The City Aetherus An Urban Design Methodology For Energy Use

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THE CITY AETHERUS
AN URBAN DESIGN METHODOLOGY FOR ENERGY USE
It is only recently that our global urbanization has been realized as an imminent step in humanity. If our largest energy consumer, the city, is set to expand then it is our job as designers of the built environment to contribute possible ways to do so. It is in the interest of this thesis that global urbanization is pursued in a sustainable and energy efficient manner. This thesis proposes that architectural, morphological form can be designed at an urban scale to reduce energy usage within cities. It also proposes a design methodology backed by design research in this document as a possible method of doing so in cities across the world.

Student Signature: Anthony Yan Date: May 1, 2020
THE CITY AETHERUS

AN URBAN DESIGN METHODOLOGY
FOR ENERGY USE

Request for Approval of Thesis Research
Project Book Presented to:

ERMAL SHPUZA, PhD

and to the
Faculty of the Department of Architecture
College of Architecture and Construction Management

by

ANTHONY YAN

In partial fulfillment of the requirements for the Degree

Bachelor of Architecture

Kennesaw State University
Marietta, Georgia

May 1, 2020
I'd like to first and foremost express my gratitude to Professor Ermal Shpuza for being such a great thesis advisor and for first introducing me to the study of urbanism in his Urban Theory class. I would also like to thank Professor Ameen Farooq for the lessons learned in his Urban Design Studio.

Thank you to my mother and father, Jie Ming Liang and Dong Ming Yan for supporting me throughout my entire college career. I would not have been able to have realized my dream of becoming an Architectural Designer without your unwavering support.

I would also like to thank my mentors that helped push me in the professional world. I owe the success I have had in my professional career to Jennifer Durham and Edwin Ortiz. I thank the both of you for your continuous support.

Lastly, I would like to thank all my friends for helping me keep my sanity (or what’s left of it) through architecture school. College is a crucial and difficult part of anyone’s life and architecture school is no exception. So thank you all for all the food, supplies, tools, and company through all of our late nights. Let’s graduate and finally get paid to stay up late.
DEDICATIONS.

To Professor Ermal Shpuza, for always being there to help me push this thesis further when I needed it...

To my mother and father, Jie Ming Liang-Yan and Dong Ming Yan, for always doing their best to support me as parents...

To Professors Ameen Farooq, Arief Setiawan, Edwin Akins, Elizabeth Martin, Christopher Welty, Arash Soleimani, Giovanni Loreto, Willie Pittman, Bronne Dytoc, Pegah Zamani, and last but not least, Dr. Anthony Rizzuto for each of your respective contributions to my architectural education either in pinups, reviews, class, or just to chat...

To all my APX brothers of the Polyidus Chapter and my big: Jesse Halverson for being such an important influence on my work drive...

To my close friends Andrian Stefanus, Gunhou Kim, Norberto Marcelo, Justin Sisavath, Sean Chang, Steven Yang, Christine Vu, Rodolfo Alcaraz, Nicole Rodriguez, Nhan Luu, Caleb Lawrence, Noah Bieber, Asbiel Samaniego, Andrew Smith, Christian Newman, Diana Gil, and Marysia Larosa for helping me keep my sanity during architecture school...

Welcome to the future I envisioned....welcome to...

THE CITY AETHERUS
This thesis research was conducted for the exploratory purposes into the topic of building morphology and its relationship to energy in urban design. Due to the importance of this subject to humankind, I think it was best to use this time to explore the possibilities this can open for the future of our built environment and humanity; while also being able to generate enough quantitative data for rigidity of research. In essence, this thesis is explorative in nature to provoke more research into the subject matter but also disciplined enough in its execution and process to come to a quantitative understanding of the subject.

To enhance the understanding of you, the reader, I have broken down the research method below.

1. Understand the biggest energy consumer; the city.
2. Observe historic and current ways to conserve/energy using building form. Understand how our current cities do not utilize these methods.
3. Develop a methodology that can be implemented throughout multiple cities to enhance urban morphologies to more efficiently use energy.
4. Implement design method across multiple cities around the world, and analyze the impact of resulting morphological form on the existing urban fabric and how it performs climatically.
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[CH. I] INTO THE AETHER

1.1 ON OUR CITIES
1.2 THESIS ABSTRACT
1.3 THE URBAN PARADIGM
1.4 THE FUTURE OF ENERGY IN URBAN DESIGN
Cities are important. Cities are places for the exchange of goods, services, ideas, people, and knowledge. This has been true of cities since the ancient times, however they can grow wildly out of control quickly and if left unchecked, cities can grow poorly and become dangerous and wasteful places of embodied energy.

That is what’s happening right now.

Our cities are growing at an alarmingly fast rate.

A study conducted by the London School of Economics and the Alfred Herrhausen Society discovered that during the time of the industrial revolution (late 1800s - early 1900s), 10% of the world’s population lived in cities.

In 2007, 50% of the world’s humans lived in cities and it is predicted to only grow even more from there.

The same study predicts that by 2050, 75% of all humans will be living in cities.

Humanity’s global urbanization is imminent

This is an undisputable trend. As developing nations modernize they will gather in cities leaving it up to governments, and urban planners to decide on how to grow the urban environments of the world.

While there are a wide range of questions on how our urban environments can grow, this thesis research is focused on one major question.

How are we to power the global expansion of our built environment?

Do we leave it to a global coalition of governments and scientists who have other problems to solve as well? Do we leave the question to our urban planners since it’s our cities that will grow? Or do we just leave the question for later as 2050 is pretty far from now?

Actually, let’s ask this question to the people that shape our built environment as a part of their livelihood; the architects.
EXPERIENTIAL DESIGN

ARCHITECTURAL DESIGN

URBAN DESIGN

ENERGY EFFICIENT
+ GENERATIVE DESIGN

BUILDING MORPHOLOGIES
“Urban Morphogenesis has depended, from its ancient beginnings in the Fertile Crescent, on intensification of the consumption of non-human energy.” - Manuel de Landa, A Thousand Years of Nonlinear History. (Brooklyn, NY: Zone Books, 1997) pg. 28

In the last few decades, there has been a growing awareness about the relationship between building design and energy use, environmental impact, and sustainability in general. Now, environmental design is a well-established field of architectural studies and practices. By contrast, it is only recently that the relationship between urban design and energy use has started to get due attention by the designer and planning communities. Due to our increasing energy needs and imminent global urbanization, humanity needs a solution to tackle the largest energy consumer: the city. This thesis is situated within the newly emerging discourse on the relationship between urban morphology and energy use in cities. It proposes that morphological design can possibly improve energy efficiency in cities by means of designing urban morphologies, and the interactions between, street network, urban tissue, and block design. This thesis proposes a design methodology to develop and study various urban morphologies in 4 world cities as representatives of 4 climatic conditions. The thesis conducts thorough research on the link between building and urban morphologies to energy use focusing on solar radiation and airflow and ventilation. It proposes methods that can extend beyond the four climates considered to tackle other climatic and micro-climatic conditions around the globe. While the energy use has been used as a yardstick to filter appropriate solutions, the thesis develops innovative urban design solutions that prioritize human activities and social functions of the city.

“What we see nowadays and what we can envisage for the immediate future is that the main drivers behind the energy (r)evolutions are the four D’s of Democratization, Decarbonization, Decentralization, and Digitalization.” - Aleksandar Ivancic, Fire in Urban Genesis
Research in the field of urbanism would not be complete without an understanding of how our cities came to be. Understanding our current state of urbanism, how we got here and how we can move forward is crucial to understanding the urban paradigm and the goal of this thesis.

Cities are complex. The state of our cities are very diverse throughout the world and no 2 cities are similar enough to be planned exactly the same. That is because cities are a physical manifestation of social hierarchy, and human survival in a dense settlement. Economies, legislation, natural features, program allocation, service allocation, and many more can all have to do with cities and how they grow.

Cities grow and change as a physical manifestation of societal changes in humanity. Much like humans, cities undergo massive changes in response to stimuli. Cairo, Egypt is one of the ancient cities of the world and a UNESCO World Heritage Site. The ancient Egyptians settled close to the floodplains due to its fertile soil in the middle of the vast saharan desert. However, they urbanised and populated an area further up away from the floodplain because the land didn’t flood, but they needed to be in proximity to the floodplain for sustenance in the form of crops and livestock raised there. They then established trade routes stretching east to west to allow for the transport of goods and services. Cairo then grew as all of these natural, and economic factors helped shape human interaction with the site. Thus, the city grew as a physical manifestation of these interactions.
The Future of Energy in Urban Design

If We Are Changing, Then So Will Our Cities.

We used to be a society of simple machinery. However, that all changed during the industrial revolution and about a century later, technology is now a fundamental component of our built environment. We are constantly growing and progressing in society in almost all directions. However, one to note in particular is how reliant on technology and the digital realm we have become.

Cities Consume Energy, and Lots of It.

