard window and then runs the simulation in order to extract it into graphical colored maps using LEONARDO 2014 therefore this program meets the requirement related to outdoor thermal condition analysis.

The study finds that implementing Bio-mimicry design strategies can be done over three levels starting at Organism level where the design replicates the organism in its shape or structure or material. And the Behavior level where the design or part of the design replicates the organism behavior or the larger context mood. while the third level is replicating the ecosystem where the organism lives in a way that the design could look like a place where this organism would live in or behave within this space. however, it is recommended to incorporate a specialized staff that can construct a solid study and generates notes about the potential of any organism or ecosystem that is selected for the design. And this could be done in two different ways either going from challenge to design where the problem is already existing and the team is working to explore solution through natural components of the other

way is design to challenge where the team is studying the potential implementation of an existing natural system or component.

This research used the beehive cell geometry to redesign the layout of an existing urban design project and it is believed that beehive geometry and cell shape could impact the layout design positively and help to create an integrated community with solid social relations similar to the organized bees community. however the study was limited to the master plan layout and did not incorporate any architectural features related to the buildings within the site, In fact it is recommended to explore a holistic implementation of the cell geometry over smaller scale details simultaneously with the master plan design studies since this is believed to be more effective and open wide window for enhancement.

Since the research covers factors that impact microclimate variables, it was essential to examine the current orientation verses three proposed orientations. Though it was proven that the current design meets the optimum orientation and has records the best values in term of Air temperature, wind speed, and relative humidity compared to other three options.

As can see from the earlier analysis the microclimate components are linked to each other and impacted by the change of each other. As for example air temperature was found linked to relative humidity since it was proven through the five simulation phases that the reduction in relative humidity is setting the base for an increase in air temperature while the increase in wind speed is linked to the reduction in relative humidity value.

For this reason, it is important to test and evaluate the impact of passive design strategies using computer simulation software since any change in one of the weather components will result in a change within all other microclimate components. Therefore it is suggested that climate computer simulation software such as climate consultant and Envi-met considered the base for any research or design evaluation as literature review is not enough to predict the

results and site field measurement and physical model experiments are high in cost and require long time frame.

As a result of this simulation analysis it was found that shading coverage is essential in hot climate conditions such as the one affecting the case study of this research and it is important to design shading elements in an efficient way that does not impact natural sunlight casting over windows and public spaces but it is recommended to consider different scissions requirement and function of each space.

6.2 Future recommended research fields

This research sets the foundation for further investigation at some topics and research areas as for example.

1) The thermal impact of adding high local trees such as palm trees or Ziziphus spina-christi known as Al Sidr to the green spaces or at the side of the driveways at the same project could be examined and the impact shell be evaluated in comparison to the cost of watering and plantation services for this trees at the selected case study in this research.

2) Since the location of this case study project is promising it is advisable to study the potential saving in energy consumption if solar power panels or PV were added to the top of the residential units. considering the fact that this project consumes high initial cost for power infrastructure and maintenance over time.

3) Study the possibilities to redesign the individual plot shape into beehive cell geometry to understand the impact of this form over the indoor spaces

4) redesign the transportation network in order to maximize the efficiency of social spaces and public transport that would provide jobs and reduce carbon emission by reducing private car trips and encourage walking and outdoor pedestrian movement.

5) The project is Designed for private villas of two floors, Ground plus one. It is advisable to examine the impact of diversity in building height at this project since it would provide variety of residential unite sizes and save building foot print as well as energy supply infrastructure as it will accommodate extra number of users for same building foot print.

7. References

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