URBAN PLAZAS FOR HUMAN COMFORT

by

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Abstract

URBAN PLAZAS FOR HUMAN COMFORT

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What new technologies and methods can be matched with older “forgotten” techniques to make a plaza more comfortable and enticing for humans? This study will examine human comfort needs in a public space through: temperature, light/shade, breeze, sense of security, sound, sight distances, environmental psychology with plants and water features, entertainment, social needs and, also scale.

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Introduction

Urban Plazas for Human Comfort

Early in the history of cities, the plaza was the prime gathering place. It was often the most comfortable place. So, the plaza shouldn't, certainly, be an afterthought or blank space between buildings. What can be done to make these spaces comfortable gathering places again? The research focuses on natural light, shade, wind, vegetation, and design. Human scale and comfort, as well as important features that draw people to the space, overshadows every item that is discussed. Figure 1-1 shows a Greek market in the ancient agora, one of the first urban outdoor spaces and where most public activity took place.

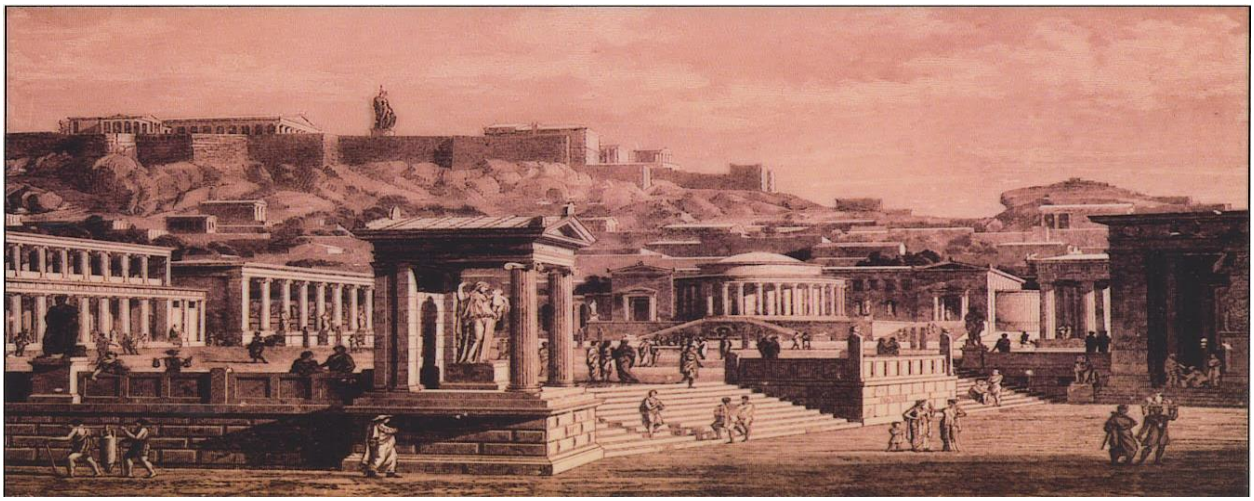

Figure1-1: Greek Agora Drawing

(architecturalmoleskine.blogspot.gr)

The plaza has a long history in urban design; these are looked at briefly for size, shape and function. Many of the early plazas were designed with nature, to increase the comfort of humans. Many of the features have been thoroughly researched and are helpful colors in painting the whole picture. Each piece is used—with some independent research and experimentation—to create a unique solution to urban plazas as modern gathering places. Especially, aquaponics is discussed as a water feature, plant

growth medium and fish habitat in a closed, self-contained ecosystem. Aquaponics is an area of independent research and experimentation; and, hopefully a future element in urban plazas.

Following a brief history and discussion of plaza function, the paper examines human comfort. A detailed understanding of the human mind and body needs—and what purpose the plaza is aimed at supplying—will help the next sections. Figure 1-2 shows one way to use ancient techniques in modern ways to create a comfortable outdoor environment.

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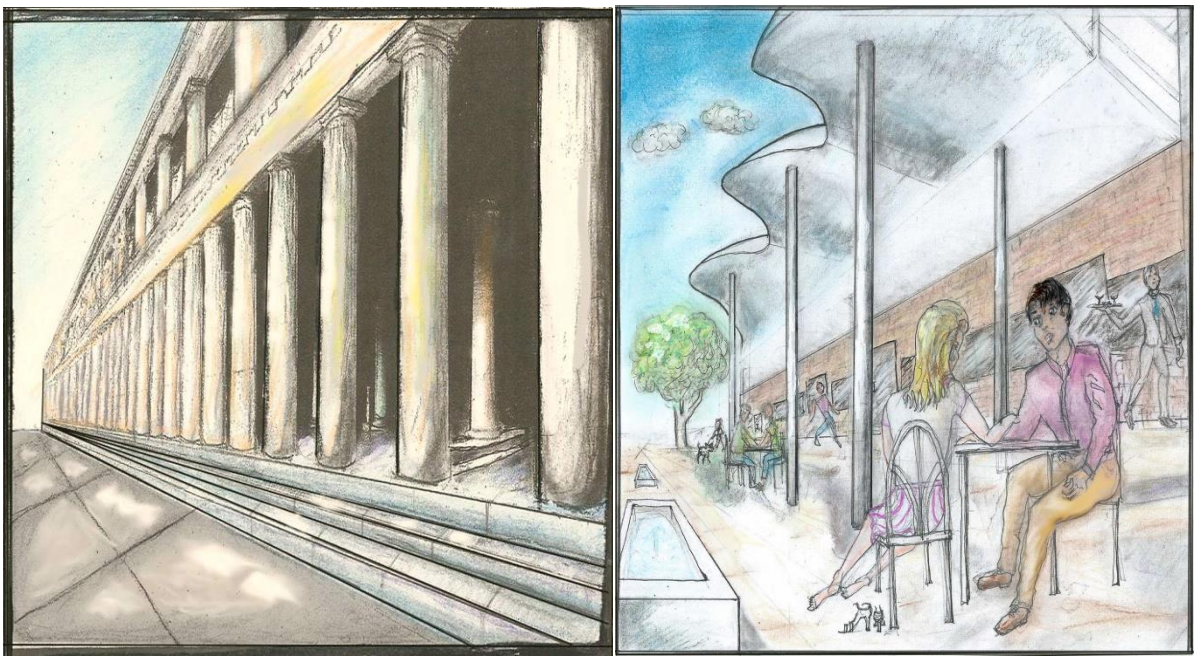


Figure 1-2: Greek stoa principals used in modern design.

(Both idea sketches by Steve Witherspoon)

After understanding the history and enormous impact these public gathering places have had on modern civilization, it is important to understand the individual human and what environment they thrive in. No matter how beautiful the space, if it is not designed to make its inhabitants comfortable, it will be avoided. Humans are animals and select favorable habitats like all other species. Some important considerations in human comfort are listed in Table 1-1.

Table 1-1: List of human comfort considerations.

Temperature	Scale
Light	Sight Distances
Air Movement	Sense of Security
Sound	Human Nature
Smell	Socialization
View	Entertainment
Environmental Psychology	Community Gathering

Many people subconsciously avoid spaces where they do not feel comfortable. Once the comfort goals are understood, the study looks at design solutions and techniques. Some solutions are ancient from when plazas were designed with nature in mind, and on a human scale. Some are found through an interdisciplinary approach of marrying techniques from science, technology, landscape architecture and architecture with planning and sociology theories. Simply applying sun path information can completely transform the comfort of a plaza. Figure 1-3 shows the seasonal and daily path of the sun in Burleson, Texas which is very important for planning shade for a plaza.

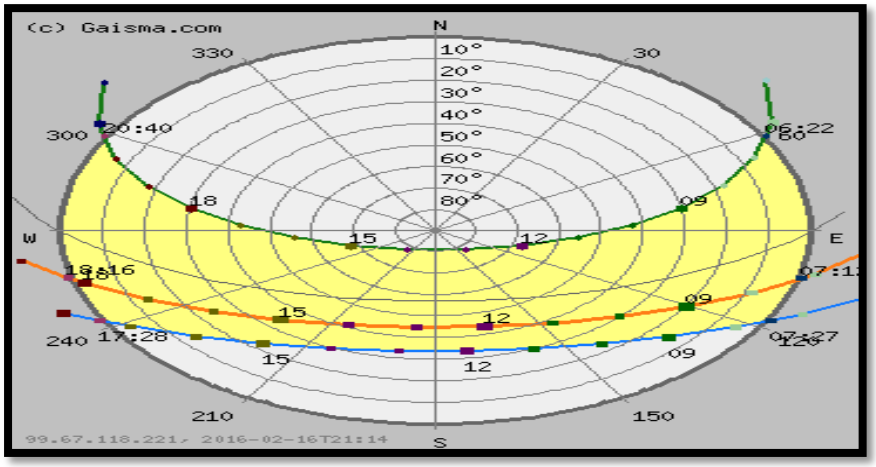


Figure 1-3: Stereographic of the sun path in Burleson, Texas.

(http://www.gaisma.com/en/location/burleson-texas.html)

Finally, the discussion falls on aquaponics before going into final analysis. Aquaponics, hydroponics and aeroponics emerged into popularity from NASA research on plant growth solutions. Aquaponics specifically is a complete ecosystem. As seen in Figure 1-4, water containers house a population of fish—like Koi ponds popular in Japan—and the nutrient rich water regularly circulates through a plant system that in turn cleans the water of ammonias and nitrates before it returns to the fish habitat. The whole system can be automated and self-contained. Many design features can be added to the set-up, like fountains and plant towers. The need for water features, plants, fish and fountain noise is established in the first part of the paper. This section describes the implementation of an innovative approach to plaza design.

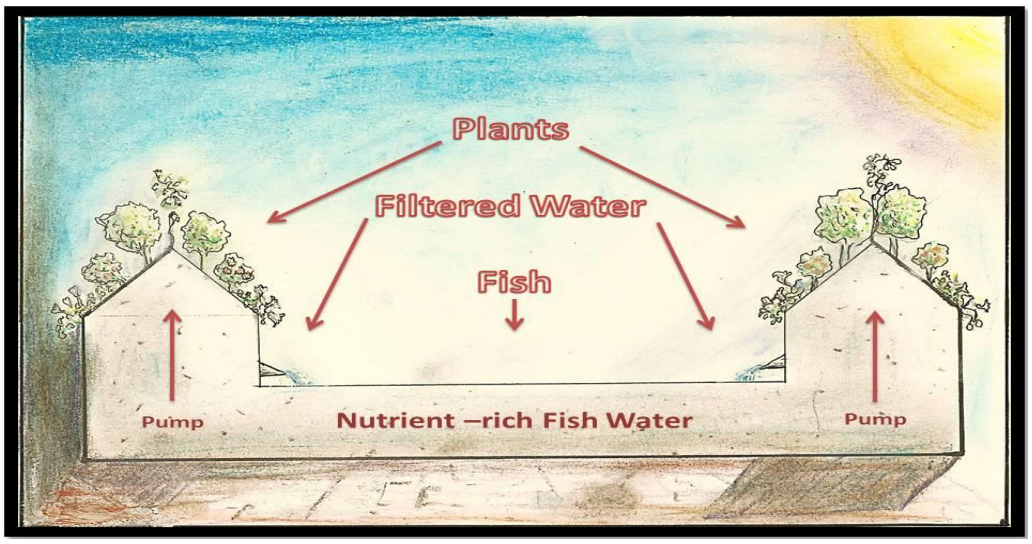


Figure 1-4: Basic diagram of aquaponics.

(Idea sketch by Steve Witherspoon)

The conclusion brings the whole package together for implementing human comfort into plaza design.

Review of Literature

At the heart of the study is the work of Jan Gehl. At least three of his books inspired the subject of this thesis. Gehl spent decades studying public spaces and literally wrote a book on how to study public spaces. His focus was on how people used space on a human scale. Much of his research is used to describe scale of human interaction. How far away can we read facial expressions? Live theatre auditoriums are designed on these factors. There are many ways to encourage social interaction and improve pedestrian traffic through Gehl's studies. He also points the way of scientific studies on temperature, sound, sight and scent for improving human comfort in public places.

Many scientific principals and studies are used in this report to understand human comfort, and describing the aquaponics system. The science is used as reference material but the principals are easily understood and intuitive, so—like most sound knowledge—are easily explained. For human comfort, much of the information is general scientific knowledge but a couple books specifically deal with this subject on the physical and social/psychological level. Two books deal with environmental psychology *Urban Place: Reconnecting with the Natural World,* and *Advances in Environmental Psychology Vol 1:*

The Urban Environment. Also, a couple of published theses contain information that deal with ancient designs of Greek public spaces and also, public space for healthy living (i.e. urban gardening, walkable).

The social factor is very important for public space. Gehl deals with this but several other books are used, such as *The Cultural Meaning of Urban Space, On the Plaza* and *Toward the Livable City.* Much material was digested for the social aspect because it underlies almost everything else that deals with public space. It is the primary reason for public space. Much of it is general knowledge though, and does not need to be heavily cited.

For the last three areas of reading, urban design is high on the list. The main source is *Fundamentals of Urban Design* by Richard Hedman. Much of the material comes from scattered sources that might apply to public space and general architectural design principal. Also, because there are personal idea sketches throughout the thesis, some drawing, coloring and computer method sources are used.

Another source of reading that has a fundamental impact but hardly noticeable appearance is: *Defensible Space* by Oscar Newman. Making a plaza safe has an enormous impact on whether it is used and, often this sense of safety is at a subconscious level.

The last subject is aquaponics. Although it is suspected that the Hanging Gardens of Babylon used this system it is a new subject and many of the sources are from the internet or from people. The main book source is *The Texas Aquaponics Guide* by Arturo Arredondo.

Methodology

Through specific involvement of the design of a plaza in Burleson Texas, targeted surveys, stakeholder, and public involvement meetings will be used to compare to more general results nationwide. The survey is used extensively to demonstrate public desire. Graphs, tables and demographic information are used to find categories and priorities to compare nationally. Specifics of this project will be used to highlight the general building and using of public space. Also it is important to take a wide view of the process, like public will, public involvement, social media, and political drive to carry out the process.

Idea sketches are used throughout the thesis to show the changing nature of the process and to demonstrate the different elements. The idea sketches are drawn by the author, inked, colored with pastel

and charcoal, then scanned to the computer and sometimes lightly rendered in Photoshop. The drawings add an original and consistent nature to the paper. Photos and graphics are used to demonstrate the ideas being explained.

Conclusion

The main goal of this thesis is to combine the best metadata with original research and ideas to make plazas more comfortable and enticing to the public. The interdisciplinary approach combines many good elements into a whole body that transforms the plaza into a place where people will want to gather. The paper describes how important it is to have a public space where ideas can be exchanged, and a public voice can be heard, as well as a pleasant place to relax and watch fellow community members.

By looking at pre-industrial, and even prehistoric public spaces, important elements of human scale and designing with nature can be “rediscovered”. Many of the modern sustainable practices can be added to make a more comfortable design. Outdoor spaces are especially influenced by nature and cannot be environmentally controlled like indoor spaces with air conditioning. Walls and overhead covering have to be used discriminately.

Social and psychological studies give insight to human nature. Something as simple as how far the eye can determine facial expressions, comfortable sound levels and types and edge zones can dramatically affect a public space. How important are water and plants in a plaza? What about seating? Starting with the human capabilities when designing a plaza can immensely improve the human experience.

This thesis is a scholarly study on what makes a plaza comfortable and enticing to humans. It aims to show all of the factors involved and combined in a way not previously published. In the end, it also intends to show original designs using these principals. And, it shows a specific process with public input.