Think about it like this. Every household in developed nations and a majority of households in developing nations now have electrical appliances like refrigerators, air conditioners, lights, as well as personal electrical devices like computers and phones. We also have offices, restaurants, stores, factories, schools and more to power in every city in every nation. On top of that, most (if not all) cities need street lights, traffic lights, and power for public transport. That’s a lot of energy consumed in a city around the world just in the time it took for someone to read this sentence. Now imagine, if all our cities grew. All of them. Around the world. Humanity is going to need a lot of electrical energy just to keep the lights on.


The 2 images on the right are satellite images of the eastern hemisphere (Europe, Asia, the Middle East, and Africa) at night. The left image was taken in 2000, and the image on the right was taken in 2012. Just Asia alone is 4x brighter than it was in the span of just over a decade. Now, imagine how much brighter it is now, in 2019.

Our Future Is Bright, Literally.

How will this image change in 20 years? 30? 40? What about the year 2100? Chances are, its going to get even brighter, much brighter. As stated before, the population of our cities are predicted to grow by half of our current population. Half of our global population lives in cities now and in 2050, that percentage is set to grow to 75%. This raises the main question that this thesis is attempting to answer, which is: How will we power our global urbanization?

There’s an Opportunity Here.

With our growing energy demand, architects, and urban designers will have an opportunity to change how we grow and adapt our cities to this new challenge. This thesis explores how we can use this new challenge to our society as a way to evolve our current cities and architecture.
12 YEARS

2012
[CH. 2] [RE]EVALUATION

2.1 Passive Design Before
2.2 Cities + Energy Now
2.3 Active + Passive Design
2.4 Cities of the Future Now
2.5 On Morphology + Energy
2.6 On Morphology + Humans
"Urban Morphogenesis has depended, from its ancient beginnings in the Fertile Crescent, on intensification of the consumption of non-human energy." - Manuel de Landa, A Thousand Years of Nonlinear History. (Brooklyn, NY: Zone Books, 1997) pg. 28

WE HAD ARCHITECTURE BEFORE TECHNOLOGY.
Our ancient civilizations use to have to rely on passive architectural design before we had electricity. We use to integrate most of the things that we use technology for into our architecture. We had to intelligently shape our built environment to protect, shade, cool, heat, and light our spaces. We had to think of where to place windows, and how to size them to help naturally light and ventilate a space. Now we flip some switches to use up massive quantities of energy to heat and light our buildings covered in glass.

OUR ANCESTORS WERE REALLY SMART. See some of the examples to the right. Civilizations in hot, dry, and arid regions of the world had numerous ways of achieving passive ventilation. Figure 2.1 shows a Persian Windcatcher, and how it used architectural form to control wind to ventilate and cool buildings. These same civilizations also realized an efficient method of irrigating and bringing water from wet areas to the dry, arid areas where their cities were located.

Figure 2.2 show how people used “Qanats” to bring water miles and miles away to their homes and cities. The ingenuity in this system lies in how they were able to understand the science of the water table, and design extensive canal networks that still work today.

Figure 2.3 shows how another ancient city used architecture to protect themselves from invaders, but more importantly, to keep them cool during the hot day, warm at night, and shade the streets of the city. The city of Shibam in Yemen is also often referred to as the old Manhattan of the Middle East, because these ancient mud towers were pretty much early high rises that helped shade the streets from the desert heat.

Another great example from our past lives is shown in Figure 2.4. The diagram shows how passive design works in Tulou Hakka walled villages. These were wide cylinders about 4-6 stories high with an open courtyard in the middle for public programs and events, with housing, and work spaces in the masses. All ventilated, shaded and protected by the roof overhangs and the form of the extruded cylinder.
CITIES + ENERGY NOW

2.2

Urbanization is imminent. Our built environment is rapidly expanding due to the exponential growth of our cities in both space occupied and population influxes. Figures 2.5 and 2.8 show the urban growth of Yiwu, China from 1984 and 2016 (respectively). In just 32 years, the city has grown from a population of 73,000 in 1984 to 1,100,000 in 2016. Cities all across the world are also growing at a similar pace along with the population.

We use a lot of dirty energy. The majority of the world still uses fossil fuels to power our cities and technology. Figure X.X shows the percentage of energy generated in the world from cleaner, more renewable resources compared to fossil fuels. You can barely see how much energy is sustainably generated, but you can see that at least 90% of energy generated within the world is from fossil fuels. This analysis was conducted only 4 years ago in 2016.

Stop poor designs. Most, buildings and most cities in the world are designed to provide a safe and efficient environment for human habitation. This is a flaw in the design of many buildings and cities and if we keep growing in the same fashion, then soon we will feel the impact of our choices. Figure 2.7 shows the glare from the “Walkie-Talkie” building (20 Fenchurch Street) in London. Designed by Rafael Vinoly, it’s aesthetic is pretty similar to most of the “modern” glass towers that we see in many cities across the world today. The building also features a curved glass facade that angles downward to the street below. This angle reflects and magnifies sunlight and will often times, melt materials in its path. It has been nicknamed the “fryscraper.” So not only does this building rely solely on power hungry mechanical systems to cool the building, its primary design feature is a danger to the pedestrians and anything below it. This is just one example of a poorly designed building in the vast number of buildings in the world.

What doesn’t work? The statistics to the right reveal the depth of our current situation in the world. At our current rate of global urban growth, we are depleting non-renewable resources and polluting the environment at an alarming rate. Cities are and will continue to be humanity’s greatest consumer of energy if we keep urbanizing the same way we have been.
DIRTY ENERGY

<1 BILLION
METRIC TONS OF CARBON EMISSIONS IN 1900

+9 BILLION
METRIC TONS OF CARBON EMISSIONS IN 2010

POOR DESIGN

93.6%
OF THE WORLD’S ENERGY IS FROM FOSSIL FUELS

64%
OF THE WORLD’S ENERGY ARE FROM RENEWABLE RESOURCES

URBANIZATION

75%
OF THE WORLD’S POPULATION TO LIVE IN CITIES BY 2050

100%
A PROBLEM.
Cultural Centers/Exhibition Hall
-Typology is like a warehouse or overexposed plaza.
-Goals:
  - Passive Daylighting
  - Passive Ventilation — Main Thing.

Multi-Family/Residential
- D&B or Triple Height Units/Street for Air Circulation.
- Main Points:
  - Passive Lighting
  - Passive Heating
  - Passive Airflow/Thermal
- Goals:
  - Cut active energy usage & lighting & Have w/ Geometry

Commerz Bank HQ
Frankfurt, Germany
Many buildings nowadays have been exploring how architectural design can help lower energy usage within the built environment. An analysis of multiple building typologies that utilize passive design strategies was conducted to understand how these strategies affect building form. The diagrams and images to the left are analysis of some of the projects that were analyzed in how they integrated passive design into building form.

It was found that many of these projects used a combination of passive and active systems. Passive design strategies were used to advantageously cut back on the use of the active systems. Meanwhile Active systems (like computer operated vents, and openings) were used to help automate the passive strategies even further for a seamless integration of passive + active, and old + new.

Imagine if we did this at the urban scale.
SOLAR CITY
LINZ, AUSTRIA

FIGURE 2.14

FIGURE 2.15

FIGURE 2.16
BETTER DESIGN AT THE URBAN SCALE WORKS REALLY WELL. In 1992, the planning of SolarCity in Linz-Pichling, Austria began and a team consisting of Norman Foster & Partners, Herzog + Partners, and the Richard Rogers Partnership was assembled to design a section of the Linz-Pichling district that used passive design at both the building and urban scale. The section was then dubbed “Solar City” as a majority of the design focused on using the sun angles and exposure to power the city as well as cut back on energy usage. This section of the city was developed with smart energy design and usage as a priority since its conception and the way it was integrated into the final product is very important.

When we integrate passive design into a single building, we can affect the performance efficiency of a single building. Now, when multiple buildings integrate passive design for efficient energy usage, then a whole area of a human settlement (city or town) can perform more efficiently. Then, when the buildings in an area of a city integrate passive design into its master plan as well as all of its buildings, the performance efficiency of an area and the buildings in the area have now been scaled to peak performance capabilities. This is the scale of the design method proposed by this thesis. Modifications to the urban environment start at an urban scale to enhance the performance efficiencies and capabilities of the area it is affecting, and exploring how the buildings in these areas can be architecturally designed to contribute to the performance of its surrounding area as well as its own entity.

WHY DESIGN AT THIS SCALE? This thesis’ design methodology is set to this scale for multiple reasons. One, cities grow using master plans that include multiple parcels of land to serve the city of which they are located in. Second, designing at this scale for this thesis is a more effective way to observe and understand the impact that this thesis can have on large urban sectors. Designing an efficient building brings a vision to just a building, but designing an efficient cluster of multiple buildings (or district, etc.) brings a vision to a new way of human society. It is this envisioning and perception of energy in the future of human society where this thesis is trying to bring attention to, so that we can collectively begin to think about the future of energy in urban design.
La Villa Radieuse

Le Corbusier

Singapore

1930

Figure 2.18

Walking City

Archigram

Figure 2.19

Figure 2.20
ENVisION THE YEAR 3000 IN 2100. The future of cityscapes are anything but unintuitive. As we get smarter, so does our built environment. There are some urban visions of what cities can become and inspiration has been drawn from multiple urban visions and has been considered with respect to what works for humanity and what does not contribute to a better environment for human society.

LE VILLE RADIEUSE. This urban vision project portrayed the concept of a city with massive apartment and office towers, with huge freeways lifted into the air to transport cars and people. It doesn’t sound like an “urban vision” because that’s how most cities are now. In the 1930’s, famous architect, Le Corbusier, showed this idea to the world and many cities modernized this way. He envisioned the massive towers to use mechanical means of heating, and cooling as well as massive park spaces in between the towers for access to green space within the city. This ultimately gave rise to slums in many cities as the vision was so out of scale that crime easily occurred in these spaces. However, this was the architectural preview to how buildings would integrate mechanical systems into our buildings as Le Corbusier’s vision were for buildings to be machines for humans to live in (Marshall, S. 2015).

THE WALKING CITY. Radical Avant-Garde ideas often rise every so often from designers and free thinkers, and one of the most unique was the Walking City by Archigram. Peter Cook (Archigram founder) showed the world his futurist take on the model previously mentioned by Le Corbusier where machines crawled like insects and housed humans as well as programs like housing, work, and etc. Although this sounds very impossible, one very important things to note is how the idea uses technological advancement and advancements in architectural design to unlock new forms of urban and architectural experience as people are now nomadic and live in these walking masses.

SINGAPORE & MASDAR CITY. Singapore is already implementing sustainability into their urban fabric as new building projects have to be thoroughly vetted by the city to see if it improves wind flow, water runoff, and more. Masdar City was a project headed up by Foster + Partners that attempted to design and build a sustainable city from scratch. No cars, no fossil fuels, only solar power, wind catchers, and public transit are some of the main highlights of the ambitious undertaking. Sadly, the project ran out of funding and was never fully realized. However, just the existence of this project shows that this thesis can be possible.
Figure 4. SpaceMate diagram of all real and ‘idealised’ morphology samples.
WHAT DO WE KNOW ABOUT MORPHOLOGY AND ENERGY? Well for starters, we know that the numbers will always fluctuate on a case by case basis as no two sites can really be completely the same. But has there been a study on these numbers and how they relate to form?

ENTER RODE AND OTHERS (RODE ET. AL. 2014). In 2014, researchers Philipp Rode, Christian Keim, Guido Robazza, Pablo Viejo and James Schofield published a research paper titled “Cities and Energy: Urban Morphology and Residential Heat-Energy Demand.” The intent of the research was simply to attain a “better understanding of the theoretical heat-energy demand of different types of urban form at a scale of 500m x 500m. (Rode et. al. 2014)” The study conducted research on the urban fabrics of Paris, London, Istanbul, and Paris. They then analyzed 500m squares of each city that were morphologically representative of the specific city. Their goal was to analyze these swatches of each city and see if there was a relationship between the morphological form of the buildings in each city and how much energy they use along with how much heat each building gains. The researchers assessed building density (F.A.R.), building height, building lot coverage ratio, surface to volume ratio, and the open space ratios of the buildings. What the research discovered was that (at the neighborhood scale of 500m x 500m) compact and tall forms are the most efficient in heat-energy demand (Rode et. al. 2014).

All the images on this page and the page to the left are diagrams from that research paper and have been a great resource for understanding the relationship between building form and energy.

SO WHY HEAT AND ENERGY? The research discovered that as cities are the largest consumers of energy and that there was a relationship between how much energy is used and how developed the city is. 40% of energy end-use occurs in buildings in 1st world countries while half of that (20%) energy-end use occurs in buildings from 2nd and 3rd world countries. The research also observed that 70% of energy use in residential buildings is heating related in Europe (Rode et. al. 2014). This means that this thesis must have a depth of exploration and knowledge on the relationship between how people use buildings depending on the climate that the building dwells in.
COMBINATORY URBANISM

Figure 2.28

Figure 2.29

Figure 2.30
2.6 Morphology + Humans

What do we know about morphologies and humans? This question actually has a lot more answers than the previous question. We have been building for centuries and suffice to say, we know what forms work for us. Not all people may see it, but there is an experiential and historic relationship between building form, how we use it, and why we like it.

Enter Morphosis from California. Research into their book “Combinatory Urbansim” (Mayne et. al. 2011) was conducted to understand a point of view on urbanism and how architects and architecture can impact the future of urbanism. Their research into urban morphologies was very interesting as they used architectural form and urban design to set the stage for human programs that accounted for longevity of usage for the community and the surrounding neighborhoods. In essence, their research shows a unique investigation into morphological form being a catalyst for civic identity, economic growth, and new human experiences. This research contributed to furthering this thesis through how they use architectural design on an urban scale to set the stage for a certain amount of predictability and unpredictability within an existing urban fabric.

Humans occupy cities and cities are built for us to occupy. Their research was also a stern reminder that human society is evolving ever so quickly, and as designers of the built environment, we need to understand the increasing complexities of our social fabrics to be integrated into our urban fabrics. This is the future of urbanism. Our future is complex and unpredictable like our society and its revolutionary and evolutionary discoveries (Mayne et. al. 2011). If this is true of our society, then our built environments need to reflect this truth as a new truth in architecture. We now see the degradation of traditional boundaries in our land and we are witnessing the emergence of an urban fabric that is not a black and white figure ground, but one with different shades of grey, where there are now layers to buildings, program, circulation and how they are all interwoven together in the x, y and z planes. The grid is still there, but gone is it’s planar understanding, and what has emerged is a volumetric understanding of urban space.

This is how architectural and urban design will be treated in the thesis, but through the lense of energy efficient & generative design so as to bring emphasis to the natural environment through it’s effects on the human environment.
[CH-3] DESIGN THEOREM

3.1 AN URBAN ENERGY FABRIC
3.2 METHOD OF INQUIRY
3.3 SITE SELECTION
3.4 DESIGN METHODOLOGY
## An Urban Energy Fabric

### 3.1 Into the Future: An Urban Energy Fabric

This thesis was based on the problematic way we are growing our cities throughout the world through the lens of energy usage. Figure 3.1 diagrams how all of our cities (with the exception of some net-zero or net-positive buildings) are powered using the same model. This model is heavily dependent on a centralized power source, the power plant (typically powered by fossil fuels). The diagram also shows what we need in urban areas like residential space, workspaces, houses of government and educational spaces (in general). Figure 3.2 shows a diagram of the proposed new power system where energy efficiency is integrated within these important functions of an urban fabric. This is with the hopes that we as designers of the built environment can begin to understand the importance of integrating the two ideas together so that we can grow our cities with this urban fabric in mind. Figure 3.3 is a conceptual rendering/diagram to show what the possibilities can be in this thesis for this proposed urban fabric/power network.
CONCEPT IMAGERY OF PROPOSED URBAN FABRIC

WIND PLATFORM AMONGST TOWERS

SOLAR CANOPY SHADING PARK

WATER TURBINES IN COLUMNS OF PIER

FIGURE 3.3
METHODOLOGY OF INQUIRY

3.2

PROCESSUAL UNDERSTANDING = DEEPER COMPREHENSION. This thesis aims to provide a body of work to help others understand the relationship between morphological form and energy in an urban context. In order to provide for a deeper comprehension of this relationship, the thesis will focus more on the process and what contributed to the development of the design methodology. Therefore, this thesis is more process-oriented vs. production centered. The thesis will employ the method of inquiry as shown to the diagram to the right (figure 3.4).

DESIGN EXERCISES ARE NEEDED TO THOROUGHLY VET A PROCESS. Therefore, the sites in question will undergo a general design scheme with an end product in mind, but the process will be refined through each exercise. Site analysis will be conducted based on local climatic factors, existing morphologies, and the existing urban experience. Designs will be implemented in areas where an opportunity is presented based on energy inefficiencies, or generative possibilities all to enhance and design a new urban experience in contrast and harmony within the existing urban fabric. Then both the quantitative and qualitative factors will be assessed to understand what was done, what changed, how it was changed and what can be observed from these findings. This will then be applied to other sites.

THE DESIGN METHOD IS THEN SYNTHESIZED AFTER UNDERSTANDING THE PROCESS(ES) IMPLEMENTED. As the thesis explores each site, the idea is to have the design process more and more refined through each “exercise.” Then the final design methodology will be synthesized and explained in section 3.4. Research findings will then be shown and explained in chapter 5 of this book to show the qualitative and quantitative discoveries that this thesis has uncovered for the betterment of our future.
3.3

SITE SELECTION

Sites were selected based on density and climate. Figure 3.5 shows the Koppen Climate map of the earth. This map is widely accepted in the scientific community as an accurate classification system for the climates of the world. Next, figure 3.6 shows a map of the world at night taken in 2012. The brighter areas show the denser urban areas of the world. Overlaying the 2 images provided an understanding of where the dense and modernized (or growing cities) cities are. Only dense cities that are consistent climates were considered. Sites were also selected based on the age of the city to study how the method changes due to age of the urban fabric. The cutoff age for cities was based on their founding in relation to the industrial revolution (late 1800s-early 1900s).