Chapter 2

History and Function of the Plaza

A plaza is an open urban public space. The word is Spanish from the Italian *piazza*, also called *platz* in German or *place* in French and English. Latin was *platea* from the Greek *plateia*, meaning broad way or street. Interestingly, the brief look at the word itself is an outline of the study of the actual plaza.

The Greek plateia was more broadly called an agora. The agora was the first documented example of an open urban public space, and what almost all public space has been modeled on since. Some of the first copies go as far back as the end of the seventh century BC; an old hamlet on Palatine Hill was demolished for the building of public space with its accompanied public buildings. Palatine Hill was one of the seven hills of ancient Rome. For the purpose of this paper, the agora will be studied as the example of pre-industrial design of public space for human comfort. An agora is an entire public space with an array of public buildings that are important to note but the focus of the thesis eventually falls on the plaza for more modern design principals.

An agora is a central meeting place at the heart of the city. It is where tradespeople, philosophers, poets and politicians rubbed shoulders. Also, it is where public complained, demonstrated, learned and entertained. Sometimes these demonstrations turned violent; perhaps that is why the fear of public places is called agoraphobia. A more modern example can be seen in China. Hundreds of people were killed in Tiananmen Square on June 5, 1989. Ironically, Tiananmen Gate means Gate of Heavenly Peace.

The agora of ancient Athens was 30 acres and contained several markets, three stoa, teaching porches, two theatres, a gymnasium, courthouse and prison, five temples and many sculptures. It was a single public space for education, politics, religion, oratory, philosophy, art and athletics. It was crucial to the Greek way of life and its democracy.

Athens, like Rome, has a hilly terrain as seen on the map in Figure 2-1. Originally, the hilltops were colonized for defensive purposes. As the area became more civilized, the groups would meet in the

valley that was in view of the surrounding hills. The agora was the place that brought the whole area together as one.

The layout of the agora appears to have grown organically as opposed to designed before built. Much like animals build their homes, the early humans built theirs according to the terrain, sunlight, breezes, defensibility and access to livelihood. This agora clearly follows the terrain.

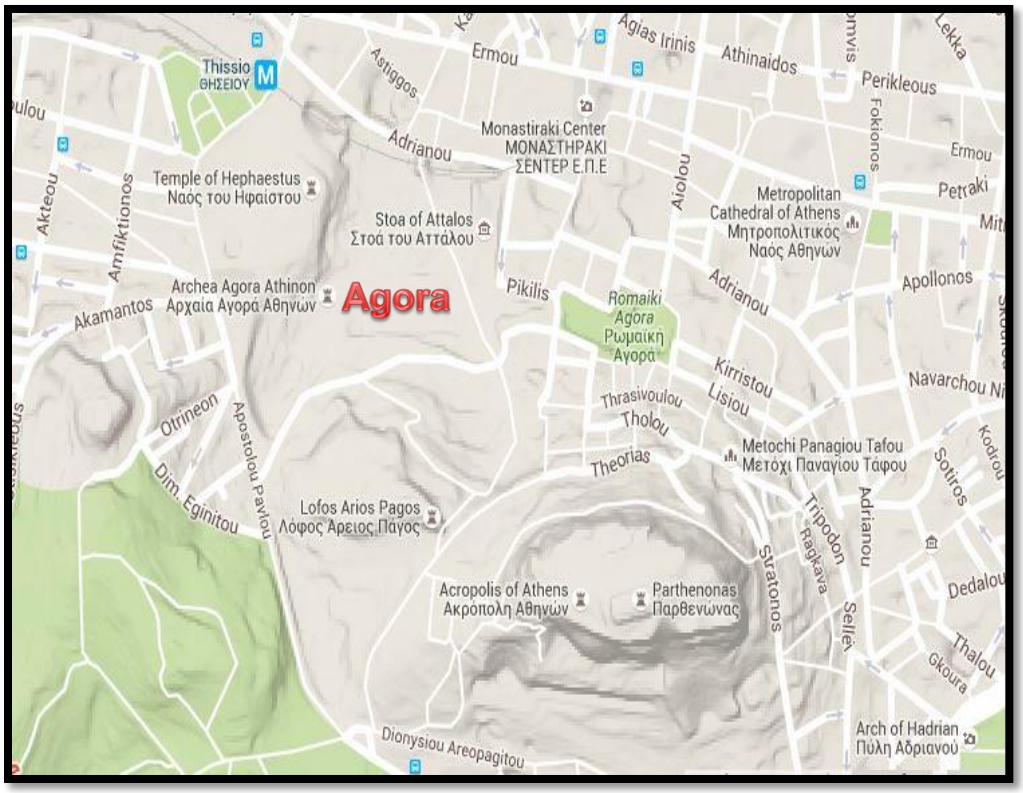


Figure 2-1: Terrain Map with Agora Location.

(http://www.maphill.com/greece/detailed-maps/terrain-map)

Using multiple image sources, an idea sketch was drawn of the agora in Figure 2-2 to acquire a better understanding of building orientation, terrain and how the surrounding hills may affect the sun and wind.

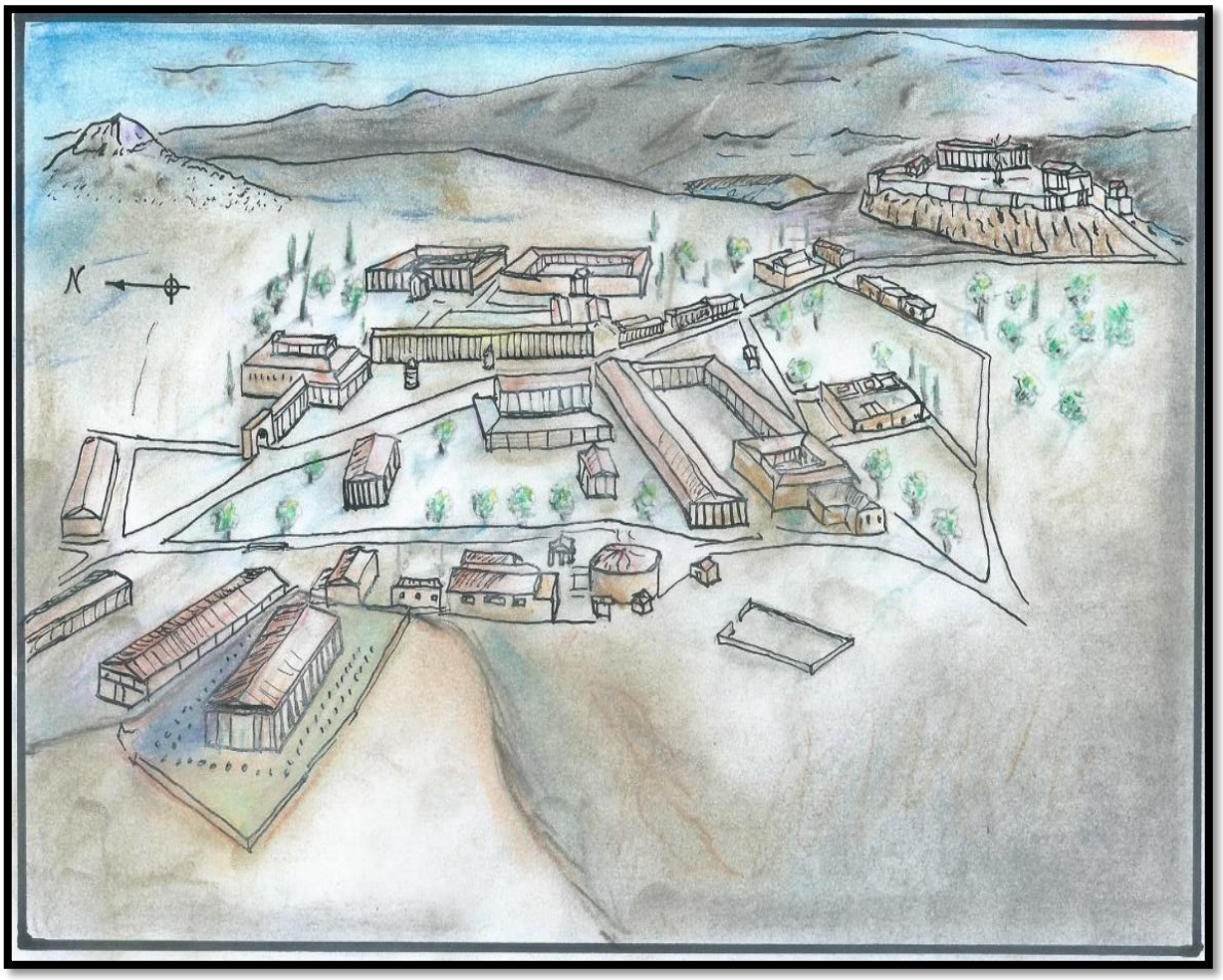


Figure 2-2: Ancient agora layout.

(Idea sketch by Steve Witherspoon)

The first element in understanding the birth of public outdoor space is the climate conditions. At the time the agora was growing into its iconic form, the climate was close to the modern climate with some year's warmer and some with more precipitation. Figure 2-3 is a graph of the temperature and precipitation around the time the agora took form.

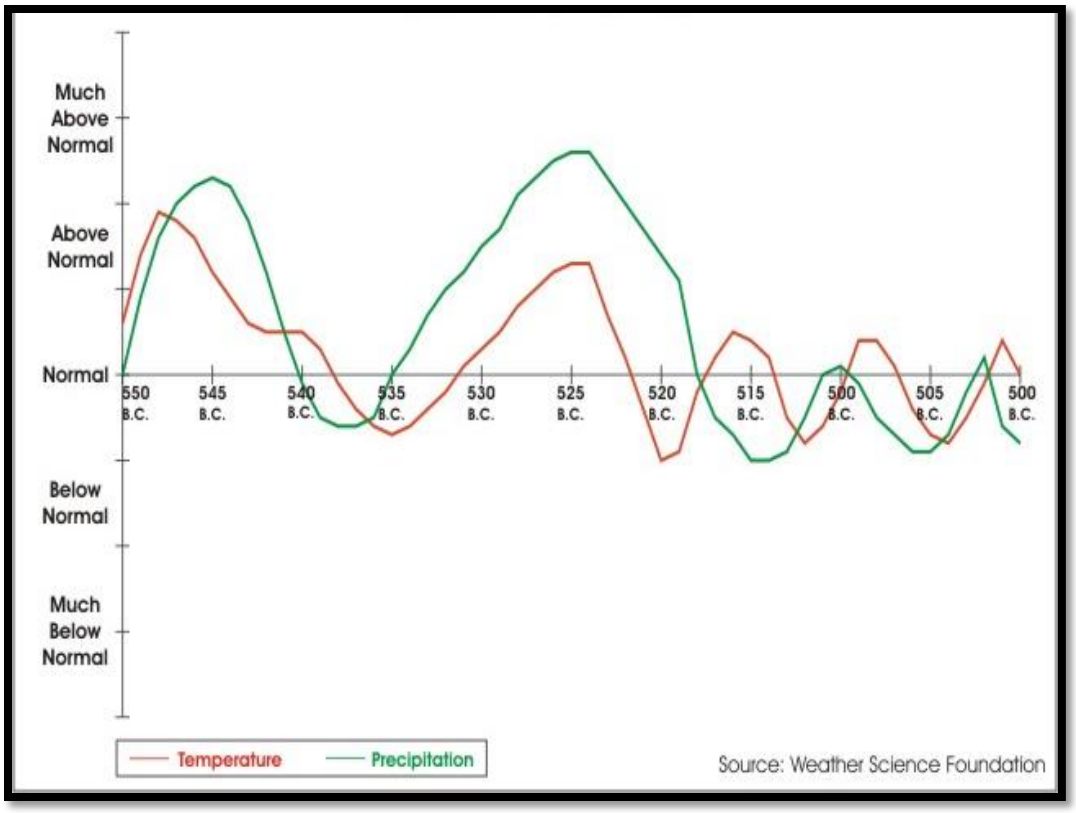


Figure 2-3: Temperature and precipitation in Athens from 550 - 500 B.C.

(http://www.longrangeweather.com/550bc.htm)

So, for the purposes of this study, modern climate data can be used. Slight variations in temperature and moisture do not greatly affect the overall design of plazas—although it could be a point of future investigations. The important point is to find the comfort levels most attractive to which are discussed in the next section. Figure 2-4 is a series of graphs showing a normal year in Athens, with average rainfall, humidity, wind speeds, and temperature maximums and minimums.

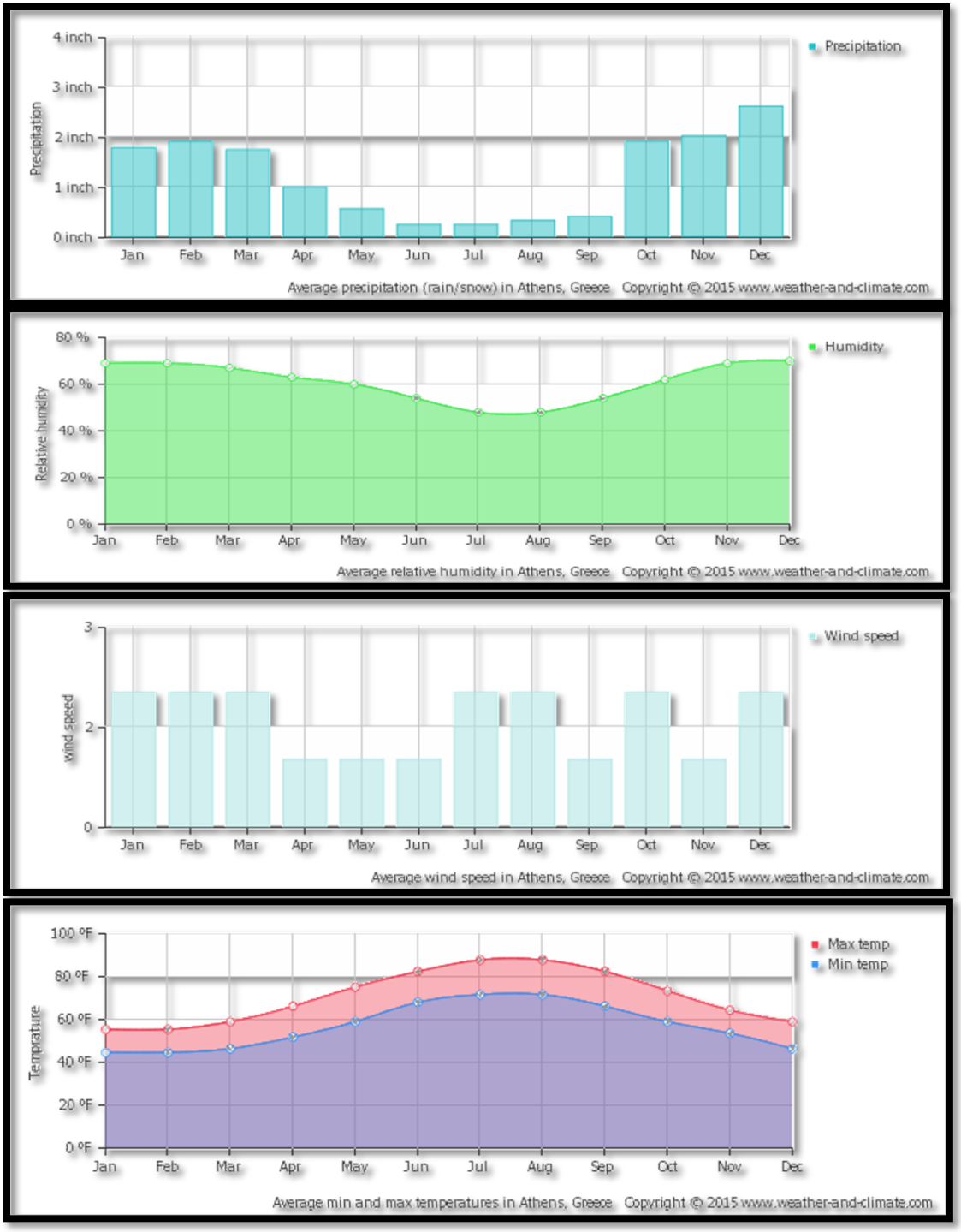


Figure 2-4: Graph of average rainfall, humidity, wind speed, and temperature in Athens, Greece. (https://weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine-fahrenheit,Athens,Greece)

In a very broad sense, in the hours of usual outdoor activity, it is in the 70s and 80s with a low chance of rain, slightly dry air with a gentle breeze out of the NNW. There is a weather event in the summer. The old Greeks called it the Etesian northern winds and is known modernly as the Meltemi winds. The Meltemi winds, shown in Figure 2-5 with the red dot at Athens, were a cooling factor during the summer but caused low rainfall.