Singapore - (New - founded 1819) - (Koppen climate-Af) Tropical Humid

Moscow, Russia - (Old - founded 1147) - (Koppen Climate-Dfb) Snow-humid, warm summers

Dubai, United Arab Emirates - (New - founded 1822) - (Koppen Climate-Bwh) Dry desert, hot arid

San Juan, Puerto Rico - (Old - founded 1509) - (Koppen Climate-Am) Tropical Monsoon
The proposed design methodology consists of 4 main steps as shown to the right in figure 3.8 and emerged out of the design processes of the design exercises in Chapter 4 of this book. The design methodology is the main proposal of this thesis for designing morphological form at an urban scale to help lessen energy usage in cities for our global urbanization.

**Some Basic Analysis First.** Before the methodology can be fully implemented, information and data gathered from the site is imperative to its proper execution. The list below contains all site data items collected during the 4 design exercises of this thesis, however, other sites may require more information prior to design. Please refer to the design exercises in Chapter 4 to see how each of these were implemented and for thorough descriptions of each.

- **Basic Environmental Data:**
  - Solar Geometry
  - Prevailing Winds
  - Yearly Temperatures
  - Yearly Solar Radiation
  - Clearness Factor (cloud cover ratio)
  - Yearly Rainfall
  - Yearly Daylight Hours
  - Humidity

- **Basic Data on Site's Urban Context:**
  - Existing Figure Ground
  - Existing Topographical Information (left out in these design exercises as no sites had existing slopes)
  - Existing Program
  - Existing Pedestrian and Vehicular Circulation Paths
  - Existing Morphologies
  - Data on Design Proposals for Site from others (if any)

- **Some Inferences Must Be Made First.** After collecting all data listed prior as well as any other data that can influence the design of a site, inferences must be made on what the primary climatic issues of a site may be as it relates to energy usage. Then, primary passive strategies must be decided on to counteract these climatic issues prior to designing. These strategies may include but are not limited to: narrow floor plates for daylighting, cross ventilation, windcatchers, and altered roof planes for shading. The design exercises in Chapter 4 show these and more on their respective initial Climatic Analysis pages.

- **Urban Circulation:**

Primary circulation routes at the urban scale must be designed first and can be used to help strengthen the primary passive strategies. This will help layout massing, programming and more. At this phase streets can be added, taken away, or left alone depending on the site context. In this design exercise, older urban fabrics (that date the city's founding before the industrial revolution) had their street networks left fully intact as it was prior to the design interventions.
Basic massing is to take place within the blocks and spaces in between the streets and thoroughways of the site. The massing step is to include considerations for basic square footages and programming for the site. The goal of this step is to understand where what primary programs need to be, how large they need to be, and how wide to make the streets. Using the existing morphological data collected prior to designing is key to understanding what the residents are use to seeing, and what they visually understand as an office building or an apartment tower from what they see in their city as well as what square footages already work for them.

Next, integration of the primary passive strategies into the masses is to take place. This step will require some back and forth, so that the primary passive strategies are integrated into the masses morphological form so that the primary passive strategies are being implemented at both the building and the urban scale. This step is crucial, as morphological design here has a chance to possibly block another building from receiving as much sunlight, or too much sunlight, or block wind flow etc. This step is also crucial because this is where the ground plane can be over or undershaded or cut off from windflow and must be carefully executed to avoid such issues.

The last step is to experiment and place the new morphologies onto the pre-defined street network and run analysis to begin fine-tuning the climatic performance of the morphologies in relation to its surrounding urban context. This is also the step where reconsideration of morphological design, or programmatic arrangement can be deliberated on to decide what is truly best for the surrounding urban context. Are more pedestrian thoroughways needed? Are more streets needed? Does the site need a park? This is the step to fine-tune the design as it relates to the experience of pedestrians in the urban realm as well as fine-tuning climatic performance.
[CH. 4] THE CITY AETHERUS

4.1 SINGAPORE
4.2 MOSCOW, RUSSIA
4.3 DUBAI, UNITED ARAB EMIRATES
4.4 SAN JUAN, PUERTO RICO (U.S.)
SITE 1 SINGAPORE

INTO THE LION CITY, Singapore is an island city nation that is known as an important trading hub for the world’s economy. The southeast asian city-nation is highly renowned for its technological innovation and competitive economy in comparison to other first-world countries. However, its city planners are also known for being extremely critical with how they develop land as that is the city’s most finite resource. This places an emphasis on population density as well as civic amenities for the community whenever they have to develop land.
- Slightly higher tilt of the solar angle (69d) during the summer reveals noticeably cool exterior walls to the south, making shaded streets a priority.

**PRIMARY PASSIVE STRATEGIES**

**SLENDER FORMS**

[SOLAR]

- Keep floor plate widths to 45’ max for even passive lighting and for cross ventilation.

**EXISTING SOLAR RADIANCE ANALYSIS.**

Average Year Analysis

Slightly higher tilt of the solar angle (69d) during the summer reveals noticeably cool exterior walls to the south, making shaded streets a priority.
Climatic Analysis

ROOF OVERHANGS
[SOLAR]
- Alter the roof plane to overhang and shade the faces of the building from intense sun.

CROSS VENTILATION
[WIND]
- provide passive ventilation in areas where high humidity is consistent inside and outside by narrowing floor plate depths and widths.

Summer Analysis
Analysis Time: 3/21 - 9/21
Slightly higher tilt of the solar angle (69°) during the summer reveals noticeably cool exterior walls to the south, making shaded streets a priority.

Winter Analysis
Analysis Time: 9/21 - 3/21
Slightly lower tilt of the solar angle (65°) during the winter reveals noticeably warmer exterior walls to the south.

Into the Tropics. An overall environmental analysis of the site’s climatic conditions reveals the most desired passive strategies to integrate into the design of the new morphologies at the urban scale. As per the diagrams above. The primary passive strategies are designed to counteract the consistent climatic conditions listed below:

- Consistently high humidity and temperatures yearly
- Fairly little change in solar angle due to site’s location in proximity to the equator (it’s a few degrees off) provides evenly dispersed natural lighting and solar exposure from the roof plane.
- Consistent rainfall.

Singapore
Age of the Urban Fabric - founded 1819
Koppen climate - Af Tropical Humid - categorized by an average monthly temperature of above 18°C or 64°F with significant precipitation.
**EXISTING MORPHOLOGIES**

**SLOTS**
- Typically 2-4 stories
- Usually holds residential or commercial programs.

**LOW-BOX**
- Typically 1 story (double heighted)
- Usually holds a warehouse/light industrial program.
- Normally around 15,000 - 55,000 sq. ft.

**MID-BOX**
- Typically 4-8 stories
- Typically holds office, educational, and heavy industrial programs.
- Typically 36,000 - 70,000 sq. ft.

**APT. TOWER**
- Typically around 20-35 stories
- Usually holds many residential flats.
- Typically around 268,000 sq. ft.

The site was analyzed in figure ground format to understand its urban context. Major roadways bound the site on land and the Kallang River to the southeast and southwest. Pedestrian paths are located along this edge as well. Spatial analysis was conducted to see how well the existing site used its space. Program analysis was also conducted to understand what needs to be accommodated (existing) and what can be in the redesign (surrounding).

Morphological analysis of the site and its surrounding area was conducted revealing the most common forms to the left and their respective typical programs and spatial statistics.

The information discovered here will now be used as a general guideline of what the new morphologies need to accommodate and how much space to accommodate for the design intervention.
**DESIGN PROCESS**

1. **URBAN DESIGN**
   - What does the urban realm need?
   - A walkable site that is more porous and aligns itself to the major streets.
   - A 200’x300’ street grid is used to break up the site for porosity and alignment to major streets to NW and NE.

2. **URBAN DESIGN**
   - What does the urban realm need?
   - Density, and public spaces with room for growth are integrated into the new grid structure.
3 ENVIRONMENTAL INTEGRATION

- How can the primary passive strategies be integrated into existing typologies?
- Alter roof plane to shade exterior walls and pull back + carve blocks to provide indirect natural light.
- Integrate cross ventilation by staggering openings.

4 URBAN RECONCILIATION

- How can the site be designed to further the effect of these strategies?
- A path (in pink) is carved for circulation, and also provides ventilation through the venturi effect from an open air theater that activates the main green space.
The design intervention of this site is based on 3 main goals:

- Provide the density and "living hub" space Singapore is already looking into.

- Provide more space for existing programs (warehouse and office) and insert more per the site's surroundings.

- Activate the ground plane.
**Urban + Morphology Impact**

**Urban Design and Morphological Highlights**

- A 200’ x 300’ grid was overlaid to break up the site and allow for street porosity.