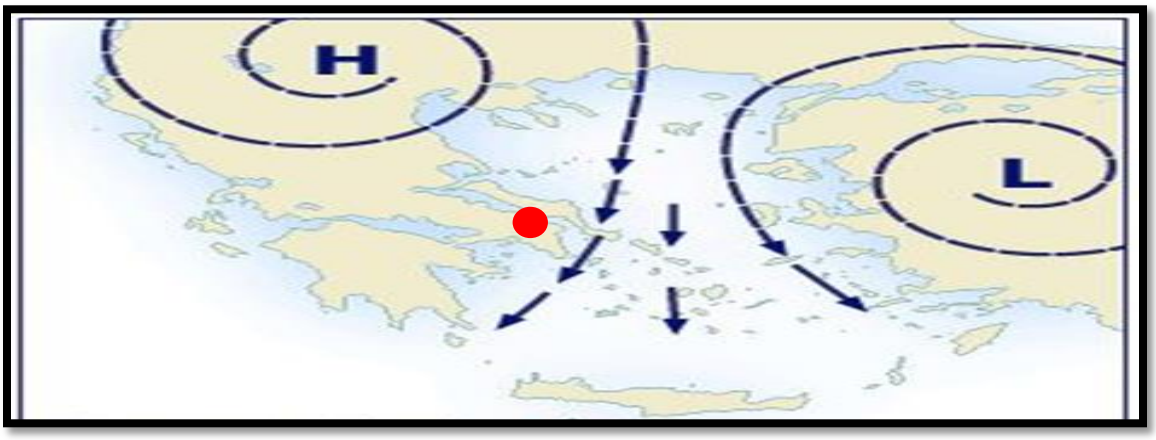


Figure 2-5: Meltemi winds.

(http://www.sailgreece.info/weather.html)

On the whole, the sun is the major influencer for weather on Earth—it heats the planet, and causes the winds through pressure difference from temperature inequalities on the different surfaces—but more locally the sun's arc and angle can have a big impact. A city-wide temperature may average 78 degrees at noon but the temperature varies in hundreds of tiny microclimates around that city. It could be 85 degrees in direct sunlight and 72 degrees in the shade. The human body derives most of its cooling from air movement and evaporative cooling. So, even if the air temperature is 78 degrees the human body will be working to maintain 98 degrees internally by utilizing shade, air movement and dry air.

With this in mind, it is important to look at the local arc and angle of the sun—the major influencer in human comfort. As a quick science reminder, the Earth rotates around the sun on a 23.5 degree tilt, as seen in Figure 2-6. Because of this tilt the sun does not shine on the equator all year but appears to move 23.5 degrees north in the summer solstice (northern hemisphere) back down to the equator for the

equinox, continue down another 23.5 degrees for the winter solstice (northern hemisphere) and back up to the equator for the equinox.

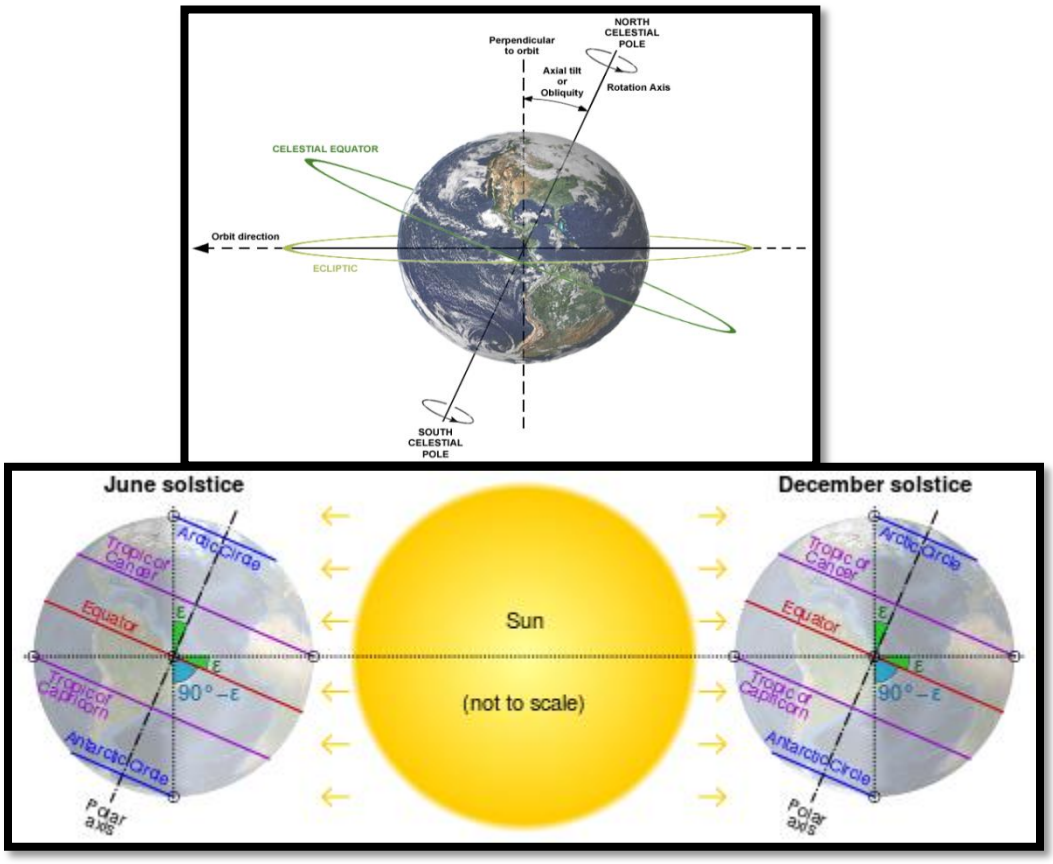


Figure 2-6: Earth angle

(http://www.edb.utexas.edu/missiontomars/bench/tl.html)

Another important factor is where on earth a person is. Because Athens is 37.98 degrees above the equator the angle of the sun's arc appears differently than other locations. The sun never arcs directly overhead because as far north as the sun "travels" is 23.5 degrees. The arc always travels across in the southern direction, especially in the winter, crossing lower on the horizon.

The sun's seasonal arc was 40 – 80 degrees from the horizon in the southern direction at noon as seen in Figure 2-7. The greatest amount of the time it was closer to 60 degrees.

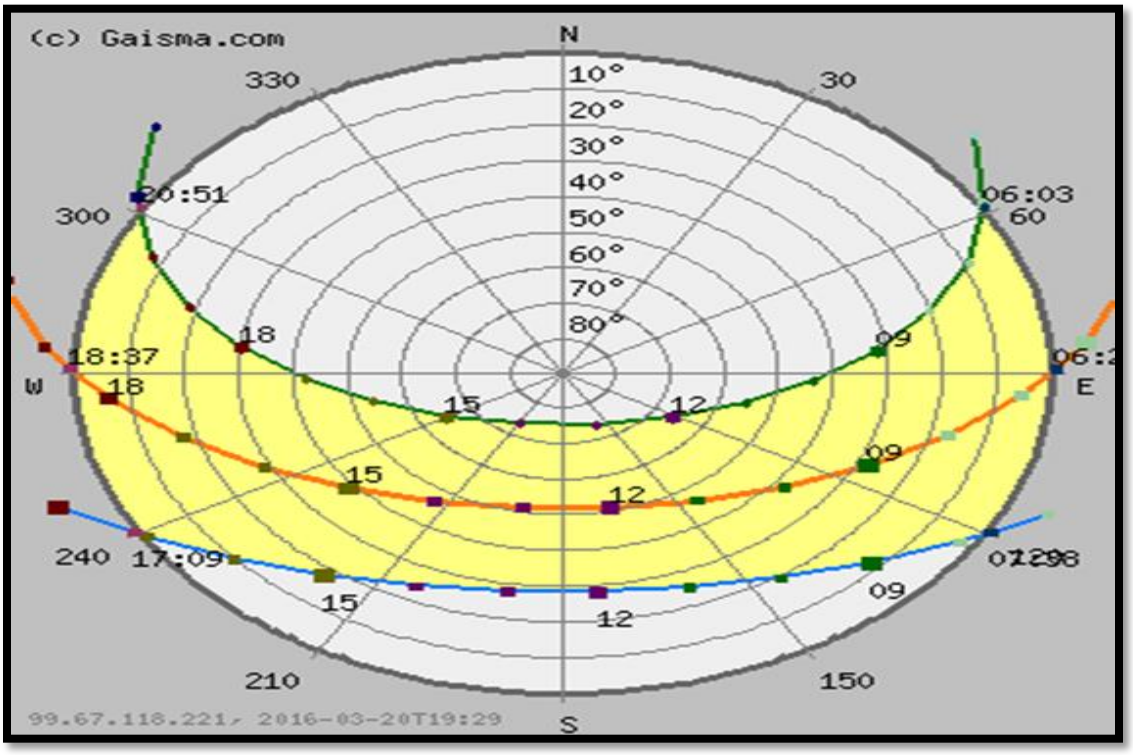


Figure 2-7: Stereograph of the sun path over Athens, Greece.

(http://www.gaisma.com/en/location/athens.html)

So, because the sun is never directly overhead, there is a higher chance of finding shade outdoors even at high noon. But, also because of the southern arc, buildings could be arranged to throw shadow on the open areas. The agora in Athens also lays in the shadow of surrounding hills, especially the Acropolis to the south with the Parthenon atop shining in the sunlight.

Because of the nature of the hills around the agora, the northern breeze is not blocked. There was airflow through the agora and buildings. The Temple of Hephaestus sits on a ramp shaped hill on the north-northwest side of the agora. Interestingly, during the summer Meltemi winds of 10 – 15 mph it would both diffuse around this hill and follow up the hill flowing over the top of the agora. This type of flow would promote air movement below it, but at a much lower rate at ground level in the agora. Also, because the

agora is in a sunken bowl, cooler air settles in it. Figure 2-8 is an artist's depiction of what it would look like in the shadow of the Acropolis.

Figure 2-8: Artist's rendering of the shaded agora with Mt. Acropolis shining on the hill.

(Leo von Klenze - Neue Pinakothek (Gallery), Munich. Reconstruction of the Acropolis and Areios Pagos in Athens, Leo von Klenze, 1846)

In nature, when an organism finds a favorable environment they thrive. Is it possible that the Greek agora was the perfect environment for man? Much of modern Western thought can be traced back to the 30 acres in the shadow of the Acropolis. Next, the factors that cause humans to be comfortable are examined.

Human Comfort and Design

To create a space for humans it is important to understand the ideal environment for them. Arguably, this should be the prime objective in the design of outdoor spaces. But putting this argument aside, what is the comfort range for humans? Some of the factors to examine:

- Temperature
- Wind movement
- Light
- Sight distances
- Walking distances
- Social distances

Several other minor factors will be examined as well. Temperature is the primary condition to understand—especially in the southern United States where the University of Texas at Arlington is located. Each site has different priorities but for clarity and brevity in this study, two areas are discussed: Athens, Greece and Dallas/Fort Worth, Texas. Yet, the implications are quite universal and applicable anywhere in the world with slight priority adjustments. The human body is the main source of study and will be the same anywhere in the world or universe. Also, it is helpful to recall some of the environmental findings in the Athens agora as this section proceeds.

As noted earlier, the sun and water are the driving forces for weather and life itself. Humankind has evolved over thousands of years to survive in Earth's atmosphere. This species further separated from the reptiles, fish and insects by being warm-blooded. Warm-blooded animals are less dependent on ambient air temperature because of the internally regulated body temperature, but still have an optimum range of operation and comfort.

The optimum internal body temperature for humans is 98 – 100 degrees Fahrenheit. Body temperature is regulated by the hypothalamus in the brain. Through metabolism the body creates heat and a series of sensors feed information to the brain like a thermostat in a house. Body heat is transferred through radiation, conduction, evaporation and convection. Now, because these four principals are so important, a quick physics review and definition is presented here:

Heat radiation: The heat from within the body is transferred to the surrounding atmosphere.

Evaporation: When moisture on the skin and clothing (sweating or any other source) evaporates, the change (work) from liquid to vapor uses up heat causing the area to drop in temperature.

Heat convection: The process of air or water flowing by the skin and carrying away body heat.

Heat conduction: The body conducts heat to whatever the skin is in direct contact with (this includes colder air or water).

Most of these functions are passive, such as heat radiating through skin, but a fairly unique mechanism to humans is evaporation through perspiration. At an internal temperature around 98.6 degrees the body begins to sweat. The perspiration begins lightly and barely noticeable at first but more and more profusely until the internal temperature reaches around 104 degrees. An internal body temperature drop of six degrees can mean hypothermia and possibly death. So, there is a 12 degree internal temperature window between life and death. In retrospect, a reptile's optimum internal temperature range is 50 – 104 degrees. But, alas, that is only half the story. The other side of the equation is controllable by planners and designers: ambient temperatures.

Fortunately, there has been a great deal of research by the heating/air conditioning industry and architects about ambient air temperature and human comfort. These findings are for controlled, indoor environments but are a great place to start. A quick note: due to metabolic changes in the body for different weather seasons the body is comfortable at slightly different temperature levels when adapted to cold or hot; also, obviously, it is slightly different from person to person. In milder climates there is less change. Table 2-1 shows the ideal temperature and humidity range for human comfort.

Table 2-1: Ideal temperature and humidity for human comfort.

Ideal condition is temperature between 68-78 F and 45% RH year round
Maximum: 78F (summer)
Maximum: 68F (winter)
Relative Humidity (RH): 30% - 60% RH

It is with the indoor environment comfort level data and the understanding of human internal thermodynamics that the outdoor space designer should begin work. There are several other factors in the less controlled outdoor space. Weather, for the most part, can't be controlled. But, by understanding it a little better, it might be used to advantage. While using the 78 degree ambient air temperature and 45% RH as ideals, it is more important to look at the 98 – 100 degree internal body temperature in the following analysis about air movement and humidity.