- Recreational and retail spaces are placed closer to the river to activate the water’s edge.

- Tallest morphologies were placed in the middle for ease of visibility from the site and for a visual anchor from outside the site.

The site is redesigned to be an example of how a densely populated urban fabric can still provide public recreational, and civic space to its citizens. All redesigned morphologies are now at least 4 stories high. The punctured towers in the middle are scaled to be 32 stories high as typical of its high density housing projects surrounding it. These can be used for office or residential space. The site’s existing F.A.R. (Floor to area ratio) was 1.99 while the redesign boasts a generous 11.175 F.A.R. for maximum density and occupancy of the site but with a massive park to the south end for public recreational space. The site’s new open space ratio is 4.1 which is almost double from the site’s existing open space ratio of 2.13 but fronts its main streets better and promote more activity on the site.

**New Morphologies**

**Punctured Towers**

- Typically around 20-35 stories
- Residential or office space
- Punctured for cross ventilation, daylighting, and shading ground and walls

**Open or Closed Courtyard**

- Double-heighted 2 story warehouse space
- Overhangs and colonnades shade streets
- Narrow form allows for cross ventilation.

**Shell**

- Open Air Theater for events and catching breezes through Venturi effect.
- Recreational structure scoops wind to the ground plane of the site.

**Splitters**

- 4-8 stories
- Office, educational, or industrial spaces
- Thin floor plates for even lighting.
- Altered roof plane for shading.
CLIMATIC PERFORMANCE

MORPHOLOGICAL PERFORMANCE DIAGRAMS
- PUNCTURED TOWERS (wind)
- OPEN/CLOSED COURTYARD
- SHELL
- SPLITTERS (solar)
**Existing Solar Radiance Analysis**

Existing Summer Analysis  
Analysis Time: 3/21 - 9/21  
Slightly higher tilt of the solar angle (69d) during the summer reveals noticeably cool exterior walls to the south, making shaded streets a priority.

Existing Winter Analysis  
Analysis Time: 9/21 - 3/21  
Slightly lower tilt of the solar angle (65d) during the winter reveals noticeably warmer exterior walls to the south.

**Post-Design Solar Radiance Analysis**

Post-Design Summer Analysis  
Analysis Time: 3/21 - 9/21  
The new morphologies are showing significantly lower amounts of solar radiation from the southeast.

Post-Design Winter Analysis  
Analysis Time: 9/21 - 3/21  
The new morphologies are also showing less solar radiance on the surfaces during this simulation time.

Post-Design Summer Analysis  
Analysis Time: 3/21 - 9/21  
The new morphologies are showing similar results from the northeast. The overhang of the courtyard forms are also proving helpful.

Post-Design Winter Analysis  
Analysis Time: 9/21 - 3/21  
The same is true from the northeast as the simulations seem to be showing similar amounts of coloration and tone in the diagram from the summer analysis.
4.2 Moscow Russia

Enter the Third Rome. Moscow is the oldest city of this study as it was founded in 1147 and nicknamed “The Third Rome” in the 15th or 16th century as it rose as the main capital of Orthodox Christianity. The site is in the Arbat District as it is one of the oldest districts in the city about a mile from the Kremlin. The goal of this design exercise is to explore how the design methodology can be implemented in a historic urban fabric that needs little to no change.
PRIMARY PASSIVE STRATEGIES

CLUSTERING [SOLAR]

- Group smaller buildings for lower surface to volume ratio for overall better heat retention

SOLAR RADIANCE ANALYSIS.

Spring Analysis
Analysis Time: 2/1 - 4/30

Significant amount of solar exposure in the atmosphere even when temperatures are around 40F and below. (Start angle at 17 and end angle at 49)
**SOLAR RECEIVER [SOLAR]**
- All south walls to be angled 57 degrees for maximum solar exposure during underheated period (Feb, to April and Sept. to Oct.) where average solar angle is 33 degrees.

**NORTH WIND EXPOSURE [WIND]**
- Use new large masses to block southern and western winter winds.
- Arrange new masses to promote northern summer breezes to ventilate existing courtyards during overheated period.

**CLIMATIC ANALYSIS**

**Fall Analysis**
Analysis Time: 9/1 - 10/31

Significantly lower solar exposure during this time but still has opportunities as previous study due to relatively similar solar angles (42 at start and 22 at end).

**Yearly Analysis**

Pockets of space maintain fairly good access to sunlight throughout the cold period. This is a desirable urban and natural feature of the site to keep.

**INTO THE ARCTIC**
An overall environmental analysis of the site’s climatic conditions reveal the most desired passive strategies to integrate into the design of the new morphologies at the urban scale, as per the diagrams above. The primary passive strategies are designed to counteract the consistent climatic conditions listed below:

- Varying Solar angles 59 (SS) and 10 (WS)
- Dramatic change in daylight hours from 7hrs in the winter to 19 hours of sunlight during the summer.
- Consistently overcast and windy.

**MOSCOW, RUSSIA**
Age of the Urban Fabric - Old - founded 1147
Koppen climate - Dfb Snow Humid Warm Summer - categorized as having at least one month averaging below 0C or 32F and at least one month averaging above 10C or 50F.
**EXISTING MORPHOLOGIES**

**BITs**
- Typically 2-4 stories
- Small and isolated buildings.
- Longer bits Join to frame an urban wall along streets.

**OBLONG COURTYARD**
- Typically 1 story (double heighted)
- Usually holds a warehouse/ light industrial program
- Normally around: 15,000 – 55,000 sq. ft.

**FLAT BOX**
- Typically 4-8 stories
- Typically holds office, educational, and heavy industrial programs.
- Usually around 36,000 – 70,000 sq. ft.

**TOWER**
- Typically 20-30 stories
- Corbusian layout and usually found along major roadways to frame the street.

The site was analyzed in figure ground format to understand it in the urban realm. The site sits at the corner of 2 major streets and then is infilled through the interior roads and thoroughways. The existing urban fabric has an organic nature to it as main buildings front the major streets and other buildings behind them creating an urban fabric consisting of large courtyards with smaller buildings infilling them sporadically. This creates a unique experience on the ground plane where pedestrians can walk along well-fronted main streets or wander and meander through large courtyards and smaller buildings.

This urban experience is understood as an integral part of Moscow’s urban fabric as the rest of the city is organized in this manner as well. Therefore, the design intervention needs to leave this design component either untouched or improved.
**Design Process**

1. **Urban Design**
   - What does the urban realm need?
   - Keep the porous, and organic nature of this old urban fabric that lends itself to wandering paths.

2. **Urban Design**
   - What does the urban realm need?
   - Identify which buildings can benefit from clustering and which ones don’t need it due to programmatic restrictions or others (like apartment buildings).
3 ENVIRONMENTAL INTEGRATION
- How can the primary passive strategies be integrated into existing typologies?
- Cluster smaller buildings together into a new mass.
- Angle all south facing walls to 57 and grow them.

4 URBAN RECONCILIATION
- How can the site be designed to further the effect of these strategies?
- Angle and arrange new masses to allow for northern summer breezes and to block winter southwestern winds.
The design of the site is based on 3 main goals:
- Keep the existing porous nature of the organic urban fabric with a network of courtyards to wander through.
- Group smaller masses together to form larger volumes with less surface area for better heat retention.
- Arrange new masses to provide similar street frontage, allow for cool summer breezes from the north and block cold winter breezes from the SW.
**Urban + Morphology Impact**

**Urban Design and Morphological Highlights**

- Tallest morphologies were placed in the rear for maximum solar access to other masses within the site.

- Morphologies grow in height with respect to solar access for other buildings surrounding it.

- New Morphologies are designed to have an enlarged southern face as a solar reciever to maximize heat gain during the underheated period between February 1st and April 30th.

A minimalist approach was taken for this design intervention by keeping buildings that fronted the street well already and that performed well on spatial density during site analysis. Smaller forms (mainly the bits) that were standing alone were clustered and consolidated for better heat retention. Their southern faces were then angled and enlarged for maximum heat gain.

The new forms were then arranged with respect to the surrounding urban fabric for solar access, preserving existing pedestrian experience (as mentioned in the urban analysis section of this design exercise) and promoting northern summer winds into the courtyards while blocking southwestern winter winds.
Southern walls of all masses are angled for maximum solar exposure to maximize heat gain for solar angles between February 1st & April 30th, and September 1st & October 31st.

January 1st (17D south) & April 30th (49D south)
September 1st (20D south) & October 31st (42D south)

49 + 17 = 66, 66/2 = 33, 90 - 33 = 57

Southern walls of all masses are angled for maximum solar exposure to maximize heat gain for same solar angles with terracing for residential balconies.

February 1st (17D south) & April 30th (49D south)
September 1st (20D south) & October 31st (42D south)

49 + 17 = 66, 66/2 = 33, 90 - 33 = 57
EXISTING SOLAR RADIANCE ANALYSIS

Spring Analysis
Analysis Time: 2/1 - 4/30

Significant amount of solar exposure in the atmosphere even when temperatures are around 40F and below. (Start angle at 17 and end angle at 49)

Fall Analysis
Analysis Time: 9/1 - 10/31

Significantly lower solar exposure during this time but still has opportunities as previous study due to relatively similar solar angles (42 at start and 22 at end).

YEARLY ANALYSIS

Pockets of space maintain fairly good access to sunlight throughout the cold period. This is a desirable urban and natural feature of the site to keep.

POST-DESIGN SOLAR RADIANCE ANALYSIS

Spring Analysis
Analysis Time: 2/1 - 4/30

New morphologies show southern faces absorbing more heat than their existing counterparts.

Fall Analysis
Analysis Time: 9/1 - 10/31

Absence of solar exposure remains, however this is where the clustering should help with heat insolation.

YEARLY ANALYSIS

Porous existing urban fabric has remained and now the infilled courtyards receive more sunlight due to increase in surface area as a byproduct of the clustering.
4.3

SITE 3
DUBAI, U.A.E.

EYE OF THE ARAB GULF TIGER. Dubai is sometimes called the Arab Gulf Tiger as it is one of the major business hubs and trading ports in the Middle East. Since the modern era, it has seen a major rise in development in both real estate, and economic growth. The city has grown so quickly and wildly because so much attention has been placed on bringing as much business as possible to the gulf port city. This has resulted in an urban fabric that is typical of cities that grow post-industrial revolution, where large freeways become the main circulatory artery for urban growth and land development. This results in a very sub-urban fabric with a major strip of towers built awkwardly in the middle of Dubai’s urban sprawl.
Overheated Period Analysis
Mid-March - Mid-Nov.

Analysis during the overheated period reveals an overheated roof plane and heavy exposure along the southeastern walls.
SHADING [SOLAR]

- Alter the roof plane to overhang and shade the faces of the building from intense sun.

CROSS VENTILATION

+ WINDCATCHERS [WIND]

- Keep floor plates at max 45’ width for cross ventilation via operable windows.
- Use windtowers to catch air, move it through buildings and out an exhaust tower.

SOLAR ACCESS ANALYSIS

Overheated Period Analysis
Mid-March - Mid-Nov.
Analysis also reveals less solar exposure along the northwestern faces and opportunities.

CLIMATIC ANALYSIS

INTO THE DESERT. An overall weather analysis of the site’s climatic conditions reveal the most desired passive strategies to integrate into the design of the new morphologies at the urban scale as per the diagrams above. The primary passive strategies are designed to counteract the consistent climatic conditions as are follows:

- Varying Solar angles 88 (SS) and 41 (WS)
- Very close to Tropic of Cancer (23.4667N while Dubai is 25N)
- Consistently harsh daylighting throughout the year
- Consistently sunny, hot and dry.
- Higher average wind speeds (9.66mph - 13.66mph)

DUBAI, UNITED ARAB EMIRATES

Age of the Urban Fabric - New - founded 1822
Koppen Climate - Bwh Dry Desert, Hot, Arid - categorized by having an excess of evaporation over precipitation in the area, as well as little to no rainfall to begin with.
**EXISTING MORPHOLOGIES**

**BITS**
- Typically 2-4 stories
- Usually holds residential or smaller commercial programs.

**TOWERS**
- Typically around 20-35 stories
- Usually holds many office spaces.

**COURTYARD**
- Typically
- Typically 2-4 stories holds office, and/or residential programs.

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The site was analyzed in figure ground format to understand its surrounding urban context. The site sits at the corner of 2 major freeways and sits in between the bustling business strip of office towers to its southeast and much smaller, quiet single family homes and retail shops to its northwest. It is currently home to a used car shop and garage. The existing urban fabric is very typical of sub-urban sprawl where the city grows through its freeways by using them as major circulatory arteries, and then land is divided into blocks divided by secondary and tertiary roads. The blocks are then developed privately in a free-market system.

However, if Dubai is to grow, it is hypothesized that commercial towers will follow along its freeways first, signaling which blocks to prioritize development for. In assuming this pattern of growth for the urban fabric of Dubai, then a transitional block structure to bridge the boundary between Dubai’s future high rises will need to be explored for a more homogenous urban landscape, as opposed to the existing abrupt eruption of towers in an otherwise low-rise city.
**DESIGN PROCESS**

1. **URBAN DESIGN**
   - What does the urban realm need?
   - A walkable porous site that can regulate the block structure as the city grows along major roads.
   - A 200’x400’ street grid is used to break up the site for porosity and alignment to major streets.
   - A centralized green space for public activity.

2. **URBAN DESIGN**
   - What does the urban realm need?
   - Density, and public spaces with room for growth are integrated into the new grid structure.
   - Warehouse space for existing light industrial programs on site.
   - Naturally denser programs are placed along the SE edge to shade the other programs and parks on the site and to face the taller towers in front of them.
   - Naturally shorter programs are placed along the NW edge to front the quieter residential neighborhoods in front of them.
3 ENVIRONMENTAL INTEGRATION

- How can the primary passive strategies be integrated into existing typologies?
- Alter roof plane to shade exterior walls and streets.
- Towers are punctured by an input windcatcher and a vertical exhaust vent.
- Towers are also terraced along the NW face for shaded outdoor amenity spaces and expands surface area for better heat dissipation.

4 URBAN RECONCILIATION

- How can the site be designed to further the effect of these strategies?
- The taller forms face the towers and the smaller forms front the smaller residential buildings providing a transition between the two urban zones.
- A centralized park acts as a massive urban courtyard for a vernacular response to the climate but on an urban scale.
A NEW CITYSCAPE FOR DUBAI

The design of the site is based on 3 main goals:

- Design a block structure that transitions between high rises and small single-family homes in the urban fabric.
- Activate and shade ground plane.
- Use vernacular windcatchers and courtyard schemes to cool and ventilate morphological forms native to this region of the world.
Urban + Morphology Impact

Urban Design and Morphological Highlights

- 200’ x 400’ grid was overlaid to break up the site and allow for street porosity.
- A park was placed in the middle for the site community civic and recreational space and for the site to behave like a massive courtyard.
- Tallest morphologies were placed along the southeast edge to shade the smaller morphologies on the northwest during the morning and afternoon. This placement also helps in visually bridging the massive towers along the Dubai Gweifat International Highway and the small neighborhoods to the northwest.

The design intervention is intended to be an example of how Dubai can grow following its currently observed pattern where major, dense developments grow along major freeways and then carving blocks from that circulatory artery. If most of this design exercise is incorporated into Dubai’s growth, then the city can grow while providing the density it is seeking, with buildings that perform well climatically to promote saving energy, enough community and civic space for its residents and have a visual continuity of low to mid to high rises in the skyline.

New Morphologies

Carved Courtyard

- Double-heighted 6 story warehouse space.
- Overhangs shade streets
- Narrow form and staggered cuts allows for cross ventilation.
- Punctures along southern face allow some sun to enter and light the courtyard.

Towers

- 22-30 stories
- Primarily office spaces with sky decks and terraces.
- Thin floor plates for even lighting.
- Altered roof plane for shading.
- NW terraces provide shaded outdoor amenity space and added surface area contributes to heat loss and openings for natural ventilation.
**Climatic Performance**

- Windcatchers catch the turbulent winds from the windward side to ventilate the building and is exhausted by the passive heating of solar chimney facing other windward side (East).

- Terracing behind can also be opened for ventilation.

- Narrow form promotes ventilation and windflow that can be enhanced with insertion of a reflecting pond inside the courtyard.

- Overhanging walls shade the street and help to slightly lower the solar radiation received on the surface while still providing ambient passive daylighting.
Overheated Period Analysis
Mid-March - Mid-Nov.

Analysis during the overheated period reveals an overheated roof plane and heavy exposure along the southeastern walls.

Overheated Period Analysis
Mid-March - Mid-Nov.

Analysis also reveals less solar exposure along the northwestern faces and opportunities.

Overheated Period Analysis
Mid-March - Mid-Nov.

Towers to the southeast reveal absence of daylighting however, also reveals the benefits of shading if taller masses were placed towards the southeast.

Overheated Period Analysis
Mid-March - Mid-Nov.

A repeat analysis reveals high solar exposure to the southern walls (which was expected) while the interior walls of the courtyard remain cool which was a priority.

Looking from the northwest of the same solar analysis, show that the terraces and the walls fronting the interior streets are kept cool as well.
San Juan, Puerto Rico, is the last site for this thesis’ set of design exercises. It used to be nicknamed “The Walled City” for how fortified the oldest part of the city is. San Juan began as a major trading port in the New World for the Spanish Empire during the Colonialization Era. Old San Juan was fortified and armed to the teeth as it sat on a barrier island that naturally protected San Juan Bay from invaders.