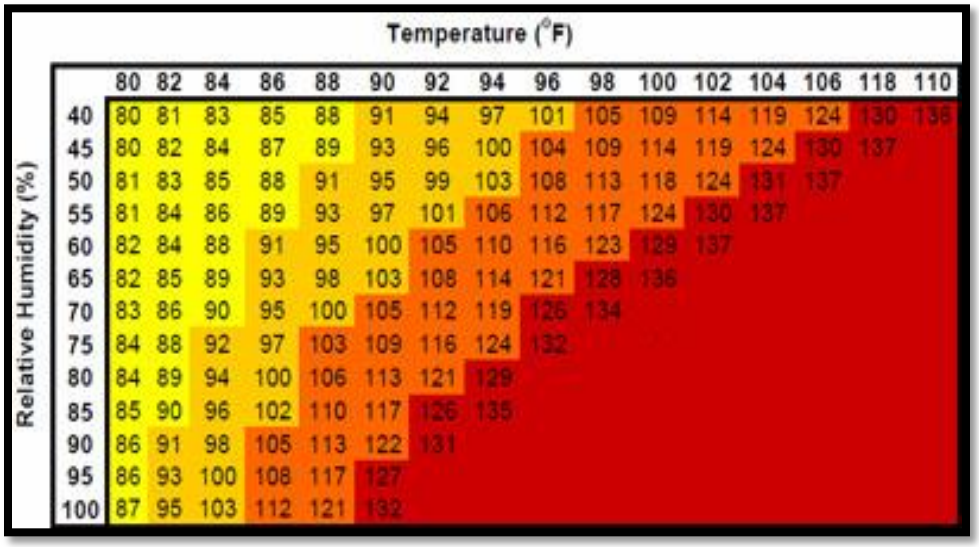
The entire space is, foremost, designed around the human being. So, without controlling the weather it is still possible to control body temperature or perception of comfort. Even the color of a space can change the perception of temperature; cooler colors like green and blue will help a space seem cooler. Another more tangible factor of temperature control is through air movement. Although the air movement itself does not change the ambient air temperature, it has a significant impact on body temperature. In the earlier discussion it was determined that the body had four methods of regulating heat: radiation, conduction, evaporation and convection. The body is constantly radiating heat but heat radiation is usually controlled on a personal level by use of clothing to retain or release heat. Evaporation is reliant on moisture but is enhanced by air movement. Conduction is dependent on temperature differences but also enhanced by air movement. Convection is the major user of air movement; convection occurs as air moves past the skin. The more wind, the more heat loss. A further note is that without any air movement the body develops a boundary layer of heat that acts as insulation. Wind is a

great tool for heat convection and cooling the body but at what level does the wind become disruptive and uncomfortable?

Luckily, there have been numerous studies on air movement and human comfort. All sources were consistent and the general consensus was that air movement became noticeable and pleasant around one mile per hour. At two miles per hour it became a matter of constant awareness. At 3 miles per hour it started to become an annoyance. Unfortunately, this is a small range to use for temperature control by convection. Fortunately though, a huge mass of air can be moved even at two miles per hour; this is around 200 feet per minute, so will keep an area constantly supplied with fresh air. Also good to know how important a gentle breeze is to the comfort of an outdoor space.

Humidity is another factor important to the body's ability to regulate temperature. The more saturated the air becomes the more it hinders evaporative cooling. The relative humidity percentage is a description of how full of moisture the air is. At certain temperatures the air can hold a certain amount of moisture. Hotter air is less dense and can hold more water. When a column of air becomes completely saturated it reaches its dew point and the water is released as dew or rain. Often rain is caused when warm air meets cold air and is rapidly cooled and as the air condenses reaching the dew points and releasing the rain. Dry air is much more receptive to the moisture on the skin and gives the impression of being cooler than the thermometer may indicate. This is the purpose of the heat index and very important to human comfort because it is the body temperature that is more crucial than the actual air temperature. A temperature of 90 degrees feels like 100 at 60% humidity but 91 at 40%—somewhat acceptable—but at 85% RH it would feel like 117 degrees! Table 2-2 is a chart to figure heat index through various temperature and humidity combinations.

Table 2-2: Temperature and humidity table to find heat index.



Relative Humidity (%) \ Temperature (°F)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	118	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	128	136					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Conversely, if the air becomes much dryer than 30% RH it can be uncomfortable to the skin and eyes, as well as drying out the mucous membranes of the nose and mouth. Also, in cooler weather, it is the wind that has the biggest impact on how the body feels. Thus, the wind chill factor combines wind speed and temperature.

There are some ways to affect the ambient temperature in an area. They will be discussed more specifically later, but bodies of water, plants and water mists can have significant impacts on temperature, among other things.

Besides feeling the sun's heat, the light is seen. Natural light vies high on the outdoor space priority list. It is important to know sun path data for an area to be designed. Buildings and trees can be placed to take advantage of this information. Morning sun can shine into a place and add life and warmth while afternoon sun can be diffused by deciduous trees in the summer that lose their leaves in the winter allowing the warm sunshine. A stage would not want to be situated with an audience glaring into a setting sun behind a performance. The Aztecs and many ancient cultures designed their whole city around the sun and stars in minute detail.

The main focus on visual comfort has traditionally been light levels, contrast, and glare, and upon these there is agreement on many principles. The first is the more intense the task, the brighter the light

required. This is the main reason operating rooms are much brighter than offices, which are in turn much brighter than living rooms. The second pertains to contrast: the greater the contrast, the easier the comprehension. This is why almost every publication uses black text on white paper. The final point is that glare is undesirable, as it makes it difficult to see the object of attention. Contrast ratios are usually best from 1:3 to 1:10. Lighting is also important for security and safety. Night lighting can transform a space and its function for the evening hours and add a mood enhancing effect.

Besides the perception of temperature through the skin, and the visual world with the eyes, the ears hear a world that some claim is more accurate than even the eyes. Sound can be heard in the day and the night. Specific footsteps can be heard and the person identified through a wall that only Superman could see through. A friend can be identified on the phone before they mention their name. Sound is, undoubtedly, an important function for the human body. So, should be no less important in the design of a public space.

Humans can hear a range of pitches lying between 20 and 20,000 Hz. The concert ”A” the orchestra plays a few moments before starting a piece is 440 Hz. The loudness of a sound starts at 0 dB when it can barely be heard and starts to cause pain to the ear at 130 dB. For comparison, Table 2-3 shows different sounds and their approximate decibel levels.

Table 2-3: Sound comparisons at different decibels.

Thunder, chain saw	**120 dB**
Rock concert	110 dB
Lawn mower	100 dB
Motorcycle @ 25'	90 dB
Garbage disposal, freight train	80 dB
Freeway @ 50'	70 dB
Restaurant, office	60 dB
Conversation at home	50 dB
Library, urban ambient sound	40 dB
Quiet rural area	30 dB
Whisper, rustling leaves	20 dB
Breathing	10 dB

Sound is a compression wave that travels at 767 miles per hour at sea level on a dry day with a 68 degree temperature. A trick that many people use to estimate the distance of a thunder storms is count the seconds between a lightning flash and the sound of the thunder. If it takes five seconds to hear the thunder after the flash, a rough estimate is that the storm is a mile away (1000fps x 5 = 5000 feet or approximately a mile). Besides the rate of speed, it is also important to know how far and how fast sounds fall off when designing a space full of sounds. It would certainly be uncomfortable to be harassed by a cacophony of sounds. Turns out, there is a difficult sounding formula—inverse square law— that is actually easy to apply. Basically, sound level drops six dB every time it doubles distance. So, when sound travels from a person at 3 feet to a person at 50 feet (double of 3 is 6 then 12,24,48) it doubles 4 times and 6x4=24. That means if normal talking is 50 dB for the person three feet away, it would drop to about 25 dB (the sound of a quiet countryside) for the person 50 feet away.

Noise management becomes the next factor in human comfort. Because of the social function of a public space, noise will be sounds that interrupt normal conversation: 60 dB and above. Yet the

loudness of background noise is not the only problem. Higher frequencies are perceived as louder and more prone to elicit annoyance. Continuous, broadband sounds are more tolerable than intermittent sounds and pure tones. Non-stationary sounds or as location ambiguous noises are more disconcerting than sounds with a locatable source. And sound that is extraneous but still perceived as information-bearing causes more annoyance than the same quality of sound perceived as unintelligible. Hearing is quite effective up to 25 feet; it is still possible to hold a conversation up to that distance. Lectures with question and answers are possible up to 100 feet, according to Gehl (Gehl 1987).

There are several strategies of defense against noise. Higher frequencies are more easily blocked by solid objects like walls, planters, water features, sculptures, other people and vegetation. The longer waves of low frequencies travel more easily through objects, like the bass and kick drum outside a club, “thump, thump, thump,” but when the door opens the guitar and voice can be heard loudly. Also, road noise may be present from a nearby street. There are sound masking techniques, commonly known as white noise—or even more technologically advanced noise canceling devices. Road noise is generally around 70 dB; to cancel this sound would take a broadband sound of similar loudness (within 3 dB). Water fountains are mostly in the 70 dB range. Water features have a long history of being strategically placed to create a peaceful environment. Feng shui is an ancient Chinese design system that has particular placements of water features. Furthermore, armed with the inverse square law, distance is a great tool in noise abatement. Even a small space can be strategically arranged for sound comfort.

Of the five human senses of hearing, sight, touch, smell, and taste the last applicable one would be smell. Olfactory experiences of space are not usually recognized within discussions of human comfort, but nonetheless the presence of smell can deeply affect our experiences in one location or another. The smell of flowers and grasses, dust, exhaust, baked goods, bleach, each suggests a particular setting and perhaps even specific memories of places and events.

Starbucks is so concerned with smell that they will retool their machines and processes to ensure that the scent identified with their product is not lost. Research has also shown that linkages do not even need to be direct—consumers will buy more cards, for instance, if it is nearer a candle. The sense of smell in humans only recognizes variations in odor within a very limited range though. Humans can smell

the weak odors of each other (hair, skin, and clothing) at less than three feet. Perfumes and other stronger smells can be detected at around 10 feet. Beyond that, only the strongest smells reach the nose and brain (Gehl 1987).

Physical comfort is highly important to draw and keep people in public spaces but the social and psychological factors are no less important. Advertising and marketing firms rely heavily on how they make people feel to sell their products. A public space is no place to manipulate people or push a specific agenda, but it is important to know what promotes happiness and comfort. It is a place to promote social interaction and comfort for all involved. Really though, even the physical comforts are subjective. Air temperature is only one part of how warm or cold a person feels. So, increasing the chances of a person being emotionally happy can increase the chance—and range—of them being physically comfortable. Now is a good time to examine the social complexity of the human animal and what activities would apply to a public space.

The theme of the next few pages could be summed up as: human scale. Like a documentary following an African elephant herd in search of water, this study embeds with the human tribe as it has been studied and tries to describe what humans need in a public space. Jan Gehl has studied human interaction in public spaces for decades and written several books on the subject. Much of his data is used in this section.

Human vision and movement are very much on the horizontal plane. Walking speed is about three miles per hour. Looking forward while walking, the zone of vision is cast downward 10 degrees to better scout the walking path. Vision to each side is close to 90 degrees both ways but the vision upward is quite limited. Good way to hide from a human is to climb a tree. The social field of vision is 0 to 325 feet. Others can be seen and perceived as people at distance from 1,600 to 3,200 feet, depending on factors such as background, lighting, and particularly, whether or not the people are moving. At approximately 325 feet, figures become human individuals (Gehl 1987).

An example of how behavior is affected by this range is a sparsely populated beach where groups distribute themselves at about 325 foot intervals, as long as there is available space. At this

distance, the groups can perceive that there are others farther along the beach, but it is not possible to see who they are or what they are doing. At a distance of between 250 and 325 feet it begins to be possible to determine with reasonable certainty a person's sex, approximate age, and what that person is doing. At this distance it is often possible to recognize people on the basis of their clothing and the way they walk (Gehl 1987).

The 250 to 325 feet limit also affects spectator situations in various sport arenas, such as football fields. The distance from the farthest seat to the middle of the field, for example, is usually 250 feet. Otherwise spectators cannot see what is going on. Not until the distance is considerably shorter does it become possible to discern enough detail to perceive other people as individuals. At a distance of approximately 100 feet, facial features, hairstyle, and age can be seen and people met only infrequently can be recognized. When the distance is reduced to 60 to 80 feet, most people can perceive the feelings and moods of others. At this point the meeting begins to become truly interesting and relevant in a social context. A related example is the theater. The distance between the stage and the farthest audience seats in a theater is usually a maximum of 100 to 115 feet. In theaters primarily feelings are communicated, and even though the actors are able to "enlarge" visual impressions by means of makeup and exaggerated movements, there are strict limits as to seeing (Gehl 1987).

At even shorter distances the amount and intensity of information is increased greatly because the other senses can now begin to supplement the sense of sight. At distances of 3 to 10 feet, at which normal conversations usually take place, the experience involves the degree of detail generally necessary for meaningful human contact. At still shorter distances, impressions and feelings are further intensified. Elevators, for example, are practically impossible spaces for ordinary conversations; there is no way to avoid undesired contacts or to back out of undesired situations. On the other hand, where an area is too large, conversations cannot get started. Surveys in Australia, Canada, and Denmark demonstrate a distance of 10 feet to be very useful in this context according to Gehl's research (Gehl 1987).

Personal distance (1 ½ to 4 ½ ft.) is the conversation distance between close friends and family. An example is the distance between people at the family dinner table. Social distance (4 ½ to 12 ft.) is the distance for ordinary conversation among friends, acquaintances, neighbors, co-workers, and so on. The sofa group with armchairs and a coffee table is a physical expression of this social distance. Finally, public distance (greater than 12 ft.) is the distance used in more formal situations—around public figures or in teaching situations with one-way communication or when someone wants to hear or see an event but does not wish to become involved (Gehl 1987).

Human sense organs tend to perceive and process the details and impressions that are received at walking and running speed, that is, 3 to 9 mph. If speed is increased, the possibility of discerning details and processing meaningful social information drops sharply. When two people walk toward each other, approximately thirty seconds pass from the time they see or recognize each other until they meet. Meanwhile a mass of perceived information increases gradually, giving each person time to react to the situation. If the reaction time is reduced, the ability to perceive and respond to the situation disappears, as is the case when a car quickly passes a small sign on the road.

Besides distance, there are several factors that can either isolate people or put them into contact. Gehl has five principles of isolation or contact:

1. Walls
2. Distance
3. Speed
4. Levels
5. Orientation toward each other

Another important factor for attracting people is people. From Gehl's research he surmises:

“Children would rather stay in and watch television because it is so dull outside. Old people do not find it particularly entertaining to sit on the benches, because there is almost nothing to see. And when there are few children playing, few people sitting on benches, and few walking by, it is not very interesting to look out of the windows. There is not much to see.” (Gehl 1987, 82)

In gauging how much a space is used, there are two factors: 1) how many people? 2) how long? If three people sit at a table for sixty minutes each, throughout the period three people are present in the space. If thirty people each sit at a table for six minutes, the activity level—the entire time spent outdoors—is the same (30 X 6 = 180 people minutes). Within the period in question there is an average of three people present in the space per hour. Also, if the speed of movement is reduced from 35 to 3.5 mph, the number of people on the streets will appear to be ten times greater, because each person will be within visual range ten times longer. Along this same strain, the farther away from the doors the cars are parked, the more will happen in the area in question, because slow traffic means lively cities. But, never the less, it is important to have diverse zones in a public space, like zones of quiet/peaceful and zones of fun/lively. Figure 2-9 is an idea sketch of various zones of interaction that could take place in a relatively small area.