The city is now the island nation’s capital and is a major tourist destination in the Caribbean islands. This is the second and final older urban fabric for this series of design exercises.
Analysis over the course of the year shows that due to the site’s consistent daylighting hours, buildings can benefit a lot from shading and possible ventilation should the prevailing winds be allowed to flow through.
SHADING [SOLAR]

- Alter the roof plane to overhang and shade the faces of the building from intense sun.

CROSS VENTILATION + WINDFLOW [WIND]

- Keep floor plates at max 45' width for cross ventilation via operable windows and carved openings.
- Allow incoming winds to flow through the blocks, ventilating each building as it blows through.

EXISTING SOLAR ACCESS ANALYSIS

Yearly Analysis
Ample daylight hours are received on the ground plane and buildings closer together show opportunities for street shading.

CROSS VENTILATION

CLIMATIC ANALYSIS

RETURN TO THE TROPICS. An overall weather analysis of the site’s climatic conditions reveal the most desired passive strategies to integrate into the design of the new morphologies at the urban scale as per the diagrams above. The primary passive strategies are designed to counteract the consistent climatic conditions are as follows:

- Varying Solar angles 82 (SS) and 47 (WS)
- Very close to Tropic of Cancer (23.4667N while San Juan is 18.47N)
- Consistently even daylighting throughout the year
- Consistently sunny, and humid.
- Highest average wind speeds of the 4 sites of this thesis (12.5mph - 17.5mph) due to its proximity to the ocean.

SAN JUAN, PUERTO RICO
Age of Urban Fabric - Old - founded 1509
Koppen Climate - Am Tropical Monsoon - categorized by an average monthly temperature of above 18C or 64F with significant precipitation yearly as well as a period of time within the year with an excessive amount of precipitation.
EXISTING MORPHOLOGIES

BITS
- Typically 2-4 stories
- Usually holds residential or smaller commercial programs.

COURTYARD
- Typically 2-4 stories holds office, and/or residential programs.

TOWERS
- Typically around 20-35 stories
- Usually holds many office spaces.

The site was analyzed in figure ground format to understand its historical urban context. The analysis shows how the city’s urban fabric is based on its old street network but its block structure has been infilled with a modernist approach as shown by the many buildings that do not front the street edge as opposed to most historical urban fabrics that brace the street edge like Moscow, Russia earlier in this book.

An analysis of its existing morphologies also reveals the modernist approach to the buildings of San Juan that is very privatized and similar to American suburbia.

This analysis incited a need for a representative morphological form to represent the Spanish heritage of San Juan that can be recognized as a vernacular architectural response by the many people that visit and live in the area, to distinguish this cityscape from American suburbia.
DESIGN PROCESS

1 URBAN DESIGN
- What does the urban realm need?
- A walkable porous site that allows the incoming winds from the sea for natural ventilation for this site and further inland.
- Eliminate the abundance of exposed surface parking lots.
- Front the street edges.

2 URBAN DESIGN
- What does the urban realm need?
- Front the existing street edges while allowing for the prevailing winds from the North and the Northeast to enter and ventilate both the ground plane and the buildings on it.
ENVIRONMENTAL INTEGRATION

- How can the primary passive strategies be integrated into existing typologies?
- Alter roof plane to shade exterior walls and streets as typical of the porches found elsewhere on the island.
- Design a puncture on the top and bottom of each form to allow the prevailing winds from the north and northeast to ventilate the streets, courtyards, and allow them to flow through more buildings further inland.

URBAN RECONCILIATION

- How can the site be designed to further the effect of these strategies?
- Align all punctures in forms to run north-south to let wind flow through them both on the ground plane and at the top of the sloped roof/possible attic space to better exhaust heat.
- Use mass from hotel towers to channel wind into beachfront wind channels.
The design of the site is based on 3 main goals:

- Allow prevailing winds to ventilate beachfront buildings and be allowed inland on the ground plane and in the courtyards.
- Activate ground plane by fronting street edge.
- Provide a true vernacular form for San Juan’s residents and visitors.
Urban + Morphology Impact

Urban Design and Morphological Highlights
- All new morphologies promote windflow inland and on the ground plane.
- A park was placed to the right of Calle Condado as public square in front of the beach.
- The hotel program occupies just around a quarter less of what’s existing but with even more occupiable square footage and now helps to channel wind.

The design intervention is intended to rethink how San Juan can deal with its extensive beach front real estate. The design of the carved courtyard form is to display a form to visitors and residents that is reminiscent of Spain’s vernacular courtyards. However, where Spain’s courtyards go from street to street, San Juan’s is to help breakup the massive block for pedestrian pathways and to help promote windflow from the northern shores.

This design intervention is also intended to show how the city can develop its beachfront blocks and inner blocks in consideration of each other.

New Morphologies

Carved Courtyard
- 8 stories typically
- Overhangs shade streets and represent porch feature typical throughout the island.
- Formed for thorough passive daylighting.
- Carved for ventilation on the ground plane.
- Roof is angled towards wind “scoop” to help exhaust heat from inside.
- Mixed use.

Prisms
- 6-8 stories and used for channeling the winds from the north and northeast on the coast.
- Designed to be for either hotel or retail programs.

Bars
- 8-32 stories and used for channeling the winds from the north and northeast on the coast to the prisms.
- Designed to be a single corridor hotel building.

Total Hotel Space
- 787,825 SQ.FT.
- 701,264 SQ.FT.
- 184,150 SQ.FT.

Total Residential Space
- 79,018 SQ.FT.
- 787,825 SQ.FT.
- 184,150 SQ.FT.
CLIMATIC PERFORMANCE

MORPHOLOGICAL PERFORMANCE DIAGRAMS

- **CARVED COURTYARDS**
  - Wind flows through sloped roof.
  - Courtyard and streets are shaded.

- **PRISMS**
  - Wind flows through puncture in the form and acts flows to a tapered opening for breezes inland.

- **BARS**
  - Wind flows through thin bars of hotel program and help to channel wind into prisms.

EXISTING SOLAR RADIANCE ANALYSIS.

**Yearly Analysis**

Analysis over the course of the year shows that due to the site's consistent daylighting hours, buildings can benefit a lot from shading and possible ventilation should the prevailing winds be allowed to flow through.

EXISTING SOLAR ACCESS ANALYSIS.

**Yearly Analysis**

Ample daylight hours are received on the ground plane and buildings closer together show opportunities for street shading.

POST-DESIGN SOLAR RADIANCE ANALYSIS.

**Yearly Analysis**

Post-design analysis from the southeast shows that solar exposure is still high, but the courtyards and pedestrian pathways are cooler and the forms now have improved access to better ventilation.

POST-DESIGN SOLAR ACCESS ANALYSIS.

**Yearly Analysis**

The same analysis shows that the northern faces remain cooler.

**Yearly Analysis**

Less daylight hours are received on the ground plane and the pedestrian pathways are well shaded. The beachfronts are still well-lit daily.
[CH.5] IMPACTS

5.1 ON THE URBAN EXPERIENCE
5.2 ON URBAN PLANNING
5.3 ON URBAN SPATIAL EFFICIENCY
5.4 ON MORPHOLOGICAL FORM
SINGAPORE

MOSCOW, RUSSIA

DUBAI, U.A.E.
THE DESIGN EXERCISES PROVED TO BE VERY REVEALING. The results of the 4 design exercises are analyzed and critiqued in this section as it relates to how the design methodology was able to alter the urban experience of these sites.

SINGAPORE. The design of the new Kallang District Park for Singapore shows an example of a “lifestyle hub” in a city where real estate is limited. The resulting master plan was able to include the necessary density along with a massive green fronting the splitting of the Kallang River. This shows the dedication of the master plan to provide the space the Singapore needs for work, living, commerce, and recreation as the green space takes up about half of the master plan.

MOSCOW, RUSSIA. The design of the Arbat District for Moscow, Russia was a very unique case where the design methodology shows its acceptance of existing, and cultural urban fabric by only clustering and consolidating smaller buildings that can benefit from improved heat retention through these methods. This left other larger buildings that front the main streets to still contribute to the macro urban experience of the oldest urban fabric of these exercises.

DUBAI, U.A.E. The design for the “New Cityscape For Dubai” shows a unique adaptation of the courtyard typology for a vernacular design response both at the urban and building scale. The master plan demonstrates a visual gradient as the buildings slowly shrink in height looking from the towers to the neighborhoods. This master plan also shows a block structure that programmatically and visually blends the small residential and the tall commercial areas of the city. The massing layout also uses building heights to shade the other part of the block as well as the ground plane.

SAN JUAN, PUERTO RICO. The design for Condado Beach is an example of how the city can design for its beachfront blocks as well as its blocks further inland. It also introduces a proposed vernacular response as opposed to the design exercise for Dubai. Here, the courtyard typology is interrogated once again, but this time as a descendant of it’s Spaniard parent. The Spaniard courtyard structure typically spans the entirety of the block, whereas this proposed smaller courtyard provides pedestrian thoroughways to promote more activity between the buildings as well as channeling the sea winds inland to the streets, thoroughways and the courtyards.
5.2 ON URBAN PLANNING

SAN JUAN, PUERTO RICO

THE DESIGN EXERCISES SHOW AN EVOLUTION IN THE URBAN FABRIC. The results of the 4 design exercises are analyzed and critiqued in this section as it relates to how the design methodology demonstrated a departure from the urban planning, typical of the surrounding context but at the same time, contributing to it.