Separating the different zones it is important to remember the usual radius of action for most people on foot is limited to 1,300 to 1,600 feet per excursion and the fact that the possibilities for seeing other people and courses of events are limited to a distance of between 65 and 330 feet, depending on what is seen. Seating should be spaced accordingly. Also seating can be arranged to encourage comfortable conversation, some studies suggest that individuals who sit in relatively close proximity and at 90-degree angles, have far more conversation than those who sit across from one another or side-by-side.

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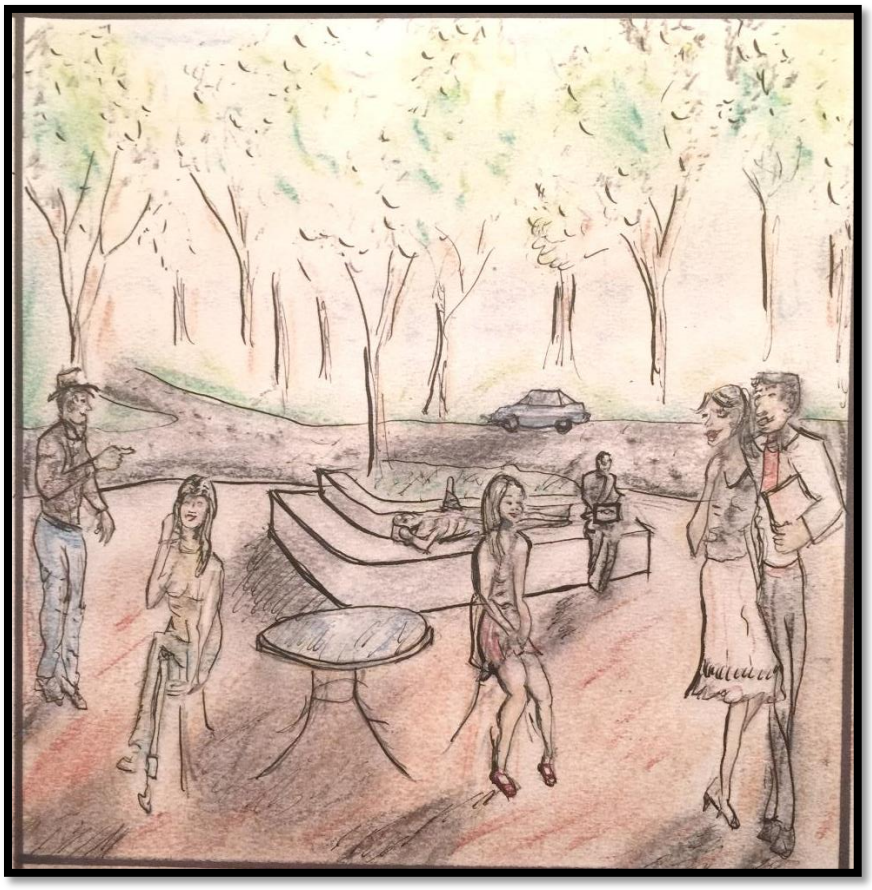


Figure 2-9: Socialization zones.

(Idea sketch by Steve Witherspoon)

The last three issues for human scale plazas are shop spacing, level changes and edge zones. The usual distance between stalls in the marketplace and in department stores is 6 to 9 feet, a size that permits pedestrian traffic, trade on both sides, and a clear view of the merchandise on both sides. In Venice the average street width is 9 feet, a dimension that provides room for a pedestrian traffic flow of forty to fifty pedestrians per minute. Most store fronts are no wider than 15 feet in pedestrian areas (the mall etc.) to keep interest. In city streets, the length of frontages should be carefully dimensioned. A rhythm frequently found in shopping streets in all parts of the world is 15-25 units per 330 feet.

Because humans interact in the horizontal plane, many plazas and businesses suffer when they use excessive level changes. Activities that take place on the same level can be experienced within the range limitation of the senses, that is, within a radius of 65 to 330 feet, depending on what is seen, and can easily move about among activities. If something happens on a level that is only a short distance up, possibilities for experiences are greatly reduced. Functions located 170 to 330 feet from one another along a street interrelate more readily than functions placed just 10 feet over or 10 feet under one another.

The last important feature in this study for human comfort in plazas is edge zones. To help understand, a person could imagine going back in time thousands of years and zooming in to the face of early man. His nostrils are flared as he sniffs the air in jolts, his eyes wide—almost crazy—and his brow deeply wrinkled as he looks left and right. He waits. He sniffs and looks left and right again. This is life and death; he stands at the edge of the forest and needs to cross a section of open savannah. He will be visible to prey and will not have any measure of protection but running or fighting: neither of these are effective against lions or any other type of horrible creature that roamed the plains in those days. Most animals have this same caution, even the lions themselves. Many researchers have observed this same behavior in public spaces. Human's first move to the edge zones and are most comfortable there. Many will stay in this comfortable area while some will move to the open areas when they look "safe". For the sake of human comfort, a plaza should have lots of edge areas.

A plaza is the living room of the community. It should be a comfortable place to talk and meet with friends and family. A good plaza would have integrated activities for all ages. So, after understanding the birth of the agora with its functions and importance to the world and then trying to understand the environment that would be comfortable to humans, the next step is using modern solutions to perhaps even rival the old agora of Athens.

Water and Vegetation

Through time, urban areas became more and more populated until recently more people live in cities than rural areas. It was around the same time the Urban Heat Island effect was noticed. Because the natural environment was mostly scraped off of the surface to add concrete and asphalt, the

temperature rose in the urban areas. Luckily, air conditioned buildings, homes and cars were a refuge of human comfort. As more of the Earth's surface becomes urban it starts to become a problem that has to be remedied at local levels. To take that a step further, for human comfort sake, a plaza needs to be an Urban Cooling Island. This is exactly what happens with a few changes—not only does the temperature drop in the plaza but cools the surrounding area as well.

Many studies have been conducted on the cooling skills of trees, plants and water features. Many of the studies simply place a thermometer in an open area next to a tree and placed another thermometer under the tree. In the right conditions it can be as high as 25 degrees cooler under a tree but the standard difference is 10 degrees Fahrenheit. Most of the cooling effect is from direct shade, the leaves and branches block the sunlight. Several degrees of drop in temperature come from evaporation; plants transpire moisture, taking advantage of the evaporation process discussed earlier—even the small plants that are not supplying direct shade. In Figure 2-10 four half-pint water bottles were set on a table: two clear and two painted black. One of each color was set in the shade and the other in the sun. The temperatures were measured from 11:25 am to 5:15 pm.

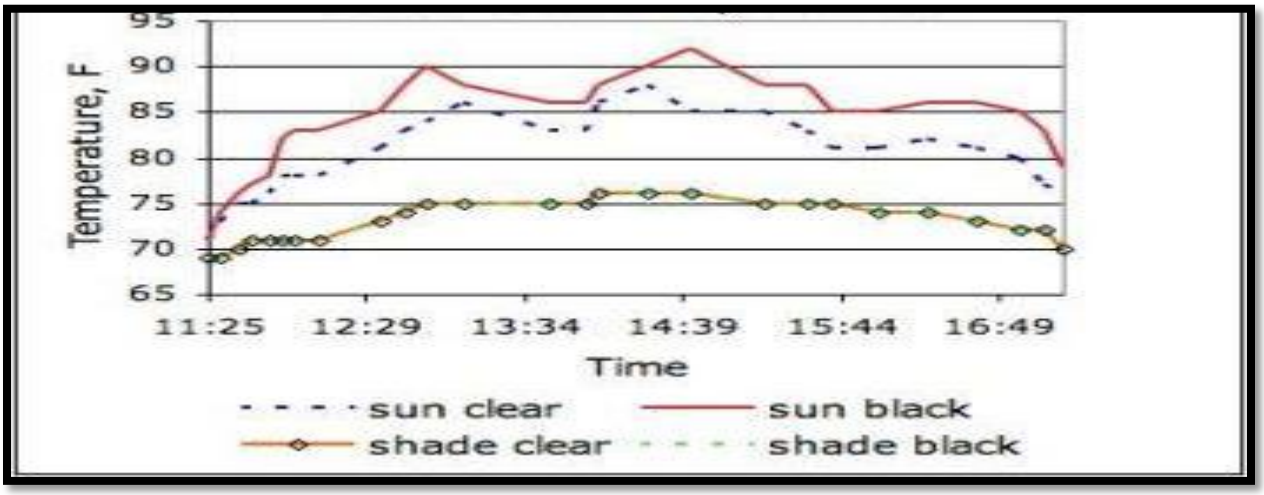


Figure 2-10: Water bottle experiment.

(http://articles.extension.org/pages/58136/trees-and-local-temperature Diana Rashash, NC Cooperative Extension.)

Bodies of water and water fountains are another resource for cooling. The presence of a water feature will cool an area 3 – 10 degrees Fahrenheit. In earlier days homes in the warmer climates had courtyards and water features. There is an added benefit with a fountain or waterfall because of evaporation can add around a five degree drop in air temperature.

The combined cooling of the plants, trees and water can significantly add to the comfort of a plaza. It is important to account for the prevailing winds and sun path. A couple strategies that landscape architects use, is to plant deciduous trees in areas that need shade in the summer but could benefit from winter sun when the leaves fall for the season. Also seen in Figure 2-12 is how an evergreen shrubs can be utilized for windbreaks since they have “leaves” in the winter when the cold wind is unwanted.

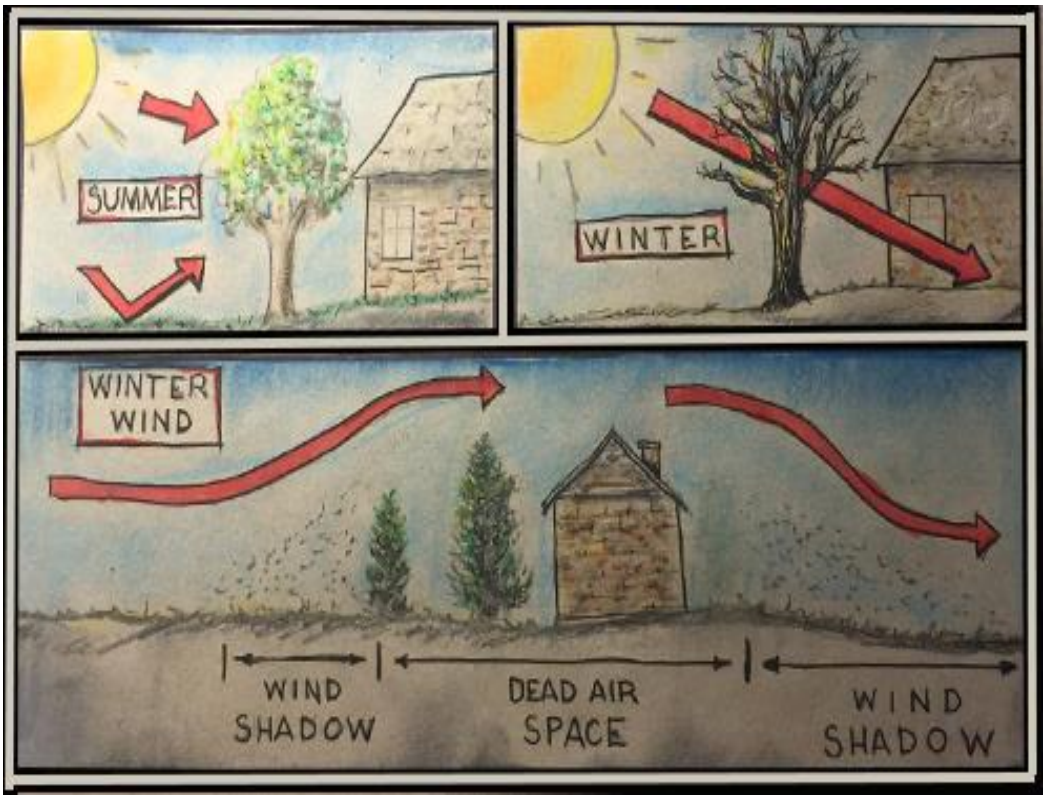
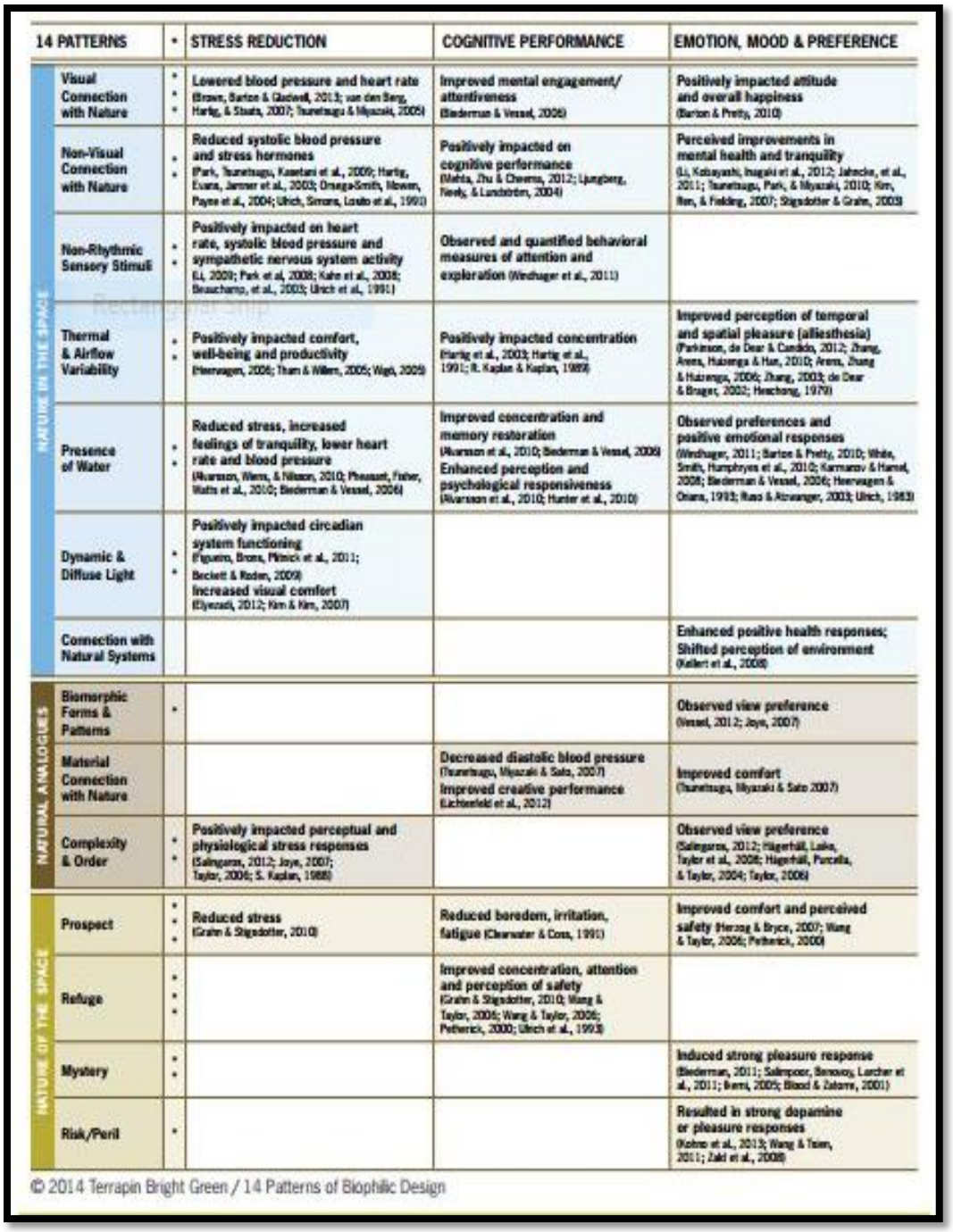


Figure 2-11: Tree functions.

(Idea sketch by Steve Witherspoon)

Another, often underappreciated, effect of water fountains and waterfalls is the production of negative ions. Normally the atmosphere is full of positive and negative ions. Air conditioning, lack of ventilation, and long dry spells remove negative ions, which usually serve to latch onto airborne dirt particles and wrestle them to the floor, rendering the air purer. Roughly one-third of the population seems to be particularly sensitive to negative-ion depletion. The proportion of negative ions is highest around moving water: storms, oceans, rivers and waterfalls. It's no wonder that people feel so energized at the beach. The best ratios of negative to positive ions are associated with waterfalls and the time before, during and after storms. The worst are found in a windowless room and closed moving vehicles. Air purifiers typically work by emitting negative ions, which purify the air in a room by attaching to impurities and sinking them. Water fountains act the same way but are more appealing to the eye.

Besides the physical help to improving the plaza environment there is a well-studied psychological enhancement from plants and water in the space. A few minutes with the sight, sound, smell and feel of nature rejuvenates and de-stresses. Many types of medical facilities have documented faster healing times when a natural area is available. Often the sound of fountains around the perimeter of a plaza can create a separate space or oasis that feels safe and unaffected by the hustle and bustle of a concrete city a few feet away. It would be even better to have birds chirping and the various sounds of nature. Watching fish, birds and squirrels give interest and comfort. Watching a fountain or rippling water can be mesmerizing like watching a camp fire and very similar to meditating. A space that is psychologically pleasing can create a sense of well-being that humans can find comfort in and crave for many trips.



14 PATTERNS	*	STRESS REDUCTION	COGNITIVE PERFORMANCE	EMOTION, MOOD & PREFERENCE
NATURE IN THE SPACE				
Visual Connection with Nature	* * *	Lowered blood pressure and heart rate (Brown, Barton & Gladwell, 2013; van den Berg, Hartig, & Staats, 2007; Tsunetsugu & Miyazaki, 2005)	Improved mental engagement/ attentiveness (Biederman & Vessel, 2006)	Positively impacted attitude and overall happiness (Barton & Pretty, 2010)
Non-Visual Connection with Nature	* *	Reduced systolic blood pressure and stress hormones (Park, Tsunetsugu, Kasetani et al., 2009; Hartig, Evans, Jamner et al., 2003; Ottosson & Grahn, 2005; Payne et al., 2004; Ulrich, Simons, Losito et al., 1991)	Positively impacted on cognitive performance (Mehta, Zhu & Cheema, 2012; Ljungberg, Neely, & Lundström, 2004)	Perceived improvements in mental health and tranquility (Li, Kobayashi, Inagaki et al., 2012; Jabucko, et al., 2011; Tsunetsugu, Park, & Miyazaki, 2010; Kim, Ren, & Fielding, 2007; Stigsdotter & Grahn, 2003)
Non-Rhythmic Sensory Stimuli	* *	Positively impacted on heart rate, systolic blood pressure and sympathetic nervous system activity (Li, 2009; Park et al, 2008; Kahn et al., 2008; Beauchamp, et al., 2003; Ulrich et al., 1991)	Observed and quantified behavioral measures of attention and exploration (Weshuger et al., 2011)	
Thermal & Airflow Variability	* *	Positively impacted comfort, well-being and productivity (Heerwagen, 2006; Tham & Willem, 2005; Wigo, 2005)	Positively impacted concentration (Hartig et al., 2003; Hartig et al., 1991; R. Kaplan & Kaplan, 1989)	Improved perception of temporal and spatial pleasure (aliesthesia) (Parkinson, de Dear & Candido, 2012; Zhang, Arens, Huizenga & Han, 2010; Arens, Zhang & Huizenga, 2006; Zhang, 2003; de Dear & Brager, 2002; Heschong, 1979)
Presence of Water	* *	Reduced stress, increased feelings of tranquility, lower heart rate and blood pressure (Alvarsson, Wiens, & Nilsson, 2010; Pheasant, Fisher, Watts et al., 2010; Biederman & Vessel, 2006)	Improved concentration and memory restoration (Alvarsson et al., 2010; Biederman & Vessel, 2006) Enhanced perception and psychological responsiveness (Alvarsson et al., 2010; Hunter et al., 2010)	Observed preferences and positive emotional responses (Weshuger, 2011; Barton & Pretty, 2010; White, Smith, Humphryes et al., 2010; Karmanov & Hamel, 2008; Biederman & Vessel, 2006; Heerwagen & Orians, 1993; Ruso & Atzwanger, 2003; Ulrich, 1983)
Dynamic & Diffuse Light	* *	Positively impacted circadian system functioning (Figueiro, Brons, Plitnick et al., 2011; Beckett & Roden, 2009) Increased visual comfort (Elyezadi, 2012; Kim & Kim, 2007)		
Connection with Natural Systems				Enhanced positive health responses; Shifted perception of environment (Kellert et al., 2008)
NATURAL ANALOGUES				
Biomorphic Forms & Patterns	*			Observed view preference (Vessel, 2012; Joye, 2007)
Material Connection with Nature			Decreased diastolic blood pressure (Tsunetsugu, Miyazaki & Sato, 2007) Improved creative performance (Lichtenfeld et al., 2012)	Improved comfort (Tsunetsugu, Miyazaki & Sato 2007)
Complexity & Order	* *	Positively impacted perceptual and physiological stress responses (Salingaros, 2012; Joye, 2007; Taylor, 2006; S. Kaplan, 1988)		Observed view preference (Salingaros, 2012; Hägerhäll, Laike, Taylor et al., 2008; Hägerhäll, Purcell, & Taylor, 2004; Taylor, 2006)
NATURE OF THE SPACE				
Prospect	* * *	Reduced stress (Grahn & Stigsdotter, 2010)	Reduced boredom, irritation, fatigue (Clearwater & Coss, 1991)	Improved comfort and perceived safety (Herzog & Bryce, 2007; Wang & Taylor, 2006; Petherick, 2000)
Refuge	* * *		Improved concentration, attention and perception of safety (Grahn & Stigsdotter, 2010; Wang & Taylor, 2006; Wang & Taylor, 2006; Petherick, 2000; Ulrich et al., 1993)	
Mystery	* *			Induced strong pleasure response (Biederman, 2011; Salimpoor, Benovoy, Larcher et al., 2011; Ikemi, 2005; Blood & Zatorre, 2001)
Risk/Peril	*			Resulted in strong dopamine or pleasure responses (Kohno et al., 2013; Wang & Tsien, 2011; Zald et al., 2008)

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Figure 2-12: Biological responses to the natural environment.

(http://www.terrapinbrightgreen.com/wp-content/uploads/2014/04/14-Patterns-of-Biophilic-Design-Terrapin-2014e.pdf)

Chapter 3

Methodology

To rediscover old, valuable methods and utilize new technology, an interdisciplinary approach was taken. After 100 years with the automobile and 75 years of air conditioning, some common knowledge slipped away. It is like forgetting how to make concrete after the Roman Empire fell or like sending a person in the woods alone with nothing after spending their entire life in a city. Some valuable lessons can be learned by examining the layout of the old agora. Taking the placement of the buildings, building types, terrain, and climate into account some basic truths can be found.

Modern western civilization began in the Greek agora. Almost all great leaps in human thought (in the western civilization) sprung from that small area. It is not much different than when other species suddenly flourish when in the optimum environment. So, a baseline is set with the ancient agora in Athens. The next step is understanding the human body and its basic comfort zones. After examining each of the optimum zones, it becomes apparent that they match up with the climate conditions within the ancient agora. These two factors are essential in understanding how to create a comfortable plaza for humans.

After acquiring important information, often, the next challenge is communicating it. Plaza design is mostly visual, yet it is very cooperative. It is an exchange of ideas among several parties. For the purposes of this thesis a special visual communication was adopted. This method is called the idea sketch.

Understanding that any visual art requires the participation of the viewer is an important element to understand. A large oval and two small ovals with some other well placed lines start to emerge as a human face to most viewers. Adding more detail makes it easier and easier on the viewer, and what each person sees becomes more and more similar. The Impressionists and Abstract artists started experimenting with that level of understanding. Some of Picasso's paintings have an eye here a nose there, hardly discernable, but if different viewers were asked what they saw it would be different. Somebody might say it gives them happy thoughts of watching their grandma make biscuits in the

morning when they were a child. Others may be repulsed and claim it a repugnant act of a mass murderer secretly hidden in the arrangement of paint colors.

So, with the idea sketches, the point is to only give enough detail to point in a certain direction, leaving it just loose enough to allow different people to see different things according to their experiences and thoughts. This way discussion and creativity is encouraged. Hand sketching with very few straight lines is used to promote the feeling of a thought in progress. Small details are also consistently used to draw participants into action. Exaggerated use of perspective is one modification to draw in idea harborers. The lines closer to the viewer are drawn crisp while the lines further away appear more blurry like the depth of field effect of a camera lens. Most objects are oriented slightly toward the viewer, departing slightly from their realistic position, but keeping with the theme of drawing in the viewer for participation. Pastels are used for coloring for the light, dreamy effect. It is nothing serious or authoritative that would discourage comment. It is a quick (30 minutes to an hour) sketch that would not create thousands of dollars to redraw for a different idea. Special care is taken with color: most warm colors are used in the foreground with cooler colors in the background to add depth even at the expense of reality. Also, human figures are drawn expressively and somewhat vaguely.

To counteract the artistic elements, there is a scientific element: an experiment. A special water, fish, and plant system is discussed. This is the culmination of a three-year study. It is suspected that the system was used by the Aztecs and the Babylonians but the most recent version came out of research by the National Aeronautics and Space Administration (NASA). Growing up as a child of a Master Gardener and completing an undergraduate degree in Urban and Environmental Studies, the experiment was of great interest. Also, of great interest are the amazing results from the system. It is a perfect fit for a plaza.

After looking at each of the elements a human requires being comfortable in an outdoor space, it would be helpful to apply it to a specific area to better understand the process. A case study is used in the closing portions of the research to give a clearer picture of the outcome. The case study is the City of Burleson in Texas. The City is proposing a plaza across from the City Hall and is in the designing phase. It is an area very similar to many plazas. A series of design proposals are suggested to fit with the

findings in this paper to create a comfortable plaza that human's enjoy regularly congregating in to feel human and be human.

Two surveys are analyzed. Any public project should include public input. Some valuable information is garnered from these surveys and some twists are encountered. Almost completely though, citizens are asking for things that would have been found in the ancient Greek agora (aside from automobile parking and Wi-Fi!). But, being involved in the process over several months has been an enlightening experience. And, it is with great hope this research is helpful to plaza designers and city planners anywhere in the world with the same mission of creating an outdoor space comfortable for the human being, foremost.

Chapter 4

Research and Analysis

Water and plants are of utmost importance in building comfortable plazas. Many times though, developers opt out of water features and larger plants due to ongoing maintenance. More recently NASA has rediscovered a water/fish/plant system called aquaponics. It is thought by many that it was the system that maintained the Hanging Garden of Babylon. The Aztecs practiced a form of early aquaponics by raising fish alongside crops. They built artificial islands known as chinampas in swamps and shallow lakes and planted them with maize, squash and other plants. Aquaponics is a completely self-contained ecosystem with all of the natural elements for a comfortable plaza. The system is mainly utilized for growing food crops in urban areas with small space, or even indoors with special lighting. The design, type of plants, and type of fish are highly adaptable though.

Aquaponics is the combination of aquaculture (fish farming) and hydroponics (soil-less plant culture). In Aquaponics, the nutrient-rich water resulting from raising fish provides a natural fertilizer for the growing plants. As the plants consume the nutrients, they help to purify the water in which the fish

live. A natural microbial process keeps both the fish and plants healthy, and helps sustain an environment where all can thrive. Essentially, Aquaponics is organic gardening, without the soil.

Aquaponics is also one of the most sustainable and productive farming systems in the world. Consider the following:

• Aquaponics uses 90% less water than a conventional garden.

• Aquaponics uses a tiny amount of energy, less than a light bulb

• Labor required to produce plentiful crops is reduced as much as 40%.

Generally, under reasonable conditions, every pound of fish can produce 70 pounds of fruit and vegetables. There should always be at least two feet of water above them at any time, including when the plant troughs are full of water. A reasonable amount of water for a fish should be about 5 gallons of water per each pound of fish. As a general rule, a 300 gallon tank will support 2 - 8' × 4' plant troughs, that is, 64 sq. ft. Therefore, a 150 gallon tank will support 1- 8' × 4' plant trough, that is, 32 sq. ft. This is all very negotiable as waste produced by your fish will be determined by many factors including fish type, temperature, feeding schedule, time of year and stress. Maintaining the bacteria level is very important to the nitrogen cycle. Mainly, it is important to remember the bacteria's susceptibility to direct sunlight; a portion of the fish tank must always be covered or shaded. Nitrifying bacteria are very light sensitive and are killed or greatly inhibited by direct sunlight.

The water pump is connected directly to the timer which is plugged into an electric socket. Generally for aquaponics applications, the timer is set to turn the water pump on for 15 minutes per hour. This fills the plant trough, hits the threshold level, and then cuts off. Since the water backflows slower through the water pump, there is a lag time and the plant roots are exposed the nutrient-rich water for about 1/ 2 an hour, each hour, which is desirable. This is known as contact time and critical to growing abundant plants. In other words, plant roots can only absorb nutrients so fast, and therefore need a specific amount of contact time with the water which carries the nutrients. Nitrifying bacteria temperature ranges for nitrifying bacteria is between 77 ° - 86 ° F. Of the 16 nutrients essential to plants, fish generally provide adequate amounts of 13: generally only lacking, iron, potassium, and calcium. These deficiencies

are common with aquaponics but can be easily supplemented if necessary. Composting worms (Red Wigglers) are a great addition to the ecosystem when a plant medium is used. Once the system is in balance it requires little maintenance besides feeding the fish. Fish feeding can be set up on an automatic timer or made available for plaza enjoyers to feed the fish if they desire.

Edible fish like Tilapia and Channel Catfish do well in this system but Goldfish and Koi are an even better species if they are not intended for food. Koi ponds are a great match for public space. Also, the plants do not need to be edible plants; normal landscaping plants do well in the system. Because of the soilless medium, the plants can be moved easily and landscaping plants moved for special projects like schools or other groups growing vegetables.

For this thesis some experiments were conducted in aquaponics. The water system and fish habitat was a series of garden ponds around 150 gallons with a small waterfall. Figure 4-1 shows some of the main items purchased at a local home improvement store.

Figure 4-1: Aquaponics parts used for the experiment.

(Lowes.com)

Garden ponds were selected to also experiment with aestetics and sound. Pictuered in Figure 4-2 are the four types of fish that were added over a period of three years. At the time the aquaponics system was added there were 23 fish:

- Plecostomus (algae eater) …….. .2
- Channel Catfish ……15
- Koi ……..2
- Gold Fish ……..4

Figure 4-2: Fish types used.

The gold fish were the first inhabitants and are the most hardy. They have survived an array of bad water conditions durring the learning process. Gold fish also produce more amonia than many species, so before the aquaponics system was added the water needed regular water changes and a robust filtering system and aerators. It can take several weeks for a new system to cycle. The water, after dechlorinating, required time to build up benefitial bacteria for a healthy nitrogen cycle. The nitrogen cycle is key to a balanced system.