SINGAPORE The design of the new Kallang District Park for Singapore shows an example of densifying and fronting the primary streets, while balancing that density with pure, uninterrupted open civic space for a lifestyle hub unique to Singapore. The resulting master plan forms its grid street network by adhering to the junction of the 2 main roads that bound the edges of the site, showing the importance of primary circulation in the master plan and the design methodology. This adherence and subjection to the primary circulational arteries of the city helped to front the street edge, while providing visual breaks to help breakdown the massive site for those traveling on the main roads.

MOSCOW, RUSSIA The design of the Arbat District for Moscow, Russia was a very unique case where the design methodology shows its acceptance of the city’s historic, radial urban fabric, originating from the Kremlin and having one of its rings bound the site’s western edge. It’s existing micro-urban context showed a porous network of interconnected courtyards, not necessarily “streets.” This porous network of courtyards lent itself to a unique experience on the ground plane of wandering and meandering around and possibly through buildings to travel. This feature is preserved in the master plan as seen on the figure grounds to the left.

DUBAI, U.A.E. The design for the “New Cityscape For Dubai” shows a unique adaptation of the courtyard typology for a vernacular design response in its street layout. A centralized park is fronted by buildings and centered in the block structure for civic and public activity but also for passive shading. The street network of the new block structure is also designed to help break down the site for pedestrian walkability and transitioning from the larger blocks to the south, to the smaller residential plots of land to the north.

SAN JUAN, PUERTO RICO The design for Condado Beach is an example of how thoroughways and masses can be laid out to promote activity on the ground plane, in the block and promote windflow from the shoreline further inland.
NUMERICAL VALUES

SINGAPORE
- EXISTING
  - FLOOR TO AREA RATIO: 1.99
  - AVERAGE BUILDING HEIGHT: 10.23 STORIES
  - OPEN SPACE RATIO: 4.1
  - % SURFACE COVERAGE: 19.6%
- DESIGN EXERCISE
  - FLOOR TO AREA RATIO: 11.175
  - AVERAGE BUILDING HEIGHT: 10.23 STORIES
  - OPEN SPACE RATIO: 4.1
  - % SURFACE COVERAGE: 32%

MOSCOW, RUSSIA
- EXISTING
  - FLOOR TO AREA RATIO: 2.1
  - AVERAGE BUILDING HEIGHT: 3.92 STORIES
  - OPEN SPACE RATIO: 1.96
  - % SURFACE COVERAGE: 33.8%
- DESIGN EXERCISE
  - FLOOR TO AREA RATIO: 2.08
  - AVERAGE BUILDING HEIGHT: 7.96 STORIES
  - OPEN SPACE RATIO: 2.1
  - % SURFACE COVERAGE: 32%

DUBAI, UNITED ARAB EMIRATES
- EXISTING
  - FLOOR TO AREA RATIO: 2.15
  - AVERAGE BUILDING HEIGHT: 4 STORIES
  - OPEN SPACE RATIO: 7.587
  - % SURFACE COVERAGE: 11.6%
- DESIGN EXERCISE
  - FLOOR TO AREA RATIO: 6.5
  - AVERAGE BUILDING HEIGHT: 16.18 STORIES
  - OPEN SPACE RATIO: 2.72
  - % SURFACE COVERAGE: 26.9%

SAN JUAN, PUERTO RICO
- EXISTING
  - FLOOR TO AREA RATIO: 2.01
  - AVERAGE BUILDING HEIGHT: 5.03 STORIES
  - OPEN SPACE RATIO: 2.65
  - % SURFACE COVERAGE: 27%
- DESIGN EXERCISE
  - FLOOR TO AREA RATIO: 2.615
  - AVERAGE BUILDING HEIGHT: 13.8 STORIES
  - OPEN SPACE RATIO: 2.19
  - % SURFACE COVERAGE: 31.4%
The design exercises reveal some interesting statistics. The results of the 4 design exercises are analyzed and critiqued in this section as it relates to how the resulting designs spatially perform (and in theory lend itself to improved energy usage as hypothesized by Steadman et. al. (1991)) displayed on an attempted Spacemate Diagram as depicted from Berghauser Pont, Meta and Haupt (2005) (and by Rode, et. al. 2014). For this analysis, the calculations were achieved as noted in Section 2.5 of this book (Rode et. al. 2014).

**Singapore** The design of the new Kallang District Park for Singapore shows an immense increase in F.A.R. with the design intervention possessing a resulting F.A.R. of 11.175 while keeping a large open space ratio of 4.1 for the public recreational green space as a civic amenity for the residents and visitors to the nearby Marina Bay.

**Moscow, Russia** The design of the Arbat District for Moscow, Russia was a very unique case where the goal of the design methodology’s implementation was to try to keep the statistics relatively the same. In this case, most of the statistics stayed the same except for the average building height that just about doubled. The statistic results in this case show that the design methodology can be intrusive but can also be delicate in its approach depending on the needs and requirements of its urban context including that of the oldest urban fabric in this study.

**Dubai, U.A.E.** The design for the “New Cityscape For Dubai” shows a statistical result similar to that of Singapore’s Kallang District Park.

**San Juan, Puerto Rico** The statistics for the design of Condado Beach show similar results to the design exercise done for Moscow, Russia’s Arbat District where a gentle and delicate approach was taken to the street network. The only circulation paths added were pedestrian thoroughways between the buildings and the design is statistically shown to perform similarly as it was before. This was intended as it is the other older urban fabric in this study that needed to be preserved.
The design exercises show an evolution in morphological form. The results of the 4 design exercises are analyzed and critiqued in this section as it relates to how the design methodology demonstrate an exploration in morphological design by integrating passive design strategies into volumetric form.

Singapore. The design of the new Kallang District Park for Singapore shows how typical tower and courtyard typologies can be designed to climatically perform for its context. The altering of the roof plane and the carving of its massing prove a departure from its existing counterparts. These dramatic features show a need to both its occupants and pedestrians for shading and windflow from building to building.

Moscow, Russia. The design of the Arbat District for Moscow, Russia was a very unique case where the design methodology had to work to improve heat gain at a very precise moment in time and consolidate for improved heat retention. The “hills” and “mountains” show a departure from the typical strategies of slimming down and doing the opposite which is to grow them larger. This strategy of consolidating and growing the forms was implemented in tandem with a solar receiver, where the south face of each building was to be angled at 57 degrees to catch an averaged solar angle that was calculated between February 1st and April 30th. This period of time is underheated in the atmosphere’s average temperatures but there were still significant enough daylight hours present during this time to warrant an entire face of each mass to receive as much solar radiation as possible throughout this underheated period.

Dubai, U.A.E. The design for the “New Cityscape For Dubai” shows a unique, morphological adaptation of the courtyard and tower morphologies for a vernacular, climatic response. Here we see some consolidation of the smaller “bits” forms that are existing, into “carved courtyards” for density and for shading purposes. The towers adapted terracing on its windward side so that heat gained on the southeast faces can dissipate quicker, by using the increase in surface area and windcatcher towers as a way to passively ventilate the large mass.

San Juan, Puerto Rico. The morphologies for Condado Beach show the importance of bringing in the prevailing winds from the ocean inland with many cuts made on its forms to channel them across buildings.
[CH. 6] BIBLIOGRAPHY

6.1 MODELS
6.2 BIBLIOGRAPHY
6.3 ILLUSTRATION CREDITS
6.1 SINGAPORE
6.1

MOSCOW, RUSSIA

SOUTH ELEVATION

NORTH ELEVATION

EAST ELEVATION

WEST ELEVATION
6.1

Dubai, UAE,
6.1 San Juan, Puerto Rico


ILLUSTRATION CREDITS

CH-1 - INTO THE AEthere

Figure 1.1 - Base Image from Xavier Portela

Figure 1.3 - Property of Anthony Yan - Base image from Google Earth.

Figure 1.4 - Image from https://www.nightearth.com/

Figure 1.5 - Image from https://www.nightearth.com/

CH-2 - [RE] EVALUATE

Figures 2.22 thru Figure 2.27 - All images are property of Phillip Rode, Christian Keim, Guido Robazza, Pablo Viejo, and James Schofield. All diagrams taken from Environment and Planning B: Planning and Design 2014, Volume 41, pages 138-162.

Figures 2.28 thru Figure 2.32 - All intellectual property in figures are property of Morphosis (architectural firm). Figures were only sketches and notes taken from their book Combinatory Urbanism.

CH-3 - DESIGN THEOREM

Figure 3.5 - Map is property of Wladimir Koppen and Rudolf Geiger.

Figure 3.6 - Image from https://www.nightearth.com/

Unless otherwise noted, all illustrations are the author’s.