The first step of a nitrgen cycle is the introduction of amonia from the fish and decaying matter (uneaten food usually). Nitrosomona bacteria are the first hungry friends to appear; they convert amonia into nitrites. Unfortunately, this is a difficult time in the initial stage because the nitrites will spike before the next group of friendly bacteria have time to populate. It is crucial to test the water daily for this nitrite spike and preform a partial water change when it occurs. When the nitrobacter bacteria has time to populate the water it will start to gobble the nitrites converting it to nitrates for the plants to absorb. Once the water regulates itself it can be a hardy system, and once the plants are added it can run on its own with very little maintenance.

The first pond was situated near a partial light soure for the aquatic plants. The light also spawned algae growth on the section receiving light. Because the aquaponic system was not integrated, the algae florished in the nitrate-rich environment. Algae was overtaking the system, clogging filters and fountain pumps. This is when the Plecostomus fish (Plecos) were introduced. The Plecos are foracious eaters of algae and florish in this environment. The drawback is they are tropical fish and cannot generally tolerate water cooler than 50 degrees—although the two in this system have survived three winters with small water heaters in the pond. Also, while most Plecos in aquariums are fairly small, these are over a foot long due to the high protein diet of algae. They are not mentioned in most farming style aquaponic systems but have proven quite valuable in the ecosystem of a system set up for aestetics and comfort. These fish are also very shy and are rarely seen. They are part of the catfish family and are hardy; especially tolerant of low oxygen environments.

The combination of the four gold fish and two Plecos settled into a low maintenance operation with filter cleaning and partial water changes about twice a month. The pond was mainly a peaceful place

to sit, watching the bright orange and white fish swim to the sound of a waterfall, and breathe in the negative-ion rich air as seen in Figure 4-3. It was by far the most popular spot of the property by the inhabitants and visitors.

The next phase was the aquaponics system as can be seen in Figure 4-4. Because of the experimental nature of the project this system was completely original with no prefabricated parts and designed to fit the specific site. The type of system was modeled on what is called the ebb and flow aquaponics and would be using a plant medium to hold the plants, bacteria and composting worms.

Figure 4-3: Main pond.

Figure 4-4: Aquaponics system set-up.

The tan plant trays were installed on a south facing wall that would receive optimum sunlight; and at a higher level than the fish pond so water would gravity feed back into the pond. Watertight drains were installed at the lowest level and the two bins joined. A vent pipe was also installed to ensure good draining. Two different water falls were added to the system to increase water oxygen and level changes. A small pump was connected to an inexpensive electrical timer to pump for 30 minutes several times during the daylight hours. The small fountain pump was submerged in the fish pond to pump water up three feet into ¾" PVC pipe with small holes at regular intervals for the plants and capped at the end to hold water pressure. Figure 4-5 shows a closer view of the plant bed and watering system.

Figure 4-5: Plant bed and watering system.

The plant beds were filled with a layer of Perlite, Spragham moss, and local riverbed gravel. In retrospect, the gravel was too high in limestone and created some minor pH problems. The plant medium should be inert and not leach any materials. Clay pellets are popular as a plant medium. A well-draining plant medium is also a great place for the beneficial bacteria and composting worms. Composting worms (in Figure 4-6) turned out to be a great addition to the aquaponics systems for a couple of reasons. First, they filled a very important niche of breaking down some of the solid matter and second—somewhat morbidly—they reproduced so profusely in the favorable environment that many of the baby worms were washing through the plant medium, drain stystem, series of waterfalls and landing in the fish pond with great delight to the fish.

Figure 4-6: Composting worms (Red Wigglers) delivered.

With the new aquaponics system fully operational it was necessary to add more fish and to plant seed. In the interest of urban food production a food fish would be the main species, but for another option a couple of high quality Koi were added. There are several species of fish that can thrive in aquaponics. The two most popular are Tilapia and channel catfish. In north Texas Tilapia are hard to aquire without special licenses because of the fear of them being released in the wild and becoming an envasive species not native to this area. Also, Tilapia are a tropical species that cannot survive the ocassional cold winters in Texas. They also like to eat other fish in the tank that are smaller than they. For this experiment, the native channel catfish were used. They are hardy enough for any of the temperatures in the region, do not need much space, and occupy a different niche than the gold fish and Koi. Catfish spend most of their time on the bottom and are night feeders. Gold fish and Koi feed during the day and are top feeders. So far, nobody has eaten another.

Figure 4-7: Catfish exploring and future precautions.

It is important to note that catfish can be vigorous swimmers and care should be taken when first introducing them to a new pond. Figure 4-7 shows the approximate size of the catfish and a net system to help prevent escapes. Some type of restraining devise is helpful for a few days and then if there is enough hiding spots—which they love—it is rare to see the catfish. Luckily, they survive for long periods of time out of the water and can simply be reintroduced to the pond even when they seem lifeless.

The plants, quite simply, florished as can be seen in the six week time lapse in Figure 4-8. This study began with an extensive background in traditional gardening, a degree in urban and environmental

studies and consulting work with organic landscape companies. The results were immediate and undeniable. Below is a thumbnail once a week for six weeks.

Figure 4-8: Six week time lapse for plant growth.

Incredibly, there was no maintenance to the system during the growing season. The system reached a point of homeostasis and as long as the balance was maintained, it took care of itself! Admittidly, it is unwise to plan on homeostasis because the nature of life itself leans toward throwing things out of balance with a constant state of adaptation. Aquaponics though, is a major step forward in creating an environment that humans can be a part of and comfortable to be in. It replicates the natural system and invites comfort. If a system is self sustaining, it implies a positive and productive environment. Plus, it is very adaptive and a good match to the plaza environment.

Design Outcomes for Human Comfort

Looking at the conditions for optimum human comfort, the ancient Greek agora was a perfect specimen. Because of the local climate and the placement of the agora it became a Garden of Eden. The modern human animal flourished in that environment and completely changed the course of history. Most of the basic tenets of modern civilization were hashed out and formulated in the ancient agora. The agora spawned modern civilization.

In modern times America suffers with health problems because people don’t spend time walking, time outdoors or socializing. A great number of people drive their cars out of the garage in the morning to an office building during the day and back home to the garage and into the house for the evening. The

human animal evolved to be outside in a 78 degree environment at 40% RH breathing in negative ions, absorbing vitamin enriching sunlight, with a slight breeze bringing the sounds of nature. Humans are social animals. The ability of humans to work together on big projects is one of the main things that separate them from wild animals. The plaza is the perfect environment for health and honing human skills. It is the perfect environment for fostering democracy and sense of community. A plaza is not simply a space in front of buildings!

For an example, this last section will look at a plaza being planned in Burleson, Texas. It is a typical situation and many of the elements discussed in this paper can be arranged in the yet undeveloped project. As seen in Figure 4-9, the plaza would be about 300 feet east to west and around 200 feet north to south depending on the final design. This area of the city is called Old Town because it is the area the town originally started in the late 1800's. The plaza benefitted by the small block sizes (300') due to being laid out before the emergence of the automobile and is already at human scale.

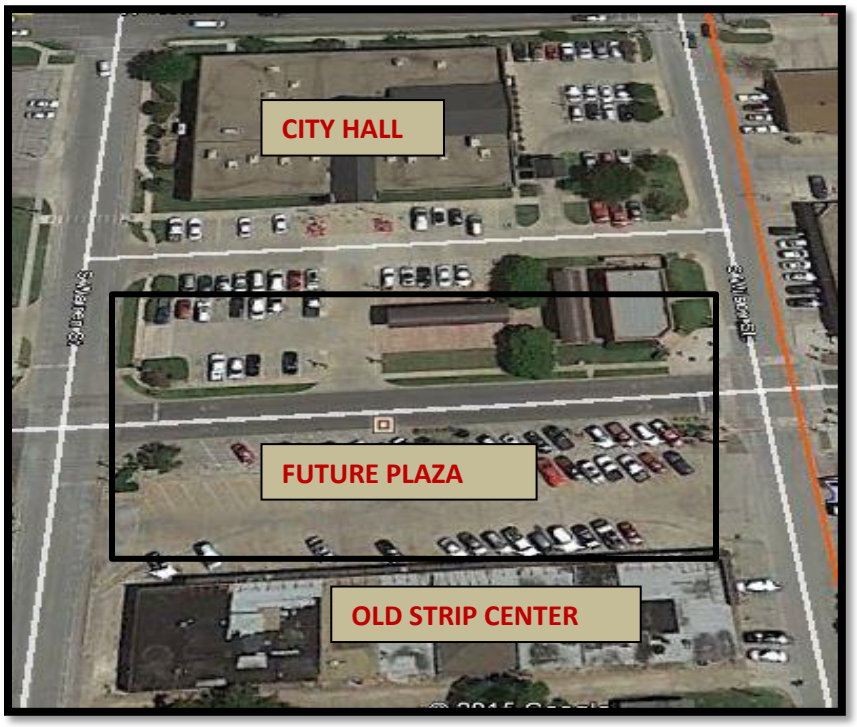


Figure 4-9: Proposed plaza site for City of Burleson, Texas.

The city is planning to remove the old strip center and build a three to five story mixed-use building for business, education and retail. The current footprint of the one story building is 300’ x 60’. Aesthetically, because the area allows it, the plaza should be 300’ x 185’. This follows the Golden Ratio found in nature and the human body (Phi, 1.618). This ratio is also used in architecture, and humans find it comforting and natural. This would only eliminate 16 parking spots in the southwest corner of City Hall parking lot and tie into the museum and rail cars on the southeast corner.

A sun path analysis shows a great fortune with the building location. A taller building on the south end of the plaza casts some shade. The shade area can be accurately predicted once the building height is determined. A building design recommendation for sun angles would also suggest an “L” shaped building with a side on the south and a side on the west. The western sun is associated with much higher temperatures than the rising sun. Also, most outdoor activities begin in the late afternoon and carry through to the evening hours. The glare of a setting sun has menaced many special occasions, ruining visibility and leaving the spectators with sunburnt faces the next day. The hottest wind comes out of the west as well.

Considering the wind, Burleson has prevailing southern winds that average 15 mph. This breeze is important for comfort, but not at 15 mph! Thinking back though at the old agora that started it all, there was a ramp shaped hill that diverted prevailing winds over the heads of its citizens. The wind above head level promoted gentle air movement but was not disruptive. So, it would be highly recommended that the building on the south side have second story breezeways as shown in the Figure 4-10 idea sketch. Breezeways would also allow a balcony area, stairs and seating space for spectators during events.

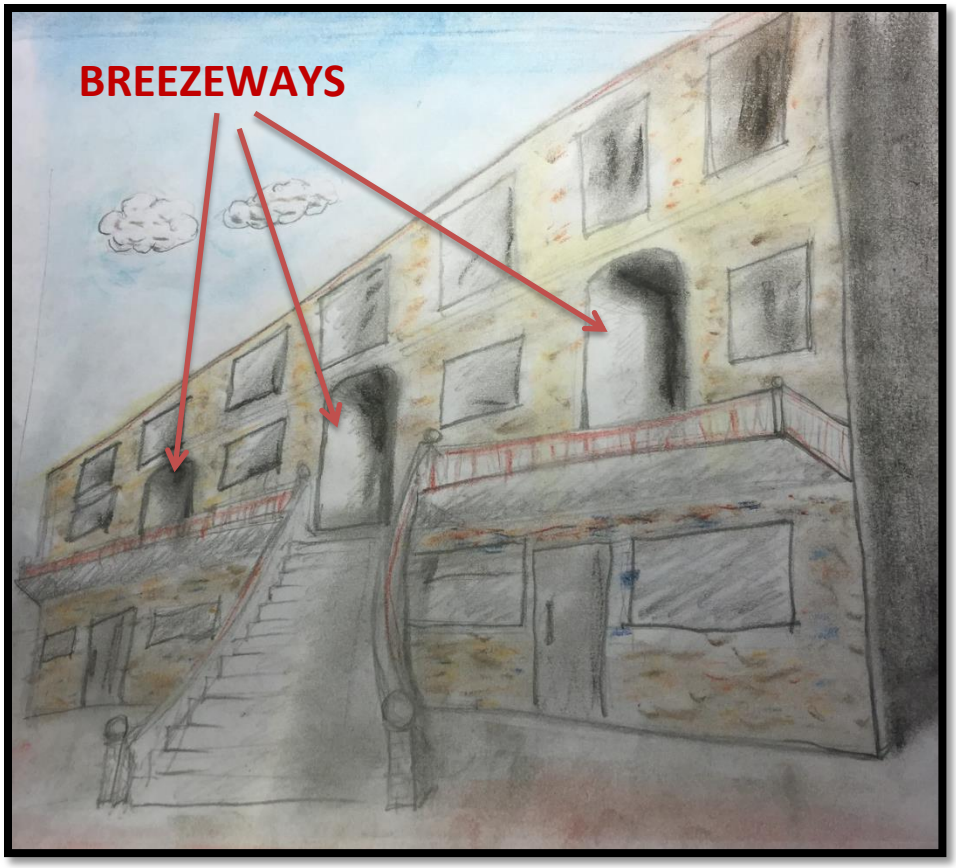


Figure 4-10: Idea sketch using wind and sun considerations for a specific site.

(Idea sketch by Steve Witherspoon).

Because of the size of the plaza, the outdoor stage would need to be near the center of the area. The west side would need plenty of shade with larger trees or another structure. Most noise would be coming from the northwest and northeast of this site so would be a great place for fountains and plants. Much of the perimeter would benefit from water features for cooling, sound masking, and extra edge areas. A further note on edge areas though, care must be taken with plants and other structures not to block views. For security, sense of safety and comfort, an area from about three feet high to around seven feet should be clear throughout the plaza. Any two people should be able to reasonably see one another no matter where they move in the plaza area. Also, a wide path would be left open through the center north to south and east to west for pedestrians and stage viewing.

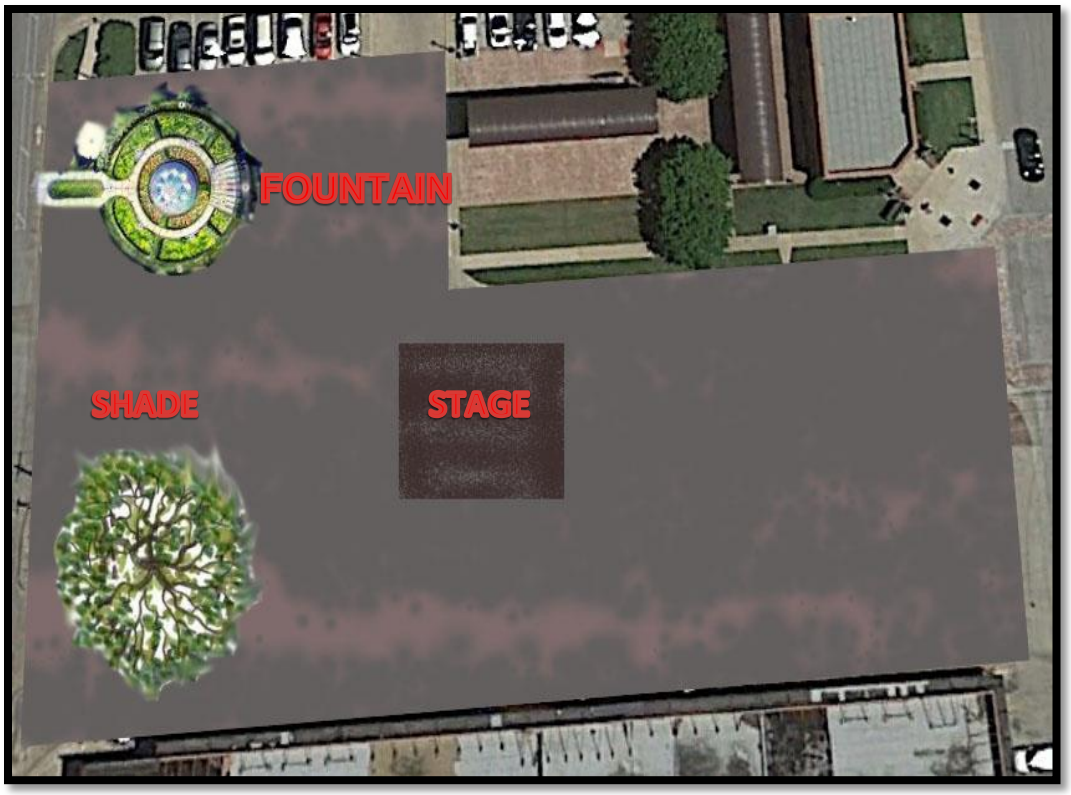
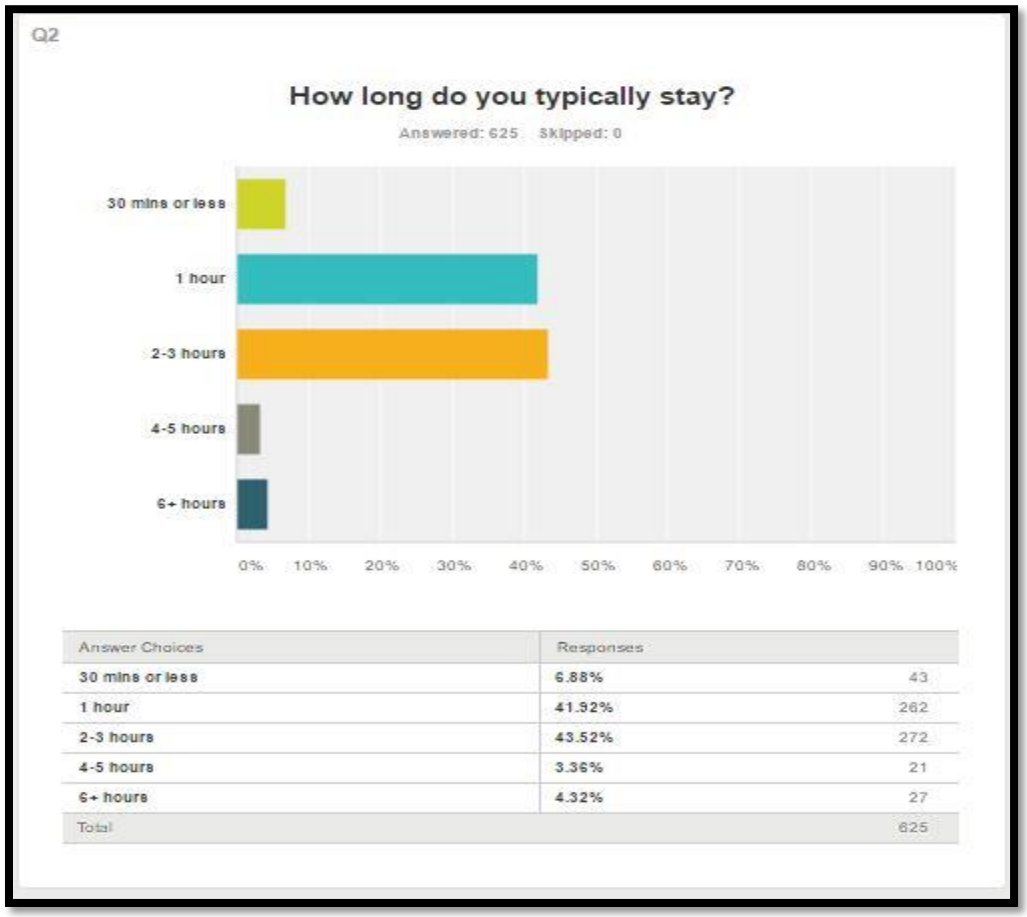


Figure 4-11: Basic elements in plan view.

After a few important considerations for human comfort, the rest would be open to design and public input. The City of Burleson has begun the process of gathering feedback from citizens and seeking consultants for design guidance. The first survey was eight questions to build a base of information for the continually narrowing process. Six pertinent questions were analyzed for the purpose of plazas for human comfort. These are the results compiled from mostly open ended questions categorized and tallied by the author of this thesis. There were 625 respondents from January 21, 2016 to February 22, 2016. Table 4-1 is the compilation of the citizen input. The next five tables and figures show the results of the survey.

Table 4-1: What currently brings you to Old Town?

Dining	167
Shopping	49
Atmosphere/Social	38
Entertainment/Special Events	31
Do not go to Old Town	15
School/Work	12
Live in Old Town	9
Exercise/Walk/Bike	4
City Hall business	2
Feel safe there	1



Answer Choices	Responses	
30 mins or less	6.88%	43
1 hour	41.92%	262
2-3 hours	43.52%	272
4-5 hours	3.36%	21
6+ hours	4.32%	27
Total		625

Figure 4-11: Question two.

Table 4-2: What would you add to Old Town?

Entertainment	149
Shopping	138
Outdoor Space	130
Dining	58
Play Area	39
Parking	35
Water Feature	23
Dog Park	14
Public Restrooms	9
Wi-Fi	4

Question four and five are not directly relevant to the plaza.

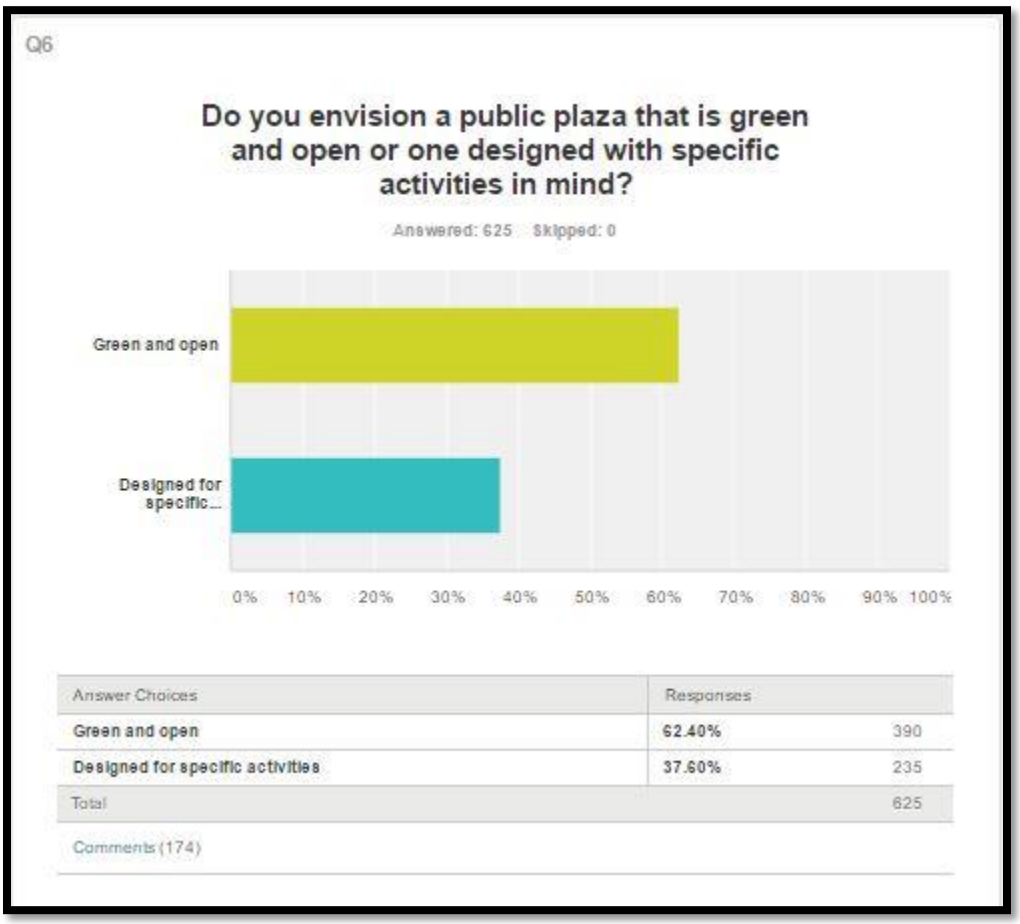
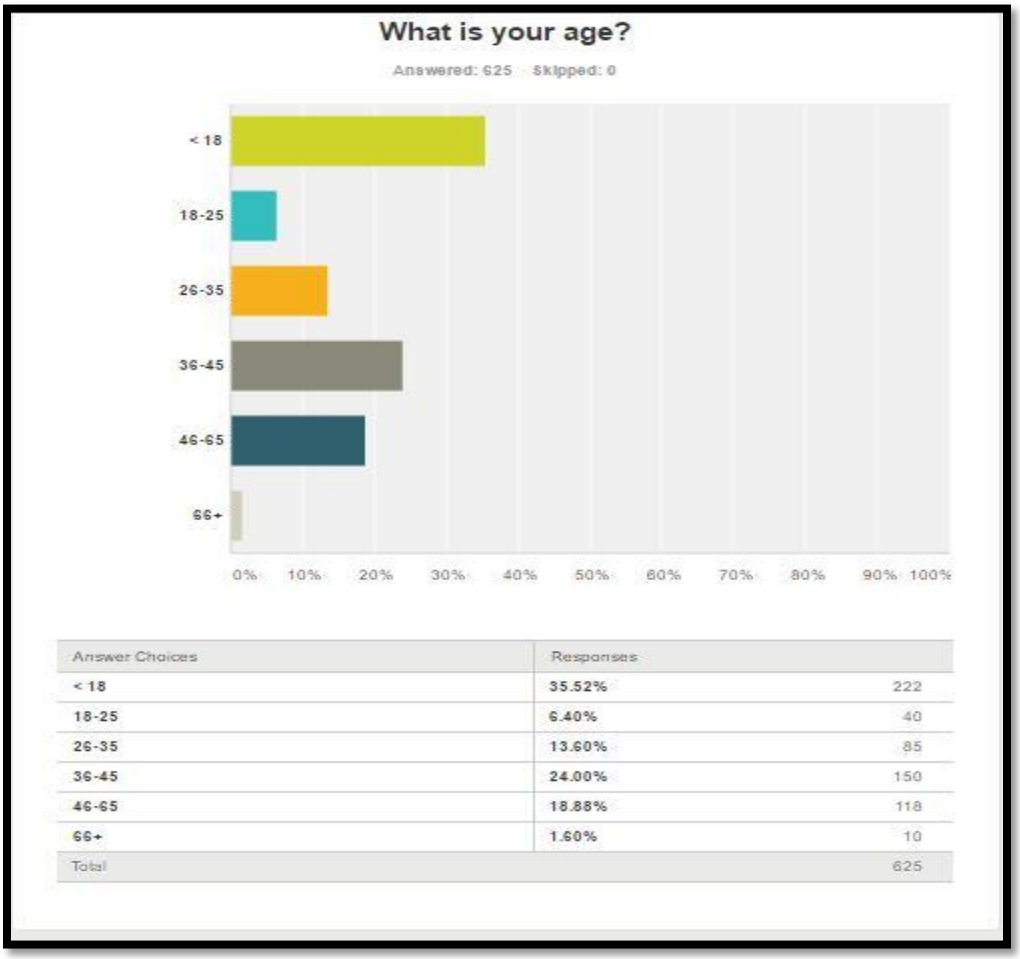


Figure 4-12: Question six.

Table 4-3: What would you like to see in a plaza?

Parking	96
Benches/Seating Area	74
Open Space/Community Area	72
Water Features	66
Entertainment	60
Green Space/Plants	54
Food	47
Shopping	47
Play Area	43
Public Restrooms	39
Stage/Music/Concerts	33
Shade	27
Walkable	27
Statue/Art/Photo Op.	22
Dog Park/Dog Friendly	12
Wi-Fi	11
Housing	3



Answer Choices	Responses	
< 18	35.52%	222
18-25	6.40%	40
26-35	13.60%	85
36-45	24.00%	150
46-65	18.88%	118
66+	1.60%	10
Total		625

Figure 4-13: Question eight.

The first survey through Survey Monkey was followed by an online Town Hall Meeting through Facebook and Twitter. Social media seems to have more citizen participation than live town hall meetings and is probably less daunting to post comments from home than to stand before a council in a grand hall with an audience. The results were similar to the first survey but slightly more focused. The trend was toward daytime activities for children and perhaps interactive sculpture for photos and to play on. There was also mention of specific retail facilities wanted for the space, like a coffee shop. Figure 4-14 is a sketch of a selfie Mayor Ken Shetter took during the Town Hall Meeting in the council chambers with the planning staff and information officer.

Figure 4-14: City of Burleson Mayor Ken Shetter selfie with (front to back) Drew Pennywell, Justin Bond, Bradley Ford, Alex Phillips, and Sally Ellertson.

(Sketch by Steve Witherspoon)

Chapter 5

Conclusion

The preceding pages are an attempt to rescue some old methods of the agora and pre-industrial plazas. A careful examination was directed at understanding human comfort needs. And, next, looking at aquaponics as a system well suited for the plaza. The case study of Burleson Texas is an attempt at showing practical applications of designing plazas for human comfort. Putting all of the elements together in a site specific condition is important, when designing with nature.

A few basic principles can completely transform the comfort level of an outdoor space. Without using human comfort as a primary design feature the plaza will fail to attract and retain people. Looking at some of the survey results, it also becomes apparent that citizens are asking for the comfort items. One unique outlier in the survey is parking. Parking is more of a general Old Town topic that comes up in most discussions in the area and has a whole separate consulting firm investigating the subject. Parking could be important in a detailed analysis of plaza design but out of the scope of this study.

A plaza is a unique area for public gathering. If the city were a home, the plaza would be the living room. It is a public space were all citizens are equal and welcome. The democratic ideas were possibly born but definitely practiced in the ancient agora. It is a place where humans can interact and share ideas. It is a place where the citizens can interact with their local government.

By embracing the outdoor effect of a plaza and celebrating it, a niche can be filled that most humans require for mental, emotional, and physical health. Not only is it a place that would benefit human health and happiness, it is a place that citizens are asking for in large numbers. Thinking back on the basic principles of Maslow's hierarchy of needs, a broad base at the foundation of the pyramid first needs a person to feel safe and have the basic element of physical and psychological well-being. If the priority stays focused on creating a healthy and comfortable environment within a plaza, many other features can be added for taste or design principles.

Looking back, this paper asks what new and old techniques can make a plaza comfortable and usable to humans? In the process of answering the question, perhaps stressing human comfort as the

first priority in designing outdoor spaces is the first priority. In nature the basic elements are the sun, water, and wind. Understanding sun, water, and wind in the context of a specific site would be of utmost importance, and also keeping these factors in mind throughout the whole process would ensure a well-used space. The basic ways of understanding the impact these elements have on a space is with sun path and local climate analysis. Besides the natural elements, understanding how they relate to human comfort needs would be the mantra that hums along with all other design elements. The physical and social comfort factors were thoroughly discussed in the second chapter including a wide range of relevant data building on the studies of Gehl (Gehl 1987). Using this data along with the natural elements would be similar to building the base of Maslow's pyramid for which the success of all other elements depend.

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